CONFERENCE BOOK

EGE 14. ULUSLARARASI UYGULAMALI BİLİMLER KONGRESİ

İZMİR

23 - 29 ARALIK 2025

EGE
14. ULUSLARARASI UYGULAMALI BİLİMLER KONGRESİ



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DECEMBER 23 - 29, 2025
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Edited By
PROF. DR. HÜLYA ÇİÇEK

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Salon	Moderator		Bildiri No ve Başlığı / Paper ID and Title	Authors
HALL / SALON 1	**Ar. Gör. Ayşenur ALKAN**	1	A HOLISTIC PERSPECTIVE ON THE DIVORCE PROCESS THROUGH PARENTAL, CHILD, AND COUPLE DYNAMICS	Uzm. Psk. Elif AYTEN KAYAR Dr. Öğr. Üyesi Ozan KAYAR
		2	DEVELOPMENT AND TREATMENT OF OVERCONTROL: A REVIEW	Ar. Gör. Ayşenur ALKAN
		3	PSİKOLOJİK İYİ OLUŞ ÜZERİNDE SEKÜLER VE DESEKÜLER TUTUMLARIN ETKİSİ	Doktora Öğrencisi, Enes KARTAL
		4	AKTARILAN AİLE İÇİ TRAVMALAR VE ÇOCUKLUK DÖNEMİ PSİKOLOJİK YARALANMALARI: LİTERATÜR TABANLI BİR İNCELEME	Yüksek Lisans Öğrencisi Selin ÜNAL Doç. Dr. Tuğba Seda ÇOLAK TURAN
		5	PSYCHOMETRIC EVALUATION OF THE TURKISH VERSION OF THE TIME STYLES SCALE	Helin GÜL Senanur AYIK Dr. Öğr. Üyesi Yılmaz Orhun Gürlük Dr. Öğr. Üyesi Mehmet Karasu
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		7	EKOLOJİK KRİZ VE PSİKOSOSYAL UYUM: SÜRDÜRÜLEBİLİRLİK BAĞLAMINDA ORMAN YANGINLARI	Doç. Dr. Betül Dilara ŞEKER Arş. Gör. Tubanur İNANÇ BOZKURT
		8	EBEVEYN DUYGUSAL ERİŞİLEBİLİRLİĞİ VE PSİKOLOJİK SAĞLAMLIK ARASINDAKİ İLİŞKİDE KİŞİLİK ÖZELLİKLERİNİN ARACI ROLÜ	Yüksek Lisans Öğrencisi Özlem URUŞ Dr. Öğr. Üyesi Gülşah ERTEKİN

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HALL / SALON 2	**Dr. Öğr. Üyesi Gamze BİLİR-SEYHAN**	1	TEK EBEVEYNLİ ÇOCUKLARIN AİLE İLİŞKİLERİ VE EĞİTİM HAYATIYLA İLGİLİ ANNE GÖRÜŞLERİ	Öznur BUĞDAY İrem GÜRGAH OĞUL
		2	ÇOCUKLARIN PROBLEMLİ EKRAN KULLANIMINA İLİŞKİN EBEVEYN GÖRÜŞLERİ	Ayça Sena ABACI Dr. Öğr. Üyesi İrem GÜRGAH OĞUL
		3	TOPLUM TEMELLİ UYGULAMALARDA ÖĞRETMEN ADAYLARININ ÖĞRENME DENEYİMLERİ	Dr. Öğr. Üyesi Gamze BİLİR-SEYHAN
		4	OKUL ÖNCESİ ÖĞRETMEN ADAYLARININ ERKEN ÇOCUKLUK DÖNEMİ EDEBİYATI DERSİNDEN KAZANDIKLARI FARKINDALIKLAR	Dr. Öğr. Üyesi Gamze BİLİR-SEYHAN
		5	Okul Öncesi Öğretmen Adaylarının, Sosyobilimsel Konulara Yönelik Tutumları İle Eleştirel Düşünme Eğilimleri Arasındaki İlişkinin İncelenmesi	Sabahat ÇEKİCİ Dr. Öğr. Üyesi Sema Nur GÜNGÖR
		6	OKUL ÖNCESİ EĞİTİM DÖNEMİNDE ÇOCUĞA SAHİP OLAN EBEVEYNLERİN YAPAY ZEKÂYA İLİŞKİN METAFORİK ALGILARININ İNCELENMESİ	Dr. Öğr. Üyesi Cansu KÖKEN Dr. Öğr. Üyesi Gözdenur IŞIKCI BAŞKAYA
		7	AN EXAMINATION OF GRADUATE THESES ON PROGRAM EVALUATION IN PRESCHOOL EDUCATION	Yüksek Lisans Öğrencisi Semanur YEŞİLBAŞ Doç. Dr. Didem KAYAHAN YÜKSEL
		8	OKUL ÖNCESİ DÖNEM 48-60 AYLIK ÇOCUKLARA UYGULANAN MÜZİKLİ OYUNLARIN ETKİLERİNİN ÇEŞİTLİ GELİŞİMSEL ÖZELLİKLERE GÖRE İNCELENMESİ	Bilim Uzmanı Berkay GÖK Prof. Dr. Sibel KARAKELLE Prof. Dr. Fatma ÇALIŞANDEMİR
		9	OKUL ÖNCESİ BÖLÜMÜ ÖĞRENCİLERİNİN MESLEKİ KAYGI VE MOTİVASYON DÜZEYLERİNİN İNCELENMESİ: KARMA YÖNTEM ARAŞTIRMASI	Bilim Uzmanı Ayşe GÖKÇEN Prof. Dr. Fatma ÇALIŞANDEMİR Prof. Dr. Özlem TAGAY
			Okul Müdürlerinin Dönüşümcü Liderlik Davranışları ile Öğretmenlerin Değişime Açıklıkları ve Teknoloji ÖzYeterlikleri Arasındaki İlişki: Bir Yapısal Eşitlik Modellemesi	Sıla DOĞAN TAŞCI Doç. Dr. Onur ERDOĞAN
		10	THE PREDICTIVE POWER OF COGNITIVE FLEXIBILITY OF UNIVERSITY STUDENTS ON CRITICAL INTERNET LITERACY	Çocuk Gelişimci Busenur ORDU Doç. Dr. Seda SAKARYA

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HALL / SALON 3	**Doç. Dr. ABİDİN KEMEÇ**	1	ULUSLARARASI YEŞİL KAMPÜS SIRALAMALARI: UŞAK ÜNİVERSİTESİ ÖRNEĞİ	Doç. Dr. ABİDİN KEMEÇ
		2	AKILLI KENTLER VE ULUSLARARASI STANDARTLAR	Doç. Dr. ABİDİN KEMEÇ
		3	DİJİTAL GÜVENLİK VE SİBER VATAN: ULUSAL EGEMENLİĞİN YENİ SINIRLARI	Dr. Begüm ÇARDAK
		4	PERFORMANCE-ORIENTED MANAGEMENT IN URBAN PUBLIC SERVICES: HUMAN RESOURCE STRATEGIES WITHIN THE FRAMEWORK OF NEW PUBLIC MANAGEMENT	Dr. Öğr. Üyesi A. Muhammet BANAZILI
		5	TRACING THE TRACES OF THE NEW PUBIC MANAGEMENT APPROACH IN THE CONSTITUTIONS OF THE REPUBLIC OF TÜRKİYE	Dr. Öğr. Üyesi A. Muhammet BANAZILI
		6	EXAMINING THE RELATIONSHIP BETWEEN JOB SATISFACTION AND INTENTION TO LEAVE IN A LOCAL GOVERNMENT: SAFRANBOLU MUNICIPALITY CASE	Assoc. Prof. Dr. Can Biçer Fatma Erdoğan
		7	MODERNLEŞME DÖNEMİ TÜRK EDEBİYATINDA, KADININ EĞİTİM HAKKI ve ÇALIŞMA HAKKI	Yüksek Lisans Öğrencisi Kader KEŞ Doç. Dr. Emre SAVUT
		8	Post-Bureaucratic State or Digital Weberianism? Rethinking Bureaucratic Authority in the Age of Digital Governance	Asst. Prof. Sevil Zengin Gupta
		9	DİJİTALLEŞEN YEREL YÖNETİŞİMDE KENT KONSEYLERİ VE ÇÖZÜM MASALARI: GELENEKSELDEN HİBRİT KATILIMCILIĞA BİR LİTERATÜR ANALİZİ	Yüksek Lisans Öğrencisi Çağrı GÖKDAĞ

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HALL / SALON 4	**Doç. Dr. Bülent AKKAYA**	1	GELECEĞİN İŞ DÜNYASINDA BİLİNÇLİ TERCİH VE YETKİNLİK: ÜNİVERSİTE ÖĞRENCİLERİNİN KARİYER PLANLAMA YETKİNLİKLERİ ÜZERİNE BİR ARAŞTIRMA	Doç. Dr. Bülent AKKAYA Prof. Dr. Akif TABAK
		2	FİNANS VE BANKACILIK ÖĞRENCİLERİN YAPAY ZEKA ALGILARI VE KAYGI DÜZEYLERİ ÜZERİNE BİR ARAŞTIRMA	Doç. Dr. Bülent AKKAYA
		3	Tüketim Kültürü Bağlamında Döngüsel Ekonomiye Bir Bakış	Öğr. Gör. Benay BULUT ŞAHİNER Öğr. Gör. Sude DIŞKAYA
		4	KAMU ÖZEL İŞBİRLİĞİ İLE YAPILAN ENERJİ ALTYAPISI PROJELERİNİN DOĞRUDAN YABANCI YATIRIMLAR ÜZERİNDEKİ ETKİSİ: GELİŞMEKTE OLAN ÜLKELER ÖRNEĞİ	Yüksek Lisans Öğrencisi Murteza BALİ Dr. Öğr. Üyesi Güneş TOPÇU
		5	KURUMSAL MİMARİDE YAPAY ZEKA TEKNOLOJİSİ	Dr. Öğr. Üyesi Sefer AYDOĞAN Doç. Dr. Sebahattin Kılınç Doç.Dr. Murat SAĞBAŞ
		6	THE IMPACT OF ENTREPRENEURSHIP AND INNOVATION INDICATORS ON THE ECONOMIC CONTRIBUTION OF SMES: TÜRKİYE 2023 ANALYSIS	Doç.Dr. Burhan AKYILMAZ Yüksek Lisans Öğrencisi Fatma KÖSE
		7	PYTHON İLE TEDARİK ZİNCİRİ PLANLAMASI	Dr.Onur Mesut ŞENARAS Doç.Dr.Şahin İNANÇ Prof.Dr.Arzu EREN ŞENARAS
		8	PYTHON İLE HAFTALIK PERSONEL ÇİZELGELEME UYGULAMASI	Doç.Dr.Şahin İNANÇ Prof.Dr.Arzu EREN ŞENARAS

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HALL / SALON 5	**Dr. Eylem ŞEVİK**	1	THE TRANSFORMATION OF FAMILY STRUCTURE AND HELICOPTER PARENTING	Öğr. Gör. Dr. Yasemin GEZER TUĞRUL
		2	EARLY MARRIAGES IN THE CONTEXT OF CHILDREN'S RIGHTS	Öğr. Gör. Dr. Yasemin GEZER TUĞRUL Öğr. Gör. Sema SANCAK
		3	ANTROPOSEN ÇAĞI'NIN VAROLUŞSAL İKİLEMLERİ, KAYGILARI VE ÇÖZÜM ÖNERİLERİ	Dr. Nihan OSMANAĞAOĞLU
		4	MESLEKİ EĞİTİMDE GÜZELLİK ALGISI: SOSYOLOJİK BİR BAKIŞ AÇISI	Eren Kahveci
		5	TAŞRA KİMLİĞİ, BOŞ ZAMAN VE FUTBOL: ÇANAKKALE İLİ EZİNE İLÇESİ ÖRNEĞİ	Dr. Eylem ŞEVİK
		6	THE FRAGMENTATİON OF SPACE, THE TRANSFORMATİON OF LAND: THE RECONFİGURATİON OF RURALİTY THROUGH HOBBY GARDENS İN MEMLİK NEİGHBORHOOD	Yüksek Lisans Öğrencisi Aleyna TAYDAŞ Doç. Dr. Günce DEMİR
		7	ARABESK KÜLTÜRÜN DÖNÜŞEN KODLARI: SINIF, GÖÇ VE KENTLEŞME BAĞLAMINDA BİR ANALİZ	Prof. Dr. Ercan ŞAHBUDAK Yüksek Lisans Öğrencisi Merve ACET Dr. İlhan KARAHAN
		8	RENKLERİN TOPLUMSAL ANLAMLARI; SEMBOLİZM, AYRIMCILIK VE DAYANIŞMA ÖRNEKLERİYLE SOSYOLOJİK BİR ANALİZ	Prof. Dr. Ercan ŞAHBUDAK Doktora Öğrencisi Elif ÖZDEMİR YARIŞ Dr. İlhan KARAHAN

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HALL / SALON 6	**Prof. Dr. Nuray DEMİREL ARICI**	1	HİLELİ FİNANSAL RAPORLAMA LİTERATÜRÜ ÜZERİNE RETROSPEKTİF BİR ÇALIŞMA	Prof. Dr. Nuray DEMİREL ARICI
		2	ENFLASYONUN GENÇ TÜKETİCİLERİN SATIN ALMA DAVRANIŞI ÜZERİNE ETKİSİ: BİR SAHA ARAŞTIRMASI	Prof. Dr. Nuray DEMİREL ARICI Yusuf MUHTAROĞLU Mert ŞALVARLI Neslihan YALÇIN
		3	FİNANSAL OKURYAZARLIK, KAYIPTAN KAÇINMA VE RİSKTEN KAÇINMA İLİŞKİLERİNİN DAVRANIŞSAL PERSPEKTİFTEN ANALİZİ	Yüksek Lisans Öğrencisi Songül KAYA Dr. Öğr. Üyesi Asena Gizem YİĞİT
		4	Going public to invest? The impact of use-of-proceeds intention disclosure on financial performance	Assoc. Prof. Dr. Lokman TÜTÜNCÜ
		5	YEŞİL TAHVİLLER VE SÜRDÜRÜLEBİLİR FİNANS: KÜRESEL EĞİLİMLER VE TÜRKİYE İÇİN GELECEK PERSPEKTİFLERİ	Yüksek Lisans Öğrencisi Sibel KINIŞ Prof. Dr. Derviş BOZTOSUN Dr. Zühal KINIŞ
		6	FİNANSAL OKURYAZARLIK LİTERATÜRÜNE GENEL BİR BAKIŞ	Şükriye AYDIN Prof. Dr. Derviş BOZTOSUN Dr. Naciye HATTATİOĞLU
		7	EVALUATING INVESTMENT SPENDING PERFORMANCE ACROSS INDUSTRIAL AND SERVİCE SECTORS: AN INTEGRATED LOPCOW–MARCOS APPROACH	Assoc. Prof. Dr. Ceyda YERDELEN KAYGIN Assoc. Prof. Dr. Musa GÜN Dr. Osman Nuri AKARSU
		8	MAKRO İHTİYATİ REGÜLASYONLARIN TÜRKİYE'DE TÜKETİCİ KREDİLERİ PİYASASINA ETKİSİ: 2020 SONRASI DÖNEM ANALİZİ	Doç. Dr. Gökhan ÖZKUL Doç. Dr. Ozan ÖZDEMİR Burcu BARLAS

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HALL / SALON 1	**Assoc. Prof. Dr. Sanjay Bhattacharya,**	1	CULTURALLY RESPONSIVE PEDAGOGY FOR ETHNIC MINORITY STUDENTS IN CHINESE MULTILINGUAL CLASSROOMS	Prof. Dr. Zhao Min, Wang Lili, Dr. Guo Qiang
		2	AI-ASSISTED ADAPTIVE LEARNING SYSTEMS FOR PERSONALIZED MATHEMATICS INSTRUCTION IN URBAN CHINA	Assoc. Prof. Dr. Liu Xiaoyan, Chen Peng, Zhang Rui
		3	MONTESSORI PRINCIPLES ADAPTED FOR EARLY CHILDHOOD EDUCATION IN RURAL CHINESE KINDERGARTENS	Dr. Hu Jing, Sun Wei, Assis. Prof. Dr. Yang Lei
		4	STEM EDUCATION INNOVATIONS THROUGH MAKERSPACES IN QATARI PUBLIC SCHOOLS	Prof. Dr. Khalid Al-Thani, Mariam Al-Kuwari
		5	TEACHER COLLABORATIVE INQUIRY COMMUNITIES FOR CURRICULUM DEVELOPMENT IN QATARI CONTEXTS	Dr. Fatima Al-Mansoori, Assoc. Prof. Dr. Nasser Ali
		6	NEUROSCIENCE-INFORMED READING INTERVENTIONS FOR DYSLEXIC STUDENTS IN INDIAN PRIVATE SCHOOLS	Prof. Dr. Aruna Menon, Rahul Nair, Dr. Lakshmi Iyer
		7	RURAL TEACHER PREPARATION THROUGH COMMUNITY-BASED PEDAGOGICAL RESIDENCIES IN INDIA	Assoc. Prof. Dr. Sanjay Bhattacharya, Priya Das
		8	CRITICAL PEDAGOGY APPROACHES TO ADDRESS CASTE DYNAMICS IN URBAN INDIAN CLASSROOMS	Dr. Kavita Sharma, Vikrant Joshi,

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HALL / SALON 2	**Dr. Xu Fei,**	1	BRONZE AGE RITUAL PRACTICES REVEALED THROUGH TERRACOTTA FIGURINES AT ANYANG ROYAL TOMBS	Prof. Dr. Zhang Wei, Li Ming, Dr. Wang Xiaoyu
		2	SILK ROAD CERAMIC TRADE NETWORKS UNCOVERED AT XINJIANG OASIS SETTLEMENTS	Assoc. Prof. Dr. Liu Jian, Chen Hao, Zhao Lin
		3	NEOLITHIC JADE WORKING TECHNOLOGIES AT LINGJIATAN CULTURE SITES IN NORTHWEST CHINA	Dr. Xu Fei, Huang Wei, Sun Ming
		4	HELLENISTIC INFLUENCES IN PRE-ISLAMIC QATARI SETTLEMENT ARCHITECTURE AND POTTERY	Prof. Dr. Khalid Al-Thani, Fatima Nasser
		5	PALEOENVIRONMENTAL RECONSTRUCTION OF EARLY ISLAMIC AGRICULTURAL TERRACES IN NORTHERN QATAR	Dr. Mariam Al-Kuwari, Assoc. Prof. Dr. Hassan Mubarak
		6	INDUS VALLEY SEAL CARVING WORKSHOPS UNCOVERED AT HARAPPAN SATELLITE SITES	Vikram Singh
		7	MEGALITHIC BURIAL COMPLEXES AND IRON AGE RITUAL LANDSCAPES IN SOUTH INDIA	Assoc. Prof. Dr. Meera Nair, Sanjay Gupta
		8	EARLY HISTORIC BUDDHIST MONASTIC ECONOMIES AT SANCHI STOOPA SATELLITE SITES	Dr. Kavita Reddy, Rahul Joshi, Assis. Prof. Dr. Neha Sharma
		9	CHALCOLITHIC ROCK SHELTER ART AND SYMBOLIC LANDSCAPES IN CENTRAL INDIA	Prof. Dr. Vikram Desai, Anjali Rao
		10	MARITIME TRADE PORTS AND ROMAN COMMERCIAL NETWORKS AT ARIKAMEDU SETTLEMENT	Dr. Sanjay Bhattacharya, Lakshmi Menon, Rohit Varma
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HALL / SALON 3	Assoc. Prof. Dr. Hassan Abdel-Rahman,	1	THE SYNCRETISM OF PRE-ISLAMIC TENGRISM AND ISLAMIC SUFISM IN CONTEMPORARY KAZAKH SPIRITUAL PRACTICES	Prof. Dr. Almaz Kairatov, Aigerim Sarsenova, Dr. Nurlan Tursunov
		2	TEXTUAL ANALYSIS OF MEDIEVAL KAZAKH MANUSCRIPTS ON ISLAMIC LEGAL INTERPRETATIONS	Assoc. Prof. Dr. Zhuldyz Abilkair, Erlan Bekbolatov
		3	CONTEMPORARY REVIVAL OF SUFI ORDERS AND NATIONAL IDENTITY FORMATION IN POST-SOVIET KAZAKHSTAN	Dr. Saltanat Makhmutova, Bekzhan Oralov, Assis. Prof. Dr. Daulet Nurpeisov
		4	EGYPTIAN SUFI POETRY TRADITIONS AND THEIR INFLUENCE ON CONTEMPORARY ARABIC DEVOTIONAL LITERATURE	Prof. Dr. Ahmed El-Sayed, Fatima Mahmoud
		5	QURANIC HERMENEUTICS IN CONTEMPORARY EGYPTIAN SCHOLARSHIP: BALANCING TRADITION AND MODERNITY	Assoc. Prof. Dr. Hassan Abdel-Rahman, Nour El-Din
		6	SHIITE-SUNNI DIALOGUE INITIATIVES AND INTERFAITH PEACEBUILDING IN PAKISTANI RELIGIOUS COMMUNITIES	Dr. Fatima Zahra, Assoc. Prof. Dr. Ali Raza, Imran Khan
		7	FOLK ISLAMIC HEALING PRACTICES AND BIOMEDICAL INTEGRATION IN RURAL PAKISTANI COMMUNITIES	Prof. Dr. Muhammad Aslam, Sobia Ahmed, Dr. Naveed Malik
		8	CONTEMPORARY REINTERPRETATIONS OF JIHAD CONCEPT IN PAKISTANI MADRASA CURRICULA REFORMS	Assis. Prof. Dr. Amina Siddiqui, Tariq Mehmood

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HALL / SALON 4	Dr. Leila Bahrami,	1	COMPARATIVE ANALYSIS OF SHARIAH PRINCIPLES IN CONTEMPORARY IRANIAN FAMILY LAW REFORMS	Prof. Dr. Mohammad Hosseini, Reza Ahmadi, Dr. Fatemeh Karimi
		2	THE ROLE OF CONSTITUTIONAL REVIEW IN SAFEGUARDING HUMAN RIGHTS UNDER IRANIAN ISLAMIC REPUBLIC FRAMEWORK	Assoc. Prof. Dr. Ali Jafari, Soraya Mahmoudi
		3	ENVIRONMENTAL LIABILITY REGIMES UNDER IRANIAN CIVIL AND ISLAMIC LAW PRINCIPLES	Dr. Leila Bahrami, Hassan Rezaei, Assis. Prof. Dr. Nima Sharifi
		4	REFORMING ADMINISTRATIVE JUDICIAL REVIEW MECHANISMS IN EGYPTIAN POST-ARAB SPRING LEGAL SYSTEMS	Prof. Dr. Ahmed El-Sayed, Mariam Hassan
		5	ISLAMIC FINANCE REGULATION CHALLENGES IN EGYPTIAN BANKING SECTOR DEVELOPMENT	Assoc. Prof. Dr. Fatima Abdel Rahman, Omar Khalil
		6	CONSTITUTIONAL REFORMS AND PROPERTY RIGHTS PROTECTION IN MOLDOVAN POST-SOVIET LEGAL TRANSITION	Dr. Ion Popescu, Prof. Dr. Maria Ceban, Victor Lupu
		7	ANTI-CORRUPTION LEGISLATION EFFECTIVENESS IN MOLDOVAN PUBLIC PROCUREMENT SYSTEMS	Assoc. Prof. Dr. Ana Gurau, Dr. Nicolae Andronic

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HALL / SALON 5	**Assoc. Prof. Dr. Sevinc Nuriyeva,**	1	HUMAN TRAFFICKING VICTIM PROTECTION FRAMEWORKS IN MOLDOVAN CRIMINAL JUSTICE REFORMS	Assis. Prof. Dr. Olga Rotaru, Stefan Balan, Dr. Elena Ciumac
		2	INNOVATIVE STEM TEACHING METHODOLOGIES FOR RURAL MOLDOVAN SECONDARY SCHOOLS ENHANCING CRITICAL THINKING SKILLS	Prof. Dr. Ion Ceban, Dr. Maria Popa,
		3	BILINGUAL EDUCATION MODELS FOR ROMANIAN AND RUSSIAN-SPEAKING STUDENTS IN NORTHERN MOLDOVAN PRIMARY SCHOOLS	Assoc. Prof. Dr. Elena Ursu, Victor Rotaru
		4	DIGITAL LITERACY DEVELOPMENT THROUGH MAKER SPACES IN URBAN MOLDOVAN VOCATIONAL TRAINING CENTERS	Dr. Natalia Gherman, Mihai Balan, Assis. Prof. Dr. Olga Crudu
		5	COMMUNITY-BASED TEACHER TRAINING PROGRAMS ADDRESSING ETHIOPIAN RURAL EDUCATION DROPOUT CRISES	Prof. Dr. Tadesse Alemu, Selamawit Getachew
		6	INTEGRATING INDIGENOUS ECOLOGICAL KNOWLEDGE INTO ETHIOPIAN PRIMARY SCIENCE CURRICULA FOR SUSTAINABLE LEARNING	Dr. Firew Assefa, Assoc. Prof. Dr. Mulugeta Bekele
		7	FLIPPED CLASSROOM MODELS ENHANCING CRITICAL READING SKILLS AMONG AZERBAIJANI UNIVERSITY STUDENTS	Prof. Dr. Aysel Mammadova, Elnur Gasimov, Dr. Leyla Aliyeva
		8	INCLUSIVE EDUCATION FRAMEWORKS FOR CHILDREN WITH SPECIAL NEEDS IN BAKU MUNICIPAL PRESCHOOLS	Assoc. Prof. Dr. Sevinc Nuriyeva, Kamran Huseynov
		9	STEAM EDUCATION INTEGRATION THROUGH AZERBAIJANI FOLK ARTS IN GANJA SECONDARY SCHOOLS	Dr. Tarana Khalilova, Assis. Prof. Dr. Rauf Mammadov, Nigar Sadigova
		10	MENTORSHIP PROGRAMS FOR FIRST-YEAR TEACHERS IN AZERBAIJANI REGIONAL VOCATIONAL SCHOOLS	Fidan Ismayilova, Dr. Vugar Aliyev
			ECOLOGICAL EDUCATION CURRICULA INCORPORATING CASPIAN SEA CONSERVATION IN AZERBAIJANI COASTAL SCHOOLS	Assoc. Prof. Dr. Sevinj Mirzayeva, Rashad Novruzov
		11	ASSESSMENT REFORMS IMPLEMENTING PORTFOLIO-BASED EVALUATION IN AZERBAIJANI LANGUAGE ARTS CLASSROOMS	Prof. Dr. Gunduz Ismayilov, Zaur Kerimov, Elmira Hasanova

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HALL / SALON 6	**Assoc. Prof. Dr. Siti Nurjanah,**	1	MIGRATION PATTERNS AND SOCIAL INTEGRATION CHALLENGES AMONG ALBANIAN DIASPORA COMMUNITIES IN EUROPE	Prof. Dr. Arben Lika, Dr. Elira Deda, Sokol Meta
		2	GENDER ROLES TRANSFORMATION IN POST-SOCIALIST ALBANIAN RURAL COMMUNITIES	Assoc. Prof. Dr. Luljeta Hoxha, Beni Qirjako
		3	URBAN POVERTY AND SOCIAL EXCLUSION DYNAMICS IN TIRANA'S INFORMAL SETTLEMENTS	Dr. Fatmir Bega, Mira Shehu, Assis. Prof. Dr. Gentian Elezi
		4	ISLAMIC REVIVALISM AND YOUTH IDENTITY FORMATION IN INDONESIAN URBAN NEIGHBORHOODS	Prof. Dr. Ahmad Syarif, Dr. Nurul Hidayah
		5	CLIMATE CHANGE ADAPTATION STRATEGIES AMONG INDONESIAN COASTAL FISHING COMMUNITIES	Assoc. Prof. Dr. Siti Nurjanah, Budi Santoso
		6	ETHNIC MINORITY INTEGRATION CHALLENGES IN MULTIETHNIC KAZAKHSTANI CITIES	Yerkebulan Tastanbekov, Dr. Aizhan Kaskyrbekova
		7	TRANSNATIONAL FAMILY NETWORKS AMONG LABOR MIGRANTS FROM RURAL KAZAKHSTAN	Dr. Zhanna Musina, Nurdaulet Abildayev
		8	URBANIZATION EFFECTS ON TRADITIONAL NOMADIC SOCIAL STRUCTURES IN KAZAKHSTAN	Assoc. Prof. Dr. Aidana Satybaldiyeva, Temirlan Orynbayev, Assis. Prof. Dr. Zhuldyz Kenzhegulova

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HALL / SALON 7	**Assoc. Prof. Dr. Rina Susanti,**	1	IMPACT OF EU INTEGRATION POLICIES ON ALBANIAN AGRICULTURAL EXPORTS AND RURAL DEVELOPMENT	Prof. Dr. Arben Hoxha, Dr. Liriana Kola, Enis Meta
		2	MICROFINANCE INITIATIVES AND WOMEN ENTREPRENEURSHIP GROWTH IN POST-SOCIALIST ALBANIAN COMMUNITIES	Assoc. Prof. Dr. Dorina Deda, Fatmir Gjinaj
		3	TOURISM DEVELOPMENT STRATEGIES AND THEIR EFFECTS ON REGIONAL ECONOMIC DISPARITIES IN ALBANIA	Dr. Blerta Vokshi, Assis. Prof. Dr. Ilir Bejleri, Mira Llagami
		4	ISLAMIC FINANCE PRINCIPLES APPLICATION IN INDONESIAN SUSTAINABLE PALM OIL SUPPLY CHAINS	Prof. Dr. Muhammad Syarif Hidayat, Aisyah Nur
		5	DIGITAL ECONOMY TRANSFORMATION AND SME ADOPTION CHALLENGIES IN RURAL INDONESIA	Assoc. Prof. Dr. Rina Susanti, Dr. Budi Santoso
		6	GREEN ENERGY INVESTMENTS AND ECONOMIC DIVERSIFICATION AWAY FROM OIL DEPENDENCE IN KAZAKHSTAN	Prof. Dr. Yerzhan Bazarov, Assis. Prof. Dr. Aizhan Kenzhegulova, Timur Sarsenov
		7	BLOCKCHAIN TECHNOLOGY APPLICATIONS IN IMPROVING TRANSPARENCY OF KAZAKHSTAN'S COMMODITY TRADING	Dr. Gulnara Abilkhanova, Nurdaulet Zhumagaliyev
		8	FISCAL DECENTRALIZATION REFORMS AND LOCAL GOVERNMENT EFFICIENCY IN KAZAKHSTAN'S REGIONS	Assoc. Prof. Dr. Saltanat Janenova, Ruslan Myachkov, Dr. Aidar Amangali

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HALL / SALON 8	**Assoc. Prof. Dr. Maria Stavros**	1	MICROFINANCE ACCESSIBILITY AND RURAL ENTREPRENEURSHIP GROWTH IN THE PHILIPPINES POST-PANDEMIC RECOVERY	Prof. Dr. Maria Santos, Dr. Jose Rizal, Ana Lopez
		2	FISCAL POLICY RESPONSES TO INFLATIONARY PRESSURES IN THE PHILIPPINE REMITTANCE-DEPENDENT ECONOMY	Assoc. Prof. Dr. Carlo Mendoza, Leila Cruz
		3	INFORMAL SECTOR DYNAMICS AND TAX COMPLIANCE STRATEGIES IN URBAN PHILIPPINE MARKETS	Dr. Sofia Reyes, Ramon Garcia, Assis. Prof. Dr. Elena Vargas
		4	EUROZONE DEBT SUSTAINABILITY AND GREEK FISCAL CONSOLIDATION POST-2010 SOVEREIGN CRISIS	Prof. Dr. Dimitri Papadopoulos, Eleni Kostas
		5	TOURISM LED GROWTH HYPOTHESIS TESTING IN THE GREEK ISLAND ECONOMY CONTEXT	Dr. Nikos Theodorou, Assoc. Prof. Dr. Maria Stavros
		6	ENERGY TRANSITION ECONOMICS AND NATURAL GAS DEPENDENCY IN THE RUSSIAN FEDERATION	Prof. Dr. Alexei Ivanov, Dr. Olga Petrova, Sergei Kuznetsov
		7	SANCTIONS IMPACT ON RUSSIAN IMPORT SUBSTITUTION INDUSTRIAL POLICIES	Assoc. Prof. Dr. Natalia Volkov, Ivan Morozov
		8	REGIONAL INEQUALITY DYNAMICS IN THE RUSSIAN FAR EAST DEVELOPMENT PROGRAMS	Dr. Elena Smirnova, Assis. Prof. Dr. Dmitry Fedorov, Anna Belova
		9	MONETARY POLICY TRANSMISSION IN POST-SANCTION RUSSIAN FINANCIAL MARKETS	Prof. Dr. Vladimir Kozlov

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HALL / SALON 9	**Assoc. Prof. Dr. Maria Georgiadou**	1	SPANISH COLONIAL ARCHITECTURE AND CULTURAL HYBRIDITY IN 17TH-CENTURY PHILIPPINE PROVINCIAL TOWNS	Prof. Dr. Maria Santos, Dr. Jose Rizalino, Ana Cruz
		2	AMERICAN OCCUPATION POLICIES AND FILIPINO ELITE LAND CONSOLIDATION DURING THE EARLY 20TH CENTURY	Assoc. Prof. Dr. Roberto Villanueva, Leila Tan
		3	JAPANESE OCCUPATION RESISTANCE NETWORKS AND GENDER DYNAMICS IN LUZON GUERRILLA MOVEMENTS	Dr. Elena Morales, Ferdinand Reyes, Assis. Prof. Dr. Sofia Lim
		4	BYZANTINE ADMINISTRATIVE REFORMS AND THEIR IMPACT ON MEDIEVAL GREEK ISLAND ECONOMIES	Prof. Dr. Nikos Papadopoulos, Eleni Stavrou
		5	OTTOMAN COMMERCIAL LAW APPLICATIONS IN 18TH-CENTURY GREEK MERCHANT COMMUNITIES	Dr. Dimitri Koukoulis, Assoc. Prof. Dr. Maria Georgiadou
		6	PORTUGUESE COMMERCIAL EXPANSION AND OMANI MARITIME AUTONOMY IN THE 16TH CENTURY INDIAN OCEAN	Prof. Dr. Ahmed Al-Harthi, Fatima Zahra, Dr. Salim Nasser
		7	BRITISH IMPERIAL TREATIES AND TRIBAL LAND RIGHTS NEGOTIATIONS IN 19TH-CENTURY OMAN	Assoc. Prof. Dr. Khalid Al-Busaidi, Mariam Said
		8	DUTCH VOC FACTORY RECORDS AND OMANI PEARL DIVERSITY IN 17TH-CENTURY GULF TRADE	Dr. Nasser Al-Maskari, Assis. Prof. Dr. Layla Harthi, Omar Khalfan

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HALL / SALON 1	**Assoc. Prof. Mustafa NAİMOĞLU Assoc. Prof. Sefa ÖZBEK**	1	A THEORETICAL ASSESSMENT OF THE EFFECTS OF GREEN TECHNOLOGICAL DEVELOPMENTS ON ENVIRONMENTAL SUSTAINABILITY	Assoc. Prof. Mustafa NAİMOĞLU Assoc. Prof. Sefa ÖZBEK
		2	THE IMPACT OF FOSSIL FUEL R&D EXPENDITURES ON ENVIRONMENTAL SUSTAINABILITY: THEORETICAL APPROACHES AND AN EVALUATION WITHIN THE CONTEXT OF THE SUSTAINABLE DEVELOPMENT GOALS	Assoc. Prof. Mustafa NAİMOĞLU Assoc. Prof. Sefa ÖZBEK
		3	KAPSAYICI BÜYÜME ENDEKSLERİ ÜZERİNE KARŞILAŞTIRMALI BİR ANALİZ	Prof. Dr. Feride GÖNEL Araştırma Görevlisi Furkan İNCEDAYI
		4	Trade Openness and Environmental Quality in the European Union: Evidence from Panel Data	Doç. Dr. Ali ALTINER Prof. Dr. Eda BOZKURT Doç. Dr. Özlem TOPÇUOĞLU
		5	OPT-OUT BEHAVIOR IN AUTO-ENROLLMENT SYSTEM IN TURKEY	Dr. Zeynep AKTAŞ KORAL Prof. Dr. Halit YANIKKAYA Prof. Dr. S. Haluk ÇİTÇİ
		6	TÜRKİYE'DE GÜVENLİK RİSKLERİNİN YABANCI SERMAYE GİRİŞLERİNE ETKİSİ	Dr.Öğr.Üyesi Ömer YILMAZ
		7	TÜRKİYE'DE ÇEVRESEL BOZULMANIN BELİRLEYİCİLERİ: MİLLİ GELİR VE DEMOGRAFİK YAPI ÜZERİNE AMPİRİK BİR İNCELEME	Dr.Öğr.Üyesi Ömer YILMAZ
		8	THE IMPACT OF ELECTRIC VEHICLES ON THE MARKET SHARE OF CONVENTIONAL MANUFACTURERS IN THE TURKISH AUTOMOTIVE SECTOR	Doktora Öğrencisi, Merve KARAMAN Prof. Dr. Gülden ÜLGEN
		9	THE ROLE OF TECHNOLOGY IN IMPERFECTLY COMPETITIVE MARKETS	Sena ERGÜDEN Prof. Dr. Gülden ÜLGEN

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HALL / SALON 2	Dr. Öğr. Üyesi Kerim Kaan GÖKÜSTÜN	1	EVALUATION OF NUTRITIONAL STATUS IN KIDNEY DISEASES: CURRENT APPROACHES	RDN. Şaziye Didar GANİ Asst. Prof. Dr. Rahime Evra KARAKAYA
		2	TİP-2 DİYABETLİ KADINLARDA BESLENME DURUMUNUN DEĞERLENDİRİLMESİ	Hilal BATMAZ SEVİNİR Prof. Dr. Fatma Esra GÜNEŞ
		3	18-65 YAŞ ARASI YETİŞKİNLERİN FONSİYONEL BESİN TÜKETİMİ İLE BKİ VE BEL ÇEVRESİ ARASINDAKİ İLİŞKİ	Diyetisyen Nur SERT Dr. Öğr. Üyesi Wida Simzari
		4	KİSTİK KİSTİK FİBROZİS HASTALARINDA METABOLİK DEĞİŞİMLERE UYGUN GÜNCEL BELENME ÖNERİLERİ	Dr. Öğr. Üyesi Kerim Kaan GÖKÜSTÜN Doç. Dr. Gülşah BARĞI
		5	İNTERSTİSYEL AKCİĞER HASTALIĞI OLAN BİREYLERDE REHABİLİTASYON GEREKÇELERİ	Doç. Dr. Gülşah BARĞI Dr. Öğr. Üyesi Kerim Kaan GÖKÜSTÜN

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HALL / SALON 3	**Öğr. Gör. Dr. Begüm Buse SERTGÖZ Dr. Öğr. Üyesi. Armağan MACİT**	1	OKUL ÖNCESİ EĞİTM KURUMLARINDA AFET TATBİKATLARININ UYGULANMASI VE YETERLİLİK DÜZEYLERİ	Fatma Aygün ÇAKAR Doç. Dr. Harun YAKA
		2	OKUL ÖNCESİ EĞİTİM KURUMLARINDA MEYDANA GELEBİLECEK KAZALAR VE İLK YARDIM	Ümmügülsüm BÜBER Dr. Öğr. Üyesi Korhan ÖKTEN
		3	PNÖMOKONYOZ MESLEK HASTALARININ ÖZELLİKLERİNİN GİZİL SINIF ANALİZİ	Zeynep BAŞAR Prof.Dr.Mithat ZEYDAN
		4	SİNOP İLİNDEKİ TEKSTİL ÇALIŞANLARININ İŞ KAZASI GEÇİRME EĞİLİMLERİ: TANIMLAYICI BİR ARAŞTIRMA	Mine Kızılkan Doç. Dr. Nurdan Karpuz
		5	MEDICAL WASTE MANAGEMENT AND SUSTAINABILITY PERSPECTIVES IN HEALTH CARE FACILITIES	Havali AKKAYA Dr. Öğr. Üyesi Fatma Didem TUNÇEZ
		6	SAĞLIK BİLİMLERİ FAKÜLTESİNDE YER ALAN RİSKLERİN L TİPİ RİSK DEĞERLENDİRME ANALİZİ METODU İLE DEĞERLENDİRİLMESİ ÜZERİNE BİR ARAŞTIRMA	Sılanur KÖSE Öğr. Gör. İsmail AKŞİT
		7	PERAKENDE SEKTÖRÜNDE ERGONOMİK RİSK FAKTÖRLERİ ÜZERİNE BİR ARAŞTIRMA	Doktora Öğrencisi Özgür CENGİZ Öğr. Gör. İsmail AKŞİT
		8	SAĞLIK KURUMLARINDA İŞ SAĞLIĞI VE GÜVENLİĞİ EĞİTİMLERİ VE POLİTİKA ETKİNLİĞİ	Yüksek Lisans Ögrencisi Ahmet AKTAR Dr.Ögretim Üyesi Süreyya YİĞİTALP RENÇBER
			SAĞLIKTA YAPAY ZEKA VE DİJİTALLEŞMENİN ROLÜ	Yüksek Lisans Ögrencisi Ahmet AKTAR Dr.Ögretim Üyesi Süreyya YİĞİTALP RENÇBER
			The Role of Corporate Leadership in Occupational Health and Safety: A Safety-Oriented Management Approach	Dr. Evin MİSER Dr. Cihan Serhat KART
			The Transformation of Training Processes in Occupational Health and Safety: Digitalization and Next-Generation Learning Models	Dr. Evin MİSER Dr. Cihan Serhat KART
			HAVACILIK OPERASYONLARINDA EMNİYET KÖRLÜĞÜ: ALGI–DAVRANIŞ KOPUKLUĞUNUN EMNİYET BOYUTU	Öğr. Gör. Dr. Begüm Buse SERTGÖZ Dr. Öğr. Üyesi. Armağan MACİT

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HALL / SALON 4	**Prof. Dr. Mustafa GÜNAY**	1	STATISTICAL MODELING OF THE EFFECT OF PROCESS PARAMETERS ON SURFACE ROUGHNESS IN PETG MATERIAL PARTS PRODUCED BY FDM METHOD	Prof. Dr. Fuat KARTAL Assist Prof. Arslan KAPTAN
		2	STABILIZATION OF HYGROSCOPIC MATERIALS (PETG/TPU) IN FDM PRINTING PROCESSES USING HIGH-SPEED 3D PRINTERS	Prof. Dr. Fuat KARTAL Assist Prof. Arslan KAPTAN
		3	TEL EROZYONLA İŞLEMEDE TOPLAM ENERJİ TÜKETİMİNİN OPTİMİZASYONU VE MODELLENMESİ	Öğr. Gör. Salih GÜVERCİN Prof. Dr. Mustafa GÜNAY
		4	TEL EROZYONLA İŞLEMEDE (WEDM) ENERJİ TÜKETİMİNİN ÖNEMİ	Prof. Dr. Mustafa GÜNAY
		5	Hafif Ticari Araç Koltuklarında Harness Konnektör Yarım Montaj Sorununun İyileştirilmesi ve Poke-Yoke Destekli Dizayn Uygulaması	Student Engineer İlbey KALE Sr. Designer Mutlu AKSOY
		6	OTOMOTİV KOLÇAK VE BİLEŞENLERİNDE CAM ELYAF TAKVİYELİ POLİPROPİLENİN MEKANİK VE FİNANSAL PERFORMANSI	Student Engineer İlbey KALE Enes Levent Kalkan R&D Manager Bilal Bayır
		7	ATOMİZASYON GEREKTİREN ÇÖZELTİLER İÇİN NOZUL TASARIMININ CFD ANALİZİ VE PYTHON İLE SAYISAL DOĞRULANMASI	Berke OKAY Galip ÇAPÇI
		8	ANTİK DÖNEM BRONZ OK UÇLARININ DENEYSEL ARKEOLOJİ YÖNTEMLERİYLE ÜRETİMİ VE MİKROYAPI ANALİZİ	Ayşegül ŞEKER Prof. Dr. Oktay ELKOCA
		9	FDM TEKNOLOJİSİ İLE İMAL EDİLEN ABS VE PA6 GF KOMPOZİT NUMUNELERİN BASMA DAYANIMI VE ENERJİ SÖNÜMLEME KAPASİTELERİNİN DENEYSEL OLARAK KARŞILAŞTIRMALI DEĞERLENDİRİLMESİ	Fadlullah YILDIRIM Burak BOZ Özcan ATEŞ Doç. Dr. Emre İsa ALBAK
		10	FDM YÖNTEMİYLE ÜRETİLEN İNCE CİDARLI ABS TÜPLERİN ÇARPIŞMA DAYANIMINA VE ENERJİ SÖNÜMLEME KAPASİTESİNE DİKİŞ POZİSYONUNUN ETKİSİ	Burak BOZ Fadlullah YILDIRIM Doç. Dr. Emre İsa ALBAK

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HALL / SALON 5	**Dr. Ahmet Turan DEMİR**	1	MOLECULAR ALTERATIONS AFFECTING COAGULATION AND EXTRACELLULAR MATRIX REMODELING PATHWAYS IN OSTEOARTHRITIS: A PLASMA PROTEOMICS STUDY	Duygu Sarı Ak Fatih Çon Alev Kural
		2	KUERSETİNİN ESKAPE PATOJENLERİ ÜZERİNE ANTİMİKROBİYAL VE ANTİBİYOFİLM ETKİLERİ	Yüksek Lisans Öğrencisi Abdülaziz İNANÇ Arş. Gör. Dr. Mustafa ÖKEER Arş. Gör. Dr. Ayşegül ATEŞ DEĞİRMENCİ Prof. Dr. Hüseyin TAŞLI
		3	A Chemometric Study on the Relationship Between Molecular Descriptors and Inhibitory Potency: Multivariate Analytical Profiling of Alzheimer's Disease Related Alkaloids	Dr. Ahmet Turan DEMİR
		4	Multivariate Chemometric Data Analysis in Determining the Water Solubility Profile of Drug Candidates: Development and Performance Validation of an Analytical Model	Dr. Ahmet Turan DEMİR
		5	ANTİMİKROBİYAL DİRENÇ VE TEK SAĞLIK YAKLAŞIMI	Dr. Öğr. Üyesi Elif ÇELİK Doç. Dr. Aliye GÜLMEZ SAĞLAM Araş. Gör. Dr. Seda GÖKDEMİR
		6	BIOFILM FORMATION IN BACTERIA: IMPORTANCE AND MECHANISMS	Doç. Dr. Aliye GÜLMEZ SAĞLAM Dr. Öğr. Üyesi Elif ÇELİK Araş. Gör. Dr. Seda GÖKDEMİR
		7	Genotoxic Effects of Aluminum Oxide Nanoparticles in Galleria mellonella	İrem ÖZGÜVEN Famil YUSUFOĞLU Dr. Zülbiye DEMİRTÜRK Dr. Öğr. Üyesi Fevzi UÇKAN
		8	DEVELOPMENT OF A NEW MICROBIAL BIOSENSOR BASED ON P.PUTIDA MODIFIED WITH PANI-GLUTARALDEHYDE-CYSTEAMINE-GOLD NANOPARTICLE-3-MPA FOR DETERMINATION OF CAFFEINE	Master of Science (MSc), Bahar NORGAZ Prof. Dr. Guven OZDEMIR Prof. Dr. Erol AKYILMAZ
		9	APOPTOSİS-RELATED MOLECULAR RESPONSES OF COLON TİSSUE TO INTERMİTTENT FASTİNG	Dr. Öğretim Üyesi. Hüseyin Allahverdi Araştırmaçı Vesila Yıldırım Araştırmaçı Sevcan Kabayer Doç. Dr. Taha Ceylani Doç. Dr. Hikmet Taner Teker

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HALL / SALON 6	**Prof. Dr. Vedat ÇELEBİ**	1	TEKNOLOJİ GELİŞİMİNİN KARL JASPERS'IN SINIR DURUMLARI ANLAYIŞINI TEHDİT ETMESİ: KONTROLLÜ MAKİNE YERİNE MAKİNE KONTROLLÜ VAROLUŞ PROBLEMİ ÜZERİNE FELSEFİ BİR İNCELEME	Dr. Öğr. Üyesi Muammer AKTAY
		2	THE METHOD LEADING TO CERTAIN KNOWLEDGE IN AL GHAZZALI AND DESCARTES: DOUBT?	Doç. Dr. Hüseyin Fırat ŞENOL
		3	CAUSALITY IN AL-ĠAZĀLĪ AND HUME: THE POSSIBILITY OF KNOWLEDGE BETWEEN REASON, REVELATION, AND HABIT	Doç. Dr. Hüseyin Fırat ŞENOL
		4	ZİHİN FELSEFESİNDE QUALİA KAVRAMI VE ÖZNEL DENEYİMİN NESNEL BİLGİSİ BAĞLAMINDA FİZİKALİZM ELEŞTİRİSİ	Prof. Dr. Vedat ÇELEBİ
		5	HAZ KAVRAMININ FELSEFİ VE NÖROBİYOLOJİK DÖNÜŞÜMÜ	YL. Öğr. Hacı Ali BAYTOK
		6	SCİENTİFİCİTY AND PSEUDOSCİENCE	Arş. Gör. Dr. Soykal YAKIN
		7	THE MYTH OF NEUTRAL LANGUAGE: TRUTH VS. APTNESS	Arş. Gör. Dr. Soykal YAKIN
		8	YAŞLILIĞIN ERDEMLERİ BAĞLAMINDA CICERO'NUN YAŞLILIĞA İLİŞKİN DÜŞÜNCELERİ	Dr. Öğr. Üyesi Celal SABANCI

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HALL / SALON 1	**Assoc. Prof. Dr. Elena Petrovska,**	1	DIGITAL TRANSFORMATION STRATEGIES FOR ENHANCING SUPPLY CHAIN RESILIENCE IN INDIAN MANUFACTURING FIRMS	Prof. Dr. Rajesh Gupta, Dr. Priya Sharma, Vikram Singh
		2	SUSTAINABLE BUSINESS MODEL INNOVATION THROUGH CIRCULAR ECONOMY PRACTICES IN THE INDIAN TEXTILE INDUSTRY	Assoc. Prof. Dr. Meera Patel, Arjun Desai, Neha Kapoor
		3	IMPACT OF ARTIFICIAL INTELIGENCE ADOPTION ON CUSTOMER EXPERIENCE MANAGEMENT IN INDIAN E-COMMERCE PLATFORMS	Dr. Sanjay Rao, Anjali Verma, Rohit Kumar
		4	FAMILY BUSINESS SUCCESSION PLANNING CHALLENGES AND STRATEGIES IN EMERGING INDIAN MARKETS	Prof. Dr. Anil Choudhary, Divya Malhotra
		5	FINTECH INNOVATION ECOSYSTEM DEVELOPMENT FOR FINANCIAL INCLUSION IN EGYPTIAN RURAL COMMUNITIES	Assoc. Prof. Dr. Ahmed El-Sayed, Dr. Fatima Hassan, Omar Khalil
		6	SUSTAINABLE TOURISM DEVELOPMENT STRATEGIES THROUGH COMMUNITY-BASED ENTERPRISE MODELS IN EGYPT	Dr. Nour Abdel-Malek, Youssef Ramadan
		7	BLOCKCHAIN APPLICATIONS FOR TRANSPARENT SUPPLY CHAIN MANAGEMENT IN EGYPTIAN AGRICULTURE EXPORTS	Prof. Dr. Karim Hassan, Sara Mahmoud, Assis. Prof. Dr. Ali Farouk
		8	STRATEGIC HUMAN RESOURCE MANAGEMENT PRACTICES FOR ENHANCING INNOVATION PERFORMANCE IN MACEDONIAN SMEs	Assoc. Prof. Dr. Elena Petrovska, Dr. Nikola Andonov
		9	CROSS-BORDER E-COMMERCE EXPANSION STRATEGIES FOR MACEDONIAN RETAILERS TARGETING EU MARKETS	Dr. Marija Kostovska, Goran Trajkovski, Prof. Dr. Vladimir Dimovski

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HALL / SALON 2	**Assis. Prof. Dr. Rubina Aslam,**	1	INDO-PERSIAN MINIATURE PAINTING TRADITIONS AND THEIR EVOLUTION IN MUGHAL-INFLUENCED PAKISTANI ART	Prof. Dr. Fatima Begum, Dr. Imran Qureshi, Aisha Rahman
		2	CALLIGRAPHY AS SPIRITUAL PRACTICE: ISLAMIC SCRIPTURAL ART IN CONTEMPORARY PAKISTANI MOSQUES	Assoc. Prof. Dr. Khalid Mahmood, Sana Parveen
		3	TRUCK ART ICONOGRAPHY: FOLK EXPRESSION AND NATIONAL IDENTITY IN PAKISTANI ROAD CULTURE	Dr. Naeem Akhtar, Zara Hussain, Bilal Khan
		4	TEXTILE DYEING TECHNIQUES AND SUSTAINABLE PRACTICES IN PAKISTANI AJRAK AND KHADDAR TRADITIONS	Assis. Prof. Dr. Rubina Aslam, Tariq Mehmood
		5	CONTEMPORARY ARABIC CALLIGRAPHY MOVEMENTS AND THEIR INTEGRATION IN DUBAI PUBLIC ART INSTALLATIONS	Prof. Dr. Saeed Al-Ketbi, Layla Mahmoud
		6	GULF ARABESQUE PATTERNS IN CONTEMPORARY UAE FURNITURE AND INTERIOR DESIGN	Dr. Fatima Al-Suwaidi, Hassan Rashed, Noor Salem
		7	STREET ART MOVEMENTS AND URBAN IDENTITY FORMATION IN DUBAI'S SATELLITE NEIGHBORHOODS	Assoc. Prof. Dr. Omar Bin Zayed, Amina Khalil
		8	MAASAI BEADWORK EVOLUTION AND CONTEMPORARY COMMERCIALIZATION IN URBAN KENYAN MARKETS	Prof. Dr. Njeri Mwaura, Dr. Kipchoge Arap, Esther Wanjiku
		9	CONTEMPORARY KENYAN SCULPTURE AND POSTCOLONIAL MEMORY POLITICS IN NAIROBI GALLERIES	Dr. Samuel Otieno, Assis. Prof. Dr. Wangari Mwangi, Juma Omondi

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HALL / SALON 3	**Prof. Dr. Khalid Al-Mansoori,**	1	CONFUCIAN ETHICS AND CONTEMPORARY PAKISTANI MUSLIM MORAL PHILOSOPHY: A COMPARATIVE ANALYSIS	Prof. Dr. Ahmed Raza, Fatima Sheikh, Dr. Imran Malik
		2	EXISTENTIALISM IN IQBAL'S POETRY: SELFHOOD AND AUTHENTICITY IN SOUTH ASIAN CONTEXT	Assoc. Prof. Dr. Sana Parveen, Khalid Hassan
		3	POSTCOLONIAL EPISTEMOLOGY: CHALLENGING WESTERN HEGEMONY IN PAKISTANI PHILOSOPHICAL DISCOURSE	Dr. Nabil Khan, Aisha Rahman, Assis. Prof. Dr. Tariq Mehmood
		4	ENVIRONMENTAL ETHICS IN PAKISTANI ISLAMIC PHILOSOPHY: KHALIFAH RESPONSIBILITY IN ECOLOGICAL CRISIS	Prof. Dr. Zubair Ahmed, Mariam Siddiqui
		5	ARABIC PERENNIALISM AND DUBAI'S COSMOPOLITAN PHILOSOPHY: SCHUONIAN PRINCIPLES IN GULF CONTEXT	Dr. Fatima Al-Suwaidi, Assoc. Prof. Dr. Omar Khalid, Hassan Rahim
		6	NIETZSCHEAN PERSPECTIVISM AND UAE EDUCATIONAL REFORM: VALUE PLURALISM IN K-12 CURRICULA	Prof. Dr. Khalid Al-Mansoori, Sara Ahmed
		7	HEIDEGGERIAN BEING-IN-THE-WORLD: DESERT PHENOMENOLOGY IN EMIRATI EXISTENTIAL THOUGHT	Dr. Mariam Hassan, Assis. Prof. Dr. Faisal Nasser
		8	AFRICAN UBUNTU ETHICS AND KENYAN DEVELOPMENT PHILOSOPHY: COMMUNITY ONTOLOGY IN POSTCOLONIAL CONTEXT	Kwame Njoroge, Amina Wanjiku
		9	KANTIAN AUTONOMY AND MAASAI MORAL AGENCY: REASON AND TRADITION IN EAST AFRICAN ETHICS	Assoc. Prof. Dr. Elias Olang, Dr. Zawadi Kiptoo, Samuel Lekishon

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HALL / SALON 4	**Assoc. Prof. Dr. Nadia Aslam**	1	DIGITAL TRANSFORMATION STRATEGIES FOR SMALL AND MEDIUM ENTERPRISES IN PAKISTAN'S TEXTILE INDUSTRY	Prof. Dr. Ahmed Zubair, Sara Khan, Dr. Faisal Mahmood
		2	SUSTAINABLE SUPPLY CHAIN PRACTICES AND FIRM PERFORMANCE IN PAKISTANI AGRI-BUSINESS SECTOR	Assoc. Prof. Dr. Nadia Aslam, Bilal Raza
		3	LEADERSHIP STYLES AND ORGANIZATIONAL RESILIENCE DURING ECONOMIC CRISES IN PAKISTANI MANUFACTURING	Dr. Imran Malik, Ayesha Siddiqui, Hassan Nawaz
		4	CONSUMER BEHAVIOR SHIFTS TOWARD HALAL CERTIFIED PRODUCTS IN URBAN PAKISTANI MARKETS	Assis. Prof. Dr. Rabia Younus, Zainab Ahmed
		5	FINTECH ADOPTION BARRIERS AND OPPORTUNITIES IN ALGERIAN SMES POST-DIGITAL REFORMS	Prof. Dr. Karim Belhadj, Dr. Nadia Lounis
		6	CORPORATE GOVERNANCE REFORMS AND FAMILY BUSINESS SUSTAINABILITY IN ALGERIA	Assoc. Prof. Dr. Samir Hadji, Amina Zerrouki, Mehdi Boualem
		7	GREEN MARKETING STRATEGIES EFFECTIVENESS IN ALGERIAN CONSUMER GOODS INDUSTRY	Dr. Yasmin Cherif
		8	INNOVATION MANAGEMENT PRACTICES IN SERBIAN TECH STARTUPS POST-PRIVATIZATION ERA	Prof. Dr. Milan Petrovic, Dr. Ana Jovanovic, Nikola Stanic
		9	CROSS-CULTURAL NEGOTIATION STRATEGIES IN SERBIAN-BALKAN BUSINESS EXPANSION	Assoc. Prof. Dr. Jelena Markovic, Igor Vukovic

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HALL / SALON 5	**Assis. Prof. Dr. Shabnam Jahan,**	1	DECENTRALIZATION REFORMS AND LOCAL GOVERNANCE EFFECTIVENESS IN RURAL BANGLADESH UNION PARISHADS	Prof. Dr. Rahman Karim, Dr. Fatima Begum, Shahidul Islam
		2	CORRUPTION PERCEPTION AND PUBLIC TRUST IN BANGLADESH CIVIL SERVICE REFORMS	Assoc. Prof. Dr. Nasrin Sultana, Arefin Hossain
		3	PUBLIC-PRIVATE PARTNERSHIP MODELS FOR INFRASTRUCTURE DEVELOPMENT IN FLOOD-PRONE BANGLADESH REGIONS	Dr. Mustafa Kamal, Laila Akter, Zahid Rahman
		4	WOMEN'S POLITICAL PARTICIPATION AND GENDER QUOTAS IN BANGLADESH LOCAL GOVERNMENT ELECTIONS	Assis. Prof. Dr. Shabnam Jahan, Rasheda Khanam
		5	E-GOVERNMENT ADOPTION CHALLENGES AND DIGITAL DIVIDE IN NIGERIAN FEDERAL AGENCIES	Prof. Dr. Adebayo Ogunleye, Chioma Eze
		6	FISCAL FEDERALISM AND REVENUE ALLOCATION FORMULAS IN MULTI-ETHNIC NIGERIA	Dr. Fatima Yusuf, Emeka Nwosu, Assoc. Prof. Dr. Bola Adeyemi
		7	ANTI-CORRUPTION AGENCIES EFFECTIVENESS AND POLITICAL INTERFERENCE IN NIGERIAN GOVERNANCE	Assis. Prof. Dr. Ngozi Okonkwo, Tunde Afolabi

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HALL / SALON 6	**Dr. Nazma Chowdhury,**	1	THE IMPACT OF CLIMATE-INDUCED DISPLACEMENT ON MENTAL HEALTH AMONG RURAL YOUTH IN BANGLADESH	Prof. Dr. Rahman Karim, Dr. Fatima Begum, Arif Hossain
		2	PARENTING STYLES AND ACADEMIC STRESS AMONG UNIVERSITY STUDENTS IN URBAN BANGLADESH	Assoc. Prof. Dr. Sultana Akter, Md. Sharif Ullah
		3	GENDER ROLES AND DEPRESSIVE SYMPTOMS IN RURAL BANGLADESH WIVES FACING EARLY MARRIAGE	Dr. Nazma Chowdhury, Rasheda Khanam, Protik Ahmed
		4	SOCIAL MEDIA ADDICTION AND SELF-ESTEEM AMONG BANGLADESHI ADOLESCENTS IN URBAN SLUMS	Assis. Prof. Dr. Imran Hossain, Laila Rahman
		5	POST-TRAUMATIC GROWTH AMONG BOKO HARAM KIDNAPPING SURVIVORS IN NORTHERN NIGERIA	Prof. Dr. Amina Yusuf, Chinedu Okoro
		6	WORKPLACE SPIRITUALITY AND EMPLOYEE WELL-BEING IN NIGERIAN OIL INDUSTRY COMPANIES	Dr. Ngozi Eze, Assoc. Prof. Dr. Tunde Adebayo, Fatima Aliyu
		7	ADOLESCENT IDENTITY FORMATION AMONG NIGERIAN STREET CHILDREN IN LAGOS METROPOLIS	Dr. Kemi Ogunleye, Samuel Nwosu
		8	CULTURAL FACTORS INFLUENCING DEPRESSION EXPRESSION AMONG MACEDONIAN ELDERLY POPULATIONS	Prof. Dr. Elena Petrovska, Dr. Marko Ivanov
		9	WORKPLACE MOBBING AND PSYCHOLOGICAL RESILIENCE AMONG MACEDONIAN PUBLIC SERVANTS	Assoc. Prof. Dr. Ana Georgieva, Nikola Todorov, Dr. Slavica Risteska

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HALL / SALON 7	**Assoc. Prof. Dr. Fatuma Chege**	1	CULTURALLY RESPONSIVE PEDAGOGY IN IRANIAN EFL CLASSROOMS: INTEGRATING PERSIAN LITERATURE WITH MODERN LANGUAGE TEACHING METHODS	Prof. Dr. Reza Ahmadi, Soraya Mahmoudi, Ali Jafari
		2	STEM EDUCATION REFORM THROUGH PROJECT-BASED LEARNING IN RURAL IRANIAN SECONDARY SCHOOLS	Assoc. Prof. Dr. Mina Hosseini, Dr. Farhad Karimi, Zahra Bahrami
		3	DIGITAL LITERACY DEVELOPMENT AMONG IRANIAN UNIVERSITY STUDENTS: CHALLENGES AND OPPORTUNITES IN HYBRID LEARNING ENVIRONMENTS	Dr. Hassan Tavakoli, Leila Najafi
		4	INCLUSIVE EDUCATION PRACTICES FOR STUDENTS WITH LEARNING DISABILITIES IN IRANIAN PRIMARY SCHOOLS	Assis. Prof. Dr. Parisa Rahmani, Mohammad Rezaei, Fatemeh Soltani
		5	MOBILE LEARNING APPLICATIONS FOR NOMADIC PASTORALIST COMMUNITIES IN KENYAN ARID REGIONS	Prof. Dr. James Mwangi, Esther Kiptoo
		6	TEACHER PROFESSIONAL DEVELOPMENT THROUGH PEER COACHING IN KENYAN PUBLIC SECONDARY SCHOOLS	Dr. Agnes Njoroge, Samuel Otieno, Miriam Chebet
		7	GENDER EQUITY INTERVENTIONS IN STEM SUBJECTS AMONG KENYAN RURAL GIRLS	Assoc. Prof. Dr. Fatuma Chege
		8	BLENDED LEARNING MODELS FOR OMANI TECHNICAL VOCATIONAL EDUCATION AND TRAINING INSTITUTES	Prof. Dr. Salim Al-Harthi, Dr. Noor Al-Maskari
		9	SUSTAINABLE EARTH LITERACY CURRICULA FOR OMANI PRIMARY SCHOOLS INCORPORATING BEDOUIN ECOLOGICAL KNOWLEDGE	Assoc. Prof. Dr. Aisha Al-Rashidi, Khalid Al-Mahrooqi

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HALL / SALON 8	**Assoc. Prof. Dr. Youssef Hadji**	1	LATE PERIOD FUNERARY PRACTICES AND SOCIAL HIERARCHY IN SAQQARA NECROPOLIS EXCAVATIONS	Prof. Dr. Ahmed El-Sayed, Dr. Fatima Hassan, Karim Abdel
		2	PREDYNASTIC POTTERY TRADITIONS AND CULTURAL INTERACTIONS ALONG THE NILE DELTA	Assoc. Prof. Dr. Nour El-Din, Mariam Saleh
		3	NEW KINGDOM TEMPLE ECONOMIES AND WORKFORCE ORGANIZATION AT KARNAK COMPLEX	Dr. Hassan Mahmoud, Layla Karim, Prof. Dr. Omar Rashad
		4	ROMAN PERIOD TEXTILE PRODUCTION AND TRADE NETWORKS IN FAYUM DEPRESION SITES	Assis. Prof. Dr. Sara Ahmed, Tariq El-Feki
		5	BERBER ROCK ART TRADITIONS AND SYMBOLIC LANDSCAPES IN TASSILI N'AJJER PLATEAU	Prof. Dr. Malik Brahimi, Dr. Amina Zeroual
		6	PUNIC-PHOENICIAN COMMERCIAL INFRASTRUCTURE IN ALGERIAN COASTAL SETTLEMENTS	Assoc. Prof. Dr. Youssef Hadji, Nadia Belkacem
		7	ISLAMIC ERA WATER MANAGEMENT SYSTEMS IN MEDIEVAL ALGERIAN KSOUR	Dr. Karim Mansouri, Assis. Prof. Dr. Leila Dahmani, Sami Nour
		8	INDUS VALLEY URBAN PLANNING PRINCIPLES IN MATURE HARAPPAN SETTLEMENTS OF PAKISTAN	Prof. Dr. Rafiq Ahmed, Sara Khan
		9	BUDDHIST STUPA COMPLEXES AND PILGRIMAGE ECONOMIES IN GANDHARAN REGIONS	Assoc. Prof. Dr. Imran Malik, Dr. Ayesha Rehman, Tariq Farooq

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HALL / SALON 9	Dr. Hala Ibrahim	1	CULTURALLY RESPONSIVE PEDAGOGY FOR INTEGRATING ISLAMIC VALUES IN EGYPTIAN STEM CLASSROOMS	Prof. Dr. Ahmed El-Sayed, Dr. Fatima Hassan, Omar Khalil
		2	DIGITAL STORYTELLING APPROACHES TO ENHANCE LITERACY DEVELOPMENT IN RURAL EGYPTIAN PRIMARY SCHOOLS	Assoc. Prof. Dr. Nadia Mahmoud, Karim Abdel Rahman
		3	TEACHER MENTORSHIP PROGRAMS FOR IMPROVING CLASSROOM MANAGEMENT IN CAIRO PUBLIC SCHOOLS	Dr. Hala Ibrahim, Youssef Salem, Assis. Prof. Dr. Mariam Fouad
		4	STEMINTEGRATED ARTS EDUCATION FOR FOSTERING CREATIVITY IN EGYPTIAN MIDDLE SCHOOLS	Prof. Dr. Khaled Osman, Sara Ahmed
		5	MULTILINGUAL PEDAGOGY STRATEGIES FOR BERBER-SPEAKING STUDENTS IN ALGERIAN PRIMARY EDUCATION	Assoc. Prof. Dr. Amina Belkacem, Dr. Karim Hadji
		6	VOCATIONAL TRAINING REFORMS INCORPORATING GENDER EQUITY IN ALGERIAN TECHNICAL INSTITUTES	Dr. Samir Lounis, Nadia Zerhouni, Rachid Boualem
		7	CRITICAL PEDAGOGY APPROACHES TO ADDRESSING POSTCOLONIAL IDENTITIES IN ALGERIAN UNIVERSITIES	Prof. Dr. Farid Benali, Leila Mansouri
		8	INCLUSIVE DIGITAL LEARNING ENVIRONMENTS FOR RURAL STUDENTS IN PAKISTANI PUBLIC SCHOOLS	Assoc. Prof. Dr. Sana Iqbal, Dr. Imran Khan, Ayesha Rahman
		9	TEACHER PROFESSIONAL LEARNING COMMUNITIES FOR IMPROVING PEDAGOGICAL PRACTICES IN KARACHI SLUMS	Dr. Zahra Malik, Bilal Ahmed, Assis. Prof. Dr. Nida Farooq

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HALL / SALON 1	**Prof. Dr. Rüştü ILGAR**	1	KIYI COĞRAFYASININ İNSAN DAVRANIŞLARINA ETKİSİ: ÇANAKKALE'DE KÜLTÜREL VE SOSYO-EKONOMİK YANSIMALAR	Prof. Dr. Rüştü ILGAR
		2	ÇANAKKALE İLİ TRAFİK SORUNLARI: 2025 YILI DEĞERLENDİRMESİ VE POLİTİKA ÖNERİLERİ	Prof. Dr. Rüştü ILGAR
		3	KIRSAL ALANLARDA SOSYAL DİRENÇLİLİĞİN ANALİZİ: TUZLA ÇAYI HAVZASI (AYVACIK)	Yüksek Lisans Öğrencisi Zeynep YALÇIN Doç. Dr. Faize SARIŞ
		4	YAT TURİZMİ VE MARİNACILIĞA COĞRAFİ YAKLAŞIMLAR: PARADİGMALAR, YÖNTEMLER VE ARAŞTIRMA EĞİLİMLERİ	Berat EMİRAL Prof. Dr. Kadir TEMURÇİN
		5	BAFRA OVASI'NDA ANIZ YAKIMININ ÇEVRESEL ETKİLERİ VE EKOSİSTEM BASKILARI	Doçent Doktor Ali İMAMOĞLU
		6	ORMAN OKULU LİSANSÜSTÜ EĞİTİMİNE YÖNELİK TEZLERİN BİBLİYOGRAFİK ANALİZİ	Doçent Doktor Ali İMAMOĞLU
		7	SCIENTIFIC EVALUATION OF THE GEOHERITAGE POTENTIAL OF YARALIGÖZ MOUNTAIN (KASTAMONU)	Prof. Dr. Ekrem MUTLU Yüksek Lisans Öğrencisi Dilara KIVANÇ
		8	SUĞLA GÖLÜ VE YAKIN ÇEVRESİNİN JEOMORFOLOJİK ÖZELLİKLERİ	Ebru YILDIRIM Prof. Dr. Yıldırım ATAYETER

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HALL / SALON 2	**Prof. Dr., BANU KARAŞAH Assoc. Prof. Dr., EMİNE TARAKCİ EREN**	1	RETHINKING CITIES FROM A METABOLIC PERSPECTIVE	Araş. Gör. Ebru ALA
		2	ÇOCUK DOSTU KENT PERSPEKTİFİNDEN MİLLET BAHÇELERİ REHBERİ'NİN DEĞERLENDİRİLMESİ	Dr. Şehir Plancısı Gizem KARACAN TEKİN
		3	İKLİM VE HİDROJEOMORFOLOJİK BASKILAR ALTINDA NEMRUT KRATER GÖLÜ'NÜN KIYI EVRİMİ (1984–2024)	Dr. Öğr. Üyesi Alperen MERAL
		4	CLIMATE-RESPONSIVE URBAN ROOFSCAPES: A SYSTEMATIC REVIEW AND A NEW HYBRID ROOF ECOSYSTEM SERVICES MATRIX	Asst. Prof. Dr. Sinan KORDON Ahmet KARCI Asst. Prof. Dr. Mahmut TUĞLUER
		5	ECO-MEMORY AND LANDSCAPE ARCHITECTURE	Arş. Gör. Büşra KUTLU Arş. Gör. İlknur YAZICI
		6	THE ROLE OF LANDSCAPE ARCHITECTURE IN RURAL TOURISM AREAS	Arş. Gör. İlknur YAZICI Arş. Gör. Büşra KUTLU
		7	COMPLEMENTARY ELEMENTS OF SPACE: FURNITURES	Prof. Dr., BANU KARAŞAH Assoc. Prof. Dr., EMİNE TARAKCİ EREN
		8	FORM EXPRESSIONS VIA LINEARITY AND EFFECTIVE ENVIRONMENT: BASIC DESIGN STUDIO EXPERIENCE	Prof. Dr., BANU KARAŞAH Assoc. Prof. Dr., EMİNE TARAKCİ EREN
			TÜRKİYE'DE KENTSEL KIYILARIN ERİŞİM VE KULLANIMI İLE İLGİLİ HAZIRLANAN LİSANSÜSTÜ TEZLERİN DEĞERLENDİRİLMESİ (1998-2025)	Doğa ÖZAKÇE Prof. Dr. Neriman YÖRÜR

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HALL / SALON 3	**Asst. Prof. Dr. Fatma CAVUS YONAR**	1	THE SCIENTIFIC FOOTPRINT OF A SILENT EPIDEMIC GLOBAL PUBLICATION TRENDS IN POSTMORTEM TOXICOLOGY STUDIES ON FENTANYL AND ITS DERIVATIVES	Asst. Prof. Dr. Fatma CAVUS YONAR
		2	FROM THE SILENT REGIONS OF THE GENOME TO ADDICTION: ncDNA and EPIGENETIC BIOMARKERS	MSc. Sena Nur KADEM Asst. Prof. Dr. Fatma CAVUS YONAR
		3	THE EFFECTS OF TECHNOLOGY-ASSISTED NEUROMOTOR TRAINING APPLICATIONS ON FUNCTIONALITY IN GERIATRIC REHABILITATION	Müşerref Ebru ŞEN Filiz ÖZDEMİR
		4	USE OF CLINICAL DECISION SUPPORT SYSTEMS IN PHYSIOTHERAPY	Müşerref Ebru ŞEN Filiz ÖZDEMİR
		5	ACİL SERVİSTE ADLİ OLGU YÖNETİMİ: İLK DEĞERLENDİRME VE BİLDİRİM SÜREÇLERİ	Dr. Öğr. Üyesi Samet KIYAK
		6	KARDİYOVASKÜLER HASTALIKLARDA EVDE BAKIM UYGULAMALARININ YAŞAM KALİTESİNE ETKİSİ	Öğr. Gör. Dr., Zeynep YILDIRIM Doç. Dr., Sonay BİLGİN
		7	HYALURONIC ACID'S BIOLOGICAL IMPORTANCE AND UTILIZATION IN HEALTHCARE	Sana TAGHVAMANESH Assoc. Prof. Fatma AYAZ
		8	THE ROLE OF NEXT GENERATION SEQUENCING IN RARE DISEASES	Dilara YILDIRIM Sinem DÖNMEZ Zeynep Azra ER Nermin AKÇALI
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HALL / SALON 4	**Doç. Dr. Öner USLU**	1	ÖĞRENCİLERİN ÖĞRENME İKLİMİ ALGILARININ İNCELENMESİ: MENTÖR DESTEKLİ ÖĞRETMEN MESLEKİ GELİŞİM PROGRAMI İÇİN ALTYAPI ARAŞTIRMASI	Doç. Dr. Öner USLU Araş. Gör. Ece ÇOKAY TAŞCIOĞLU Dr. Nil AYKOL Dr. Duygu KANDEMİRCİ BAYIZ
		2	ÖĞRENCİLERİN OKUL DOYUMUNUN İNCELENMESİ: MENTÖR DESTEKLİ ÖĞRETMEN MESLEKİ GELİŞİM PROGRAMI İÇİN ALTYAPI ARAŞTIRMASI	Doç. Dr. Öner Uslu Dr. Nil AYKOL Dr. Duygu KANDEMİRCİ BAYIZ Araş. Gör. Ece ÇOKAY TAŞCIOĞLU
		3	İLKÖĞRETİM KURUMLARINDA GÖREV YAPAN SINIF ÖĞRETMENLERİNİN YAPAY ZEKA DESTEKLİ DERS ÖĞRETİMİNE İLİŞKİN GÖRÜŞ VE DENEYİMLERİ, KARŞILAŞILAN SORUNLAR VE ÇÖZÜM ÖNERİLERİ	Prof. Dr. Necdet KONAN Şeyma DAĞDELEN
		4	OKUL YÖNETİCİLERİNİN OKUL YÖNETİMİNDE YAPAY ZEKÂ UYGULAMALARINA İLİŞKİN GÖRÜŞ, DENEYİM VE ÖNERİLERİ	Prof. Dr. Necdet KONAN Olcay SOLMAZ
		5	THE RELATIONSHIP BETWEEN DEMOGRAPHIC STATUS AND PSYCHOLOGICAL CONSTRUCTION AND EMOTIONAL INTELLIGENCE IN CHILDREN	Dr. İskender GÜLER Burcu FİDEL
		6	ASSESSMENT OF EMOTIONAL INTELLIGENCE AND PSYCHOLOGICAL CHARACTERISTICS IN CHILDREN	Burcu FİDEL Dr. İskender GÜLER
		7	2018 VE 2024 HAYAT BİLGİSİ DERSİ ÖĞRETİM PROGRAMLARININ KARŞILAŞTIRILMASI	Sultan ERTURAL Bengü Gizem AYAZ
		8	ÖĞRETMEN VE OKUL İDARECİLERİNİN ÖĞRETMENLİK KARİYER BASAMAKLARININ OKUL İKLİMİNE YANSIMALARINA YÖNELİK GÖRÜŞLERİ	Özgür DEMİRDAŞ Doç. Dr. Zeynep DEMİRTAŞ

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HALL / SALON 5	**Assistant Professor, Hasan Giray Ankara Assistant Professor, Hakan Değerli**	1	THE EFFECT OF CAMPAIGNS ON HEALTH PRODUCTS IN E-COMMERCE: DETERMINANTS OF VITAMIN SALES RANKINGS DURING THE BLACK FRIDAY PERIOD	Res. Asst. Gökçen ÇELİKER Res. Asst. Burak TEKEREK
		2	AN EXAMINATION OF PERCEPTIONS TOWARD HEALTHCARE INSTITUTIONS IN TÜRKİYE THROUGH EKŞİ SÖZLÜK USER ENTRIES	Res. Asst. Burak TEKEREK Res. Asst. Gökçen ÇELİKER
		3	THE EFFECT OF HEALTHCARE WORKERS' MENTAL WORKLOAD PERCEPTION ON ORGANIZATIONAL COMMITMENT: A QUALITATIVE STUDY	Assistant Professor Tuğba MERT EMİROĞLU Mevlüt SARIÇAM
		4	THE EFFECTS OF DIGITAL HEALTH APPLICATIONS ON THE PHARMACEUTICAL MARKET AND HEALTH ECONOMICS: A LITERATURE-BASED REVIEW	Dr. Sümeyye GÖKÇENOĞLU
		5	SAĞLIK ÇALIŞANLARININ MEDİKAL TURİZME YÖNELİK FARKINDALIKLARI: BİR LİTERATÜR ARAŞTIRMASI	Yüksek Lisans Öğrencisi Yağmur Okumuş Prof. Dr. Emine Öter Gerçek
		6	OPINIONS OF HEALTHCARE EMPLOYEES ON INTERNAL AND EXTERNAL AUDITS: A QUALITATIVE STUDY	Dr. Öğr. Üyesi Tuğba MERT EMIROĞLU Mehmet Veysel SAYAN
		7	SAĞLIK TURİZMİ KAPSAMINDA HASTA DENEYİMLERİ ÜZERİNE BİR İNCELEME	Doktora Öğrencisi Sibel YAĞCİ Doç. Dr. Sevim KOÇER
		8	ECONOMIC OUTCOMES OF GREEN AND SUSTAINABLE MANAGEMENT PRACTICES IN HOSPITALS: A SYSTEMATIC REVIEW	Assistant Professor, Hasan Giray Ankara Assistant Professor, Hakan Değerli

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		2	AN AGILE APPROACH FOR THE INTEGRATION OF SYSTEMS ENGINEERING AND SOFTWARE DEVELOPMENT TEAMS IN THE DEFENSE INDUSTRY THROUGH THE NEXUS FRAMEWORK	Dr. Pürnur FIRAT
		3	PARÇACIK SÜRÜ OPTİMİZASYONUNA DAYALI SEZGİSEL BULANIK REGRESYON FONKSİYONLARI YAKLAŞIMI	Prof. Dr. Eren Baş Prof. Dr. Erol EĞRİOĞLU
		4	PREDICTION OF GROUNDWATER LEVELS WITH MULTI-MODEL APPROACHES: ARIMAX, VAR, MACHINE LEARNING AND SHAP-BASED EXPLAINABILITY ANALYSIS	Melike Nur KOÇAK KATİPOĞLU Asst. Prof. Zeynep Özge TERZİOĞLU
		5	MODERN ORDULARDA İNSANSIZ HAVA ARAÇLARININ TAKTİK KULLANIMINDA YAPAY ZEKANIN ETKİNLİĞİ	Serkan BALCI Dr. Sonay GÖRGÜLÜ BALCI Doç. Dr. Zühtü Onur PEHLİVANLI
		6	B2C E-TİCARET SİPARİŞ SÜREÇLERİNİN SÜREÇ MADENCİLİĞİ İLE ANALİZİ: SİPARİŞTEN TESLİMAT, İPTAL VE İADE SÜREÇLERİ ÜZERİNE BİR İNCELEME	Dr. Fettah KURTULUŞ
		7	OPTIMIZATION STABILITY UNDER VARYING LEARNING RATES FOR RETINAL DISEASE CLASSIFICATION	Asst. Prof. Dr. İsmail IRMAKÇI
		8	REGULARIZATION SENSITIVITY OF DEEP LEARNING ARCHITECTURES ON THE OCTMNIST BENCHMARK	Asst. Prof. Dr. İsmail IRMAKÇI
			HYBRID META-HEURISTIC FEATURE SELECTION FOR RESNET101-BASED OLIVE PEACOCK EYE DISEASE DETECTION	Dr. Cumali TÜRKMENOĞLU Ar-Ge Müdürü, Murat In

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HALL / SALON 7	**Res. Asst. Ender Can YAKAR**	1	EFFECT OF NANOSILICA REINFORCEMENT ON THE MICROHARDNESS, DENSITY, AND MICROSTRUCTURES OF EPOXY RESIN COMPOSITES	Mikail Aslan
		2	EFFECT OF MICROSIZED MGO REINFORCEMENT ON THE MICROHARDNESS, DENSITY, AND MICROSTRUCTURES OF EPOXY RESIN COMPOSITES	Mikail Aslan
		3	ASSESSMENT OF EXPERIMENTAL VARIABLES IN FIBRE LASER POLISHING OF TI6AL4V ALLOY UTILISING COMSOL SIMULATION	Res. Asst. Ender Can YAKAR Prof. Sinan FİDAN Prof. Satılmış ÜRGÜN Prof. Mustafa Özgür BORA
		4	THERMAL MODELLING OF LASER ABLATION GEOMETRY AND SURFACE ROUGHNESS ON TI6Al4V USING COMSOL MULTIPHYSICS	Res. Asst. Ender Can YAKAR Prof. Sinan FİDAN Prof. Satılmış ÜRGÜN Prof. Mustafa Özgür BORA
		5	STRUCTURAL and MORPHOLOGICAL PROPERTIES of Fe 3 O 4 NANOPOWDERS	Öğr. Gör. Tarık BAYDAR Doç. Dr. Naim ASLAN Prof. Dr. Hüseyin ERTAP Prof. Dr. Seydi DOĞAN
		6	EFFECT OF SURFACE PURGING ON THE MECHANICAL PROPERTIES OF COMPOSITE/METAL HYBRID SYSTEMS	Y.L. Öğrenci, Mustafa ÖZDEMİR Doç. Dr., S. Bahar BAŞTÜRK
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HALL / SALON 8	Doç. Dr. Demet DÖNMEZ	1	E-TİCARET PLATFORMLARININ ÇOK KRİTERLİ KARAR VERME YÖNTEMİ VE BİBLİYOMETRİK ANALİZ İLE SEÇİMİ	Aslı GÜLER Doç. Dr. Ayten YILMAZ YALÇINER
		2	HAVACILIK SEKTÖRÜNDE UÇUŞ BAZLI KARBON DİOKSİT EMİSYONLARININ AZALTILMASINA YÖNELİK VERİ TABANLI BİR KARAR DESTEK MODELİ	Huzeyfe ÖZSOY Doç. Dr. Ayten YILMAZ YALÇINER
		3	AÇIK ÇALIŞMA VERİLERİYLE ÖZ-YÖNETİMİN ÖLÇÜMÜ: UZAKTAN VE DİJİTAL ÇALIŞMADA OTONOMİ, İZLEME VE DAVRANIŞSAL UYUMUN NİCEL ANALİZİ	Doç. Dr. Demet DÖNMEZ
		4	AÇIK SOSYAL POLİTİKA VERİLERİYLE ÖZ-DÜZENLEME SÖYLEMİ: AVRUPA'DA BİREYSEL SORUMLULUK, SOSYAL KORUMA VE DEVLET BEKLENTİSİ İLİŞKİSİ	Doç. Dr. Demet DÖNMEZ
		5	ALGORİTMİK ŞEFFAFLIK Mİ, BÜROKRATİK SESSİZLİK Mİ? AVRUPA BİRLİĞİ KOMİSYONU'NDA KARAR ALMA SÜREÇLERİNİN AÇIK VERİYLE HARİTALANMASI	Doç. Dr. Soner AKIN
		6	GÖRÜNÜR TEMSİL, ÖLÇÜLEBİLİR ETKİ: AVRUPA PARLAMENTOSU'NDA SİYASAL GÜCÜN NİCEL ANATOMİSİ	Doç. Dr. Soner AKIN
		7	ÜRÜN DEĞİŞİKLİKLERİNİN SÜRDÜRÜLEBİLİR YÖNETİMİ: PLM- KONFİGÜRASYON-DÖNGÜSEL EKONOMİ ÜÇGENİ	Gökhan TOLUK
		8	ÖZBEKİSTAN MOBİLYA ENDÜSTRİSİNİN EKONOMİK POTANSİYELİ VE GELECEĞİ	Dr. Öğr. Üyesi Belgin ŞEKER HIRÇIN
		9	TÜRKMENİSTAN MOBİLYA SEKTÖRÜ- EKONOMİ, DIŞ TİCARET VE GİRİŞİMCİLİK	Gulzira GULMURATOVA Dr. Öğr. Üyesi Belgin ŞEKER HIRÇIN
		10	DIGITALIZATION IN LABOR MARKETS AND THE TRANSFORMATION OF WORK: A THEORETICAL FRAMEWORK	Asistant Profesor Dr. Cihan Serhat Kart Lecturer Dr. Evin Miser
		11	THE DIALECTICAL RELATIONSHIP BETWEEN ECONOMIC GROWTH AND INCOME INEQUALITY: A THEORETICAL AND STRUCTURAL ANALYSIS FROM THE CLASSICAL PARADIGM TO MODERN APPROACHES	Asistant Profesor Dr. Cihan Serhat Kart Lecturer Dr. Evin Miser
		12	SOSYAL GÜVENLİK VE BAKIM REJİMİ KADIN İSTİHDAMINI ŞEKİLLENDİRİR Mİ? EUROSTAT AÇIK VERİLERİYLE NUTS-2 DÜZEYİNDE MEKÂNSAL PANEL ANALİZ	Prof. Dr. Mehmet DURUEL Mehmet MUTLU
		13	SOSYAL GÜVENLİK HARCAMALARININ YENİDEN DAĞITIM ETKİNLİĞİ: OECD SOCX VE SWIID AÇIK VERİLERİYLE BİLEŞİM-TEMELLİ PANEL ANALİZİ	Prof. Dr. Mehmet DURUEL Mehmet MUTLU

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HALL / SALON 9	**Doç. Dr. Bilge Kaan TEKELİOĞLU**	1	KARS İLİNDE SÜT SIĞIRI İŞLETMELERİNDE YETİŞTİRİCİLERİN ÖĞRENİM DURUMUNUN KOLOSTRUM YÖNETİMİ, SÜTTEN KESME YAŞI VE SAĞIM UYGULAMALARINA ETKİSİ	Veteriner Hekim Bahar GÜLBUDAK Doç. Dr. Buket BOĞA KURU
		2	SÜT SIĞIRI İŞLETMELERİNDE YETİŞTİRİCİ YAŞI KOLOSTRUM YÖNETİMİNİ, SÜTTEN KESME YAŞINI VE SAĞIM UYGULAMALARINI ETKİLER Mİ? KARS İLİ ÖRNEĞİ	Veteriner Hekim Bahar GÜLBUDAK Doç. Dr. Buket BOĞA KURU
		3	İNFLAMATUVAR BAĞIRSAK HASTALIKLARINDA OKSİDATİF STRES BELİRTEÇLERİ	Veteriner Hekim Özge AVŞAR Arş.Gör.Haceli ÖCAL Dr.Öğr.Üyesi Ali ŞENOL
		4	AVIAN CORONAVIRUSES	Doç. Dr. Bilge Kaan TEKELİOĞLU
		5	PARVOVIRIDAE	Duygu ARSLANHAN Doç. Dr. Bilge Kaan TEKELİOĞLU
		6	RATLARDA KİMYASAL KARSİNOJENLERLE İNDÜKLENEN ORGAN SPESİFİK KANSER MODELLERİ	Öğr. Gör. Muhammed Zahid ARI Prof.Dr.Miyase ÇINAR Dr.Öğr.Üyesi Ali ŞENOL
		7	THE EFFECTS OF CLIMATE CHANGE ON INFECTIOUS DISEASES IN GREY PARROTS (PSITTACUS ERITHACUS)	Mustafa Necati MUZ, Ebu Derda Günay, Dilek MUZ, Emine İrem DEVECİ, İpek Nur KARAKUŞ,
		8	MEDIBEES EU PROJECT: CLIMATE CHANGE AND THE FUTURE OF MEDITERRANEAN BEEKEEPING	Mustafa Necati Muz Raquel Martín-Hernández Antonio Nanetti Alice Pinto Marion Zammit Mangion Chadi Hosri Noureddine Adjlane Banan Al Shagoor Dilek MUZ
			LABORATUVAR HAYVANLARINDA DENEYSEL TÜMÖR MODELLERİ	Merve Bişkin Türkmen

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HALL / SALON 10	**Dr. Öğr. Üyesi Merve Nihan ERTEKİN KAYA**	1	PERSONALIZED LEARNING IN INSTRUMENTAL EDUCATION WITH GENERATIVE ARTIFICIAL INTELLIGENCE: AN EXAMINATION OF APPLICATIONS FOR INSTRUMENT LEARNING AND PERFORMANCE ANALYSIS	Dr. Öğr. Üyesi Merve Nihan ERTEKİN KAYA
		2	GRADUATE MUSIC EDUCATION STUDENTS' PERCEPTIONS OF SCIENTIFIC RESEARCH AND PUBLICATION ETHICS	Dr. Öğr. Üyesi Merve Nihan ERTEKİN KAYA
		3	THE THREE PIONEERING FIGURES OF MODERN MUSICOLOGY: ADORNO, KERMAN AND DAHLHAUS	Asst. Prof. Dr. İsmail GÜNGÖR
		4	TEMSİL, DÖNÜŞÜM VE YORUM: GOETHE'NİN FAUST METNİYLE GOUNOD'NUN FAUST OPERASI ARASINDA DİSİPLİNLERARASI ANALİZ	Can Reha GÜN
		5	BIBLIOMETRIC EVALUATION OF TURKISH MUSIC STUDIES ON THE WEB OF SCIENCE DATABASE	Okan Umut AKSEL
		6	TRENDS IN METAPHOR RESEARCH WITHIN THE FIELD OF MUSIC: AN EXAMINATION OF PUBLICATIONS FROM 2023–2025	Yüksek Lisans Öğrencisi, Zeynep VARDAR Dr. Öğr. Üyesi, Ezgi ERTEK-BABAÇ
		7	ŞİLE MANAV TÜRKLERİNİN MÜZİK GELENEĞİNDE MÜZİK ALETLERİNİN ÖZELLİKLERİ VE YERİ	Doç. Dr. Leyla GAFAROVA Yüksek Lisans Öğrencisi Sinem Perihan CAN
		8	MÜZİK ENDÜSTRİSİNDE İŞ BİRLİĞİ AĞLARI: SOSYAL AĞ ANALİZİ PERSPEKTİFİNDEN BİR LİTERATÜR TARAMASI	Arş. Gör. Aslı KILIÇ

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HALL / SALON 1	**Dr. Sofia Kotsi**	1	METAPHORICAL CONCEPTUALIZATIONS OF TIME IN PERSIAN POETRY FROM THE SAFAVID ERA	Prof. Dr. Reza Hosseini, Soraya Ahmadi, Ali Tavakoli
		2	PRAGMATIC FUNCTIONS OF INDIRECT SPEECH ACTS IN CONTEMPORARY IRANIAN POLITICAL DISCOURSE	Dr. Mina Karimi, Assoc. Prof. Dr. Farhad Jafari
		3	DISCOURSE ANALYSIS OF GENDER REPRESENTATIONS IN POST-REVOLUTIONARY IRANIAN CINEMA	Fatemeh Rahmani, Dr. Babak Salehi, Neda Zamani
		4	COGNITIVE LINGUISTICS APPROACH TO COLOR TERMINOLOGY IN CLASSICAL PERSIAN TEXTS	Assoc. Prof. Dr. Shahram Nemati
		5	POLYSEMY AND CONTEXTUAL DISAMBIGUATION IN MODERN GREEK POLITICAL METAPHORS	Prof. Dr. Eleni Papadopoulos, Dr. Kostas Dimitriou
		6	INTERTEXTUALITY IN BYZANTINE RHETORICAL TEXTS: A DISCOURSE-SEMANTIC PERSPECTIVE	Maria Stavropoulou, Assoc. Prof. Dr. Nikos Georgiadis, Theo Angelakis
		7	PRAGMATICS OF IRONY IN CONTEMPORARY GREEK SOCIAL MEDIA DISCOURSE	Dr. Sofia Kotsi
		8	COGNITIVE METAPHORS OF EMOTION IN SANSKRIT PHILOSOPHICAL TEXTS	Prof. Dr. Arjun Sharma, Priya Venkatesh
		9	DISCOURSE MARKERS AND CONVERSATIONAL STRUCTURE IN BILINGUAL HINDI-ENGLISH INDIAN PARLIAMENTARY DEBATES	Dr. Neha Kapoor, Anjali Rao

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HALL / SALON 2	**Dr. Maria Economou,**	1	IRANIAN FOREIGN POLICY TOWARD CENTRAL ASIA POST-2015 NUCLEAR AGREEMENT IMPLICATIONS	Prof. Dr. Reza Hosseini, Ali Mahmoudi, Dr. Sara Karim
		2	DOMESTIC POLITICS AND IRAN'S REGIONAL SECURITY DOCTRINE IN THE SYRIAN CONFLICT	Assoc. Prof. Dr. Fatima Rahimi, Hossein Javadi
		3	WOMEN'S POLITICAL PARTICIPATION AND GENDER POLICY REFORMS IN CONTEMPORARY IRAN	Dr. Leila Ahmadi, Neda Sharifi, Assis. Prof. Dr. Parisa Ebrahimi
		4	ENERGY DIPLOMACY AND IRAN'S PETROLEUM EXPORT STRATEGIES UNDER SANCTIONS REGIMES	Prof. Dr. Mohammad Jafari, Zahra Khalili
		5	GREEK-TURKISH MARITIME DISPUTES AND EU COMMON FOREIGN POLICY COHERENCE CHALLENGES	Assoc. Prof. Dr. Dimitrios Pappas, Eleni Stavrou, Dr. Kostas Nikolaou
		6	EUROPEAN INTEGRATION IMPACTS ON GREEK FISCAL SOVEREIGNTY POST-2010 DEBT CRISIS	Dr. Maria Economou, Antonis Papadopoulos
		7	MIGRATION POLICY DILEMMAS AND NATIONAL SECURITY FRAMINGS IN CONTEMPORARY GREECE	Dr. Sophia Karagianni, Nikos Theodorou, Assis. Prof. Dr. Yiorgos Lyras
		8	CLIMATE CHANGE ADAPTATION GOVERNANCE AND FEDERALISM CHALLENGES IN INDIA	Prof. Dr. Arjun Mehra, Priya Venkatesh, Dr. Sanjay Rao
		9	DIGITAL GOVERNANCE REFORMS AND ELECTION MANAGEMENT INNOVATIONS IN INDIA	Assoc. Prof. Dr. Neha Kapoor, Vikram Desai

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HALL / SALON 3	**Assoc. Prof. Dr. Maria Georgiou**	1	LINGUISTIC DIMENSIONS OF PERSIAN CODE-SWITCHING PATTERNS IN TEHRAN BILINGUAL COMMUNITIES	Prof. Dr. Reza Ahmadi, Soraya Mahmoudi, Ali Karimi
		2	PHONOLOGICAL ADAPTATION STRATEGIES IN LOANWORDS FROM ARABIC TO MODERN PERSIAN	Dr. Fatemeh Hosseini, Assoc. Prof. Dr. Mohammad Jafari
		3	DISCOURSE MARKERS AND CONVERSATIONAL FLOWS IN PERSIAN ACADEMIC ORAL PRESENTATIONS	Leila Bahrami, Dr. Hassan Rezaei, Neda Sharifi
		4	SYNTACTIC COMPLEXITY MEASURES IN PERSIAN EFL WRITING DEVELOPMENT TRAJECTORIES	Assis. Prof. Dr. Mina Tavakoli, Parisa Ghasemi
		5	BILINGUAL EDUCATION POLICY IMPLEMENTATION CHALLENGES IN GREEK-THRACIOTURKISH COMMUNITIES	Prof. Dr. Eleni Papadopoulos, Dr. Kostas Dimitriadis
		6	DIALECTAL VARIATION IN CYPRIOT GREEK PHONOLOGY AND ITS IMPLICATIONS FOR LANGUAGE TEACHING	Assoc. Prof. Dr. Maria Georgiou, Nikos Stavrou
		7	PRAGMATIC FUNCTIONS OF GREEK DISCOURSE PARTICLE "RE" IN SPONTANEOUS INTERACTION	Dr. Sophia Antoniou, Panagiotis Lazos, Katerina Tsoulaki
		8	LANGUAGE ATTITUDES TOWARD HINDI-ENGLISH CODE-MIXING IN URBAN DELHI YOUTH SPEECH	Prof. Dr. Anjali Gupta, Rahul Sharma
		9	TAMIL-SANSKRIT PRAGMATIC BORROWINGS IN CLASSICAL DRVIDIAN DISCOURSE STRUCTURES	Dr. Priya Venkatesh, Assoc. Prof. Dr. Karthik Raman, Lakshmi Nair

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HALL / SALON 4	**Assoc. Prof. Dr. Eleni Papadopoulos,**	1	RITUAL PRACTICES AND GENDER ROLES IN CONTEMPORARY ZOROASTRIAN COMMUNITIES OF YAZD PROVINCE	Prof. Dr. Reza Ahmadi, Soraya Mahmoudi, Ali Karimi
		2	NOMADIC PASTORALISM TRANSFORMATIONS AMONG BAKHTIARI TRIBES IN POST-REVOLUTIONARY IRAN	Dr. Fatemeh Hosseini, Assoc. Prof. Dr. Mehdi Rezaei
		3	URBAN KURDISH IDENTITY NEGOTIATIONS THROUGH MUSIC AND FESTIVALS IN MAHABAD CITY	Leila Bahrami, Dr. Hassan Tavakoli, Nima Jafari
		4	SHIITE PILGRIMAGE ECONOMIES AND SOCIAL MOBILITY IN MASHHAD'S HOLY SHRINE COMPLEX	Prof. Dr. Zahra Mahmoudi, Saeed Alavi
		5	MEDITERRANEAN ISLAND REFUGEE INTEGRATION THROUGH CULINARY EXCHANGE IN LESVOS COMMUNITIES	Assoc. Prof. Dr. Eleni Papadopoulos, Dr. Kostas Nikolaidis
		6	BYZANTINE RELIGIOUS ICONOGRAPHY AND CONTEMPORARY ORTHODOX IDENTITY IN THESSALONIKI NEIGHBORHOODS	Dr. Maria Stavropoulou, Nikos Georgiadis, Assis. Prof. Dr. Anna Koukidou
		7	RURAL AGROTOURISM AND HERITAGE REVITALIZATION AMONG CRETE MOUNTAIN VILLAGES	Prof. Dr. Dimitris Tsoukalas, Sofia Petraki
		8	BEDOUIN GENDER DYNAMICS AND MOBILITY PATTERNS IN SAUDI ARABIA'S NORTHERN PROVINCES	Dr. Fatima Al-Ghamdi, Assoc. Prof. Dr. Khalid Al-Mansour
		9	HAJ JOURNEYS AND TRANSNATIONAL PILGRIM KINSHIP NETWORKS FROM THE HEJAZ REGION	Prof. Dr. Nasser Al-Qahtani, Aisha Rahman
		10	AYNU ETHNIC REVITALIZATION THROUGH BEAR FESTIVALS IN HOKKAIDO INDIGENOUS COMMUNITIES	Dr. Hiroshi Tanaka, Assoc. Prof. Dr. Yuko Sato, Kenji Nakamura
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HALL / SALON 5	**Assis. Prof. Dr. Amel Harzi**	1	URBAN SHRINE VISITATION AND SPIRIT MEDIUMSHIP AMONG TOKYO SALARYMEN COMMUNITIES	Prof. Dr. Akihiro Mori, Sakura Ikeda
		2	DIGITAL MEDIA LITERACY AND FAKE NEWS DISSEMINATION AMONG KAZAKHSTANI UNIVERSITY STUDENTS	Prof. Dr. Aizhan Kulanova, Yerbolat Nurgaliyev, Dr. Madina Sarsenova
		3	SOCIAL MEDIA'S ROLE IN SHAPING YOUTH POLITICAL ACTIVISM DURING KAZAKHSTANI PROTESTS	Assoc. Prof. Dr. Ruslan Bekov, Aidana Zhumagaliyeva
		4	CROSS-CULTURAL COMMUNICATION CHALLENGES IN MULTILINGUAL KAZAKHSTANI WORKPLACES	Dr. Gulnara Tolegenova, Nurlan Abildayev, Assis. Prof. Dr. Zhanna Kassenova
		5	INFLUENCER MARKETING STRATEGIES AND CONSUMER TRUST IN KAZAKHSTANI E-COMMERCE PLATFORMS	Prof. Dr. Erlan Mukhametov, Dana Sadykova
		6	ARABIC DIALECTAL VARIATIONS AND THEIR IMPACT ON DIGITAL COMMUNICATION IN TUNISIAN SOCIAL NETWORKS	Assoc. Prof. Dr. Sami Ben Romdhane, Nadia Kallel
		7	PUBLIC RELATIONS STRATEGIES DURING TUNISIA'S POST-REVOLUTIONARY POLITICAL CRISES	Dr. Lilia Trabelsi, Prof. Dr. Hassen Zghal, Meriem Jrad
		8	MIGRANT MEDIA CONSUMPTION PATTERNS AND INTEGRATION CHALLENGES IN TUNISIAN URBAN COMMUNITIES	Assis. Prof. Dr. Amel Harzi
		9	DIGITAL STORYTELLING AND CULTURAL PRESERVATION AMONG MOROCCAN BERBER COMMUNITIES	Dr. Fatima Zahra El Amrani, Assoc. Prof. Dr. Youssef Belkadi
		10	CORPORATE COMMUNICATION STRATEGIES ADDRESSING CLIMATE CHANGE IN MOROCCAN SUSTAINABLE TOURISM	Prof. Dr. Hassan Derfoufi, Amina Naji, Karim El Fassi
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HALL / SALON 6	Dr. Fatemeh Hosseini,	1	DIGITAL TRANSFORMATION STRATEGIES FOR SMALL AND MEDIUM ENTERPRISES IN AZERBAIJAN'S OIL DEPENDENT ECONOMY	Prof. Dr. Elnur Mammadov, Aysel Karimova, Farid Huseynov
		2	SUSTAINABLE SUPPLY CHAIN PRACTICES AND FIRM PERFORMANCE IN AZERBAIJANI AGRICULTURE	Assoc. Prof. Dr. Nigar Aliyeva, Rashad Ibrahimov
		3	BLOCKCHAIN TECHNOLOGY ADOPTION BARRIERS IN AZERBAIJAN'S FINANCIAL SERVICES SECTOR	Dr. Leyla Hasanova, Elvin Gurbanov, Zara Mammadova
		4	CORPORATE GOVERNANCE REFORMS AND INVESTOR CONFIDENCE IN BAKU STOCK EXCHANGE	Kamran Abbasov, Prof. Dr. Sevinc Nuriyeva
		5	ISLAMIC FINANCE INNOVATIONS AND ECONOMIC RESILIENCE IN IRANIAN SMEs	Assoc. Prof. Dr. Reza Ahmadi, Soraya Mahmoudi, Ali Karimi
		6	CIRCULAR ECONOMY MODELS FOR TEXTILE INDUSTRY SUSTAINABILITY IN IRAN	Dr. Fatemeh Hosseini, Mohammad Jafari
		7	AGILE METHODOLOGIES ADOPTION IN IRANIAN SOFTWARE DEVELOPMENT FIRMS	Prof. Dr. Hassan Rezaei, Leila Bahrami
		8	FAMILY BUSINESS SUCCESSION PLANNING IN NORTH MACEDONIA'S MANUFACTURING SECTOR	Assoc. Prof. Dr. Nikola Popovski, Elena Ivanovska
		9	TOURISM DIGITAL MARKETING STRATEGIES POST-COVID RECOVERY IN NORTH MACEDONIA	Dr. Marija Petrovska, Goran Trajkovski, Assis. Prof. Dr. Biljana Angelova
		10	ESG INVESTING FRAMEWORKS FOR EMERGING EUROPEAN CAPITAL MARKETS: NORTH MACEDONIA CASE	Saso Kostovski, Prof. Dr. Daniela Trbovska
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HALL / SALON 7	**Prof. Dr. Mina Sharifi,**	1	STRATEGIC ALLIANCES BETWEEN AZERBAIJANI OIL COMPANIES AND INTERNATIONAL ENERGY GIANTS	Prof. Dr. Vugar Aliyev, Sevda Mirzayeva, Rauf Gahramanov
		2	FINTECH DISRUPTION AND TRADITIONAL BANKING TRANSFORMATION IN AZERBAIJAN	Assoc. Prof. Dr. Gunel Ismayilova, Elshan Nuriyev
		3	BRAND MANAGEMENT STRATEGIES FOR AZERBAIJANI EXPORTS IN COMPETITIVE EMERGING MARKETS	Nigar Sadigova, Prof. Dr. Orkhan Nadirov
		4	CROWDFUNDING PLATFORMS AND ENTREPRENEURIAL ECOSYSTEM DEVELOPMENT IN IRAN	Assoc. Prof. Dr. Babak Mehregan, Neda Karimi, Saeed Ahmadi
		5	SUPPLY CHAIN RESILIENCE STRATEGIES FOR IRANIAN AUTOMOTIVE INDUSTRY UNDER SANCTIONS	Dr. Parisa Hosseini, Amir Rezaei
		6	WOMEN ENTREPRENEURSHIP IN IRAN'S HANDICRAFT SECTOR: OVERCOMING INSTITUTIONAL BARRIERS	Prof. Dr. Mina Sharifi, Zahra Mahmoudi
		7	DIGITAL MARKETING TRANSFORMATION IN NORTH MACEDONIA'S AGROFOOD EXPORTS	Assoc. Prof. Dr. Viktorija Stojkovska, Marko Petrovski
		8	SUSTAINABLE TOURISM DEVELOPMENT MODELS FOR OHRID LAKE UNESCO HERITAGE SITE	Dr. Ana Blazevska, Nikola Jovanovski, Elena Risteska
		9	BLOCKCHAIN APPLICATIONS IN NORTH MACEDONIA'S WINE INDUSTRY TRACEABILITY	Prof. Dr. Dejan Canev, Sara Kostovska, Assis. Prof. Dr. Filip Temelkov

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HALL / SALON 8	**Assoc. Prof. Dr. Theresa Lim,**	1	THE ROLE OF COLLECTIVISTIC FAMILY STRUCTURES IN SHAPING ADOLESCENT IDENTITY FORMATION AMONG IRANIAN URBAN YOUTH	Prof. Dr. Reza Mohammadi, Sara Hosseini, Ali Karimi
		2	MINDFULNESS INTERVENTIONS INCORPORATING ISLAMIC CONTEMPLATION PRACTICES FOR ANXIETY REDUCTION IN IRANIAN UNIVERSITY STUDENTS	Assoc. Prof. Dr. Fatemeh Ahmadi, Dr. Hassan Rezaei
		3	WORKPLACE GENDER DYNAMICS AND PSYCHOLOGICAL DISTRESS AMONG FEMALE PROFESSIONALS IN TEHRAN CORPORATE SETTINGS	Leila Jafari, Nima Bahrami, Prof. Dr. Zahra Mahmoudi
		4	RESILIENCE FACTORS AMONG IRANIAN REFUGEE CHILDREN DISPLACED BY ECONOMIC MIGRATION TO NEIGHBORING COUNTRIES	Dr. Mehran Tavakoli, Assis. Prof. Dr. Yasaman Sharifi
		5	CULTURAL ADAPTATIONS OF COGNITIVE BEHAVIORAL THERAPY FOR DEPRESSION AMONG FILIPINO MIGRANT WORKERS IN METRO MANILA	Prof. Dr. Maria Santos, Dr. Jose Rizalino, Ana Cruz
		6	SOCIAL MEDIA INFLUENCE ON BODY IMAGE DISTURBANCE AMONG FILIPINO ADOLESCENT GIRLS IN URBAN POVERTY SETTINGS	Assoc. Prof. Dr. Theresa Lim, Ramon Dela Cruz
		7	TRAUMA-INFORMED SCHOOL COUNSELING FOR CHILDREN AFFECTED BY PHILIPPINE NATURAL DISASTERS	Dr. Elena Vargas, Mark Anthony Reyes, Sofia Mendoza
		8	WORKPLACE PSYCHOLOGICAL SAFETY AND EMPLOYEE VOICE BEHAVIOR IN OMANI OIL AND GAS SECTOR	Prof. Dr. Ahmed Al-Harthi, Fatima Al-Maskari
		9	PARENTING STYLES AND ACADEMIC RESILIENCE AMONG OMANI BEDOUIN HERITAGE STUDENTS IN URBAN SCHOOLS	Assoc. Prof. Dr. Khalid Al-Busaidi, Dr. Noor Al-Harthy, Salim Al-Mahrooqi
		10	MIGRATION STRESS AND COPING STRATEGIES AMONG EXPATRIATE COMMUNITIES IN MUSCAT WORK ENVIRONMENTS	Layla Al-Rashidi, Prof. Dr. Tariq Al-Ghanboosi
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HALL / SALON 9	**Assoc. Prof. Dr. Fatima Zahra El Amrani,**	1	YORUBA TEXTILE TRADITIONS AND CONTEMPORARY FASHION IDENTITY IN NIGERIAN URBAN CENTERS	Prof. Dr. Amina Okonkwo, Chidi Eze, Ngozi Ude
		2	NOK TERRACOTTA SCULPTURE INFLUENCES ON CONTEMPORARY NIGERIAN CERAMIC ART PRACTICES	Assoc. Prof. Dr. Emeka Nwosu
		3	MASQUERADES AND PERFORMANCE ART IN POSTCOLONIAL IDENTITY EXPRESSION AMONG IGBO COMMUNITIES	Dr. Ifeoma Okoro, Obi Nwankwo, Chioma Adebayo
		4	CALABAR CARNIVAL AS URBAN CULTURAL RESISTANCE AND TOURISM DEVELOPMENT STRATEGY	Prof. Dr. Bassey Ekanem, Ekaette Udoh
		5	BERBER ORNAMENTAL GEOMETRY IN CONTEMPORARY MOROCCAN CALLIGRAPHY PRACTICES	Assoc. Prof. Dr. Fatima Zahra El Amrani, Hassan Bouachrine
		6	GN AWA MUSIC TRADITIONAL INFLUENCES ON MODERN MOROCCAN FUSION GENRES	Dr. Aicha Lmrabet, Karim El Fassi
		7	MARABOUTIC PORTRAITURE AND PHOTOGRAPHIC INNOVATION IN 20TH-CENTURY MOROCCAN STUDIO PRACTICE	Youssef Bennani, Prof. Dr. Nadia Cherkaoui
		8	MAASAI BEADWORK EVOLUTION AND CONTEMPORARY KENYAN JEWELRY DESIGN INNOVATIONS	Assoc. Prof. Dr. Jepchumba Kiptoo, Naserian ole Lekishon
		9	LUKASA MEMORY BOARDS AND DIGITAL ARCHIVING OF LUBA COSMOLOGY IN CONTEMPORARY ART	Dr. Wanjiku Mwangi, Kofi Amankwaa
		10	KIKUYU SCULPTURE TRADITIONS AND CONTEMPORARY KENYAN PUBLIC ART INSTALLATIONS	Prof. Dr. Muthoni Kariuki, Juma Omondi, Zawadi Mwikali
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HALL / SALON 1	**Doç. Dr. Sait Yıldırım**	1	SOSYAL MEDYANIN ERGENLERDE AKRAN ZORBALIĞINA ETKİSİ	Doç. Dr. Sait Yıldırım Doç. Dr. Bahri Gür Doktora Öğrencisi Buket Bağrıyanık Yıldırım
		2	ALGORİTMALARIN GÖLGESİNDE BÜYÜMEK: ÇOCUKLARDA DİJİTAL BAĞIMLILIĞIN VE SOSYALLEŞME BİÇİMLERİNİN DÖNÜŞÜMÜ	Doç. Dr. Sait Yıldırım
		3	İklim Değişikliği Endişesi ile Psikolojik Sıkıntı Arasındaki İlişkide Algılanan Stres ve Duygu Düzenleme Güçlüğünün Aracı Rolü	Lisans Öğrencisi Asude Yalın Lisans Öğrencisi Melike Yalın Doç. Dr. Sümeyye Derin
		4	EBEVEYN DUYGUSAL ERİŞİLEBİLİRLİĞİN DUYGUSAL ZEKA BECERİLERİ ÜZERİNDEKİ ETKİSİ ÜZERİNE KAVRAMSAL BİR ÇALIŞMA	Psikolog BÜŞRA AYDOĞDU Dr. Öğr. Üyesi ALİYE ATEŞ ÖS
		5	THE MEDIATING ROLES OF ENERGY AND SELF-REGULATION IN THE RELATIONSHIP BETWEEN PERSEVERANCE AND STRESS RESILIENCE AMONG ADOLESCENTS: A PARALLEL MEDIATION ANALYSIS	Doç. Dr. Mehmet ŞATA Doç. Dr. Mahmut Sami KOYUNCU
		6	COLLABORATION PROFILES AND THEIR DETERMINANTS IN ADOLESCENTS: A LATENT PROFILE ANALYSIS AND MULTINOMIAL LOGISTIC REGRESSION APPROACH	Doç. Dr. Mehmet ŞATA Doç. Dr. Mahmut Sami KOYUNCU
		7	AYDINLIK ÜÇLÜ KİŞİLİK ÖZELLİKLERİNİN GELİŞMELERİ KAÇIRMA KORKUSU ÜZERİNDEKİ ETKİSİNE DAİR KAVRAMSAL BİR ÇERÇEVE	Psikolog, SERRA NUR AKGÜN
		8	ERGENLERDE SİBER OBSESİF TAKİP MAĞDURİYETİ: ANNE-BABA TUTUMU, DEMOGRAFİK DEĞİŞKENLER VE SOSYAL MEDYA KULLANIM ALIŞKANLIKLARIYLA İLİŞKİSİ	Yüksek Lisans Öğrencisi Sedef MELEMEZ Prof. Dr. Hülya ERCAN

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HALL / SALON 2	**Asst. Prof. Dr., Fatih TAKTAK**	1	COMPARATIVE PERSPECTIVES ON URBAN TRANSFORMATION: GLOBAL APPROACHES AND OUTCOMES ACROSS TEN COUNTRIES	Asst. Prof. Dr., Fatih TAKTAK
		2	BUILDING AMNESTY AND LAND USE GOVERNANCE: COMPARATIVE INSIGHTS WITH A FOCUS ON TURKEY	Asst. Prof. Dr., Fatih TAKTAK
		3	6 ŞUBAT 2023 DEPREMLERİ SONRASINDA KİLİS VE HATAY'DA İLÇE BAZINDA NÜFUSUN MEKÂNSAL SÜREKLİLİĞİ: CBS VE WORLDPOP VERİLERİ ÜZERİNDEN BİR ANALİZ	Dr. Öğretim Üyesi Ceren YAĞCI
		4	AMSTERDAM SCHİPHOL HAVALİMANI VE ANKARA ESENBOĞA HAVALİMANI ÇEVRESİNİN KENTSEL GELİŞİMİNİN UYDU GÖRÜNTÜLERİ YARDIMIYLA ZAMANSAL ANALİZİ	Kübra BAŞ YOLCU Dr. Öğretim Üyesi Aycan Murat MARANGOZ
		5	KENTSEL YEŞİLLENDİRME YAKLAŞIMLARINDA DİKEY BAHÇELER: WEB OF SCİENCE TABANLI BİBLİYOMETRİK BİR ARAŞTIRMA	Öğr. Gör. Dr. İlhami AY Doç. Dr. Şefika ERGİN
		6	TEMATİK HARİTALAR BAĞLAMINDA KÜLTÜREL MİRAS ÇALIŞMALARININ GELİŞİMİ: WEB OF SCİENCE BİBLİYOMETRİK DEĞERLENDİRMESİ	Öğr. Gör. Dr. İlhami AY Doç. Dr. Şefika ERGİN

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HALL / SALON 3	**Prof. Dr. Muammer CENGİL**	1	International positions on the war on Gaza and its repercussions on societal stability and peace	Dr. Amira Ismail Muhammad Al-Ubaidi
		2	FIKHÎ AÇIDAN DÜNYEVİLEŞMENİN SOMUT TEZAHÜRLERİNE DAİR BİR DEĞERLENDİRME	Doç. Dr. Taha YILMAZ
		3	MANEVİYATIN PSİKOLOJİK İYİ OLUŞ ÜZERİNDEKİ ETKİSİ: KÜLTÜRLERARASI BİR DEĞERLENDİRME	Prof. Dr. Muammer CENGİL
		4	DİNSEL KİMLİK VE SOSYAL AİDİYET: PSİKOLOJİK BİR İNCELEME	Prof. Dr. Muammer CENGİL
		5	TEŞBİHLERİ AÇISINDAN YAHYÂ B. SELÂME EL-HASKEFÎ'NİN ŞİİRLERİ	Doç. Dr. Halil AKÇAY Yahya AKÇAY
		6	KUR'AN'IN AİLE BİRLİĞİNİN KORUNMASINA YÖNELİK BOŞANMA ÖNCESİ HAKEMLİK ÖNERİSİ	Doç. Dr. Mustafa TUNÇER
		7	KUR'ÂN PERSPEKTİFİNDEN İNSANIN YERYÜZÜNDE HALİFE KILINMASI	Doç. Dr. Mustafa TUNÇER
		8	The Possibility of a Psychological Exegesis of the Qur'an: A Nafs-Centered, Discourse-Analytical Approach	Tuğçe GÜNEŞ Doç. Dr. Ramazan ŞAHAN

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HALL / SALON 4	**Doç. Dr. Erkan DENK**	1	SİVAS HEALTH TOURISM SWOT ANALYSIS	Dr. Öğr. Üyesi Çiğdem YEL
		2	ETHICAL ISSUES OF MASS TOURISM AND ITS DAMAGES TO THE ENVIRONMENT AND CULTURAL HERITAGE	Yüksek Lisans Öğrencisi Özge SARAÇOĞLU Dr. Öğr. Üyesi Fatma EBAN
		3	FAMILY FRIENDLY TOURİSM DESTİNATİONS AND TOURİSM BUSİNESSES	Doç. Dr. Sine ERDOĞAN MERCAN Sinem AYSU
		4	LEISURE MANAGEMENT IN FAMILIES FROM THE PERSPECTIVE OF DIGITAL LIFE SKILLS	Ömer TUFAN Doç. Dr. Sine ERDOĞAN MERCAN
		5	GASTRONOMİK KİMLİĞİN GÖRSEL TEMSİLİ: SEÇİLMİŞ ÜLKE BANKNOTLARI ÜZERİNE BİR ANALİZ	Dr. Öğr Üyesi Nilgün KARAMAN Yüksek Lisans Öğrencisi Mustafa Tolgay ERTAN
		6	REGIONAL DISTRIBUTION OF GEOGRAPHICAL INDICATIONS IN TÜRKİYE AND CLASSIFICATION ACCORDING TO PRODUCT GROUPS	Doç. Dr. Erkan DENK
		7	A RESEARCH ON BALIKESİR GEOGRAPHİCAL INDICATED PRODUCTS AND THEIR EVALUATION IN THE DEVELOPMENT OF REGIONAL TOURİSM	Lisans Öğrencisi Nimet TURAN Lisans Öğrencisi İklim ÇELİK Doç. Dr. Gizem ÖZGÜREL
		8	WORLD FEDERATION OF TOURIST GUIDE ASSOCIATIONS (WFTGA) RESMİ INSTAGRAM HESABININ İNCELENMESİ	Yüksek Lisans Öğrencisi Hatice Nur KESİMAL Dr. Öğr. Üyesi Hasret ULUSOY MUTLU

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HALL / SALON 5	**Prof. Dr. Mevlüt ÇELEBİ**	1	THE IMPACT OF WORLD WAR II ON MILITARY AND CIVILIAN HEALTH SERVICES: MEDICAL INNOVATIONS, PUBLIC HEALTH TRANSFORMATION, AND CONTRIBUTIONS TO THE INSTITUTIONALIZATION OF MODERN MEDICINE	Dr. Özlem KARAPINAR GÖK
		2	STRATEGIC ORIENTATIONS İN TURKISH FOREIGN POLICY: THE HISTORICAL, POLITICAL, AND REGIONAL IMPLICATIONS OF THE BAGHDAD PACT	Dr. Özlem KARAPINAR GÖK
		3	MUSSOLINI'NİN TÜRKİYE'Yİ İŞGAL PLANI	Prof. Dr. Mevlüt ÇELEBİ
		4	RUMELİ'YE VEDA EDERKEN SULTAN REŞAD'IN KOSOVA'YI ZİYARETİ	Prof. Dr. Mevlüt ÇELEBİ
		5	A COMPARİSON OF CERTAİN KAZAS AND NAHİYES İN THE PROVİNCE OF ALEPPO ACCORDİNG TO THE AVÂRIZ-HÂNE REGİSTER NO. 678	Prof. Dr. Ahmet GÜNDÜZ
		6	THE CONTENT AND SOURCE VALUE OF THE AVÂRIZ-HÂNE REGISTER NUMBERED MAD 678	Prof. Dr. Ahmet GÜNDÜZ
		7	THE ROLE AND INFLUENCE OF GEORGIAN WOMEN IN THE HISTORICAL PROCESS: FROM RELIGIOUS LEADERS TO INTER-IMPERIAL POLITICAL FIGURES	Öğr. Gör. Dr. Hatice ERTÜRK
		8	MOĞOLLARDA ELÇİ KABULÜ	Mehmet İSTEMİHAN

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HALL / SALON 6	**Assoc. Prof. Dr. Filiz EROĞLU**	1	E-TİCARETTE KAMPANYA PERFORMANSININ ÇOK BOYUTLU ANALİZİ: ROI, SEGMENTASYON VE ZAMANLAMA OPTİMİZASYONU ÜZERİNE BİR ARAŞTIRMA	Doç. Dr. Pınar ÖZKAN Prof. Dr. İpek DEVECİ KOCAKOÇ
		2	EVCİL HAYVAN GİYİM ENDÜSTRİSİNDE YOUTUBE İÇERİK STRATEJİLERİ: İÇERİK UZUNLUĞU VE REKLAM YATIRIMLARININ ETKİLEŞİM KALİTESİ ÜZERİNE BİR ANALİZ	Doç. Dr. Pınar ÖZKAN Prof. Dr. İpek DEVECİ KOCAKOÇ
		3	BOP'TA DİJİTALLEŞME VE PAZARLAMA KARMASININ YENİDEN YAPILANDIRILMASI: 8A TEMELLİ BİR YAKLAŞIM	Arş. Gör. Dr. Sevi BALOĞLU SEVİNÇ
		4	AN EXPLORATORY RESEARCH ON YOUNG CONSUMERS' SOFT SAVING TENDENCIES	Assoc. Prof. Dr. Filiz EROĞLU
		5	DEVELOPING THE SERVICE BRAND LOVE SCALE: A CONTEXT-SPECIFIC INSTRUMENT FOR EMOTIONAL ATTACHMENT IN SERVICE SETTINGS	Assist. Prof. Dr. Pınar Alyar
		6	ENDÜSTRİ 4.0 SÜRECİNDE AKILLI ÜRÜNLER VE TÜKETİCİ ETKİLEŞİMİ: KAVRAMSAL BİR ÇERÇEVE	Arş. Gör. Dr. Sinem SARGIN
		7	TÜKETİCİLERİN YOUTUBE REKLAM VİDEOLARINDAKİ DUYGU ÇAĞRIŞIMLARINA VERDİKLERİ TEPKİLER: BİR İÇERİK ANALİZİ	Öğrt. Gör.Dr. Pınar COŞKUN
		8	THE IMPACT OF ARTIFICIAL INTELLIGENCE IN DIGITAL MARKETING: TRANSITION FROM SEARCH ENGINE OPTIMIZATION (SEO) TO GENERATIVE ENGINE OPTIMIZATION (GEO)	Muhammed Mustafa GÖKTAŞ Hatice KÖSE Prof. Dr. Ahmet GÜRBÜZ

Nur Sert Burada sunum yapacak .

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HALL / SALON 7	**Öğr. Gör. Gizem TÜRE**	1	ALMANYA'DAKİ TÜRK GÖÇMENLERİN İKİNCİ DİL EDİNİM SÜREÇLERİNİN TÜRKİYE'DEKİ SURİYELİ ÇOCUKLARIN TÜRKÇE EDİNİM SÜRECİ İLE KARŞILAŞTIRMALI ANALİZİ: POLİTİKALAR VE ÖNERİLER	Doktora Öğrencisi Ahmet CİHANGİR Doç. Dr. Demet KARDAŞ
		2	YABANCI DİL OLARAK TÜRKÇE ÖĞRETİMİN ALANINDA YAPILAN TEZLERİN DİL BİLGİSİ AÇISINDAN META-SENTEZ YÖNTEMİ İLE İNCELENMESİ	Doktora Öğrencisi Ahmet CİHANGİR Doç. Dr. Demet KARDAŞ
		3	Mobile-Assisted Language Learning (MALL) in Türkiye's K–12 English Education: A PRISMA-Based Systematic Review (2020–2025)	Govher YAZDURDYYEVA Fidel ÇAKMAK
		4	A COGNITIVE COMPARISON OF READING COMPREHENSION QUESTIONS IN TEACHING TURKISH AS A FOREIGN LANGUAGE: A STUDY ON A2 AND B1 LEVELS	Öğr. Gör, ZEYNEP ARICI Öğr. Gör. Gizem TÜRE
		5	AN ANALYSIS OF VISUALS IN THE 5TH GRADE MIDDLE SCHOOL ENGLISH TEXTBOOK WITHIN THE CONTEXT OF INCLUSIVE EDUCATION	Graduate Student Ayşe YILMAZ
		6	İNGİLİZCE ÖĞRETİMİNDE YAPAY ZEKÂ UYGULAMALARINA İLİŞKİN LİSE İNGİLİZCE ÖĞRETMENLERİNİN GÖRÜŞ VE ÖNERİLERİ	Prof. Dr. Necdet KONAN Sueda Zişan TÜRKÖZ
		7	CONCEPTUAL FRAMEWORK FOR COMPARING ADVANTAGES OF NON-GAME-BASED LEARNING AND GAME-BASED LEARNING	Havva İrem TAŞDEMİR Zeynep ALTUNEL Fidel ÇAKMAK
		8	9 TH GRADE LISTENING SKILLS IN THE TÜRKIYE CENTURY MAARIF MODEL: A QUALITATIVE DOCUMENT ANALYSIS	Havva İrem Taşdemir Zeynep ALTUNEL Fidel ÇAKMAK

Sevil Zengin Gupta burada sunacak

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		2	DUVARIN ARDINDAKİ KADIN: ATIK DUVAR KAĞITLARINDAN SANATSAL MODA TASARIMLARI	Doç. Dr. Hüseyin ÖZDEMİR Yüksek Lisans Öğrencisi Seda ÇOLAK
		3	MODA TASARIMINDA EPOKSİ REÇİNE UYGULAMASI; FARKLI KUMAŞ TÜRLERİ ÜZERİNDEKİ ETKİLERİNİN İNCELENMESİ	Doç.Dr. Şengül EROL Shaghayegh TAJAMMOLI MOHADDES
		4	BİYOMİMİKRİ VE MİTOLOJİ BAĞLAMINDA YILAN EJDERHA METAFORUNUN GİYSİ TASARIMLARINA YANSIMALARI	Doç.Dr. Şengül EROL Rumeysa ÇOBAN
		5	FARKLI COĞRAFYALARIN GÖRSEL MİRASININ GÜNCEL TASARIMLARA AKTARIMI	Sibel ERDURAN Zeynep DUMAN
		6	SARAY RİTÜELLERİNİN GİYSİYE YANSIMASI: OSMANLI KAFTANLARININ TARİHSEL VE TEKNİK BAĞLAMI	Dr. Öğretim Üyesi Emine ERDOĞAN
		7	TAY-TECH TEKNİK KUMAŞLARIN FONKSİYONEL ÜRÜN TASARIMINDAKİ ROLÜ	Kıdemli Tasarımcı Selcan Korkmaz Dursun
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HALL / SALON 9	**Dr. Öğr. Üyesi Sevil ÖZTAŞ**	1	MICROBIOTA–IMMUNE SYSTEM INTERACTIONS IN MULTIPLE SCLEROSIS: CURRENT EVIDENCE AND CLINICAL IMPLICATIONS	Dr. Öğr. Üyesi Sevil ÖZTAŞ
		2	CRISPR–CAS SYSTEMS AND ANTIMICROBIAL RESISTANCE: MECHANISMS, CHALLENGES, AND CLINICAL POTENTIAL	Dr. Öğr. Üyesi Sevil ÖZTAŞ
		3	THEOBROMINE AS A NATURAL SCAFFOLD FOR ANTICANCER DRUG DESIGN: DOCKING AND ADMET-BASED INSIGHTS	Assist. Prof.Dr. Emine TERZİ Assist. Prof.Dr. Beyza Ecem Öz Bedir
		4	COMPARATIVE INVESTIGATION OF PHENOLIC COMPOUNDS, ANTIOXIDANT CAPACITY AND PROTEIN CONTENT OBTAINED FROM ETHANOL AND WATER EXTRACTIONS OF VITEX AGNUS-CASTUS L. SEEDS	Assist. Prof. Dr. Muammer TEPE Assoc. Prof. Dr Hafize DİLEK TEPE
		5	THE EFFECTS OF DIFFERENT SOIL pH LEVELS ON THE HISTOLOGY OF Eisenia fetida	Irmak ZENGİN Res. Asst. Muhterem Elif DEMİRAĞ Res. Asst. Dr. Melodi YENMİŞ Assoc. Prof. Dr. Esra AKAT ÇÖMDEN
		6	INVESTIGATION OF COD, TOC, AND MEOH REMOVAL FROM BIODIESEL WASTEWATER USING THE O_3/H_2O_2/UV PROCESS	PhD. Meryem AKSU Doç.Dr. Nazire Pınar TANATTI
		7	ADVANCED OXIDATION PROCESSES IN THE TREATMENT OF PHARMACEUTICAL MANUFACTURING INDUSTRY WASTEWATER	Zehra ÖZTÜRK Emine CAN GÜVEN
		8	PİYASADA SATILAN İNCİR ÇEKİRDEĞİ YAĞLARININ ANTİOKSİDAN KAPASİTELERİNİN KARŞILAŞTIRMALI ANALİZİ	Ecz. Nursema MENEKŞE Doç. Dr. DUYGU TAŞKIN

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HALL / SALON 10	**Doç. Dr. Abdullah SEVİN**	1	SİMÜLASYONLARDA KULLANILAN SÖZDE RASTGELE SAYI ÜRETEÇLERİNİN PERFORMANS VE İSTATİSTİKSEL KARŞILAŞTIRMASI	Doç. Dr. Abdullah SEVİN
		2	KRİPTOGRAFİK SÖZDE RASTGELE SAYI ÜRETEÇLERİNİN PERFORMANS VE İSTATİSTİKSEL KARŞILAŞTIRMASI	Doç. Dr. Abdullah SEVİN
		3	BÜYÜK DİL MODELLERİNDE ATTENTİON MEKANİZMALARININ AÇIKLAYICILIĞININ YENİDEN DEĞERLENDİRİLMESİ	Dr. Volkan ALTINTAŞ
		4	AN ANALYTIC HIERARCHY PROCESS (AHP) ANALYSIS OF FACTORS INFLUENCING THE ADOPTION OF ONLINE PAYMENT SYSTEMS FROM INDIVIDUAL AND CORPORATE PERSPECTIVES	Zeynep Büşra KARAKOÇ Assis. Prof. Dr. Cafer Erhan BOZDAĞ
		5	DATASET BIAS IN COLONOSCOPY-BASED POLYP SEGMENTATION	Lect. Nurhan DEĞİRMENCİ BİNGÖL Asst. Prof. Dr. Özkan BİNGÖL Prof. Dr. Kemal TURHAN
		6	DATA CLEANING AND SEMI-AUTOMATED LABELING WITH ACTIVE LEARNING FOR NOISY DATASETS	Asst. Prof. Dr. Özkan BİNGÖL
		7	HALLUCINATION ISSUES IN ENTERPRISE AI CHATBOTS AND THE RAG APPROACH	Mehmet Emin ERSÖZ Dr. Öğr. Üyesi Mehmet BİLEN
		8	EXPLORING THE INTERSECTION OF GENETICS, CREATIVITY, AND ARTIFICIAL INTELLIGENCE: A BIBLIOMETRIC ANALYSIS	Asst. Prof. Şeyma BOZKURT UZAN Research Assistant, Yasemin SİPAHİ Undergraduate Student, Şevval ARABACIOĞLU
		9	DİKKAT EKSİKLİĞİ VE HİPERAKTİVİTE BOZUKLUĞU İLAÇLARINA YÖNELİK HASTA GERİ BİLDİRİMLERİNİN DOĞAL DİL İŞLEME VE BÜYÜK DİL MODELLERİ İLE ANALİZİ	Yüksek Lisans Öğrencisi Mertcan Sarıgül Doç. Dr. Özgür Gümüş
		10	KURUMSAL KİMLİK VE ERİŞİM YÖNETİMİ (IAM) SİSTEMLERİNDE ANOMALİ TESPİTİ	Sedat KARADAĞ Dr. Senem ŞAHAN VAHAPLAR Mehmet Hakkı ERSOY Doç. Dr. Ahmet FEYZİOĞLU
		11	GÖRÜNTÜ TABANLI MALZEME VE BİLEŞEN ÖNERİSİ İÇİN DERİN TEMSİL ÖĞRENME YAKLAŞIMI	Sedat KARADAĞ Dr. Senem ŞAHAN VAHAPLAR Mehmet Hakkı ERSOY Doç. Dr. Ahmet FEYZİOĞLU

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HALL / SALON 1	**Dr. Karim Mansouri**	1	INTEGRATING ARABIC LANGUAGE PRESERVATION INTO MODERN ALGERIAN BILINGUAL CURRICULA	Prof. Dr. Ahmed Belkacem, Fatima Zahraoui
		2	STEM EDUCATION CHALLENGES AND SOLUTIONS IN RURAL ALGERIAN SECONDARY SCHOOLS	Assoc. Prof. Dr. Nadia Cherif, Yacine Boualem, Samir Lounis
		3	TEACHER PROFESSIONAL DEVELOPMENT THROUGH PEER OBSERVATION IN ALGERIAN VOCATIONAL TRAINING	Dr. Karim Mansouri, Amina Hadji
		4	INCLUSIVE EDUCATION PRACTICES FOR STUDENTS WITH DISABILITIES IN ALGERIAN URBAN SCHOOLS	Laila Zerhouni, Prof. Dr. Mehdi Bouziane
		5	BLENDED LEARNING MODELS FOR RURAL CHINESE VOCATIONAL EDUCATION POST-PANDEMIC	Assoc. Prof. Dr. Li Wei, Zhang Hao
		6	AI-POWERED PERSONALIZED LEARNING SYSTEMS IN CHINESE PRIMARY MATHEMATICS CLASSROOMS	Dr. Wang Jing, Chen Ming, Liu Yang
		7	MORAL EDUCATION REFORM THROUGH CONFUCIAN VIRTUE CURRICULA IN MODERN CHINESE SCHOOLS	Xu Peng, Prof. Dr. Zhou Qian
		8	NEP 2020 IMPLEMENTATION CHALLENGIES FOR MULTILINGUAL EDUCATION IN INDIAN HILL STATES	Assoc. Prof. Dr. Rajesh Kumar, Priya Sharma
		9	VOCATIONAL EDUCATION ALIGNMENT WITH MAKE IN INDIA INITIATIVE IN SOUTHERN STATES	Dr. Sanjay Patel, Neha Gupta, Amit Singh
		10	TEACHER AGENCY AND CURRICULUM ADAPTATION IN REMOTE INDIAN TRIBAL EDUCATION	Anjali Desai, Prof. Dr. Meera Joshi
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HALL / SALON 2	**Assoc. Prof. Dr. Elena Cebotari**	1	URBAN MIGRATION PATTERNS AND SOCIAL INTEGRATION CHALLENGES AMONG RURAL MIGRANTS IN CAIRO'S INFORMAL SETTLEMENTS	Prof. Dr. Ahmed El-Sayed, Fatima Hassan, Omar Khalil
		2	GENDER ROLES TRANSFORMATION IN POST-ARAB SPRING EGYPTIAN UNIVERSITY CAMPUSES	Assoc. Prof. Dr. Nadia Abdel Rahman, Karim Fouad
		3	RELIGIOUS PLURALISM AND INTERFAITH DYNAMICS IN ALEXANDRIA'S COSMOPOLITAN NEIGHBORHOODS	Dr. Salma Ibrahim, Youssef Nasser, Prof. Dr. Hala Mostafa
		4	YOUTH UNEMPLOYMENT AND POLITICAL RADICALIZATION PATHWAYS IN GREATER CAIRO	Mona El-Gendy, Assoc. Prof. Dr. Tarek Mahmoud
		5	POST-SOVIET IDENTITY NEGOTIATIONS AMONG MOLDOVAN DIASPORA COMMUNITIES IN EUROPE	Prof. Dr. Ion Creangă, Maria Lupu
		6	RURAL DEPOPULATION AND SOCIAL CAPITAL EROSION IN MOLDOVA'S NORTHERN REGIONS	Dr. Ana Popescu, Victor Rusu, Liliana Andronati
		7	LANGUAGE POLITICS AND ETHNIC MINORITY INTEGRATION IN URBAN CHISINAU	Assoc. Prof. Dr. Elena Cebotari
		8	CASTE PERSISTENCE AND URBAN LABOR MARKET DISCRIMINATION IN MUMBAI MEGACITY	Prof. Dr. Ravi Shankar, Priya Mehta,
		9	CLIMATE CHANGE ADAPTATION STRATEGIES AMONG INDIA'S SMALLHOLDER FARMING COMMUNITIES	Dr. Lakshmi Nair, Assoc. Prof. Dr. Vikram Singh
		10	DIGITAL DIVIDE AND RURAL YOUTH EMPOWERMENT THROUGH E-GOVERNANCE INITIATIVES	Sanjay Gupta, Dr. Neha Kapoor, Rahul Verma
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HALL / SALON 3	Assoc. Prof. Dr. Fatima Rahman	1	THE IMPACT OF MINDFULNESS INTERVENTIONS ON EMOTIONAL REGULATION IN GREEK PRIMARY SCHOOL CHILDREN	Prof. Dr. Maria Papadopoulos, Dr. Nikos Antoniou, Eleni Stavrou
		2	SCREEN TIME EFFECTS ON LANGUAGE DEVELOPMENT AND ATTENTION SPANS IN TODDLERS FROM ATHENS	Assoc. Prof. Dr. Sophia Dimitriadou, Kostas Georgiou
		3	FAMILY DYNAMICS AND ANXIETY PATTERNS IN ADOLESCENTS FROM GREEK ISLAND COMMUNITIES	Dr. Anna Theodorou, Panagiotis Lazos, Maria Koukoula
		4	PLAY THERAPY EFFICACY FOR TRAUMA RECOVERY IN CHILDREN AFFECTED BY GREEK WILDFIRES	Georgios Papageorgiou, Prof. Dr. Eirini Tsakiridou
		5	NUTRITIONAL DEFICIENCIES AND COGNITIVE DEVELOPMENT IN BANGLADESH RURAL PRESCHOOLERS	Assoc. Prof. Dr. Fatima Rahman, Dr. Arif Hossain
		6	MATERNAL DEPRESSION EFFECTS ON ATTACHMENT FORMATION IN DHAKA URBAN INFANTS	Ruma Begum, Dr. Shahidul Islam, Nusrat Jahan
		7	FLOOD-INDUCED TRAUMA AND RESILIENCE BUILDING IN BANGLADESH RIVERINE CHILDREN	Prof. Dr. Khaleda Akter, Sumaiya Chowdhury
		8	DIGITAL LEARNING PLATFORMS AND SOCIAL SKILLS DEVELOPMENT IN INDONESIAN PRIMARY STUDENTS	Dr. Wayan Sari, I Made Putra, Ni Luh Astuti
		9	CULTURAL PLAY PATTERNS AND CREATIVITY FOSTERING IN BALINESE PRESCHOOL CHILDREN	Assoc. Prof. Dr. Ketut Widana, Ayu Dewi

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HALL / SALON 4	**Assis. Prof. Dr. Zhanna Tastanbekova,**	1	LABOR MIGRATION PATTERNS FROM RURAL KAZAKHSTAN TO RUSSIAN FEDERATION CITIES: SOCIOECONOMIC DRIVERS AND FAMILY IMPACTS	Prof. Dr. Gulnara Abayeva, Yerzhan Tolegenov, Aidana Kurmangaliyeva
		2	URBANIZATION AND INTERNAL MIGRATION FLOWS IN POST-SOVIET KAZAKHSTAN: ALMATY VS ASTANA CASE COMPARISON	Assoc. Prof. Dr. Ruslan Zhumatov, Nurlan Bekbolatov
		3	CLIMATE-INDUCED ENVIRONMENTAL MIGRATION FROM ARAL SEA REGION IN SOUTHERN KAZAKHSTAN	Dr. Aizhan Kassenova, Dina Sarsenbayeva
		4	KAZAKH DIASPORA RETURN MIGRATION AND NATIONAL IDENTITY FORMATION PROCESSES	Assis. Prof. Dr. Zhanna Tastanbekova, Erlan Nurgaliyev
		5	CIRCULAR LABOR MIGRATION BETWEEN RUSSIA AND CENTRAL ASIA: CENTRAL ASIAN MIGRANT EXPERIENCES IN MOSCOW	Prof. Dr. Irina Petrova, Dr. Sergei Kuznetso
		6	HIGHLY SKILLED RUSSIAN EMIGRATION POST-2022: BRAIN DRAIN TO GEORGIA AND ARMENIA	Assoc. Prof. Dr. Elena Volkova, Mikhail Ivanov
		7	UKRAINIAN REFUGEES IN RUSSIA: INTEGRATION CHALLENGES AND STATE-SOCIETY TENSIONS	Dr. Natalia Smirnova, Pavel Morozov, Anna Kuzmina
		8	BALKAN LABOR MIGRATION TO EU COUNTRIES: NORTH MACEDONIAN WORKERS IN GERMANY AND AUSTRIA	Assoc. Prof. Dr. Nikola Popovski, Elena Ivanovska
		9	INTERNAL RURAL-URBAN MIGRATION AND SOCIAL COHESION IN POST-SOCIALIST NORTH MACEDONIA	Dr. Marija Petrovska, Goran Trajkovski

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HALL / SALON 5	**Dr. Olga Smirnova,**	1	COMMUNITY-BASED CONSERVATION INITIATIVES AND WILDLIFE PROTECTION IN KENYAN SAVANNAS	Prof. Dr. Kamau Njoroge, Amina Otieno
		2	GENDER ROLES EVOLUTION IN URBAN KENYAN SLUM ECONOMIES POST-DEVOLUTION	Assoc. Prof. Dr. Wanjiku Mwangi, Dr. Elias Kiprop
		3	YOUTH RADICALIZATION PATHWAYS AND PEACEBUILDING INTERVENTIONS IN COASTAL KENYA	Fatima Hassan, Prof. Dr. Juma Omondi
		4	CLIMATE CHANGE ADAPTATION STRATEGIES AMONG PASTORALISTS IN NORTHERN KENYA	Dr. Sarah Lekule, Nathan ole Kipury
		5	URBAN INFORMALITY AND SOCIAL CAPITAL FORMATION IN NAIROBI'S MATATU SECTOR	Miriam Wairimu, Assoc. Prof. Dr. Peter Njoroge
		6	RUSSIA'S SOFT POWER PROJECTION THROUGH CULTURAL DIPLOMACY IN POST-SOVIET SPACE	Prof. Dr. Irina Petrova, Dr. Alexei Volkov
		7	ETHNIC FEDERALISM CHALLENGES AND IDENTITY POLITICS IN CONTEMPORARY RUSSIA	Assoc. Prof. Dr. Natalia Kuznetsova, Sergei Ivanov
		8	MEMORY POLITICS AND WWII NARRATIVES IN RUSSIAN EDUCATION SYSTEMS	Dr. Olga Smirnova, Mikhail Kuzmin
		9	URBAN RURAL DIVIDE AND SOCIAL MOBILITY PATTERNS IN MODERN JAPAN	Prof. Dr. Hiroshi Tanaka, Aiko Nakamura
		10	AGING SOCIETY CHALLENGES AND INTERGENERATIONAL SOLIDARITY IN JAPAN	Dr. Yumi Sato, Kenji Yamamoto
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HALL / SALON 6	**Prof. Dr. Luan Rama, Dr. Anila Godo**	1	WORK-LIFE BALANCE AND GENDER EQUALITY IN CORPORATE JAPAN	Assoc. Prof. Dr. Mika Kobayashi
		2	SHIITE-SUNNI DYNAMICS AND SECTARIAN PEACEBUILDING IN CONTEMPORARY IRAN	Prof. Dr. Reza Mohammadi, Fatemeh Karimi
		3	WOMEN'S POLITICAL PARTICIPATION UNDER THEOCRATIC GOVERNANCE IN IRAN	Dr. Soraya Ahmadi, Ali Jafari
		4	URBAN MIGRATION AND FAMILY STRUCTURE TRANSFORMATIONS IN RURAL IRAN	Assoc. Prof. Dr. Hassan Rezaei, Leila Bahrami
		5	EDUCATION REFORMS AND YOUTH EMPLOYABILITY IN POST-TALIBAN AFGHANISTAN NEIGHBORHOODS	Prof. Dr. Ahmed Khan, Sara Malik, Bilal Rehman
		6	CLIMATE INDUCED MIGRATION AND BORDERLAND IDENTITIES IN BALOCHISTAN	Dr. Fatima Zahra, Omar Siddiqui
		7	RELIGIOUS PLURALISM AND INTERFAITH DIALOGUE INITIATIVES IN URBAN PAKISTAN	Assoc. Prof. Dr. Ayesha Rahman, Zainab Noor
		8	DIGITAL ETHNOGRAPHY OF DIASPORA IDENTITIES AMONG ALBANIAN COMMUNITIES IN EUROPE	Prof. Dr. Luan Rama, Dr. Anila Godo
		9	TRANSITIONAL JUSTICE MECHANISMS AND POST-COMMUNIST RECONCILIATION IN ALBANIA	Assoc. Prof. Dr. Erion Veliaj, Mira Xhaxho
		10	RURAL TOURISM DEVELOPMENT AND CULTURAL HERITAGE PRESERVATION IN NORTHERN ALBANIA	Dr. Blerta Hoxha, Krenar Gashi
		11	YOUTH POLITICAL ENGAGEMENT IN POST-SOCIALIST ALBANIAN DEMOCRACY	Mirela Dervishi, Prof. Dr. Sokol Lloshi

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HALL / SALON 7	**Assoc. Prof. Dr. Ana Martínez,**	1	THE INTERSECTION OF SUFISM AND KYRGYZ NOMADIC SPIRITUALITY IN CENTRAL ASIAN ISLAMIC TRADITION	Prof. Dr. Almazbek Asanov, Gulnara Ibraimova EXISTENTIAL THEMES IN
		2	BUDDHIST INFLUENCES ON PRE-ISLAMIC KYRGYZ SHAMANISM AND TENGRISM	Dr. Bakyt Omuraliev, Janyl Myrzakmatova, Erlan Kadyrov
		3	THOMAS AQUINAS' NATURAL LAW THEORY AND CONTEMPORARY SPANISH BIOETHICS DEBATES	Prof. Dr. Miguel Hernández, Carmen López
		4	EXISTENTIAL PHENOMENOLOGY AND SPANISH MYSTICAL THEOLOGY: A COMPARATIVE STUDY	Assoc. Prof. Dr. Ana Martínez, Javier Ruiz
		5	NIETZSCHE'S CRITIQUE OF CHRISTIANITY AND CONTEMPORARY SPANISH SECULARIZATION PROCESSES	Dr. Elena García, Prof. Dr. Roberto Sánchez
		6	MAHAYANA BUDDHISM'S EMPTINESS DOCTRINE AND CAMBODIAN THERAVADA PRACTICES	Sovannarith Kim, Dr. Chhay Lay
		7	HINDU INFLUENCES ON PRE-ANGKORIAN CAMBODIAN COSMOLOGY AND RITUAL PRACTICES	Assoc. Prof. Dr. Vireak Soth, Maly Phoung
		8	CHRISTIAN MISSIONARY ENCOUNTERS WITH CAMBODIAN BUDDHISM DURING FRENCH COLONIAL PERIOD	Prof. Dr. Sopheap Nguon, Rithy Chum
		9	KYRGYZ EPIC POETRY AND THEIR PARALLELS WITH NIETZSCHEAN PHILOSOPHY	Assoc. Prof. Dr. Nurlan Toktonaliev, Aidana Sarybaeva
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HALL / SALON 8	**Assoc. Prof. Dr. Karim Belkacem,**	1	ISLAMIC FINANCE CONTRACTS AND SHARIA COMPLIANCE IN SAUDI ARABIAN COMMERCIAL LAW	Prof. Dr. Abdullah Al-Saud, Dr. Fatima Al-Ghamdi, Khalid Al-Mansour
		2	DATA PROTECTION REGULATIONS AND CYBERSECURITY CHALLENGES IN THE KINGDOM OF SAUDI ARABIA	Assoc. Prof. Dr. Nasser Al-Qahtani, Sara Al-Harbi
		3	WOMEN'S RIGHTS EVOLUTION UNDER GUARDIANSHIP SYSTEM REFORMS IN SAUDI FAMILY LAW	Dr. Laila Al-Otaibi, Mohammed Al-Sharif, Prof. Dr. Huda Al-Ghanmi
		4	CONSTITUTIONAL REFORMS AND PUBLIC LAW CHALLENGES IN POST-INDEPENDENCE ALGERIA	Assoc. Prof. Dr. Karim Belkacem, Yacine Hadji
		5	INTERNATIONAL HUMAN RIGHTS LAW IMPLEMENTATION IN ALGERIAN DOMESTIC JURISPRUDENCE	Dr. Nadia Zerhouni, Samir Lounis, Amina Boualem
		6	COMMERCIAL ARBITRATION LAW REFORM AND FOREIGN INVESTMENT PROTECTION IN ALGERIA	Prof. Dr. Ahmed Larbi, Fatima Zerrouki
		7	CROSS-BORDER DATA FLOWS AND CYBERSECURITY REGULATION IN LEBANESE FINANCIAL SECTOR	Assoc. Prof. Dr. Elie Salem, Dr. Nadia Khoury, Michel Aoun
		8	REFUGEE LAW CHALLENGES AND NON-REFOULEMENT PRINCIPLE IN LEBANESE JURISPRUDENCE	Dr. Carla Haddad, Rami Nasr, Assis. Prof. Dr. Lina Hayek
		9	ANTI-MONEY LAUNDERING REGULATIONS AND TERRORIST FINANCING PREVENTION IN LEBANON	Prof. Dr. Antoine Habchi, Sarah El-Khoury

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HALL / SALON 1	**Prof. Dr. Mehmet ÖZMENLİ**	1	FERUDUN ZAİMOĞLU VE ALMANYA'DA YAŞAYAN TÜRKLERİN TOPLUMSAL VE DİLSEL PROBLEMLERİ	Doç. Dr. Seriyye Gündoğdu
		2	TÜRK ŞİİRİNDE MASALIN PROPP'UN MASAL TEORİSİNE GÖRE YENİDEN YORUMLANIŞI: SEZAİ KARAKOÇ ÖRNEĞİ	Doç. Dr. Canan OLPAK KOÇ Dilek Rabia ERGÜL
		3	LATİFE TEKİN'İN SEVGİLİ ARSIZ ÖLÜM ROMANINDA ÇOCUK GÖZÜYLE AİLE KAVRAMI	Doç. Dr. Canan OLPAK KOÇ Dilek Rabia ERGÜL
		4	ESKİ ANADOLU TÜRKÇESİYLE YAZILMIŞ BİR SATIR ARASI KUR'AN TERCÜMESİ	Öğr. Gör. Mutlu KAYA
		5	Occupational Folklore in Sait Faik Abasıyanık's Adapazarı Stories	Dr. Oğuz YILDIRIM
		6	ROMANTİK YALANIN ÇÖKÜŞÜ: RENÉ GIRARD'IN ÜÇGEN ARZU MODELİYLE MEHMET RAUF'UN GENÇ KIZ KALBİ ROMANI	Doç. Dr. Nazlı MEMİŞ BAYTİMUR
		7	GÖÇ OLGUSU BAĞLAMINDA MEVLANA İDRİS'İN HALEPLİ ZEYNEP ADLI ÇOCUK KİTABININ İNCELENMESİ	Prof. Dr. Elif AKTAŞ Arş. Gör. Ahmet Turan EŞ
		8	KARAKTER ÖZELLİKLERİ AÇISINDAN MERT ARIK'IN BENİM ZÜRAFAM UÇABİLİR ADLI ÇOCUK KİTABININ İNCELENMESİ	Prof. Dr. Elif AKTAŞ Arş. Gör. Ahmet Turan EŞ
			BOZKIR HAYATININ ÜÇ TEMEL UNSURU: ÇADIR, AT VE DEMİR	Prof. Dr. Mehmet ÖZMENLİ Öğr. Gör. Gökhan HAMZAÇEBİ
			RİTİM, İKTİDAR VE KİMLİK: TÜRK KÜLTÜRÜNDE DAVULUN İNANÇ, NEVBET VE HALK OYUNLARI BAĞLAMINDAKİ DÖNÜŞÜMÜ	Prof. Dr. Mehmet ÖZMENLİ Öğr. Gör. Gökhan HAMZAÇEBİ

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HALL / SALON 2	**Dr.Öğr.Üyesi Pınar GÜMÜŞ AKAR**	1	MICROECONOMIC OUTCOMES OF FINANCIAL LITERACY	Assistant Professor, PhD, Kutlu ERGÜN
		2	"TAVAN FİYAT MI KURUMSAL AYARLAMA MI?" 1009/1600 NARH DEFTERİ ÜZERİNDEN OSMANLI'DA MAL BAZLI FİYAT MÜDAHALESİNİN MİKRO ANALİZİ	Arş. Gör. M. Ali Yapıcı Prof. Dr. Gülden Ülgen
		3	THE INTERACTION BETWEEN INCOME INEQUALITY AND DEFENSE EXPENDITURES: THE CASE OF CHINA	Dr. Öğr. Üyesi Fatih AKIN Dr. Ayşe ERYER
		4	KAMU HARCAMALARININ BİLEŞİMİ VE EKONOMİK PERFORMANS ÜZERİNE TEORİK BİR ARAŞTIRMA	Doç. Dr. Burcu YILMAZ ŞAHİN Dr. Öğr. Üyesi Halit Levent ORMAN
		5	TEKNOLOJİK YAYILMA TEORİLERİ ÇERÇEVESİNDE DİJİTAL DÖNÜŞÜM VE EKONOMİK PERFORMANS: TEORİK BİR İNCELEME	Doç. Dr. Burcu YILMAZ ŞAHİN Dr. Öğr. Üyesi Halit Levent ORMAN
		6	HAVAYOLU TAŞIMACILIĞI VE DOĞRUDAN YABANCI YATIRIM GİRİŞLERİ ARASINDAKİ İLİŞKİ: EN YÜKSEK DYY STOKUNA SAHİP ÜLKELER ÜZERİNE AMPİRİK BİR ANALİZ	Dr.Öğr.Üyesi Pınar GÜMÜŞ AKAR
		7	YAPAY ZEKÂ VE İSTİHDAM İLİŞKİSİ: MESLEKLER TEMELLİ AMPİRİK BİR ANALİZ	Suat MUMCU Doç. Dr. Abdullah ALTUN
		8	TÜRKİYE'DE GIDA FİYAT ARTIŞLARININ TÜKETİCİ MAL SEPETİNDEKİ KAYMALARA ETKİSİ	Arş. Gör. Merve BENGÜ DEMİRKIRAN Prof. Dr. Gülden ÜLGEN
		9	BİRLEŞMİŞ MİLLETLER SÜRDÜRÜLEBİLİR KALKINMA HEDEFLERİ İLE KAMU BÜTÇELEME SÜREÇLERİNİN KURAMSAL KESİŞİMİ: TÜRKİYE ÖRNEĞİ	Dr. Öğretim Üyesi Emrah KIRATOĞLU
		10	BRİCS ÜLKELERİNDE DİJİTAL EKONOMİ VE DIŞA AÇIKLIKLIĞIN İŞSİZLİK ORANINA ETKİLERİ: AMPİRİK KANITLAR	Dr. Öğr. Üyesi Nuran ÖZTÜRK OFLUOĞLU
		11	ANALYSIS OF CONSANGUINEOUS MARRIAGE RATES IN TURKEY	Prof. Dr. Ersin KIRAL Prof. Dr. Gülsen KIRAL

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HALL / SALON 3	**Yrd.Doç.Dr.Burak KURTCEBE**	1	TRUMPİZM 2.0 VE 3. DÜNYA SAVAŞI SÖYLEMİNİN GÜVENLİKLEŞTİRİLMESİ	Salih EROĞLU
		2	RUS ASKERİ DOKTRİNİ MASKİROVKA'NIN UKRAYNA SAVAŞI ÜZERİNDEN İNCELENMESİ	Salih EROĞLU
		3	EGEMENLİK ÇATIŞMASI: KIBRIS HELEN MİLLİYETÇİSİ PARTİLERİNİN 'SİYASİ EŞİTLİK' KAVRAMINA YAKLAŞIMI VE AVRUPA BİRLİĞİ NORMLARI İLE ÇELİŞKİSİ	Yrd.Doç.Dr.Burak KURTCEBE
		4	BATI-SONRASI DÜNYADA ORTAK KİMLİK İNŞASI: YENİ BÖLGESELCİLİK BAĞLAMINDA TÜRK DEVLETLERİ TEŞKİLATI	Yüksek Lisans Öğrencisi Inkar KANAT Dr. Öğr. Üyesi Haluk DOĞAN
		5	INVESTIGATION OF THE CROWDSOURCING UTILIZATION MODEL IN LOGISTICS	Prof.Dr. Aydın KAYABAŞI Doç.Dr. Hakan Kiracı Doç.Dr. Fatma Demirağ
		6	KÜRESEL VE YEREL E TİCARET PLATFORMLARA YÖNELİK GÜVEN VE SATIN ALMA DÜŞÜNCESİ	Emine BÜYÜKER ARITÜRK
		7	GEOPOLITICAL RISKS AND CANAL PROJECTS IN INTERNATIONAL LOGISTICS WITHIN THE FRAMEWORK OF MAHAN'S SEA POWER THEORY: A COMPARATIVE ANALYSIS OF THE KIEL CANAL AND THE DON-VOLGA CANAL	Doktora Öğrencisi Mehmet ERDOĞDU Doç. Dr. Nihan Tomris KÜÇÜN
		8	A REVIEW OF LOGISTICS INFORMATION SYSTEMS	Doç. Dr. Yasin ŞEKER Doç. Dr. Oğuz Yusuf ATASEL Doç. Dr. Nevzat GÜNGÖR
			A REVIEW OF WAREHOUSE MANAGEMENT, OPERATIONS, AND EFFICIENCY	Doç. Dr. Nevzat GÜNGÖR Doç. Dr. Yasin ŞEKER Doç. Dr. Oğuz Yusuf ATASEL

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HALL / SALON 4	**Doç. Dr. Mustafa POLAT**	1	A BIBLIOMETRIC ANALYSIS OF RESEARCH ON INTERNATIONAL STUDENTS' SENSE OF BELONGING	Doç. Dr. Mustafa POLAT Prof. Dr. Fatih KIRIŞIK
		2	BIG ARTIFICIAL INTELLIGENCE COMPANIES AND DIGITAL SOVEREIGNTY	Prof. Dr., FATİH KIRIŞIK Öğr. Gör. Dr., HÜLYA ÖZÇAĞLAR EROĞLU
		3	TÜRKÇE EĞİTİMİ BAĞLAMINDA ÜRETKEN YAPAY ZEKA: ÖĞRETMEN ADAYLARININ ALGILARI VE DENEYİMLERİ	Prof. Dr. Hasan BAĞCI Arş. Gör. Ömer ACAR
		4	TÜRKÇE ÖĞRETMENİ ADAYLARININ MANTIK HATALARI FARKINDALIK DÜZEYLERİNİN ÇEİŞİTLİ DEĞİŞİKENLER AÇISINDAN İNCELENMESİ	Prof. Dr. Hasan BAĞCI Mehmet İZCİ
		5	MÜZİK EĞİTİMİ ÇERÇEVESİNDE MÜKEMMELİYETÇİLİK VE PERFORMANS KAYGISI	İrem Ayça DEMİR Prof.Dr.Birsen JELEN
		6	AN EXAMINATION OF TEACHERS' SELF-EFFICACY IN SPECIAL EDUCATION NEEDS BY TOTAL WORK EXPERIENCE: A NON-PARAMETRIC ANCOVA	Doç. Dr. Mahmut Sami KOYUNCU Doç. Dr. Mehmet ŞATA
		7	AN EXAMINATION OF TEACHERS' WORKPLACE STRESS AND WELL-BEING LEVELS BY CLASS SIZE	Doç. Dr. Mahmut Sami KOYUNCU Doç. Dr. Mehmet ŞATA
		8	EVALUATION OF DIGITAL APPLICATIONS USED IN TURKISH LANGUAGE TEACHING THROUGH META-THEMATHICAL ANALYSIS	Sergen Aydın
		9	2025 LGS FEN BİLİMLERİ SORULARININ YENİLENMİŞ BLOOM TAKSONOMİSİNİN BİLİŞSEL ALAN BASAMAKLARINA GÖRE İNCELEMESİ	Uzman Öğretmen Adem ERTAÇ Doç. Dr. Bilge ÖZTÜRK
		10	EĞİTİMDE DİJİTAL OKURYAZARLIĞA İLİŞKİN YAPILAN ARAŞTIRMALARIN DEĞERLENDİRİLMESİ	Hatice KAYNAK Dr. Öğr. Üyesi Ramazan YURTSEVEN

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HALL / SALON 5	**Prof.Dr. Şükran UÇUŞ GÜLDALI**	1	EĞİTİMDE WEB 2.0 ARAÇLARI KULLANIMINA İLİŞKİN ÖĞRETMEN GÖRÜŞLERİ	Şule AYDIN ÜNLÜ Dr. Öğr. Üyesi Mustafa Enes TEPE Dr. Öğr. Üyesi Ramazan YURTSEVEN
		2	OKUL ÖNCESİ DÖNEMDE ÇOCUĞA SAHİP ANNELERDE GELİŞİMSEL NİŞ İLE ANNELİK BECERİLERİNDEKİ ÖZ YETERLİK İLİŞKİSİNİN İNCELENMESİ	Bilim Uzmanı, Ömrüm UZUN YOLCU Dr. Öğr. Üyesi, Nalan ARABACI
		3	TOULMİN ARGÜMANTASYON YAKLAŞIMINA GÖRE ÖĞRETMEN ADAYLARININ DEĞER ALGILARI: EYLEM ARAŞTIRMASI	Prof.Dr. Şükran UÇUŞ GÜLDALI Yüksek Lisans Öğrencisi Durdu Nur DOĞAN Yüksek Lisans Öğrencisi Ebrar Şilan AYDEMİR
		4	2018 ve 2024 HAYAT BİLGİSİ ÖĞRETİM PROGRAMLARININ YARATICI DÜŞÜNME AÇISINDAN KARŞILAŞTIRILMASI	Prof.Dr. Şükran UÇUŞ GÜLDALI Şebnem ÇAĞLAR
		5	DİJİTAL DAYANIKLILIK ÖLÇEĞİ'NİN TÜRKÇE'YE UYARLANMASI: GEÇERLİK VE GÜVENİRLİK ÇALIŞMASI	Doç. Dr. Yahya AKTU Dr. Öğr. Üyesi Ercan ARAS Dr.Ayfer İLYAS
		6	AN ANALYSIS OF ASSESSMENT AND EVALUATION TOOLS IN THE 2024 CURRICULUM UNDER THE CENTURY OF TÜRKIYE EDUCATION MODEL	Cansel ÖZYİĞİT HOŞAFCI Metin HOŞAFCI Assist. Prof. Dr., Hasan Fehmi ÖZDEMİR Assoc. Prof. Dr., Ömer NAYCİ
		7	TIMSS VE PIRLS BAĞLAMINDA LETONYA EĞİTİM SİSTEMİNİN İNCELENMESİ VE TÜRKİYE AÇISINDAN ÇIKARIMLAR	Damla ERDOĞAN Doç. Dr. Hasan Fehmi ÖZDEMİR
		8	14–18 YAŞ ÖĞRENCİLERİNİN FİZİKSEL UYGUNLUK DÜZEYİ KAPASİTELERİNE COVID-19 PANDEMİ SÜRECİNİN ETKİSİNİN İNCELENMESİ	Öğretmen Asuman PEHLİVAN Prof Dr. Mustafa ALTINKÖK
			14–18 YAŞ ÖĞRENCİLERİNİN BESLENME ÖZ – YETERLİK TUTUMLARINA COVID-19 PANDEMİ SÜRECİNİN ETKİSİNİN İNCELENMESİ	Öğretmen Asuman PEHLİVAN Prof Dr. Mustafa ALTINKÖK

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HALL / SALON 6	**Doç. Dr. Hilal KUŞCU KARATEPE**	1	HEMŞİRELİK MESLEKİ KİMLİK ALGISI	Doç. Dr. Muhammet Ali ÇELEBİ Yüksek Lisans Öğrencisi Şevket BAŞTUĞ
		2	TIP HEKİMİ MESLEKİ KİMLİĞİ	Doç. Dr. Muhammet Ali ÇELEBİ Yüksek Lisans Öğrencisi İlyas UÇAR
		3	THE IMPORTANCE OF ARTIFICIAL INTELLIGENCE IN HEALTH CARE	Beyza YILDIZ Doç.Dr. Sevtap SARIOĞLU UĞUR
		4	SAĞLIK ÇALIŞANLARININ DEMOGRAFİK ÖZELLİKLERİ BAKIMINDAN ALGILANAN LİDERLİK TARZLARININ ÇALIŞANLARIN MOTİVASYON DÜZEYİNE ETKİSİ	Prof. Dr. Ali ŞAHİN Bilim Uzmanı Selin GEVREK
		5	SAĞLIK SEKTÖRÜ ÇALIŞANLARI VE YÖNETİCİLERİNİN LİDERLİK ALGISI KONYA SELÇUKLU ÖRNEĞİ	Prof. Dr. Ali ŞAHİN Bilim Uzmanı Selin GEVREK
		6	SAĞLIK KURUMLARINDA İSG EĞİTİMLERİ: KAPSAM, MEVZUAT VE UYGULAMA YAKLAŞIMLARI	Yüksek Lisans Öğrencisi Ahmet Aktar Dr. Öğretim Üyesi Süreyya YİĞİTALP RENÇBER
		7	SAĞLIKTA YAPAY ZEKA VE DİJİTALLEŞMENİN ROLÜ	Yüksek Lisans Öğrencisi Ahmet Aktar Dr. Öğretim Üyesi Süreyya YİĞİTALP RENÇBER
		8	ARTIFICIAL INTELLIGENCE AND DIGITAL LITERACY IN NURSES	Doç. Dr. Hilal KUŞCU KARATEPE
			DETERMINING THE EFFECT OF COGNITIVE FLEXIBILITY ON INNOVATIVE BEHAVIOR	Doç. Dr. Hilal KUŞCU KARATEPE

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HALL / SALON 7	**Doç. Dr. İbrahim YIKILMAZ**	1	SİBER ZORBALIĞIN PSİKOSOSYAL BİR YORDAYICISI OLARAK AHLAKİ DUYARSIZLAŞMA: EMPATİNİN ARACI ETKİSİ	Prof.Dr. Yunus ZENGİN
		2	THE APPROPRIATENESS OF TEAL ORGANIZATIONS FOR GENERATION Z	Doç. Dr. Aysel Arslan
		3	CHALLENGING WORK ENVIRONMENTS: INTERPERSONAL DEVIANCE, TURNOVER INTENTION, AND THE MODERATING ROLE OF OPTIMISM	Dr. Gülay Murat Eminoğlu
		4	PERSONNEL MANAGEMENT IN THE OTTOMAN PUBLIC HEALTH ORGANIZATION:AN EXAMINATION OF AN 1889 INSTRUCTION	Arş. Gör. Dr. Ramazan Furkan ÖZKUL
		5	DONANMA-YI OSMÂNÎ'DE PERSONEL YÖNETİMİ: 1910 TARİHLİ BİR TALİMATNAME İNCELEMESİ	Arş. Gör. Dr. Ramazan Furkan ÖZKUL
		6	WELL-BEING IN WORK LIFE: MODELS AND INTERVENTION APPROACHES	Prof. Dr. Devrim VURAL YILMAZ Doç. Dr. Demet VURAL YÜZBAŞI
		7	JOB SEARCH ANXIETY IN EMERGING ADULTHOOD: A THEORETICAL EVALUATION	Prof. Dr. Devrim VURAL YILMAZ Doç. Dr. Demet VURAL YÜZBAŞI
		8	YÖNETİCİLERİN Z KUŞAĞI ÇALIŞANLARA YÖNELİK ALGILARI VE YÖNETİMSEL İSTEKSİZLİĞİN NEDENLERİ	Ömer KARADEMİR
			COFFEE BADGING: CONCEPTUALIZING SYMBOLIC PRESENTEEISM IN HYBRID WORK CONTEXTS	Doç. Dr. İbrahim YIKILMAZ Dr. Ögr. Üyesi Havva DEĞİRMENCİ TARAKÇI
			QUIET THRIVING: CONCEPTUALIZING SILENT AND SUSTAINABLE EMPLOYEE GROWTH IN CONTEMPORARY WORKPLACES	Doç. Dr. İbrahim YIKILMAZ Prof. Dr. Muhsin HALİS

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HALL / SALON 8	**Dr. Öğretim Üyesi Ayşe YAVUZ**	1	GÜÇLENDİRİCİ LİDERLİK VE ÇALIŞANLARDA İŞ BAĞLILIĞI ARASINDAKİ İLİŞKİ: META ANALİTİK BİR YAKLAŞIM	Dr. Öğr. Üyesi Onur OKTAYSOY Doç. Dr. Selen UYGUNGİL ERDOĞAN Doç. Dr. Ethem TOPÇUOĞLU
		2	YAPAY ZEKÂ VE ÇALIŞAN REFAHI: BİBLİYOMETRİK BİR ANALİZ	Doç. Dr. Selen UYGUNGİL ERDOĞAN Doç. Dr. Ethem TOPÇUOĞLU Dr. Öğr. Üyesi Onur OKTAYSOY
		3	KARİYER KEŞFİNİN BAZI DEMOGRAFİK DEĞİŞKENLER AÇISINDAN İNCELENMESİ: HAVACILIK YÖNETİMİ ÖĞRENCİLERİ ÜZERİNDE BİR ARAŞTIRMA	Dr. Öğretim Üyesi Tugay ÖNEY Havacılık Yönetimi Lisans Öğrencisi Özge Mislina ERDEM
		4	YEREL İSTİHDAMIN GELİŞTİRİLMESİNDE STRATEJİK BİR ARAÇ OLARAK EĞİTİM YÖNETİMİ; İBB'DE BİR ARAŞTIRMA.	Nursev GARİPDOĞAN Dr.Öğr. Üyesi Meriç Esat BEBİTOĞLU
		5	ÜNİVERSİTE ÖĞRENCİLERİNİN ÜNİVERSİTE LİDERLİĞİNE İLİŞKİN METAFORİK ALGILARI	Dr. Ejder Güven
		6	HAVA TAŞIMACILIĞINDA YOLCU PROFİLİ VE TERCİHLERİ: KASTAMONU ÜZERİNE BİR ARAŞTIRMA	Yüksek Lisans Öğrencisi Özcan ÖZVEREN Dr. Öğr. Üyesi Şafak AKTEMUR Dr. Öğr. Üyesi Abdulkadir ALICI Dr. Öğr. Üyesi Ahmet ERTEK
		7	İŞ DÜNYASINDA YENİ BİR TEHDİT: SESSİZ ÇATLAMA (QUİET CRACKİNG) VE ÖRGÜTSEL YANSIMALARI	Dr. Öğretim Üyesi Ayşe YAVUZ
		8	İŞ YAŞAMINDA TOKSİK POZİTİFLİK: NEDENLERİ VE SONUÇLARI ÜZERİNE KAVRAMSAL BİR İNCELEME	Dr. Öğr. Üyesi Ayşe YAVUZ
		9	FİRMA PERFORMANSININ BELİRLEYİCİSİ OLARAK SOSYO-DUYGUSAL ZENGİNLİK: BİR ARAŞTIRMA MODEL ÖNERİSİ	Dr. Ömer Samet KAZDAL Dr. Öğr. Üyesi Derya ÇELİK

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HALL / SALON 9	**Doç. Dr. Mustafa BABADAĞ**	1	MUHASEBE SÜREÇLERİ AÇISINDAN ARTAN VERGİ VE HARÇLAR	YÜKSEK LİSANS ÖĞRENCİSİ SAMET BABACAN Doç. Dr. MURAT KARAHAN
		2	THE EFFECT OF POSITIVE ATTITUDES TOWARDS ARTIFICIAL INTELLIGENCE ON INTERNET ENTREPRENEURSHIP INTENTION	Doç. Dr. Mustafa BABADAĞ
		3	ENFLASYON MUHASEBESİ KONUSUNDA YAPILMIŞ LİSANSÜSTÜ ÇALIŞMALARIN BİBLİYOMETRİK ANALİZİ	ÖMER FARUK EFE Doç. Dr. AZİZE ESMERAY
		4	ARACI KURUMLARDA FİNANSAL İLETİŞİM YOĞUNLUĞU VE ÇIKAR ÇATIŞMALARI	Gizem KALAYLAR Doç. Dr. Özen AKÇAKANAT
		5	ÜNİVERSİTE ÖĞRENCİLERİ ARASINDA KRİPTO PARA BİRİMLERİNE İLİŞKİN FARKINDALIK DÜZEYLERİ ÜZERİNE BİR ARAŞTIRMA	Yüksek Lisans Öğrencisi Norina KABIRI Doç. Dr. Canan YILDIRAN
		6	ACCOUNTING FOR CONSOLIDATION UNDER IFRS 10 AND IFRS 12	Assoc. Prof. Dr. Ahmet ÖZCAN
		7	THE EFFECTS OF SUNK COST FALLACY ON INVESTOR PERSISTENCE, LOSS AVERSION BEHAVIOR, AND PORTFOLIO MANAGEMENT	Doktora Öğrencisi Didar KAYİŞ BEŞİKTAŞLI Prof. Dr. Fatih KONAK
		8	A CONCEPTUAL ANALYSIS OF FINANCIAL CONVERGENCE IN THE GLOBAL SOUTH: A THEORETICAL APPROACH TO THE INTERCONNECTIVITY BETWEEN BORSA ISTANBUL AND BRICS MARKETS	Doktora Öğrencisi Didar KAYİŞ BEŞİKTAŞLI Prof. Dr. Fatih KONAK
			AN ANALYSIS OF THE INTEREST-FREE FINANCIAL STRUCTURE IN TURKEY USING SWOT ANALYSIS	Asst. Prof. Dr. Esra ERİK AKYOL
			2015-2024 YILLARI ARASINDA MUHASEBE ALANINDA YAZILMIŞ YÜKSEK LİSANS TEZLERİNİN BİBLİYOMETRİK YÖNTEMLE ANALİZİ	Doktora Öğrencisi Ayşe EKER Dr. Öğr. Üyesi Hatice ÇİÇEKAY Prof. Dr. Mehmet DEMİR

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HALL / SALON 10	**Prof. Dr. Uluç ÇAĞATAY**	1	STRATEJİK UFKUN HARİTALANMASI: UZAY GÜVENLİĞİ ALANINA BİBLİYOMETRİK BİR YAKLAŞIM	Dr. Öğr. Üyesi Deniz ALCA Doç. Dr. Mehmet KIRLIOĞLU Dr. Öğr. Üyesi Abdül Samet ÇELİKÇİ
		2	TÜRKİYE'DE SİYASET BİLİMİ ALANINDA "YENİ SAĞ" ÜZERİNE YAPILMIŞ ÇALIŞMALARIN VOSVIEWER İLE BİBLİYOMETRİK BİR ANALİZİ	Dr. Öğr. Üyesi Abdül Samet ÇELİKÇİ Doç. Dr. Mehmet KIRLIOĞLU Dr. Öğr. Üyesi Deniz ALCA
		3	BÜYÜKŞEHİR BELEDİYELERİNİN STRATEJİK PLANLARINDAKİ KIRSAL KALKINMA HEDEFLERİNİN İNCELENMESİ: EGE BÜYÜKŞEHİR BELEDİYELERİ ÖRNEĞİ	Prof. Dr. Ahmet UÇAR Prof. Dr. Uluç ÇAĞATAY
		4	TÜRKİYE'DE BÜYÜKŞEHİR STATÜSÜNDE OLMAYAN İL BELEDİYELERİNİN VİZYON İFADELERİNİN DEĞERLENDİRİLMESİ	Prof. Dr. Uluç ÇAĞATAY Prof. Dr. Ahmet UÇAR
		5	YEREL YÖNETİMLERDE YAPAY ZEKA KULLANIMININ ULUSLARARASI KARŞILAŞTIRMALI ANALİZİ	Doç.Dr. İsmail GÜNEŞ Emine KÜÇÜK AYDIN
		6	THE PLACE OF THE CONCEPT OF POWER AND THE INFLUENCE OF LEADERSHIP IN PUBLIC DIPLOMACY: THE CASE OF DONALD TRUMP	MA Student, İREM ATAŞ
		7	İŞLETME PERSPEKTİFİNDEN YEREL YÖNETİMLERDE İNSAN KAYNAKLARI YÖNETİMİ: KAVRAMSAL BİR DERLEME	Abdullah Nuri ARSLAN
		8	AKP'NİN İDEOLOJİK DÖNÜŞÜMÜ: KONVANSİYONEL MUHAFAZAKARLIKTAN MİLLİ MUHAFAZAKARLIĞA	ARAŞ.GÖR.DR. İLTERİŞ ERGUN

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HALL / SALON 11	**Assist. Prof. Dr. Zülküf KILIÇ**	1	ATAOL BEHRAMOĞLU'NUN "OKYANUSLA İLK KARŞILAŞMA" ADLI KİTABINDA NİTELEME SIFATI VE SIFAT FİİLLERLE KURULAN YAPILARIN ŞİİR DİLİNE ETKİSİ	Öğr. Gör. Hilal TAMTÜRK
		2	ÇOCUK EDEBİYATINDA BENLİK İNŞASI: ORADA MISIN? BENİM MARGARET	Arş. Gör. F. Yağmur YEĞİN
		3	The Hidden Meanings Of Turkish Reduplications: An Etymological Analysis	Dr. Öğr. Üyesi. Ali Koç
		4	FOOTBALL CLUBS' NAMING PRACTICES: THE CASE OF ELAZIĞ PROVINCE	Dr. Öğr. Üyesi. Ali Koç Doç. Dr. Muhammed Bahadır Sandıkçı
		5	THE LİNGUİSTİC MECHANİSM AND FUNCTİONİNG OF THE POSSESSİVE SYSTEM İN TURKMEN TURKİSH	Hatice BELENLİ Doç. Dr. Meriç GÜVEN
		6	THE DIALECTIC OF HUMAN AND NATURE IN DIVAN POETRY: AN ECO-CRITICAL READING AND RE-EVALUATION IN THE CONTEXT OF CONTEMPORARY ENVIRONMENTAL ETHICS	Assist. Prof. Dr. Zülküf KILIÇ
		7	WOMEN'S REPRESENTATION AND THE PERFORMATIVE CONSTRUCTION OF GENDER IN DİVAN POETRY: A FEMINIST CRITICAL READING	Assist. Prof. Dr. Zülküf KILIÇ
		8	THE SPATIALIZATION OF TIME AND THE TEMPORALIZATION OF SPACE IN DIVAN POETRY: AN EXAMINATION OF THE APPLICABILITY OF THE CONCEPT OF CHRONOTOPE TO CLASSICAL TURKISH POETRY	Assist. Prof. Dr. Zülküf KILIÇ

Hatice Belenli Sevra hocanın salonunda sunum yapacak .

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HALL / SALON 1	**Assoc. Prof. Dr. Karim Belkacem,**	1	ISLAMIC FINANCE CONTRACTS AND SHARIA COMPLIANCE IN SAUDI ARABIAN COMMERCIAL LAW	Prof. Dr. Abdullah Al-Saud, Dr. Fatima Al-Ghamdi, Khalid Al-Mansour
		2	DATA PROTECTION REGULATIONS AND CYBERSECURITY CHALLENGES IN THE KINGDOM OF SAUDI ARABIA	Assoc. Prof. Dr. Nasser Al-Qahtani, Sara Al-Harbi
		3	WOMEN'S RIGHTS EVOLUTION UNDER GUARDIANSHIP SYSTEM REFORMS IN SAUDI FAMILY LAW	Dr. Laila Al-Otaibi, Mohammed Al-Sharif, Prof. Dr. Huda Al-Ghanmi
		4	CONSTITUTIONAL REFORMS AND PUBLIC LAW CHALLENGES IN POST-INDEPENDENCE ALGERIA	Assoc. Prof. Dr. Karim Belkacem, Yacine Hadji
		5	INTERNATIONAL HUMAN RIGHTS LAW IMPLEMENTATION IN ALGERIAN DOMESTIC JURISPRUDENCE	Dr. Nadia Zerhouni, Samir Lounis, Amina Boualem
		6	COMMERCIAL ARBITRATION LAW REFORM AND FOREIGN INVESTMENT PROTECTION IN ALGERIA	Prof. Dr. Ahmed Larbi, Fatima Zerrouki
		7	CROSS-BORDER DATA FLOWS AND CYBERSECURITY REGULATION IN LEBANESE FINANCIAL SECTOR	Assoc. Prof. Dr. Elie Salem, Dr. Nadia Khoury, Michel Aoun
		8	REFUGEE LAW CHALLENGES AND NON-REFOULEMENT PRINCIPLE IN LEBANESE JURISPRUDENCE	Dr. Carla Haddad, Rami Nasr, Assis. Prof. Dr. Lina Hayek
		9	ANTI-MONEY LAUNDERING REGULATIONS AND TERRORIST FINANCING PREVENTION IN LEBANON	Prof. Dr. Antoine Habchi, Sarah El-Khoury

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HALL / SALON 2	**Assoc. Prof. Dr. Samir Lounis**	1	STRATEGIC ALLIANCES BETWEEN SERBIAN MANUFACTURING FIRMS AND GERMAN AUTOMOTIVE SUPPLIERS	Prof. Dr. Milan Petrovic, Dr. Ana Jovanovic, Marko Stanisic
		2	DIGITAL MARKETING TRANSFORMATION IN SERBIAN RETAIL SECTOR POST-PANDEMIC RECOVERY	Assoc. Prof. Dr. Jelena Radovic, Nikola Vukovic
		3	ESG INVESTMENT FRAMEWORKS AND FIRM VALUATION IN BELGRADE STOCK EXCHANGE	Dr. Stefan Markovic, Ivana Petrovic, Luka Djordjevic
		4	FAMILY BUSINESS SUCCESSION PLANNING CHALLENGES IN ALGERIAN MANUFACTURING SECTOR	Prof. Dr. Karim Belkacem, Nadia Zerhouni
		5	ISLAMIC FINANCE INNOVATIONS FOR SME FINANCING IN ALGERIAN POST-PANDEMIC RECOVERY	Assoc. Prof. Dr. Samir Lounis, Yassine Amrani, Amina Bouzid
		6	CIRCULAR ECONOMY IMPLEMENTATION IN ALGERIAN TEXTILE AND APPAREL INDUSTRY	Dr. Farid Benali, Soumia Haddad
		7	DIGITAL TRANSFORMATION STRATEGIES FOR EGYPTIAN SMES IN POST-PANDEMIC ECONOMY	Prof. Dr. Ahmed El-Sayed, Dr. Fatima Hassan, Omar Khalil
		8	SUSTAINABLE TOURISM DEVELOPMENT MODELS IN EGYPT'S RED SEA RESORTS	Assoc. Prof. Dr. Nour El-Din Mahmoud, Sara Ahmed
		9	BLOCKCHAIN APPLICATIONS IN EGYPTIAN AGRICULTURAL SUPPLY CHAIN TRANSPARENCY	Dr. Mohamed Salem, Assis. Prof. Dr. Layla Karim, Hassan El-Badry

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HALL / SALON 3	**Assoc. Prof. Dr. Ibrahim Garba**	1	EFFECTS OF SOIL MICROPLASTICS ON EARTHWORM REPRODUCTION AND COMMUNITY DYNAMICS IN SERBIAN AGRICULTURAL FIELDS	Prof. Dr. Milan Petrovic, Dr. Ana Jovanovic, Stefan Radovic
		2	CARBON SEQUESTRATION POTENTIAL OF AGROFORESTRY SYSTEMS IN VOJVODINA PLAIN SOILS	Assoc. Prof. Dr. Jelena Lukic, Marko Nesic
		3	BIOSORPTION OF HEAVY METALS FROM MINE TAILINGS USING SERBIAN NATIVE BACTERIAL CONSORTIA	Dr. Ivana Petrovic, Nikola Vukovic, Tamara Stankovic
		4	IMPACT OF URBAN EXPANSION ON FERTILITY STATUS OF LAGOS ISLAND COASTAL SOILS	Prof. Dr. Chukwuma Okeke, Adebayo Ogunleye
		5	PHYTOREMEDIATION OF OIL-CONTAMINATED DELTA SOILS USING NIGERIAN INDIGENOUS HYDROCARBON-TOLERANT PLANTS	Dr. Fatima Yusuf, Emmanuel Achu, Chioma Nwosu
		6	CHARACTERIZATION AND MANAGEMENT OF SALT-AFFECTED SOILS IN BORNO STATE IRRIGATED FARMLANDS	Assoc. Prof. Dr. Ibrahim Garba, Aisha Mohammed
		7	MICROBIAL ENHANCEMENT OF PHOSPHORUS AVAILABILITY IN PAKISTANI ARID ZONE CALCAREOUS SOILS	Prof. Dr. Khalid Mahmood, Amina Khan, Dr. Faisal Shahzad
		8	EFFECTS OF CONSERVATION AGRICULTURE ON SOIL QUALITY INDICATORS IN PUNJAB RICE-WHEAT SYSTEMS	Sadia Aslam, Assoc. Prof. Dr. Muhammad Iqbal
		9	RECLAMATION OF SALT-AFFECTED SOILS THROUGH ORGANIC AMENDMENTS IN SINDH PROVINCE	Dr. Zahra Ali, Hassan Raza
		10	NUTRIENT DYNAMICS AND LEACHING LOSSES UNDER INTENSIVE VEGETABLE PRODUCTION IN KARACHI PERI-URBAN SOILS	Naveed Akhtar, Prof. Dr. Safdar Ali, Mehwish Jabeen
		11	BIOCHAR APPLICATION EFFECTS ON GREENHOUSE GAS EMISSIONS FROM PAKISTANI RICE PADDIES	Assis. Prof. Dr. Rabia Sultana, Umar Farooq

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HALL / SALON 4	**Prof. Dr. Helmut Becker,**	1	BYZANTINE-GEORGIAN DIPLOMATIC ALLIANCES AND THEIR ROLE IN CAUCASUS POWER DYNAMICS	Prof. Dr. Nino Tsiklauri, Levan Beridze, Mariam Kapanadze
		2	MEDIEVAL GEORGIAN CHRONICLERS AND THE CONSTRUCTION OF NATIONAL IDENTITY NARRATIVES	Assoc. Prof. Dr. Tamar Lomidze, Giorgi Gelashvili
		3	OTTOMAN-GEORGIAN BORDERLAND INTERACTIONS IN THE 17TH CENTURY CAUCASUS	Dr. Irakli Chikvaidze, Assis. Prof. Dr. Lali Tsintsadze
		4	PRUSSIAN MILITARY REFORMS AND GERMAN NATIONALISM IN THE NAPOLEONIC ERA	Dr. Friedrich Wagner, Assoc. Prof. Dr. Lena Hoffmann
		5	WEIMAR REPUBLIC CULTURAL POLICIES AND THE BAUHAUS MOVEMENT	Prof. Dr. Helmut Becker, Sophie Krause, Dr. Markus Lehmann
		6	COLD WAR TAJIKISTAN: SOVIET MODERNIZATION AND LOCAL RESISTANCE STRATEGIES	Assoc. Prof. Dr. Farrukh Rahimov, Dilnoza Karomatova
		7	PERSIANATE CULTURAL INFLUENCES ON PRE-MODERN TAJIK INTELLECTUAL TRADITIONS	Dr. Shirin Azimova, Prof. Dr. Rustam Burhonov
		8	SOVIET HYDROPOWER PROJECTS AND ECOLOGICAL DISASTERS IN TAJIK PAMIR REGION	G ulnoza Sobirova, Dr. Javohir Ismoilov, Assis. Prof. Dr. Nigora Rahmonova
		9	THE HOLY ROMAN EMPIRE'S ECONOMIC POLICIES AND HANSEATIC LEAGUE EXPANSION	Prof. Dr. Klaus Müller, Anna Schmidt

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HALL / SALON 5	**Dr. Lena Schmidt,**	1	COMMUNITY-BASED TOURISM DEVELOPMENT AND RURAL REVITALIZATION IN GEORGIA'S HIGH CAUCASUS REGION	Prof. Dr. Nino Tsiklauri, Levan Beridze, Mariam Kapanadze
		2	YOUTH EMPOWERMENT PROGRAMS AND SOCIAL COHESION IN POST-SOVIET GEORGIA	Assoc. Prof. Dr. Tamar Gelashvili, Giorgi Chikhradze
		3	WOMEN'S COOPERATIVES AND GENDER EQUITY IN GEORGIAN AGRICULTURAL COMMUNITIES	Dr. Lasha Tsintsadze, Prof. Dr. Maka Lomidze, Ana Japaridze
		4	MIGRATION RETURNEE INTEGRATION AND REGIONAL DEVELOPMENT IN RURAL GERMANY	Prof. Dr. Hans Berger, Felix Neumann
		5	INTERGENERATIONAL LEARNING FOR SUSTAINABLE COMMUNITY FORESTRY IN GERMANY	Dr. Lena Schmidt,
		6	URBAN COMMUNITY GARDENS AND SOCIAL INCLUSION IN MULTICULTURAL GERMAN NEIGHBORHOODS	Assis. Prof. Dr. Amina Hassan, Markus Klein
		7	RURAL DIGITAL INFRASTRUCTURE AND ENTREPRENEURIAL DEVELOPMENT IN TAJIKISTAN	Prof. Dr. Farrukh Saidov, Nigora Rahimova
		8	WOMEN'S HANDICRAFT COOPERATIVES AND CULTURAL PRESERVATION IN TAJIK PAMIR	Dr. Gulnora Ismoilova, Aziza Nazarova, Farhod Rahmonov
		9	COMMUNITY HYDROPOWER MICROGRIDS FOR ENERGY ACCESS IN TAJIKISTAN'S MOUNTAIN VILLAGES	Assoc. Prof. Dr. Sherali Mirzoev, Dilnoza Ubaidullaeva
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HALL / SALON 6	**Dr. Giorgi Khutsishvili,**	1	BLACK SEA REGIONAL SECURITY DYNAMICS AND GEORGIA'S STRATEGIC POSITIONING IN NATO-EU ALIGNMENT	Prof. Dr. Nino Tsiklauri, Levan Beridze, Mariam Kapanadze
		2	ENERGY DIPLOMACY AND PIPELINE POLITICS: GEORGIA'S ROLE IN EU-RUSSIA ENERGY DIVERSIFICATION	Assoc. Prof. Dr. Irakli Gelashvili, Tamar Lomidze
		3	RUSSIAN HYBRID WARFARE TACTICS AND GEORGIA'S CYBERSECURITY RESILIENCE BUILDING MEASURES	Dr. Giorgi Khutsishvili, Assis. Prof. Dr. Salome Chikvaidze
		4	QATAR'S MEDIATION DIPLOMACY IN MIDDLE EAST CONFLICT RESOLUTION INITIATIVES	Prof. Dr. Ahmed Al-Thani, Fatima Rahman
		5	GCC ECONOMIC DIVERSIFICATION STRATEGIES AND QATAR'S NATIONAL VISION 2030 IMPLEMENTATION	Assoc. Prof. Dr. Khalid Al-Mansoori, Noor Hassan
		6	QATARI SOFT POWER PROJECTION THROUGH SPORTS DIPLOMACY AND FIFA WORLD CUP LEGACY	Dr. Sara Al-Khalifa, Omar Bin Nasser
		7	CENTRAL ASIAN WATER DIPLOMACY AND TAJIKISTAN'S REGIONAL HYDROPOWER LEADERSHIP	Prof. Dr. Farrukh Saidov, Dilnoza Rahimova
		8	TAJIKISTAN'S POSITION IN BELT AND ROAD INITIATIVE CONNECTIVITY CORRIDORS	Assoc. Prof. Dr. Rustam Juraev, Nigora Karomatova, Azizullo Hayitov
		9	AFGHANISTAN STABILITY IMPACTS ON TAJIKISTAN NATIONAL SECURITY FRAMEWORKS	Dr. Parvina Sobirova, Assis. Prof. Dr. Sherali Mirzoev
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HALL / SALON 7	**Assoc. Prof. Dr. Karim El-Fassi**	1	CLIMATE CHANGE POLICY IMPLEMENTATION CHALLENGES IN TANZANIA'S COASTAL COMMUNITIES	Prof. Dr. Amina Juma, Elias Kweka
		2	YOUTH POLITICAL PARTICIPATION AND DEMOCRATIC CONSOLIDATION IN POST-ELECTION TANZANIA	Assoc. Prof. Dr. Hamisi Mponda, Zawadi Nyerere
		3	FOREIGN AID DEPENDENCY AND POLICY AUTONOMY IN TANZANIA'S HEALTH SECTOR REFORMS	Dr. Fatma Kikoti, Juma Ramadhani
		4	TRANSITIONAL JUSTICE MECHANISMS AND NATIONAL RECONCILIATION IN POST-ARAB SPRING TUNISIA	Prof. Dr. Sami Ben Romdhane, Nadia Cherif
		5	WATER DIPLOMACY AND TRANSBOUNDARY GOVERNANCE IN THE MAGHREB REGION: TUNISIAN PERSPECTIVE	Assoc. Prof. Dr. Karim El-Fassi, Laila Zouari
		6	EU-TUNISIA MOBILITY PARTNERSHIP: MIGRATION GOVERNANCE OR NEO-COLONIALISM?	Dr. Hassen Zghal, Mariem Trabelsi
		7	MORROCAN FOREIGN POLICY IN SAHEL COUNTRIES: COUNTER-TERRORISM OR REGIONAL HEGEMONY?	Prof. Dr. Ahmed El-Khatib, Fatima Zahra
		8	WOMEN'S POLITICAL EMPOWERMENT THROUGH PARITY LAWS IN MOROCCAN LOCAL GOVERNANCE	Assoc. Prof. Dr. Nadia El-Fassi, Youssef Bennani
		9	ENERGY TRANSITION POLITICS AND PHOSPHATE DEPENDENCY IN MOROCCAN DEVELOPMENT STRATEGY	Dr. Karim Lahlou, Salma El-Ouardi
		10	ASEAN CENTRALITY AND MALAYSIAN FOREIGN POLICY IN SOUTH CHINA SEA DISPUTES	Prof. Dr. Abdul Rahman Embong, Nurul Ain
		11	ISLAMIC GOVERNANCE MODELS AND SECULAR RESISTANCE IN CONTEMPORARY MALAYSIAN POLITICS	Assoc. Prof. Dr. Syed Farid Alatas, Aishah Rohani

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HALL / SALON 8	**Dr. Zuberi Ramadhani**	1	INTEGRATING TASK-BASED LANGUAGE TEACHING WITH DIGITAL STORYTELLING FOR ADVANCED EFL PROFICIENCY IN HUNGARIAN UNIVERSITIES	Prof. Dr. Katalin Szabó, Dr. István Nagy, Eszter Kovács
		2	NEUROSCIENCE-INFORMED VOCABULARY ACQUISITION STRATEGIES FOR HUNGARIAN ADOLESCENT LEARNERS OF ENGLISH	Assoc. Prof. Dr. Zsolt Hermann, Laura Tóth
		3	CLIL METHODOLOGY IMPLEMENTATION CHALLENGES AND SUCCESS FACTORS IN HUNGARIAN STEM SUBJECTS	Dr. Anikó Balogh, Péter Szabó, Réka Kovács
		4	MOBILE-ASSISTED LANGUAGE LEARNING EFFECTIVENESS AMONG RURAL TANZANIAN SECONDARY STUDENTS	Assoc. Prof. Dr. Amina Hassan, Juma Mkude
		5	CODE-SWITCHING PATTERNS AND THEIR PEDAGOGICAL IMPLICATIONS IN TANZANIAN EFL CLASSROOMS	Dr. Fatma Said, Elias Nkya, Zawadi Mushi
		6	COMMUNICATIVE LANGUAGE TEACHING ADAPTATIONS FOR MULTILINGUAL TANZANIAN PRIMARY SCHOOLS	Dr. Zuberi Ramadhani
		7	FLIPPED CLASSROOM MODELS ENHANCING CRITICAL THINKING IN INDIAN ENGINEERING ESL PROGRAMS	Assoc. Prof. Dr. Priya Sharma, Rahul Mehra
		8	CORPUS-BASED APPROACHES TO BUSINESS ENGLISH VOCABULARY INSTRUCTION AT INDIAN B-Schools	Dr. Anjali Desai, Vikram Reddy
		9	GAMIFICATION STRATEGIES IMPROVING SPEAKING FLUENCY AMONG RURAL INDIAN UNDERGRADUATES	Neha Sanjay
		10	INTERCULTURAL COMPETENCE DEVELOPMENT THROUGH VIRTUAL EXCHANGE PROGRAMS IN INDIAN EFL CONTEXTS	Prof. Dr. Meera Joshi, Rohan Mehra, Anjali Singh
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HALL / SALON 9	**Dr. Anjali Rao**	1	DIGITAL MEDIA LITERACY PROGRAMS AND THEIR EFFECTIVENESS IN COMBATING FAKE NEWS AMONG HUNGARIAN UNIVERSITY STUDENTS	Prof. Dr. István Kovács, Dr. Eszter Nagy, Balázs Tóth
		2	SOCIAL MEDIA POLARIZATION DYNAMICS DURING NATIONAL ELECTIONS IN HUNGARY	Assoc. Prof. Dr. Zsófia Szabó, Tamás Herczeg
		3	THE ROLE OF PUBLIC SERVICE BROADCASTING IN COUNTERING POPULIST DISCOURSE IN CONTEMPORARY HUNGARY	Dr. Kinga Molnár, Gábor Farkas, Prof. Dr. András Balogh
		4	MOBILE PHONE COMMUNICATION PATTERNS AND SOCIAL CONNECTIVITY IN RURAL TANZANIA COMMUNITIES	Assoc. Prof. Dr. Amina Hassan, Juma Kweka
		5	RADIO LISTENERSHIP TRENDS AND INFORMATION ACCESS DURING COVID-19 IN URBAN TANZANIA	Dr. Fatma Zuberi, Elias Nchimbi, Assis. Prof. Dr. Rehema Mushi
		6	YOUTH PARTICIPATION IN DIGITAL ACTIVISM FOR CLIMATE JUSTICE IN TANZANIA	Lucas Mgaya, Prof. Dr. Salma Mbaga
		7	WHATSAPP MISINFORMATION CAMPAIGNS TARGETING ELECTIONS IN NORTHERN INDIA	Dr. Anjali Rao
		8	BOLLYWOOD'S GLOBAL SOFT POWER THROUGH OTT PLATFORMS AND DIASPORA AUDIENCES	Rahul Mehra, Dr. Neha Sanjay
		9	RURAL BROADBAND DEPLOYMENT AND DEVELOPMENT COMMUNICATION IN INDIA'S HINTERLANDS	Prof. Dr. Meera Joshi, Karan Desai

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HALL / SALON 1	Dr.Öğr.Üyesi İlkay Sibel KERVANCI	1	BARAJ YÖNETİMİ İÇİN SİSTEM DİNAMİĞİ UYGULAMASI	Doç.Dr.Şahin İNANÇ Prof.Dr.Arzu EREN ŞENARAS
		2	YEŞİL ARAÇ ROTALAMA PROBLEMİ ÇÖZÜMÜ İÇİN GENETİK ALGORİTMA UYGULAMASI	Dr.Onur Mesut ŞENARAS Doç.Dr.Şahin İNANÇ Prof.Dr.Arzu EREN ŞENARAS
		3	TURNAROUNDAI: Real-Time Analysis of Apron Turnaround Processes with Multi-Camera, Sensor Fusion, and AI Algorithms	Gamze Öztürk
		4	IOT BASED INTELLIGENT PUBLIC TRANSPORTATION SYSTEM FOR OCCUPANCY PREDICTION USING IN VEHICLE AIR POLLUTION DATA	Sn. Eng. Seren ÇARIKCI Dr. Melek ESEMEN ERTAŞ
		5	MULTIDISCIPLINARY APPROACHES TO THE PREVENTABLE STAGES OF COPD: AI-DRIVEN EARLY RISK PREDICTION, ENVIRONMENTAL AND BEHAVIORAL ANALYSIS, AND DIGITAL HEALTH ECOSYSTEMS	Assistant Professor Denizhan DEMİRKOL
		6	AI-ASSISTED TUBERCULOSIS DIAGNOSIS IN RESOURCE-CONSTRAINED REGIONS: PERSPECTIVES ON ACCESSIBILITY, INEQUITY, AND SAFETY	Assistant Professor Denizhan DEMİRKOL
		7	EĞİTİMİN MERKEZİYETSİZLEŞTİRİLMESİ: DİPLOMA VE TRANSKRİPT YÖNETİMİNDE GÜVEN VE VERİMLİLİK	Dr.Öğr.Üyesi İlkay Sibel KERVANCI
		8	SHORT-TERM ELECTRICITY CONSUMPTION FORECASTING USING XGBOOST WITH CALENDAR FEATURES	Dr.Öğr.Üyesi İlkay Sibel KERVANCI
			YAPAY ZEKA YÖNTEMLERİ KULLANILARAK ÇİMENTO FABRİKALARINDA HAVA KİRLİLİĞİNİN TESPİT EDİLMESİ VE ANALİZİ	Ar-Ge Mühendisi Berkay ÖZDEMİR Doç.Dr. Burak TANYERİ ARŞ.GÖR. CEVHER KÜRŞAT MACİT

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HALL / SALON 2	**Assoc. Dr. Aysel AKBENİZ**	1	THE ROLE OF MOTHER UNITS IN MEETING POSTPARTUM PSYCHOSOCIAL NEEDS	Assoc. Dr. Aysel AKBENİZ
		2	KATETER İLİŞKİLİ ÜRİNER SİSTEM ENFEKSİYONLARINDA HEMŞİRELİK YAKLAŞIMLARI	Prof. Dr. Gülay İpek Çoban Hemşire Gül Çiçekçi
		3	KAFA İÇİ BASINÇ ARTIŞINDA HEMŞİRELİK YAKLAŞIMLARI	Prof. Dr. Gülay İpek Çoban Hemşire Gül Çiçekçi
		4	CERRAHİ TAKIMDA PSİKOLOJİK GÜVENLİK: HATA BİLDİRİMİ	Duygu ALTUNOĞLU Dr. Öğr. Üyesi Hatice ERDOĞAN
		5	HASTANEDE YATAN 3-6 YAŞ GRUBU KRONİK HASTALIĞI OLAN ÇOCUKLARIN HASTANEDEKİ AKTİVİTELERİ VE ETKİLEYEN FAKTÖRLERİN İNCELENMESİ	Cansever Kaya Şenay Çetinkaya
		6	THE STATUS OF THE NURSES WORKING IN THE FIELD OF CHILD HEALTH AND DISEASES IN IMPLEMENTING THEIR ROLES AND FUNCTIONS, AND THE FACTORS AFFECTING THIS	Şenay Çetinkaya
		7	DİJİTAL EKRAN BAĞIMLILIĞININ SAĞLIK İNANÇ MODELİNE UYARLANMASI	Doç. Dr. Semra KOCATAŞ Şule SEVİMLİGÜL Esra ÖZ
		8	THE IMPACT OF URINARY INCONTINENCE ON QUALITY OF LIFE, SURGICAL TREATMENT, AND POSTOPERATIVE NURSING APPROACH	Irmak ŞAHİN Prof.Dr. Şenay ÜNSAL ATAN
			PREVENTION AND PROTECTION OF URINARY INCONTINENCE IN THE POSTMENOPAUSAL PERIOD: Lifestyle Changes, and Behavioral Approaches	Nur Efşan KARAKILIÇ Prof. Dr. Şenay ÜNSAL ATAN

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HALL / SALON 3	**Profesör Mustafa KÜÇÜKÖNER**	1	BUCAK VE ÇEVRE KÖYLERDE DOKUNAN HALI SECCADELER	Dr. Öğr.Üyesi Ayşe YILDIRIM
		2	GÜNEYBATI ANADOLU YÖRÜK YERLEŞİMLERİNDE HAVSIZ (KİRKİTLİ) SECCADE	Dr. Öğr.Üyesi Ayşe YILDIRIM
		3	TOURNEFORT'UN ANADOLU TOPRAKLRAINDA YAPTIĞI GRAVÜRLERİN SANATSAL ANALİZLERİ	Dr. Öğr. Üyesi Hava KÜÇÜKÖNER Profesör Mustafa KÜÇÜKÖNER
		4	SEMERKAND'DA BULUNAN TARİHİ YAPILARINA AİT GÜNÜMÜZ GRAVÜRLERİNİN SANATSAL ANALİZLERİ	Profesör Mustafa KÜÇÜKÖNER Dr. Öğr. Üyesi Hava KÜÇÜKÖNER
		5	ENKAUSTİK TEKNİĞİ'NİN DÜNÜ BUGÜNÜ	Doç. Dr. Aysun CANÇAT
		6	THE CONCEPTUAL AND SPATİAL USE OF THE COLOR RED İN CONTEMPORARY ART PRACTİCES	Doç. Dr. Tülay GÜMÜŞER Esra ERDOĞAN KARAGÖZ
		7	OP-ART (OPTİK SANAT) İLKELERİNİN MEKAN GRAFİĞİ UYGULAMALARINDA KİNETİK ALGI YARATIMI	Yüksek Lisans Öğrencisi Berkan DERYAL Dr. Öğr. Üyesi Burak YAVUZYILMAZ
		8	SEMIOTIC ANALYSIS OF ENVIRONMENTAL STORYTELLING IN THE THE LAST OF US SERIES (PART I–II) VIDEO GAMES	Suida DURSUN Dr. Öğr. Üyesi Hasan Tekinalp GÜREKEN

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HALL / SALON 4	**Assist. Prof. Ali Rauf KARATAŞ**	1	THE COMPOSITION OF FOOD INFLATION: EVIDENCE FROM ARGENTINA	Dr. Gülşah Adam
		2	INFLATION AND WELFARE LOSS: AN ANALYSIS OF CONSUMPTION EXPENDITURES BY INCOME QUANTILES IN TÜRKİYE, 2004–2024	Doç. Dr. Mustafa ZUHAL Dr. Öğr. Üy. Dilek TOKEL
		3	TEKNOLOJİK DÖNÜŞÜM VE TOPLUMSAL CİNSİYET: TÜRKİYE'DE TARIMDA MAKİNELEŞMENİN TARIMDAKİ KADIN İSTİHDAMI ÜZERİNDEKİ ETKİSİ	Kazım SAKA Özgür ÖZAYDIN
		4	TÜRKİYE'DE TARIMSAL İSTİHDAMIN İHRACAT PERFORMANSINA ETKİSİ: YAPISAL KIRILMA ALTINDA ARDL ANALİZİ	Özgür ÖZAYDIN Anıl DAĞDEMİR
		5	DIŞ TİCARET ANALİZLERİNDE NOMİNAL VE REEL DEĞİŞKEN KULLANIMI: KARŞILAŞTIRMALI BİR YAKLAŞIM	Dr. Ferdi AKPİLİÇ
		6	ASYMMETRIC RESPONSES OF YOUTH UNEMPLOYMENT TO ECONOMIC GROWTH, EXPORTS, AND INFLATION IN TURKEY: A NARDL APPROACH	Assist. Prof. Ali Rauf KARATAŞ Assoc. Prof. Ahmet Tayfur AKCAN
		7	EXCHANGE RATE SHOCKS AND PURCHASING POWER PARITY: A PERIODIC ANALYSIS FOR TÜRKİYE, 1995–2025	Assist. Prof. Ali Rauf KARATAŞ
		8	Neo-Fisher Hipotezi Üzerine Bir Literatür Taraması	Neslihan Bünül

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HALL / SALON 5	**Doç. Dr. Muharrem DOĞAN**	1	THE IMPACT OF NUCLEAR WEAPONS ON THE MIDDLE EAST PEACE	Dr. Sibel Elif ÖZDİLEK
		2	ÖTEKİNİN SİYASETİ: ULUSLARARASI DÜZEN VE FİLİSTİNİN KONUMLANDIRILMASI	Doç. Dr. Muharrem DOĞAN
		3	PAN-TÜRKİZMİN TARİHSEL DÖNÜŞÜMÜ VE TÜRK DEVLETLERİ TEŞKİLATININ KURUMSAL ÇERÇEVESİ	Doç. Dr. Muharrem DOĞAN
		4	THE U-8 GYUMRI INCIDENT IN TURKISH FOREIGN POLICY	Prof. Dr. Ersin MÜEZZİNOĞLU
		5	BIR ULUSLARARASI ÖRGÜT OLARAK İSLAM İŞBIRLİĞİ TEŞKİLATI: YAPI, İŞLEYIŞ VE ETKİNLİK	Doktora Öğrencisi Safa MAHMOOD Doç. Dr. Neşe YILDIZ
		6	AZERBAYCAN CUMHURİYETİ'NİN İSLAM İŞBİRLİĞİ TEŞKİLATIN'DAKİ ROLÜ	Doktora Öğrencisi Abbasali KHUDUZADE Doç. Dr. Neşe YILDIZ
		7	INTERNATIONAL EDUCATION PARTNERSHIPS AND SOFT POWER COMPETITION IN THE TURKESTAN REGION	Dr. Ersoy Yılmaz DİNİZ Dilara Cansın KEÇİALAN
		8	GÜVENLİKLEŞTİRME PERSPEKTİFİNDEN İKLİM DEĞİŞİKLİĞİ VE GÜVENLİK	Adem YILMAZ Prof. Dr. Ömer UĞUR
			AVRUPA YEŞİL MUTABAKATI: STRATEJİK ÇERÇEVE VE KÜRESEL ETKİLERİ	Prof. Dr. Ömer UĞUR Doç. Dr. Candan YILMAZ UĞUR
			SINIRLARDA DİJİTAL BAN-OPTİKON: GÖZETİM TEKNOLOJİLERİNİN GERİ İTME MEKANİZMALARINDAKİ İKİLİ ROLÜ	Arş. Gör. Dr. Yusuf FİDAN

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HALL / SALON 6	**Dr. Muhammet KUSAN**	1	SPORCULARDA ENERJİ DENGESİ VE MİKRO BESİN ÖĞELERİ	Lisans Öğrencisi, Gamze KILIÇASLAN Arş. Gör., Polat YÜCEDAL Prof. Dr. Vedat ÇINAR
		2	KETOJENİK DİYETİN FİZİKSEL AKTİVİTEYE ETKİSİ	Lisans Öğrencisi, Gamze KILIÇASLAN Arş. Gör., Polat YÜCEDAL Prof. Dr. Vedat ÇINAR
		3	AI-DRİVEN SPORTS MANAGEMENT: DATA-DRİVEN DECİSİON-MAKİNG PROCESSES	İsmet SEVAL Doç. Dr. Şakir TÜFEKÇİ Prof. Dr. Talha MURATHAN
		4	SPORTS MANAGEMENT İN THE AGE OF ARTİFİCİAL INTELLİGENCE AND THE JUSTİCE PARADOX	İsmet SEVAL Doç. Dr. Şakir TÜFEKÇİ Prof. Dr. Talha MURATHAN
		5	REKREATİF AYAKTA KÜREK SÖRFÜ (Stand up Paddle Boarding-SUP) EĞİTİMİNE KATILAN YETİŞKİN BİREYLERİN KATILIM MOTİVLERİ	Prof.Dr. Nurper ÖZBAR Prof.Dr.Müberra ÇELEBİ Doç.Dr.Cüneyt TAŞKIN Doç.Dr.Şengül DEMİRAL Dr.Öğr.Üyesi Aykut AKSU Dr.Öğr.Üyesi Şerife Gamze ÜLKER
		6	SPORCULARDA KARİYER SONLANMA KAYGISININ SPORDA ETKİLİ KARAR VERME ÜZERİNE ETKİSİ	Zeynep KAÇAR Dr. Muhammet KUSAN Prof. Dr. Soner ÇANKAYA
		7	SPOR BİLİMLERİ FAKÜLTESİ ÖĞRENCİLERİNİN SOSYAL MEDYA BAĞIMLILIĞI İLE AKADEMİK KAYGI DÜZEYLERİ ARASINDAKİ İLİŞKİ	Zehra Eylül NARİN Dr. Muhammet KUSAN Prof. Dr. Soner ÇANKAYA
		8	VÜCUT GELİŞTİRME SPORCULARINDA SPOR BESİN TAKVİYE İNANCI VE SPORCU DEĞER YÖNELİMİNİN İNCELENMESİ	Damla AKSAMAZ Dr. Muhammet KUSAN
			VÜCUT GELİŞTİRME SPORCULARINDA SPOR BESİN TAKVİYE İNANCI VE SPORCU DEĞER YÖNELİMİNİN İNCELENMESİ	Melike BAYRAKDAR Dr. Muhammet KUSAN

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HALL / SALON 7	**Doç. Dr. Seval ÖZGEL FELEK**	1	BÜKÜM MERKEZİ MAKİNESİNDE BÜKÜM PARÇASININ AKIM DÖNGÜSÜYLE KONTROLÜ VE KARŞILAŞTIRILMASI	Yüksek Elektrik-Elektronik Mühendisi Emirhan Toprak
		2	A NOVEL BIDIRECTIONAL FLOATING INTERLEAVED QUASI-Z-SOURCE DC-DC CONVERTER	Furkan AKAR
		3	EMERGING DEVELOPMENTS AND ADVANCES IN SOLAR PHOTOVOLTAIC PANEL CLEANING TECHNOLOGIES	Arş. Gör. Dr. Abdurrahman YAVUZDEĞER
		4	INVESTIGATION OF THE EFFECT OF SLOT TYPE ON THE EFFICIENCY OF PERMANENT MAGNET SYNCHRONOUS GENERATORS FOR WIND TURBINE APPLICATIONS	Arş. Gör. Dr. Abdurrahman YAVUZDEĞER
		5	PARAMETRİK TASARIM VE DİJİTAL ÖZELLEŞTİRME YAKLAŞIMIYLA TEKİL BİR OTURMA ELEMANININ HESAPLAMALI TASARIMI	Doç. Dr. Seval ÖZGEL FELEK
		6	MODEL SELECTION IN CONTAINER HANDLING FORECASTING: AN APPLICATION TO THE PORTS OF THE AEGEAN REGION	Dr. Elvan DENİZ
		7	PV SİSTEMLERDE DEĞİŞKEN ÇEVRESEL KOŞULLARDA FARKLI MPPT ALGORİTMALARININ PERFORMANS VE SİSTEM STABİLİTESİ ÜZERİNE KARŞILAŞTIRMALI ANALİZİ	Tuğçe ÇEVRİM Tahir YAVUZ
		8	ENGINEERING DIELECTRIC SURFACE AREA IN TRIBOELECTRIC NANOGENERATORS FOR HIGH EFFICIENCY	Assoc. Prof. Dr. Abdulkerim Karabiber Assoc. Prof. Dr. Dursun Öztürk Assoc. Prof. Dr. Muzaffer Aslan

Furkan AKAR 28 Aralık saat 13: - 15 salon 6 da sunacak

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HALL / SALON 8	**Mete Han İLMEÇİ**	1	PHASE CHANGE MATERIALS IN BATTERY THERMAL MANAGEMENT SYSTEMS	Burak AKGÜL Dr. İsmail ATA
		2	KATI YAKITLARDA YANMA HIZININ DENEYSEL İNCELENMESİ	Doc.Dr.Hayri YAMAN Mete Han İLMEÇ
		3	GIS APPLICATIONS IN SOLID WASTE COLLECTION AND TRANSFER	Hasan İhsan KALELİ Doç. Dr. Sedat YALÇINKAYA
		4	COĞRAFİ BİLGİ SİSTEMLERİ ARACILIĞIYLA ULAŞIM MODLARININ KARŞILAŞTIRILMASI: KARABÜK İLİ ÖRNEĞİ	Yüksek Lisans Öğrencisi Emine Berfin ŞAHİN Dr. Öğr. Üyesi Uğur ACAR
		5	THRUST PERFORMANCE EVALUATION OF TOROIDAL VERSUS CONVENTIONAL PROPELLERS	Mehmet Alperen ANDAÇ Ayhan AKBULUT Dr. İsmail ATA
		6	TEK YÖNLÜ VE İKİ YÖNLÜ EŞLEME YÖNTEMLERİ İLE YÜZER YAPILARIN HİDROELASTİK ANALİZİ	Ömer Faruk AYTEMİZ Serdar Turgut INCE
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HALL / SALON 9	**Dr. Öğr. Üyesi Meliha Fındık**	1	ERGENLERDE GENİTAL HİJYEN DAVRANIŞLARI VE SAĞLIK ÜZERİNE ETKİLERİ	Dr. Öğr. Üyesi Nuriye ERBAŞ Duygunur ÇAKIR
			ZOONOSES AND CLIMATE CHANGE	Araş.Gör.Dr. Seda GÖKDEMİR Doç.Dr. Aliye GÜLMEZ SAĞLAM Dr. Öğr. Üyesi Elif ÇELİK
		2	İNFERTİLİTEDE GÖRÜNMEYEN YÜK: DAMGALANMA VE PSİKOSOSYAL SONUÇLARI	Assi. Prof., Demet ÇAKIR Assi. Prof., Emine AKSÜT AKÇAY Lecturer, Arslan SAY
		3	ÖSTROJEN HORMONLARI VE PRENATAL TARAMA TESTLERİNDE KULLANIMLARI	Dr.Öğr.Üyesi Demet ÇAKIR Öğr.Gör. Arslan SAY Dr.Öğr.Üyesi Emine AKSÜT AKÇAY
		4	DIGITAL BURNOUT: A NEW OCCUPATIONAL RISK İN THE DIGITALIZING WORKPLACE	Uzm. Hem. Feyza ACAR Uzm. Hem. Güllü YAZKAN Prof.Dr. Nezihe BULUT UĞURLU Doç.Dr. Fatma BİRGİLİ
		5	THE “STAY-AT-HOME YOUTH” PHENOMENON: SOCİAL WİTHDRAWAL AMONG NEET YOUTH AND THE EFFECTS OF DİGİTAL LİFE ON MENTAL HEALTH	Uzm. Hem. Feyza ACAR Doç.Dr. Fatma BİRGİLİ Uzm. Hem. Güllü YAZKAN Prof.Dr. Nezihe BULUT UĞURLU
		6	INVESTIGATION OF THE RELATIONSHIP BETWEEN PERCEIVED STRESS LEVELS AND SOCIAL PARTICIPATION IN UNIVERSITY STUDENTS	Ergoterapist Sümeyra CERAN Dr. Volkan TÜRKMEN
		7	LYMPHEDEMA ASSESSMENT METHODS	Hagar Mahmoud Ali ABOUSHEISHAA Prof. Dr.Özlem ÇİNAR ÖZDEMİR
		8	MULTIMODAL PHYSIOTHERAPY IN CANCER-RELATED LYMPHEDEMA	Assala Obaid Prof. Dr.Özlem Çinar Özdemir
		9	SEPSİSİN TANISINDA YENİLİKLER: İYOBELİRTEÇLERDEN YAPAY ZEKAYA	Dr. Öğr. Üyesi Meliha Fındık
		10	FONKSİYONEL SÜT ÜRÜNLERİ VE KARDİYOVASKÜLER SAĞLIK: YENİLİKÇİ YAKLAŞIMLAR	Dr. Selin Elmas
		11	PLANLI DAVRANIŞ KURAMI TEMELLİ AKILCI İLAÇ KULLANIMI YAKLAŞIMI	Doç. Dr. Semra KOCATAŞ Mehmet Nur İMTAN Ahmet Remzi BAYIR

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HALL / SALON 10	**Doç.Dr., SERİR UZUN**	1	KENT PARKLARININ İYİ OLMA HALİ ÜZERİNDEKİ ETKİLERİNİN İNCELENMESİ	Prof. Dr. Nurdan ERDOĞAN Eda TOPRAK
		2	MİKROKLİMA DEĞERLENDİRME YÖNTEMLERİ: ÖLÇÜM TEKNİKLERİ ve UYGULAMALARIN KARŞILAŞTIRILMASI	Prof. Dr. Nurdan ERDOĞAN Bilge TEPELİ
		3	KIYI ALANLARINDA YER ALAN MİLLET BAHÇELERİNİN KULLANIM VE MEMNUNİYET DÜZEYLERİNİN DEĞERLENDİRİLMESİ: ÜNYE BATIPARK MİLLET BAHÇESİ ÖRNEĞİ	Doç.Dr., SERİR UZUN
		4	A COMPREHENSIVE REVIEW ON PHOTOCATALYTIC DEGRADATION OF ORGANIC POLLUTANTS FROM WASTEWATER	Nazli TURKTEN Yunus KARATAS

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HALL / SALON 1	**Prof. Dr. Rakesh Sakshi**	1	SYNTHESIS AND CHARACTERIZATION OF SILVER-DOPED TITANIUM DIOXIDE NANOPARTICLES FOR WATER PURIFICATION	Prof. Dr. Shodmon Safarov Dr. Mahmud Bakhtiyorov
		2	TUNGSTEN OXIDE NANOSHEETS: SYNTHESIS, OPTICAL PROPERTIES, AND GAS SENSING APPLICATIONS	Dr. Nigora Tursunova
		3	GREEN SYNTHESIS OF GOLD NANOPARTICLES USING DATE PALM EXTRACT: APPLICATIONS IN ANTICANCER THERAPY	Prof. Dr. Salma Youssef Dr. Ayman Hassan Mona El-Adl
		4	MAGNETIC IRON OXIDE NANOPARTICLES FOR ENHANCED MRI CONTRAST AGENTS	Assis. Prof. Dr. Ahmed El-Naggar Dr. Nada Fathy
		5	PREPARATION OF CARBON QUANTUM DOTS FROM WASTE BIOMASS FOR SENSING APPLICATIONS	Dr. Shirin Hosseini Assis. Prof. Dr. Mahsa Azizi Prof. Dr. Razieh Mohammadi
		6	MULTIFUNCTIONAL ZINC OXIDE NANORODS: ANTIMICROBIAL, OPTICAL, AND PHOTOCATALYTIC PROPERTIES	Assis. Prof. Dr. Parviz Bahrami Leila Golestani
		7	NANOCLAY-REINFORCED POLYMER COMPOSITES: IMPROVEMENTS IN MECHANICAL AND THERMAL PROPERTIES	Prof. Dr. Rakesh Sakshi
		8	SYNTHESIS OF GOLD NANORODS FOR TARGETED PHOTOTHERMAL CANCER THERAPY	Dr. Neha Agarwal Assoc. Prof. Dr. Rajesh Singh
		9	DESIGN OF NANOSTRUCTURED SILICA AEROGELS FOR GAS STORAGE AND DELIVERY APPLICATIONS	Dr. Marta Rodríguez
		10	GRAPHENE-BASED NANOCOMPOSITES FOR ELECTROCHEMICAL SENSOR DEVELOPMENT	Assoc. Prof. Dr. Laura Gómez Dr. Daniel Paredes Marina Ruiz Dr. Javier Torres
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HALL / SALON 2	**Assoc. Prof. Dr. Mohammed Hassan,**	1	ADVANCES IN 3D-PRINTED TITANIUM IMPLANTS FOR MAXILLARY RECONSTRUCTION IN CHINESE ORAL SURGERY PATIENTS	Prof. Dr. Zhang Wei, Dr. Liu Fang, Chen Ming
		2	EFFICACY OF NANOHYDROXYAPATITE TOOTHPASTE IN REMINERALIZING EARLY CARIES LESIONS AMONG CHINESE ADOLESCENTS	Assoc. Prof. Dr. Wang Li, Zhao Xin, Dr. Sun Hao
		3	LASER-ASSISTED PERIODONTAL REGENERATION TECHNIQUES FOR CHINESE PATIENTS WITH AGGRESSIVE PERIODONTITIS	Dr. Huang Mei, Li Qiang, Assis. Prof. Dr. Yang Bo
		4	DIGITAL SMILE DESIGN PROTOCOLS FOR ESTHETIC REHABILITATION IN QATARI PRIVATE DENTAL CLINICS	Prof. Dr. Ali Al-Thani, Dr. Sara Khalid
		5	ORTHODONTIC MANAGEMENT OF IMPACTED CANINES USING LOW-DOSE CBCT GUIDANCE IN QATARI ADOLESCENTS	Assoc. Prof. Dr. Mohammed Hassan, Fatima Al-Mansoori
		6	CLINICAL EVALUATION OF BIOCERAMIC SEALERS IN ENDODONTIC RETREATMENT OF INDIAN PATIENTS WITH FAILED ROOT CANAL THERAPY	Prof. Dr. Rajeshwari Nair, Priya Menon
		7	LASER FLUORESCENCE DETECTION AND MINIMALLY INVASIVE MANAGEMENT OF OCCLUSAL CARIES IN INDIAN SCHOOL CHILDREN	Dr. Amit Suresh
		8	ALVEOLAR RIDGE PRESERVATION USING PLATELET-RICH FIBRIN IN IMMEDIATE IMPLANT PLACEMENT FOR INDIAN PATIENTS	Assoc. Prof. Dr. Karan Malhotra, Anjali Desai
		9	DIGITAL WORKFLOWS FOR FULL-ARCH ZIRCONIA PROSTHESES IN COMPLEX INDIAN EDENTULOUS PATIENTS	Dr. Rohit Sharma, Meera Joshi, Prof. Dr. Vikrant Jadhav
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HALL / SALON 3	**Assoc. Prof. Dr. Gulnara Zhumadilova,**	1	EPIDEMIOLOGICAL PATTERNS OF CARDIOVASCULAR DISEASES AMONG URBAN POPULATIONS IN ALMATY	Prof. Dr. Aigerim Sarsenova, Dr. Bekzat Nurpeisov, Aidana Tolegenova
		2	NUTRITIONAL STATUS ASSESSMENT AND INTERVENTION STRATEGIES FOR RURAL CHILDREN IN EASTERN KAZAKHSTAN	Assoc. Prof. Dr. Gulnara Zhumadilova, Yerzhan Kairbekov
		3	MENTAL HEALTH CHALLENGES AND TELEHEALTH SOLUTIONS FOR POST-PANDEMIC ADOLESCENTS IN NUR-SULTAN	Dr. Dana Alimova, Nurlan Bekbolat, Assis. Prof. Dr. Saltanat Myrzakhmetova
		4	TRADITIONAL EGYPTIAN HERBAL MEDICINE INTEGRATION INTO DIABETES MANAGEMENT PROTOCOLS	Prof. Dr. Ahmed El-Sayed, Dr. Fatima Hassan
		5	HEPATITIS C ELIMINATION STRATEGIES THROUGH COMMUNITY SCREENING IN EGYPTIAN RURAL PROVINCES	Assoc. Prof. Dr. Mohamed Khalil, Nour El-Din
		6	MATERNAL MORTALITY REDUCTION THROUGH MIDWIFERY TRAINING IN PAKISTANI DISTRICT HOSPITALS	Prof. Dr. Saima Rehman, Ayesha Malik, Dr. Imran Khan
		7	TUBERCULOSIS CONTROL AMONG MULTIDRUG-RESISTANT CASES IN KARACHI URBAN SLUMS	Dr. Bilal Ahmed, Sana Gul, Assoc. Prof. Dr. Faisal Siddiqui
		8	NON-COMMUNICABLE DISEASE PREVENTION THROUGH WORKPLACE WELLNESS PROGRAMS IN LAHORE INDUSTRIES	Assis. Prof. Dr. Hina Raza, Muhammad Arif

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HALL / SALON 4	**Assoc. Prof. Dr. Elena Rusu, Victor Moraru**	1	GENETIC DIVERSITY AND CONSERVATION STRATEGIES FOR ENDANGERED BESSARABIAN WILDFLOWER POPULATIONS	Prof. Dr. Ion Ceban, Dr. Maria Popa, Andrei Lupu
		2	MICROBIAL DIVERSITY IN DANUBE DELTA SEDIMENTS AND THEIR ROLE IN NITROGEN CYCLING	Assoc. Prof. Dr. Elena Rusu, Victor Moraru
		3	PHYTOREMEDIATION POTENTIAL OF MOLDOVAN VINEYARD WEEDS FOR CADMIUM-CONTAMINATED SOILS	Dr. Natalia Grozavu, Sergiu Balan, Assis. Prof. Dr. Olga Cimpoes
		4	ENDOPHYTIC FUNGI DIVERSITY AND BIOACTIVE COMPOUNDS FROM ETHIOPIAN COFFEE PLANTS	Prof. Dr. Tadesse Woldemariam, Selamawit Getachew
		5	AQUATIC MACROINVERTEBRATE ASSEMBLAGES AS BIOINDICATORS OF RIFT VALLEY LAKE POLLUTION	Dr. Alemayehu Tesfaye, Rahel Bekele, Assoc. Prof. Dr. Firew Bekele
		6	MOLECULAR PHYLOGENY AND BIOGEOGRAPHY OF CAUCASUS ENDEMIC SALMONID FISHES	Prof. Dr. Elchin Gasimov, Aysel Mammadova, Dr. Rashad Aliyev
		7	ANTIOXIDANT PROPERTIES AND PHYTOCHEMICAL PROFILES OF ZERBAIJANI MEDICINAL HERBS	Assoc. Prof. Dr. Sevinc Aliyeva, Nurlan Huseynov
		8	MICROPLASTIC ACCUMULATION IN CASPIAN SEA BENTHIC COMMUNITIES AND TROPHIC TRANSFER	Dr. Leyla Karimova, Farid Gurbanov, Assis. Prof. Dr. Nigar Rahimova
		9	SYMBIOTIC ASSOCIATIONS BETWEEN AZERBAIJANI TRUFFLES AND NATIVE OAK MYCORRHIZAE	Zaur Mammadov, Prof. Dr. Irada Huseynova
		10	PHYLOGENETIC ANALYSIS OF ENDANGERED CAUCASUS LEOPARD POPULATIONS USING NON-INVASIVE SAMPLING	Dr. Elnur Bagirov, Kamilla Abbasova, Assoc. Prof. Dr. Vugar Aliyev
		11	BIOREMEDIATION OF OIL-CONTAMINATED ABSHERON PENINSULA SOILS USING RHIZOSPHERE MICROBIOMES	Samir Gadirov, Dr. Tarana Mammadova, Gunel Ismayilova

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HALL / SALON 5	**Dr. Zhanna Musina,**	1	MIGRATION PATTERNS AND SOCIAL INTEGRATION CHALLENGES AMONG ALBANIAN DIASPORA COMMUNITIES IN EUROPE	Prof. Dr. Arben Lika, Dr. Elira Deda, Sokol Meta
		2	GENDER ROLES TRANSFORMATION IN POST-SOCIALIST ALBANIAN RURAL COMMUNITIES	Assoc. Prof. Dr. Luljeta Hoxha, Beni Qirjako
		3	URBAN POVERTY AND SOCIAL EXCLUSION DYNAMICS IN TIRANA'S INFORMAL SETTLEMENTS	Dr. Fatmir Bega, Mira Shehu, Assis. Prof. Dr. Gentian Elezi
		4	ISLAMIC REVIVALISM AND YOUTH IDENTITY FORMATION IN INDONESIAN URBAN NEIGHBORHOODS	Prof. Dr. Ahmad Syarif, Dr. Nurul Hidayah
		5	CLIMATE CHANGE ADAPTATION STRATEGIES AMONG INDONESIAN COASTAL FISHING COMMUNITIES	Assoc. Prof. Dr. Siti Nurjanah, Budi Santoso
		6	ETHNIC MINORITY INTEGRATION CHALLENGES IN MULTIETHNIC KAZAKHSTANI CITIES	Prof. Dr. Gulnara Aidarova, Yerkebulan Tastanbekov, Dr. Aizhan Kaskyrbekova
		7	TRANSNATIONAL FAMILY NETWORKS AMONG LABOR MIGRANTS FROM RURAL KAZAKHSTAN	Dr. Zhanna Musina, Nurdaulet Abildayev
		8	URBANIZATION EFFECTS ON TRADITIONAL NOMADIC SOCIAL STRUCTURES IN KAZAKHSTAN	Assoc. Prof. Dr. Aidana Satybaldiyeva, Temirlan Orynbayev, Assis. Prof. Dr. Zhuldyz Kenzhegulova

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HALL / SALON 6	**Assoc. Prof. Dr. Elena Cruz,**	1	OPTIMIZATION OF FERMENTATION PARAMETERS FOR ENHANCED BIOACTIVE COMPOUND EXTRACTION FROM FILIPINO COCONUT WATER	Prof. Dr. Maria Santos, Dr. Jose Rizal, Ana Lim
		2	DEVELOPMENT OF GLUTEN-FREE RICE NOODLES FORTIFIED WITH MORINGA OLEIFERA LEAF PROTEIN FOR MALNOURISHED POPULATIONS	Assoc. Prof. Dr. Elena Cruz, Ramon Garcia, Sofia Reyes
		3	ULTRASOUND-ASSISTED EXTRACTION OF POLYPHENOLS FROM BANANA PEEL WASTE FOR NATURAL FOOD PRESERVATIVES	Dr. Carlo Mendoza, Liza Torres, Assis. Prof. Dr. Pedro Aquino
		4	MICROENCAPSULATION OF GREEK OLIVE LEAF EXTRACTS FOR FUNCTIONAL DAIRY PRODUCT APPLICATIONS	Prof. Dr. Dimitrios Papadopoulos, Eleni Stavrou, Dr. Katerina Georgiou
		5	HIGH-PRESSURE PROCESSING EFFECTS ON FETA CHEESE MICROSTRUCTURE AND BIOACTIVE PEPTIDE BIOAVAILABILITY	Assoc. Prof. Dr. Nikolaos Katsaros, Maria Panagiotou
		6	NANOTECHNOLOGY-ENHANCED PACKAGING FILMS INCORPORATING RUSSIAN WILD BERRY EXTRACTS FOR MEAT PRESERVATION	Dr. Irina Petrova, Prof. Dr. Sergei Ivanov, Alexei Morozov
		7	FERMENTATION OPTIMIZATION OF KVASS USING RUSSIAN RYE BREWING STRAINS FOR FUNCTIONAL BEVERAGE DEVELOPMENT	Assoc. Prof. Dr. Olga Kuznetsova, Dr. Viktor Smirnov,
		8	CRYOCONCENTRATION TECHNOLOGIES FOR RUSSIAN HONEY DEWATERING AND QUALITY PRESERVATION	Dr. Natalia Volkov, Mikhail Orlov, Assis. Prof. Dr. Anna Sokolova
		9	EXTRUDED BUCKWHEAT-BASED SNACKS FORTIFIED WITH SIBERIAN PINENUT FLOUR FOR PROTEIN ENRICHMENT	Prof. Dr. Dmitry Fedorov, Tatiana Kuzmina
		10	SYNTHESIS AND CHARACTERIZATION OF NOVEL PORPHYRIN-BASED SENSORS FOR HEAVY METAL DETECTION IN PHILIPPINE WATER SOURCES	Prof. Dr. Maria Santos, Dr. Carlo Reyes, Ana Lim
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HALL / SALON 7	Assoc. Prof. Dr. Kostas Nikolaou,	1	GREEN SYNTHESIS OF SILVER NANOPARTICLES USING ENDOPHYTIC PLANT EXTRACTS FOR ANTIBACTERIAL APPLICATIONS	Assoc. Prof. Dr. Jose Ramirez, Liana Torres, Dr. Miguel Cruz
		2	ELECTROCHEMICAL IMMOBILIZATION OF ENZYMES ON CARBON NANOTUBES FOR GLUCOSE BIOSENSING IN TROPICAL CLIMATES	Dr. Elena Vargas, Ramon Dela Cruz, Sophia Mendoza
		3	PHOTOCHEMICAL DEGRADATION PATHWAYS OF EMERGING CONTAMINANTS USING TITANIUM DIOXIDE NANOCOMPOSITES	Prof. Dr. Dimitri Papadopoulos, Dr. Eleni Stavrou
		4	SYNTHETIC METHODOLOGIES FOR HETEROCYCLIC NATURAL PRODUCT ANALOGS TARGETING ANTIBIOTIC RESISTANCE	Assoc. Prof. Dr. Kostas Nikolaou, Maria Georgiou
		5	DEVELOPMENT OF MAGNESIUM-BASED HYDRIDES FOR HYDROGEN STORAGE IN ARID CLIMATES	Dr. Fatima Al-Harthi, Omar Al-Maskari, Assis. Prof. Dr. Khalid Al-Siyabi
		6	CATALYTIC CONVERSION OF PLASTIC WASTE TO AROMATIC HYDROCARBONS USING ZEOLITE CATALYSTS	Prof. Dr. Salim Al-Rashdi, Dr. Noor Al-Mahrooqi, Ahmed Al-Belushi
		7	BIOSORPTION MECHANISMS OF DYE POLLUTANTS USING ALGAE-DERIVED CARBON FROM OMANI COASTAL BIOMASS	Assoc. Prof. Dr. Layla Al-Kindi, Hassan Al-Ghafari, Zahra Al-Maskari

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HALL / SALON	**Assoc. Prof. Dr. Georgios Markakis**	1	PREVALENCE AND ANTIBIOTIC RESISTANCE PATTERNS OF SALMONELLA IN BACKYARD POULTRY FARMS IN THE PHILIPPINES	Prof. Dr. Maria Santos, Dr. Jose Ramirez, Ana Cruz
		2	IMPACT OF CLIMATE CHANGE ON TICK-BORNE DISEASES IN PHILIPPINE WATER BUFFALO POPULATIONS	Assoc. Prof. Dr. Roberto Villanueva, Liza Torres
		3	NUTRITIONAL MANAGEMENT STRATEGIES FOR IMPROVING DAIRY PRODUCTION IN PHILIPPINE SMALLHOLDER FARMS	Dr. Elena Garcia, Miguel Santos, Assis. Prof. Dr. Carla Mendoza
		4	EPIDEMIOLOGICAL SURVEILLANCE OF AFRICAN SWINE FEVER IN GREEK COMMERCIAL PIG FARMS	Prof. Dr. Dimitrios Papadopoulos, Eleni Stavrou
		5	ADVANCES IN SHEEP MASTITIS CONTROL USING PLANT-BASED ANTIBACTERIAL FORMULAS IN GREEK DAIRY HERDS	Dr. Katerina Nikolopoulou, Assoc. Prof. Dr. Georgios Markakis
		6	PARASITE MANAGEMENT PROTOCOLS FOR CAMELID HERDS IN OMANI ARID ENVIRONMENTS	Dr. Ahmed Al-Harthi, Fatima Al-Maskari, Salim Al-Balushi
		7	VACCINE DEVELOPMENT AGAINST NEWCASTLE DISEASE IN OMANI POULTRY SYSTEMS	Assoc. Prof. Dr. Khalid Al-Rashdi, Mariam Al-Hinai
		8	THERMAL STRESS MITIGATION STRATEGIES FOR DAIRY GOATS IN OMANI SUMMER CONDITIONS	Prof. Dr. Nasser Al-Kindi, Dr. Aisha Al-Mahrooqi, Omar Al-Ghafri

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HALL / SALON 1	**Dr. Khorram Manafidizaji**	1	HEKİMLERDE İŞ SAĞLIĞI VE GÜVENLİĞİ ALGI PROFİLLERİ VE TÜKENMİŞLİK DÜZEYLERİ: ÖRTÜK PROFİL ANALİZİ BULGULARI	Prof. Dr. Burcu Güler Doç. Dr. Filiz Künüroğlu İnal Arş. Gör. Dilara TURGUT
		2	KADIN ÇALIŞANLARDA İNSANA YAKIŞIR İŞ VE RUHSAL BELİRTİLER: GİZİL PROFİL ANALİZİ	Arş. Gör. Dilara TURGUT Prof. Dr. Burcu Güler
		3	OTİZM SPEKTRUM BOZUKLUĞU OLAN ÇOCUKLARIN EBEVEYNLERİNDE SOSYAL DESTEK, PSİKOLOJİK DAYANIKLILIK VE İYİ OLUŞ İLİŞKİSİ	Dilara TANFER TEK
		4	KÜÇÜK ‘t’ TRAVMALAR İLE SOSYAL DIŞLANMA ARASINDAKİ İLİŞKİYE DAİR KAVRAMSAL BİR ÇERÇEVE	Psikolog BESİM KARABULUT Dr. Öğr. Üyesi ALİYE ATEŞ ÖS
		5	ROMANTİK İLİŞKİLERDEN BEKLENTİLERE DAİR FARKINDALIK İLE EVLİLİK KORKUSU ARASINDAKİ İLİŞKİDE KARANLIK DÖRTLÜ KİŞİLİK ÖZELLİKLERİNİN DÜZENLEYİCİ ROLÜ	Psikolog Aslıhan BOSTANCI
		6	ÜNİVERSİTE ÖĞRENCİLERİNDE DUYGU DÜZENLEME GÜÇLÜĞÜ VE BENLİK SAYGISI ARASINDAKİ İLİŞKİDE MÜKEMMELİYETÇİLİĞİN ARACI ROLÜ	Klinik Psikoloji Tez Öğrencisi, Memnune YAMAN Doç. Dr. Burcu Rahşan ERİM
		7	BORDERLİNE KİŞİLİK ÖZELLİKLERİ VE ROMANTİK İLİŞKİLERDE SOSYAL MEDYA KISKANÇLIĞI ARASINDAKİ İLİŞKİDE DUYGU DÜZENLEME GÜÇLÜĞÜNÜN ARACI ROLÜ	Hatice Rana ÖZKOL
		8	BELİREN YETİŞKİNLİKTE MENTALİZASYONUN YEME BOZUKLUĞU BELİRTİLERİYLE OLAN İLİŞKİSİNDE REDDEDİLME DUYARLILIĞININ DÜZENLEYİCİ ROLÜ	Melisa Girgiç
		9	DEVELOPMENT OF THE PEER KINDNESS SCALE FOR ADOLESCENTS: A VALIDITY AND RELIABILITY STUDY	Yüksek Lisans Öğrencisi Kübra ŞAHİN Prof. Dr. Fulya TÜRK
		10	YAŞLILIKTA YOGA UYGULAMALARININ BİLİŞSEL İŞLEVLER VE PSİKOLOJİK İYİ OLUŞ ÜZERİNDEKİ ETKİLERİNİN İNCELENMESİ VE TÜRKİYE BAĞLAMINDA ARAŞTIRMA BOŞLUKLARI	Öğr. Gör. Dr Hatice ÇINAR

Çiğdem Yel burada sundu

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HALL / SALON 2	**Dr. Amaneh MANAFİDİZAJİ**	1	QURAN-CENTERED NARRATIVE IN THE CLASSICAL MASNAVI TRADITION: THE EXAMPLE OF BAYBURTLU AĞLAR İRŞÂDÎ BABA'S YUSUF AND ZELIHA MASNAVI	Dr. Mehmet KESKİN
		2	ALT YAZI ÇEVİRİSİNDE MAKİNE ÇEVİRİSİ KULLANIMININ ÇEVİRİ KALİTESİ BAĞLAMINDA DEĞERLENDİRİLMESİ	Öğr. Gör. Muhammed GÜNAYDIN
		3	ATAOL BEHRAMOĞLU'NUN ŞİİRLERİNDE SIFAT TAMLAMALARIYLA KURULAN İMGE DÜNYASI	Öğr. Gör. Elif KUTUM
		4	THE RELATIONSHIP BETWEEN INTELLIGENCE AND LIES IN SEPHARDIC JEWISH TALES	Öğr. Gör. Dr. Fatma ÜÇLER
		5	COMPUTERIZED ANALYSIS AND CONCEPT MAPPING OF POEMS IN PIYALE	Öğr. Gör. Dr. Fatma ÜÇLER
		6	İSLAMİ ROMANLARDA KADIN KİMLİĞİ (1980-2000)	Dr. Arş. Gör. Okan ANCAK
		7	AN EVALUATION OF THE NOVEL "THE SHIRT OF FIRE" IN THE CONTEXT OF NATIONALISM THEORIES	Assistant Professor Ali Rıza SAVAŞ
		8	THE FEMALE BODY AND THE MALE MORAL CONCEPTION IN VEDAT TURKALI'S NOVEL "WHAT IS FATMAGUL'S CRIME"	Doç. Dr. SEVRA FIRINCIOĞULLARI

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HALL / SALON 3	**Doç. Dr. HAYATİ OLĞAR**	1	WEAK FIXED POINT PROPERTY FAILURE IN A KÖTHE–TOEPLITZ TYPE FUNCTION SPACE ASSOCIATED WITH A SCALED–WEIGHT α–DUAL STRUCTURE	Doç. Dr. Veysel NEZİR
		2	PERİYODİK SINIR ŞARTLARI İLE VERİLEN SÜREKSİZ STURM-LİOUVİLE PROBLEMİNİN ÖZDEĞER VE ÖZFONKSİYONLARI	YL. Öğrencisi, ZİYAEDDİN ŞEKER Prof., KADRİYE AYDEMİR Prof., OKTAY Sh. MUKHTAROV
		3	YÖNLÜ AĞIRLIKLI ÇİZGE DEĞERLİ ESNEK KÜMELER İLE ÇOK KRİTERLİ KARAR VERME UYGULAMALARI	Doç. Dr. Serkan ATMACA Hülya ÇAKIR
		4	BİR SÜREKSİZ STURM-LİOUVİLLE SINIR-DEĞER-GEÇİŞ PROBLEMİNİN ÖZDEĞERLERİNİN ALTTAN SINIRLILIĞI ÜZERİNE	Doç. Dr. HAYATİ OLĞAR Prof. Dr. OKTAY MUHTAROĞLU Prof. Dr. KADRİYE AYDEMİR
		5	ÇOK-ARALIKLI STURM-LİOUVİLLE TİPİNDE BİR SINIR-DEĞER-İLETİM PROBLEMİNİN GENELLEŞTİRİLMİŞ ÖZFONKSİYONLARI ÜZERİNE	Doç. Dr. HAYATİ OLĞAR Prof. Dr. KADRİYE AYDEMİR Prof. Dr. OKTAY MUHTAROĞLU
		6	A FIXED POINT THEOREM FOR CHATTERJEA CONTRACTIONS IN MULTIPLICATIVE MODULAR METRIC SPACES	Asst. Prof. Elif KAPLAN Assoc. Prof. Dr. Nihal TAŞ
		7	REICH TYPE CONTRACTION IN CONTROLLED ULTRAMETRIC-TYPE SPACES	Tuğçe YOĞUNALİ Asst. Prof. Elif KAPLAN
		8	TOTAL DOMINATION RUPTURE DEGREE OF GRAPHS	Ayten ALTUNBAŞ Prof. Dr. Alpay KIRLANGIÇ
		9	TÜRKİYE'DE ENFLASYON ALGISINDAKİ FARKLILIKLAR ÜZERİNE EKONOMETRİK BİR ANALİZ	Alper Kaan SOLAK Doç.Dr. Hatice AKDAĞ
		10	Analysis of Oscillation in Fractional Order Systems	Gülsüm Ulusoy ADA Mussa Yousef MOHAMED
		11	Approximation Properties of -Baskakov Operators Involving Modified Euler Polynomials	Gülsüm Ulusoy ADA Mussa Yousef MOHAMED

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		2	STRUCTURAL PROPERTİES OF ST14 STEEL JOİNED BY FRİCTİON STİR WELDİNG	Assist. Prof. Dr. Semih Mahmut AKTARER
		3	YEŞİL SENTEZ YÖNTEMİ İLE ACHILLEA MILLEFOLIUM VE ECHINACEA PURPUREA ÖZÜTLERİ KULLANILARAK PLATİN NANOPARTİKÜLLERİNİN SENTEZİ VE KARAKTERİZASYONU	Dr. Öğr. Üyesi FATİH TURAN Prof. Dr. AYLİN M. DELİORMANLI
		4	FİZYOLOJİK ORTAMDA CaO 2 NANOPARTİKÜLLERİNİN OKSİJEN SALIM DAVRANIŞINDA STABİLİZATÖR VE KATALİZÖRLERİN ETKİSİNİN İNCELENMESİ	Elif YAĞLI Dr. Öğr. Üyesi FATİH TURAN Prof. Dr. AYLİN M. DELİORMANLI
		5	ALAŞIM ELEMENTLERİNİN KAYNAKLI ÇELİKLERİN MİKROYAPI VE MEKANİK ÖZELLİKLERİNE ETKİSİ	Dr. Fatih GÜVEN
		6	S690 ÇELİĞİNİN BENZER OLMAYAN MALZEMELERLE KAYNAKLANMASINDA KULLANILAN YÖNTEMLER VE DOLGU TELİNİN SEÇİMİ	Dr. Fatih GÜVEN
		7	METAKAOLENDEN SiC PARTİKÜL TAKVİYELİ MÜLLİT SERAMİK KOMPOZİT ÜRETİMİ	Öğr. Gör. TURGAY TEHÇİ YAPRAK SAC Prof. Dr. Fatih ÇALIŞKAN
		8	AA 6082 ALÜMİNYUM ALAŞIMININ MIG KAYNAĞINDA ISI GİRDİSİNİN SERTLİK, KIRILMA DAVRANIŞI VE İÇYAPIYA ETKİSİ	Öğr. Gör. TURGAY TEHÇİ SAMET OĞURLU Prof. Dr. Fatih ÇALIŞKAN

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HALL / SALON 5	**Assoc. Prof. Gökhan UŞMA**	1	BİR KONUT POLİTİKASI ÖNERİSİ OLARAK YATAY MİMARİ: KARABÜK ÖRNEĞİ	Prof. Dr. Hatice Selma ÇELİKYAY Doç. Dr. Beyza ONUR Dr. Öğr. Üyesi Fuat FİDAN Arş. Gör. Dr. Ayşe Merve SARAÇOĞLU GEZER Arş. Gör. Dr. Ece KAYA
		2	MİMARİ PLANLAMA KARARLARININ DEPREM YÖNETMELİĞİ ÇERÇEVESİNDE ANALİZİ: L, T VE U FORMLU KONUT YAPILARINDA PLANDA DÜZENSİZLİK SORUNU	Yüksek Mimar Rabia Safa ÖZEN Prof. Dr. Serra Zerrin KORKMAZ
		3	TEMSİL ARACI OLARAK MİMARİ FOTOĞRAF	Y. Mimar Funda KELEŞ Doç. Dr. Beyza ONUR
		4	ANALYSIS OF THE SMART CITIES CONCEPT AND SUSTAINABLE DEVELOPMENT GOALS IN THE KARABAKH REGION OF AZERBAIJAN	Elnarə ƏHMƏDOVA Assoc. Prof. Gökhan UŞMA
		5	SOCIAL SUSTAINABILITY IN URBAN TRANSFORMATION: THE CASE STUDY OF BAYRAKLI, İZMİR	Zeynep Tutku EREN
		6	TEMEL FORMLARDAN OLUŞAN MEKÂNLARIN İÇ MEKÂN AYDINLATMASI AÇISINDAN İNCELENMESİ	Yüksek Lisans Öğrencisi Büşra KILIÇTAŞ Doç. Dr. Şensin YAĞMUR
		7	KAPALI ALAN WiFi KONUM BELİRLEME SİSTEMLERİNDE LOG-MESAFE YOL KAYBI MODELİ VE GAUSS SÜREÇ REGRESYONU YÖNTEMLERİNİN KARŞILAŞTIRMALI ANALİZİ	Dr. Öğretim Üyesi Recep ÇAKIR
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HALL / SALON 6	**Assoc. Prof. Dr. Fadil Kuyucuoglu**	1	ANALYSIS OF ANNUAL CHANGES IN THE CONSTRUCTION COST OF OVERHEAD POWER LINES USING INDEX NUMBERS	Electrical Eng. Alper YILDIZ Prof. Dr. Selim AY
		2	ECONOMIC ANALYSIS OF SERIES COMPENSATION FACILITIES IN ENERGY TRANSMISSION SYSTEMS	Electrical Eng. Alper YILDIZ Prof. Dr. Selim AY
		3	COMPARATIVE EVALUATION OF NONLINEAR INDUCTOR MODELS FOR SMPS APPLICATIONS	Dr. Öğr. Üyesi Halime HIZARCI
		4	INVESTIGATION OF THE TRANSMISSION CHARACTERISTICS OF TE-POLARIZED ELECTROMAGNETIC WAVES THROUGH MULTILAYER DIELECTRIC LAYERS	Assoc. Prof. Dr. Fadil Kuyucuoglu
		5	ANALYSIS OF THE TRANSMISSION CHARACTERISTICS OF TM-POLARIZED ELECTROMAGNETIC WAVES THROUGH MULTILAYER DIELECTRIC STRUCTURES	Assoc. Prof. Dr. Fadil Kuyucuoglu
		6	12MVA 6,3-10,5KV YG-YG KURU TİP TRANSFORMATÖR PROTOTİP İMALATI VE TESTLERİ	Hamza BİRGENÇ
		7	PREMAG SARGISI İLE MANYETİK ALANIN DÜZGÜN ŞEKİLDE OLUŞMASINI SAĞLAYACAK 23 MVA 33/33 KV GÜÇ TRANSFORMATÖRÜNÜN TASARIMI, PROTOTİP ÜRETİMİ VE TESTLERİ	DİLARA GÜRKAN
		8	TRANSFORMATÖR ALTINDA ANTİVİBRASYON PEDİ KULLANILARAK SES SEVİYESİ DÜŞÜRÜLECEK 20(26) MVA 115/33 KV GÜÇ TRANSFORMATÖRÜNÜN TASARIMI, PROTOTİP ÜRETİMİ VE TESTLERİ	Sıla YETER
			MUKAVEMETİ GÜÇLENDİRİLMİŞ İLETKENLİ, 31.5 MVA 33/11.5 KV TRANSFORMATÖR TASARIMI , PROTOTİP ÜRETİMİ VE TESTLERİ	Kübra Örnek KOCABEY Meltem SELEK
			OTOMOTİV BOYA YÜZEYLERİNDEKİ RENK SAPMALARI VE MİKRO KUSURLARIN TESPİTİNDE YÜKSEK CRI (>97) AYDINLATMA KOŞULLARININ ROLÜ	Onur ÇELİK Melikenur ER Ramazan ALTIN Samet YAVAŞ Burak DEMİROK Sinan ŞAHİN

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HALL / SALON 7	**Doç. Dr., Selcen SARI-AYTEKİN**	1	YENGEÇ SEPETİ SENDROMU İLE İLGİLİ TÜRK AKADEMİSİNİN BİLİMSEL ETKİNLİKLERİ: SİSTEMATİK DERLEME	Doç. Dr., Selcen SARI-AYTEKİN
		2	DIGITAL TWIN CITIES: THE FINAL STOP IN DATA-DRIVEN URBAN GOVERNANCE	Doç. Dr. Sinem ŞAHNAGİL
		3	THE INSTITUTIONALISM OF ARTIFICIAL INTELLIGENCE AND ITS EFFECTS ON LARGE AND SMALL BUSINESSES	Associate Professor Dr. Emine KAMBUR
		4	ARTIFICIAL INTELLIGENCE, CULTURE, CORPORATE RESPONSIBILITY	Associate Professor Dr. Emine KAMBUR
		5	Z KUŞAĞI BAĞLAMINDA PSİKOLOJİK SERMAYENİN SINIRSIZ KARİYER YÖNELİMİ ÜZERİNDEKİ ETKİSİ	Öğr. Gör. Dr. Bedirhan ELDEN
		6	SÜRDÜRÜLEBİLİRLİK VE KURUMSAL SOSYAL SORUMLULUK, SÜRDÜRÜLEBİLİR KALKINMA HEDEFLERİ	Kübra DEMİRCİ Dr.Öğr.Üyesi Oya ÖNALAN
		7	THE CSR ANATOMY OF AN EMERGING MARKET: SECTORAL AND SCALE- BASED ANALYSIS OF CSR ACTIVITIES IN BIST CORPORATE GOVERNANCE INDEX COMPANIES IN TURKIYE	Dr. Öğr. Üyesi Olcay Bektaş Dilan Çimen Ayşe Nur Karadaş Yağmur Sezgin
		8	ÖRGÜTSEL ADALET ALGISININ ÖRGÜTSEL SESSİZLİĞE ETKİSİ	Doç. Dr. Berat ÇİÇEK Doç. Dr. İnan KAYNAK
			İŞİN ANLAMLILIĞININ İŞ YERİNDE SIKILMAYA ETKİSİ	Doç. Dr. İnan KAYNAK Doç. Dr. Berat ÇİÇEK
			ALGORİTMİK YÖNETİMİN PSİKOLOJİK SONUÇLARI: ÇALIŞANLARDA YABANCILAŞMA, STRES VE ÖZERKLİK KAYBI	Elif Buse KORKUSUZ Ceylin DOĞAN Dr. Öğr. Üyesi Serap YÜCEL Prof. Dr. Oya Ġnci BOLAT

Emine KAMBUR 27 Aralık / Dec 27, 2025 / 15:00 – 17:00 salon 1 de sunacak .

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HALL / SALON 8	**Prof. Dr. Çiğdem KILIÇ**	1	MEDDAHLIK GELENEĞİ İLE EPİK TİYATRONUN KURAMSAL BAĞLAMDA YENİDEN OKUNMASI	Gizem YÖNGÜL Harun Osman TİMUR
		2	İSTANBULİMPRO'NUN "KELEBEĞİN PEŞİNDEN KOŞMAK" OYUNUNUN DOĞAÇLAMA TİYATRONUN LONG FORMU AÇISINDAN İNCELENMESİ	Yüksek Lisans Öğrencisi Pınar ÖZBAKIŞ
		3	GELENEĞİN DİRENCİ: EŞEĞİN GÖLGESİ OYUNUNDA GELENEKSEL TÜRK TİYATROSU ESTETİĞİNİN ÇAĞDAŞ DRAMATURJİYLE DÖNÜŞÜMÜ	Sercan ÖZKAYA
		4	TOM STOPPARD'IN MAGRİTTE'TEN SONRA OYUNUNDA GÖRSEL SANATLARIN DRAMATİK YAPIYA YANSIMALARI	Yüksek Lisans Öğrencisi Furkan Tuğçe AÇIKEL
		5	ORTAOYUNU VE KARAGÖZ'DE SEYİRCİ ANLAYIŞI	Prof. Dr. Çiğdem KILIÇ
		6	THE POLİTİCS OF THE UNSEEN: EMPTY FORM AND THE CRİSİS OF REPRESENTATİON İN THE WORKS OF TERESA MARGOLLES AND SANTİAGO SİERRA	Prof. Ayşegül Türk

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HALL / SALON 9	**Doç. Dr. Rana DAYIOĞLU ERUL**	1	EKONOMİK REFAH ANALİZİ: TOPLUMSAL CİNSİYET PERSPEKTİFİNDEN KURAMSAL BİR DEĞERLENDİRME	Sinem MUŞLU Prof. Dr. Meral ALTAN
		2	Geopolitical Risk Shocks and the Turkish Economy: Evidence from Nonlinear SVAR and Threshold Impulse Response Analysis	Dr. Öğr. Üyesi Semih KARACAN
		3	RE-EVALUATİNG THE COBWEB THEORY FROM A BEHAVİORAL ECONOMİCS PERSPECTİVE	Arş. Gör. Mert ALTUN Prof. Dr. Meral UZUNÖZ ALTAN
		4	THE IMPACT OF DIGITALIZATION AND ARTIFICIAL INTELLIGENCE ON EXPORT DIVERSIFICATION: EVIDENCE FROM TURKEY	Lecturer Tülay ÖLMEZ
		5	THE ROLE OF BANK-SOURCED BORROWING ON THE IMPACT OF INFLATION ON INCOME INEQUALITY	Ömer Faruk Erenbaş
		6	AVRUPA BİRLİĞİ'NİN İKTİSADİ EVRİMİ VE EKONOMİK BÜTÜNLEŞME SÜRECİ	Ezgi Yılmaz Başdaş
		7	OECD ÜLKELERİNDE VERGİ REFORMLARININ YÖNÜ: SERVET ÜZERİNDEN ALINAN VERGİLER	Doç. Dr. Rana DAYIOĞLU ERUL
		8	ELEKTRİKLİ ARAÇ SATIŞINDA UYGULANAN VERGİLERİN ARAÇ SATIŞINA ETKİSİ: OECD ÖRNEĞİ	Doç. Dr. Rana DAYIOĞLU ERUL

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HALL / SALON 10	**Prof. Dr. Nuri BAŞUSTA**	1	ASLAN BALIĞININ (PTEROIS MILES) İSKENDERUN KÖRFEZİ'NDEN YENİ KAYITLARI	Prof. Dr. Nuri BAŞUSTA
		2	İSTİLACI FISTULARIA COMMERSONII VE FISTULARIA PETIMBA TÜRLERİNİN İSKENDERUN KÖRFEZİ'NDEN YENİ KAYITLARI	Prof. Dr. Nuri BAŞUSTA Prof. Dr. Gülnaz ÖZCAN
		3	İKLİM DEĞİŞİKLİĞİNİN DENİZ ÇAYIRLARI EKOSİSTEMLERİNE ETKİLERİ	Araş. Gör. Kaan Kırşan Prof. Dr. Sevim Polat
		4	USE OF ARTIFICIAL INTELLIGENCE IN THE DIAGNOSIS, MONITORING AND MANAGEMENT OF PLANT DISEASES	Assoc. Prof. Dr. Filiz ÜNAL
		5	THE ROLE OF RENEWABLE ENERGY IN AGRICULTURAL PRODUCTION	Prof.Dr. Havva Eylem POLAT Res.Ass. Ahmet Cengiz YILDIRIM
		6	THE IMPORTANCE OF ENERGY EFFICIENCY AND INSULATION IN COLD STORAGE FACILITIES	Prof. Dr. Havva Eylem POLAT Res. Ass. Ahmet Cengiz YILDIRIM
		7	The Relationship Between Minerals, Rocks, and Soil	Yüksek Lisans Öğrencisi Naci Kubilay DONİ Prof. Dr. Salih AYDEMİR
		8	EVALUATION OF THE PREVALENCE OF Pseudomonas tolaasii IN EDIBLE CULTIVATED MUSHROOM PRODUCTION AREAS IN ANTALYA PROVINCE AND ITS SURROUNDINGS: 2023-2025	Prof. Dr. Hüseyin BASIM Prof. Dr. Esin BASIM
		9	DETERMINATION OF PATHOGENS IN BANANA PRODUCTION AREAS SURROUNDING ANTALYA PROVINCE	Prof. Dr. Hüseyin BASIM Prof. Dr. Esin BASIM
		10	ASSESSING THE KNOWLEDGE LEVELS OF PRODUCERS IN ANTALYA PROVINCE REGARDING THE ROLE OF BIOLOGICAL CONTROL IN VEGETABLE AND FRUIT PRODUCTION	Prof. Dr. Esin BASIM Prof. Dr. Hüseyin BASIM
		11	DETERMINATION OF FUNGAL PATHOGENS ISOLATED FROM SUGAR BEET PRODUCTION AREAS IN BURDUR PROVINCE AND THEIR PREVALENCE	Prof. Dr. Esin BASIM

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HALL / SALON 1	**Dr. Sanjay Rao,**	1	**FORMULATION AND EVALUATION OF HERBAL NANOPARTICLES FOR ENHANCED ANTI-DIABETIC ACTIVITY IN INDIAN TRADITIONAL MEDICINE**	**Prof. Dr. Rajesh Kumar Singh**
		2	**PHARMACOKINETIC OPTIMIZATION OF CURCUMIN-LOADED LIPOSOMES FOR NEUROPROTECTIVE EFFECTS IN ALZHEIMER'S MODELS**	**Assoc. Prof. Dr. Meera Desai, Vikram Gupta, Neha Kapoor**
		3	**DEVELOPMENT OF SUSTAINED-RELEASE MATRIX TABLETS CONTAINING METFORMIN HYDROCHLORIDE USING NATURAL POLYMERS**	**Dr. Sanjay Rao, Anjali Verma, Rohit Jain**
		4	**ANTIMICROBIAL EFFICACY OF SILVER NANOPARTICLES SYNTHESIZED FROM NEEM LEAF EXTRACT AGAINST MULTIDRUG-RESISTANT BACTERIA**	**Assis. Prof. Dr. Kavita Sharma, Deepak Mishra**
		5	**FORMULATION OF ORAL FLOATING MICROSPHERES FOR ERADICATION OF HELICOBACTER PYLORI IN EGYPTIAN PATIENTS**	**Prof. Dr. Ahmed Hassan, Dr. Fatima Mahmoud**
		6	**PHARMACEUTICAL EVALUATION OF EGYPTIAN MEDICINAL PLANTS FOR ANTI-INFLAMMATORY DRUG DISCOVERY**	**Assoc. Prof. Dr. Mohamed Salem, Nour El-Din**
		7	**DEVELOPMENT OF TOICAL EMULSION GEL FOR PSORIASIS TREATMENT USING EGYPTIAN CASTOR OIL DERIVATIVES**	**Dr. Sara Ahmed, Khaled Osman, Assis. Prof. Dr. Reem Hassan**
		8	**BIOSYNTHETIC APPROACHES FOR PRODUCTION OF NOVEL ANTIBIOTICS FROM MACEDONIAN SOIL MICROBIOMES**	**Prof. Dr. Nikola Petrovski, Dr. Elena Risteska**
		9	**BIOSYNTHETIC APPROACHES FOR PRODUCTION OF NOVEL ANTIBIOTICS FROM MACEDONIAN SOIL MICROBIOMES**	**Prof. Dr. Nikola Petrovski, Dr. Elena Risteska**
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HALL / SALON 2	Dr. Esther Njoroge,	1	DEVELOPMENT OF COST-EFFECTIVE SOLAR-POWERED IRRIGATION SYSTEMS FOR PAKISTANI AGRICULTURAL COMMUNITIES	Prof. Dr. Ahmed Raza Khan, Dr. Sara Iqbal, Bilal Hassan
		2	STRUCTURAL OPTIMIZATION OF EARTHQUAKE-RESISTANT BRIDGE DESIGNS USING PAKISTANI LOCAL MATERIALS	Assoc. Prof. Dr. Fatima Zahra, Khalid Mehmood, Dr. Imran Malik
		3	ADVANCES IN LOW-COST WASTEWATER TREATMENT TECHNOLOGIES FOR INDUSTRIAL ZONES IN KARACHI	Dr. Nadeem Akhtar, Ayesha Siddiqui, Assis. Prof. Dr. Zubair Khan
		4	AERODYNAMIC ENHANCEMENTS FOR SMALL-SCALE WIND TURBINES IN PAKISTANI OFF-GRID COMMUNITIES	Prof. Dr. Hassan Rauf, Mariam Shah, Tariq Javed
		5	SMART BUILDING ENERGY MANAGEMENT SYSTEMS FOR DUBAI'S HIGH-RISE COMMERCIAL DEVELOPMENTS	Dr. Omar Al-Fahim, Layla Hassan, Assoc. Prof. Dr. Khalid Nasser
		6	DESIGN OF SUSTAINABLE DESALINATION PLANTS UTILIZING WASTE HEAT RECOVERY IN DUBAI	Prof. Dr. Fatima Al-Suwaidi, Ahmed Khalil
		7	3D PRINTING APPLICATIONS IN CUSTOM PROSTHETICS FOR DUBAI'S DIVERSE EXPATRIATE POPULATION	Dr. Mariam Rashid, Salim Al-Mansoori, Assis. Prof. Dr. Noor Khan
		8	GEOTHERMAL ENERGY EXPLORATION AND WELL DESIGN METHODOLOGIES FOR KENYAN RIFT VALLEY	Prof. Dr. James Mwangi, Dr. Esther Njoroge, Kevin Otieno
		9	BIOMASS CONVERSION TECHNOLOGIES FOR RURAL ELECTRIFICATION IN KENYAN ARID REGIONS	Assoc. Prof. Dr. Lilian Kiptoo, Samuel Wanjala, Amina Hassan
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HALL / SALON 3	**Assoc. Prof. Dr. Fatima Zohra,**	1	CLIMATICALLY RESPONSIVE MOSQUE ARCHITECTURE INCORPORATING INDIGENOUS VERNACULAR ELEMENTS IN PAKISTANI PUNJAB	Prof. Dr. Ahmed Zubair, Dr. Sara Khan, Bilal Ahmed
		2	EARTHQUAKE-RESILIENT MUD BRICK CONSTRUCTION TECHNIQUES FOR HERITAGE CONSERVATION IN NORTHERN PAKISTAN	Assoc. Prof. Dr. Fatima Rehman, Omar Siddiqui
		3	URBAN INFILL HOUSING MODELS ADDRESSING LAND SCARCITY IN KARACHI'S INFORMAL SETTLEMENTS	Dr. Nadia Gul, Hassan Malik, Ayesha Tariq
		4	SUSTAINABLE MARKET ARCHITECTURE REVITALIZING TRADITIONAL BAZAARS IN PESHAWAR'S OLD CITY	Assis. Prof. Dr. Imran Khan, Zainab Noor
		5	POST-COLONIAL HOUSING MORPHOLOGIES BLENDING OTTOMAN AND FRENCH ARCHITECTURAL LEGACIES IN ALGIERS	Prof. Dr. Karim Belkacem, Dr. Nadia Cherif, Samir Lounis
		6	SAHARAN VERNACULAR STRATEGIES FOR CONTEMPORARY DESERT ARCHITECTURE IN SOUTHERN ALGERIA	Assoc. Prof. Dr. Fatima Zohra, Yacine Hadji
		7	PUBLIC SPACE RECONFIGURATION STRATEGIES FOR POST-WAR URBAN RECOVERY IN ORAN'S MEDINA	Dr. Mehdi Bouziane, Amina Bouzid
		8	BYZANTINE INFLUENCES IN SERBIAN ORTHODOX MONASTERY ARCHITECTURE AND SPATIAL ORGANIZATION	Prof. Dr. Milan Petrovic, Dr. Ana Jovanovic, Nikola Radovic

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HALL / SALON 4	**Dr. Chinedu Okonkwo,**	1	STRUCTURAL ANALYSIS OF BANGLADESH RICE VARIETAL ENZYMES UNDER SALINITY STRESS USING X-RAY CRYSTALLOGRAPHY	Prof. Dr. Rahman Karim, Dr. Fatima Begum, Shahid Islam
		2	MITOCHONDRIAL MEMBRANE POTENTIAL DYNAMICS IN BANGLADESH DIABETIC PATIENT LYMPHOCYTES	Assoc. Prof. Dr. Nazma Akter, Md. Faisal Ahmed
		3	QUANTUM DOTS CONJUGATION EFFECTS ON PROTEIN FOLDING KINETICS IN BANGLADESH SERICIN NANOPARTICLES	Dr. Shabnam Jahan, Rashedul Islam, Assis. Prof. Dr. Tasnim Sultana
		4	NMR SPECTROSCOPY REVEALS CONFORMATIONAL CHANGES IN BANGLADESH MANGROVE PEROXIDASE UNDER HEAVY METAL EXPOSURE	Prof. Dr. Mustafa Kamal, Laila Rahman
		5	AFRICAN YAM BEAN LECTIN GLYCAN RECOGNITION PATTERNS IN NIGERIAN CANCER CELL LINES	Dr. Chinedu Okonkwo,
		6	MEMBRANE FLUIDITY ALTERATIONS IN NIGERIAN SICKLE CELL ERYTHROCYTES UNDER OXIDATIVE STRESS	Prof. Dr. Olusegun Adebayo, Chioma Nwosu
		7	STRUCTURAL CHARACTERIZATION OF NIGERIAN SHEA BUTTER FATTY ACID BINDING PROTEINS USING CD SPECTROSCOPY	Assis. Prof. Dr. Fatima Yusuf, Emeka Okafor, Dr. Aisha Mohammed
		8	MACEDONIAN WINE YEAST MEMBRANE PROTEOMICS UNDER ETHANOL STRESS VIA MASS SPECTROMETRY	Prof. Dr. Nikola Petrovski, Dr. Elena Markova, Goran Trajkovski
		9	QUANTUM MECHANICAL CALCULATIONS OF MACEDONIAN HERBAL ALKALOID-DNA INTERCALATION	Assoc. Prof. Dr. Viktorija Stefanoska, Ivancho Arsov

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HALL / SALON 5	**Assoc. Prof. Dr. Hassan Tavakoli**	1	OPTIMIZATION OF TURBINE BLADE COOLING CHANNELS USING COMPUTATIONAL FLUID DYNAMICS IN HIGH-TEMPERATURE GAS ENVIRONMENTS	Prof. Dr. Mohammad Rezaei, Ali Karimi, Dr. Sara Hosseini
		2	VIBRATION ANALYSIS AND DAMPING TECHNIQUES FOR ROTOR SYSTEMS IN INDUSTRIAL CENTRIFUGAL COMPRESSORS	Assoc. Prof. Dr. Hassan Tavakoli, Fatemeh Jafari
		3	THERMO-MECHANICAL FATIGUE MODELING OF CYLINDER HEADS IN HEAVY-DUTY DIESEL ENGINES	Dr. Reza Mahmoudi, Nima Bahrami, Assis. Prof. Dr. Leila Ahmadi
		4	ADVANCED MANUFACTURING OF LIGHTWEIGHT ALUMINUM ALLOYS FOR AUTOMOTIVE SUSPENSION COMPONENTS VIA FRICTION STIR PROCESSING	Prof. Dr. Amir Hosseinpour, Zahra Mahmoudi
		5	DESIGN AND PERFORMANCE EVALUATION OF BIOMASS GASIFICATION SYSTEMS FOR RURAL ELECTRIFICATION IN KENYAN COMMUNITIES	Dr. James Mwangi, Esther Kiptoo, Assoc. Prof. Dr. Paul Njoroge
		6	THERMAL MANAGEMENT SOLUTIONS FOR SOLAR-POWERED REFRIGERATION SYSTEMS IN OFF-GRID KENYAN MARKETS	Samuel Otieno, Dr. Grace Wanjiku
		7	DEVELOPMENT OF LOW-COST WIND TURBINE BLADES USING NATURAL FIBER COMPOSITES FOR KENYAN MICROGRIDS	Prof. Dr. David Kariuki, Miriam Chebet
		8	ADVANCED HEAT EXCHANGER DESIGNS FOR PETROCHEMICAL PROCESSES USING ADDITIVE MANUFACTURING IN OMAN	Assoc. Prof. Dr. Ahmed Al-Rashdi, Fatima Al-Maskari
		9	FATIGUE LIFE PREDICTION MODELS FOR OFFSHORE DRILLING RISER SYSTEMS UNDER IRREGULAR WAVE LOADING	Dr. Khalid Al-Belushi, Mariam Al-Harthi, Assis. Prof. Dr. Nasser Al-Siyabi
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HALL / SALON 6	**Assis. Prof. Dr. Amir Ghasemi,**	1	DEVELOPING FEDERATED LEARNING FRAMEWORKS FOR PRIVACY-PRESERVING MEDICAL IMAGE ANALYSIS IN DISTRIBUTED IRANIAN HOSPITALS	Prof. Dr. Reza Hosseini, Dr. Sara Mahmoudi, Ali Karimi
		2	EXPLAINABLE AI MODELS FOR CREDIT RISK ASSESSMENT IN IRANIAN BANKING SECTORS UNDER ECONOMIC SANCTIONS	Assoc. Prof. Dr. Mohammad Jafari, Fatemeh Ahmadi
		3	GAN-BASED SYNTHETIC DATA GENERATION FOR AUGMENTING RARE DISEASE DIAGNOSIS IN PERSIAN MEDICAL DATABASES	Dr. Leila Nazari, Hossein Rezaei, Neda Tavakoli
		4	REINFORCEMENT LEARNING OPTIMIZATION OF SMART GRID ENERGY DISTRIBUTION IN IRANIAN URBAN NETWORKS	Assis. Prof. Dr. Amir Ghasemi, Zahra Khalili
		5	AI-DRIVEN CROP DISEASE DETECTION SYSTEMS FOR SMALLHOLDER FARMERS IN KENYAN ARID REGIONS	Prof. Dr. James Mwangi, Dr. Esther Kiptoo
		6	NLP MODELS FOR SWAHILI LANGUAGE PRESERVATION AND EDUCATIONAL APPLICATIONS IN KENYAN PRIMARY SCHOOLS	Assoc. Prof. Dr. Peter Njoroge, Amina Hassan, Caleb Omondi
		7	DRONE-BASED AI MONITORING FOR WILDLIFE CONSERVATION IN KENYAN SAVANNA ECOSYSTEMS	Dr. Miriam Chege
		8	BLOCKCHAIN-ENABLED AI SUPPLY CHAIN OPTIMIZATION FOR OMANI DATE PALM EXPORTERS	Prof. Dr. Ahmed Al-Rashdi, Dr. Fatima Zahra, Khalid Al-Maskari
		9	AI-POWERED WATER RESOURCE MANAGEMENT FOR SUSTAINABLE AGRICULTURE IN OMANI WADI SYSTEMS	Assoc. Prof. Dr. Salem Al-Harthy, Mariam Said
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HALL / SALON 7	**Dr. Amina Fouad**	1	OPTIMIZATION OF TURBINE BLADE COOLING CHANNELS USING COMPUTATIONAL FLUID DYNAMICS IN HIGH-TEMPERATURE ENVIRONMENTS	Prof. Dr. Ahmed Hassan, Dr. Mohamed Salem, Karim El-Sayed
		2	VIBRATION ANALYSIS AND DAMPING TECHNIQUES FOR ROTOR SYSTEMS IN EGYPTIAN PETROCHEMICAL COMPRESSORS	Assoc. Prof. Dr. Fatima Abdel Rahman, Omar Khalil
		3	DEVELOPMENT OF NANO-COMPOSITE MATERIALS FOR HIGH-STRENGTH AUTOMOTIVE COMPONENTS UNDER FATIGUE LOADING	Dr. Nour El-Din Mahmoud, Youssef Ibrahim, Assis. Prof. Dr. Sara Hassan
		4	THERMAL MANAGEMENT SYSTEMS FOR SOLAR THERMAL POWER PLANT RECEIVERS IN ARID ENVIRONMENTS	Prof. Dr. Khaled Mostafa, Dr. Amina Fouad
		5	ADVANCES IN FRICTION STIR WELDING TECHNIQUES FOR ALUMINUM-LITHIUM ALLOYS IN AEROSPACE APPLICATIONS	Assoc. Prof. Dr. Rachid Belkacem, Dr. Samir Hadji
		6	NUMERICAL MODELING OF MULTIPHASE FLOW IN OFFSHORE OIL-GAS SEPARATORS FOR ALGERIAN FIELDS	Dr. Nadia Zerhouni, Karim Mansouri, Lounis Brahimi
		7	DESIGN OF LIGHTWEIGHT SANDWICH COMPOSITES FOR HIGH-SPEED RAILCAR BODIES UNDER IMPACT LOADING	Prof. Dr. Farid Benali, Assis. Prof. Dr. Amina Bouzid
		8	HYBRID SOLAR-GEOTHERMAL POWER GENERATION SYSTEMS OPTIMIZED FOR PAKISTANI GRID INTEGRATION	Assoc. Prof. Dr. Bilal Ahmed, Dr. Sana Malik, Arif Khan
		9	TRIBOLOGICAL PERFORMANCE ENHANCEMENT OF CYLINDER LINERS THROUGH LASER TEXTURING FOR PAKISTANI AUTOMOBILE INDUSTRY	Dr. Hina Gul, Muhammad Faisal, Prof. Dr. Rabia Saleem
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HALL / SALON 8	Assis. Prof. Dr. Amir Ghasemi,	1	QUANTUM ENTANGLEMENT DYNAMICS IN GRAPHENE-BASED NANOSTRUCTURES UNDER EXTERNAL MAGNETIC FIELDS	Prof. Dr. Reza Hosseini, Dr. Mina Ahmadi,
		2	TOPOLOGICAL PHASE TRANSITIONS IN PERIODICALLY DRIVEN DIRAC MATERIALS WITH NON-RECIPROCAL INTERACTIONS	Assoc. Prof. Dr. Farhad Jafari, Sara Mahmoudi
		3	HIGH-HARMONIC GENERATION FROM RELATIVISTIC PLASMA MIRRORS IN ULTRA-INTENSE LASER FIELDS	Dr. Hossein Rezaei, Prof. Dr. Behnam Sabouri, Neda Khalili, Parisa Ebrahimi
		4	THERMODYNAMIC PHASE DIAGRAMS OF STRONGLY CORRELATED ELECTRON SYSTEMS NEAR QUANTUM CRITICAL POINTS	Assis. Prof. Dr. Amir Ghasemi,
		5	STUDY OF NEUTRON STAR EQUATIONS OF STATE THROUGH GW170817 MULTIMESSENGER OBSERVATIONS	Prof. Dr. Dimitris Kapodistrias, Dr. Eleni Papadopoulou
		6	PHOTONIC TOPOLOGICAL INSULATORS BASED ON PERIODICALLY PERFORATED METAMATERIALS	Assoc. Prof. Dr. Kostas Eleftheriadis, Maria Stavroula
		7	DARK MATTER DETECTION THROUGH ANNUAL MODULATION SIGNALS IN XENON TIME PROJECTION CHAMBERS	Dr. Nikolaos Voulgarakis, Prof. Dr. Georgios Katsioulas
		8	STUDY OF QUARK-GLUON PLASMA PROPERTIES THROUGH HEAVY ION COLLISIONS AT THE LHC	Dr. Vikram Singh,
		9	INVESTIGATION OF MAJORANA ZERO MODES IN IRON-BASED SUPERCONDUCTOR NANOWIRES	Dr. Rajesh Kumar
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HALL / SALON 1	**Doç. Dr. Burcu GEZER ŞEN**	1	GÜNÜMÜZDE ÇOCUĞUN SOSYAL DEĞERİ: GENÇ KADINLAR PERSPEKTİFİNDEN NİTEL BİR ANALİZ	Prof. Dr. Dolunay ŞENOL Dr. Gıyasettin YILDIZ
		2	YAŞAM DÖNEMLERİ VE TOPLUMSAL CİNSİYET BAĞLAMINDA YAŞLI KADINLARIN PİŞMANLIKLARI: NİTEL BİR İNCELEME	Prof. Dr. Dolunay ŞENOL Dr. Gıyasettin YILDIZ
		3	A Life Course Perspective on the Loneliness Experiences of Turkish Migrants in Germany: A Literature Review Across Three Generations	Süheyla Sönmez Demirci
		4	AN EVALUATION OF KORKUT TUNA'S CONTRIBUTIONS TO URBAN SOCIOLOGY	Doç. Dr. Emrullah TÜRK
		5	CULTURAL AND SOCIAL DIMENSIONS OF PUPPET THEATRE-BASED NARRATIVES IN EARLY CHILDHOOD	Doç. Dr. Burcu GEZER ŞEN
		6	EVALUATION OF PUPPET-BASED PROGRAM CONTENT IN THE CONTEXT OF LEARNING EXPERIENCES IN EARLY CHILDHOOD	Doç. Dr. Burcu GEZER ŞEN
		7	TOPLUMSAL SINIRLARIN YENIDEN ÜRETIMI: SURIYE'YE GERI DÖNÜŞTE YABANCILAŞMA VE YEREL KABUL	Öğr. Gör. Dr. Abdullah Gökhan YAŞA
		8	DIASPORA DENEYIMI SONRASI SOSYAL HAVALELER: SURIYE BAĞLAMINDA NORM, PRATIK VE KURUMSAL PRATIK TRANSFERI	Öğr. Gör. Dr. Abdullah Gökhan YAŞA

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HALL / SALON 2	**Doç. Dr. Salih DEĞİRMENCİ**	1	FEN BİLİMLERİ DERSİNDE PERFORMANS GÖREVLERİNİN ALTERNATİF DEĞERLENDİRME ARACI OLARAK KULLANIMINA İLİŞKİN ÖĞRENCİ GÖRÜŞLERİ	Yüksek Lisans Öğrencisi Yunus BOLAT Prof.Dr. Şafak ULUÇINAR SAĞIR
		2	FEN BİLİMLERİ DERSİNDE ARGÜMANTASYON TEMELLİ ÖĞRETİMİN ETKİLİĞİNİN BİLİŞSEL DÜZEYDE İNCELENMESİ	Prof.Dr. Şafak ULUÇINAR SAĞIR Fatma AYKUL KOÇ
		3	FEN BİLİMLERİ ÖĞRETMENLERİNİN DERSLERİNDE SİMÜLASYON VE SANAL LABORATUVAR KULLANIMINA YÖNELİK GÖRÜŞLERİNİN BELİRLENMESİ	Prof. Dr. Hülya YILMAZ Sanem HANER
		4	TÜRKİYE YÜZYILI MAARİF MODELİ KAPSAMINDA 9. SINIF BİYOLOJİ DERS KİTABINDA BİLİM İNSANLARININ TEMSİLLERİNİN ANALİZİ	Dr. Öğr. Üyesi Sultan ÇIKRIK
		5	BİYOLOJİ ÖĞRETMEN ADAYLARININ GELECEK PLANLARI VE ENDİŞELERİNİN ZİHİN HARİTASI YÖNTEMİ İLE ANALİZİ	Dr. Öğr. Üyesi Sultan ÇIKRIK
		6	AN ERROR-BASED ACTİVİTY DESİGN FOCUSED ON ELECTRİCAL RESİSTANCE	Doç. Dr. Salih DEĞİRMENCİ
		7	ÇEVRESEL BOZULMAYA YENİ BİR BAKIŞ AÇISI: EĞİTİM VE EKOLOJİK AYAK İZİ ARASINDAKİ İLİŞKİ	Prof. Dr. FINDIK ÖZLEM ALPER ESRA AKBAŞ ZARA GÜLER CANBAY
		8	İNSAN SİNİR VE ENDOKRİN SİSTEMİ KONUSUNUN ÖĞRETİMİNDE UNPLUGGED BİLGİ-İŞLEMSEL DÜŞÜNME YAKLAŞIMI	Dr. Aydan AYTEKİN Prof. Dr. Mustafa Sami TOPÇU
			K-12 DÜZEYİNDE OKUL YÖNETİCİLERİNİN YAPAY ZEKA ASİSTANLARINA YÖNELİK TUTUMLARININ İNCELENMESİ	Dr. Öğretim Üyesi Mehmet Akın Bulut Esra DEMİRCİ Ahmet ORAKÇI Rabi YAKIŞIKLI Mustafa Hamza BİRSİN

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HALL / SALON 3	**Assistant Prof. Melike PAK**	1	SOSYAL HİZMET UZMANLARININ UYGULAMADA KARŞILAŞTIĞI ŞİDDET VE GÜVENLİK SORUNLARI	Yüksek Lisans Öğrencisi Hatice ACAR
		2	AN EVALUATION OF THE RELATIONSHIP BETWEEN EDUCATIONAL DURATION AND AGE AT FIRST MARRIAGE İN TERMS OF BIRTH RATES İN TÜRKIYE	Res. Asst. Mustafa Emin AKÇİN
		3	A REVIEW OF GRADUATE THESES ON DOWN SYNDROME IN TÜRKİYE	Res. Asst. Mustafa Emin AKÇİN
		4	TRABZON'DA YAŞAYAN AFGANİSTAN UYRUKLU KADIN GÖÇMENLERİN YEREL TOPLUMLA YAŞAM PRATİKLERİ	Öğr. Gör. Muhlise CANLI
		5	CROSS-CULTURAL COMPARİSON OF PARENTS' KNOWLEDGE AND ATTİTUDES REGARDİNG HEALTHY SEXUAL DEVELOPMENT İN CHİLDREN	Öğr.Gör.Tuğba YAZICI ÇAKIROĞLU
		6	EFFECTS OF NATURAL DISASTERS ON FAMILY FUNCTIONING	Assistant Prof. Melike PAK
		7	GENÇ SOSYAL HİZMET UZMANLARININ EKSİK İSTİHDAMDA DENEYİMLERİ	Yüksek Lisans Öğrencisi Fatmanur DUMAN
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HALL / SALON 4	**Doç. Dr. Rıdvan ERGİN**	1	BEDEN EĞİTİMİ VE SPOR ARAŞTIRMALARINDA KULLANILAN SOSYOLOJİK ÖLÇEKLER	Arş. Gör. Nazlıcan TAŞTAN Dr. Öğr. Üyesi Gamze Yıldırım ARAZ Doç. Dr. Cüneyt TAŞKIN Arş. Gör. Berkant AYDEMİR
		2	BEDEN EĞİTİMİ VE SPOR ARAŞTIRMALARINDA KULLANILAN PSİKOMETRİK ÖLÇEKLER	Doç. Dr. Cüneyt TAŞKIN Arş. Gör. Nazlıcan TAŞTAN Arş. Gör. Berkant AYDEMİR Dr. Öğr. Üyesi Gamze Yıldırım ARAZ
		3	DİJİTAL VE GELENEKSEL SPORCULARDA YARATICILIK VE MOTİVASYON EĞİLİMLERİ	Arş. Gör. Berkant AYDEMİR Doç. Dr. Cüneyt TAŞKIN Dr. Öğr. Üyesi Gamze Yıldırım ARAZ Arş. Gör. Nazlıcan TAŞTAN
		4	SPORTİF PERFORMANSTA DİKKATİ ETKİLEYEN BİREYSEL FAKTÖRLER: TEORİK BİR İNCELEME	Dr. Öğr. Üyesi Gamze Yıldırım ARAZ Arş. Gör. Berkant AYDEMİR Arş. Gör. Nazlıcan TAŞTAN Doç. Dr. Cüneyt TAŞKIN
		5	DEBT MANAGEMENT IN FOOTBALL CLUBS: SUCCESSFUL AND UNSUCCESSFUL EXAMPLES	Dr. İsmail ÖNER Asst Prof Tarkan SÖĞÜT Doç. Dr. Emine ÖZTÜRK KARATAŞ Prof. Dr. Özgür KARATAŞ
		6	Management Issues in the Recreational Use of Sports Facilities	Doç. Dr. Emine ÖZTÜRK KARATAŞ Dr. İsmail ÖNER Asst Prof Tarkan SÖĞÜT Prof. Dr. Özgür KARATAŞ
		7	EVALUATION OF AGILITY PERFORMANCE IN VOLLEYBALL	Doç. Dr. Rıdvan ERGİN
		8	THE RELATİONSHİP BETWEEN ATTİTUDES TOWARD SPORTS AND INTERNET ADDİCTİON AMONG GENERATİON Z UNİVERSİTY STUDENTS	Res. Assist. Yağmur ÖZTÜRK Hatice UĞUZ
		9	EMOTION RECOGNITION TECHNOLOGIES IN SPORTS	Prof. Dr. Talha MURATHAN Murat ATAY
		10	DIGITAL TRANSFORMATION IN COMBAT SPORTS	Murat ATAY Prof. Dr. Talha MURATHAN

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HALL / SALON 5	**Assoc. Prof. Dr. Melek ERDEK**	1	Melilotus indica (L.) All. KÖK NODÜLÜNDEN İZOLE EDİLEN Sinorhizobium meliloti 3BVE'NİN GENOMİK KARAKTERİZASYONU	Dr. Asiye Esra EREN EROĞLU Dr. Volkan EROĞLU Prof. Dr. İhsan YAŞA
		2	FERMENTE MEYVELERDEN İZOLE EDİLEN ETANOL DİRENÇLİ ASETİK ASİT BAKTERİLERİNİN FENOTİPİK-MOLEKÜLER KARAKTERİZASYONU	Gülperi BULUT ÖZBAY Prof. Dr. İhsan YAŞA
		3	AN EVALUATION ON THE EXTERNAL MORPHOLOGY OF THE SPECIES KARSCHIA (KARSCHIA) MASTIGOPHORA BIRULA, 1890 (SOLIFUGAE, KARSCHIIDAE)	Assoc. Prof. Dr. Melek ERDEK
		4	Cydonia Oblonga (AYVA) SULU EKSTRAKTININ ANTİBİYOFİLM AKTİVİTESİ	Arş. Gör. Pınar Elife DOĞAN Doç. Dr. Arzu ÖZKARA Doç. Dr. Dilek AKYIL Prof. Dr. İbrahim Hakkı CİĞERCİ
		5	Thymus serpyllum (YABANİ KEKİK) BİTKİSİNİN SULU EKTRAKTININ Staphylococcus aureus ve Pseudomonas aeruginosa ÜZERİNDE ANTİBİYOFİLM AKTİVİTESİNİN BELİRLENMESİ	Doç. Dr. Arzu ÖZKARA Doç. Dr. Dilek AKYIL Arş. Gör. Pınar Elife DOĞAN Prof. Dr. İbrahim Hakkı CİĞERCİ
		6	Tilia tomentosa (GÜMÜŞİ IHLAMUR)'UN POTANSİYEL ANTİBİYOFİLM AKTİVİTESİNİN ARAŞTIRILMASI	Doç. Dr. Dilek AKYIL Arş. Gör. Pınar Elife DOĞAN Doç. Dr. Arzu ÖZKARA Prof. Dr. İbrahim Hakkı CİĞERCİ
		7	AYDIN İLİ'NDEN TOPLANAN KESTANE YAPRAKLARIYLA İLİŞKİLİ MİKOBİYOTA	Doç. Dr. Çiğdem YAMANER Yüksek Lisans Öğrencisi Kevser ALTAN
		8	FARKLI Trichoderma spp. İZOLATLARININ BAZI BİTKİ PATOJENİ FUNGUSLARA KARŞI In vitro ANTAGONİSTİK ETKİLERİNİN BELİRLENMESİ	Doç. Dr. Çiğdem YAMANER Yüksek Lisans Öğrencisi Hande Nur SÜRÜCÜ

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HALL / SALON 6	**Prof. Dr. Şebnem YILDIZ YAR**	1	An Application Of The Theorem On Absolute Matrix summability	Prof. Dr. Şebnem YILDIZ YAR
		2	ANALYTICAL OR SEMI-ANALYTICAL SOLUTIONS TO NONLINEAR TIME FRACTIONAL DIFFERENTIAL EQUATIONS THROUGH A HYBRID METHOD	Asst. Prof. Dr. Suleyman CETINKAYA Prof. Dr. Ali DEMIR
		3	NUMERICAL SOLUTION OF TIME FRACTIONAL DIFFERENTIAL EQUATION THROUGH A NUMERICAL METHOD	Asst. Prof. Dr. Suleyman CETINKAYA Prof. Dr. Ali DEMIR
		4	A CONSTRUCTION OF THE SHAPE OPERATOR OF A RULED HYPERSURFACE	Assist. Prof. Dr. Gül UĞUR KAYMANLI
		5	ABSOLUTE SUMMABILITY FACTORS RELATED TO THE SUMMABILITY $\|C^q,\varphi\|(\lambda)$	Assoc. Prof. Dr. Fadime GÖKÇE
		6	SOME COMPARISON RELATIONSHIPS IN ABSOLUTE q-CESA`RO METHODS	Assoc. Prof. Dr. Fadime GÖKÇE
		7	SONSUZ ARALIKTA İKİNCİ MERTEBEDEN IMPULSIVE SINIR DEĞER PROBLEMLERİ	Yüksek Lisans öğrencisi Vildan Havle AKER Prof.Dr.İlkay KARACA
		8	NEW GENERALIZED CONTRACTIONS ON S-METRIC SPACES	Assoc. Prof. Dr. Nihal TAŞ Asst. Prof. Elif KAPLAN
			C_G-KHAN TYPE FIXED-CIRCLE RESULTS ON G-METRIC SPACES	Assoc. Prof. Dr. Nihal TAŞ

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HALL / SALON 7	**Dr. Gültekin Gürçay**	1	EMERGING TECHNOLOGIES AND AFRICA: AI AND DIGITALIZATION	Joel John Omini
		2	SUSTAINABLE CONCRETE FROM WASTE: SYNERGISTIC USE OF SEWAGE SLUDGE ASH, SILICA FUME AND RECYCLED PLASTIC.	Babatunde Olufunso Oluwole Ömer Damdelen Stephen Babajide Olabimtan
		3	BIOCHAR-ENHANCED CEMENT MORTAR USING PYROLYZED POSIDONIA OCEANICA LEAVES: MECHANICAL, AND DURABILITY PROPERTIES	Stephen Babajide Olabimtan Mohammad Ali Mosaberpanah Babatunde Olufunso Oluwole
		4	BREAST CANCER DETECTION USING DEEP LEARNING POWERED APPROACH	Misbahu Koramar Boko Lawal Pwadubashiyi Coston Pwavodi Abdullahi Umar Ibrahim Abdullahi Garba Usman
		5	Impact of climate change on the quality and safety of water resources for the agri-food industry	Ali Khalfa Azzeddine Senouci Mounir Chihab Bouazza Sofiane
		6	INFLUENCE OF HEAT TREATMENT ON THE COMPRESSION STRENGTH OF PINE (Pinus nigra Arn.) AND BEECH (Fagus sylvatica L.)	Holta ÇOTA Besar SHEHU Entela LATO Doklea QUKU

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HALL / SALON 8	**Dr. Amaneh Manafidizaji**	1	THE PERCEPTIONS OF NURSING STUDENTS REGARDING ORGAN DONATION	Dr. Julian Kraja Erisilda Hasramaj Elsjona Qallija Sebastjan Mjekaj
		2	Tinospora Cordifolia-Mediated Nanoparticles: Bridging Ethnomedicine and Modern Cancer Therapy	Assist. Prof. K.R.Padma
		3	DIAGNOSIS OF PINWORM INFECTION BY USING SCOTCH-TEST: A CROSS SECTION-BASED EPIDEMIOLOGICAL SURVEY	Prof. Asoc. ERJONA ABAZAJ Prof. Asoc. OLTIANA PETRI Dr. ELA ALI Dr. BRUNILDA HYSAJ Msc. LEDIA ZHGABA Prof. Dr. SHPËTIM QYRA
		4	PREVALENCE OF HEALTHCARE-ASSOCIATED INFECTIONS IN “MOTHER TERESA” UNIVERSITY HOSPITAL AND REGIONAL DURRES HOSPITAL	MD.PhD. Zahide Sulejmani Prof. Asoc. Gjergji Koja Prof. Asoc. Erjona Abazaj Elja Sulejmani
		5	IMPACT OF PROBIOTICS, PREBIOTICS, AND THE GUT MICROBIOME ON SPORTS PERFORMANCE IN ADOLESCENTS: A STRUCTURED PRISMA-STYLE REVIEW	Phd (c) Dorian Meta Assoc. Prof. Oltiana Petri MD
		6	LEVEL OF STRESS, AND BURNOUT AMONG NURSING STAFF IN THE WORKPLACE: A CORRELATIONAL STUDY IN A REGIONAL HOSPITAL	Dr. can. Silvana Belisha Prof. Dr. Ilirjana Zekja Prof. Dr. Erjona Abazaj Doc. Valbona Dibra Dr. cand. Elsjona Qallija
		7	SUPPLEMENTS IN ATHLETES; TRENDS AND AWARENESS IN IMPLICATION WITH MICROBIOTIA	Oltiana Petri Erjona Abazaj Dorian Meta Genti Pano Albana Daka Vjollca Shpata

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HALL / SALON 9	**Lawson Domingo Adeniyi**	1	THE ROLE OF TOURISM IN PROMOTING ENVIRONMENTAL SUSTAINABILITY	Lawson Domingo Adeniyi
		2	BANKING AND FINANCE IN THE DIGITAL ERA: IMPLICATIONS FOR INCLUSION, STABILITY AND SUSTAINABLE GROWTH	Geoffrey Eboson
		3	COOPERATIVE SECURITY IN THE EAST MEDITERRANEAN: RECONCILING POWER COMPETITION, MIGRATION, AND CLIMATE RISKS	Adewale Rotimi Ologuntoye
		4	Turkey's Strategic Balancing Act: Navigating Refugee Politics and Regional Security in the Middle East	Paul Kaffo Lahai
		5	STRATEGIC APPROACHES TO ENHANCING ORGANIZATIONAL PERFORMANCE IN CONTEMPORARY BUSINESS MANAGEMENT	Godwin Nwachukwu
		6	INSIGHTS INTO A TEACHER-INFLUENCER'S (E)-TEACHING PRACTICES WITH EFL ALGRIAN SECONDARY STUDENTS	Rafik El-Amine GHOBRINI Younes Rami AOUN Yasmine BELKHIR
		7	THE ROLE OF BLOCKCHAIN TECHNOLOGY IN STRENGTHENING CUSTOMER RELATIONSHIP MANAGEMENT SYSTEMS (CRM)	OLAWUNMI AZEEZAT AKANBI
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HALL / SALON 10	**Mehdi Seraj**	1	IMPACT OF EMOTIONAL INTELLIGENCE AND LEADERSHIP EMPOWERMENT ON WORK ENGAGEMENT AND PSYCHOLOGICAL EMPOWERMENT	Christopher Richard Omoike
		2	Talent Management: The Impact of Artificial Intelligence (AI) inTransforming Human Resources in a Company.	Mamadou Samba Koulibaly
		3	ANALYSIS OF WAYS AND MEANS TO REDUCE POVERTY: THE CASE OF 18 COUNTRIES IN SUB- SAHARAN AFRICA FROM 1993 TO 2021.	Narcisse Wynton Dagbaud Mehdi Seraj
		4	THE SOIL PRODUCTIVITY PARADOX: ANALYZING THE ROLE OF FERTILIZERS, FDI, AND HUMAN CAPITAL IN AFRICAN AGRICULTURE	Levi Mbaka Matimbia Mehdi Seraj
		5	A PROTOCOL IN COLLECTING SOCIAL SCIENCES DATA FROM MINORS IN MALAYSIA	Siti Nurhayati Khairatun
		6	THE IMPACT OF ARTIFICIAL INTELLIGENCE ON THE CRITICAL THINKING OF FUTURE COACHES WHEN DRAWING UP TRAINING PLANS: AN AID OR A SUBSTITUTE?	Algirdas Pupkis

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HALL / SALON 1	Dr. Andreas Karras,	1	NOVEL NANOPARTICLE-BASED DRUG DELIVERY SYSTEMS FOR TARGETED BREAST CANCER THERAPY IN IRANIAN PATIENTS	Prof. Dr. Reza Mahmoudi, Dr. Sara Ahmadi, Ali Jafari
		2	GENETIC MARKERS OF TYPE 2 DIABETES SUSCEPTIBILITY IN IRANIAN POPULATIONS WITH CONSANGUINEOUS MARRIAGES	Assoc. Prof. Dr. Hossein Rezaei, Mina Karimi, Dr. Farhad Tavakoli
		3	STEM CELL THERAPY APPLICATIONS FOR CHRONIC WOUND HEALING IN DIABETIC PATIENTS FROM RURAL IRAN	Dr. Leila Hosseini, Assoc. Prof. Dr. Amir Ghasemi
		4	NEUROPROTECTIVE EFFECTS OF SAFFRON EXTRACT IN EARLY-STAGE ALZHEIMER'S DISEASE PATIENTS	Prof. Dr. Mohammad Aliabadi, Zahra Mahmoudi
		5	MEDiterranean DIET ADHERENCE AND CARDIOVASCULAR RISK REDUCTION IN GREEK ISLAND POPULATIONS	Dr. Eleni Papadopoulos, Prof. Dr. Kostas Dimitriadis, Maria Stavrou
		6	GENE THERAPY APPROACHES FOR BETA-THALASSEMIA MAJOR IN GREEK PEDIATRIC COHORTS	Assoc. Prof. Dr. Sophia Antoniou, Nikos Georgiou
		7	TELEMEDICINE IMPLEMENTATION FOR RHEUMATOID ARTHRITIS MANAGEMENT IN RURAL GREEK REGIONS	Dr. Andreas Karras, Assis. Prof. Dr. Elena Markou
		8	AYURVEDIC INTEGRATIVE APPROACHES FOR CHRONIC KIDNEY DISEASE MANAGEMENT IN INDIAN DIABETIC PATIENTS	Prof. Dr. Vikram Sharma, Dr. Priya Menon, Rajesh Nair
		9	NEURAL NETWORK MODELS FOR EARLY LUNG CANCER DETECTION USING LOW-DOSE CT SCANS IN SMOKING PREVALENT REGIONS	Assoc. Prof. Dr. Anjali Patel, Sanjay Gupta, Dr. Meera Joshi
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HALL / SALON 2	Assis. Prof. Dr. Reza Tavakoli	1	ADVANCES IN APPLICATIONS OF FUZZY TOPOLOGY TO MEDICAL IMAGE SEGMENTATION PROBLEMS	Prof. Dr. Mohammad Rezaei, Ali Karimi, Dr. Sara Ahmadi
		2	GRAPH-THEORETIC MODELS FOR OPTIMIZING URBAN TRAFFIC NETWORKS UNDER UNCERTAINTY	Assoc. Prof. Dr. Hossein Jafari, Fatemeh Mahmoudi
		3	NUMERICAL SOLUTIONS FOR NONLINEAR FRACTIONAL DIFFERENTIAL EQUATIONS IN BIOMEDICAL MODELING	Dr. Leila Hosseini, Nima Bahrami, Assis. Prof. Dr. Reza Tavakoli
		4	ALGEBRAIC STRUCTURES AND CRYPTOGRAPHIC PROTOCOLS BASED ON QUANTUM ERROR CORRECTION CODES	Prof. Dr. Amir Ghasemi, Zahra Khalili
		5	STOCHASTIC PROCESSES AND RISK ASSESSMENT MODELS FOR RENEWABLE ENERGY GRIDS	Dr. Konstantinos Papadopoulos, Maria Stavropoulou
		6	GEOMETRIC ANALYSIS OF RIEMANNIAN MANIFOLDS WITH NON-POSITIVE CURVATURE	Assoc. Prof. Dr. Dimitrios Nikolaou, Elias Georgiou
		7	FUNCTIONAL ANALYSIS APPROACHES TO QUANTUM FIELD THEORY ON CURVED SPACEMANIFOLDS	Prof. Dr. Ioannis Antoniadis
		8	NUMERICAL METHODS FOR SOLVING PARTIAL DIFFERENTIAL EQUATIONS IN PETROLEUM RESERVOIR SIMULATION	Dr. Faisal Alghamdi, Assoc. Prof. Dr. Noor Alotaibi
		9	COMBINATORIAL OPTIMIZATION TECHNIQUES FOR LOGISTICS NETWORK DESIGN IN ARABIAN PENINSULA	Assis. Prof. Dr. Khalid Alharbi, Sarah Mansour
		10	ALGEBRAIC GEOMETRY METHODS IN CODING THEORY FOR 6G COMMUNICATION SYSTEMS	Prof. Dr. Hiroshi Tanaka, Dr. Yuko Nakamura
		11	STOCHASTIC DIFFERENTIAL EQUATIONS MODELING NEURONAL DYNAMICS IN JAPANESE AGING POPULATIONS	Assoc. Prof. Dr. Kenji Sato, Aiko Mori, Dr. Taro Ikeda

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HALL / SALON 3	Assis. Prof. Dr. Daulet Moldagulov	1	ADVANCED NANOCOMPOSITES FOR HIGH-STRENGTH LIGHTWEIGHT STRUCTURAL APPLICATIONS IN CENTRAL ASIA	Prof. Dr. Aibek Tulegenov, Dr. Madina Sarsenova
		2	THERMOELECTRIC MATERIAL OPTIMIZATION FOR ENERGY HARVESTING IN HARSH CLIMATES	Assoc. Prof. Dr. Nurzhan Bekbolatov, Aidana Zhumagaliyeva
		3	BIODEGRADABLE POLYMER BLENDS FOR SUSTAINABLE PACKAGING SOLUTIONS	Dr. Erlan Korganbayev, Saltanat Abildinova, Assis. Prof. Dr. Daulet Moldagulov
		4	CERAMIC MATRIX COMPOSITES FOR HIGH-TEMPERATURE TURBINE BLADES	Prof. Dr. Zhanna Iskakova
		5	PHOTOVOLTAIC MODULE ENCAPSULANTS WITH ENHANCED UV STABILITY FOR DESERT CONDITIONS	Assoc. Prof. Dr. Sami Ben Ali, Dr. Nadia Kallel
		6	TITANIUM ALLOYS WITH IMPROVED WEAR RESISTANCE FOR OFFSHORE APPLICATIONS	Dr. Hassen Trabelsi, Mariem Jrad, Prof. Dr. Anis Bouaziz
		7	FUNCTIONALIZED CARBON NANOTUBES FOR SUPERCAPACITOR ELECTRODES	Assis. Prof. Dr. Wajdi Ghorbal
		8	BIOCOMPATIBLE HYDROGELS FOR BONE TISSUE ENGINEERING SCAFFOLDS	Prof. Dr. Fatima Zahra El Alaoui, Dr. Karim El Khadiri
		9	MAGNETORHEOLOGICAL FLUIDS FOR ADAPTIVE VIBRATION DAMPING SYSTEMS	Assoc. Prof. Dr. Youssef El Hamzaoui, Amina Lahlou

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HALL / SALON 4	Dr. Hassan Tavakoli,	1	ANTHELMINTIC RESISTANCE PATTERNS IN SHEEP HELMINTH POPULATIONS ACROSS AZERBAIJAN'S SHEKI REGION	Prof. Dr. Aysel Mammadova, Dr. Elvin Kerimov, Zara Huseynova
		2	MASTITIS PATHOGEN PREVALENCE AND ANTIMICROBIAL SUSCEPTIBILITY IN DAIRY COWS FROM BAKU SUBURBS	Assoc. Prof. Dr. Rashad Abbasov, Leyla Ismayilova
		3	VIRAL HEMORRHAGIC SEPTICEMIA IMPACT ON AQUACULTURE RAINBOW TROUT FARMS IN AZERBAIJAN	Dr. Nigar Gafarova, Kamran Mirzayev, Prof. Dr. Sevinc Nuriyeva
		4	NUTRITIONAL MANAGEMENT OF POSTPARTURIENT METABOLIC DISORDERS IN AZERBAIJANI DAIRY HERDS	Elchin Safarov, Dr. Aida Kerimova
		5	CAMELID DERMATOPHILOSIS CONTROL STRATEGIES IN IRANIAN SEMI-ARID REGIONS	Assoc. Prof. Dr. Mohammad Rezaei, Fatemeh Karimi
		6	EQUINE GASTRIC ULCER SYNDROME PREVALENCE AMONG RACING THOROUGHBREDS IN TEHRAN	Dr. Hassan Tavakoli, Soraya Mahmoudi, Ali Jafari
		7	ANTIVIRAL HERBAL FORMULATIONS FOR NEWCASTLE DISEASE PREVENTION IN BACKYARD POULTRY	Prof. Dr. Zahra Ahmadi, Leila Bahrami
		8	PORCINE REPRODUCTIVE AND RESPIRATORY SYNDROME CONTROL IN INTENSIVE PIG FARMS OF NORTH MACEDONIA	Assoc. Prof. Dr. Nikola Petrovski, Elena Georgieva
		9	ANTIBIOTIC STEWARDSHIP PROGRAMS IN NORTH MACEDONIAN POULTRY INTEGRATION	Assis. Prof. Dr. Biljana Stojanova, Saso Kostovski
		10	BOVINE TUBERCULOSIS TRANSMISSION DYNAMICS AT LIVESTOCK-WILDLIFE INTERFACES IN MACEDONIA	Dr. Marija Ivanovska, Goran Trajkovski
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HALL / SALON 5	Dr. Elena Garcia,	1	EPIDEMIOLOGICAL INVESTIGATION OF BRUCELLOSIS IN DAIRY CATTLE HERDS ACROSS NORTHERN IRAN	Prof. Dr. Mohammad Rezaei, Sara Ahmadi, Ali Jafari
		2	THERAPEUTIC EFFICACY OF HERBAL NANOPARTICLES AGAINST MASTITIS IN IRANIAN SHEEP FLOCKS	Assoc. Prof. Dr. Fatemeh Karimi, Hassan Tavakoli
		3	PARASITOLOGICAL SURVEY OF GASTROINTESTINAL NEMATODES IN CAMELS UNDER INTENSIVE FARMING	Dr. Leila Hosseini, Nima Bahrami, Zahra Mahmoudi
		4	VACCINE DEVELOPMENT FOR NEWCASTLE DISEASE VIRUS IN BACKYARD POULTRY SYSTEMS	Reza Jalali, Prof. Dr. Mina Sharifi
		5	ANTIMICROBIAL STEWARDSHIP PROGRAMS FOR SWINE RESPIRATORY DISEASES IN PHILIPPINE FARMS	Assoc. Prof. Dr. Maria Santos, Dr. Jose Rizalino
		6	ZOONOTIC LEPTOSPIROSIS TRANSMISSION DYNAMICS IN URBAN-RURAL INTERFACE COMMUNITIES	Luzviminda Cruz, Roberto Villanueva, Assis. Prof. Dr. Ana Reyes
		7	NUTRITIONAL MANAGEMENT OF FOOT-AND-MOUTH DISEASE RECOVERY IN CARABAO DAIRY HERDS	Dr. Elena Garcia, Mark Torres
		8	THERMAL STRESS MITIGATION STRATEGIES FOR DAIRY GOATS IN OMAN'S ARID ENVIRONMENTS	Prof. Dr. Ahmed Al-Maskari, Fatima Said
		9	THERMAL STRESS MITIGATION STRATEGIES FOR DAIRY GOATS IN OMAN'S ARID ENVIRONMENTS	Prof. Dr. Ahmed Al-Maskari, Fatima Said
		10	PARATUBERCULOSIS CONTROL PROGRAMS IN OMANI SHEEP AND GOAT POPULATIONS	Dr. Mariam Al-Kindi, Hassan Mubarak
		11	INNOVATIVE WASTEWATER TREATMENT USING Moringa oleifera SEEDS FOR RURAL NIGERIAN COMMUNITIES	Prof. Dr. Chukwuma Okonko, Ngozi Eze, Adebayo Ojo
		12	BIOREMEDIATION OF OIL-SPILL CONTAMINATED SOILS USING CONSORTIUM OF INDIGENOUS MICROORGANISMS	Dr. Fatima Yusuf, Emeka Nwankwo

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HALL / SALON 6	Assoc. Prof. Dr. Chen Hao,	1	QUANTUM ENTANGLEMENT IN NON-LOCAL CORRELATIONS USING ALGERIAN PHOTONIC SYSTEMS	Prof. Dr. Karim Belkacem, Dr. Nadia Zerhouni, Yassine Amrani
		2	SUPERCONDUCTING THIN FILMS FOR HIGH-FIELD MAGNET APPLICATIONS IN ALGERIA	Assoc. Prof. Dr. Samir Lounis, Amina Bouzid
		3	PLASMA PHYSICS MODELING FOR MAGNETIZED FUSION CONFINEMENT STUDIES	Dr. Mehdi Chergui, Farid Benali, Samia Haddad
		4	NONLINEAR OPTICS IN PERIODICALLY POLED LITHIUM NIOBATE FOR ALGERIAN QUANTUM SOURCES	Assis. Prof. Dr. Houari Boukhari, Nourredine Mansouri
		5	TOPOLOGICAL INSULATORS FOR SPINTRONIC DEVICES IN ADVANCED CHINESE FABRICATION	Prof. Dr. Zhang Wei, Li Ming, Wang Jing
		6	STRONG FIELD LASER PHYSICS FOR ATTOSECOND PULSE GENERATION	Assoc. Prof. Dr. Chen Hao, Liu Yang
		7	NEUTRON SCATTERING STUDIES OF QUANTUM MAGNETS IN CHINESE RESEARCH REACTORS	Dr. Xu Peng, Zhou Qian, Sun Lei
		8	QUANTUM DOTS FOR SINGLE PHOTON SOURCES IN INDIAN OPTOELECTRONICS	Prof. Dr. Rajesh Kumar, Priya Sharma
		9	GRAVITATIONAL WAVE DETECTION WITH INDIAN LASER INTERFEROMETRY	Assoc. Prof. Dr. Sanjay Patel, Amit Singh, Neha Gupta
		10	2D MATERIALS FOR VALLEYTRONICS AND OPTOVALLEYTRONICS APPLICATIONS	Dr. Vikram Reddy, Anjali Desai
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HALL / SALON 7	**Dr. Youssef Idrissi**	1	PLASTIC WASTE VALORIZATION THROUGH PYROLYSIS FOR ENERGY RECOVERY IN LAGOS METROPOLIS	Assoc. Prof. Dr. Olusegun Adeyemi, Chioma Okoro
		2	CLIMATE-ADAPTIVE URBAN DRAINAGE SYSTEMS FOR FLOOD MITIGATION IN ABUJA CITY	Dr. Aminu Bello, Tunde Afolabi, Prof. Dr. Grace Eke
		3	DESALINATION TECHNOLOGIES FOR COASTAL WATER SECURITY IN MOROCCAN AGRICULTURE	Assoc. Prof. Dr. Hassan El Amrani, Fatima Zahra, Karim Bennani
		4	WIND-BREAK VEGETATION BELTS FOR COMBATING SAHARAN DESERTIFICATION IN MOROCCO	Prof. Dr. Amina Serghini, Dr. Youssef Idrissi
		5	MICROPLASTIC REMOVAL FROM MARINE AQUACULTURE EFFLUENTS IN CASABLANCA COASTAL WATERS	Nabil Khaddour, Assoc. Prof. Dr. Salma El Ouardi
		6	BIOGAS PRODUCTION FROM MUNICIPAL ORGANIC WASTE FOR NAIROBI ENERGY ACCESS	Prof. Dr. James Mwangi, Dr. Esther Wanjiku, Kevin Ochieng
		7	WETLAND RESTORATION FOR HEAVY METAL PHYTOREMEDIATION IN NAIROBI RIVER BASIN	Wangui Kariuki, Assoc. Prof. Dr. Paul Mwaniki
		8	SOLAR-DRIVEN ATMOSPHERIC WATER HARVESTING FOR ARID NORTHERN KENYAN COMMUNITIES	Dr. Amina Hassan, Elias Kipchoge, Prof. Dr. Miriam Chege

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HALL / SALON 1	**Arş. Gör. Afra Banu ERGİN Öğr. Gör. Hilal Ok BOSTAN**	1	EKSTREMİTELER VE ABDOMİNAL BÖLGEYİ TUTAN YAYGIN LİPOMATOZİS: OLGU SUNUMU	Uzman Doktor Fatih TAHAK Uzman Doktor Sezgin Kıymık
		2	SİGARA İÇEN BİREYLERDE SPELEOTERAPİNİN SOLUNUM FONKSİYONLARINA ETKİSİ	Ögr. Gör. Uğur BAĞCI Prof. Dr. Hasan Kerem ALPTEKİN Dr. Öğr. Üyesi Sefa Haktan HATIK Dr. Öğr. Üyesi Emine Büşra AYDIN
		3	EVALUATION OF HUMAN PAPILLOMAVIRUS (HPV) KNOWLEDGE LEVELS AMONG UŞAK UNIVERSITY STUDENTS	Fatma Nur AKDOĞAN KİTTANA Soycan TÜNER Yunus Alp Soysal Ayşe KARAKUŞ Muhammed Kadir YÖRÜYEN Ceylin ERDOĞAN Ceren Sıla TÜRK Aleyna BAŞ Selen Ece TOPBAŞ İsmail YETGİN Dilara POLAT Sudenur KABUKÇU Ahu Beyza KOŞARHAN
		4	BEYİN KAYNAKLI NÖROTROFİK FAKTÖR ve BEYİN SAĞLIĞINDAKİ ÖNEMİ	Esra YILMAZ MENGÜÇ Prof. Dr. Tünay KONTAŞ AŞKAR
		5	UNUSUAL ONSET OF SACROTUBEROUS LIGAMENT	Mehmet Batuhan Solmazer Gülşen Deren Yaman Birtan Demir Okan Bilge
		6	ZİRKONYA MARYLAND KÖPRÜLERİNİN KLİNİK UYGULAMASI: İKİ OLGU SUNUMU	Arş.Gör.Elisa ÇELİK Arş.Gör.Dağlar AKSAKAL Öğr.Gör.Hilal OK BOSTAN
		7	CASE REPORT: PROSTHETIC REHABILITATION OF AN ANTERIOR OPEN BITE CASE	Arş. Gör. Afra Banu ERGİN Öğr. Gör. Hilal Ok BOSTAN
		8	CASE REPORT: USE OF THE EXTRACTED TOOTH AS A PONTIC AND PROSTHETIC REHABILITATION WITH MONOLITHIC ZIRCONIA IN A PATIENT WITH PERIODONTAL AND ESTHETIC COMPLAINTS	Arş. Gör. Afra Banu ERGİN Öğr. Gör. Hilal Ok BOSTAN

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HALL / SALON 2	Dr. Öğr. Üyesi Deniz ÇOBAN ÖZKAN Doç. Dr. Fikret SÖNMEZ	1	ARAÇ RENKLERİNİN TERMAL PERFORMANS ÜZERİNE ETKİSİ VE YANSITICI KAPLAMA UYGULAMASI	Yüksek Lisans Öğrencisi Dilek Simge Karagül Dr. Öğr. Üyesi Mehmet Bakırcı
		2	SWCNT, DWCNT VE MWCNT KATKILARI İLE OLUŞTURULAN PROPANOL-DİZEL KARIŞIMLARININ EMİSYON KARAKTERİSTİKLERİNE ETKİSİ	Yahya ÇELEBİ
		3	TİTANYUM MALZEMELERDE ZAMANA BAĞLI OLARAK YÜZEY PÜRÜZLÜLÜĞÜ VE TAKIM AŞINMASININ İNCELENMESİ	Dr. Öğr. Üyesi Deniz ÇOBAN ÖZKAN Doç. Dr. Fikret SÖNMEZ
		4	CAM ELYAF TAKVİYELİ POLİPROPİLEN YÜZEY TABAKALI ALÜMİNYUM BAL PETEĞİ SANDVİÇ KOMPOZİTLERİN YARI STATİK PENETRASYON DAVRANIŞININ İNCELENMESİ	Emre KOLCULAR Okan ÖZDEMİR Mustafa Mert KURDİŞ
		5	TAKVİYE KULLANIMININ ÇİFT BİNDİRMELİ YAPIŞTIRICI BAĞLANTILARIN MEKANİK DAVRANIŞINA ETKİSİ: SAYISAL BİR ÇALIŞMA	Makine Müh. Gizem Damla EKE Prof. Dr. Murat Yavuz SOLMAZ
		6	COMPARATIVE STUDY OF LASER SURFACE TEXTURING AND THERMAL OXIDATION ON TI6AL4V TRIBOLOGY	Suzan SAKARYA Dr.Öğr.Gör. Niyazi ÇAVUŞOĞLU Dr. Öğr. Üyesi Abdullah SERT
		7	NUMERICAL ANALYSIS OF THE CHANGE IN STABILITY BEHAVIOR OBSERVED IN WASHING MACHINES DEPENDING ON THE CONFIGURATION OF DAMPING ELEMENTS	Musa Uzun Zeki Kıral Onur Çolak Cahit Atagün
		8	Afet ve Kriz Yönetiminde Sürdürülebilir Çözüm: Güneş Enerjili Mobil Gıda Pişirme ve Dağıtım Ünitesi Tasarımı	Sefa DÖKECEKLİ Dr. Öğr.Üyesi İsmet Tıkız Şuayip Demir
		9	STUDY ON SEALING PERFORMANCE OF GREASE LUBRICATED ROTARY LIP SEALS WITH DETERMINISTIC MICRO-GROOVE TEXTURED ON SHAFT SURFACE	Görkem ARSLAN
		10	PELTIER ETKİLİ BİR SOĞUTMA SİSTEMİNİN TASARIMI, GERÇEKLENMESİ VE PERFORMANS ANALİZİ	Doç. Dr. SİBEL AKKAYA OY Yüksek lisans Öğrencisi İLAYDA ARSLAN

FDM TEKNOLOJİSİ İLE İMAL EDİLEN ABS VE PA6 GF KOMPOZİT NUMUNELERİN BASMA DAYANIMI VE ENERJİ SÖNÜMLEME KAPASİTELERİNİN DENEYSEL OLARAK KARŞILAŞTIRMALI DEĞERLENDİRİLMESİ
Fadlullah YILDIRIM
Burak BOZ
Özcan ATEŞ
Doç. Dr. Emre İsa ALBAK
FDM YÖNTEMİYLE ÜRETİLEN İNCE CİDARLI ABS TÜPLERİN ÇARPIŞMA DAYANIMINA VE ENERJİ SÖNÜMLEME KAPASİTESİNE DİKİŞ POZİSYONUNUN ETKİSİ Burak BOZ
Fadlullah YILDIRIM

Doç. Dr. Emre İsa ALBAK - **Yaptı**

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HALL / SALON 3	**Arş. Gör. Cemre EMİR Prof. Dr. Betül TAŞPINAR**	1	FUTBOLCULARDA ALT EKSTREMİTE BACAK YARALANMALARI	Lisans Öğrencisi, Mehmet Ali ÇAL Arş. Gör. Polat YÜCEDAL Prof. Dr. Vedat ÇINAR
		2	PERFORMANSIN GÖRÜNMEYEN YÜZÜ: SPORCULARDA BESLENME VE YEME BOZUKLUKLARI	Lisans Öğrencisi, Gamze KILIÇASLAN Arş. Gör. Polat YÜCEDAL Prof. Dr. Vedat ÇINAR
		3	A COMPARISON OF PHYSICAL FITNESS PARAMETERS BETWEEN INDIVIDUALS WITH INTELLECTUAL DISABILITIES RECEIVING ADAPTED PHYSICAL ACTIVITY EDUCATION AND THOSE RECEIVING SWIMMING TRAINING	Seçil BULUŞ Prof. Dr. Betül AKYOL
		4	THE EFFECTS OF PHYSICAL ACTIVITY ON MOTOR DEVELOPMENT İN AUTISM SPECTRUM DİSORDER	Zehra POLAT Prof. Dr. Betül AKYOL
		5	KINOVEA-BASED VIDEO ANALYSIS APPROACHES IN THE EVALUATION OF SWIMMING PERFORMANCE	İsmet Safa KAPLAN Doç. Dr. Mehmet İMAMOĞLU
		6	COMPARISON OF FREESTYLE SWIMMING PERFORMANCES BY GENDER	İsmet Safa KAPLAN Doç. Dr. Mehmet İMAMOĞLU
		7	BEL AĞRISI OLAN HASTALARIN KAYROPRAKTİK TEDAVİ SONRASINDA SUBJEKTİF SAĞLIK ŞİKAYETLERİNİN YAŞAM KALİTESİ ÜZERİNE ETKİSİNİN İNCELENMESİ	Uzman Fizyoterapist Armin ASLANOĞLU Dr. Öğr. Üyesi Berkay Eren PEHLİVANOĞLU Dr. Öğr. Üyesi Sefa Haktan HATIK Dr. Öğr. Üyesi Demet BİÇKİ
		8	ALT EKSTREMİTE KAS OKSİJENASYONU VE NON-İNVAZİV DEĞERLENDİRİLMESİ	Arş. Gör. Cemre EMİR Prof. Dr. Betül TAŞPINAR
			PERİFERİK ARTER HASTALIĞINDA EGZERSİZE UYUM VE FİZYOTERAPİ TEMELLİ YAKLAŞIMLAR	Arş. Gör. Cemre EMİR Prof. Dr. Betül TAŞPINAR

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HALL / SALON 4	**Assist. Prof. Dr. Serkan ENGİN**	1	SÜLFATLI SULARA MARUZ BETONLARIN BASINÇ DAYANIMI AÇISINDAN ARAŞTIRILMASI	Dr. Öğr. Üyesi Korkmaz Yıldırım
		2	EFFECT OF TOBACCO UNDERSIZE WASTE ON TECHNICAL PROPERTIES OF CEMENTITIOUS LIGHTWEIGHT COMPOSITE MORTARS	Civil Engineer Yasin DURMAZ Assist. Prof. Dr. Şevket Onur KALKAN Prof. Dr. Lütfullah GÜNDÜZ
		3	INFLUENCE OF RED MUD INCORPORATION ON THE SELF-CLEANING PERFORMANCE OF GYPSUM–LIME–SILICA FUME TERNARY BLENDED CEMENTLESS MORTARS	Civil Engineer Mehmet Tuna ERCEYLAN Assist. Prof. Dr. Şevket Onur KALKAN Assist. Prof. Dr. Üyesi Ahmet YAVAŞ Prof. Dr. Lütfullah GÜNDÜZ
		4	INVESTIGATION OF THE EFFECTS OF THE 2007 AND 2018 TURKISH EARTHQUAKE CODES ON THE SEISMIC DEMANDS OF MID-RISE REINFORCED CONCRETE STRUCTURES	Assist. Prof. Dr. Serkan ENGİN
		5	INFLUENCE OF NEAR-FAULT DIRECTIVITY EFFECTS ON BASE SHEAR DEMANDS OF SINGLE-DEGREE-OF-FREEDOM SYSTEMS	Civil Eng. Emirhan YILDIRIM Assist. Prof. Dr. Serkan ENGİN
		6	STATISTICAL AND ARTIFICIAL INTELLIGENCE-BASED APPROACHES IN PERFORMANCE EVALUATION AND HYDRAULIC MODELING OF WASTEWATER TREATMENT PLANTS	Araştırma Görevlisi Burak ÇIRAĞ Prof. Dr. Reşat ACAR
		7	Integrated Analysis of Geological, Geochemical, and Remote Sensing Data for Determining Uranium (U) Potential Areas	Zehra TAŞ Prof. Dr. Berna YAVUZ PEHLİVANLI
		8	MAPPING OF GEOCHEMİCAL ANOMALIES AND MİNERAL POTENTİAL IN THE GIS ENVIROMENT	Graduate Student, Zehra TAŞ
		9	IDENTIFICATION OF DIFFERENT AE SIGNATURES IN CFRP-STRENGTHENED CONCRETE	İnşaat Mühendisi İmray Deniz ÇELİK VAROL Doç. Dr. Sena TAYFUR Prof. Dr. Ninel ALVER
		10	POZZOLANIC ACTIVITY OF BAYBURT STONE	Ömer BAYRAK Prof. Dr. Emin ERDEM
		11	USE OF BAYBURT GREEN SPOTTED WHITE TUFF AS A CEMENT ADDITIVE	Ömer BAYRAK Prof. Dr. Emin ERDEM

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HALL / SALON 5	**Dr. Öğr. Üyesi, NAZLI ÖZTÜRK**	1	YENİ HEGZADECA-SÜBSTİTÜE KOBALT (II) FTALOSİYANİN; SENTEZ VE ÇÖZÜNÜRLÜK	Dr. Öğr. Üyesi, NAZLI ÖZTÜRK
		2	COMPARISON OF PHOTOCATALYTIC EFFICENY OF CeNiO 3 /N-CQDs AND NiTiO 3 /N-CQDs HETEROJUNCTIONS IN ANTIBIOTIC REMOVAL SYSTEM	Büşra EMİR Özlem TUNA Şeyda KARADİREK
		3	EXPLORING DUAL METAL–ORGANIC FRAMEWORK AS NEXT-GENERATION PHOTOCATALYST IN WASTEWATER REMEDIATION PROCESSES	Özlem TUNA Şeyda KARADİREK
		4	C1 b KÜBİK YAPILI SmPtBi YARI-HEUSLER BİLEŞİĞİNİN ELASTİK VE TİTREŞİMSEL ÖZELLİKLERİ ÜZERİNE BİR İLK PRENSİP ÇALIŞMASI	Prof. Dr. Salih AKBUDAK Prof. Dr. Abdullah CANDAN
		5	BİRİNCİ PRENSİPLER HESAPLAMALARI YOLUYLA GdIr 2 LAVES FAZI BİLEŞİĞİNİN KAPSAMLI BİR ARAŞTIRMASI	Prof. Dr. Salih AKBUDAK Dr. Abdullah CANDAN
		6	CYCLIC SEED COATING FOR SUGAR BEET SEEDS	Researcher Hatice Bülbül Researcher Hatice Özsolak
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HALL / SALON 6	**Doç. Dr. Pınar AKSU KILIÇLE Dr. Öğr. Üyesi Özlem ÖNEN ÇELEBİ**	1	THE EFFECT OF EXERCISE ON IL-6 AND IL-1BETA: A META-ANALYSIS	Hamit Hakan ALP Ökkeş DERELİ Salih ÖNER
		2	EFFECT OF VITAMIN D SUPPLEMENTATION ON MUSCLE RECOVERY AFTER EXERCISE: A META-ANALYSIS	Salih ÖNER Furkan KIZILTAŞ Beyza ERTAN
		3	PREDİYABETTE BAĞIRSAK KAYNAKLI İMMÜNOMETABOLİK DEĞİŞİMLER: MİKROBİYOTA–İMMÜN–ENDOKRİN EKSENİNİN DEĞERLENDİRİLMESİ	Dr. Pınar Ellergezen
		4	PREDİYABETTE ADİPOİMMÜN DENGENİN BOZULMASI: ERKEN DÖNEMDE ORTAYA ÇIKAN YENİ BİR FENOTİPİN DEĞERLENDİRİLMESİ	Dr. Pınar Ellergezen
		5	TÜRKİYE'DE YETİŞEN SİLENE L. (CARYOPHYLLACEAE) TAKSONLARININ ETNOBOTANİK KULLANIMLARI	Muhammed Burak TATLİ Prof. Dr. Mustafa KORKMAZ
		6	ÜNİVERSİTE ÖĞRENCİLERİNİN GELENEKSEL TIBBİ BİTKİ KULLANIM DÜZEYLERİNİN BELİRLENMESİ	Prof. Dr. Mustafa KORKMAZ Aleyna ÖZDEMİR
		7	YÜKSEK RAKIMDA YETİŞEN AHUDUDUNUN FENOLİK ÖZELLİKLERİ VE KULLANIM ALANLARI	Doç. Dr. Pınar AKSU KILIÇLE Dr. Öğr. Üyesi Özlem ÖNEN ÇELEBİ
			MİTOMİSİN-C KAYNAKLI GENETİK HASAR VE BİTKİSEL EKSTRAKTLARIN İN VİVO KORUYUCU POTANSİYELİ	Doç. Dr. Pınar AKSU KILIÇLE Dr. Öğr. Üyesi Özlem ÖNEN ÇELEBİ
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HALL / SALON 7	**Prof. Dr. Şermin TAĞ KALAFATOĞLU**	1	İZLEYİCİ PERSPEKTİFİNDEN SÜRDÜRÜLEBİLİRLİK TEMALI REKLAMLAR	Dr. Öğr. Üyesi Sevgi N. KURUŞ
		2	NEW HOLLYWOOD CINEMA: ITS HISTORICAL CONTEXT AND FUNDAMENTAL PRINCIPLES	Prof. Dr. Şermin TAĞ KALAFATOĞLU
		3	THE NATIONAL FILM BOARD OF CANADA AND EXAMPLES OF ITS INTERACTIVE DOCUMENTARIES	Prof. Dr. Şermin TAĞ KALAFATOĞLU
		4	BÜTÜNLEŞİK PAZARLAMA İLETİŞİMİ ÇERÇEVESİNDE REKLAM VE HALKLA İLİŞKİLER UYGULAMALARININ TÜKETİCİ ETKİLEŞİMİ ÜZERİNDEKİ ROLÜ	Y.L. Öğrencisi, Nafile Gül TOPRAK
		5	PUBLIC RELATIONS PRACTICES ON ENVIRONMENT AND SUSTAINABILITY: A STUDY ON TURKISH BANK ADVERTISEMENTS	Dr. Öğr. Üyesi: Mevlüde Canan CAN
		6	CORPORATE MARKETING STRATEGIES IN THE DIGITAL TRANSFORMATION PROCESS	Prof. Dr. Zekiye Beril AKINCI VURAL Doktorant Yasin HAYAL

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HALL / SALON 8	**Doç. Dr. Nilgün DOĞAN Prof. Dr. Hakan ADANACIOĞLU**	1	TÜKETİCİLERİN MEYVE-SEBZE ALIŞVERİŞİNDE ÇEVRİMİÇİ KANALLARI KULLANIM DURUMU	Doç. Dr. Nilgün DOĞAN Prof. Dr. Hakan ADANACIOĞLU
		2	TÜRKİYE'DE TARIM ÜRÜNLERİ DIŞ TİCARETİNE YÖNELİK BİR DEĞERLENDİRME	Doç. Dr. Nilgün DOĞAN Prof. Dr. Hakan ADANACIOĞLU
		3	FARKLI KİREÇ DOZLARININ 'VİKİNG' ARONYA ÇEŞİDİNİN VERİM VE POMOLOJİK ÖZELLİKLERİ ÜZERİNE ETKİLERİ	Arş. Gör. Zeynep NAS Ziraat Mühendisi Cengiz BAYDAR Lisans Öğrencisi Melik KAVAK Prof. Dr. Lütfi PIRLAK
		4	INVESTIGATION OF THE POSSIBILITY OF USING SEWAGE SLUDGE AS A PEAT SUPPLEMENTARY MATERIAL AND RECYCLED WASTEWATER AS A SOURCE OF IRRIGATION WATER IN SEEDLING PRODUCTION	Student, Nisa Nur ADIGUZELOGLU Student, Nurten YILDIZ Assoc. Prof. Caner YERLI
		5	ENDEMİK HUŞ GÖVDELİ KIZILAĞACIN (Alnus glutinosa subsp. betuloides) POPULASYON ANALİZİ	Rüveyda ARSLAN Doç. Dr. Seyran PALABAŞ-UZUN
		6	DETERMINATION OF AROMA COMPOUNDS OF CALAMINTHA NEPETA (L.) COLLECTED FROM DERİNDERE PLATEAU, TRABZON	Assoc. Prof. Dr. Emine YURTERİ Sümeyye Beyza BUÇAN
		7	REVEALING THE DEVELOPMENTAL CHANGES OF PHENOLIC COMPOUNDS IN TEA FLOWERS BY HPLC ANALYSIS	Assoc. Prof. Dr. Emine YURTERİ Salih Sedatcan SARIKAYA
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HALL / SALON 9	İlter KİLERCİ	1	SUSTAINABLE VALORIZATION OF TEXTILE WASTE THROUGH HYBRID NATURAL–SYNTHETIC FIBER COMPOSITES: MECHANICAL AND DYNAMIC PERFORMANCE OPTIMIZATION	Mehmet BOZDAĞ Ramazan ERCAN Mehmet KARAHAN
		2	DEAD TIME ANALYSIS USING a NaI(Tl) DETECTOR in GAMMA SPECTROSCOPY: EFFECTS of MATERIAL and THICKNESS	Laman SEYFIYEVA Prof. Dr. Latife SAHIN Esra KAYA Pınar İSEL
		3	DESIGN AND IMPLEMENTATION OF AN IMAGE PROCESSING-ASSISTED MEASURING MACHINE IN AUTOMOTIVE PARTS PRODUCTION BY USING COLD AND HOT FORGING TECHNIQUES: A SMART APPROACH FOR DIMENSIONAL QUALITY CONTROL IN-PRODUCTION CELL	İlter KİLERCİ
		4	NADİR TOPRAK ELEMENTLERİNİN ELEKTRİKSEL, ELEKTRONİKSEL, SAVUNMA SANAYİ, ÇİMENTO VE İNŞAAT SEKTÖRLERİNDE KULLANIMI	Burak Samet ÖZGEN Arş. Gör. Cevher Kürşat MACİT Doç. Dr. Burak TANYERİ
		5	1.35 BAR İÇ BASINCA DAYANIKLI BİR ŞÖNT REAKTÖR TANKININ TASARIMI VE ANSYS TABANLI YAPISAL ANALİZİ	Çağrı AKSAKAL Murat KAVUK Alper Buğra TARAKÇI
		6	INVESTIGATION OF SURFACE ROUGHNESS DEPENDING ON POWER AND FREQUENCY AFTER FIBER LASER PROCESSİNG OF ASA SAMPLES PRODUCED BY FDM METHOD	Asst. Prof. Yusuf Burak BOZKURT Lecturer Ömer ERDOĞAN Research Assistant Dr. Burak ATİK Research Assistant Dr. Şükran Merve TÜZEMEN Research Assistant Dr. Yeşim SEÇER KAVASOĞLU Prof. Dr. Halim KOVACI Assoc. Prof. Yakup UZUN Prof. Dr. Ayhan ÇELİK
		7	INVESTIGATION OF THE RELATIONSHIP BETWEEN PORE MORPHOLOGY AND MECHANICAL PROPERTIES IN PERLITE-FILLED RIGID FOAMS	Aysel Sıla TOPÇU Muhammet Barış EKİCİ Eren ERTİK Murat ZENGİN Prof. Dr. Fatih ÇALIŞKAN
		8	STRESS DİSTRİBUTİON AND MECHANİCAL BEHAVİOR ANALYSİS OF BEDDİNG SPRİNGS MANUFACTURED FROM AISI 1060 CARBON STEEL	Aysel Sıla TOPÇU Muhammet Barış EKİCİ Mehmet YÜCE Murat ZENGİN Prof. Dr. Fatih ÇALIŞKAN
		9	MİNİBAR YÜZEYİNDE YERLİ HAMLE PROJESİ: YÜZEY KAPLAMA TEKNOLOJİLERİNDE YERLİ ÜRETİM VE SÜRDÜRÜLEBİLİRLİK YAKLAŞIMI	Sevim KARAAYAK
		10	YAPAY ZEKA DESTEKLİ OTONOM TARIM ROBOTUNUN GELİŞTİRİLMESİ	Sinan GÖKÇE, Esat UZSES, Halil Tardu YAKUT, Bülent İyihuylu, Ali ORAL,
		11	Liquid-Dependent Wettability Behavior of Lotus-Inspired Surfaces Fabricated by FDM	Kübra YILDIZ Arş. Gör. Dr. Yeşim SEÇER KAVASOĞLU Dr. Öğr. Üyesi. Yusuf Burak BOZKURT Prof. Dr. Halim KOVACI Prof. Dr. Ayhan ÇELİK

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HALL / SALON 10	**Dr. Öğr. Üyesi Fuat FİDAN Doç. Dr. Beyza ONUR Doç. Dr. Merve TUNA KAYILI**	1	THE IMPACT OF SUSTAINABLE DEVELOPMENT GOALS ON CULTURAL HERITAGE MANAGEMENT: THE CASE OF KAYSERI CASTLE	Asst. Prof. Dr. Leyla KADERLİ Architect Fatma KOÇ
		2	REUSE AND CONTEMPORARY ADDITIONS IN HISTORIC BUILDINGS: THE CASE OF THE TUMO CENTER FOR CREATIVE TECHNOLOGIES	Prof. Dr. Gonca BÜYÜKMIHÇI Architect Fatma KOÇ
		3	A STUDY ON THE KAYSERİ ERKİLET ARCHAEOLOGİCAL SİTE WİTHİN THE FRAMEWORK OF THE SUSTAİNABLE DEVELOPMENT GOALS	Dr. Öğr. Üyesi Leyla KADERLİ Yüksek Mimar Fatma GÜLER
		4	TARİHİ ÇEVRE ÖZELLİKLERİNİN YENİ YAPILAŞMAYA YANSIMALARININ SAFRANBOLU ÖRNEĞİNDE İRDELENMESİ	Dr. Öğr. Üyesi Fuat FİDAN Doç. Dr. Beyza ONUR Doç. Dr. Merve TUNA KAYILI
		5	TARİHİ KENTLERİN İKLİM DEĞİŞİKLİĞİNE UYUMU: SAFRANBOLU ÖRNEĞİNDE UYUM TEDBİRLERİ	Doç. Dr. Merve TUNA KAYILI Doç. Dr. Beyza ONUR Dr. Öğr. Üyesi Fuat FİDAN
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HALL / SALON 1	Dr. Elena Cojocaru,	1	FORMULATION AND EVALUATION OF NANOSTRUCTURED LIPOSOMAL CARRIERS FOR ENHANCED DOXORUBICIN DELIVERY IN BREAST CANCER THERAPY	Prof. Dr. Ahmed El-Sayed, Dr. Fatima Hassan, Mohamed Khalil
		2	PHYTOCHEMICAL PROFILING AND ANTIMICROBIAL ACTIVITY OF EGYPTIAN MEDICINAL PLANTS AGAINST MULTIDRUG-RESISTANT BACTERIA	Assoc. Prof. Dr. Nour El-Din Ahmed, Sara Mahmoud
		3	DEVELOPMENT OF ORAL FLOATING MATRIX TABLETS FOR SUSTAINED PROPRANOLOL HYDROCHLORIDE RELEASE IN HYPERTENSION MANAGEMENT	Dr. Khaled Ramadan, Youssef Ali, Prof. Dr. Heba Salem
		4	BIOSYNTHESIS OF SILVER NANOPARTICLES USING EGYPTIAN DATE PALM EXTRACT FOR WOUND HEALING APPLICATIONS	Mina Girgis, Assoc. Prof. Dr. Randa Abdel-Latif
		5	PHARMACOKINETIC OPTIMIZATION OF ARTEMISININ DERIVATIVES FOR IMPROVED ANTIMALARIAL EFFICACY IN ENDEMIC REGIONS	Prof. Dr. Ion Perju, Dr. Maria Cebotari, Andrei Lupu
		6	FORMULATION OF MUCOADHESIVE BUCCAL FILMS FOR RAPID NICORANDIL DELIVERY IN ANGINAL ATTACKS	Assoc. Prof. Dr. Valentina Rusu, Stefan Popa
		7	DEVELOPMENT OF LIPID POLYMER HYBRID NANOPARTICLES FOR ORAL INSULIN DELIVERY	Dr. Elena Cojocaru, Nicolae Donici
		8	CURCUMIN-LOADED SOLID LIPID NANOPARTICLES FOR NEUROPROTECTIVE THERAPY IN ALZHEIMER'S DISEASE	Prof. Dr. Rajesh Kumar, Dr. Priya Sharma, Amit Patel
		9	PHARMACEUTICAL COCRYS TAL ENGINEERING FOR ENHANCING POORLY SOLUBLE ANTIFUNGAL AZOLES	Assoc. Prof. Dr. Sanjay Gupta, Neha Singh
		10	3D-PRINTED ORAL TABLETS WITH PROGRAMMABLE DRUG RELEASE PROFILES FOR PERSON ALIZED MEDICINE	Dr. Anjali Desai, Rohan Mehra, Prof. Dr. Vikram Reddy
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HALL / SALON 2	Dr. Anna Sokolova	1	HYDROGEN PRODUCTION OPTIMIZATION FROM KAZAKHSTAN NATURAL GAS USING PLASMA REFORMING TECHNOLOGY	Prof. Dr. Almaz Tolegenov, Yerzhan Kairatov, Aizhan Sarsenova
		2	GEOTHERMAL ENERGY EXTRACTION FROM ABANDONED OIL WELLS IN WESTERN KAZAKHSTAN	Assoc. Prof. Dr. Gulnara Bekbolatova, Nurlan Abildayev
		3	WIND POWER INTEGRATION CHALLENGES IN KAZAKHSTAN'S STEPPE REGIONS	Dr. Dana Zhumagaliyeva, Ruslan Tastanbekov, Aidana Kurmanova
		4	CARBON CAPTURE UTILIZATION AND STORAGE FROM KAZAKHSTAN'S GAS PROCESSING PLANTS	Assis. Prof. Dr. Erlan Sadykov, Zhanna Kenzhegulova
		5	SMALL MODULAR REACTORS FOR REMOTE SIBERIAN INDUSTRIAL APPLICATIONS	Prof. Dr. Ivan Petrov, Dr. Anna Sokolova, Mikhail Ivanov
		6	HYDROGEN BLENDING IN EXISTING RUSSIAN NATURAL GAS TRANSMISSION NETWORKS	Assoc. Prof. Dr. Sergei Kuznetsov, Elena Petrova
		7	ADVANCED NUCLEAR FUEL CYCLE TECHNOLOGIES FOR CLOSED FUEL MANAGEMENT	Dr. Dmitry Volkov, Natalia Smirnova, Prof. Dr. Vladimir Loginov
		8	BIOMASS-TO-POWER TECHNOLOGIES FOR RURAL ELECTRIFICATION IN NORTH MACEDONIA	Assoc. Prof. Dr. Nikola Ivanov, Marija Petrovska
		9	ENERGY EFFICIENCY RETROFITS IN NORTH MACEDONIA'S SOVIET-ERA INDUSTRIAL FACILITIES	Dr. Goran Trajkovski, Elena Kostovska, Assis. Prof. Dr. Biljana Risteska
		10	HYBRID RENEWABLE MICROGRIDS FOR REMOTE MOUNTAIN COMMUNITIES IN NORTH MACEDONIA	Stefan Popovski, Prof. Dr. Daniela Angelova
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HALL / SALON 3	Assoc. Prof. Dr. Sultana Akter,	1	SYNTHESIS AND CHARACTERIZATION OF GRAPHENE OXIDE NANOCOMPOSITES FOR WATER DESALINATION MEMBRANES	Prof. Dr. Dimitris Papadopoulos, Dr. Eleni Stavrou, Nikos Karagiannis
		2	SILVER NANOPARTICLES EMBEDDED POLYMERIC FILMS FOR ANTIMICROBIAL MEDICAL DEVICE COATINGS	Assoc. Prof. Dr. Maria Antoniou, Kostas Theodoropoulos
		3	CARBON NANOTUBE-REINFORCED EPOXY NANOCOMPOSITES FOR AEROSPACE STRUCTURAL APPLICATIONS	Dr. Georgios Laskaris, Sofia Dimitriadou, Prof. Dr. Panagiotis Tsakaras
		4	QUANTUM DOT-POLYMER HYBRIDS FOR FLEXIBLE OPTOELECTRONIC DEVICES	Assis. Prof. Dr. Anna Vlachou, Ioannis Papageorgiou
		5	ZINC OXIDE NANOROD ARRAYS FOR PIEZOELECTRIC ENERGY HARVESTING IN WEARABLE TEXTILES	Prof. Dr. Rahman Karim, Dr. Fatima Begum, Shahidul Islam
		6	GOLD NANOPARTICLES FOR MALARIA RAPID DIAGNOSTIC TEST SENSITIVITY ENHANCEMENT	Assoc. Prof. Dr. Sultana Akter, Md. Rafiqul Islam
		7	MANGANESE DIOXIDE NANOFLOWERS FOR SUPERCAPACITOR ELECTRODES IN OFF-GRID SOLAR SYSTEMS	Dr. Nasir Uddin, Ayesha Siddiqua, Prof. Dr. Jamal Hossain
		8	BARIUM TITANATE NANOPARTICLES FOR PIEZOCATALYTIC WATER PURIFICATION	Assoc. Prof. Dr. Budi Santoso, Dr. Rina Wijaya
		9	SILICA NANOPARTICLES FROM RICE HUSK ASH FOR DRUG DELIVERY SYSTEMS	Dr. Agus Pramono, Sari Dewi, Prof. Dr. Hendra Nurochim
		10	TITANIUM DIOXIDE NANOTUBES FOR PHOTOELECTROCHEMICAL HYDROGEN PRODUCTION	Assis. Prof. Dr. Lina Sari, Muhammad Faisal, Rudi Hermawan
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HALL / SALON 4	Prof. Dr. Aizhan Kassenova,	1	ENGINEERED MICROBIAL CONSORTIA FOR BIOREMEDIATION OF OIL-CONTAMINATED SOILS IN KAZAKHSTANI STEPPE REGIONS	Prof. Dr. Aizhan Kassenova, Yerzhan Tolegenov, Dina Sarsenbayeva
		2	CRISPR-CAS9 EDITING OF WHEAT GENOMES FOR DROUGHT TOLERANCE IN CENTRAL ASIAN AGRICULTURE	Assoc. Prof. Dr. Ruslan Zhumatov, Aidana Kurmangaliyeva
		3	NANOCELLULOSE-BASED SCAFFOLDS FOR CARTILAGE TISSUE ENGINEERING FROM KAZAKH TRADITIONAL MEDICINAL PLANTS	Dr. Gulnara Abayeva, Nurlan Bekbolatov
		4	SYNTHETIC BIOLOGY PLATFORMS FOR STEVIA GLYCOSIDE PRODUCTION USING KAZAKH HALOTOLERANT YEAST	Assis. Prof. Dr. Erlan Nurgaliyev, Zhanna Kenzhegulova
		5	BACTERIOPHAGE COCKTAILS FOR ANTIBIOTIC-RESISTANT INFECTIONS IN RUSSIAN HOSPITAL SETTINGS	Prof. Dr. Ivan Petrov, Dr. Maria Sokolova, Alexei Volkov
		6	GENE THERAPY VECTORS FOR SPINAL MUSCULAR ATROPHY USING RUSSIAN AAV ISOLATES	Assoc. Prof. Dr. Elena Kuznetsova, Dmitry Ivanov
		7	MICROALGAE BIOFUEL PRODUCTION FROM SIBERIAN WASTEWATER TREATMENT PLANTS	Dr. Sergei Morozov, Natalia Petrova, Vladimir Smirnov
		8	FERMENTATIVE PRODUCTION OF RECOMBNANT HUMAN INSULIN USING MACEDONIAN YEAST STRAINS	Assoc. Prof. Dr. Nikola Popovski, Elena Ivanovska
		9	CRISPR-BASED VIRUS RESISTANCE IN BALKAN GRAPE CULTIVARS FOR SUSTAINABLE VITICULTURE	Dr. Marija Petrovska, Goran Trajkovski
		10	LIGNOCELLULOSIC BIOREFINERY FOR PHARMACEUTICAL PRECURSORS FROM BALKAN FOREST WASTE	Prof. Dr. Biljana Angelova, Saso Kostovski
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HALL / SALON 5	Dr. Samuel Kiptoo,	1	LOW-COST SOLAR-POWERED IRRIGATION SYSTEMS FOR SMALLHOLDER FARMERS IN ARID KENYAN REGIONS	Prof. Dr. James Mwangi, Esther Njoroge
		2	IOMASS GASIFICATION TECHNOLOGIES FOR RURAL ELECTRIFICATION IN WESTERN KENYA	Assoc. Prof. Dr. Peter Ochieng, Mary Atieno, David Kiprop
		3	DRONE-BASED PRECISION PESTICIDE APPLICATION FOR MAIZE CROPS IN KENYAN HIGHLANDS	Dr. Samuel Kiptoo, Grace Wanjiku
		4	WIND HYBRID MINIGRID SOLUTIONS FOR OFF-GRID COASTAL COMMUNITIES IN KENYA	Fatima Hassan, Prof. Dr. Ali Mohammed
		5	IOT-ENABLED SMART WATER METERS FOR URBAN LEAK DETECTION IN NAIROBI	Assis. Prof. Dr. Rachel Mwangi
		6	ADVANCED NUCLEAR REACTOR SAFETY SYSTEMS FOR SMALL MODULAR DESIGNS IN RUSSIA	Prof. Dr. Ivan Petrov, Dr. Anna Kuznetsova
		7	CRYOGENIC HYDROGEN STORAGE SYSTEMS FOR ARCTIC LNG TRANSPORT	Assoc. Prof. Dr. Sergei Volkov, Mikhail Ivanov
		8	QUANTUM DOT LASERS FOR HIGH-SPEED DATA CENTERS IN MOSCOW	Dr. Elena Smirnova, Prof. Dr. Dmitry Fedorov
		9	CARBON NANOTUBE FIELD EFFECT TRANSISTORS FOR 2NM TECHNOLOGY NODE	Takeshi Yamamoto, Dr. Aiko Nakamura
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HALL / SALON 6	Prof. Dr. Hassan Rezaei	1	GaN POWER DEVICES FOR ELECTRIC VEHICLE FAST CHARGING INFRASTRUCTURE	Assoc. Prof. Dr. Hiroshi Tanaka, Yumi Sato
		2	FLEXIBLE ORGANIC PHOTOVOLTAICS FOR WEARABLE ENERGY HARVESTING	Prof. Dr. Kenji Suzuki, Rina Kobayashi
		3	5G MILLIMETER WAVE BEAMFORMING ARRAYS FOR BASE STATION DEPLOYMENT	Dr. Reza Mohammadi, Sara Ahmadi
		4	AI-OPTIMIZED MICROGRID CONTROL FOR REMOTE ISLANDS	Assoc. Prof. Dr. Ali Karimi, Fatima Hosseini
		5	QUANTUM KEY DISTRIBUTION NETWORKS FOR SECURE COMMUNICATIONS	Prof. Dr. Hassan Rezaei
		6	HYBRID SOLAR THERMAL DESALINATION FOR COASTAL COMMUNITIES	Dr. Ahmed Khan, Sobia Malik, Bilal Ahmed
		7	6G TERAHERTZ COMMUNICATIONS FOR SMART CITIES	Assoc. Prof. Dr. Fatima Zahra, Imran Siddiqui
		8	WASTE-TO-ENERGY PLANTS FOR URBAN SOLID WASTE MANAGEMENT	Prof. Dr. Nadeem Raza, Ayesha Khan
		9	OFFSHORE WIND FARM DEVELOPMENT FOR COASTAL ENERGY SECURITY	Dr. Omar Farooq, Sana Malik
		10	SMART TRAFFIC MANAGEMENT SYSTEMS FOR LAHORE METROPOLIS	Reza Berisha, Prof. Dr. Luan Kuci
		11	GEOTHERMAL ENERGY EXPLOITATION FOR INDUSTRIAL PROCESS HEAT	Assoc. Prof. Dr. Dorina Marku, Erion Hoxha

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HALL / SALON 7	Dr. Anila Shehu	1	AUTONOMOUS UNDERWATER VEHICLES FOR MARINE RESOURCE MAPPING	Dr. Anila Shehu
		2	HYDROGEN FUEL CELL BUSES FOR PUBLIC TRANSPORTATION	Klodian Deda, Prof. Dr. Valbona Kolici, Mira Bushati
		3	PREDICTIVE MAINTENANCE FRAMEWORKS FOR RICE MILLING MACHINERY USING IOT SENSOR NETWORKS	Dr. Rithy Seng, Sophea Ly, Chhay Nak
		4	DESIGN OF LOW-COST CNC ROUTERS FOR RURAL WOODWORKING COOPERATIVES USING LOCALLY SOURCED COMPONENTS	Assoc. Prof. Dr. Sothy Khim, Meng Heng
		5	THERMOELECTRIC WASTE HEAT RECOVERY SYSTEMS FOR HEAVY-DUTY TRUCK ENGINES IN DEVELOPING MARKETS	Prof. Dr. Sokha Chan, Dr. Vanna Sok
		6	MULTI-OBJECTIVE OPTIMIZATION OF OFFSHORE WIND FARM LAYOUTS CONSIDERING MAINTENANCE ACCESSIBILITY	Dr. Antonio Fernández, Sofia Navarro, Raúl Pérez
		7	ADAPTIVE ROBOTIC ASSEMBLY SYSTEMS FOR AUTOMOTIVE CUSTOMIZATION IN HIGH-VARIETY PRODUCTION	Assoc. Prof. Dr. Miguel Ángel Rodríguez, Elena García
		8	ENERGY-EFFICIENT COGENERATION SYSTEM DESIGN FOR INDUSTRIAL DISTRICT HEATING IN MEDITERRANEAN CLIMATES	Prof. Dr. Javier Morales, Dr. Carmen López
		9	LEAN MANUFACTURING IMPLEMENTATION FRAMEWORK FOR SMALL-SCALE MINING EQUIPMENT PRODUCTION IN KYRGYZSTAN	Dr. Mirlan Bektemirov, Aidana Kurmanalieva, Nurlan Asanov
		10	VIBRATION ANALYSIS AND DYNAMIC STABILITY IMPROVEMENT IN HYDRAULIC TURBINE SYSTEMS FOR MOUNTAIN HYDROPOWER PLANTS	Assoc. Prof. Dr. Bakytbek Osmonov, Gulnara Toktogonova
		11	OPTIMIZATION OF SUPPLY CHAIN LOGISTICS FOR CENTRAL ASIAN TEXTILE EXPORTS USING HYBRID METAHEURISTIC ALGORITHMS	Prof. Dr. Aida Sadykova, Ermek Nurtaziev

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HALL / SALON 1	Dr. Öğretim Üyesi Özlem GÜLERYÜZ	1	Assessing the Influence of ICT and Financial Development on Economic Growth in Arab Countries: Evidence from a Feasible Generalized Least Squares Approach	Ponle Henry KAREEM Ashraf M.S. ABUSIDA
		2	Exploring the Moderating Role of Organizational Readiness and Regulatory Compliance in AI-Driven Forensic Accounting: Evidence from Jordan.	Wagdi M S Khalifa
		3	Identifying Critical Success Factors for the Implementation of AI in the Tourism Industry	Seyed Mohammadbagher Jafari Sarehsadat Rahmani
		4	VALIDATION AND PRIORITIZATION OF DIMENSIONS OF THE MODEL FOR APPLYING GAMIFICATION CONCEPTS IN ELEMENTARY EDUCATION	Fatemeh Heidari Seyed Mohammadbagher Jafari Seyfollah Fazlollahi Ghomshi
		5	THE PSYCHOLOGICAL ORIGINS OF THE STATE	Dr. Öğretim Üyesi Yağız AKSAKALOĞLU
		6	EXPLORING THE IMPACT OF AUGMENTED REALITY APPLICATIONS ON CUSTOMER EXPERIENCE IN THE FASHION INDUSTRY THROUGH TAM	Melis Gizem AKKAYA Prof. Dr. Sevtap ÜNAL
		7	RPA SİSTEMLERİ KULLANIMINDA ÖRGÜTLERİN DEĞİŞEBİLME YETENEĞİ ÜZERİNE NİCEL BİR ARAŞTIRMA	Dr. Öğretim Üyesi Özlem GÜLERYÜZ
		8	DISADVANTAGED GROUPS AND ACCESSIBILITY ON CAMPUSES: SULEYMAN DEMIREL UNIVERSITY EAST-WEST CAMPUS EXAMPLE	Research Assistant Dr. Sema ÇETİNKAYA
		9	ÜSTÜN YETENEKLİ ÖĞRENCİLERİN KÜLTÜREL MİRASA DUYARLILIKLARI İÇİN BİR UYGULAMA	Eren Efe EFE Dora Ege SU Bilge Atış
		10	GENÇ KADINLARIN İŞGÜCÜNE KATILIMINDA SOSYOEKONOMİK VE KÜLTÜREL DİNAMİKLER: SAKARYA ÜNİVERSİTESİ ÖRNEĞİ	Dr. Öğr. Üye. Sayın SAN Melek YAZICI Arda GÖKALP
		11	THE BÜYÜKÇEKMECE URBAN CHARTER FROM THE PERSPECTIVE OF URBAN RIGHTS	Dr. Özlem TEMİZEL
		12	AN EXAMINATION OF THE ATTITUDES AND SATISFACTION LEVELS OF CONSUMERS WHO SHOPPED ON THE TEMU ELECTRONIC COMMERCE WEBSITE	Yüksek Lisans Öğrencisi Dilara KEÇECİ Dr. Öğr. Üyesi İlknur SARAL DİNLEYİCİ AZİZ YILMAZ

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HALL / SALON 1	**Prof. Dr. Hakan AYDIN**	1	LIBATION SCENES ON THE SEALS FROM ASSYRIAN TRADE COLONIES ERA	Assistant Professor Ebru ORAL
		2	NATURE'S ENERGIES ARE WITH US: YOUNG LEADERS ENVIRONMENTAL COMMUNICATION AND MEDIA NETWORK	Prof. Dr. Hakan AYDIN
		3	INVESTIGATING INDIVIDUALS' PERCEPTIONS OF NEW TECHNOLOGIES USING AN ONLINE NETWORK ANALYSIS APPROACH	PhD Candidate Ayşe Nur BÜYÜKYAVUZ DENİZ
		4	ERGENLERDE SİBER ZORBALIĞIN PSİKOSOSYAL ETKİLERİ, DİNAMİKLERİ VE BAŞA ÇIKMA STRATEJİLERİ	Rabia Nur KOYUNCU SÜR
		5	KRONİK YORGUNLUKLA YAŞAMAK: SOSYAL HİZMET BAKIŞ AÇISIYLA GÜNLÜK YAŞAM MÜCADELELERİ	Rabia Nur KOYUNCU SÜR Doç. Dr. Fatih ALTUN
		6	ATHEİSM POLİCİES DURİNG THE SOVİET PERİOD İN CENTRAL ASİA: THE CASE OF KYRGYZSTAN	Dr. Öğrencisi Yüsra İSENÇ
		7	Savaş Sonrası Britanya'da Kadın Emeği ve Tanınma: "The Landswomen" (1918-1920) Üzerine Söylem Analizi	Yüksek Lisans Öğrencisi Taner Uzunpınarlı Dr. Öğr. Üyesi Onur Yamaner
		8	İSG' DE ÖNLEME YATIRIMLARININ ÖNEMİ VE İŞ KAZALARINA ETKİSİ	Dr. Cihandar HASANHANOĞLU
		9	İŞ DOYUMUNUN İŞ VERİMLİLİĞİ VE İŞ KAZALARI ÜZERİNE ETKİSİ	Dr. Cihandar HASANHANOĞLU
		10	TEMPORAL BRIDGE SYMPTOMS BETWEEN DEPRESSION AND ANXIETY WORRY SYMPTOMS IN ADOLESCENCE: DIFFERENCES BETWEEN HIGH-RISK AND COMMUNITY SAMPLES	Dr. Öğr. Üyesi Deniz Konaç Professor Edward D. Barker

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HALL / SALON 2	**Prof.Dr. Aysel Güven**	1	IS WOMEN'S HAPPINESS AND LIFE SATISFACTION A DETERMINANT OF COSMETIC SURGERY ACCEPTANCE? LATENT PROFILE ANALYSIS	Dr. Öğr. Üyesi Yağmur SÜRMELİ Dr. Öğr. Üyesi Esma GÖKÇE
		2	The Main Factor Determining Professional Attitude in Nursing: A Study on First-Year Students	Arş. Gör., Büşra Yürük, Dr. Öğr. Üyesi, Yağmur Sürmeli,
		3	BÖBREK NAKLİ ALICILARINDA KARDİYOVASKÜLER RİSK FAKTÖRLERİ	Araş. Gör. Dr. Hatice Nihan BOZKURT
		4	VISUAL AND QUANTITATIVE INVESTIGATION OF ATMOSPHERIC MICROPLASTICS IN ISTANBUL EUROPEAN SIDE NATURE PARKS THROUGH Xanthoria parietina LICHEN MONITORING	AYŞE BETÜL KONAR Prof. Dr. Gülşah ÇOBANOĞLU
		5	Nanofibriler Protein Eldesi için Kabak Çekirdeği Bazlı Başlangıç Materyali Geliştirmesi	Bihter AYDIN Prof. Dr. Seher KUMCUOĞLU
		6	FROM AMPELOGRAPHY TO DİGİTAL AMPELOGRAPHY: CONVOLUTİONAL NEURAL NETWORK APPROACHES İN PRECİSİON VİTİCULTURE	Adnan DOĞAN Deniz Uğur GÜZEL
		7	DIGITAL TRANSFORMATION IN VITICULTURE: INTEGRATED USE OF ARTIFICIAL INTELLIGENCE, REMOTE SENSING, IOT, AND AUTONOMOUS SYSTEMS	Adnan DOĞAN Deniz Uğur GÜZEL
		8	ANTIOXIDATIVE INGREDIENTS AND BIOCHEMICAL METABOLISM OF TEA AND GRAPES	Prof.Dr. Aysel Güven

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HALL / SALON 2		1	AMBİYANSIN İZİNDE RICOEUR'CÜ BİR HERMENEUTİK İNCELEME: TRABZON KADINLAR PAZARI'NIN ANLATI KİMLİĞİ	Prof. Dr. Serap DURMUŞ ÖZTÜRK Arş. Gör. Asude BALİ Yüksek Mimar M. Enes ÖKSÜZ
		2	CALIBRATION OF UNDRAINED PARAMETERS WITH PLAXIS SOILTEST MODULE BASED ON LABORATORY TRIAXIAL TESTING OF A FINE-GRAINED SOIL	Civil Eng., Jhandra Mishelle REDONDO PİNTO Prof. Dr., MSc., Civil Eng., Sedat SERT Research Assistant, MSc., Civil Eng., Eylem ARSLAN
		3	INVESTIGATION OF THE APPLICABILITY OF FILTER PRESS MUD WASTE FROM THE SUGAR INDUSTRY IN SOIL IMPROVEMENT	Civil Eng., Jhandra Mishelle REDONDO PİNTO Prof. Dr., MSc., Civil Eng., Sedat SERT
		4	KOMPRESÖR BİYEL KOLU UYGULAMASI İÇİN KARBONİTRASYONLU AISI 1018 VE DIN 1705 (Rg 5) BRONZ KAPLAMALI BURÇLARIN TRİBOLOJİK PERFORMANSININ BELİRLENMESİ	Metin KOÇAK Onur Emre BAYRAKCI Arş. Gör. Mehmet Esat AYDIN Prof. Dr. Mehmet BAĞCI
		5	HAVA YÖNLENDİRİCİ TASARIMININ PERFORMANSA ETKİSİNİN NÜMERİK VE DENEYSEL YÖNTEMLERLE KARŞILAŞTIRILMASI	Sistem Tasarım Mühendisi, Büşra YILDIRIM Kıdemli Mekanik Tasarım Uzmanı, Yaşar Seccat KESİCİ
		6	COMPARISON OF BROACHING AND CNC TURNING PROCESSES IN THE PRODUCTION OF AN INVOLUTE PROFILED CONNECTION ADAPTER IN TERMS OF SURFACE QUALITY, CYCLE TIME, AND COST	M.Sc. Student in Mechanical Engineering Ömer ÖZKAN M.Sc. Mechanical Engineer Mehmet GÜN Prof. Dr. Mehmet BAĞCI

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HALL / SALON 1	**Dr. İlhan POLAT**	1	TÜRKİYE YÜZYILI MAARİF MODELİNE GÖRE HAZIRLANAN 5.SINIF MATEMATİK DERS KİTABINDA BULUNAN KAREKOD DESTEKLİ İÇERİKLERİN İNCELENMESİ	Yüksek Lisans Öğrencisi Şevval ÖZDEMİR ÖZBEK Dr. Öğr. Üyesi Hilal YILDIZ
		2	TÜRKİYE YÜZYILI MAARİF MODELİNE GÖRE HAZIRLANAN 5.SINIF MATEMATİK DERS KİTABINDAKİ DİNAMİK MATEMATİK YAZILIMI DESTEKLİ İÇERİKLERİN İNCELENMESİ	Yüksek Lisans Öğrencisi Samedhan AKÇAY Dr. Öğr. Üyesi Hilal YILDIZ
		3	AN EVALUATION OF THE IB-PYP “HOW WE EXPRESS OURSELVES” THEME AND STEAM INTEGRATION İN MATHEMATICS INSTRUCTION	Müberra MERCAN Prof. Dr. Bülent ALCI
		4	ÜSTBİLİŞİ DESTEKLEYEN MATEMATİK ÖĞRENME ORTAMLARININ ÖĞRENCİLERİN ELEŞTİREL DÜŞÜNMELERİNE ETKİSİNİN İNCELENMESİ	Semih UMAY Prof. Dr. Ayten Pınar BAL
		5	İLKOKUL 3. SINIF ÖĞRENCİLERİNİN MATEMATİK KAYGISI VE PROBLEM ÇÖZME BECERİLERİ ARASINDAKİ İLİŞKİDE CİNSİYETİN DÜZENLEYİCİ ROLÜ	Dr. İlhan POLAT
		6	MATEMATİK KAYGISINI AŞMAK: İLKOKULDA MATEMATİK PROBLEMİ ÇÖZME BAŞARISI İÇİN BİR REHBER	Dr. İlhan POLAT
		7	GERÇEKÇİ MATEMATİK EĞİTİMİ TEMELLİ ETKİNLİKLERİN 4.SINIF ÖĞRENCİLERİNİN MATEMATİK BAŞARISI VE MATEMATİK OKURYAZARLIK BECERİLERİNE ETKİSİ	Zeynep Yıldız Şeyda Nur AY
		8	İLKÖĞRETİM MATEMATİK ÖĞRETMENLİĞİ ÖĞRENCİLERİNİN ALTGRUP KAVRAMINI ANLAMLANDIRMA SÜRECİNDE YAŞADIKLARI ZORLUKLAR	Kübra KIZILKAPLAN Kübra ÖZCAN Enise AKDAŞ Elif UÇAR Cihan TAŞ Doç. Dr. Mustafa AKINCI

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HALL / SALON 2	**Doç. Dr. Halime Göktaş Kulualp**	1	BRAINSTORMING OR BRAIN SYMPHONY?	Prof. Dr. Süleyman DÜNDAR Elif SEYİTOĞU
		2	WILLINGNESS OF EMPLOYEES TO PARTICIPATE IN MANAGEMENT	Rabiya Deniz KOÇ Prof. Dr. Süleyman DÜNDAR
		3	THE PSYCHOLOGICAL CONSEQUENCES OF ALGORITHMIC MANAGEMENT: ALIENATİON, STRESS, AND LOSS OF AUTONOMY AMONG EMPLOYEES	Elif Buse KORKUSUZ Ceylin DOĞAN Prof. Dr. Oya İnci BOLAT
		4	KİŞİSEL SATIŞ TEMSİLCİLERİNİN BAŞARISIZLIK DUYGUSUNU YÖNETMELERİNDE MARKA İMAJI VE MARKAYA GÜVENİN ROLÜ	Prof. Dr. Yusuf BİLGİN Esra ARİKAN Dr. Öğr. Üyesi Bilal ÇELİK
		5	BANKACILIK HİZMETLERİNDE MARKA İMAJI VE MARKA GÜVENİNİN KİŞİSEL SATIŞ TEMSİLCİLERİNİN PERFORMANSINA ETKİSİ	Prof. Dr. Yusuf BİLGİN Esra ARİKAN Dr. Öğr. Üyesi Bilal ÇELİK
		6	THE CONCEPT OF QUIET QUITTING VIEWED THROUGH THE VOSVIEWER WINDOW	Doç. Dr. Halime Göktaş Kulualp
		7	INVESTIGATING THE RELATIONSHIP BETWEEN PSYCHOLOGICAL SAFETY AND ORGANIZATIONAL COMMITMENT FOR ORGANIZATIONAL DEVELOPMENT	Doç. Dr. Halime Göktaş Kulualp Eray Ekinci (Doktorant)
		8	THE EFFECT OF INDIVIDUAL DIFFERENCES ON EMPLOYEE JOB SATISFACTION AND INTENT TO LEAVE: A STUDY ON RAILWAY EMPLOYEES	Ayşenur ŞAHİN ARSLAN Doç. Dr. Şebnem ZORLUTUNA
			SOSYAL KURUMLARDAKİ HİZMET KALİTESİNİN TEKRAR TERCİH VE MEMNUNİYET ÜZERİNDEKİ ETKİSİNİN BELİRLENMESİ	Prof. Dr. Abdulvahap BAYDAŞ Doç. Dr. Murat BAYAT
			TKY'NİN MAVİ YAKALI ÇALIŞAN MOTİVASYONU ÜZERİNDEKİ ETKİSİNE YÖNELİK BİR ARAŞTIRMA	Prof. Dr. Abdulvahap BAYDAŞ Doç. Dr. Murat BAYAT

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HALL / SALON 3	**Öğr. Gör. Meryem Karapınar**	1	ON-FARM BIOSECURITY: DISEASE CONTROL, RISK MANAGEMENT, AND SUSTAINABILITY	Prof. Dr. Zehra BOZKURT Y.L. Öğrencisi, Taha ELÇARPAR
		2	WELFARE INDICATORS AND ASSESSMENT PROTOCOLS FOR LAYING HENS	Prof. Dr. Zehra BOZKURT Y.L. Öğrencisi, Mehmet Furkan DOĞAN
		3	TÜRKİYE'DEKİ ENDEMİK OMURGALI HAYVANLAR	Halis Mümin YILMAZ Hediye PEKTOPAL Yusuf Emre KILINÇASAN Zeynep Sude ÜSTÜNDAĞ Emine ÇİFTÇİ Yasin ÜNAL Mevlüt ZENBİLCİ
		4	TÜRKİYE'DE YAYILIŞ GÖSTEREN GEYİK TÜRLERİNİN (CERVIDAE) MORFOLOJİK ÖZELLİKLERİNİN KARŞILAŞTIRILMASI	Yasin Ünal Mevlüt ZENBİLCİ Halis Mümin YILMAZ
		5	Effects of Milk Thistle (Silymarin) and Ginkgo biloba Extracts Supplementation to Laying Hen Diets on Egg Quality Traits	Prof. Dr. Tarkan ŞAHİN Doç. Dr. Mükremin ÖLMEZ Prof. Dr. Özlem KARADAĞOĞLU Res. Asst. Benian YILMAZ Asst. Prof. Roshan RİAZ
		6	Effects of Milk Thistle (Silymarin) and Ginkgo biloba Extracts on Survival and Egg Production in Laying Hens	Prof. Dr. Tarkan ŞAHİN Doç. Dr. Mükremin ÖLMEZ Prof. Dr. Özlem KARADAĞOĞLU
		7	Hayvanlarda Alternatif bir Tedavi Yöntemi Olarak Fitoterapi ve Aromaterapi	Öğr. Gör. Meryem Karapınar
		8	ALTERATIONS IN SOME HEMATOLOGICAL PARAMETERS OF BROILERS COMBINED SUPPLEMENTED WITH CITRIC ACID AND HIGH FRUCTOSE CORN SYRUP	Ruhi Kabakçı Taha Altuğ Gökhan Şen

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HALL / SALON 4	**Araş. Gör. Dr. Umut MUCAN Dr. Öğretim Üyesi Ezgi KURTULMUŞ**	1	SANTRİFÜJ SEPARATÖR GÜÇ TÜKETİMİNİN YAPAY SİNİR AĞLARI İLE TAHMİNİ	Erdem SAĞLAM
		2	İzmir İlinde SPI ve SPEI İndeksleri Kullanılarak Meteorolojik Kuraklık Analizi	Araş. Gör. Dr. Umut MUCAN Dr. Öğretim Üyesi Ezgi KURTULMUŞ
		3	HYDROCARBON POTENTIAL OF PALEOZOIC SEQUENCES (SE TÜRKİYE)	Dr.Muhittin ŞENALP Prof.Dr. Sema TETİKER
		4	INNOVATIVE PRODUCT DESIGN FOR ENHANCED STAND-UP PERFORMANCE AND LOAD-BEARING CAPACITY IN RECYCLABLE POLYETHYLENE PACKAGING	Eda ARKON Alperen KONUK Ömer Lütfi YILDIRIM
		5	INCREASING POLYPROPYLENE CONTENT IN MONO PACKAGING STRUCTURES USING EXTRUSION LAMINATION TECHNOLOGY	Alperen KONUK Eda ARKON Ömer Lütfi YILDIRIM
		6	Circular Economy Compliance in Electric Motors: PLM-Based Calculation of Recyclability Rates	Erman Engüzel
		7	INVESTIGATION OF THE EFFECT OF ADL ON REWET PERFORMANCE IN ADULT DIAPERS	Mustafa ÖZGEÇ Şeyma ÖZDEMİR
		8	GERİ DÖNÜŞTÜRÜLMÜŞ MALZEME İLE YEŞİL DÖNÜŞÜM ODAKLI PAKETLEME UYGULAMASI	Doğukan GÜNEŞ Merih GÜLEN Abdullah Emre DEMİR

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HALL / SALON 5	**Dr. Öğr. Üyesi Rıza ADIGÜZEL**	1	THE LIMITS OF THE CONCEPTS OF POLITICAL POWER AND THE STATE	Dr. Öğr. Üyesi Rıza ADIGÜZEL
		2	BİREYSEL BAŞVURU KARARLARINDA MASUMİYET KARİNESİ HUKUK VE İDARI YARGILAMA ÖRNEĞI	Dr. Hilmi Can TURAN
		3	KİRA BEDELİNİN ÖDENMEMESİ SEBEBİYLE TAŞINMAZIN İLAMSIZ İCRA YOLUYLA TAHLİYESİNDE ARABULUCULUK	Av. Ecem ÇIKRIKÇIOĞLU
		4	SÜRENİN BİTİMİ NEDENİYLE TAŞINMAZIN İLAMSIZ TAKİP YOLU İLE TAHLİYESİ	Av. Kerem ÖZER
		5	BİLGİSAYAR TABANLI BULUŞLARDA BEKLENMEDİK TEKNİK ETKİLERİN PATENTLENEBİLİRLİĞE KATKISI: TOPLU ULAŞIM SİSTEMLERİ ÜZERİNDEN UYGULAMALI BİR İNCELEME	Ayşegül Ece YILMAZ Dr. Melek ESEMEN ERTAŞ
		6	GIDA GÜVENLİĞİNİN CEZA HUKUKU BOYUTU: TCK m. 186 ÇERÇEVESİNDEN BİR ANALİZ	Öğr. Gör. Dr. Aslı AYDIN
		7	TÜRK HUKUKUNDA ÇOCUĞUN ÜSTÜN YARARI BAKIMINDAN ORTAK VELAYET	YL. Öğr. İrem YONCU
		8	ENTROPİ-ARAS BÜTÜNLEŞİK YÖNTEMİ İLE CEZA MAHKEMELERİNİN PERFORMANSLARININ DEĞERLENDİRİLMESİ	Yüksek Lisans Öğrencisi, Ayşena AKINCI, Prof. Dr.Nuri ÖMÜRBEK,
		9	NORMATIVITY WITHOUT INVOCATION: AGAINST THE CLAIMABILITY CONDITION IN RIGHTS-BASED THEORIES	Dr. Mustafa Kenan USTAHALİLOĞLU
		10	THE COMPENSATION FALLACY - WHY THE INABILITY TO CLAIM OR SPEND DOES NOT JUSTIFY RIGHT	Dr. Mustafa Kenan USTAHALİLOĞLU
		11	TCK 220/6 VE 314/3 KAPSAMINDA CEZA HUKUKUNDA KANUNİLİK VE BELİRLİLİK İLKESİ: AYM'NİN E.2024/81, K.2024/189 SAYILI KARARI ÜZERİNE BİR İNCELEME	Furkan DÜZEN

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HALL / SALON 6	**Dr. Öğr. Üyesi Firdevs KUZU**	1	SKIN CHANGES IN THE TERMINAL PHASE AND NURSING CARE	Arş. Gör., Leyla Senem ÜN Prof. Dr., Sevilay ERDEN Prof. Dr., Songül KARADAĞ
		2	PERIPHERAL ARTERIAL DISEASE AND ITS MANAGEMENT	Arş. Gör., Leyla Senem ÜN Prof. Dr., Sevilay ERDEN Prof. Dr., Songül KARADAĞ
		3	KRONİK HASTALIKLAR VE HEMŞİRELİK BAKIMI	Öğr. Gör. Dr. Sedat DOĞAN Dr. Öğr. Üyesi İsmail KELEŞ
		4	KRONİK OBSRÜKTİF AKCİĞER HASTALIĞI(KOAH) VE HEMŞİRELİK BAKIMI	Öğr.Gör.Yunus DEMİREL Dr. Öğr. Üyesi İsmail KELEŞ Öğr. Gör. Dr. Sedat DOĞAN
		5	The role of nurses in determining and managing delirium in children's intensive care units	Doç. Dr., Gülay MANAV Prof. Dr. Gonca KARAYAĞIZ MUSLU Zeynep KURT
		6	REVIEW OF POSTGRADUATE THESES ON SMARTPHONE ADDICTION AND SLEEP IN TURKEY: A SYSTEMATIC REVIEW	Necibe DAĞCAN ŞAHİN
		7	THE RELATIONSHIP BETWEEN BRAIN FOG AND NURSING	Seda YAĞMUR SÖNMEZ Dr. Öğr. Üyesi, Burcu Kübra SÜHA
		8	Patient Safety Risks in Emergency Nursing	Nilay ÇAKICI Fatma Zehra UÇAK
		9	Views And Challenges of Nurses Working Night Shifts Regarding The Monitoring of Vital Signs: A Triangulation Study	Fatma Zehra UÇAK Nilay ÇAKICI
		10	EVDE SAĞLIK HİZMETLERİNDE UZAKTAN SAĞLIK HİZMETLERİ VE UYGULAMALARI	Dr. Öğr. Üyesi Firdevs KUZU
		11	AŞI TEREDDÜTÜ, AŞI OKURYAZARLIĞI VE HALK SAĞLIĞI HEMŞİRELİĞİ	Dr. Öğr. Üyesi Firdevs KUZU
		12	SLEEP DISORDERS DURING MENOPAUSE: BIOSYCHOSOCIAL DETERMINANTS, PHYSIOLOGICAL MECHANISMS, AND CLINICAL MANAGEMENT	Assistant Professor Hatice BULUT
		13	HPV VACCINE ACCEPTABILITY AND DECISION-MAKING: AN UMBRELLA THEMATIC SYNTHESIS OF FINDINGS FROM QUALITATIVE SYSTEMATIC REVIEWS	Assistant Professor Hatice BULUT

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HALL / SALON 1	Assoc. Prof. Dr. Noor Al-Ghamdi,	1	EPIDEMIOLOGICAL TRENDS AND PREVENTION STRATEGIES FOR TYPE 2 DIABETES MELLITUS IN SAUDI ARABIAN URBAN POPULATIONS	Prof. Dr. Ahmed Al-Saudi, Dr. Fatima Zahra, Khalid Rahman
		2	ADVANCES IN PRECISION MEDICINE FOR BREAST CANCER TREATMENT IN SAUDI WOMEN	Assoc. Prof. Dr. Noor Al-Ghamdi, Sarah Mansour
		3	MENTAL HEALTH CHALLENGES AND TELEPSYCHIATRY SOLUTIONS AMONG SAUDI UNIVERSITY STUDENTS	Dr. Omar Bin Laden, Aisha Khalid, Prof. Dr. Salem Al-Mansoori
		4	ANTIBIOTIC RESISTANCE PATTERNS AND INFECTION CONTROL MEASURES IN ALGERIAN HOSPITALS	Assoc. Prof. Dr. Karim Belkacem, Nadia Zerhouni
		5	NUTRITIONAL STATUS ASSESSMENT AND INTERVENTION PROGRAMS FOR ALGERIAN SCHOOL CHILDREN	Dr. Samir Lounis, Yacine Hadji, Amina Boualem
		6	CARDIOVASCULAR DISEASE PREVENTION THROUGH COMMUNITY HEALTH WORKER PROGRAMS IN RURAL ALGERIA	Prof. Dr. Mehdi Bouziane
		7	NEONATAL INTENSIVE CARE OUTCOMES AND QUALITY IMPROVEMENT INITIATIVES IN LEBANESE HOSPITALS	Dr. Elie Karam, Assoc. Prof. Dr. Lara Haddad, Maya Fares
		8	TRAUMA MANAGEMENT PROTOCOLS AND OUTCOMES IN BEIRUT'S EMERGENCY MEDICAL SYSTEMS	Prof. Dr. Georges Salameh, Dr. Rima Nassar
		9	PALLIATIVE CARE INTEGRATION IN LEBANESE ONCOLOGY SERVICES FOR TERMINAL PATIENTS	Assis. Prof. Dr. Nadine Atallah, Sami Hayek, Prof. Dr. Bassam Mattar
		10	MENTAL HEALTH SERVICES FOR REFUGEE POPULATIONS IN LEBANESE COMMUNITY SETTINGS	Dr. Carla Bou Daher
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HALL / SALON 2	Prof. Dr. Ahmed Belkacem,	1	INVESTIGATION OF NATURAL PRODUCT-DERIVED INHIBITORS TARGETING MULTIDRUG-RESISTANT BACTERIA IN SERBIAN CLINICAL ISOLATES	Prof. Dr. Milan Petrovic, Dr. Ana Jovanovic, Marko Stanisic
		2	PHARMACODYNAMIC EVALUATION OF NOVEL STATIN ANALOGUES FOR ENHANCED LIPID LOWERING IN METABOLIC SYNDROME MODELS	Assoc. Prof. Dr. Jelena Vukovic, Nikola Radovic
		3	NEUROPROTECTIVE EFFECTS OF SERBIAN MEDICINAL HERBS AGAINST GLUTAMATE-INDUCED EXCITOTOXICITY IN HIPPOCAMPAL NEURONS	Dr. Sofia Petrovic, Luka Markovic, Tamara Nesic
		4	INVESTIGATION OF TRADITIONAL ALGERIAN PLANTS AS ANTI-INFLAMMATORY AGENTS TARGETING NF-KAPPA B PATHWAY	Prof. Dr. Ahmed Belkacem, Fatima Zerhouni
		5	PHARMACOLOGICAL SCREENING OF ALGERIAN MARINE SPONGES FOR NOVEL ANTICANCER METABOLITES	Assoc. Prof. Dr. Samir Bouzid, Nadia Cherif
		6	EVALUATION OF ALGERIAN ESSENTIAL OILS AS INSECTICIDAL AGENTS AGAINST AGRICULTURAL PESTS	Dr. Karim Mansouri, Yassine Amrani, Leila Hadji
		7	FORMULATION DEVELOPMENT OF EGYPTIAN MEDICINAL PLANT-BASED WOUND HEALING OINTMENTS	Prof. Dr. Hassan El-Sayed, Mariam Ahmed, Omar Khalil
		8	PHARMACOKINETIC OPTIMIZATION OF EGYPTIAN DATE PALM POLYPHENOLS FOR EURODEGENERATIVE DISEASES	Assoc. Prof. Dr. Fatima Zahra, Ahmed Nassar
		9	ANTIVIRAL POTENTIAL OF EGYPTIAN NILOTIC PLANTS AGAINST EMERGING HEPATITIS C GENOTYPES	Dr. Nour El-Din, Sara Mahmoud, Karim Hassan
		10	DEVELOPMENT OF EGYPTIAN HERBAL FORMULATIONS FOR METABOLIC SYNDROME MANAGEMENT	Prof. Dr. Layla Ibrahim, Tarek Salem
		11	PHARMACOGENETIC PROFILING OF EGYPTIAN POPULATIONS FOR PERSONALIZED ANTICONVULSANT THERAPY	Assoc. Prof. Dr. Rania Fouad, Mohamed El-Gendy

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HALL / SALON 3	Assoc. Prof. Dr. Laura Fischer	1	SEISMIC PERFORMANCE ENHANCEMENT OF REINFORCED CONCRETE FRAMES USING DISSIPATIVE STEEL BRACES IN SERBIAN SEISMIC ZONES	Prof. Dr. Milan Petrovic, Dr. Ana Jovanovic, Marko Stankovic
		2	SUSTAINABLE GEOPOLYMER CONCRETE DEVELOPMENT USING INDUSTRIAL WASTES FOR SERBIAN INFRASTRUCTURE PROJECTS	Assoc. Prof. Dr. Nikola Radovic, Jelena Markovic
		3	BRIDGE SCOUR COUNTERMEASURE EVALUATION UNDER EXTREME FLOOD EVENTS IN THE DANUBE RIVER BASIN	Dr. Vladimir Stevanovic, Sofia Petrovic, Igor Djordjevic
		4	DIGITAL TWIN IMPLEMENTATION FOR REAL-TIME STRUCTURAL HEALTH MONITORING OF HIGH-RISE BUILDINGS	Prof. Dr. Klaus Müller, Anna Schmidt, Dr. Thomas Weber
		5	PREFABRICATED MODULAR CONSTRUCTION SYSTEMS FOR ACCELERATED URBAN HOUSING DEVELOPMENT	Assoc. Prof. Dr. Laura Fischer, Markus Klein
		6	ADVANCED FIBER-REINFORCED POLYMER RETROFITTING OF HISTORIC MASONRY STRUCTURES	Dr. Hans Becker, Sophia Lehmann, Prof. Dr. Peter Hoffmann
		7	EARTHQUAKE EARLY WARNING SYSTEMS INTEGRATION IN JAPANESE HIGH-SPEED RAIL INFRASTRUCTURE	Prof. Dr. Hiroshi Tanaka, Dr. Yumi Sato, Kenji Nakamura
		8	CARBON-NEUTRAL CONCRETE DEVELOPMENT USING CO2 CAPTURE AND MINERALIZATION TECHNOLOGIES	Assoc. Prof. Dr. Akihiro Yamamoto, Mika Kobayashi
		9	AI-OPTIMIZED TUNNEL LINING DESIGN FOR DEEP UNDERGROUND CONSTRUCTION IN URBAN TOKYO	Dr. Takeshi Mori, Sachiko Ikeda, Prof. Dr. Ryoji Suzuki
		10	TSUNAMI-RESILIENT COASTAL BRIDGE PIER DESIGN INCORPORATING FLUID-VISCOPLASTIC DAMPERS	Kenzo Fujimoto, Dr. Noriko Hayashi
		11	3D-PRINTED REINFORCED CONCRETE ELEMENTS FOR POST-DISASTER RAPID RECONSTRUCTION	Assoc. Prof. Dr. Tetsuya Ishida, Hana Yamamoto, Dr. Junpei Kuroda

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HALL / SALON 4	Dr. Klaus Becker	1	NURSE-LED PAIN MANAGEMENT PROTOCOLS FOR POSTOPERATIVE PATIENTS IN GEORGIAN HOSPITALS	Prof. Dr. Nino Tsiklauri, Dr. Levan Beridze, Mariam Kapanadze
		2	TELEHEALTH NURSING INTERVENTIONS FOR CHRONIC DISEASE MANAGEMENT IN RURAL GEORGIA	Assoc. Prof. Dr. Tamar Gelashvili, Giorgi Lomidze
		3	FAMILY-CENTERED CARE MODELS FOR PEDIATRIC ONCOLOGY PATIENTS IN TBILISI	Dr. Lasha Chikvaidze, Assis. Prof. Dr. Salome Khvedelidze, Ana Tsintsadze
		4	MINDfulness-BASED STRESS REDUCTION PROGRAMS FOR GERMAN INTENSIVE CARE NURSES	Dr. Klaus Becker
		5	INTERPROFESSIONAL EDUCATION MODELS FOR GERMAN NURSING AND MEDICAL STUDENTS	Assoc. Prof. Dr. Sabine Weber, Thomas Klein, Lena Hoffmann
		6	DIGITAL HEALTH LITERACY INTERVENTIONS FOR GERMAN COMMUNITY NURSES	Dr. Maria Schmidt, Prof. Dr. Hans Wagner
		7	PREVENTIVE HOME CARE MODELS FOR FALL PREVENTION AMONG TAJIK ELDERLY POPULATIONS	Assoc. Prof. Dr. Dilnoza Rahimova, Farrukh Saidov
		8	MATERNAL AND NEWBORN HEALTH TRAINING PROGRAMS FOR RURAL TAJIK NURSES	Dr. Gulnora Karomatova, Nigora Yunusova, Assis. Prof. Dr. Azizullo Nazarov
		9	COMMUNITY HEALTH NURSING MODELS FOR TUBERCULOSIS CONTROL IN TAJIKISTAN	Prof. Dr. Rustam Juraev, Malika Boboeva
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HALL / SALON 5	Dr. Nadia Cherif	1	PREVALENCE AND MANAGEMENT OF DENTAL CARIES AMONG SCHOOL CHILDREN IN RURAL TANZANIA	Prof. Dr. Amina Hassan, Dr. Juma Kilonzo
		2	ORAL HEALTH IMPACTS OF HIV/AIDS ON ADULT PATIENTS IN DAR ES SALAAM COMMUNITIES	Assoc. Prof. Dr. Elias Mushi, Fatma Swai
		3	TRADITIONAL HERBAL REMEDIES EFFICACY FOR DENTAL PAIN MANAGEMENT IN TANZANIAN VILLAGES	Dr. Zuberi Nkya, Rehema Joseph
		4	DIGITAL DENTISTRY APPLICATIONS FOR PROSTHODONTIC REHABILITATION IN TUNISIAN ELDERLY	Prof. Dr. Karim Ben Ali, Dr. Nadia Cherif
		5	ORTHODONTIC TREATMENT OUTCOMES USING CLEAR ALIGNERS IN TUNISIAN ADOLESCENTS	Assoc. Prof. Dr. Sami Karray, Leila Hadji
		6	PERIODONTAL REGENERATIVE THERAPIES USING TUNISIAN DATE PALM DERIVED BIOMATERIALS	Dr. Hassen Trabelsi, Monia Ben Salem
		7	LASER-ASSISTED CARIES REMOVAL TECHNIQUES IN MARRAKECH PEDIATRIC DENTISTRY	Prof. Dr. Ahmed El Amrani, Dr. Fatima Zahra
		8	3D PRINTED SURGICAL GUIDES FOR DENTAL IMPLANT PLACEMENT IN MARRAKECH CLINICS	Assoc. Prof. Dr. Youssef Bennani, Sara El Khadim
		9	NANOHYDROXYAPATITE TOOTHPASTE EFFICACY FOR ENAMEL REMINERALIZATION IN MARRAKECH	Dr. Rachid Lahlou, Amina Serghini
		10	REGENERATIVE ENDODONTICS PROTOCOLS FOR IMMATURE PERMANENT TEETH IN MALAYSIAN CHILDREN	Prof. Dr. Noor Azlin, Dr. Kumarasan Retnam
		11	LASER-ASSISTED PERIODONTAL THERAPY OUTCOMES IN MALAYSIAN DIABETIC PATIENTS	Assoc. Prof. Dr. Siti Mariam, Ahmad Fariz

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HALL / SALON 6	Assoc. Prof. Dr. Juma Mfinanga,	1	EFFECTS OF PERIODIZED RESISTANCE TRAINING ON MUSCLE HYPERTROPHY AND STRENGTH GAINS IN ELITE HUNGARIAN WEIGHTLIFTERS	Prof. Dr. László Kovács, Dr. Anna Szabó, Tamás Nagy
		2	NEUROMUSCULAR ADAPTATIONS TO HIGH-INTENSITY INTERVAL TRAINING IN PROFESSIONAL HUNGARIAN SOCCER PLAYERS	Assoc. Prof. Dr. Gábor Tóth, Zoltán Kiss
		3	BIOKINEMATIC ANALYSIS OF OLYMPIC FENCING TECHNIQUES IN HUNGARIAN NATIONAL TEAM ATHLETES	Dr. Orsolya Farkas, Miklós Varga, Prof. Dr. István Szabó
		4	NUTRITIONAL STRATEGIES FOR ENDURANCE PERFORMANCE ENHANCEMENT AMONG TANZANIAN MARATHON RUNNERS	Assoc. Prof. Dr. Juma Mfinanga, Amina Hassan
		5	HEAT ACCLIMATION PROTOCOLS FOR TEAM SPORTS PERFORMANCE IN TANZANIA'S TROPICAL CLIMATE	Dr. Elias Ndugu, Fatuma Kikoti, Prof. Dr. Salum Ramadhani
		6	ANTHROPOMETRIC PROFILING AND TALENT IDENTIFICATION IN TANZANIAN YOUTH SOCCER ACADEMIES	Samwel Massawe, Dr. Rehema Kweka
		7	HYDRATION STRATEGIES AND COGNITIVE PERFORMANCE DURING PROLONGED CRICKET MATCHES IN INDIA	Assoc. Prof. Dr. Sanjay Patel, Neha Gupta
		8	WEARABLE TECHNOLOGY APPLICATIONS FOR LOAD MANAGEMENT IN INDIAN KABADDI PLAYERS	Dr. Vikram Reddy, Anjali Desai
		9	MENTAL TOUGHNESS TRAINING PROGRAMS FOR INDIAN SHOOTING ATHLETES PREPARING FOR OLYMPIC QUALIFICATION	Prof. Dr. Meera Joshi, Rohan Mehra
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HALL / SALON 7	Assoc. Prof. Dr. Juma Kayange	1	IMPROVED DROUGHT-TOLERANT MAIZE VARIETIES THROUGH GENOMIC SELECTION IN HUNGARIAN FIELD TRIALS	Prof. Dr. István Nagy, Dr. Anna Kovács, László Tóth
		2	PRECISION VITICULTURE TECHNOLOGIES FOR ENHANCING GRAPE QUALITY IN TOKAJ WINE REGION	Assoc. Prof. Dr. Gábor Szöllősi, Eszter Balogh
		3	BIOLOGICAL CONTROL OF COLORADO POTATO BEETLE USING ENTOMOPATHOGENIC NEMATODES IN HUNGARIAN POTATO CROPS	Dr. Zoltán Vajda, Márton Farkas, Prof. Dr. Judit Halász
		4	CLIMATE-RESILIENT CASSAVA VARIETIES FOR SMALLHOLDER FARMERS IN TANZANIA'S DRYLANDS	Assoc. Prof. Dr. Juma Kayange, Amina Hassan
		5	IMPROVED PIGEON PEA PRODUCTION SYSTEMS FOR INTERCROPPING IN TANZANIAN SMALLHOLDER FARMS	Dr. Elias Nchimbi, Fatuma Mushi, Lucas Swai
		6	VERTICAL SOIL PROFILING FOR PRECISION FERTILIZER APPLICATION IN TANZANIAN MAIZE SYSTEMS	Prof. Dr. Hamisi Kilama, Zawadi Joseph
		7	ORGANIC HORTICULTURE SYSTEMS FOR MARKET-ORIENTED VEGETABLE PRODUCTION IN INDIA	Assoc. Prof. Dr. Rajesh Kumar, Priya Sharma, Amit Singh
		8	DRONE-BASED PHENOTYPING FOR SORGHUM BREEDING IN RAINFED SEMI-ARID REGIONS OF INDIA	Dr. Sanjay Patel, Neha Gupta
		9	MICRO-IRRIGATION SYSTEMS OPTIMIZATION FOR WATER-SCARCE FRUIT ORCHARDS IN RAJASTHAN	Prof. Dr. Meera Joshi, Vikram Reddy, Anjali Desai
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HALL / SALON 8	Prof. Dr. Odgerel Chuluunbaatar,	1	GENOMIC DIVERSITY AND ADAPTIVE EVOLUTION IN CAUCASUS POPULATIONS OF GEORGIA	Prof. Dr. Nino Tsiklauri, Dr. Levan Beridze, Mariam Kapanadze
		2	CRISPR-CAS9 MEDIATED GENE EDITING FOR RARE CARDIOMYOPATHIES IN GEORGIAN COHORTS	Assoc. Prof. Dr. Irakli Gelashvili, Tamar Lomidze
		3	MITOCHONDRIAL GENOME VARIATION AND MATERNAL LINEAGE TRACING IN GEORGIAN ETHNIC GROUPS	Dr. Giorgi Khutsishvili, Lasha Tsintsadze, Prof. Dr. Maka Chikvaidze
		4	EPIGENETIC MODIFICATIONS ASSOCIATED WITH NOMADIC LIFESTYLES IN MONGOLIAN HERDER POPULATIONS	Assis. Prof. Dr. Batbold Enkhtur, Sarantuya Ganbold
		5	GENETIC DIVERSITY OF LIVESTOCK BREEDS AND CONSERVATION STRATEGIES IN MONGOLIAN STEPPES	Dr. Tumentsogt Ganzorig, Enkhjargal Munkhbayar
		6	MICROBIOME-GENOME INTERACTIONS IN MONGOLIAN HORSE DIGESTIVE TRACT ADAPTATIONS	Prof. Dr. Odgerel Chuluunbaatar, Bolormaa Tsogt
		7	TELOMERE LENGTH DYNAMICS AND CANCER SUSCEPTIBILITY IN IRANIAN HIGH-RISK FAMILIES	Assoc. Prof. Dr. Reza Mohammadi, Sara Langaroodi, Ali Rezaei
		8	PHARMACOGENOMICS OF ANTI-EPILEPTIC DRUG RESPONSE IN IRANIAN PEDIATRIC POPULATIONS	Dr. Mina Hosseini, Yasaman Sharifi

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HALL / SALON 1	**Assoc. Prof. Dr. Nilay ERDEM AYYILDIZ**	1	INVESTIGATION OF THE OPINIONS OF BRANCH TEACHERS TAKING COURSES IN UNIVERSITY PREPARATORY CLASSES ABOUT THE CLASSROOM ENVIRONMENT	Dr. Öğr. Üyesi Erkan GÖKTAŞ Yüksek Lisans Öğrencisi Betül HAFIZOĞLU
		2	THE IMPACT OF THE TUBITAK 2237-A PROJECT TRANINING ON PRE-SERVICE ENGLISH TEACHERS' PERCEPTIONS OF SELF-EFFICACY IN USING LITERARY GENRES AS TOOLS IN TEACHING ENGLISH	Assoc. Prof. Dr. Nilay ERDEM AYYILDIZ
		3	YARATICILIK VE AKADEMİK BAŞARI ÜZERİNE REACT STRATEJİSİNİN ETKİSİ: SES VE ÖZELLİKLERİ ÜNİTESİ	Öğrt. Kadir Ulaş TEKMANLI Doç. Dr. Seda OKUMUŞ
		4	DIGITAL QUALITY INDICATORS IN HIGHER EDUCATION: A COMPARATIVE WEB ANALYSIS OF TÜRKİYE'S LAKES REGION UNIVERSITIES	Assoc. Prof. Dr. Umut Can Öztürk
		5	ORTAOKUL ÖĞRENCİLERİNDE YAŞ DÜZEYİNE UYGUN OLMAYAN KİTAP TERCİHLERİ: ÇOCUĞA GÖRELİK İLKESİ BAĞLAMINDA KURAMSAL BİR İNCELEME	FADİME AĞDAŞ NURULLAH AYDIN
		6	EĞİTİMDE DİJİTALLEŞME SÜRECİNİN COVID-19 ÖNCESİ VE SONRASI EĞİLİMLERİ: TÜRKİYE'DEKİ ÇALIŞMALAR ÜZERİNE SİSTEMATİK BİR ANALİZ	Dr. Fikriye SEZER Züleyha ÇEVİK Erhan BOSTAN Esra KARATAŞ Merve şenlik
		7	YAPAY ZEKÂ DESTEKLİ MATERYAL GELİŞTİRME EĞİTİMİNİN BRANŞ ÖĞRETMENLERİNİN EĞİTİMDE YAPAY ZEKÂ KULLANIMINA YÖNELİK ALGILARINA ETKİSİ	Doç. Dr. Müzeyyen BULUT ÖZEK Dr. Öğr. Üyesi Büşra ÖZMEN YAĞIZ
		8	BİBLİYOTERAPİ YOLUYLA MÜKEMMELİYETÇİLİK FARKINDALIĞININ GELİŞTİRİLMESİ: "HİÇ HATA YAPMAYAN KIZ" KİTABI İLE ÖZEL YETENEKLİ ÖĞRENCİLERDE FENOMENOLOJİK BİR İNCELEME	Dr. Meltem TÜRKER Kaan Ahmet ÜNSALDİ Ekinsu AYDOĞDU
			K-12 DÜZEYİNDE OKUL YÖNETİCİLERİNİN YAPAY ZEKA ASİSTANLARINA YÖNELİK TUTUMLARININ İNCELENMESİ	Dr. Öğretim Üyesi Mehmet Akın Bulut Esra DEMİRCİ Ahmet ORAKÇI Rabi YAKIŞIKLI Mustafa Hamza BİRSİN

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HALL / SALON 2	**Dr. Öğretim Üyesi Rabia BÖLÜKBAŞ**	1	EXAMINING PERCEPTIONS OF THE CONCEPT OF COMFORT FOOD THROUGH METAPHOR ANALYSIS	Fatih KATRAN Dr. Öğr. Üyesi Merve ONUR
		2	EDIBLE INSECTS FROM A SUSTAINABLE FOOD SYSTEMS PERSPECTIVE	Dr. Öğretim Üyesi Rabia BÖLÜKBAŞ Doç. Dr. Gizem Sultan KAMAN Prof. Dr. İrfan YAZICIOĞLU
		3	ANALYSIS OF ACADEMIC STUDIES IN THE FIELD OF GASTRONOMY AND ARTIFICIAL INTELLIGENCE	Dr. Öğretim Üyesi Rabia BÖLÜKBAŞ Doç. Dr. Gizem Sultan KAMAN Prof. Dr. İrfan YAZICIOĞLU
		4	GLUTENSİZ DİYETLER, GIDA OKURYAZARLIĞI VE BESLENME TRENDLERİNDE GÜNCEL EĞİLİMLER VE ZORLUKLAR: TANIMLAYICI BİR LİTERATÜR TARAMASI	Öğr. Gör. Eda Duygu ÖZER SÜT
		5	SIFIR ATIK YAKLAŞIMIYLA İLERİ DÖNÜŞÜM ÖRNEĞİ OLARAK SEBZE–MEYVE KABUĞU TOZLARINDAN BAHARAT YAPIMI ÜZERİNE DERLEME	YL. Öğrencisi Emre TEMÜR Dr. Öğr. Üyesi Selin İLSAY
		6	THE RELATIONSHIP BETWEEN GASTRONOMY AND CULINARY STUDENTS' EATING-OUT HABITS AND THE SLOW FOOD MOVEMENT	Yüksek Lisans Öğrencisi Gülşah ARSLANHAN Dr.Öğr. Üyesi Erol GEÇGİN
		7	A RESEARCH TO DETERMINE THE RELATIONSHIP BETWEEN PRICE PERCEPTION AND SATISFACTION İN LOCAL RESTAURANTS : THE EXAMPLE OF VAN PROVINCE	Ayşe Nur GÜVEN Dr. Öğr. Üyesi Pelin KOÇ Dr. Öğr. Üyesi Erol GEÇGİN
		8	MOLEKÜLER MUTFAK TEKNİKLERİ İLE GELENEKSEL HATAY YEMEKLERİNİN YENİDEN YORUMLANMASI	İrem ERYILMAZ Doç. Dr. İbrahim ÇEKİÇ
		9	EVALUATION OF FOOD WASTES AS FUNCTIONAL FOOD INGREDIENTS	Öğr. Gör. Zeynep Nur KARAKUŞ Doç. Dr. Gülşah ÇALIŞKAN KOÇ Doç. Dr. Yasemin ÇELEBİ
		10	EVALUATION OF EMERGING TRENDS IN FUTURE GASTRONOMY FROM THE PERSPECTIVE OF FOOD SCIENCE, TECHNOLOGY, AND ENGINEERING	Öğr. Gör. Zeynep Nur KARAKUŞ Doç. Dr. Gülşah ÇALIŞKAN KOÇ Doç. Dr. Yasemin ÇELEBİ

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HALL / SALON 3	**Dr. Öğr. Üyesi Sema ÜSTGÖRÜL**	1	EMZİRME SONLANDIRMA SÜRECİNİN DESTEKLENMESİNDE YENİ BİR YAKLAŞIM: EBE-LİDERLİĞİNDE DİJİTAL DESTEKLİ EMZİRME SONLANDIRMA DANIŞMANLIĞI	Dr. Öğr. Üyesi Vasviye EROĞLU Dr. Öğr. Üyesi Demet ÇAKIR Öğr. Gör. Arslan SAY
		2	İNFERTİLİTE YÖNETİMİNDE YOGANIN ROLÜ: PSİKOLOJİK VE ÜREME SAĞLIĞINA YÖNELİK KANITLAR	Dr. Öğr. Üyesi Vasviye EROĞLU Öğr. Gör. Arslan SAY Dr. Öğr. Üyesi Demet ÇAKIR
		3	GENITAL HYGIENE BEHAVIORS DURING PREGNANCY	Ebe Meltem YAVUZ Doç. Dr. Ayça ŞOLT KIRCA Doç. Dr. Elif DAĞLI
		4	VACCINATIONS DURING PREGNANCY	Ebe Meltem YAVUZ Doç. Dr. Ayça ŞOLT KIRCA Doç. Dr. Elif DAĞLI
		5	THE ROLE OF ARTIFICIAL INTELLIGENCE IN PATIENT EDUCATION	Öğr. Gör. GÜLİSTAN UYMAZ ARAS
		6	ADVANCED TECHNOLOGIES IN POSTOPERATIVE CARE	Öğr. Gör. GÜLİSTAN UYMAZ ARAS
		7	EBELERİN CİNSEL SAĞLIK VE DANIŞMANLIK ROLÜ: HİZMET ALANLARI VE POTANSİYEL SORUMLULUKLAR	Dr. Öğr. Üyesi Sema ÜSTGÖRÜL
		8	EBE ADAYLARININ YAPAY ZEKA KAYGI DÜZEYLERİ ÜZERİNE BİR ARAŞTIRMA	Dr. Öğr. Üyesi Sema ÜSTGÖRÜL
		9	Doğum Sonrası Yas Sürecinde Yayın Trendlerinin ve Araştırma Odak Noktalarının Haritalandırılması: 45 Yıllık Bibliyometrik Analiz	Ebe Kübra ÇORU Esra Sabancı Baransel, Osman Tayyar Çelik
		10	GAMIFICATION IN HEALTH EDUCATION AND TREATMENT	Asst. Prof. Ayşegül UNUTKAN
		11	PSYCHOSOCIAL INTERVENTIONS TO SUPPORT POST-TRAUMATIC GROWTH IN WOMEN VICTIMS OF VIOLENCE	Asst. Prof. Ayşegül UNUTKAN Prof. Dr. Sultan GÜÇLÜ

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HALL / SALON 4	**Dr. Öğr. Gör., Necmettin BİLİK**	1	GHAZI MUSBEY MUSTAFA KEMAL ATATÜRK AS A BILKADIR LEADER	Lecturer, Murat GÖKMEN M.A. Graduate, Seda GÖKMEN
		2	WAR STRATEGY AND THE BENEFITS OF WAR IN THE NEW ASSYRIAN PERIOD IN MESOPOTAMIA	Dr. Yavuz ARSLAN
		3	THE TRANSITION FROM ROME TO NOVA ROMA: EMPEROR CONSTANTINE'S ESTABLISHMENT OF CONSTANTINOPLE AS THE CAPITAL OF THE EASTERN ROMAN EMPIRE	Buket YILMAZ Prof.Dr. Mustafa HİZMETLİ
		4	NİZAM AL-MULK AND THE NİZAMİYYA MADRASAS: SCHOLARLY AND INSTİTUTİONAL STRUGGLE AGAİNST SHİ'İTE AND BATİNİSM	Halit Ünlüer Prof. Dr. Mustafa Hizmetli
		5	THE SPATIAL EFFECT OF MUQARNAS IN THE ALHAMBRA PALACE: LIGHT, SHADOW, AND ACOUSTIC AESTHETICS	Özge Ünlüer Prof. Dr. Mustafa Hizmetli
		6	HAGİA SOPHIA: THE MONUMENT THAT ESTABLISHED CONSTANTINOPLE AS THE CENTER OF EASTERN CHRISTENDOM	İnci Tomris TEKERLEK Prof. Dr. Mustafa HİZMETLİ
		7	WHY IS JEWİSH HISTORY UNDER ROMAN RULE A HISTORY OF REVOLT?	Dr. Öğr. Gör., Necmettin BİLİK
		8	JEWISH IDENTITY, ARAMEANS AND THE MYTH OF "THE LOST TRİBES OF ISRAEL"	Dr. Öğr. Gör., Necmettin BİLİK

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HALL / SALON 5	**Dr. Öğr. Üyesi Dr. Öğr. Üyesi Nazmiye EKİNCİ Dr. Öğr. Üyesi Eray Ekin SEZGİN**	1	A CONTENT ANALYSIS OF GRADUATE THESES ON MEDICAL ACCOUNTING WRITTEN IN TURKIYE	Dr. Öğr. Üyesi Enes KAYA Dr. Öğr. Üyesi Nazmiye EKİNCİ Dr. Öğr. Üyesi Eray Ekin SEZGİN
		2	CONTENT ANALYSIS OF GRADUATE THESES WRITTEN IN TURKIYE ON EFFECTIVE PROJECT MANAGEMENT PRACTICES IN HEALTHCARE INSTITUTIONS	Dr. Öğr. Üyesi Nazmiye EKİNCİ Dr. Öğr. Üyesi Enes KAYA Dr. Öğr. Üyesi Figen ÖZŞAHİN
		3	BAĞIMSIZ DENETİM STANDARDI 701, KİLİT DENETİM KONULARININ BAĞIMSIZ DENETÇİ RAPORLARINDA BİLDİRİLMESİ	Dr.Öğr.Üyesi. Hayrettin UZUNOĞLU Yüksek Lisans Öğrencisi (Tezli) Fatih YILMAZ
		4	DEVLET MUHASEBESİNDE TAHAKKUK ESASLI MUHASEBEYE GEÇİŞ TÜRK DÜNYASI ÜZERİNE KARŞILAŞTIRMALI BİR İNCELEME	Dr. Oğuz KUYUMCU Arş. Gör. Dr. Süleyman BAYRAKCIOĞLU
		5	YAPAY ZEKÂ VE MAKİNE ÖĞRENMESİNİN MUHASEBE VE FİNANS ALANINDA UYGULAMALARI	Yüksek Lisans Öğrencisi Tuğçe ÖZKAN Dr. Öğr. Üyesi Emre Hayri BARAZ
		6	E-DÖNÜŞÜM SÜRECİNDE ELEKTRONİK VERGİ UYGULAMALARININ VERGİ DENETİMİNE ETKİSİ	Yüksek Lisans Öğrencisi TUĞBA DİŞBUDAK Doç. Dr. MURAT KARAHAN
		7	FROM TRADITIONAL TO DIGITAL IN ACCOUNTING EDUCATION: AI- SUPPORTED ASSESSMENT AND EVALUATION	Dr. Öğr. Üyesi Elçin DALKILIÇ Dr. Öğr. Üyesi Nurettin ÖZDEMİR
		8	THE ROLE OF TFRS 18 IN BUILDING TRANSPARENCY IN FINANCIAL STATEMENT PRESENTATION AND ITS CAPACITY TO REDUCE FRAUDULENT REPORTING	Doç. Dr. Tuba DERYA BASKAN Fatma Nur YARDIMCI
		9	TAŞINMAZ DEĞERLEME LİTERATÜRÜNÜN BİBLİYOMETRİK ANALİZİ	Tuğçe KARADAĞ ALMALI

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HALL / SALON 6	**Prof. Dr. Cengiz KARACA**	1	Elucidating the Molecular Ecology of Euroleon judaeus and Euroleon nostras: Implications for the Evolutionary History of Mediterranean Phylogeography	Hakan Bozdoğan
		2	Genome Skimming in Chrysoperla (Neuroptera: Chrysopidae): A Comprehensive Review of Current Advances, Challenges, and Future Directions	Hakan Bozdoğan
		3	USE OF ZINC CHELATES IN REDUCING CADMIUM STRESS IN WHEAT	Zeynep AKÇA Assoc. Prof. Dr. Gülsüm Ebru ÖZER UYAR
		4	PLANT DISEASES CAUSED BY Rhizopus oryzae	Assoc. Prof. Dr. Gülsüm Ebru ÖZER UYAR Prof. Dr. Aysun CAVUSOGLU
		5	YENİ KONSERVELİK BEZELYE ÇEŞİTLERİNİN EGE VE MARMARA BÖLGESİNDEKİ PERFORMANSLARININ DEĞERLENDİRİLMESİ	Mert ARSLAN Prof. Dr. İbrahim DUMAN
		6	THE CONVERSION OF LIVESTOCK MANURE INTO ENERGY AND THE ENVIRONMENTAL BENEFITS: THE CASE OF MANİSA PROVINCE	Prof. Dr. Cengiz KARACA
		7	AGRICULTURAL RESIDUES AS A REGIONAL ENERGY RESOURCE: BIOMASS ENERGY POTENTIAL OF MANİSA PROVINCE	Prof. Dr. Cengiz KARACA
		8	FARKLI FESLEĞEN ÇEŞİTLERİNDE TUZ STRESİNİN ETKİLERİ	Prof. Dr. Şebnem KUŞVURAN Doç. Dr. Ebru DERELLİ TÜFEKÇİ Selahattin MUTLU
			KUZUKULAĞINDA (Rumex acetosella L.) FARKLI BİYOSTİMULANT UYGULAMALARININ TUZLULUĞA TOLERANS ÜZERİNDEKİ ETKİSİ	Prof. Dr. Şebnem KUŞVURAN Doç. Dr. Ebru DERELLİ TÜFEKÇİ Selahattin MUTLU

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HALL / SALON 1	**Dr. Amina Korir,**	1	EPIDEMIOLOGICAL SURVEILLANCE OF FOOT-AND-MOUTH DISEASE IN KENYAN LIVESTOCK POPULATIONS	Prof. Dr. James Mwangi, Dr. Amina Korir,
		2	ASSESSMENT OF ANTIBIOTIC RESISTANCE PATTERNS IN MASTITIS CAUSING BACTERIA FROM DAIRY COWS	Assoc. Prof. Dr. Esther Njoroge, Kipchoge Chebet, Dr. Miriam Wanjiku , Samuel Otieno
		3	NUTRITIONAL INTERVENTIONS FOR IMPROVING POULTRY GROWTH PERFORMANCE IN ARID REGIONS	Dr. Patrick Omondi, Fatma Ali, Joseph Kiptoo
		4	IMPACT OF CLIMATE CHANGE ON TICK-BORNE DISEASES IN EAST AFRICAN WILDLIFE	Assis. Prof. Dr. Leah Simiyu, Benson Mutua, Grace Wambui
		5	DEVELOPMENT OF VACCINES AGAINST AVIAN INFLUENZA IN PAKISTANI POULTRY FARMS	Prof. Dr. Khalid Mahmood, Ayesha Khan
		6	PARASITIC INFESTATIONS AND ANTHELMINTIC EFFICACY IN SHEEP FLOCKS OF PUNJAB	Dr. Faisal Rehman, Sana Malik, Zainab Noor
		7	STRATEGIES FOR CONTROLLING AFRICAN SWINE FEVER IN BRAZILIAN PIG PRODUCTION	Assoc. Prof. Dr. Carlos Silva, Dr. Mariana Costa, João Pereira , Dr. Beatriz Lima
		8	BIOLOGICAL CONTROL OF NEEM-BASED REPELLENTS AGAINST CATTLE TICKS IN BRAZIL	Prof. Dr. Ana Oliveira, Rodrigo Santos,
		9	EFFECTS OF PROBIOTICS ON GUT MICROBIOTA IN NEWBORN CALVES	Eduardo Ramos, Assis. Prof. Dr. Sofia Mendes, Larissa Ferreira
		10	EPIDEMIOLOGICAL SURVEILLANCE OF FOOT-AND-MOUTH DISEASE IN KENYAN LIVESTOCK POPULATIONS	Prof. Dr. James Mwangi, Dr. Amina Korir, Samuel Otieno
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HALL / SALON 2	**Assoc. Prof. Dr. Nadia Ismail,**	1	IMPACT OF NURSE-LED PATIENT EDUCATION PROGRAMS ON DIABETES MANAGEMENT OUTCOMES IN EGYPTIAN RURAL COMMUNITIES	Prof. Dr. Fatima Abdelrahman, Dr. Ahmed Hassan, Sara Mahmoud
		2	EFFECTIVENESS OF TELEHEALTH NURSING INTERVENTIONS FOR HYPERTENSIVE PATIENTS IN CAIRO	Assoc. Prof. Dr. Nadia Ismail, Mohamed Salem, Dr. Layla Karim
		3	POSTOPERATIVE PAIN MANAGEMENT STRATEGIES IMPLEMENTED BY NURSES IN EGYPTIAN SURGICAL WARDS	Dr. Omar Khalil, Aisha Rahman, Karim El-Sayed
		4	PREVENTIVE CARE TRAINING FOR NURSES TARGETING MATERNAL MORTALITY REDUCTION IN UPPER EGYPT	Assoc. Prof. Dr. Hala Mostafa, Dr. Youssef Nasser, Fatima Ali
		5	NURSE EDUCATION MODELS FOR EMERGENCY RESPONSE IN TB PATIENT CARE IN TBILISI HOSPITALS	Prof. Dr. Nino Gelashvili, Dr. Levan Tsiklauri
		6	MENTORSHIP PROGRAMS FOR NOVICE NURSES IN PEDIATRIC INTENSIVE CARE UNITS IN GEORGIA	Dr. Tamar Kapanadze, Irakli Beridze, Lali Chikhradze
		7	CHALLENGES IN NURSE TRAINING FOR INFECTIOUS DISEASE CONTROL IN YEMEN CONFLICT ZONES	Assoc. Prof. Dr. Ahmed Al-Mansoori, Dr. Faisal Saleh ,Khalid Rahman, Noor Alawi
		8	COMMUNITY HEALTH NURSING STRATEGIES FOR MALNUTRITION PREVENTION AMONG YEMENI CHILDREN	Dr. Sana Hussein,
		9	WOUND CARE PROTOCOLS DEVELOPED BY NURSES FOR CHRONIC ULCERS IN YEMENI REFUGEE CAMPS	Prof. Dr. Mohammed Qasim, Amina Tariq
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HALL / SALON 3	Dr. Fatima El-Sayed	1	GENETIC DIVERSITY ANALYSIS OF NILOTIC ENDANGERED FISH SPECIES UNDER CLIMATE CHANGE PRESSURES	Prof. Dr. Ahmed Hassan, Dr. Fatima El-Sayed, Omar Khalil
		2	MICROBIAL BIOREMEDIATION STRATEGIES FOR HEAVY METAL CONTAMINATION IN EGYPTIAN AGRICULTURAL SOILS	Assoc. Prof. Dr. Nadia Mahmoud, Karim Abdelaziz, Layla Hassan
		3	PHYTOCHEMICAL PROFILING AND ANTIOXIDANT ACTIVITY OF MEDICINAL PLANTS FROM SINAI DESERT ECOSYSTEMS	Dr. Mohamed Salem, Sara Ahmed, Prof. Dr. Ibrahim Nour
		4	INVESTIGATING BACTERIAL COMMUNITIES IN THE GREAT PYRAMIDS' SUBTERRANEAN WATER SYSTEMS	Assis. Prof. Dr. Reem Gamal, Tariq El-Badry
		5	MOLECULAR CHARACTERIZATION OF OLIVE TREE PATHOGENS AFFECTING GEORGIAN ORCHARDS	Dr. Giorgi Tsiklauri, Nino Beridze, Lasha Kapanadze
		6	ECOLOGICAL IMPACTS OF INVASIVE SPECIES ON BLACK SEA COASTAL WETLAND BIODIVERSITY	Assoc. Prof. Dr. Mariam Gelashvili, Irakli Lomidze
		7	PHYLOGENETIC ANALYSIS OF ENDANGERED YEMENI MOUNTAIN GOAT POPULATIONS	Prof. Dr. Abdullah Al-Mansoori, Faisal Ahmed
		8	MICROALGAE DIVERSITY AND BIOTECHNOLOGICAL POTENTIAL IN RED SEA CORAL REEFS	Dr. Sana Al-Hadhrami, Khalid Saeed, Noor Ibrahim
		9	BIOACTIVE COMPOUNDS FROM YEMENI DESERT PLANTS FOR ANTIBIOTIC-RESISTANT INFECTIONS	Assis. Prof. Dr. Huda Al-Qadhi, Rami Nasser
		10	GENE EXPRESSION PATTERNS IN DATE PALM TREES UNDER DROUGHT STRESS CONDITIONS	Dr. Amal Saleh, Tariq Mahdi, Prof. Dr. Yusuf Al-Ghamdi
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HALL / SALON 4	**Dr. Yuki Nakamura Dr. Yuki Nakamura**	1	ADVANCES IN ROBOTIC AUTOMATION FOR INDUSTRIAL MANUFACTURING	Dr. Yuki Nakamura
		2	OPTIMIZATION OF RENEWABLE ENERGY SYSTEMS USING MACHINE LEARNING	Assoc. Prof. Dr. Akiko Yamamoto, Dr. Koji Fujimoto
		3	SUSTAINABLE INFRASTRUCTURE DEVELOPMENT IN URBAN BANGLADESH	Dr. Md. Raihan Chowdhury, Assis. Prof. Dr. Farzana Akter
		4	APPLICATION OF IoT FOR SMART TRANSPORT SYSTEMS IN BANGLADESH	Farid Hasan, Dr. Nazmul Karim, Wasim Ahmed, Nahid Chowdhury
		5	DESIGN AND ANALYSIS OF WIND TURBINES FOR SUDANESE CLIMATE CONDITIONS	Prof. Dr. Ahmed Elshazly, Mustafa Saeed
		6	SMART WATER MANAGEMENT TECHNOLOGIES FOR ARID REGIONS	Dr. Salma Abdalla, Assoc. Prof. Dr. Mohamed Hassan, Dina Elsayed
		7	DEVELOPMENT OF ENERGY-EFFICIENT BUILDINGS THROUGH THERMAL INSULATION	Assoc. Prof. Dr. Nguyen Van An, Pham Thi Lan
		8	AUTOMATION AND CONTROL SYSTEMS FOR VIETNAMESE MANUFACTURING SECTOR	Dr. Tran Quang Minh, Le Thi Huong, Hoang Van Binh, Assis. Prof. Dr. Pham Duc Hoang
		9	APPLICATION OF ARTIFICIAL INTELLIGENCE IN CIVIL ENGINEERING DESIGN	Pham Tuan Anh, Hoang Thi Mai Linh, Dr. Nguyen Tuan Kiet
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HALL / SALON 5	**Assoc. Prof. Dr. Hua Chen,**	1	ADVANCES IN NANOMATERIALS FOR ENERGY STORAGE APPLICATIONS	Prof. Dr. Wei Zhang, Dr. Li Ming, Chen Yu
		2	SYNTHESIS AND CHARACTERIZATION OF BIOCOMPATIBLE POLYMER COMPOSITES	Assoc. Prof. Dr. Hua Chen, Zhang Lei
		3	NANOSTRUCTURED CERAMICS FOR HIGH-TEMPERATURE APPLICATIONS: CHALLENGES AND PROSPECTS	Dr. Saeed Moghaddam, Assis. Prof. Dr. Leyla Hamidi, Reza Farrokhi
		4	MICROSTRUCTURAL ANALYSIS OF METAL ALLOYS UNDER CYCLIC LOADING CONDITIONS	Mehrdad Rouhani, Dr. Fatemeh Ghorbani
		5	MECHANICAL PROPERTIES ENHANCEMENT IN ALBANIAN ALUMINUM ALLOYS	Prof. Dr. Arben Kodra, Dr. Elena Hoxha, Ilir Meta
		6	CORROSION BEHAVIOR AND MITIGATION TECHNIQUES OF STEEL IN MARINE ENVIRONMENTS	Dr. Fatos Dervishi, Kujtim Leka
		7	DEVELOPMENT OF BIODEGRADABLE MATERIALS FOR MEDICAL IMPLANTS	Prof. Dr. Amira El-Sayed, Dr. Karim Hassan
		8	EFFECTS OF HEAT TREATMENT ON TITANIUM ALLOY MICROSTRUCTURE	Assoc. Prof. Dr. Maha Abdallah, Nourhan Adel, Ahmed Fathy

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HALL / SALON 6	**Prof. Dr. Mona Samir,**	1	APPLICATIONS OF DEEP LEARNING IN MEDICAL IMAGE ANALYSIS	Prof. Dr. Wei Zhang, Li Na
		2	ETHICAL IMPLICATIONS OF AI IN SOCIETY: A CHINESE PERSPECTIVE	Dr. Minghui Chen, Assoc. Prof. Dr. Xiaoling Zhao, Feng Liu
		3	ENHANCING NATURAL LANGUAGE PROCESSING WITH TRANSFER LEARNING TECHNIQUES	Sahar Mohammadi, Dr. Navid Rahimi
		4	AI-DRIVEN PREDICTION MODELS FOR ENVIRONMENTAL MONITORING	Dr. Hamed Shirazi, Assis. Prof. Dr. Mahsa Kiani, Neda Azizi
		5	MACHINE LEARNING APPROACHES TO CYBERSECURITY THREATS DETECTION	Arben Dervishi
		6	INNOVATIONS IN AI FOR AGRICULTURAL OPTIMIZATION	Prof. Dr. Elira Hoxha, Arjan Kola, Dr. Sokol Dobi
		7	DEVELOPING SMART CITY INITIATIVES USING ARTIFICIAL INTELLIGENCE	Dr. Ahmed Hassan, Assoc. Prof. Dr. Mariam El-Sharif, Tarek Khaled, Sara Abdo
		8	AI IN EDUCATION: PERSONALIZED LEARNING SYSTEMS FOR STUDENTS	Prof. Dr. Mona Samir, Mohamed Fawzy
		9	AUTONOMOUS VEHICLES AND THE FUTURE OF TRANSPORTATION IN EGYPT	Assis. Prof. Dr. Youssef Adel, Rania Sherif, Dr. Mahmoud Fathy

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HALL / SALON 7	**Dr. Saltanat Kenzhegulova**	1	ECO-FRIENDLY MATERIALS IN SUSTAINABLE INTERIOR DESIGN	Prof. Dr. Chinedu Okeke, Dr. Ifeoma Nwosu, Adaobi Eze
		2	THE IMPACT OF NATURAL VENTILATION ON INDOOR AIR QUALITY IN URBAN BUILDINGS	Ibrahim Musa, Assoc. Prof. Dr. Amina Abdullahi
		3	SMART WATER MANAGEMENT SYSTEMS FOR URBAN ENVIRONMENTS	Alikhan Baimuratov, Assis. Prof. Dr. Dana Zhussupova, Murat Kulmanov, Yasmina Serikova
		4	GREEN INFRASTRUCTURE STRATEGIES IN CITY PLANNING: A CASE STUDY	Dr. Saltanat Kenzhegulova, Jamilya Umirzakova
		5	BIODIVERSITY AND URBAN LANDSCAPE INTEGRATION IN SPAIN	Assoc. Prof. Dr. Marta Sanchez, Dr. Luis Fernandez
		6	ADVANCED WASTE RECOVERY TECHNIQUES IN ENVIRONMENTAL ENGINEERING	Josep Martinez, Clara Gomez, Prof. Dr. Elena Ruiz, Miguel Ortega, Sara Diaz
		7	ENERGY-EFFICIENT HVAC SYSTEMS FOR COMMERCIAL BUILDINGS IN DUBAI	Dr. Saeed Al Mansouri, Assis. Prof. Dr. Fatima Khalid
		8	SUSTAINABLE URBAN WATER RESOURCES MANAGEMENT AND PLANNING	Mohammed Al Falasi, Prof. Dr. Layla Ibrahim, Youssef Nasser, Hana Saeed, Dr. Khalid Ahmed
		9	INNOVATIVE LIGHTING DESIGN FOR HEALTHIER INTERIOR ENVIRONMENTS	Prof. Dr. Mariam Al Kaabi, Hassan Jaber, Salim Al Harthy, Assoc. Prof. Dr. Amal Rashid, Fatima Al Nuaimi, Ali Saeed
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HALL / SALON 8	**Assoc. Prof. Dr. Meron Tadesse**	1	SUSTAINABLE URBAN DESIGN STRATEGIES FOR RAPIDLY GROWING CITIES	Prof. Dr. Alemayehu Gebremedhin, Selamawit Tesfaye, Dawit Abebe
		2	TRADITIONAL ETHIOPIAN ARCHITECTURE AND ITS INFLUENCE ON MODERN DESIGN	Assoc. Prof. Dr. Meron Tadesse
		3	INTEGRATING CULTURAL HERITAGE INTO CONTEMPORARY AZERBAIJANI ARCHITECTURE	Dr. Leyla Mammadova, Farid Huseynov, Nigar Safarova
		4	ADVANCES IN DIGITAL TOOLS FOR ARCHITECTURAL DESIGN AND VISUALIZATION	Assis. Prof. Dr. Kamran Aliyev, Dr. Elvin Hasanov
		5	CLIMATE-RESPONSIVE ARCHITECTURE: CASE STUDIES FROM CHILE	Prof. Dr. Pablo Rojas, Maria Sanchez, Jorge Alvarez, Lucía Herrera
		6	URBAN REGENERATION AND COMMUNITY PARTICIPATION IN CHILEAN CITIES	Dr. Sofía Martínez, Assoc. Prof. Dr. Rodrigo Escobar
		7	INNOVATIONS IN ARCHITECTURAL MATERIALS FOR DESERT ENVIRONMENTS	Dr. Fatima Al-Kuwari, Assis. Prof. Dr. Saeed Al-Thani
		8	THE ROLE OF SMART CITIES IN THE FUTURE OF QATARI URBAN PLANNING	Prof. Dr. Ahmed Al-Mulla, Nourah Al-Hajri, Dr. Omar Bin Saeed, Lubna Al-Kuwari, Khalid Al-Sheeb, Aisha Hasan

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HALL / SALON 1	**Assoc. Prof. Dr. Emre DEMİRER DURAK**	1	TUZ STRESİ ALTINDAKİ ASTER (Aster amellus L.) BİTKİLERİNDE GA 3 UYGULAMALARININ BAZI BİTKİ BÜYÜME PARAMETRELERİ ÜZERİNDEKİ ETKİLERİ	Yük. Zir. Müh. Ömer ÖZTAŞ Doç. Dr. Özlem ÜZAL Prof. Dr. Fikret YAŞAR
		2	ÜŞÜME STRESİNİN ASTER (Aster amellus L.) BİTKİLERİNDE BAZI BÜYÜME PARAMETRELERİNE YANSIMALARI	Yük. Zir. Müh. Ömer ÖZTAŞ Doç. Dr. Özlem ÜZAL Prof. Dr. Fikret YAŞAR
		3	ORGANİK SOFRALIK DOMATES ÜRÜNÜNE YÖNELİK BLOCKCHAİN GIDA İZLENEBİLİRLİĞİ TEKNOLOJİSİ KULLANIMI	SEHER POLATDEMİR Prof. Dr. GÖKHAN ÇINAR
		4	THE ROLE OF PLANT EXTRACTS IN ENHANCING ABIOTIC STRESS TOLERANCE IN VEGETABLES	Dr. Öğr. Üyesi Gökçe AYDÖNER ÇOBAN Doç. Dr. Müjgan GÜNEY Doç. Dr. Servet ARAS Doç. Dr. Hakan KELES
		5	MICROGREEN CULTIVATION IN SOILLESS CULTURE SYSTEMS	Dr. Öğr. Üyesi Gökçe AYDÖNER ÇOBAN Doç. Dr. Murat GÜNEY Doç. Dr. Servet ARAS Doç. Dr. Hakan KELES
		6	EFFECTS OF VOLATILE ORGANIC COMPOUNDS (VOCs) PRODUCED BY TRICHODERMA HARZIANUM ON SEED GERMINATION UNDER IN VITRO CONDITIONS	Assoc. Prof. Dr. Emre DEMİRER DURAK
		7	AGRICULTURAL DROUGHT AND SUSTAINABLE WATER MANAGEMENT	Prof. Dr. Yasemin KUŞLU Assistant Professor Hasan ER
		8	YEM BİTKİLERİ ISLAH AMAÇLARINDA YERALAN BAZI ABİOTİK VE BİOTİK STRES FAKTÖRLERİ	Doç. Dr. Ertan ATEŞ Doç. Dr. Hazım Serkan TENİKECİER
		9	THE USE OF POLLUTION INDICES IN DETERMINING HEAVY METAL POLLUTION IN SOIL	Asst. Prof. Dr. Enise SUKUŞU

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HALL / SALON 2	**Berkay YILMAZ**	1	A Numerical Analysis of Cylinder Positioning Effects on Natural Convection Heat Transfer within Parabolic Enclosures	Cem İLTER Doç. Dr. Zerrin SERT
		2	ADDITIVELY MANUFACTURED HEAT EXCHANGERS AND HVAC COMPONENTS: DESIGN FREEDOM, THERMAL PERFORMANCE AND SUSTAINABILITY	Tuğçe TEZEL Volkan KOVAN
		3	ENGINEERING ASSESSMENT OF FIRE AND EXPLOSION BEHAVIOUR IN METALLIC AND COMPOSITE PRESSURE VESSELS	Tuğçe TEZEL Volkan KOVAN
		4	INDOOR AIR QUALITY CHANGES DURING PLA-BASED FDM PRINTING	Tuğçe TEZEL Volkan KOVAN
		5	BUCKLE COVER DAYANIKLILIK TESTLERİ VE SONUÇLARI	Berkay YILMAZ
		6	MODERN KAPLAMA TESİSLERİNDE ADIMLI YÜZEY HAZIRLIK HATLARININ ROLÜ VE SİSTEMSEL ÜSTÜNLÜKLERİ	Gözde KADIRMAN Uğur DEMİR Burak KAPTAN
		7	Experimental Investigation of Height Retention Performance in Adjustable Headrest Systems within the Scope of ECE R17 Annex 13	Project Engineer Gizem Can Student Engineer İlbey Kale
		8	KAMYON ÜRETİMİNDE ECE R58 REGÜLASYONUNA UYGUN ARKA KORUMA CİHAZLARININ İNCELEMELERİ	Bekir Can ÇİBUK Dr. Öğr. Üyesi Fatih UYSAL

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HALL / SALON 3	**Orhan GÖZTAŞ**	1	AB EKO-TASARIM REGÜLASYONUNUN TEKSTİL SEKTÖRÜNDE YARATTIĞI YAPISAL DÖNÜŞÜM: BİRBİRİYLE BAĞLANTILI REGÜLASYONLAR IŞIĞINDA ENTEGRE, İZLENEBİLİR VE VERİ TEMELLİ TEDARİK ZİNCİRİ YAKLAŞIMI	Orhan GÖZTAŞ
		2	ÖRME KUMAŞLARIN SES YUTUM ÖZELLİKLERİNİN İNCELENMESİ	Mine GENÇER Prof. Dr. Erhan Kenan ÇEVEN Doç. Dr. Fatih SÜVARİ
		3	MODAL İÇERİKLİ DOKUMA KUMAŞLARA UYGULANAN TERBİYE İŞLEMLERİNİN MEKANİK VE HASLIK ÖZELLİKLERİNE ETKİSİNİN İNCELENMESİ	Safiye Berfin DEMİRCAN Prof. Dr. Erhan KENAN ÇEVEN Doç.Dr. Gizem KARAKAN GÜNAYDIN Nejla ÇEVEN
		4	YAPAY ZEKÂNIN TEKSTİL TASARIMINDA KULLANIMI: YARATICI SÜRECİN YENİ DÖNÜŞÜMÜ	Pervin Beysir Prof. Dr. Erhan KENAN ÇEVEN Doç.Dr. Gizem KARAKAN GÜNAYDIN
		5	THE STRATEGİC CONTRİBUTİON OF PRODUCT LİFECYCLE MANAGEMENT (PLM) TO THE TEXTİLE INDUSTRY İN SUPPORTİNG CİRCULAR BUSİNESS MODELS	Sevgi GÖKÇE TOPER
		6	HAFİF TİCARİ ARAÇLARDA BİYOBOZUNUR DUKUMASIZ KUMAŞLARIN KULLANILMASI	Kılıf Mühendisi İrem Esin Meral Proje Mühendisi Berkay Yılmaz
		7	OTOMOTİV SEKTÖRÜNDE KULLANILAN YERLİ VİNİL PVC MALZEMESİ GELİŞTİRİLMESİ	Kılıf Mühendisi İrem Esin Meral Proje Mühendisi Gizem Can
		8	GERİ DÖNÜŞTÜRÜLMÜŞ PİGMENT BOYALARLA DENİM ÜRETİMİNDE SÜRDÜRÜLEBİLİR BOYAMA UYGULAMALARI	Ar-Ge Uzmanı Tuncay TOYDEMİR
			SÜRDÜRÜLEBİLİR LİFLER KULLANILARAK YÜKSEK KONFORLU PİJAMA TAKIMI TASARIMI VE GELİŞTİRİLMESİ	Ahmet KUPAL Doç. Dr. Ahmet FEYZİOĞLU

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		2	THE POSSIBILITY OF SUSTAINING THE TRADITIONAL FAMILY DESPITE MODERNITY	Doç. Dr. Eyüp KURT
		3	MİR'ÂTÜ'L-CEMÂL'DE İNSAN-I KÂMİL ANLAYIŞI	Sena Tekin
		4	MUHAMMED EMİN ER'S FATWA METHODOLOGY	Mustafa TAŞDEMİR
		5	THE PLACE OF THE FIRST CAUSE IN FARABI'S UNDERSTANDING OF CAUSALITY	Res. Asst, Merve YÜKSEL
		6	A COMPARİSON OF GHAZALİ'S CONCEPT OF MİRACLE AND CARL SCHMİTT'S STATE OF EXCEPTİON	Res. Asst, Merve YÜKSEL
		7	NAKŞÎ-HÂLİDÎ GELENEĞİNDE İLİM VE TASAVVUFUN BÜTÜNLEŞMESİ ÖRNEĞİ OLARAK NORŞİN	Büşra Bezci
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HALL / SALON 5	**Prof. Dr. Kemal YAMAN Doç. Dr. Hikmet AKYOL**	1	SIFIR ATIK PERPEKTİFİNDEN DÖNGÜSEL EKONOMİ	Prof. Dr. Kemal YAMAN
		2	THE ROLE OF LEGAL REGULATIONS IN ECONOMIC EFFICIENCY	Dr.Öğr. Ü.Gülten ŞEN Öğr.Grv.Serdar AYDINYURT
		3	FINANCIAL DYNAMICS AND TECHNOLOGICAL DEVELOPMENT IN SHAPING INCOME DISTRIBUTION: LONG- AND SHORT-RUN EVIDENCE FROM TÜRKİYE	Assoc. Prof. Dr. Ömer Uğur BULUT
		4	CARBON BORDER ADJUSTMENT MECHANISM (CBAM) AND EMISSIONS TRADING SYSTEM (ETS): AN ASSESSMENT FROM THE PERSPECTIVE OF THE EUROPEAN UNION AND TURKEY	Doktora Öğrencisi Barış ERÇİN Dr. Öğr. Üyesi HAYRİYE BAŞCI NUR
		5	THE IMPACTS OF THE ISRAEL-PALESTINE WAR ON TÜRKİYE-ISRAEL FOREIGN TRADE	Doktora Öğrencisi Barış ERÇİN Prof. Dr. Doğan UYSAL
		6	DIGITALIZATION IN THE INTERNATIONAL MONETARY SYSTEM: THE HEGEMONY OF THE DOLLAR AND THE CBDC COMPETITION	Bahar MATUR Prof. Dr. Doğan UYSAL
		7	THE IMPACT OF CARBON TAX ON SECTORAL COMPETITION IN TURKEY	Bahar MATUR DR. Öğr. Üyesi, Hayriye BAŞCI NUR
		8	BAKIM EKONOMİSİ VE KADIN EMEĞİ: ILO'NUN SOSYAL KORUMA YAKLAŞIMI	Doç. Dr. Neşe YILDIZ
			BRICS ÜLKELERİNDE SOSYO-EKONOMİK GÖSTERGELERİN ORMANSIZLAŞMA ÜZERİNDEKİ ETKİSİ	Doç. Dr. Melahat BATU AĞIRKAYA Doç. Dr. Hikmet AKYOL

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HALL / SALON 6	Doç. Dr. Ali CİNGÖZ	1	THE USE OF PSEUDO-CEREALS IN BOZA PRODUCTION AND THEIR EFFECT ON QUALITY CHARACTERISTICS	Doç. Dr. Ali CİNGÖZ
		2	USE OF COFFEE BY-PRODUCTS IN MODEL FOOD SYSTEMS: THE BISCUIT APPLICATION	Doç. Dr. Ali CİNGÖZ
		3	YÜKSEK PROTEİN VE YÜKSEK LİF İÇEREN FONKSİYONEL MUFFİN KEKLERDE YAPISAL STABİLİTE PROBLEMLERİNİN İNCELENMESİ	Anı KUŞCU
		4	BESİN İÇERİĞİNCE ZENGİNLEŞTİRİLMİŞ SOS/DOLGU SİSTEMLERİNDE FARKLI SÜT BAZLI PROTEİN KAYNAKLARININ TEKNOLOJİK FONKSİYONLARININ KARŞILAŞTIRILMASI	Anı KUŞCU
		5	KOMBUCHA ÇAYININ SAĞLIK ÜZERİNE ETKİLERİ	Ferzan Öznil ÖZDİL Prof.Dr. Tünay KONTAŞ AŞKAR
		6	The Importance of Egg White in Nutrition and Its Applications in Food Technology	Öğr. Gör. Zeynep Nur KARAKUŞ Doç. Dr. Gülşah ÇALIŞKAN KOÇ Doç. Dr. Yasemin ÇELEBİ
		7	Extraction of Sulforaphane from Foods and Its Health Potential	Öğr. Gör. Zeynep Nur KARAKUŞ Doç. Dr. Gülşah ÇALIŞKAN KOÇ Doç. Dr. Yasemin ÇELEBİ
		8	EVALUATION OF LABORATORY-SCALE DEXTRANASE PRODUCTION POTENTIAL USING FUNGAL ISOLATES FROM VARIOUS SOURCES	Hatice Gül SOLMAZ M.Sc. Biologist Fatma ŞİMŞEK M.Sc. Chemical Engineer Özgür ALSAN M.Sc. Biologist Yeliz TAŞÇI M.Sc. Biologist Enfal ÇÖMLEKÇİ
		9	2020-2025 DÖNEMİNDE TÜRKİYE MENŞELİ LİMONLARA İLİŞKİN RASFF BİLDİRİMLERİNİN ANALİZİ	Dr. Senem TÜFEKÇİ
		10	PASTRAMİ TADIN MARİNE EDİLMİŞ PİLİÇ PARÇALARINA KAPLAMA MATERYALİ YARDIMIYLA ENTEGRE EDİLMESİ	Rabia EZEN
		11	THE EFFECTS OF HOT AIRFRYER USE ON HUMAN HEALTH AND FOOD QUALITY	Rabia İrem KARAKUZU Cemal KAYA
		12	PROTEIN QUALITY OF EDIBLE INSECTS	Ayşen BAŞ Prof.Dr. Sedef Nehir EL

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HALL / SALON 7	**Lecturer PhD. Gürkan KILIÇ**	1	SOSYAL MEDYAYLA BİRLİKTE DÖNÜŞEN MAHREMİYET ALGISI	Yüksek Lisans Öğrencisi, Büşra ÖZCAN ÖZOĞLU
		2	İLETİŞİM ÖĞRENCİLERİNİN TOPLUMSAL CİNSİYET BAĞLAMINDA MEDYA İLETİLERİNİ ANALİZ ETME BECERİLERİ	Dr. Öğr. Üyesi Funda İNCE BAKİ
		3	CONSPICUOUS CONSUMPTION IN GEN Z: THE ROLE OF FEAR OF NEGATIVE EVALUATION AND CONSUMER SUSCEPTIBILITY TO INTERPERSONAL INFLUENCES.	Dr. Öğretim. Üyesi İsmail Gökhan CİNTAMÜR
		4	GENÇLİK VE SPOR BAKANLIĞI'NIN HEDEF ODAKLI İLETİŞİM STRATEJİLERİ, YAPAY ZEKÂ DESTEKLİ YAKLAŞIMLAR VE GÜVENLİK GÖREVLİLERİNİN ROLÜ	Esra YİĞİT
		5	WOMAN IMPRISONED IN THE BOTTLE: AN ANALYSIS OF THE OBJECTIFIED FEMALE BODY IN ADVERTISING VISUALS	Yüksek Lisans Öğrencisi Aslıhan AKGÜL Doç. Dr. Ömer AYDINLIOĞLU
		6	THE RISE OF SHORT-FORM VIDEO CONTENT: THE IMPACT OF INSTAGRAM REELS ON THE DIGITAL MEDIA ECOSYSTEM	Dr. Alya Şahin Sarı
		7	DIGITAL CONSPICUOUS CONSUMPTION: THE REPRESENTATION AND REPRODUCTION OF LUXURY ON INSTAGRAM	Dr. Alya Şahin Sarı
		8	THE DIGITAL TRANSFORMATION OF JOURNALISM AND THE ISSUE OF TRUST	Lecturer PhD. Gürkan KILIÇ
		9	THE FUTURE OF TRADITIONAL MEDIA	Lecturer PhD. Gürkan KILIÇ
			BİR POPÜLER KÜLTÜR ARACI OLARAK SOSYAL MEDYA: KAVRAMSAL BİR DEĞERLENDİRME	Doç.Dr. Ersin DİKER Kemal Can TÜRK

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HALL / SALON 8	**Prof. Dr. Bahattin DEMİRTAŞ**	1	THE POSITION OF THE TRANSLATION OFFICE IN THE OTTOMAN POLITICAL AND ADMINISTRATIVE STRUCTURE	Muhammet Fatih BOZAN
		2	A REVIEW OF THE REIGN OF SULTAN ABDULHAMID II THROUGH EXAMPLES FROM THE IRISH PRESS	Merve DOĞAN
		3	AN ANALYSIS OF PERICLES' STRATEGY DURING THE PELOPONNESIAN WAR FROM A MILITARY PERSPECTIVE	Doç. Dr. Olcay Turan
		4	TÜRKLERDE ASKERÎ EĞİTİM VE AV KÜLTÜRÜ	Dr. Umut YOLSEVER
		5	ESKİ TÜRKLERDE SU KÜLTÜ VE DOĞA İNANCI	Dr. Umut YOLSEVER
		6	PAPA VI. PAUL'UN TÜRKİYE ZİYARETİ (1967)	Prof. Dr. Bahattin DEMİRTAŞ
		7	PAPA II. JOHN PAUL'UN TÜRKİYE ZİYARETİ (1979)	Prof. Dr. Bahattin DEMİRTAŞ
		8	SON DÖNEM OSMANLI İKTİSADİ HAYATINDA ALMAN MODELİ: AVANZÂDE MEHMED SÜLEYMAN'IN "ALMAN USULÜ TİCARET VE SERVET USULLERİ" ESERİ ÜZERİNE BİR İNCELEME	Prof. Dr. Ahmet Sait ÖZKUL
		9	ERKEN CUMHURİYET DÖNEMİ'NDE TİCARET KURSLARI: 1927 TARİHLİ "KIZ VE ERKEKLERE MAHSUS TİCARET KURSLARI MÜFREDAT PROGRAMI" ÜZERİNE BİR İNCELEME	Prof. Dr. Ahmet Sait ÖZKUL
		10	AN OTTOMAN–BRITISH ENCOUNTER IN THE MID-NINETEENTH CENTURY: THE TRAVELOGUE OF AN OTTOMAN COMMANDER IN ENGLAND	Dr. Öğr. Üyesi Hüseyin YILMAZ

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HALL / SALON 9	**Prof. Dr. Erkan FİDAN**	1	TRANSFORMATION OF SPACE: AN ARCHITECTURAL AND SOCIAL EVALUATION OF THE TRANSITION FROM CUMBA TO BALCONY İN SAFRANBOLU	Doç. Dr. Bülent ORAL
		2	CITY-MEMORY-SPACE: AN EVALUATION OF THE RE-FUNCTIONALIZATION AND REOPENING OF THE TEKEL ADMINISTRATIVE BUILDINGS	Arş. Gör. Rumeysa TEKE Öğr. Gör. Osman Ziyaettin YAĞCI Doç. Dr. Ayşen Esra BÖLÜKBAŞI ERTÜRK
		3	REPRESENTATION OF ANKARA EDUCATIONAL BUILDINGS DURING THE REPUBLICAN PERIOD ON STAMPS: THE PTT STAMP MUSEUM COLLECTION	Arş. Gör. Rumeysa TEKE Arş. Gör. Hasan SÖYLEMEZ Arş. Gör. Dr. Ayşe Merve SARAÇOĞLU GEZER Doç. Dr. Ayşen Esra BÖLÜKBAŞI ERTÜRK
		4	METAL PRODUCTION AND THE SCOPE OF METALLURGICAL KNOWLEDGE IN ANCIENT LITERARY SOURCES	Begüm AKI Dr. Öğr. Üyesi Handegül CANLI
		5	KÜLTÜREL VARLIKLARIN DOĞAL AFETLERDEN KORUNMASI VE YEREL YÖNETİMLER	Arkeolog Ali KARAKAYA
		6	AUXILIARY SCIENCES IN ARCHAEOLOGY: INTERDISCIPLINARY APPROACHES AND ANALYTICAL METHODS	Prof. Dr. Erkan FİDAN
		7	TAVŞANLI HÖYÜK: BRONZE AGE INTERACTIONS BETWEEN INLAND WESTERN ANATOLIA AND THE AEGEAN WORLD	Prof. Dr. Erkan FİDAN Dr. Sezer SEÇER FİDAN
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HALL / SALON 10	**Prof. Dr. Semiha Şahin**	1	TÜRKİYE YÜZYILI MAARİF MODELİ ÖĞRETİM PROGRAMLARINDA HATA KÜLTÜRÜNÜN ÖRTÜK YANSIMALARI: BİR DOKÜMAN ANALİZİ	Prof.Dr. Sevda KOÇ AKRAN
		2	NEETS IN TÜRKİYE FROM THE PERSPECTIVE OF EDUCATIONALADMINISTRATION AND STRUCTURAL INEQUALITY	Dr. Kübra YENEL
		3	ARŞİMET'İN ÇOKGEN YÖNTEMİNE DAYALI BİR ÖĞRENME ETKİNLİĞİNİN ÖĞRETMEN ADAYLARININ II SAYISINA İLİŞKİN KAVRAMSAL ANLAYIŞLARI ÜZERİNDEKİ ETKİSİ	Doç. Dr. S. Deniz KILIÇ
		4	MATEMATİK TARİHİ TEMELLİ BİR ETKİNLİK OLARAK ARŞİMET'İN II YÖNTEMİNİN MATEMATİK ÖĞRETMEN ADAYLARI TARAFINDAN DEĞERLENDİRİLMESİ	Doç. Dr. S. Deniz KILIÇ
		5	Okul Yönetiminde Çevik Liderlik	Prof. Dr. Semiha Şahin
		6	Okul Yönetiminde Sürdürülebilir Liderlik	Prof.Dr. Semiha ŞAHİN
		7	AN INVESTIGATION OF TEACHERS' CULTURAL INTELLIGENCE LEVELS ACCORDING TO PERSONAL VARIABLES	Zeynep DAMAR Prof. Dr., Hasan Basri MEMDUHOĞLU
		8	EĞİTİM BİLİMLERİNDE SOSYAL AĞ ANALİZİ ARAŞTIRMALARINA DAYALI KURAMSAL BİR SENTEZ	Mehmet Emin ÖREN Prof. Dr. Hasan Basri MEMDUHOĞLU
		9	ÖĞRETİM TASARIM MODELLERİNDE DOĞAL DİL İŞLEME TEKNOLOJİLERİ KULLANILABİLİR Mİ?	Arş. Gör. Dr. Erhan CEYLAN
		10	UYARLANABİLİR ÖĞRENME ORTAMLARINDA YAPAY ZEKA ETKİSİ	Doç. Dr. Barış AYAZ
		11	YAPAY ZEKA TEKNOLOJİLERİNİN BİRLEŞTİRİLMİŞ TEKNOLOJİ KABUL VE KULLANIM MODELİ BAĞLAMINDA DEĞERLENDİRİLMESİ	Doç. Dr. Barış AYAZ

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HALL / SALON 1	**Assoc. Prof. Dr. Enkhjargal Munkhbayar,**	1	TRADITIONAL GEORGIAN WINE FERMENTATION TECHNIQUES AND THEIR MODERN GASTRONOMIC APPLICATIONS	Prof. Dr. Nino Tsiklauri, Levan Beridze, Mariam Kapanadze
		2	SUPRA FEAST RITUALS: GEORGIAN HOSPITALITY TRADITIONS IN CONTEMPORARY FINE DINING	Assoc. Prof. Dr. Tamar Gelashvili, Irakli Chikhradze
		3	FERMENTED DAIRY PRODUCTS AND PROBIOTIC HERITAGE IN HIGH CAUCASUS GASTRONOMY	Dr. Lasha Tsintsadze, Maka Lomidze, Giorgi Khutsishvili
		4	MONGOLIAN HORSE MILK FERMENTATION: TRADITIONAL AIRAG PRODUCTION AND MODERN APPLICATIONS	Prof. Dr. Batbold Enkhtur, Sarantuya Dashdondog
		5	TRADITIONAL MONGOLIAN BUUZ STEAMING TECHNIQUES AND TEXTURAL ENGINEERING	Dr. Tumentsogt Jigjid, Oyundelger Bat-Erdene, Assis. Prof. Dr. Ganbold Tsogt
		6	NOMADIC MEAT PRESERVATION METHODS: BIKHESHI AND FERMENTED SAUSAGES OF MONGOLIA	Assoc. Prof. Dr. Enkhjargal Munkhbayar, Boldbaatar Dorj
		7	PERSIAN RICE COOKING MASTERY: TAH DIG FORMATION CHEMISTRY AND TEXTURAL PERFECTION	Prof. Dr. Reza Mahmoudi, Soraya Ahmadi, Dr. Ali Jafari
		8	SAFFRON INFUSION TECHNIQUES IN CLASSICAL PERSIAN CUISINE AND MOLECULAR APPLICATIONS	Fatemeh Karimi, Assoc. Prof. Dr. Hassan Rezaei, Nima Bahrami
		9	PERSIAN FRUIT AND NUT HARVEST FESTIVALS: GASTRONOMIC RITUALS AND SEASONAL INNOVATIONS	Dr. Zahra Hosseini, Leila Tavakoli, Prof. Dr. Mohammad Shirazi
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HALL / SALON 2	**Assoc. Prof. Dr. Bolormaa Tsogt**	1	INTEGRATING DIGITAL STORYTELLING INTO GEORGIAN PRIMARY EDUCATION FOR ENHANCED LITERACY DEVELOPMENT	Prof. Dr. Nino Tsiklauri, Levan Beridze, Mariam Kapanadze
		2	STEM EDUCATION REFORM THROUGH PROJECT-BASED LEARNING IN RURAL GEORGIAN SCHOOLS	Assoc. Prof. Dr. Tamar Gelashvili, Dr. Giorgi Khutsishvili
		3	INCLUSIVE EDUCATION PRACTICES FOR CHILDREN WITH AUTISM SPECTRUM DISORDER IN TBILISI KINDERGARTENS	Dr. Lasha Chikhradze, Assis. Prof. Dr. Nino Lomidze, Elene Tsintsadze
		4	NOMADIC HERITAGE INTEGRATION IN MONGOLIAN MODERN CURRICULUM THROUGH EXPERIENTIAL LEARNING	Prof. Dr. Bat-Erdene Tsend, Sarantuya Enkhbayar
		5	BLENDED LEARNING MODELS FOR VOCATIONAL EDUCATION IN MONGOLIA'S MINING REGIONS	Dr. Otgonbayar Jargalsaikhan, Enkhjargal Batbold, Assis. Prof. Dr. Davaajargal Munkhbayar
		6	MULTILINGUAL PEDAGOGY FOR ETHNIC MINORITY STUDENTS IN MONGOLIAN BORDER SCHOOLS	Assoc. Prof. Dr. Bolormaa Tsogt, Ganbold Dorj
		7	STEAM EDUCATION INTEGRATION THROUGH TRADITIONAL IRANIAN ARTS AND CRAFTS	Dr. Fatemeh Ahmadi, Assoc. Prof. Dr. Hassan Tavakoli
		8	MONTESSORI METHOD ADAPTATION FOR PRESCHOOLERS IN URBAN IRANIAN COMMUNITIES	Leila Mahmoudi, Dr. Zahra Jafari, Nima Bahrami

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HALL / SALON 3	**Dr. Nasir Uddin**	1	FISCAL POLICY RESPONSES TO COMMODITY PRICE SHOCKS IN KAZAKHSTAN'S RESOURCE ECONOMY	Prof. Dr. Yerzhan Abayev, Aizhan Kassenova
		2	MONETARY POLICY TRANSMISSION MECHANISMS IN KAZAKHSTAN'S FINANCIALLY DOLLARIZED ECONOMY	Assoc. Prof. Dr. Ruslan Zhumatov, Nurlan Bekbolatov
		3	TRADE DIVERSIFICATION STRATEGIES AND ECONOMIC RESILIENCE IN POST-SOVIET KAZAKHSTAN	Dr. Gulnara Abayeva, Dina Sarsenbayeva, Aidana Kurmangaliyeva
		4	MICROFINANCE IMPACT ON RURAL POVERTY ALLEVIATION IN BANGLADESH FLOOD-PRONE REGIONS	Prof. Dr. Rahman Karim, Fatima Begum
		5	REMITTANCE UTILIZATION PATTERNS AND HOUSEHOLD INVESTMENT DECISIONS IN BANGLADESH	Assoc. Prof. Dr. Hossain Mohammad, Ayesha Siddiqua
		6	FISCAL FEDERALISM CHALLENGES IN BANGLADESH DECENTRALIZATION REFORMS	Dr. Nasir Uddin, Shabnam Jahan
		7	OIL SUBSIDY REFORM IMPACTS ON ENERGY POVERTY AND INEQUALITY IN NIGERIA	Prof. Dr. Chukwuma Soludo, Ngozi Okonjo
		8	TRADE POLICY LIBERALIZATION AND MANUFACTURING VALUE ADDED GROWTH IN NIGERIA	Assoc. Prof. Dr. Akinwumi Adesina,
		9	FINANCIAL INCLUSION STRATEGIES AND MSME GROWTH CONSTRAINTS IN NORTHERN NIGERIA	Dr. Obadiah Nwankwo, Aisha Mohammed, Emeka Okoro
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HALL / SALON 4	**Assoc. Prof. Dr. Sharif Ahmed,**	1	INTERNATIONAL HUMAN RIGHTS LAW APPLICATIONS IN POST-SOVIET CENTRAL ASIAN LEGAL SYSTEMS: KAZAKHSTAN PERSPECTIVE	Prof. Dr. Aizhan Kassenova, Yerzhan Tolegenov, Dina Sarsenbayeva
		2	DIGITAL PRIVACY LEGISLATION AND DATA PROTECTION FRAMEWORKS IN KAZAKHSTAN'S CYBERSPACE GOVERNANCE	Assoc. Prof. Dr. Ruslan Zhumatov, Aidana Kurmangaliyeva
		3	ANTI-CORRUPTION LEGAL REFORMS AND INSTITUTIONAL EFFECTIVENESS IN KAZAKHSTAN'S PUBLIC PROCUREMENT SYSTEMS	Dr. Nurlan Bekbolatov, Gulnara Abayeva
		4	CLIMATE CHANGE LITIGATION STRATEGIES UNDER BANGLADESH ENVIRONMENTAL JUSTICE FRAMEWORKS	Prof. Dr. Rahman Chowdhury, Fatima Islam
		5	MARITIME BOUNDARY DISPUTE RESOLUTION MECHANISMS IN BAY OF BENGAL LEGAL REGIMES	Assoc. Prof. Dr. Sharif Ahmed, Ayesha Rahman
		6	WOMEN'S PROPERTY RIGHTS REFORMS IN BANGLADESH ISLAMIC FAMILY LAW CONTEXTS	Dr. Nazma Khanam, Bilkis Akter
		7	FOREIGN DIRECT INVESTMENT REGULATION AND DISPUTE SETTLEMENT IN NIGERIAN OIL AND GAS SECTOR	Prof. Dr. Chukwudi Okeke, Ngozi Eze
		8	ANTI-MONEY LAUNDERING COMPLIANCE FRAMEWORKS IN NIGERIA'S FINANCIAL INSTITUTIONS	Assoc. Prof. Dr. Fatima Yusuf, Adebayo Ogunleye
		9	CONSTITUTIONAL FEDERALISM AND RESOURCE CONTROL DISPUTES IN NIGERIA'S OIL PRODUCING REGIONS	Dr. Aminu Bello, Chioma Nwosu,
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HALL / SALON 5	**Assoc. Prof. Dr. Nasrin Sultana,**	1	POST-SOVIET IDENTITY NEGOTIATION IN CONTEMPORARY KAZAKHSTAN NOVELS	Prof. Dr. Aigul Zhumadilova, Yerzhan Kudaibergenov
		2	EPIC TRADITIONS AND MODERN ECOLOGICAL CONCERNS IN KAZAKH STAN WRITING	Assoc. Prof. Dr. Gulnara Sarsenova, Nurlan Abildayev
		3	FEMINIST DISCOURSES IN URBAN KAZAKH SHORT FICTION POST-IND EPENDENCE	Dr. Aidana Tolegenova, Zhuldyz Kairatkyzy
		4	POSTCOLONIAL HYBRIDITY IN BANGLADESHI DIASPORIC POETRY WRITING TRADITIONS	Prof. Dr. Rehana Begum, Md. Faisal Ahmed
		5	CLIMATE FICTION AND RIVERINE IDENTITIES IN CONTEMPORARY BANGLADESHI NOVELS	Assoc. Prof. Dr. Nasrin Sultana, Karim Hossain
		6	URBAN SLUM NARRATIVES AND SUBALTERN VOICES IN DHAKA LITERATURE	Dr. Shabnam Jahan, Rafiqul Islam
		7	ORAL TRADITION REVIVAL IN CONTEMPORARY NIGERIAN YORUBA POETRY	Prof. Dr. Adebayo Ogunleye, Chioma Nwosu
		8	POSTCOLONIAL GHOST STORIES AND HAUNTED NATIONALISM IN IGBO LITERATURE	Assoc. Prof. Dr. Ifeoma Okonkwo, Emeka Chukwu
		9	PIDGIN ENGLISH NOVELS AND LAGOS UNDERCLASS RESISTANCE AESTHETICS	Dr. Tunde Bakare,
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HALL / SALON 6	**Assoc. Prof. Dr. Yerlan Toregeldiev,**	1	THE ESCHATOLOGICAL VISION IN CENTRAL ASIAN SUFI TEXTS: KAZAKH INTERPRETATIONS OF THE DAY OF JUDGMENT	Prof. Dr. Almaz Kenzhegulov, Aizhan Sarsenova
		2	INTERFAITH DIALOGUE PRACTICES IN MULTIETHNIC KAZAKHSTAN: THEOLOGICAL FOUNDATIONS AND CONTEMPORARY CHALLENGES	Assoc. Prof. Dr. Yerlan Toregeldiev, Dina Abilova, Nursultan Bekov
		3	THE CONCEPT OF DIVINE UNITY (TAWHID) IN CONTEMPORARY KAZAKH MUSLIM THOUGHT	Dr. Gulnara Zhumaliyeva, Timur Kairatov
		4	CHRISTIAN-MUSLIM RELATIONS IN BANGLADESH: THEOLOGICAL PERSPECTIVES ON PEACEBUILDING	Prof. Dr. Mohammad Rahman, Fatima Begum
		5	SUFI MYSTICISM AND FOLK RELIGIOSITY IN RURAL BANGLADESH: THEOLOGICAL SYNCRETISM ANALYSIS	Assoc. Prof. Dr. Abdul Karim, Rehana Akter, Jamal Uddin
		6	SCRIPTURAL HERMENEUTICS IN BANGLADESH CHRISTIANITY: CONTEXTUALIZING THE INCARNATION	Dr. Joshua Paul, Sister Maria Gomes
		7	AFRICAN TRADITIONAL RELIGIONS AND PENTECOSTAL ENCOUNTERS IN CONTEMPORARY NIGERIA	Prof. Dr. Emmanuel Okonkwo, Chinedu Eze
		8	ISLAMIC ESCHATOLOGY IN HAUSA MUSLIM COMMUNITIES: NORTHERN NIGERIAN PERSPECTIVES	Assoc. Prof. Dr. Amina Yusuf, Ibrahim Garba
		9	TRINITY DOCTRINE IN YORUBA CHRISTIAN THEOLOGY: CONCEPTUAL CONVERGENCES	Dr. Olusegun Adebayo, Funmi Ojo, Tunde Bakare
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HALL / SALON 7	**Assoc. Prof. Dr. Nadia Farouk**	1	INTERGENERATIONAL FAMILY CONFLICTS AND RESOLUTION STRATEGIES IN TRADITIONAL AFGHAN HOUSEHOLDS	Prof. Dr. Abdul Rahman Khan, Fatima Azizi, Noorullah Safi
		2	MATERNAL MENTAL HEALTH IMPACT ON CHILD DEVELOPMENT IN POST-CONFLICT AFGHAN COMMUNITIES	Assoc. Prof. Dr. Zahra Malalai, Dr. Hamidullah Wardak
		3	EXTENDED FAMILY SUPPORT SYSTEMS AND WOMEN'S ECONOMIC PARTICIPATION IN AFGHAN RURAL AREAS	Layla Nouri, Dr. Mohammad Qasem, Soraya Hakimi
		4	MARRIAGE ARRANGEMENTS AND FAMILY DYNAMICS IN OMANI TRIBAL COMMUNITIES	Prof. Dr. Ahmed Al-Harthi, Fatima Al-Maskari
		5	PARENTING PRACTICES AND CHILD SOCIALIZATION IN URBAN OMANI FAMILIES	Assoc. Prof. Dr. Khalid Al-Belushi, Dr. Nour Al-Hinai, Salim Al-Mahrooqi
		6	ELDER CARE RESPONSIBILITIES AND INTERGENERATIONAL SOLIDARITY IN OMANI SOCIETY	Mariam Al-Rashdi, Dr. Hassan Al-Ghafri
		7	FAMILY BUSINESS GOVERNANCE AND SUCCESSION IN EGYPTIAN ENTERPRISES	Prof. Dr. Omar Khalil, Dr. Amina Hassan, Karim Abdel
		8	WOMEN'S ROLES IN EGYPTIAN FAMILY DECISION-MAKING PROCESSES	Assoc. Prof. Dr. Nadia Farouk, Youssef Salem
		9	CHILD REARING PRACTICES AND EDUCATIONAL ASPIRATIONS IN EGYPTIAN URBAN FAMILIES	Dr. Layla Mahmoud, Prof. Dr. Ahmed Sorour, Fatima Reda
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HALL / SALON 8	**Assoc. Prof. Dr. Ibrahim Musa**	1	**COMMUNITY-BASED INTERVENTIONS FOR ELDERLY SUPPORT IN RURAL RUSSIAN REGIONS**	**Prof. Dr. Irina Petrova, Dr. Sergei Kuznetsov, Anna Volkova**
		2	**MENTAL HEALTH SUPPORT SYSTEMS FOR MIGRANT WORKERS IN MOSCOW METROPOLITAN AREA**	**Assoc. Prof. Dr. Elena Smirnova, Mikhail Ivanov**
		3	**CHILD PROTECTION STRATEGIES AGAINST DOMESTIC VIOLENCE IN POST-SOVIET RUSSIAN FAMILIES**	**Dr. Natalia Fedorova, Pavel Sokolov, Olga Dmitrieva**
		4	**WOMEN EMPOWERMENT PROGRAMS THROUGH VOCATIONAL TRAINING IN DUBAI MIGRANT COMMUNITIES**	**Fatima Al-Mansoori, Dr. Khalid Rahman**
		5	**YOUTH MENTAL HEALTH INITIATIVES ADDRESSING SOCIAL MEDIA ADDICTION IN DUBAI SCHOOLS**	**Assoc. Prof. Dr. Aisha Al-Ketbi, Sara Hassan, Noor Salem**
		6	**HOMELESS FAMILY REINTEGRATION PROGRAMS IN DUBAI'S LABOR MARKETS**	**Prof. Dr. Omar Al-Fahim, Layla Mahmoud**
		7	**COMMUNITY DEVELOPMENT AGAINST STREET CHILDREN EXPLOITATION IN LAGOS URBAN SLUMS**	**Prof. Dr. Chinedu Okoro, Ngozi Eze, Dr. Adebayo Yusuf**
		8	**GENDER-BASED VIOLENCE RESPONSE SYSTEMS IN NORTHERN NIGERIAN RURAL COMMUNITIES**	**Assoc. Prof. Dr. Ibrahim Musa**
		9	**MENTAL HEALTH SUPPORT FOR CONFLICT-AFFECTED IDPS IN NORTHEAST NIGERIA**	**Dr. Fatima Aliyu, Samuel Okafor, Rahma Ibrahim**

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HALL / SALON 9	**Assis. Prof. Dr. Sara Jafari**	1	INTEGRATING DIGITAL TECHNOLOGIES IN RURAL AZERBAIJANI PRIMARY EDUCATION CURRICULA	Prof. Dr. Aysel Mammadova, Dr. Elvin Huseynov, Nigar Aliyeva
		2	EFFECTIVENESS OF BILINGUAL TEACHING METHODS FOR AZERBAIJANI STEM SUBJECTS	Assoc. Prof. Dr. Kamal Rahimov, Farid Gurbanova, Dr. Leyla Ismayilova
		3	IMPACT OF TEACHER TRAINING PROGRAMS ON CLASSROOM INNOVATION IN IRANIAN HIGH SCHOOLS	Dr. Reza Mohammadi, Assis. Prof. Dr. Sara Jafari
		4	DEVELOPING CRITICAL THINKING SKILLS THROUGH PROJECT-BASED LEARNING IN IRAN	Fatemeh Karimi, Prof. Dr. Ali Hosseini, Mina Bahrami
		5	ADDRESSING GENDER DISPARITIES IN ALGERIAN VOCATIONAL EDUCATION PROGRAMS	Assoc. Prof. Dr. Zahra Belkacem, Yassine Amrani
		6	ENHANCING LITERACY RATES THROUGH COMMUNITY SCHOOL INITIATIVES IN ALGERIA	Dr. Samir Bouzid, Nadia Cherif, Karim Mansouri
		7	REFORMING GEORGIAN UNIVERSITY CURRICULA FOR SUSTAINABLE DEVELOPMENT GOALS	Prof. Dr. Nino Chikhradze, Dr. Levan Tsiklauri, Mariam Gelashvili
		8	TECHNOLOGY INTEGRATION CHALLENGES IN GEORGIAN RURAL SECONDARY EDUCATION	Assis. Prof. Dr. Tamar Kvernadze, Irakli Beridze
		9	INCLUSIVE EDUCATION PRACTICES FOR STUDENTS WITH SPECIAL NEEDS IN GEORGIA	Dr. Giorgi Lomidze, Lali Kapanadze, Prof. Dr. Maka Tsintsadze
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HALL / SALON 10	**Prof. Dr. Vladimir Lupu**	1	INNOVATIVE STEM EDUCATION METHODOLOGIES FOR POST-WAR RECONSTRUCTION IN UKRAINIAN SCHOOLS	Prof. Dr. Olena Kovalenko, Dr. Mykhailo Petrenko, Anna Sydorenko
		2	DIGITAL LITERACY PROGRAMS ENHANCING INCLUSIVE EDUCATION FOR RURAL UKRAINIAN STUDENTS	Assoc. Prof. Dr. Iryna Bohdanova, Viktor Melnyk, Sofia Hrytsenko
		3	TEACHER TRAINING INITIATIVES ADDRESSING MULTILINGUAL CLASSROOMS IN ERITREAN PRIMARY EDUCATION	Dr. Selam Tekle, Assis. Prof. Dr. Yonas Berhe
		4	VOCATIONAL EDUCATION REFORMS FOR YOUTH EMPLOYMENT IN ERITREAN COASTAL COMMUNITIES	Meron Asmelash, Dr. Dawit Girmay, Helen Yohannes
		5	CURRICULUM DEVELOPMENT FOR SUSTAINABLE DEVELOPMENT GOALS IN ALGERIAN UNIVERSITIES	Prof. Dr. Fatima Zahra Belkacem, Karim Amrane
		6	GENDER EQUITY STRATEGIES IN ALGERIAN HIGHER EDUCATION STEM PROGRAMS	Assoc. Prof. Dr. Nadia Cherif, Dr. Samir Lounis, Amina Hadji
		7	REMOTE LEARNING TECHNOLOGIES FOR RURAL EDUCATION ACCESS IN MOLDOVA	Dr. Ion Ceban, Mariana Popa, Alexei Rotaru
		8	TEACHER PROFESSIONAL DEVELOPMENT THROUGH INTERNATIONAL PARTNERSHIPS IN MOLDOVA	Assis. Prof. Dr. Elena Ciorba, Prof. Dr. Vladimir Lupu
		9	INCLUSIVE EDUCATION MODELS FOR CHILDREN WITH DISABILITIES IN MOLDOVAN SCHOOLS	Dr. Natalia Gurau, Sergiu Balan, Cristina Dodon
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HALL / SALON 1	**Dr. Lecturer Betül ÇATAL**	1	THE FRAGILE BALANCE BETWEEN COMBATING DISINFORMATION on the INTERNET and FREEDOM of EXPRESSION	Dr. Lecturer Betül ÇATAL
		2	ARTIFICIAL INTELLIGENCE-BASED SURVEILLANCE SYSTEMS and THE CORE OF PRIVATE LIFE: THE EROSION of THE PRINCIPLE of PROPORTIONALITY	Dr. Lecturer Betül ÇATAL
		3	ANAYASAL DEMOKRASİNİN ASGARİ KOŞULLARI ÇERÇEVESİNDE İNSAN HAKLARI: İFADE ÖZGÜRLÜĞÜ VE BİLGİ EDİNME HAKKI	Ayça SERİN
		4	VİYANA SATIM ANLAŞMASI UYARINCA SÖZLEŞMENİN İHLALİ HÂLİNDE TARAFLARIN SAHİP OLDUĞU HUKUKİ İMKÂNLAR	Necla ÖZTÜRK Güven YARAR
		5	TÜRK HUKUKUNDA YATIRIM YOLUYLA VATANDAŞLIK KAZANIMINA İLİŞKİN DÜZENLEMELERİN BAZI İLKELER ÇERÇEVESİNDE DEĞERLENDİRİLMESİ	Necla ÖZTÜRK Güven YARAR
		6	AN ASSESSMENT OF WHETHER COVID-19 SHOULD BE CONSIDERED AN OCCUPATIONAL DISEASE FOR HEALTHCARE WORKERS	Attorney Berfin Uyma Bulut
		7	BİLİŞİM HUKUKU AÇISINDAN BÜYÜK VERİ: HUKUKİ, TEKNİK VE ETİK BOYUTLARIYLA KAPSAMLI BİR İNCELEME	Dr. Öğr. Üyesi Ali CENGİZ Doç. Dr. Sadullah ÇELİK Dr. Öğr. Üyesi Bilge DOĞANLI
		8	MARKA VE COĞRAFİ İŞARETLER İLE GELENEKSEL ÜRÜN ADLARININ TÜRK SINAI MÜLKİYET HUKUKU KAPSAMINDA KARŞILAŞTIRILMASI	Dr. Öğr. Üyesi Ali CENGİZ Dr. Öğr. Üyesi Bilge DOĞANLI Doç. Dr. Sadullah ÇELİK
		9	AB Yapay Zekâ Tüzüğü Kapsamında Yasaklı ve Yüksek Riskli Alanlardan Elde Edilen Delillerin Ceza Muhakemesinde Kullanılması ve Değerlendirilmesi	Av. Fahriye ÖZKORKMAZ ÖZKAN
		10	Blokzincir Tabanlı Genel Kurulların Türk Ticaret Hukuku Bakımından Değerlendirilmesi	Dr. Öğr. Üyesi Emel TEKTEN
		11	Ticari Kredilerde Bankalar Tarafından Alınan Senetlerin İfa Yerine mi İfa Uğruna mı Verildiği Sorunu	Dr. Öğr. Üyesi Emel TEKTEN
		12	ÜRÜN HİZMET VE DENEYİM PAZARLAMASINDA İLETİŞİM STRATEJİLERİ	Dr. Öğr. Üyesi Oğuz YAVUZYILMAZ
		13	TİCARET, SATIŞ VE PAZARLAMA KAVRAMLARI BAĞLAMINDA SİYASETNAME	Dr. Öğr. Üyesi Oğuz YAVUZYILMAZ

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HALL / SALON 2	**Doç. Dr. Güzin PIHTILI YILDIZ**	1	USE OF NOVEL SOLVENT SYSTEMS IN THE DETERMINATION OF MYCOTOXINS FROM FOOD SAMPLES	Prof. Dr. Adil ELİK Prof. Dr. Nail ALTUNAY Arş. Gör. Seçkin FESLİYAN
		2	THE ROLE OF DEEP EUTECTIC SOLVENTS IN MICROEXTRACTION TECHNIQUES	Prof. Dr. Adil ELİK Prof. Dr. Nail ALTUNAY Arş. Gör. Seçkin FESLİYAN
		3	AYÇİÇEĞİ TABLASINDAN AKTİF KARBON ÜRETİMİ VE BOYARMADDE GİDERİMİNDE KULLANIMI	Burcu DEMİRDAL Prof. Dr. İlknur DEMİRAL
		4	DEVELOPMENT OF A SULFATE-FREE SHAMPOO CONTAINING PUMPKIN EXTRACT	Sibel ÖZKÖMÜRCÜ TUNCER Öğr. Gör. Dr. Beste KARADENİZ Öğr. Gör. Dr. Şeref KARADENİZ Prof. Dr. Emine TEKİN
		5	Fe_3O_4 İLE MODİFİYE EDİLMİŞ BUĞDAY SAMANI KULLANILARAK SULU ÇÖZELTİDEN ADSORPSİYONLA METİLEN MAVİSİ GİDERİMİ	Büşra YAZICI Prof. Dr. Neşe ÖZTÜRK
		6	REMOVAL OF CR(VI) FROM AQUEOUS SOLUTIONS BY CROSS-LINKED POROUS SA1YA POLYMERIC ADSORBENT: INVESTIGATION OF THE EFFECT OF ADSORBENT AMOUNT	Ali İhsan DİKMEOĞLU Araş. Gör. Yağmur YANIKTEPE Prof. Dr. Ali KARA
		7	GRAFEN İÇERİKLİ POLİMER KOMPOZİTİN TAN δ DAVRANIŞININ YANIT YÜZEY YÖNTEMİ İLE MODELLENMESİ	Doç. Dr. Güzin PIHTILI YILDIZ
		8	TEKSTİL KUMAŞLARI ÜZERİNE SÜRDÜRÜLEBİLİR POLİMER KAPLAMA MALZEMELERİNİN ARAŞTIRILMASI	Ertuğrul YILMAZ Prof. Dr. Ali Kara Halim ÇİMCİLER

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HALL / SALON 3	**Dr. Öğr. Üyesi Mehmet Fethi ERTENLİ**	1	İNCE DANELİ ZEMİNLERİN BÜZÜLME LİMİTLERİNİN BELİRLENMESİ	İnşaat Müh. Güliz HACIHASANOĞLU Prof. Dr. Ertan BOL
		2	ÇİFT EĞRİLİKLİ FGM SANDVİÇ KABUKLARDA POROZİTE ORANI VE YÜZEY KATMANI TÜRÜNÜN TERMAL BURKULMA ÜZERİNDEKİ ETKİLERİ	Dr. Öğr. Üyesi Mehmet Fethi ERTENLİ
		3	DEPREM ANALİZ YÖNTEMLERİNİN BETONARME YAPI DAVRANIŞINA ETKİSİNİN KARŞILAŞTIRMALI ANALİZİ	Lisans Bitirme Projesi Öğrenci Houssam JABIRI Dr. Öğr. Üyesi Mehmet Fethi ERTENLİ
		4	ZEMİN ÇİVİLİ İSTİNAT DUVARLARININ KARŞILAŞTIRMALI ANALİZİ	İnşaat Mühendisi Tuğçe YILDIZTAŞ Dr. Öğr. Üyesi Kurban ÖNTÜRK Prof. Dr. Sedat SERT
		5	INVESTIGATION OF ATTERBERG LIMITS AND FREEZE–THAW BEHAVIOR OF CLAY SOILS IMPROVED WITH LIQUEFIED PET WASTE	Yük. İnş. Müh. Namenur İBİŞ Dr. Fatih ARTUK Prof. Dr. Ahmet Şahin ZAİMOĞLU
		6	GEOTECHNICAL ANALYSIS AND MAPPING OF SOIL PROPERTIES USING GEOGRAPHIC INFORMATION SYSTEMS: A CASE STUDY OF ALTINORDU, ORDU	Taha Emre ZENGİN Prof. Dr. Sıddıka Nilay KESKİN
		7	Current Challenges and Emerging Strategies for Sustainable Ready-Mixed Concrete	Zehra Funda AKBULUT Prof. Dr. Soner Güler
		8	Basic Overview of Concrete Classes and Their Engineering Applications	Zehra Funda AKBULUT Prof. Dr. Soner Güler
			Trend Analysis of Monthly Total Precipitation in Kastamonu, Türkiye	Gamze TUNCER EVCIL Osman SONMEZ

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HALL / SALON 4	**Dr. Öğr. Üyesi, Tahire HÜSEYİNLİ**	1	SOCIAL MEDIA INFLUENCERS' IMPACT ON BRAND TRUST: A QUALITATIVE STUDY BASED ON FOLLOWERS' PERCEPTIONS	Shoira KURBONNAZOROVA
		2	ANALYSIS OF HOTEL REVIEWS IN TERMS OF SERVICE QUALITY DIMENSIONS AT LOCAL AND INTERNATIONAL LEVELS	PhD Student Heydar SALAMOV Dr. Lecturer Abdulkadir ŞENCAN
		3	KADIN TÜKETİCİLERİN SATIN ALMA DAVRANIŞLARINDA MAĞAZA ORTAM KOKULARININ ROLÜ: İZMİR İLİ ALIŞVERİŞ MERKEZLERİNDEKİ GİYİM MAĞAZALARINDA YAPILAN BİR İNCELEME	Dr. Öğr. Üyesi, Tahire HÜSEYİNLİ
		4	THE IMPACT OF CONSUMER CONFİDENCE INDEX ON THE DEMAND FOR DURABLE GOODS: A VAR ANALYSİS ON THE TURKİSH CASE	Prof. Dr. Ferhat PEHLİVANOĞLU Doktora Öğrencisi Erhan Haluk ERGÜL
		5	The New Face of Digital Advertising: A Conceptual Overview of Artificial Intelligence Based Marketing Strategies	Öğr. Gör. Dr. Öznur AKTAŞ
		6	ELEKTRONİK ALIŞVERİŞTE YAPAY ZEKA DESTEKLİ UYGULAMALARDA TÜKETİCİ TUTUMLARI VE TEKRAR SATIN ALMA NİYETİ ARASINDAKİ İLİŞKİNİN İNCELENMESİ	Ayşegül KAYGISIZ Dr.Öğr.Üy. Bilge MEYDAN Prof.Dr. Aydın Kayabaşı
		7	A BIBLIOMETRIC ANALYSIS OF VIRTUAL INFLUENCERS IN THE CONTEXT OF INFLUENCER MARKETING	Doç. Dr. Buket BORA SEMİZ YL Öğrencisi Mehmet Kerem HANLI
		8	SOSYAL MEDYA PAZARLAMASINDA YAPAY ZEKA INFLUENCER'LARIN TÜKETİCİ ALGISINA ETKİSİ: FORD & VİRTUALALİN ÖRNEĞİ	Yüksek Lisans Öğrencisi Zeynep TÜRK
		9	KURUMSAL İTİBAR KONUSU LİSANSÜSTÜ TEZLERDE NASIL ELE ALINIYOR? BİBLİYOMETRİK BİR ANALİZ	Prof. Dr. Burcu ÖKSÜZ KAYA Doç. Dr. Handan GÜLER İPLİKÇİ
		10	ORGANİK ÜRÜN SÖYLEMİNDE ÇİFTÇİ TEMSİLİ: META FETİŞİZMİ PERSPEKTİFİNDEN SEMİYOTİK BİR İNCELEME	Doç. Dr. Handan GÜLER İPLİKÇİ Prof. Dr. Burcu ÖKSÜZ KAYA

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HALL / SALON 5	**Prof. Dr. Sultan GÜÇLÜ**	1	VOLUNTEERING IN SOCIAL WORK: AN ASSESSMENT IN THE CONTEXT OF SOCIAL SOLIDARITY, EMPOWERMENT, AND SUSTAINABILITY	Prof. Dr. Sultan GÜÇLÜ
		2	ACCESS TO HEALTH SERVICES FOR WOMEN IN RURAL AREAS: GLOBAL TRENDS, THE CASE OF TURKEY, AND AN INTERDISCIPLINARY ASSESSMENT	Prof. Dr. Sultan GÜÇLÜ Asst. Prof. Ayşegül UNUTKAN
		3	YAPAY ZEKA DESTEKLİ MOBİL TANIŞMA UYGULAMALARIYLA TANIŞAN ÇİFTLERİN EVLİLİKTE BAĞLANMA STİLLERİ VE EVLİLİK İLİŞKİLERİNİN İNCELENMESİ	Sosyal Hizmet Uzmanı Merve SERT Arş. Gör. Merve İBRAHİMOĞLU Prof. Dr. Ercümend ERSANLI
		4	YETİŞKİN BİLİŞSEL KONTROL VE ESNEKLİĞİ: ALGILANAN EBEVEYN KABUL-REDDİNİN YORDAYICI ROLÜ	Psikolog Asena Begüm ZENGİN Arş. Gör. Merve İBRAHİMOĞLU Prof. Dr. Ercümend ERSANLI
		5	YARGI ALANINDA ÇALIŞAN PSİKO-SOSYAL MESLEK GRUPLARININ KARŞILAŞTIKLARI ZORLUKLAR	Sosyal Çalışmacı Onur BAYDAR
		6	DİJİTALLEŞMENİN ENGELLİ BİREYLERE BAKIM VERENLER AÇISINDAN YERİ VE SOSYAL HİZMET	Doç. Dr. Aslıhan AYKARA
		7	HOW CAN SCHOOL SOCIAL WORK INTERVENTIONS BE IMPLEMENTED TO ADDRESS PEER BULLYING?	Assoc. Prof. Dr. Umut Yanardağ
		8	KAPSAYICI LİDERLİK VE PSİKOLOJİK GÜVEN: KAVRAMSAL BİR MODEL ÖNERİSİ	Öğr. Gör. Seda ÇOLAK Doç. Dr. Yasemin KAYA
			AFET YÖNETİMİNDE HAVALİMANLARININ ROLÜ	Öğr. Gör. Seda ÇOLAK Dr. Öğr. Üyesi Özge ÜSTÜN

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HALL / SALON 6	**Doç.Dr. Muhammed Emre AYHAN**	1	SYNERGISTIC EFFECTS OF SODIUM METABORATE AND GRAPHENE OXIDE COMPOSITES ON SERS PERFORMANCE	Doç.Dr. Muhammed Emre AYHAN
		2	LIFECYCLE MANAGEMENT AND PREVENTIVE MAINTENANCE PLANNING SUPPORTED BY MACHINE LEARNING	Emir KARA Ömer KOÇBİL Doç. Dr. Mustafa NAMDAR Doç. Dr. Arif BAŞGÜMÜŞ
		3	COMPARATIVE ANALYSIS OF LTE NETWORK PERFORMANCE AND SIGNAL QUALITY OF MOBILE OPERATORS IN KUTAHYA	Ömer Furkan YANIK Doç. Dr. Mustafa NAMDAR Doç. Dr. Arif BAŞGÜMÜŞ
		4	ELECTROMAGNETİC CHARACTERİZATİON OF HEALTHY AND CANCEROUS CELLS USİNG A VİVALDİ ANTENNA WİTH A NEAR-FİELD APPROACH: A ΔS_{21}-BASED S-PARAMETER ANALYSİS	Doktora Öğrencisi: Mahammad Isayev Doç. Dr. Seyfettin Sinan Gültekin
		5	KABLOSUZ VÜCUT ALAN AĞI (WBAN) UYGULAMALARI İÇİN KOT KUMAŞ TABANLI GİYİLEBİLİR ANTEN TASARIMI VE DEĞERLENDİRMESİ	Dr. Öğr. Üyesi Hakan KİŞİOĞLU
		6	ARDUİNO TABANLI KARTLI VE PLAKA TANIMA DESTEKLİ BİR OTOPARK OTOMASYON SİSTEMİ	Öğr. Gör. Büşra TUNÇ Öğrenci, Hamza ÇETİN Öğrenci, Selim DİKBAŞ
		7	DÜŞÜK ATALETLİ ŞEBEKELERDE VSC-HVDC TABANLI AKTİF SÖNÜMLEME YAKLAŞIMI	Özlem Rabia GÜLER Doç. Dr. BEHÇET KOCAMAN
		8	XLPE GÜÇ KABLOLARINDA SAHA ÖLÇÜM VERİLERİNE DAYALI KISMİ DEŞARJ İNCELENMESİ VE MODELLENMESİ	Mustafa Harun BAL Doç. Dr. Ali AJDER Dr. Öğr. Üyesi Celal Fadıl Kumru
		9	COMPARATIVE ANALYSIS FOR HYPERNUCLEAR MASS DISTRIBUTIONS	Asst. Prof. Dr. Ayşegül ERGUN

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HALL / SALON 7	**Lect. Dr. Yasemin ÇAKIR**	1	EATING DISORDERS IN ADOLESCENCE: RISK FACTORS AND PSYCHOSOCIAL DYNAMICS	Lect. Dr. Yasemin ÇAKIR Assoc. Prof. Dr. Nurullah ÇALIŞ
		2	SCHOOL-BASED INTERVENTIONS WITHIN THE FRAMEWORK OF MULTICULTURALISM: A REVIEW OF PRACTICES FOR REFUGEE CHILDREN	Lect. Dr. Yasemin ÇAKIR Assoc. Prof. Dr. Nurullah ÇALIŞ
		3	TRAVMA YAŞANTISI OLAN GENÇ YETİŞKİNLERİN PSİKOLOJİK ESNEKLİK DÜZEYLERİNİN DEMOGRAFİK DEĞİŞKENLER AÇISINDAN İNCELENMESİ	Sümeyye KAPLAN DOÇ. DR. Seher Merve ERUS
		4	THE MODERATING ROLE OF COPARENTING IN THE RELATIONSHIP BETWEEN PARENT'S SELF-EFFICACY AND PARENTING STRESS	Psychologist Şura Nur ÖZDEMİR
		5	THE MODERATING ROLE OF PERFECTIONISM IN THE RELATIONSHIP BETWEEN THE NEED FOR SOCIAL APPROVAL AND INTOLERANCE OF UNCERTAINTY	Dr. Öğr. Üyesi Reyhan ÇALIŞAN KİNTER Psikolog Ecmel KUTLUĞ
		6	İZLENİM YÖNETİMİNDE ''İDDİACI OLMAK''	Prof. Dr. Fatma Gül CİRHİNLİOĞLU Uzm. Aybike GİRENTE Prof. Dr. Zafer CİRHİNLİOĞLU
		7	ROMANTİK İLİŞKİLERDE MANİPÜLASYON	Prof. Dr. Fatma Gül CİRHİNLİOĞLU Uzm. Aybike GİRENTE
		8	ÜNİVERSİTE ÖĞRENİMİ GÖREN KIZ ÖĞRENCİLERDE SOSYAL GÖRÜNÜŞ KAYGISI VE ÖZGÜVEN DÜZEYİ	Erbaş NURİYE Selver ÖZGÜL
			KADINLARIN ŞİDDETE YÖNELİK TUTUMLARI İLE EVLİLİK UYUMU ARASINDAKİ İLİŞKİ	Dr. Öğr. Üyesi Nuriye ERBAŞ Şeydanur DİKTAŞ

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HALL / SALON 8	**Dr. Gültekin Gürçay**	1	HABERMAS'IN İLETİŞİM KURAMI İLE ŞİDDETSİZ İLETİŞİM ARASINDA BİR OKUMA: ORTAKLIKLAR, İMKÂNLAR VE SINIRLILIKLAR	Büke KOYUNCU KAHVECİOĞLU
		2	ERKEN ÇOCUKLUK DÖNEMİNDE NÖROÇEŞİTLİLİĞE YÖNELİK TERAPÖTİK MÜDAHALELERİN SAĞLIK SOSYOLOJİSİ ÇERÇEVESİNDE DEĞERLENDİRİLMESİ	Büke KOYUNCU KAHVECİOĞLU
		3	ALGILANAN PSİKOLOJİK GÜVENLİĞİN ÖRGÜTSEL BAĞLILIK ÜZERİNDEKİ ETKİSİ: SAVUNMA SANAYİ ÇALIŞANLARI ÜZERİNDE BİR ARAŞTIRMA	Yakup TURGUTALP Dr. Öğr. Üyesi Sefa CEYHAN
		4	BAKIM VEREN NESNE İLE İLİŞKİ VE BAĞLANMANIN TRAVMATİK YAS SÜRECİ ÜZERİNDEKİ ETKİLERİNİN İNCELENMESİ	Yüksek Lisans Öğrencisi Yasemin Esra BULUT Doç. Dr. Abdi GÜNGÖR Doç. Dr. Ahmet SAPANCI
		5	Social Media Use and Sleep Quality: A Platform-Based Analysis	Psikolog Sündüs Aslı GÜVEN Dr. Öğr. Üyesi Zehra ERTUĞRUL-YAŞAR
		6	EMOTION MAPPING OF HIKIKOMORI DISCOURSE ON REDDIT: A DUAL- LAYER SEMANTIC AND AFFECTIVE ANALYSIS	Dr. Sezai TUNCA
		7	YAŞAM DOYUMUNUN YORDAYICILARI OLARAK SÜREKLİ UMUT, ÖZ ANLAYIŞ VE MADDİ KAYGININ İNCELENMESİ	Yüksek Lisans Öğrencisi Funda Nur ÇUKUR Dr. Öğr. Üyesi Hacer YILDIRIM KURTULUŞ
		8	FAMILY WELFARE AND DIGITAL RADICALIZATION: INCELS, THE DARKWEB, GENDER-BASED VIOLENCE, AND CHILD SAFETY	Dr.Öğretim Üyesi Emine Ebru BOZÇELİK
			EVLİLİK DOYUMU İLE İLGİLİ YAYINLANAN MAKALELERİN BİBLİYOMETRİK ANALİZİ	Psikolog Şeyma SÖZSOY Doç. Dr. Tuba BAĞATARHAN
			ERGENLERDE SİBER ZORBALIK: SİSTEMATİK GÖZDEN GEÇİRME	Aile Danışmanı Aysel TAŞKIN Doç. Dr. Tuba BAĞATARHAN

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HALL / SALON 9	**Assoc. Prof. Dr. Ebru KORKMAZ**	1	THE EFFECT OF GEOGEBRA SOFTWARE ON BELIEFS ABOUT GEOMETRIC THINKING HABITS	Assoc. Prof. Dr. Ebru KORKMAZ
		2	GRADUATE STUDENTS' EXPERIENCES WITH PROJECT 2237: AN EVALUATION OF GEOMETRY FIELD KNOWLEDGE, TECHNOLOGY USE, AND GEOMETRIC THINKING	Assoc. Prof. Dr. Ebru KORKMAZ
		3	DIGITAL CITIZENSHIP	Melisa ZANKİ Prof. Dr. Semra BENZER
		4	AI-SUPPORTED LEARNING ENVIRONMENT: GLOBAL CLIMATE CHANGE ASSISTANT APPLICATION WITH PICTOBLOX	Melisa ZANKİ Prof. Dr. Semra BENZER
		5	AN ACTIVITY PROPOSAL ON ETHICAL ISSUES IN THE 'TECHNOLOGY AND LIFE' UNIT OF THE 2024 SECONDARY EDUCATION PHILOSOPHY CURRICULUM	Sinem Sert Ekrem Ziya Duman
		6	2024 FELSEFE DERSİ ÖĞRETİM PROGRAMI SİYASET FELSEFESİ ÜNİTESİ İÇİN ETKİNLİK ÖNERİSİ: SANAL BELEDİYE MECLİSİ ADALETLİ ŞEHİR TASARIMI	Aybüke KIRCAN Prof. Dr. Ekrem Ziya Duman
		7	TÜRKİYE'DE OKUL YÖNETİCİLERİNİN DİJİTAL DÖNÜŞÜM ALGISI VE UYGULAMALARI	Dr. Yasin DEMİRCİ
		8	KIRSAL VE KENTSEL OKULLARDA AİLE KATILIMININ YÖNETİMİ: KARŞILAŞTIRMALI BİR ANALİZ	Dr. Yasin DEMİRCİ
			9 TH GRADE SPEAKING SKILLS IN THE TÜRKIYE CENTURY MAARIF MODEL: A QUALITATIVE DOCUMENT ANALYSIS	Ruken KIZILELMA FİDEL ÇAKMAK
			EĞİTİMDE ÖĞRETMENLER TARAFINDAN KULLANILAN YAPAY ZEKÂ TEKNOLOJİLERİNİN FIRSATLARI VE POTANSİYEL RİSKLERİ	Kübra Öztürk Dr. Adem Yurdunkulu

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HALL / SALON 10	**Doç. Dr. Firdevs SAĞLAM**	1	REFLECTING CREATIVE PRACTICE THROUGH STUDENT OUTCOMES: PURE CINEMA SHORT FILMS	Ersin ERTAN
		2	MİTOLOJİ, DİN VE SANAT ÜÇGENİNDE: BRYAN CROCKETT VE KIKI SMITH'İN SANATINDA ORTAK TEMALAR	Doç. Dr. Firdevs SAĞLAM
		3	KİMLİK, CİNSİYET VE BEDENİN ÇAĞDAŞ SANATTA YENİDEN İNŞASI	Doç. Dr. Firdevs SAĞLAM
		4	PLASTIC READINGS OF THE USE OF WRITING AS A PROPAGANDA ELEMENT IN POSTMODERN PAINTINGS	Dr. Öğretim Üyesi Mavi ÇAKMAKÇI
		5	The Mysterious Source Of Art: Magic, Image And Ritual	Öğr. Gör. Dr. Gamze URAY
		6	A READING ON ENVIRONMENTAL POLICIES IN CONTEMPORARY ART	Assoc. Prof. Dr. Burcu GÜNAY
		7	A SELECTION OF ARTISTS SHOWING A TENDENCY TOWARDS TEXTILES IN CONTEMPORARY ART	Yüksek lisans Öğrencisi Hayriye BIÇAK Doç. Dr. Burcu GÜNAY
		8	ARTIFICIAL INTELLIGENCE AS A VISUALIZATION PRACTICE IN INFOGRAPHIC DESIGNS: ALTERNATIVE INFOGRAPHIC DESIGNS OF HUMAN ANATOMY WITH INTERNAL ORGANS	Prof. Dr. Tarık YAZAR Mithat ALADAĞ
			THE USE OF MEDICAL ILLUSTRATIONS IN SURGICAL PRACTICES: BRAIN AND NERVE SURGERY INFOGRAPHIC DESIGN	Prof. Dr. Tarık YAZAR Şeymanur GENİŞ

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HALL / SALON 1	**Dr. Dawit Tesfai,**	1	INTERNATIONAL HUMANITARIAN LAW APPLICATIONS IN POST-CONFLICT RECONSTRUCTION LEGAL FRAMEWORKS	Prof. Dr. Olena Kovalenko, Dr. Mykhailo Petrenko, Iryna Sydorenko
		2	CONSTITUTIONAL REFORMS AND CIVIL LIBERTIES PROTECTION DURING ARMED CONFLICTS	Assoc. Prof. Dr. Viktoriya Melnyk, Andriy Shevchenko, Nataliya Bondarenko
		3	REFUGEE LAW CHALLENGES AND BORDER MANAGEMENT IN ERITREAN REGIONAL CONTEXTS	Dr. Dawit Tesfai, Selam Berhe
		4	MARITIME LAW DISPUTES AND FISHERIES GOVERNANCE IN RED SEA TERRITORIAL WATERS	Assis. Prof. Dr. Yonas Gebremichael, Meron Asmerom, Dr. Helen Kahsai
		5	COMPARATIVE ANALYSIS OF ISLAMIC FAMILY LAW AND SECULAR LEGAL SYSTEMS IN ALGERIA	Prof. Dr. Amina Zahir, Karim Belkacem
		6	CONSTITUTIONAL COURT JURISPRUDENCE ON HUMAN RIGHTS LITIGATION IN NORTH AFRICA	Assoc. Prof. Dr. Nadia Cherif, Samir Lounis, Yassine Hadji
		7	SHARIA LAW INTERPRETATIONS IN CONTEMPORARY OMANI COMMERCIAL CONTRACTS	Dr. Ahmed Al-Harthi, Fatima Al-Mansoori
		8	INTERNATIONAL ENVIRONMENTAL LAW COMPLIANCE IN OMAN'S OIL AND GAS SECTOR	Sultan Al-Busaidi, Assoc. Prof. Dr. Khalid Al-Maskari
		9	OIL AND GAS ARBITRATION UNDER OMANI LAW IN GCC REGIONAL DISPUTES	Prof. Dr. Nasser Al-Rashdi, Dr. Layla Al-Hinai, Tariq Al-Mahrooqi
		10	IRANIAN CYBERSECURITY LEGISLATION AND INTERNATIONAL LAW OBLIGATIONS	Dr. Reza Jafari, Soraya Mahmoudi
		11	COMPARATIVE CYBERCRIME LAWS BETWEEN IRAN AND INTERNATIONAL STANDARDS	Assoc. Prof. Dr. Mohammad Karimi, Fatemeh Hosseini

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HALL / SALON 2	**Assoc. Prof. Dr. Samir Lounis,**	1	MACROECONOMIC STABILITY CHALLENGES AND FISCAL POLICY RESPONSES IN POST-WAR UKRAINE	Prof. Dr. Olena Kovalenko, Dr. Mykhailo Petrenko, Iryna Sydorenko
		2	AGRICULTURAL EXPORT DIVERSIFICATION STRATEGIES FOR ECONOMIC RESILIENCE IN UKRAINE	Assoc. Prof. Dr. Viktor Melnyk, Dr. Natalia Bohdanova
		3	IMPACT OF FOREIGN AID ON ERITREAN NATIONAL DEVELOPMENT PROGRAMS	Dr. Dawit Tesfai, Selam Berhe
		4	PUBLIC DEBT SUSTAINABILITY ANALYSIS IN ERITREA'S CLOSED ECONOMY MODEL	Assis. Prof. Dr. Yonas Haile, Meron Ghebrezgiabher
		5	MONETARY POLICY TRANSMISSION MECHANISMS IN ALGERIAN HYDROCARBON ECONOMIES	Prof. Dr. Karim Belkacem, Dr. Nadia Cherif
		6	TRADE LIBERALIZATION EFFECTS ON ALGERIAN MANUFACTURING SECTOR COMPETITIVENESS	Assoc. Prof. Dr. Samir Lounis, Amira Bouzid
		7	INFLATION DYNAMICS AND CENTRAL BANK INDEPENDENCE IN SUDANESE ECONOMY	Dr. Ahmed El-Sayed, Fatima Hassan, Omar Khalid
		8	MICROFINANCE IMPACT ON RURAL HOUSEHOLD INCOME IN SUDAN	Prof. Dr. Ibrahim Musa, Aisha Abdelrahman
		9	EXCHANGE RATE VOLATILITY AND EXPORT PERFORMANCE IN SUDAN	Dr. Layla Mahmoud, Khalid Rahman, Sara Ali
		10	FISCAL FEDERALISM AND REGIONAL DISPARITY REDUCTION IN SUDAN	Assoc. Prof. Dr. Hassan Tavakoli, Noor Salem, Bilal Ahmed
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HALL / SALON 3	Dr. Mykola Petrenko,	1	ADVANCED MACHINING TECHNIQUES FOR HIGH-STRENGTH STEEL ALLOYS IN AEROSPACE COMPONENTS	Prof. Dr. Olena Kovalenko, Dr. Mykola Petrenko, Viktor Symonenko
		2	OPTIMIZATION OF CNC TURNING PROCESSES FOR PRECISION AUTOMOTIVE PARTS MANUFACTURING	Assoc. Prof. Dr. Iryna Bohdanova, Taras Melnyk, Dr. Sofia Lozinska
		3	ULTRASONIC ASSISTED MACHINING OF TITANIUM ALLOYS FOR MEDICAL IMPLANTS	Dawit Gebremichael, Dr. Selam Tekle
		4	ELECTROCHEMICAL MACHINING STRATEGIES FOR COMPLEX GEOMETRIES IN AEROSPACE TURBINES	Assoc. Prof. Dr. Yonas Berhe, Meron Asrat, Dr. Helen Yohannes
		5	WIRE EDM PROCESS IMPROVEMENTS FOR HARDENED TOOL STEEL DIE PRODUCTION	Prof. Dr. Elias Habte, Lina Tesfay
		6	HIGH-SPEED MILLING OPTIMIZATION FOR ALUMINUM AIRCRAFT STRUCTURAL COMPONENTS	Dr. Karim Nassar, Assis. Prof. Dr. Layla Hassan, Rami Khoury
		7	ADDITIVE MANUFACTURING POST-PROCESSING TECHNIQUES FOR METAL 3D PRINTED PARTS	Nour El-Din Mahmoud, Dr. Sara Abou-Zeid, Fadi Saliba
		8	PRECISION GRINDING METHODS FOR OPTICAL LENS MOLDING SURFACES	Prof. Dr. Ahmed El-Sayed, Dr. Fatima Ali, Omar Khalil, Nadia Rahman
		9	LASER SURFACE TEXTURING FOR ENHANCED TRIBOLOGICAL PERFORMANCE IN ENGINE PISTONS	Assoc. Prof. Dr. Hassan Ibrahim, Dr. Mariam Siddiq
		10	HYBRID MACHINING PROCESSES FOR CERAMIC MATRIX COMPOSITES IN TURBINE BLADES	Yusra Abdelrahman, Dr. Khalid Osman, Assis. Prof. Dr. Safia El-Tayeb, Amir Hassan
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HALL / SALON 4	**Assoc. Prof. Dr. Sami Khoury,**	1	THE IMPACT OF KYIVAN RUS PRINCIPALITY ON EARLY EASTERN EUROPEAN STATE FORMATION PROCESSES	Prof. Dr. Olena Kovalenko, Dr. Mykhailo Petrenko, Iryna Sydorenko
		2	OTTOMAN INFLUENCES ON 17TH-CENTURY COSSACK DIPLOMACY AND MILITARY ALLIANCES	Assoc. Prof. Dr. Volodymyr Hryhorenko, Taras Shevchenko, Nataliya Bondarenko
		3	COLONIAL ITALIAN ADMINISTRATION POLICIES AND ERITREAN IDENTITY FORMATION 1890-1941	Dr. Selam Tekle, Assis. Prof. Dr. Yonas Berhe
		4	POST-WWII BRITISH MILITARY ADMINISTRATION AND ERITREAN NATIONALIST MOVEMENTS	Meron Haile, Dr. Dawit Asmerom, Fisum Ghebrezgi
		5	FRENCH MANDATE IMPACT ON LEBANESE SECTARIAN POLITICAL STRUCTURES 1920-1943	Prof. Dr. Elias Rahbani, Dr. Nour El-Din
		6	PALESTINIAN REFUGEE INFLUENCES ON LEBANESE CIVIL WAR DYNAMICS 1975-1990	Assoc. Prof. Dr. Sami Khoury, Layla Nassar
		7	BRITISH SUDAN CAMPAIGN STRATEGIES AGAINST MAHDIST FORCES 1880S-1898	Dr. Ahmed El-Sayed, Fatima Hassan
		8	ANGLO-EGYPTIAN CONDOMINIUM POLICIES AND SUDANESE NATIONALIST AWAKENING	Prof. Dr. Omar Khalil, Dr. Mariam Siddig
		9	OTTOMAN LEGACY IN SUDANESE ISLAMIC SCHOLARSHIP AND ARCHITECTURAL PATRONS	Assoc. Prof. Dr. Yusuf Al-Tayib, Layla Ibrahim
		10	MAHDIST STATE ECONOMIC SYSTEMS AND AGRICULTURAL REFORMS IN 19TH-CENTURY SUDAN	Dr. Hassan El-Nour, Assis. Prof. Dr. Safia Ahmed, Khalid Osman
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HALL / SALON 5	**Prof. Dr. Ahmed Al-Mansoori**	1	RUSSIAN AVANT-GARDE PAINTING TECHNIQUES AND THEIR INFLUENCE ON MODERN ABSTRACT EXPRESSIONISM	Prof. Dr. Elena Petrova, Dr. Sergei Ivanov, Anna Kuznetsova
		2	ICONOGRAPHIC SYMBOLISM IN 19TH-CENTURY RUSSIAN REALIST LANDSCAPE PAINTINGS	Assoc. Prof. Dr. Mikhail Volkov, Olga Smirnova, Dmitri Fedorov
		3	CZECH CUBIST ARCHITECTURE AND URBAN SPACE TRANSFORMATION IN PRAGUE	Dr. Jana Novakova, Tomas Kral
		4	POST-WAR SURREALIST MOVEMENTS AND SCULPTURAL INNOVATIONS IN CZECH ART	Prof. Dr. Petr Svoboda, Klara Dvorakova, Lukas Hruska
		5	LEBANESE CALLIGRAPHY EVOLUTION THROUGH CONTEMPORARY ARABIC TYPOGRAPHY	Assoc. Prof. Dr. Layla Hassan, Dr. Karim El-Sayed
		6	PHoenICIAN MOTIFS IN MODERN LEBANESE CONTEMPORARY PAINTING TRADITIONS	Rami Abou Nasr, Assis. Prof. Dr. Nadia Fares, Samir Younes
		7	YEMENI TRADITIONAL TATTOO ARTISTRY AND CULTURAL IDENTITY PRESERVATION	Prof. Dr. Ahmed Al-Mansoori, Fatima Saleh
		8	WAR-TORN YEMENI STREET ART AS RESISTANCE AND SOCIAL COMMENTARY	Dr. Hassan Qasem, Noor Al-Hamdani, Yusuf Bahran
		9	SANAA WOODCARVING TECHNIQUES IN CONTEMPORARY YEMENI FURNITURE DESIGN	Assoc. Prof. Dr. Salem Al-Ghurbani, Mariam Thabit
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HALL / SALON 6	**Assis. Prof. Dr. Nadia Fares,**	1	URBAN MIGRATION PATTERNS AND SOCIAL INTEGRATION CHALLENGES IN POST-SOVIET KAZAKHSTAN	Prof. Dr. Aigerim Nurlanova, Dr. Yerzhan Tolegenov, Aidana Kassenova
		2	ETHNIC IDENTITY FORMATION AMONG MULTIGENERATIONAL KAZAKH FAMILIES IN ALMATY	Assoc. Prof. Dr. Gulnara Abayeva, Ruslan Zhumatov, Dina Sarsenbayeva
		3	GLOBALIZATION EFFECTS ON TRADITIONAL FAMILY STRUCTURES IN CZECH RURAL COMMUNITIES	Dr. Petr Novak, Klara Svobodova, Martin Dvorak
		4	SOCIAL MOBILITY BARRIERS FOR ROMA MINORITIES IN CONTEMPORARY CZECH SOCIETY	Assoc. Prof. Dr. Jana Horakova, Tomas Kral
		5	SECTARIAN CONFLICT DYNAMICS AND URBAN SEGREGATION IN POST-WAR BEIRUT	Prof. Dr. Rania Saliba, Dr. Elias Harb, Maya Nassar
		6	GENDER ROLES EVOLUTION AMONG LEBANESE DIASPORA COMMUNITIES IN EUROPE	Assis. Prof. Dr. Nadia Fares, Sami Hayek
		7	TRIBAL LOYALTY SYSTEMS VERSUS MODERN STATE FORMATION IN YEMENI SOCIETY	Dr. Ahmed Al-Mansoori, Faisal Rahman
		8	WATER SCARCITY AND INTER-TRIBAL CONFLICT ESCALATION IN YEMENI RURAL AREAS	Assoc. Prof. Dr. Huda Alawi, Khalid Saeed, Noor Al-Hadhrami
		9	YOUTH RADICALIZATION PROCESSES IN YEMEN'S CONFLICT-ZONES	Prof. Dr. Salem Qasem, Dr. Lubna Hadrami
		10	WOMEN'S SOCIAL NETWORKS AND RESILIENCE STRATEGIES DURING YEMEN CIVIL WAR	Fatima Al-Zarqa, Assis. Prof. Dr. Tariq Bin Laden, Aisha Mohammed
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HALL / SALON 7	**Assoc. Prof. Dr. Gulnara Abayeva,**	1	POST-SOVIET IDENTITY FORMATION IN KAZAKH LITERATURE THROUGH NOMADIC MOTIFS	Prof. Dr. Aigerim Tolegenova, Dr. Yerzhan Kassenov, Aidana Zhumaliyeva
		2	FEMINIST VOICES IN CONTEMPORARY KAZAKHSTANI NOVELS ADDRESSING PATRIARCHAL TRADITIONS	Assoc. Prof. Dr. Gulnara Abayeva, Nurlan Bekbolatov, Dina Sarsenbayeva
		3	CZECH SURREALISM'S INFLUENCE ON POST-COMMUNIST NARRATIVE EXPERIMENTATION	Dr. Petr Novak, Klara Svobodova
		4	KAFLKA'S LEGACY IN CONTEMPORARY CZECH GRAPHIC NOVELS AND URBAN ALIENATION THEMES	Assoc. Prof. Dr. Jana Horakova, Tomas Kral, Eva Dvorakova
		5	ARABIC POETRY TRADITIONS AND LEBANESE CIVIL WAR TRAUMA REPRESENTATIONS	Prof. Dr. Layla Harb, Dr. Sami Nader, Nour El-Khoury
		6	POSTCOLONIAL DISCOURSE IN LEBANESE DIASPORIC LITERATURE ACROSS MULTILINGUAL CONTEXTS	Assis. Prof. Dr. Rima Saliba, Elias Mitri
		7	YEMENI FOLK TALES ADAPTATION IN MODERN PROSE ADDRESSING CONFLICT AND RESILIENCE	Dr. Ahmed Al-Thawr, Fatima Saleh
		8	MAGICAL REALISM TECHNIQUES IN CONTEMPORARY YEMENI SHORT FICTION	Assoc. Prof. Dr. Khaled Bahran, Mariam Qasim, Hassan Alawi
		9	ORAL STORYTELLING TRADITIONS EVOLUTION IN YEMENI CONTEMPORARY POETRY	Prof. Dr. Yusuf Al-Amri, Dr. Lina Harb
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HALL / SALON 8	**Dr. Aizhan Kairatova,**	1	EXISTENTIAL PHILOSOPHY AND POST-SOVIET IDENTITY FORMATION IN KAZAKHSTANI SOCIETY	Prof. Dr. Almaz Tolegenov, Dr. Aizhan Kairatova, Yerzhan Nurlan
		2	NOMADIC EPISTEMOLOGY AND MODERN KAZAKH CONCEPTIONS OF KNOWLEDGE ACQUISITION	Assoc. Prof. Dr. Gulnara Sarsenova, Ruslan Bekbolatov, Dina Abayeva
		3	ALBANIAN NATIONALISM THROUGH THE LENS OF HEGELIAN DIALECTICAL PROCESSES	Dr. Liridon Hoxha, Eralda Meta, Prof. Dr. Besnik Sulaj
		4	POST-COMMUNIST ETHICS AND MORAL RECONSTRUCTION IN ALBANIAN PHILOSOPHICAL DISCOURSE	Assis. Prof. Dr. Anila Deda, Klevis Bega
		5	ISLAMIC PHILOSOPHY AND SUFISM IN CONTEMPORARY SUDANESE INTELLECTUAL TRADITIONS	Prof. Dr. Ahmed El-Sadig, Dr. Fatima Nur, Omar Khalid
		6	AFRICAN UBUNTU ETHICS VERSUS WESTERN INDIVIDUALISM IN SUDANESE MORAL PHILOSOPHY	Assoc. Prof. Dr. Hassan Al-Mahdi, Safa Ibrahim, Dr. Yassir Gumaa
		7	CONFUCIAN VIRTUE ETHICS ADAPTATION IN VIETNAMESE EDUCATIONAL PHILOSOPHY	Nguyen Thi Lan, Prof. Dr. Tran Van Minh, Le Hoang Anh
		8	EXISTENTIALISM AND BUDDHIST NON-SELF DOCTRINE IN VIETNAMESE METAPHYSICAL THOUGHT	Dr. Pham Quoc Hung, Vo Thi Mai, Assoc. Prof. Dr. Doan Van Tuan
		9	MARXIST DIALECTICS AND VIETNAMESE REVOLUTIONARY AESTHETICS IN MODERN CONTEXT	Assis. Prof. Dr. Hoang Thi Nga, Nguyen Duc Linh, Bui Kim Chi
		10	PHENOMENOLOGICAL ANALYSIS OF VIETNAMESE RURAL CONSCIOUSNESS AND URBAN TRANSITION	Dr. Le Thi Thu, Tran Minh Duc, Prof. Dr. Vuong Thi Huong
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HALL / SALON 9	**Prof. Dr. Liriana Kuci**	1	PSYCHOLOGICAL IMPACTS OF URBAN MIGRATION ON FAMILY DYNAMICS IN KAZAKHSTANI CITIES	Prof. Dr. Aigerim Sarsenova, Dr. Yerzhan Kudaibergenov, Aidana Tolegenova
		2	EFFECTS OF SOCIAL MEDIA ADDICTION ON ACADEMIC PERFORMANCE AMONG KAZAKHSTANI UNIVERSITY STUDENTS	Assoc. Prof. Dr. Gulnara Abilkair, Nurlan Bekbolatov, Dina Sarsenbayeva
		3	CULTURAL TRAUMA AND IDENTITY FORMATION IN POST-COMMUNIST ALBANIAN YOUTH	Dr. Eralda Lame, Assis. Prof. Dr. Besnik Hoxha
		4	WORKPLACE STRESS AND BURNOUT PREVALENCE AMONG ALBANIAN HEALTHCARE PROFESSIONALS	Prof. Dr. Liriana Kuci, Fatmir Deda, Anila Godo
		5	POST-TRAUMATIC STRESS DISORDER PREVALENCE AMONG SUDANESE CONFLICT SURVIVORS	Dr. Amal Hassan, Khalid Mohammed, Sara Ahmed
		6	PARENTING STYLES AND CHILD DEVELOPMENT OUTCOMES IN SUDANESE RURAL COMMUNITIES	Assoc. Prof. Dr. Fatima El-Sayed, Omar Abdelrahman
		7	MINDfulness INTERVENTIONS FOR ANXIETY REDUCTION AMONG VIETNAMESE UNIVERSITY STUDENTS	Prof. Dr. Nguyen Thi Lan, Dr. Tran Minh Hoang, Lan Anh Nguyen
		8	INTERGENERATIONAL TRAUMA EFFECTS ON MENTAL HEALTH IN VIETNAMESE FAMILIES	Dr. Pham Van Duc, Assis. Prof. Dr. Le Thi Mai
		9	DIGITAL ADDICTION AND SLEEP PATTERNS AMONG VIETNAMESE ADOLESCENTS	Assoc. Prof. Dr. Hoang Van Tuan, Nguyen Thi Hien, Vu Minh Quang
		10	RESILIENCE FACTORS IN VIETNAMESE MIGRANT WORKERS FACING LABOR EXPLOITATION	Dr. Le Ngoc Thuy, Prof. Dr. Bui Anh Tuan, Tran Thi Kim, Hoang Minh
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HALL / SALON 10	**Dr. Besnik Hoxha,**	1	IMPACT OF PHYSICAL EDUCATION PROGRAMS ON ACADEMIC PERFORMANCE AMONG IRAQI HIGH SCHOOL STUDENTS	Prof. Dr. Ahmed Al-Samarrai, Dr. Fatima Hassan, Omar Khalid
		2	EFFECTS OF TEAM SPORTS PARTICIPATION ON SOCIAL SKILLS DEVELOPMENT IN IRAQI UNIVERSITY STUDENTS	Assoc. Prof. Dr. Layla Mahmoud, Karim Nasser, Zainab Ali
		3	ROLE OF TRADITIONAL MARTIAL ARTS IN PHYSICAL EDUCATION CURRICULA FOR ALBANIAN YOUTH	Dr. Besnik Hoxha, Enea Deda
		4	INFLUENCE OF OUTDOOR ADVENTURE ACTIVITIES ON STUDENT MOTIVATION IN ALBANIAN SCHOOLS	Assis. Prof. Dr. Anila Hoxhaj, Dr. Erion Gega, Mira Lleshi
		5	ASSESSING THE IMPACT OF SPORTS PROGRAMS ON NUTRITIONAL AWARENESS AMONG SUDANESE ADOLESCENTS	Prof. Dr. Mustafa Osman, Sara Ahmed, Khalid El-Sayed
		6	EFFECTIVENESS OF PHYSICAL ACTIVITY INTERVENTIONS FOR IMPROVING CONCENTRATION IN SUDANESE PRIMARY SCHOOLS	Dr. Amina Khalil, Assoc. Prof. Dr. Hassan Ibrahim, Noor Hassan
		7	DEVELOPMENT OF SWIMMING EDUCATION PROGRAMS FOR VIETNAMESE RURAL SCHOOL CHILDREN	Nguyen Van Hai, Tran Thi Lan, Dr. Le Minh Duc
		8	INTEGRATION OF TRADITIONAL VIETNAMESE GAMES INTO MODERN PHYSICAL EDUCATION CURRICULA	Prof. Dr. Pham Thi Hong, Vo Van Truong, Nguyen Thi Mai
		9	EFFECTS OF AEROBIC EXERCISE ON COGNITIVE FUNCTION AMONG VIETNAMESE UNIVERSITY ATHLETES	Assoc. Prof. Dr. Hoang Van Nam, Le Thi Thu, Dr. Bui Quang Vinh
		10	ROLE OF SPORTS COACHING IN LEADERSHIP SKILL DEVELOPMENT FOR VIETNAMESE HIGH SCHOOL STUDENTS	Assis. Prof. Dr. Do Thi Hanh, Nguyen Van Long, Tran Minh Tuan, Pham Thi Nga
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HALL / SALON 1	**Asst. Prof. Meltem GÖKSEL KABALCI**	1	THE VISIBILITY OF ECO-COSMOLOGICAL THINKING IN CONTEMPORARY ART	Dr. Melike SUBAŞI
		2	THE WHEEL OF FORTUNE MOTIF IN TURKISH CARPET ART	Asst. Prof. Meltem GÖKSEL KABALCI
		3	HALI SANATINA ALTERNATİF ARAYIŞLAR BAĞLAMINDA: TAFTİNG HALILAR	Oğuzhan KABALCI
		4	GÖRSEL SANATLAR EĞİTİMİNDE ATIK ve KAVRAMSAL SANAT	Dr. Öğr. Üyesi Tuğba ÇELEBİ Nuran FİGEN
		5	CONTEMPORARY APPROACHES İN WEDDİNG RİNG DESİGNS	Öğretim Görevlisi Müjgan Emre
		6	Yasumasa Morimura Örneğinde Temellük Sanatı ve Anakronik Temsil	Dr. Öğr. Üyesi Aysun CANCAN Yüksek Lisans Öğrencisi Ahu Gaye EREN
		7	THE REFLECTİON OF KARA MEMİ'S UNDERSTANDİNG OF RULELESS	Doç. Mine DİLBER
		8	BİLİM KURGU SİNEMASINDA İÇ MEKÂN TASARIMI VE UZAY: 2001: A SPACE ODYSSEY ÖRNEĞİ	Doç.Dr. ÇAĞRI YALÇIN Doç.ELİF ÖZDOĞLAR
		9	ÇAĞDAŞ MEKÂN TASARIMINDA KİNETİK MEKÂN KAVRAMI: ES DEVLİN ÜZERİNDEN BİR İNCELEME	Doç.Dr. ÇAĞRI YALÇIN Doç.ELİF ÖZDOĞLAR

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HALL / SALON 2	**Dr. Öğr. Üyesi, İsa UĞUR**	1	COĞRAFİ İŞARETİN GÖRÜNMEYEN YÜZÜ: OLUMSUZ ETKİLER ÜZERİNE BİR DEĞERLENDİRME	Doç. Dr. Oya ÖZKANLI Arş. Gör. Çağlar BAYAR
		2	MODERN GASTRONOMİDE ANTİK TAHILLARIN ROLÜ VE UYGULAMA ALANLARI	Doç. Dr. Hatice PEKMEZ Arş. Gör. Çağlar BAYAR
		3	SOME OF OUR CULTURAL ASSETS RECOVERED IN OUR MUSEUMS AND THE ROLE OF OUR COUNTRY	Nevin EYİDOĞAN
		4	GASTRONOMİ VE DİJİTALLEŞME KONULU AKADEMİK YAYINLARIN TR DİZİN KAPSAMINDA BİBLİYOMETRİK ANALİZİ	Öğretim Görevlisi Meryem SET
		5	GÜNCEL BİR YAKLAŞIM OLARAK “FOOD PAIRING” AKIMI	Doç. Dr., İrfan YURT Dr. Öğr. Üyesi, İsa UĞUR
		6	SÜRDÜRÜLEBİLİR RESTORANLARDA YEREL ÜRÜN VE COĞRAFİ İŞARETLERİN ROLÜ: BİBLİYOMETRİK BİR HARİTALAMA	Doç.Dr., İrfan YURT Muhammet HASAN Dr.Öğr.Üyesi, İsa UĞUR
		7	DİJİTAL ÇAĞDA VERİ HÂKİMİYETİ: OTORİTER İLETİŞİM ORTAMLARININ YÜKSELİŞİ VE DİJİTAL DİKTATÖRLÜK	Dr. Öğr. Üyesi Mehmet Ali GAZİ
		8	SENTETİK MAĞDURİYET: YAPAY ZEKÂ TEMELLİ YARDIM GÖRSELLERİNDE AŞIRILAŞTIRILMIŞ TEMSİL VE VİCDAN DÖNGÜSÜ	Dr. Öğr. Üyesi Mehmet Ali GAZİ

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HALL / SALON 3	**Doç. Dr. Gökhan ÇAKIR**	1	UEFA ŞAMPİYONLAR LİGİ'NİN ÜLKELERE GÖRE ANALİZİ	Doç. Dr. Erdal ARI Dr. Öğr. Üyesi Abdullah ÇETİNDEMİR
		2	TÜRK FUTBOL KULÜPLERİNİN UEFA PERFORMANSI	Doç. Dr. Erdal ARI Dr. Öğr. Üyesi Abdullah ÇETİNDEMİR Kıymet UZUNER
		3	AN INVESTIGATION OF TEACHER CANDIDATES' 21ST CENTURY SKILLS AND LIFELONG LEARNING TENDENCIES	Kenan KOÇ Mustafa Soner YÜCE
		4	SCIENTIFIC RESEARCH ATTITUDES AND CAREER AWARENESS IN SPORT SCIENCES: A NARRATIVE REVIEW	Doç. Dr. Gökhan ÇAKIR
		5	SPOR BİLİMLERİ FAKÜLTESİ ÖĞRENCİLERİNDE SPORA BAĞLILIKLARININ ARAŞTIRILMASI	Gamze TEMEL Doç. Dr. Egemen ERMİŞ Prof. Dr. Osman İMAMOĞLU
		6	SPOR YAPMA DAVRANIŞ AŞAMALARINA GÖRE ÜNİVERSİTELİ ÖĞRENCİLERDE BESLENME DURUMLARI	Gamze TEMEL Doç. Dr. Egemen ERMİŞ Prof. Dr. Osman İMAMOĞLU
		7	CULTURAL IMPORTANCE OF TRADITIONAL SPORTS	Prof. Dr. Tamer KARADEMİR Gözde DUMAN
		8	INVESTIGATION OF EXERCISE ADDICTION LEVELS OF INDIVIDUALS ENGAGED IN PILATES AND FITNESS IN PRIVATE SPORTS CENTERS	Prof. Dr. Tamer KARADEMİR Gözde DUMAN
			SERUM MMP 2, MMP 9 LEVELS AND EXERCİSE: A META-ANALYSİS	Salih ÖNER Emine BÜYÜKKAYA Beyza ERTAN
			SERUM KYNURENE, TRYPTOPHAN, SEROTONIN LEVELS AND EXERCİSE: A META-ANALYSİS	Salih ÖNER İslam TARANDİR Ökkeş DERELİ
			SPOR LİSESİ ÖĞRENCİLERİNİN ALGILANAN STRES DÜZEYLERİNİN DEMOGRAFİK DEĞİŞKENLER AÇISINDAN İNCELENMESİ	Yükseklisans Öğrencisi Döne ÖKTEM Dr. Öğr. Üyesi Demet ÖZTÜRK ÇELİK

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HALL / SALON 4	**Dr. Öğretim Üyesi Zeynep KURNAZ Dr. Öğretim Üyesi Özkan ÖZTÜRK**	1	YAŞLILIĞIN TEKİLLEŞMESİ: DEMOGRAFİK DÖNÜŞÜM VE AKTİF YAŞLANMA BAĞLAMINDA TEK BAŞINA YAŞAM (SOLO LİVİNG)	Dr. Öğretim Üyesi Zeynep KURNAZ Dr. Öğretim Üyesi Özkan ÖZTÜRK
		2	ÇEVRECİ SİYASETİN NORMATİF UFKU: DEMOKRASİ, EKOLOJİK YURTTAŞLIK VE ÇEVRESEL ADALET	Dr. Öğretim Üyesi Özkan ÖZTÜRK Dr. Öğretim Üyesi Zeynep KURNAZ
		3	BİR MEKÂNSAL PRATİK OLARAK MÜDAVİMLİK	Dr. Ezgi KARMAZ
		4	GÜNDELİK HAYAT: SIRADAN OLANIN BİLİMSELLEŞTİRİLMESİ ÜZERİNE	Dr. Ezgi KARMAZ
		5	Toplumsal Kutuplaşma ve Oyun: Riskler ve Avantajlar	Öğr. Gör. Dr. Mert EREKMEKÇİ
		6	İŞGÜCÜ PİYASASI KONUMLANMASI VE SOSYAL GÜVENCE AÇIĞI: GÖÇMENLER ÜZERİNE AVRUPA ÜLKELERİNDE KARŞILAŞTIRMALI ANALİZ	Prof. Dr. Mehmet DURUEL Mehmet MUTLU
		7	GÖÇMENLERİN SOSYAL GÜVENCEYE ERİŞİMİNDE KURUMSAL EŞİTSİZLİKLER: OECD–EU-SILC AÇIK VERİLERİYLE ÇOK DÜZEYLİ BİR ANALİZ	Prof. Dr. Mehmet DURUEL Mehmet MUTLU
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HALL / SALON 5	**Doç. Dr. Selin BİTİRİM OKMEYDAN**	1	YAPAY ZEKA HABERLERİNDE KULLANILAN FOBİK TEMSİL: TRT HABER VE BİRGÜN ÖRNEĞİ	Arş. Gör. Aleyna ÖNAL Prof. Dr. Gülsüm ÇALIŞIR
		2	Disaster Communication Literature on Civil Society and Social Media: A Literature Review on the 6 February 2023 Earthquakes	Öğr. Gör. Yasemin MERİÇ Prof. Dr. Gülsüm ÇALIŞIR
		3	SOSYAL MEDYADA İÇERİK ÜRETİMİ İLE DİJİTAL SÜRDÜRÜLEBİLİRLİK FARKINDALIĞI	Dr. Öğr. Üyesi Saadet UĞURLU Nisa KÖRÜKÇÜ Celalettin AKTAŞ Ahmet Onur DAĞCI Osman AYTEKİN Yakup YENER Batuhan AKBAŞ Mahmut Cihan TOKER
		4	ÇOCUKLARDA TEKNOLOJİ BAĞIMLILIĞI TEMALI KAMU SPOTU: YEŞİLAY ÖRNEĞİ	Doç. Dr. Fikriye ÇELİK Dr. Öğr. Gör. Mustafa GÜLSÜN
		5	TRANSHÜMANİST DÜŞÜNCENİN SİNEMASAL TEMSİLİ: I AM MOTHER FİLMİ ÜZERİNE BİR İNCELEME	Dr. Öğr. Gör. Mustafa GÜLSÜN Doç. Dr. Fikriye ÇELİK
		6	SHARENTING AND THE FAMILY'S ROLE IN THE CONSTRUCTION OF DIGITAL IDENTITY	Doç. Dr. Tülay YAZICI
		7	YENİ MEDYA ÇAĞINDA GÜNDELİK HAYAT EŞLİKÇİSİ OLARAK YOUTUBE EKRANI VE ESKİ YERLİ DİZİLER: AVRUPA YAKASI ÖRNEĞİ	Nisa YILDIRIM
		8	TÜRKİYE ULUSAL BASININDA İKLİM KRİZİNİN HABER BAŞLIKLARI ÜZERİNDEN İNCELENMESİ	Öğr. Gör. Dr. Bahar BALCI AYDOĞAN
			EXAMPLES OF ARTIFICIAL INTELLIGENCE–FOCUSED STRATEGIES IN NEXT-GENERATION MARKETING	Doç. Dr. Selin BİTİRİM OKMEYDAN
			DIMENSIONS AND APPLICATION AREAS OF EXPERIENTIAL MARKETING	Doç. Dr. Selin BİTİRİM OKMEYDAN

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HALL / SALON 6	**Prof. Dr. Yusuf Sait TÜRKAN**	1	NEGATIVE EFFECTS OF ARTIFICIAL INTELLIGENCE USE ON ACADEMIC AND PERSONAL DEVELOPMENT	Prof. Dr. Yusuf Sait TÜRKAN
		2	ANALYSIS OF ARTIFICIAL INTELLIGENCE USE AND ACADEMIC ETHICAL PERCEPTION AMONG ENGINEERING STUDENTS	Prof. Dr. Yusuf Sait TÜRKAN
		3	CULTURAL ANALYSIS OF TURKISH SERIES BROADCAST IN RUSSIA IN PSYCHOLOGICAL AND SOCIOLOGICAL CONTEXT: THE EXAMPLE OF MUHTEŞEM YÜZYIL AND YALI ÇAPKINI	Yüksek Lisans Öğrencisi Deniz Rzaeva
		4	A CRITICAL EVALUATION OF THE INSTRUMENTALIZATION OF CULTURE IN THE DISCOURSE OF SUSTAINABLE DEVELOPMENT	Özlem ÖRÇEN
		5	Eleştirel Söylem Analizi Bağlamında Haber Metinlerinin İncelenmesi: 31 Mart 2024 Yerel Seçimleri Örneği	Serdar BİLİCİ Doç. Dr. Ahmet GÜNEŞ
		6	BAĞIMSIZ SİNEMANIN DAĞITIM SERÜVENİ: ANA AKIM SİNEMA KARŞISINDA ALTERNATİF ARAYIŞLAR	Doç. Dr. Erdinç Yılmaz
		7	CRISIS COMMUNICATION ON SOCIAL MEDIA: A QUANTITATIVE ANALYSIS OF X COMMENTS ON THE SHIFTDELETE.NET CASE	Oğuzhan SAYLAR Doç. Dr. İhsan TÜRKAL
		8	ERGENLİK DÖNEMİNDEKİ BİREYLERİN SOSYAL MEDYADA BİLGİYİ DEĞERLENDİRME BİÇİMLERİ: FENOMENOLOJİK BİR ARAŞTIRMA	Ece YILDIRIM Doç. Dr. Mustafa CINGI
			THE HOMME FATALE IN TURKISH CINEMA: AN ANALYSIS WITHIN THE FRAMEWORK OF NURİ ALÇO AND FARUK PEKER	Doç. Dr. M. Özer ÖZKANTAR

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HALL / SALON 7	**Prof. Dr. CANAN NAKİBOĞLU**	1	DIGITALIZATION AND ARTIFICIAL INTELLIGENCE IN EDUCATION	Doç. Dr. Celalettin KORKMAZ Prof. Dr. İmam Bakır ARABACI
		2	SCHOOL LEADERSHIP IN THE AGE OF ARTIFICIAL INTELLIGENCE AND ALGORITHMIC LEADERSHIP	Prof. Dr. İmam Bakır ARABACI Doç. Dr. Celalettin KORKMAZ
		3	DEVELOPMENT OF AN ANALYTIC RUBRIC FOR EVALUATING CHEMISTRY COURSE PUZZLES AND ASSESSING OF THE PUZZLES PREPARED BY PRE-SERVICE CHEMISTRY TEACHERS	Prof. Dr. CANAN NAKİBOĞLU
		4	PRE-SERVICE CHEMISTRY TEACHERS' PRE-INSTRUCTION LEVELS OF UNDERSTANDING AND EXEMPLIFICATION REGARDING RENEWABLE ENERGY AND ITS SOURCES	Prof. Dr. CANAN NAKİBOĞLU Prof. Dr. NURİ NAKİBOĞLU
		5	AN EVALUATION OF VISUAL ARTS EDUCATION FOR STUDENTS AGED 8-15 WITH DOWN SYNDROME: INSIGHTS FROM TEACHER PERSPECTIVES	Doç. Dr. Tülay GÜMÜŞER YL Öğrenci Hatice Merve ÖZASLAN
		6	PARENTEL PERSPECTIVES ON THE EVALUATION OF VISUAL ARTS FOR STUDENTS WTIH DOWN SYNDROME AGED 8-15	Doç. Dr. Tülay GÜMÜŞER YL Öğrenci Hatice Merve ÖZASLAN
		7	SOSYAL- DUYGUSAL ÖĞRENME BECERİLERİ BAĞLAMINDA 6. SINIF TÜRKÇE DERS KİTABININ İNCELENMESİ	Mehmet Furkan DEDE Doç. Dr. Bilal ŞİMŞEK Doç. Dr. Bekir DİREKCİ Arş. Gör. Dr. Betül KOPARAN
		8	6. SINIF TÜRKÇE DERS KİTABININ OKURYAZARLIK BECERİLERİ BAĞLAMINDA İNCELENMESİ	Ceren ÜSTÜN Doç. Dr. Bilal ŞİMŞEK Doç. Dr. Bekir DİREKCİ Arş. Gör. Dr. Betül KOPARAN
			ÖZEL GEREKSİNİMLİ ÇOCUĞU OLAN ANNELERİN İYİ OLUŞLARINA YÖNELİK DENEYSEL BİR ÇALIŞMA	Yüksek Lisans Öğrencisi Mustafa Baki Ulutaşlı Dr. Öğr. Üyesi Muhammet Fatih Yılmaz
			SPECIAL EDUCATION TEACHERS' VIEWS ON INDIVIDUALIZED EDUCATION PROGRAM PROCESSES	Elif ONUR KÖSE

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HALL / SALON 8	**Doç. Dr. Mehmet Baki BİLİK**	1	THE IMPORTANCE OF RİSK MANAGEMENT AND VULNERABİLİTY IN DİSASTERS	Doç. Dr. Mehmet Baki BİLİK
		2	ETHICAL STANDARDS IN DISASTER MANAGEMENT AND THEIR IMPORTANCE IN PRACTICE	Doç. Dr. Mehmet Baki BİLİK
		3	KOCAELİ ÜNİVERSİTESİ SOSYAL HİZMET BÖLÜMÜ ÖĞRENCİLERİNİN ALGILANAN AFET RİSK DÜZEYLERİNİN İNCELENMESİ	Hilal Narin
		4	SOSYAL HİZMET ALANINDA ÇALIŞAN MESLEK ELEMANLARININ ROL ÇATIŞMASI YAŞAMA DURUMLARININ İNCELENMESİ: İZMİT İLÇESİ ÖRNEĞİ	Sosyal Hizmet Uzmanı – Hilal KANDAZ YILDIZ
		5	AFETLERDE DEZAVANTAJLI GRUPLAR: KADINLAR ÜZERİNDEKİ ETKİLER VE HALK SAĞLIĞI HEMŞİRELİĞİ PERSPEKTİFİ	Doç. Dr. Sonay BİLGİN Öğr. Gör. Dr. Selen ÖZDEMİR
		6	ADLİ SİSTEME DAHİL OLAN ÇOCUKLARIN, ADLİ SÜREÇTE GÖZLEMLENEN DENEYİMLERİNİN ADLİYEDE GÖREV YAPAN PSİKOSOSYAL DESTEK ELEMANLARI TARAFINDAN DEĞERLENDİRİLMESİ	Simge ŞİRET
		7	TÜRKİYE'DE KAZALAR, CİNAYET/SALDIRI VE İNTİHAR KAYNAKLI ÖLÜMLERİN CİNSİYETE GÖRE DAĞILIMI (2018–2024)	Arş. Gör. Sümeyra SEZER KAPLAN

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HALL / SALON 9	**Prof. Dr. Ünal İMİK Öğr. Gör. Aykut Alp TETİK**	1	HACI TASAN'S ARTISTIC PERSONALITY AND CONTRIBUTIONS TO TURKISH FOLK MUSIC	Prof. Dr. Ünal İMİK Öğr. Gör. Aykut Alp TETİK
		2	EROL PARLAK'S ARTISTIC PERSONALITY AND HIS CONTRIBUTIONS TO THE TRT TURKISH FOLK MUSIC BROKEN REPERTOIRE	Öğr.Grv. Aykut Alp Tetik Prof. Dr. Ünal İMİK
		3	CARL JOACHİM ANDERSEN'İN OP.41 NO.7 ETÜDÜNÜN FLÜT EĞİTİMİ BAĞLAMINDA TEKNİK VE BİÇİMSEL ANALİZİ	Lara Nil KARCIK Dr. Öğr. Üyesi Ezgi ERTEK BABAÇ Dr. Öğr. Muzaffer Soner YILMAZ
		4	ORTAOKUL DÜZEYİNDE PİYANO EĞİTİMİNİN ELEŞTİREL DÜŞÜNME BECERİLERİNE KATKISI	Yüksek Lisans Öğrencisi Yunus Emre AÇIKGÖZ Doç. Dr. Verda KARAÇİL CERİT
		5	PİYANO EŞLİKÇİLİĞİNİN ÖNEMİ VE TARİHSEL GELİŞİMİ	Can HACIOĞLU Prof. Dr. Zeynep Ebru AYATA
		6	Güfte Mecmualarından Örneklerle Osmanlı'da Bir Kadın Bestekar: Dilhayat	Ceren KARTAL Doç.Dr. Şeyma ERSOY ÇAK
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HALL / SALON 10	**Doç. Dr. Demet DÖNMEZ**	1	KAMU İHALE PİYASALARINDA REKABET VE ŞEFFAFLIK: AVRUPA TED AÇIK İHALE İLANLARIYLA ÜLKE DÜZEYİNDE SATIN ALMA PERFORMANSI ANALİZİ	Doç. Dr. Demet DÖNMEZ
		2	YÖNETSEL KAPASİTE KAMU HİZMET ÇIKTILARINI İYİLEŞTİRİR Mİ? DÜNYA BANKASI WGI–WDI AÇIK VERİLERİYLE PANEL VERİ ANALİZİ (1996–2024)	Doç. Dr. Demet DÖNMEZ
		3	KAMU GÖREVLİLERİ ETİK KURULUNUN PERSONEL SİSTEMİNDEKİ DENETİM MEKANİZMASINA OLASI ETKİLERİ	Rukiye DEVELİ TAŞ Doç. Dr. Hava TAHTALIOĞLU
		4	AB BÜTÇESİNDE DOĞRUDAN YÖNETİLEN FONLARDA YARARLANICI YOĞUNLAŞMASI VE KURUMSAL ERİŞİM: FTS–ŞEFFAFLIK SİCİLİ–KOMİSYON GÖRÜŞMELERİ VERİLERİYLE DİNAMİK AĞ ANALİZİ	Doç. Dr. Soner AKIN
		5	AB DÜZENLEYİCİ YÖNETİŞİM: DSA KAPSAMINDA PLATFORMLARIN “UYUM DAVRANIŞI” ANALİTİĞİ	Doç. Dr. Soner AKIN
		6	BÖLGESEL VE YEREL KALKINMADA İKLİM DEĞİŞİKLİĞİNİN ROLÜ	Günay GÖNÜLLÜ Ç. Ozan GÖNÜLLÜ
		7	YEŞİL ŞEHİR POLİTİKALARI VE YEREL YÖNETİMLERİN ROLÜ: DÜNYA VE TÜRKİYE ÜZERİNE BİR ANALİZ	Doç. Dr. Makbule ŞİRİNER ÖNVER Doç. Dr. Günay GÖNÜLLÜ
		8	TÜRKİYE’NİN AFET RİSK PROFİLİNİN KAMU YÖNETİMİ PERSPEKTİFİNDEN DEĞERLENDİRİLMESİ	Dr. Öğr. Üyesi Galip USTA Dr. Öğr. Üyesi Ezgi ATALAY
		9	The Politicization of Urban Space: The Diplomatic Utilization of “City Space” at the Intersection of Domestic and Foreign Policy	Aslıhan ÇİÇEK Dr. Öğr. Üyesi ALİ ÇİÇEK
		10	SOSYAL BELEDİYECİLİK ve YEREL YÖNETİMLER	Doç.Dr.İsmail GÜNEŞ Batuhan İNALTEKİN
		11	TÜRKİYE VE AZERBEYCAN AİLE VE SOSYAL POLİTİKALAR BAKANLIĞININ FAALİYETLERİNİN VE POLİTİKALARININ WEB SAYFASI İÇERİĞİ İLE KARŞILAŞTIRILMASI	Mansur Mehdiyev

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HALL / SALON 11	**Asst. Prof. Dr. Derya YÜCEL**	1	THE POWER OF SOCIAL MEDIA IN DIGITAL ENTREPRENEURSHIP	Dr. Meftun Deniz Prof. Dr. Seyhun Doğan
		2	ANTI-SOCIAL WORKING HOURS	Assistant Professor Yusuf Erdem TUNÇ
		3	FAMILY-BASED CARE POLICIES	Assistant Professor Yusuf Erdem TUNÇ
		4	THE EFFECTS OF EXPERİMENTAL WORKSHOP STRUCTURES ON ORGANİZATİONAL CREATİVİTY İN TEXTİLE INDUSTRY DESİGN CENTERS	Doç. Vildan TOK DERECİ Sinem ÇAVDAR
		5	THE IMPACT OF DIGITAL EDUCATION PLATFORMS ON CORPORATE IMAGE AND PERCEPTION MANAGEMENT: A QUALITATIVE STUDY ON UNIVERSITY STUDENTS	Gözde KUZU ULUÇAY
		6	THE IMPACT OF ARTIFICIAL INTELLIGENCE–SUPPORTED PERSONALIZATION APPROACHES IN LEARNING MANAGEMENT SYSTEMS ON LEARNING PROCESSES	Ahmet Gökhan ULUÇAY
		7	THE IMPACT OF PROACTIVE PERSONALITY ON EMPLOYEE MOTIVATION: A STUDY ON EMPLOYEES IN DIFFERENT SECTORS	Yasamin Ghaffari Jourabi Doç. Dr. Öğretim Üyesi Ali Leventeli
		8	DO EASTBOUND AND WESTBOUND FREIGHT RATES LEAD EACH OTHER? A LINEAR GRANGER CAUSALITY ANALYSIS ON THE SHANGHAI–ROTTERDAM ROUTE	Abdullah Açık Bunyamin Kamal
		9	STATE-DEPENDENT EFFECTS OF CARBON PRICES ON DRY BULK FREIGHT MARKETS: EVIDENCE FROM QUANTILE REGRESSION	Abdullah Açık Bunyamin Kamal
		10	THE IMPORTANCE OF SOCIAL SUSTAINABILITY WITHIN THE FRAMEWORK OF SUSTAINABILITY MANAGEMENT: A COMPARATIVE CASE ANALYSIS OF GLOBAL AND TÜRKİYE CONTEXTS	Asst. Prof. Dr. Derya YÜCEL
		11	THE EVOLUTION AND FUTURE TRENDS OF SOCIAL SUSTAINABILITY LITERATURE: A COMPREHENSIVE BIBLIOMETRIC ANALYSIS (1993-2025)	Asst. Prof. Dr. Derya YÜCEL Res. Asst. Fatih EROĞLU
		12	TÜKETİCİLERİN KARBON AYAK İZİ FARKINDALIĞININ KURUMSAL SÜRDÜRÜLEBİLİRLİK STRATEJİLERİNDEKİ ROLÜ	Doç. Dr. Talha BAYIR

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HALL / SALON 1	**Dr. Budi Santoso,**	1	PUBLIC ADMINISTRATION REFORMS FOR POST-CONFLICT GOVERNANCE RECONSTRUCTION IN IRAQ	Prof. Dr. Ahmed Al-Samarrai, Dr. Fatima Hassan, Omar Khalid
		2	DECENTRALIZATION CHALLENGES AND LOCAL GOVERNMENT CAPACITY BUILDING IN IRAQI PROVINCES	Assoc. Prof. Dr. Layla Mahmoud, Dr. Sami Rashid, Noor Ibrahim
		3	E-GOVERNMENT IMPLEMENTATION STRATEGIES FOR ENHANCING PUBLIC SERVICE DELIVERY IN INDONESIA	Dr. Budi Santoso, Assoc. Prof. Dr. Sari Wijaya
		4	CORRUPTION PREVENTION MECHANISMS AND ADMINISTRATIVE TRANSPARENCY IN INDONESIAN BUREAUCRACY	Prof. Dr. Agus Pratama, Lina Setiawati, Rina Kusuma
		5	PUBLIC SECTOR REFORM INITIATIVES ADDRESSING CIVIL SERVICE PROFESSIONALIZATION IN SUDAN	Dr. Abdelrahman El-Siddig, Fatima Ali, Assis. Prof. Dr. Omar Hassan
		6	LOCAL GOVERNANCE MODELS FOR CONFLICT MANAGEMENT AND COMMUNITY DEVELOPMENT IN SUDAN	Assoc. Prof. Dr. Nadia Khalil, Dr. Mustafa Osman
		7	DIGITAL GOVERNANCE TRANSFORMATION THROUGH SMART CITY INITIATIVES IN TAIWAN	Prof. Dr. Chen Wei-Ling, Dr. Lin Mei-Hua, Wang Hao
		8	PUBLIC POLICY EVALUATION FRAMEWORKS FOR SUSTAINABLE DEVELOPMENT IN TAIWAN	Dr. Huang Pei-Chen, Assis. Prof. Dr. Tsai Ming-Jie, Liu Chun-Yi
		9	CIVIL SERVICE REFORM AND PERFORMANCE MANAGEMENT SYSTEMS IN TAIWANESE ADMINISTRATION	Assoc. Prof. Dr. Wu Li-Chun, Chang Yu-Ting
		10	INTERGOVERNMENTAL FISCAL RELATIONS AND LOCAL BUDGET AUTONOMY IN TAIWAN	Prof. Dr. Lee Hsiao-Wen, Dr. Yeh Shu-Fen, Chen Yi-Jing, Kao Ming-Hsien
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HALL / SALON 2	**Assoc. Prof. Dr. Huang Tsung**	1	WOMEN'S COOPERATIVES AS CATALYSTS FOR SOCIAL COHESION IN SUDANESE REFUGEE CAMPS	Dr. Aisha Mohammed, Fatima El-Sayed
		2	RESTORATIVE JUSTICE CIRCLES FOR CONFLICT RESOLUTION IN DARFUR COMMUNITIES	Assis. Prof. Dr. Hassan Ibrahim, Mariam Ahmed, Khalid Osman
		3	TRADITIONAL CONFUCIAN MEDIATION MODELS FOR URBAN NEIGHBORHOOD DISPUTES IN TAIWAN	Prof. Dr. Chen Wei-Ling, Dr. Lin Mei-Hua, Wang Jia-Hao
		4	INDIGENOUS RITUALS AND MODERN PSYCHOSOCIAL SUPPORT FOR TAIWAN ABORIGINAL HEALING	Assoc. Prof. Dr. Huang Tsung-Yi, Li Pei-Chen, Chang Yu-An
		5	ECOLOGICAL RESTORATION PROJECTS FOSTERING COMMUNITY SOLIDARITY IN TAIWANESE RURAL VILLAGES	Dr. Tsai Ming-Ju, Liu Hao-Wei, Prof. Dr. Wu Shu-Fen, Chen Li-Ting
		6	COMMUNITY RECONCILIATION PROGRAMS FOR POST-CONFLICT HEALING IN IRAQI SUNNI-SHIA NEIGHBORHOODS	Prof. Dr. Ahmed Al-Samarrai, Dr. Fatima Hassan, Omar Khalid
		7	TRAUMA RECOVERY INITIATIVES THROUGH INTERGENERATIONAL DIALOGUE IN IRAQI KURDISTAN	Assoc. Prof. Dr. Layla Mahmoud, Karim Aziz, Dr. Nadia Rahman, Sara Ismail
		8	INTEGRATING TRADITIONAL HEALING PRACTICES IN INDONESIAN POST-DISASTER COMMUNITY RECOVERY	Dr. Budi Santoso, Assoc. Prof. Dr. Sari Wijaya
		9	YOUTH-LED PEACEBUILDING WORKSHOPS ADDRESSING ETHNIC TENSIONS IN ACEH PROVINCE	Prof. Dr. Rina Setiawati, Adi Pratama, Lina Sari
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HALL / SALON 3	**Dr. Kiptoo Arap,**	1	DIGITAL MEDIA INFLUENCE ON YOUTH POLITICAL MOBILIZATION DURING KENYAN ELECTIONS	Prof. Dr. Jane Mwangi, Dr. Kiptoo Arap, Sarah Njoroge, Elias Ochieng
		2	SOCIAL MEDIA PROPAGANDA TACTICS IN ETHNIC CONFLICT NARRATIVES IN KENYA	Assoc. Prof. Dr. Paul Kimani, Miriam Wanjiku, Dr. Hassan Omar
		3	COMMUNITY RADIO'S ROLE IN HIV/AIDS AWARENESS CAMPAIGNS IN RURAL KENYA	Dr. Agnes Kiptoo, Samuel Otieno, Grace Muthoni
		4	SMARTPHONE ADOPTION PATTERNS AND INFORMATION ACCESS IN KENYAN SLUMS	Assis. Prof. Dr. Ruth Ndung'u, James Kariuki, Amina Hassan, Peter Mbugua
		5	WHATSAPP MISINFORMATION CAMPAIGNS DURING PAKISTANI POLITICAL CRISES	Prof. Dr. Fatima Ahmed, Dr. Bilal Khan, Sana Rehman
		6	TELEVISION FRAMING OF GENDER ISSUES IN CONSERVATIVE PAKISTANI SOCIETY	Assoc. Prof. Dr. Nadeem Malik, Ayesha Siddiqui, Imran Farooq
		7	BOLSONARO ERA FAKE NEWS ECOSYSTEMS ON BRAZILIAN SOCIAL PLATFORMS	Dr. Carlos Silva, Prof. Dr. Mariana Costa, Lucas Pereira, Sofia Ramos
		8	TELEVISÃO FRAMING OF AMAZON RAINFOREST DESTRUCTION IN BRAZILIAN MEDIA	Assoc. Prof. Dr. Roberto Lima, Ana Beatriz, João Mendes
		9	PODCAST INFLUENCE ON YOUTH POLITICAL ENGAGEMENT IN URBAN BRAZIL	Dr. Fernanda Oliveira, Gabriel Santos
		10	DIGITAL DIVIDE AND RURAL BROADBAND ACCESS CHALLENGES IN BRAZIL	Assis. Prof. Dr. Thiago Correa, Isabela Nunes, Pedro Almeida, Dr. Laura Mendes
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HALL / SALON 4	**Dr. Samuel Otieno,**	1	**IMPACT OF CLIMATE-INDUCED RURAL-TO-URBAN MIGRATION ON NAIROBI SLUM COMMUNITIES**	Prof. Dr. Mwangi Kiptoo, Dr. Amina Hassan, Joseph Njoroge
		2	**SOCIOECONOMIC INTEGRATION CHALLENGES FOR SOMALI REFUGEES IN KENYAN BORDER TOWNS**	Assoc. Prof. Dr. Esther Wanjiku, Omar Abdullahi, Grace Muthoni
		3	**GENDER DYNAMICS IN INTERNAL DISPLACEMENT PATTERNS ACROSS KENYAN ARID LANDS**	Dr. Samuel Otieno, Fatma Ali, Peter Kimani
		4	**EDUCATIONAL BARRIERS FACING REFUGEE CHILDREN IN DADAAB CAMPS LONG-TERM**	Njeri Mwangi, Prof. Dr. David Kariuki, Salma Ibrahim
		5	**LABOR MIGRATION PATTERNS FROM RURAL PAKISTAN TO GULF COUNTRIES ECONOMIC IMPACTS**	Dr. Ahmed Khan, Fatima Zahra, Bilal Rehman
		6	**AFGHAN REFUGEE RESETTLEMENT EXPERIENCES IN PAKISTANI URBAN NEIGHBORHOODS**	Assoc. Prof. Dr. Sara Malik, Imran Siddiqui
		7	**URBAN INFORMAL ECONOMY PARTICIPATION AMONG BRAZILIAN NORTHEASTERN MIGRANTS**	Prof. Dr. Carlos Silva, Maria Oliveira, João Pereira
		8	**VENEZUELAN MIGRANT INTEGRATION CHALLENGES IN SÃO PAULO LABOR MARKETS**	Dr. Ana Ribeiro, Lucas Santos, Camila Ferreira
		9	**CLIMATE MIGRATION EFFECTS ON AMAZON RURAL COMMUNITIES AND INDIGENOUS POPULATIONS**	Assis. Prof. Dr. Rafael Lima, Dr. Isabel Costa

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HALL / SALON 5	**Prof. DR. Nourredine Cherifi,**	1	THE INTERPLAY OF RELIGION AND PHILOSOPHY IN AZERBAIJANI CULTURAL CONTEXT	Nigar Mammadova, Elvin Huseynov,
		2	PHILOSOPHICAL FOUNDATIONS OF RELIGIOUS BELIEFS IN MODERN AZERBAIJAN	Farid Aliyev, Leyla Ismayilova
		3	THE INFLUENCE OF ISLAMIC PHILOSOPHY ON CONTEMPORARY ETHICS IN IRAN	Dr. Mohammad Rezaei, Lec. Simin Ahmadi,
		4	RELIGION AND PHILOSOPHY: A CRITICAL STUDY OF REASON AND FAITH IN IRANIAN THOUGHT	Ali Karimi, Fatemeh Hosseini,
		5	RELIGIOUS PHILOSOPHY AND NATIONAL IDENTITY IN ALGERIA	Assoc. Prof. Dr. Yacine Belkacem, Amira Bouzid, Karim Mansouri,
		6	THE ROLE OF PHILOSOPHY IN SHAPING ALGERIAN THEOLOGICAL DISCOURSE	Prof. DR. Nourredine Cherifi,
		7	THE SYNTHESIS OF RELIGIOUS AND PHILOSOPHICAL THOUGHT IN GEORGIAN INTELLECTUAL TRADITIONS	Dr. Nino Beridze, Dr. Levan Tsereteli,
		8	MODERN GEORGIAN PHILOSOPHICAL REFLECTIONS ON THE MEANING OF FAITH	Tamar Javakhishvili, Assis. Prof. Dr. Giorgi Kapanadze,

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HALL / SALON 6	**Dr. Roya Ebrahimi,**	1	INNOVATIVE TEACHING METHODS TO ENHANCE STUDENT ENGAGEMENT	Altynay Kussainova, Dr. Yerlan Sadykov
		2	THE IMPACT OF DIGITAL TOOLS ON LEARNING OUTCOMES IN HIGHER EDUCATION	Assoc. Prof. Dr. Aigerim Nurgalieva, Didar Zhumabaev
		3	CHALLENGES OF REMOTE EDUCATION AND STRATEGIES FOR IMPROVEMENT	Dr. Roya Ebrahimi, Assis. Prof. Dr. Seyed Karim Hosseini
		4	THE ROLE OF CULTURAL CONTEXT IN CURRICULUM DEVELOPMENT	Leila Mortazavi, Dr. Hamid Reza Balouchi
		5	ASSESSING THE EFFECTIVENESS OF INCLUSIVE EDUCATION POLICIES IN INDIA	Prof. Dr. Anjali Rajan, Dr. Vikram Singh
		6	TEACHER TRAINING PROGRAMS AND THEIR EFFECT ON CLASSROOM MANAGEMENT	Assoc. Prof. Dr. Priya Menon, Sunil Sharma
		7	THE USE OF PROJECT-BASED LEARNING TO BOOST CRITICAL THINKING SKILLS	Prof. Dr. Nino Gelashvili, Irakli Donadze
		8	IMPROVING STUDENT MOTIVATION THROUGH PERSONALIZED LEARNING PATHWAYS	Assis. Prof. Dr. Mariam Beridze, Giorgi Kvaratskhelia
		9	THE EFFECT OF EDUCATIONAL TECHNOLOGY ON STUDENT ACHIEVEMENT RATES	Dr. Khatuna Bakradze, Prof. Dr. Levan Tsiklauri, Natia Chikhradze

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HALL / SALON 7	**Assoc. Prof. Dr. Fatemeh Zare**	1	STRATEGIC MANAGEMENT PRACTICES AND THEIR IMPACT ON ORGANIZATIONAL PERFORMANCE	Prof. Dr. Saima Ahmed, Dr. Faraz Khan, Ayesha Malik
		2	THE ROLE OF LEADERSHIP STYLES IN ENHANCING EMPLOYEE MOTIVATION	Assoc. Prof. Dr. Imran Siddiqui, Ali Raza, Dr. Sana Javed
		3	DIGITAL TRANSFORMATION AND ITS EFFECT ON BUSINESS COMPETITIVENESS	Cristina Popescu, Prof. Dr. Andrei Ionescu
		4	SUSTAINABILITY INITIATIVES IN SMALL AND MEDIUM ENTERPRISES: A ROMANIAN PERSPECTIVE	Dr. Elena Georgescu, Assis. Prof. Dr. Mihai Dumitrescu
		5	THE INFLUENCE OF CUSTOMER RELATIONSHIP MANAGEMENT ON SALES GROWTH	Dr. Sara Mohammadi, Prof. Dr. Reza Kazemi
		6	ANALYZING MARKET ENTRY STRATEGIES FOR IRANIAN STARTUPS	Mohammad Rahimi, Assoc. Prof. Dr. Fatemeh Zare
		7	EFFECTS OF CORPORATE GOVERNANCE ON FIRM PERFORMANCE IN EGYPT	Prof. Dr. Ahmed El-Sayed, Dr. Mona Hassan
		8	IMPLEMENTING INNOVATION MANAGEMENT TO DRIVE BUSINESS SUCCESS	Assis. Prof. Dr. Youssef Abdelrahman, Sara Ibrahim
		9	THE IMPACT OF ECONOMIC POLICIES ON ENTREPRENEURSHIP DEVELOPMENT	Dr. Hany Mostafa, Prof. Dr. Salma Farouk, Tarek Adel
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HALL / SALON 8	**Assis.Prof. Dr. Hanaa Abdelaziz,**	1	ECONOMIC IMPACT OF TOURISM DEVELOPMENT IN CUBA	Prof. Dr. Maria Fernandez, Dr. Carlos Ruiz, Ana Lopez Jose Martinez,
		2	ANALYSIS OF SOCIAL POLICIES AND ECONOMIC GROWTH IN CUBAN ECONOMY	Assoc. Prof. Dr. Elena Garcia
		3	THE ROLE OF SMALL AND MEDIUM ENTERPRISES IN ALBANIAN ECONOMIC TRANSITION	Dr. Arben Kola, Assis. Prof. Dr. Elira Shehu, Gentian Dervishi
		4	FINANCIAL MARKET DEVELOPMENT AND INVESTMENT STRATEGIES IN ALBANIA	Prof. Dr. Ervin Meta, Dr. Blerina Hoxha
		5	INFLATION DYNAMICS AND MONETARY POLICY EFFECTIVENESS IN IRAN	Dr. Reza Kian, Prof. Dr. Leila Mohammadi
		6	LABOR MARKET CHALLENGES AND UNEMPLOYMENT TRENDS IN IRANIAN ECONOMY	Mohammad Salehi, Assoc. Prof. Dr. Sara Razavi Prof. Dr. Mona Youssef
		7	ANALYSIS OF FISCAL POLICIES AND PUBLIC DEBT MANAGEMENT IN EGYPT	Dr. Ahmed Naguib,
		8	AGRICULTURAL SECTOR'S CONTRIBUTION TO EGYPTIAN ECONOMIC DEVELOPMENT	Assoc. Prof. Dr. Karim Hassan, Mostafa El-Sayed, Sarah Kamal Omar Said

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HALL / SALON 9	**Assoc. Prof. Dr. Somchai Phanvilay,**	1	THE EVOLUTION OF TRADITIONAL LAO POETRY IN CONTEMPORARY LITERATURE	Assoc. Prof. Dr. Somchai Phanvilay,
		2	CULTURAL IDENTITY AND LANGUAGE PRESERVATION IN LAO FOLKTALES	Assoc. Prof. Dr. Bounmy Keomany, Phouthone Phommasane, Dr. Sombath Vilay Dr. Ketsana Vang
		3	THE INFLUENCE OF ANCIENT EGYPTIAN MYTHOLOGY ON MODERN LITERARY THEMES	Dr. Ahmed El-Sayed, Prof. Dr. Mona Hassan
		4	POSTCOLONIAL NARRATIVES IN EGYPTIAN LITERATURE: A CRITICAL ANALYSIS	Assis. Prof. Dr. Youssef Mohamed, Dina Abdelrahman Prof. Dr. Habibullah Rahimi, Dr
		5	REPRESENTATIONS OF WAR AND PEACE IN AFGHAN LITERATURE	. Fariba Saeedi
		6	THE ROLE OF ORAL TRADITIONS IN AFGHANISTAN'S LITERARY IDENTITY	Nazan Gul, Assoc. Prof. Dr. Ahmad Wali
		7	EXPLORING KYRGYZ EPIC POETRY AND ITS SOCIAL FUNCTIONS	Assoc. Prof. Dr. Bekmamat Umetaliev Dr. Aizada Toktogulova
		8	THE IMPACT OF SOVIET LITERARY LEGACY ON KYRGYZ WRITERS	Prof. Dr. Zamira Usupova, Nurjan Sadykova Dr. Mirbek Isakov, Assis. Prof. Dr. Aigul Tynchtykbekova, Elmira Bakytova
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HALL / SALON 10	**Dr. Elena Smirnova**	1	THE EVOLUTION OF INTERNATIONAL HUMAN RIGHTS LAW IN AFRICA	Prof. Dr. Amina Dube, Kwame Nkrumah, Zanele Khumalo
		2	LEGAL FRAMEWORKS FOR ENVIRONMENTAL PROTECTION IN SUB-SAHARAN AFRICA	Dr. Michael Owusu, Assoc. Prof. Dr. Thandi Mbeki, Samuel Adeyemi
		3	THE ROLE OF SHARIAH LAW IN OMAN'S LEGAL SYSTEM	Fatima Al-Harthy, Dr. Saif Al-Rawahi
		4	ANALYSIS OF COMMERCIAL LAW REFORMS IN OMAN FOR FOREIGN INVESTMENTS	Assoc. Prof. Dr. Khalid Al-Amri, Nawal Said, Faisal Al-Hinai, Dr. Mariam Al-Kindi
		5	CYBERSECURITY LEGISLATION AND DATA PROTECTION IN RUSSIA	Igor Petrov, Dr. Elena Smirnova
		6	CRIMINAL JUSTICE REFORMS AND HUMAN RIGHTS PROTECTION IN RUSSIA	Assoc. Prof. Dr. Alexei Volkov, Dr. Oksana Kuznetsova, Ivan Morozov
		7	CHALLENGES OF ENFORCING INTELLECTUAL PROPERTY RIGHTS IN NIGERIA	Prof. Dr. Chinedu Okeke, Ifeoma Nwosu
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Melilotus indica (L.) All. KÖK NODÜLÜNDEN İZOLE EDİLEN *Sinorhizobium meliloti* 3BVE'NİN GENOMİK KARAKTERİZASYONU

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ÖZET

Rizobium–baklagil simbiyozu, karasal ekosistemlerde sürdürülebilir azot döngüsünün temel bileşenlerinden biridir. Bu çalışmada, Türkiye'nin batısında yer alan İzmir ili Ödemiş ilçesi Bozdağ Kayak Merkezi çevresindeki subalpin bir bölgeden (1550 m rakım) toplanan *Melilotus indica* (Herbaryum No: EGE-44028) kök nodüllerinden *Sinorhizobium meliloti* suşu 3BVE izole edilmiştir. İzolatın taksonomik tanımlaması, öncelikle 16S rRNA ve recA genlerine dayalı PCR ve dizi analizleri ile gerçekleştirilmiş; ardından izolatın ayrıntılı genomik karakterizasyonu amacıyla tüm genom dizilemesi yapılmıştır. Taslak genom dizisi, toplam 6.927.931 baz çifti uzunluğa ve %62,10 GC içeriğine sahip olup 268 kontigden oluşmaktadır. Genom anotasyonu sonucunda 7.207 tahmini kodlama dizisi (CDS), 52 tRNA geni ve 5 rRNA operonu tanımlanmıştır. Fonksiyonel genomik analizler, nodülasyonla ilişkili temel genlerin (*nodABCDN* ve nolO) varlığını ortaya koyarak izolatın işlevsel bir nodülasyon kapasitesine sahip olduğunu göstermiştir. Buna ek olarak, nitrojenaz kompleksinin temel bileşenlerini kodlayan *nifABEHN* genlerinin tespiti, izolatın simbiyotik azot fiksasyonu potansiyelini genomik düzeyde ortaya çıkarmıştır. Yüksek rakımlardaki baklagil türlerinden izole edilen Rhizobial suşlar çevresel strese dayanıklı genetik kaynaklar oluşturarak, çölleşme ve kuraklık gibi küresel tehditler karşısında ekosistem dayanıklılığının sürdürülmesinde potansiyel bir rol oynayabilir.

Anahtar Kelimeler: *Sinorhizobium meliloti*, azot fiksasyonu, genomik

1. GİRİŞ

Simbiyotik azot fiksasyonu, atmosferde bol miktarda bulunmasına karşın biyolojik olarak inert olan moleküler azotun (N_2), canlılar tarafından kullanılabilir formlara dönüştürülmesini sağlayan en kritik biyokimyasal süreçlerden biridir (Newton vd., 1983). Bu süreç, yalnızca prokaryotik organizmalara özgü olan nitrojenaz enzim kompleksi aracılığıyla gerçekleştirilir ve küresel azot döngüsünün temelini oluşturur. Özellikle baklagil bitkileri ile *Rhizobial* bakteriler arasında gelişen simbiyotik ilişki, biyolojik azot fiksasyonunun en verimli ve evrimsel açıdan en rafine edilmiş örneği olarak kabul edilmektedir (Lindström ve Mousavi, 2020). Bu mutualistik ortaklık sonucunda, bitki köklerinde oluşan nodüller içerisinde bakteriler tarafından atmosferik azot indirgenirken, bitki de bakterilere karbon kaynakları ve korunaklı bir niş sağlamaktadır (Zahran, 2001).

Rhizobium–legümen simbiyozu, taraflar arasında yüksek derecede özgüllük içeren moleküler bir iletişim ve genetik koordinasyon gerektirir. Nodül oluşumu, bakteriler tarafından sentezlenen Nod faktörlerinin bitki tarafından algılanması ve ortak simbiyotik sinyal yolunun aktive edilmesiyle başlatılır. Nodül iç ortamında ise oksijene son derece duyarlı olan nitrojenaz enziminin korunması, mikroaerobik koşulların oluşturulması ve leghemoglobin aracılığıyla kontrollü oksijen taşınması sayesinde mümkün olmaktadır. Bu hassas denge, simbiyozun işlevselliğini sürdürebilmesini sağlar (Gorgia ve Tsikou, 2025).

Melilotus indica (L.) All., Fabaceae (Leguminosae) familyasına ait, tek yıllık veya kısa ömürlü iki yıllık otsu bir baklagil türüdür ve özellikle Akdeniz havzası, Orta Doğu ve Güney Asya kökenli olup günümüzde dünyanın birçok ılıman ve yarı kurak bölgesine yayılmıştır Azani vd., 2017). Düşük besin içerikli, kuraklığa ve tuzluluğa toleranslı topraklarda gelişebilme yeteneği sayesinde doğal ve tarımsal ekosistemlerde önemli bir öncü tür olarak kabul edilmektedir. *M. indica*, *Sinorhizobium*/*Ensifer* türleriyle kurduğu simbiyotik ilişki aracılığıyla biyolojik azot fiksasyonu gerçekleştirebilmekte, bu sayede toprak verimliliğini artırarak sürdürülebilir tarım ve mera ıslahı uygulamalarında değerlendirilmektedir (Sonju vd., 2017).

S. meliloti, toprak ekosistemlerinde hem ekolojik sürdürülebilirlik hem de endüstriyel biyoteknoloji açısından stratejik öneme sahip bir Gram-negatif bakteridir. Serbest yaşayan bir organizma olmasının yanı sıra, *Medicago* türleri başta olmak üzere baklagil bitkileriyle kurduğu yüksek özgüllüğe sahip simbiyotik ilişki sayesinde biyolojik azot fiksasyonunun en verimli örneklerinden birini oluşturur (Djordjevic, 2004). Son yıllarda geliştirilen ileri düzey genetik mühendisliği araçları, S. meliloti'nin bu potansiyelini önemli ölçüde genişletmiştir. Tn5 transpozon mutagenezi ve yere özgü rekombinasyon sistemleri ile başlayan genom manipülasyonu çalışmaları, günümüzde CRISPR/Cas tabanlı genom düzenleme, baz editörleri, CRISPRi ve CRISPR-ilişkili transpozaz sistemleriyle yüksek hassasiyet ve ölçeklenebilirlik kazanmıştır. Bu teknolojiler sayesinde gen silme, gen ifadesinin baskılanması, nokta mutasyonları ve büyük genetik yolların entegrasyonu mümkün hâle gelmiştir (Liu vd., 2024). Bu gelişmeler, *S. meliloti*'yi yalnızca ekolojik açıdan önemli bir simbiyont değil, aynı zamanda geleceğin biyolojik üretim sistemlerinde merkezi rol oynayabilecek, programlanabilir bir biyoteknolojik platform konumuna taşımaktadır.

2. DENEYSEL ÇALIŞMALAR

2.1. Örnek toplanması ve izolasyon

Melilotus indica Türkiye'nin batısında yer alan İzmir ili Ödemiş ilçesi Bozdağ Kayak Merkezi çevresinden, deniz seviyesinden yaklaşık 1550 m yükseklikte doğal yayılış gösteren alanlardan toplanmıştır. Kök sistemleri zarar görmeyecek şekilde yaklaşık 40–50 cm derinliğe kadar kazılarak el çapası yardımıyla alınarak, steril örnek torbalarına yerleştirilmiştir. Toplanan örnekler, Ege Üniversitesi Temel ve Endüstriyel Mikrobiyoloji Laboratuvarı'na getirilmiştir. Bitki materyalinin taksonomik tanımlaması Ege Üniversitesi Botanik Bahçesi ve Herbaryum Araştırma ve Uygulama Merkezi tarafından yapılmış olup, örnek Ege Üniversitesi Herbaryumu'nda EGE-44028 erişim numarası ile muhafaza altına alınmıştır.

Kök nodülleri, bitkinin kök sisteminden steril koşullar altında dikkatlice ayrılmış ve yüzeydeki toprak kalıntılarının uzaklaştırılması amacıyla steril damıtılmış su ile iyice yıkanmıştır. Yüzey sterilizasyonu için nodüller sırasıyla %70 (v/v) etanolde 3 dakika bekletilmiş, ardından 2 dakika boyunca cıva(II) klorür ($HgCl_2$) çözeltisi ile muamele edilmiştir. Sterilizasyon işleminin ardından nodüller, steril damıtılmış su ile dört kez durulanmıştır. Daha sonra steril cam çubuk yardımıyla ezilerek homojenize edilmiş ve elde edilen süspansiyon, yayma plak yöntemi kullanılarak Yeast Ekstrakt Mannitol Agar (YEMA) besiyeri üzerine ekilmiştir (Eren Eroğlu vd., 2023). Petri kapları 28 °C'de 3–10 gün süreyle inkübe edilmiştir. Gelişen koloniler arasından morfolojik olarak ayırt edilebilir tek koloniler seçilerek, daha sonraki fenotipik ve moleküler analizlerde kullanılmak üzere YEMA besiyerinde 28 °C'de 3–4 gün inkübe edilerek saf kültür elde edilmiştir.

2.2. 16S rDNA ve recA gen bölgelerinin dizi analizi

Genomik DNA, High Pure PCR Template Preparation Kit protokolü izlenerek izole edilmiştir. DNA konsantrasyonu Qubit™ ile kontrol edildi. 3BVE suşunun 16S ribozomal DNA (rDNA) ve DNA rekombinaz A (recA) gen dizileri, sırasıyla 27F-1492R ve recAF-recAR primer çiftleri kullanılarak çoğaltılmıştır (Eren Eroğlu vd., 2023). PCR ürünleri Letgen Biyoteknoloji Şirketi'nde (İzmir, Türkiye) dizilenmiştir. Yakın ilişkili suşlara ait gen dizileri, BLASTn kullanılarak NCBI (Ulusal Biyoteknoloji Bilgi Merkezi) GenBank veritabanlarından alınmıştır. Filogenetik ağaçlar, Moleküler Evrimsel Genetik Analiz (MEGA) yazılımı sürüm 11'e entegre edilmiş Komşu birleştirme (NJ) yöntemi ile oluşturulmuştur(Tamura vd., 2021).

2.3. Tüm genom dizileme ve genom açıklaması

3BVE suşuna ait genomik DNA (50 ng/µL), Refgen Biotechnology Inc. (Ankara, Türkiye) tarafından Illumina NovaSeq 6000 platformu kullanılarak dizilenmiştir. Elde edilen ham okuma verileri, Shovill v1.0.4 yazılımı kullanılarak varsayılan parametrelerle de novo olarak monte edilmiştir. Genom açıklaması, NCBI Genom Gönderim Portalı üzerinden NCBI Prokaryotik Genom Açıklama Hattı (PGAP) kullanılarak gerçekleştirilmiştir. Fonksiyonel

genom analizleri kapsamında, metabolik yolakların belirlenmesi için Pathway Tools (Patric/BRVC), antibiyotik direnç genlerinin tespiti için CARD, CRISPR dizilerinin belirlenmesi için CRISPRCasFinder kullanılmıştır. Genom haritalaması ve dairesel genom görselleştirmeleri ise Proksee ve CGView araçları ile oluşturulmuştur (Wonglapsuwan vd., 2024; Eren Eroğlu vd., 2025).

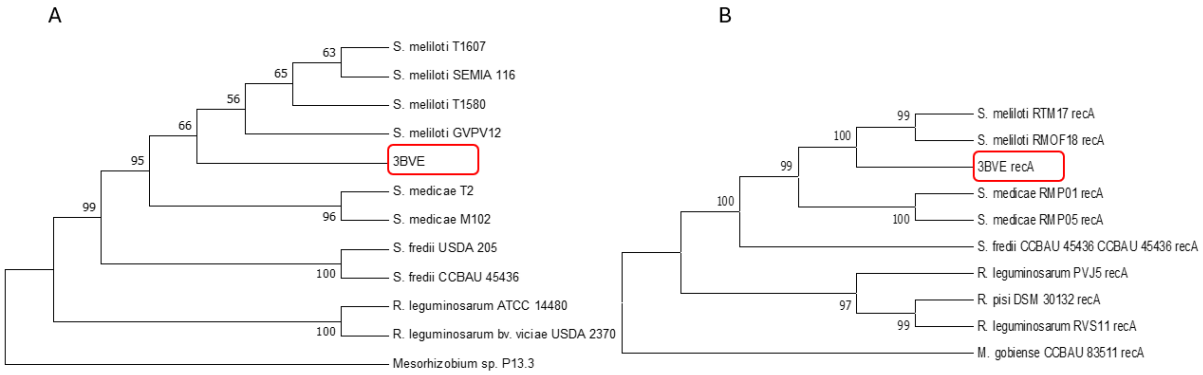
3. SONUÇLAR VE DEĞERLENDİRME

Melilotus indica kök nodüllerinden gerçekleştirilen izolasyon çalışmaları sonucunda rhizobiyal bir suş elde edilmiş ve bu suş 3BVE olarak adlandırılmıştır. Çalışmada kullanılan bitkinin genel morfolojik özellikleri ile kök nodüllerinin makroskobik görünümü Görsel 1'de sunulmuştur.



Görsel 1.*Melilotus indica* ve köklerinde tespit edilen simbiyotik nodüller

3BVE suşunun taksonomik konumunun belirlenmesi amacıyla öncelikle 16S rRNA ve recA genlerine dayalı PCR amplifikasyonu ve dizi analizleri gerçekleştirilmiştir. Elde edilen dizilerin GenBank veritabanındaki referans dizilerle karşılaştırılması sonucunda, her iki gen bölgesinin de *Sinorhizobium meliloti* türüne ait dizilerle %98'in üzerinde nükleotid homolojisi gösterdiği tespit edilmiştir. Tür düzeyindeki ilişkiyi doğrulamak amacıyla 16S rRNA ve recA gen dizileri kullanılarak Neighbor-Joining (NJ) yöntemi ile filogenetik ağaçlar oluşturulmuştur. Filogenetik analiz sonuçları, 3BVE suşunun *S. meliloti* referans suşları ile aynı klaster içerisinde yer aldığını ve elde edilen homoloji sonuçlarını desteklediğini göstermiştir (Görsel 2).



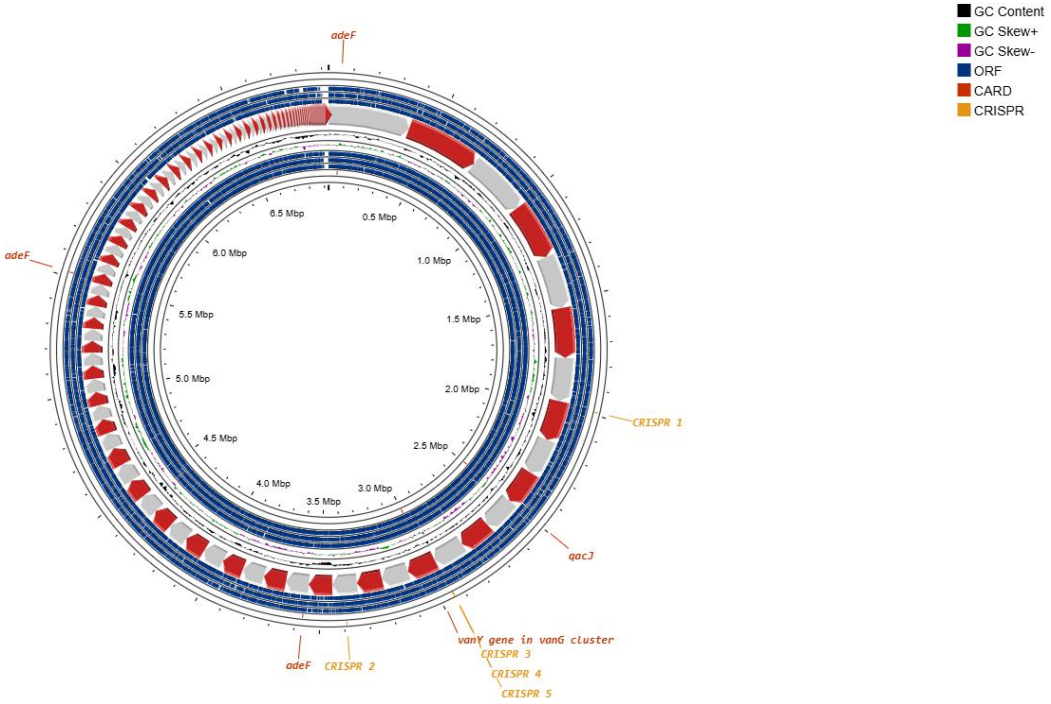
Görsel 2. *S. meliloti* 3BVE suşunun 16S rDNA (A) ve recA (B) dizilerine dayalı yakın ilişkili türler ile oluşturulan filogenetik ağacı.

3BVE suşuna ait genomik DNA izole edilmiş ve yeni nesil dizileme (NGS) teknolojisi kullanılarak dizilenmiştir. Dizileme verilerinin de novo montajı sonucunda genom, toplam 6.927.931 bp uzunluğa sahip taslak (draft) bir genom olarak 268 contig halinde elde edilmiştir (Görsel 3). Genomun GC içeriği %62,10 olarak hesaplanmıştır. Montaj kalitesini değerlendiren metrikler incelendiğinde, contig N50 değeri 108.832 bp, L50 değeri ise 18 olarak belirlenmiş olup, bu sonuçlar genom montajının iyi düzeyde sürekliliğe sahip olduğunu göstermektedir. Genom anotasyonu sonucunda toplam 7.207 kodlayıcı dizi (CDS) tanımlanmıştır. Bu CDS'lerin 1.948'i (%37,32) hipotetik (varsayımsal) protein olarak tahmin edilmiş olup, bu sonuçlar genomda henüz fonksiyonu karakterize edilmemiş genlerin varlığına işaret etmektedir. CDS'lerin 6.786'sı (%94,16) PLFAM veri tabanı kullanılarak fonksiyonel olarak sınıflandırılmıştır. Ayrıca genomda 52 tRNA ve 5 rRNA geni tespit edilmiş olup, protein sentez mekanizmasının genom düzeyinde eksiksiz biçimde temsil edildiğini göstermektedir. Genom kalitesinin değerlendirilmesi amacıyla yapılan analizlerde oldukça yüksek bütünlük ve tutarlılık değerleri elde edilmiştir. CheckM analizine göre genomun tamlığı %100 olarak hesaplanmış, coarse consistency %99,6 ve fine consistency %96,6 olarak belirlenmiştir. Tüm bu kalite parametreleri birlikte değerlendirildiğinde, 3BVE suşuna ait genomun yüksek kaliteli olduğu ve ileri düzey karşılaştırmalı genomik ile fonksiyonel analizler için uygun olduğu sonucuna varılmıştır.

CARD (Comprehensive Antibiotic Resistance Database) analizi sonucunda, 3BVE suşu genomunda antibiyotik direnci ile ilişkili genlerin ağırlıklı olarak effluks temelli mekanizmalar kapsamında yer aldığı belirlenmiştir. Özellikle RND ve SMR ailesine ait antibiyotik taşıyıcılarını kodlayan genler tespit edilmiş olup, bu genlerin farklı antibiyotik sınıfları ile ilişkili olduğu görülmüştür (Görsel 3). Ayrıca vanY genini içeren bir direnç gen kümesinin genomda bulunduğu belirlenmiştir. Tanımlanan genlerin büyük çoğunluğunun, antibiyotiklerin hücre içi birikimini sınırlayan taşıma sistemleri ile ilişkili olduğu anlaşılmıştır.

CRISPRCasFinder analizi 3BVE suşu genomunda farklı contigler üzerinde konumlanmış birden fazla CRISPR dizisi tanımlamıştır. Bu CRISPR bölgeleri 81–146 bp uzunluk aralığında olup, 24–27 bp uzunluğunda korunmuş tekrar dizileri ve sınırlı sayıda spacer

içermektedir (Görsel 3). Tanımlanan CRISPR dizilerinin büyük bir kısmı tek veya iki spacer içermekte ve yüksek tekrar korunumu göstermektedir. CRISPR tekrar dizilerinin CRISPRdb veri tabanında tanımlı bilinen tekrarlarla eşleşmediği belirlenmiş olup, bu bölgeler düşük kanıt düzeyinde (1) CRISPR yapıları olarak sınıflandırılmıştır.



Görsel 3.*S. meliloti* 3BVE'nin dairesel genom haritası

3BVE suşunun genomik analizi, simbiyotik azot fiksasyonu ve nodülasyon ile ilişkili genlerin genomda açık biçimde temsil edildiğini ortaya çıkarmıştır. Azot fiksasyonu ile ilişkili olarak nif gen kümesinin büyük ölçüde korunmuş olduğu ve *nifA*, *nifB*, *nifH*, *nifE*, *nifN* genlerinin yanı sıra nitrogenazın yapısal bileşenlerini kodlayan *nifD* (alfa zincir) ve *nifK* (beta zincir) genlerinin genomda birlikte yer aldığı belirlenmiştir (Çizelge 1). Ayrıca nitrogenaz aktivitesi için gerekli elektron transferinde rol alan 4Fe–4S ferredoksin proteinlerini kodlayan genler de tespit edilmiştir. Bu genlerin organizasyonu, FeMo-kofaktör biyosentezi, taşınması ve montajı ile ilişkili proteinlerin genomda eksiksiz olarak bulunduğunu göstermektedir. Bununla birlikte, nodülasyon sürecinde ifade edilen *nodA*, *nodB*, *nodC*, *nodD* ve *nolO* genlerinin varlığı belirlenmiş; özellikle *nodD* geninin LysR ailesine ait transkripsiyonel düzenleyici olarak birden fazla kopya halinde genomda yer aldığı saptanmıştır (Çizelge 1).Bu bulgular, 3BVE suşunun *Melilotus indica* ile etkili bir simbiyotik ilişki kurabilme ve biyolojik azot fiksasyonu gerçekleştirme potansiyelinin genomik determinantlarıdır.

Çizelge 1. *S. meliloti* 3BVE'de simbiyotik azot fiksasyonu regülasyonunda rol oynayan genler

	Başlangıç	*Bitiş*	*Nükleotit(bç)*	*İplik*	*AA*	*Enzim*
1	32724	32918	195	-	64	4Fe-4S ferredoxin, nitrogenase-associated
2	32950	34422	1473	-	490	Nitrogenase FeMo-cofactor synthesis FeS core scaffold and assembly protein NifB
3	34639	36264	1626	-	541	Nitrogenase (molybdenum-iron)-specific transcriptional regulator NifA
4	42284	43177	894	+	297	Nitrogenase (molybdenum-iron) reductase and maturation protein NifH
5	43277	44779	1503	+	500	Nitrogenase (molybdenum-iron) alpha chain (EC 1.18.6.1)
6	44870	46411	1542	+	513	Nitrogenase (molybdenum-iron) beta chain (EC 1.18.6.1)
7	46465	47892	1428	+	475	Nitrogenase FeMo-cofactor scaffold and assembly protein NifE
8	48324	48821	498	+	165	Nitrogenase FeMo-cofactor carrier protein NifX
9	49496	49813	318	+	105	4Fe-4S ferredoxin, nitrogenase-associated
10	8831	10156	1326	+	441	Nitrogenase FeMo-cofactor scaffold and assembly protein NifN
11	256244	258076	1833	+	610	Nodulation protein nolO (EC 2.1.3.-)
12	93194	93682	489	-	162	Nodulation protein N
13	13929	15359	1431	+	476	Nodulation
14	3333	4265	933	+	310	Nodulation protein D (transcriptional regulator, LysR family)
15	51405	52427	1023	-	340	Nodulation protein D (transcriptional regulator, LysR family)
16	4083	5363	1281	-	426	Nodulation protein C
17	5378	6031	654	-	217	Nodulation protein B
18	6028	6618	591	-	196	Nodulation protein A
19	6882	7808	927	+	308	Nodulation protein D (transcriptional regulator, LysR family)

4. GENEL DEĞERLENDİRME VE SONUÇLAR

Bu çalışmada, *Melilotus indica* kök nodüllerinden izole edilen 3BVE suşunun genomik özellikleri araştırılmıştır. 16S rRNA ve recA genlerine dayalı dizi analizleri ile filogenetik değerlendirmeler, suşun *Sinorhizobium meliloti* ile %98'in üzerinde homoloji gösterdiğini ve referans suşlarla aynı dalda kümelendiğini açıkça ortaya koymuştur. Genomik analizler, *nifA, nifB, nifH, nifD, nifK, nifE, nifN* ile *nodA, nodB, nodC, nodD* ve *nolO* genlerinin genomda birlikte bulunmasıyla, 3BVE suşunun *M. indica* ile etkili bir simbiyotik ilişki kurma ve biyolojik azot fiksasyonu gerçekleştirme potansiyeline sahip olduğunu göstermiştir. *Nod* ve *nif* gen kümelerinin korunmuş organizasyonu, bu simbiyotik özelliklerin evrimsel olarak stabilize edilmiş olabileceğine işaret etmektedir.

Simbiyotik azot fiksasyonu, kimyasal gübre kullanımının azaltılması açısından sürdürülebilir tarım ve gıda güvenliği için kritik bir süreçtir. Bu bağlamda, 3BVE gibi yerel rhizobiyal izolatların genomik olarak tanımlanması, hem ekolojik uyum hem de tarımsal uygulamalar açısından değerli bir kaynak sunmaktadır. Güncel genetik mühendisliği ve sentetik

biyoloji yaklaşımları göz önüne alındığında, *S. meliloti* suşlarının simbiyotik verimliliklerinin artırılması ve farklı konak sistemlerine uyarlanması, geleceğe yönelik biyoteknolojik uygulamalar için umut vadedicidir.

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FERMENTE MEYVELERDEN İZOLE EDİLEN ETANOL DİRENÇLİ ASETİK ASİT BAKTERİLERİNİN İZOLASYONU, FENOTİPİK-MOLEKÜLER KARAKTERİZASYONU

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ÖZET

Asetik asit bakterileri (AAB), etanolü asetik aside okside edebilme yetenekleri nedeniyle gıda ve fermentasyon endüstrisinde önemli bir mikroorganizma grubunu oluşturmaktadır. Bu çalışmada, doğal fermentasyon süreçlerine sahip meyvelerden AAB izolasyonu ve moleküler düzeyde tanımlanması amaçlanmıştır. Bu kapsamda bozunma sürecindeki üzüm ve elma gibi çeşitli meyvelerden örnekler alınmış ve seyreltme plaka yöntemi kullanılarak izolasyon çalışmaları gerçekleştirilmiştir. Ekimler, etanol ve sikloheksimid içeren seçici besiyerlerine yapılarak 30 °C'de inkübe edilmiştir. Üreme gözlenen petrilerden koloniler alınarak çizgi plaka yöntemiyle saf kültürler elde edilmiştir. Elde edilen izolatlar fenotipik olarak Gram boyama ve katalaz testleri ile karakterize edilmiştir. Tüm izolatların Gram negatif ve katalaz pozitif olduğu belirlenmiştir. Moleküler identifikasyon amacıyla izolatlardan total DNA ekstrakte edilmiş, 16S rRNA gen bölgesi 27F-1492R evrensel primer çifti kullanılarak PCR ile çoğaltılmıştır. PCR ürünleri agaroz jel elektroforezi ile doğrulanmış ve dizileme analizleri gerçekleştirilmiştir. Elde edilen diziler NCBI-BLAST veritabanında karşılaştırılmıştır. 16S rRNA dizi analizleri sonucunda izolatların %99'un üzerinde benzerlik oranlarıyla *Acetobacter ghanensis* türleri ile eşleştigi belirlenmiştir. Bulgular, şekerce zengin ve hafif oksijenli fermentatif ortamlarda AB'lerin baskın mikroorganizma grubunu oluşturduğunu göstermektedir. Sonuç olarak bu çalışma, doğal meyve fermentasyonlarının AAB izolasyonu açısından önemli bir kaynak olduğunu ortaya koymakta ve elde edilen izolatların biyoteknolojik ve endüstriyel potansiyelinin ileri çalışmalarla değerlendirilmesine zemin hazırlamaktadır.

Anahtar Kelimeler: Asetik Asit Bakterileri, *Acetobacter* sp., etanol toleransı

1. GİRİŞ

Fermentasyon, gıda maddelerinin besinsel ve fonksiyonel özelliklerinin iyileştirilmesinin yanı sıra raf ömrünün uzatılmasını sağlayan, insanlık tarihinin en eski ve en yaygın biyoteknolojik uygulamalarından biri olarak kabul edilmektedir (Campbell-Platt 2009). Özellikle meyve temelli fermentasyon sistemlerinde rol alan mikroorganizmalar, doğal mikrobiyal ekosistemlerin çeşitliliğini yansıtmakta olup aynı zamanda endüstriyel ölçekte önem arz eden çeşitli metabolik ürünlerin sentezinden sorumludur (Ray ve Montet 2014). Bu mikroorganizma grupları içerisinde yer alan asetik asit bakterileri (AAB), etanolü oksidatif fermentasyon mekanizmaları aracılığıyla asetik aside dönüştürebilme yetenekleri sayesinde sirke ve benzeri fermente ürünlerin üretiminde temel biyolojik ajanlar olarak tanımlanmaktadır. Asetik asit bakterileri; *Acetobacter, Komagataeibacter, Gluconobacter ve Gluconacetobacter* gibi cinsleri kapsayan, Gram-negatif, aerobik ve asit toleranslı mikroorganizmalardır (Brenner et al. 2005). Bu bakteriler, özellikle yüksek etanol ve asetik asit konsantrasyonlarında hayatta kalabilme ve metabolik aktivitelerini sürdürebilme yetenekleriyle dikkat çekmektedir. Etanol direnci, AAB'lerin hücre zarı yapısı, solunum zinciri enzimleri ve stres yanıt mekanizmaları ile doğrudan ilişkili olup, bu özellik endüstriyel fermantasyon süreçlerinde yüksek verimli ve stabil üretim açısından kritik öneme sahiptir (Matsushita et al., 2016). Fermente meyveler; doğal şeker içeriği, uygun pH değerleri ve zengin besin profilleri sayesinde asetik asit bakterileri için ideal bir ekolojik niş oluşturmaktadır (Gullo et al. 2016**)**. Elma, üzüm, nar, incir ve armut gibi meyvelerden elde edilen fermente ürünlerde, etanol dirençli AAB suşlarının yaygın olarak bulunduğu ve bu suşların asetik asit üretim kapasitelerinin izolasyon kaynağına bağlı olarak değişkenlik gösterdiği bildirilmiştir (Saichana et al., 2015). Bu durum, fermente meyvelerin yeni ve endüstriyel açıdan değerli bakteri suşlarının izolasyonu için önemli bir kaynak olduğunu ortaya koymaktadır. AAB'lerin tanımlanmasında geleneksel olarak koloni morfolojisi, Gram boyama, katalaz-oksidaz testleri, karbon kaynağı kullanımı ve etanol/asetik asit tolerans testleri gibi fenotipik yöntemler kullanılmaktadır (Madigan et al., 2018). Ancak bu yöntemler, özellikle yakın akraba türlerin ayrımında yetersiz kalabilmekte ve yanlış sınıflandırmalara yol açabilmektedir. Bu nedenle son yıllarda moleküler karakterizasyon teknikleri, AAB taksonomisinde vazgeçilmez bir araç haline gelmiştir (Cleenwerck ve De Vos, 2008).

Moleküler düzeyde yapılan çalışmalar, başta 16S rRNA gen dizilemesi olmak üzere, 16S–23S rRNA ara bölge analizi ve çoklu gen dizileme (MLSA) yaklaşımlarının, asetik asit bakterilerinin tür ve suş düzeyinde güvenilir şekilde tanımlanmasını sağladığını ortaya koymuştur. Fenotipik ve moleküler verilerin birlikte değerlendirilmesi, yalnızca doğru tür tayini yapmakla kalmayıp, aynı zamanda bakterilerin teknolojik potansiyelinin ve stres tolerans mekanizmalarının anlaşılmasına da katkı sağlamaktadır (De Roos ve De Vuyst, 2018).

Bu bağlamda, fermente meyvelerden izole edilen daha önceki çalışmalarda etanol toleransı belirlenen asetik asit bakterilerinin fenotipik ve moleküler karakterizasyonunun birlikte ele alınması, hem doğal fermentasyon mikrobiyotasının aydınlatılması hem de sirke ve benzeri fermentasyon endüstrilerinde kullanılabilecek yüksek performanslı suşların belirlenmesi açısından büyük önem taşımaktadır. Bu çalışma, fermente meyve örneklerinden izole edilen AAB suşlarının fenotipik özelliklerini ve

moleküler kimliklerini ortaya koyarak, mevcut literatüre katkı sağlamayı ve uygulamalı mikrobiyoloji alanına yeni veriler sunmayı amaçlamaktadır.

2. DENEYSEL ÇALIŞMALAR

2.1. Asetik Asit Bakterilerinin İzolasyonu

Asetik asit bakterilerinin izolasyonu amacıyla, doğal fermentasyon sürecindeki üzüm, elma ve benzeri çeşitli fermente meyvelerden örnekler alınmıştır. Alınan örnekler steril koşullar altında fizyolojik tuzlu su (FTS) içeren deney tüplerine aktarılmış ve seri seyreltme yöntemi kullanılarak 10^{-1}–10^{-9} aralığında seyreltilmiştir. Elde edilen seyreltmelerden paralel olarak dökme plaka ve yayma plaka yöntemleriyle ekimler gerçekleştirilmiştir. Ekimler, asetik asit bakterilerinin gelişimini desteklemek amacıyla seçici besiyeri kullanılarak yapılmış ve petriler 30 °C'de aerobik koşullarda inkübasyona bırakılmıştır. İnkübasyon süresi sonunda koloni gelişimi gözlenen petrilerden, morfolojik olarak farklı koloniler steril öze yardımıyla alınarak çizgi plaka yöntemi ile yeniden ekilmiş ve saf kültür elde edilinceye kadar bu işlem tekrarlanmıştır.

İzolasyon çalışmalarında kullanılan besiyerinin içeriği şu şekildedir: KH_2PO_4 (1.0 g), $(NH_4)_2SO_4$ (1.0 g), $MgSO_4 \cdot 7H_2O$ (0.5 g), maya ekstraktı (5.0 g), glukoz (20.0 g), agar (20.0 g) ve distile su (1000 ml). Hazırlanan besiyeri 121 °C'de 15 dakika süreyle otoklavda sterilize edilmiş, soğutma işleminden sonra ortama %100 etanol (40 ml) (daha önceki çalışmalarda belirlenmiştir) ve maya gelişimini baskılamak amacıyla sikloheksimid 50 µg/ml (2000 µl) ilave edilmiştir (Raspor vd., 2008).

2.2. İzolatların Fenotipik Karakterizasyonu

Saf kültür elde edilen izolatların fenotipik özelliklerinin belirlenmesi amacıyla temel mikrobiyolojik testler uygulanmıştır. Bu kapsamda izolatlara Gram boyama testi yapılarak hücre morfolojileri ve Gram reaksiyonları belirlenmiş, ayrıca katalaz testi uygulanarak izolatların katalaz enzim aktivitesi değerlendirilmiştir. Asetik asit bakterilerinin Gram-negatif ve katalaz pozitif özellik göstermesi beklenmiş ve elde edilen sonuçlar bu doğrultuda yorumlanmıştır. Fenotipik test sonuçları, izolatların ön tanımlanması ve moleküler analizlere yönlendirilmesi amacıyla kullanılmıştır.

2.3. Moleküler Tanımlama

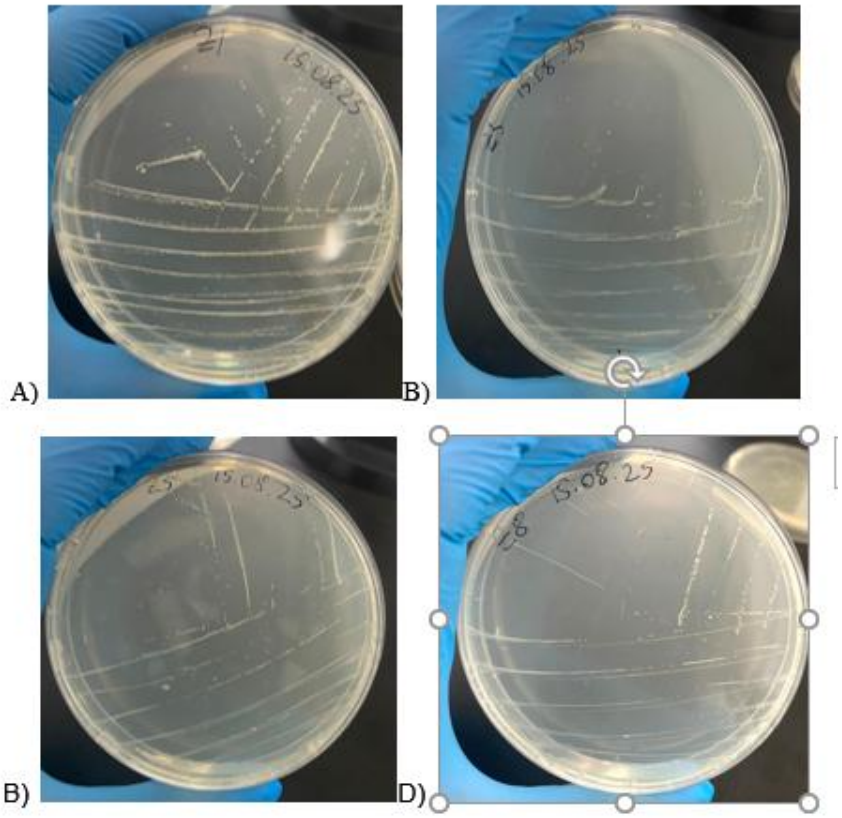
Fenotipik olarak ön tanımlaması yapılan izolatların moleküler düzeyde identifikasyonu amacıyla genomik DNA izolasyonu gerçekleştirilmiştir. DNA ekstraksiyonu, üretici firmanın protokolü doğrultusunda yapılmıştır. İzole edilen DNA örnekleri, asetik asit bakterilerinin tanımlanmasında yaygın olarak kullanılan 16S rRNA gen bölgesi

hedeflenerek PCR yöntemi ile çoğaltılmıştır. PCR amplifikasyonu için evrensel bakteriyel primer çifti olan 27F ve 1492R primerleri kullanılmıştır.
PCR ürünleri elektroforez yöntemi ile kontrol edilmiş ve uygun bantlar dizileme analizine gönderilmiştir. Elde edilen dizi verileri, GenBank veritabanındaki referans diziler ile karşılaştırılarak izolatların tür düzeyinde tanımlanması sağlanmıştır.

3. SONUÇLAR VE DEĞERLENDİRME

3.1. İzolasyon

Bozunma sürecindeki çeşitli meyvelerden elde edilen örneklerde inkübasyon sonrasında üreme gerçekleşti. Üreme gerçekleşen petrilerden, saf kültür elde etmek amacıyla koloniler çizgi plaka yöntemiyle saflaştırıldı.

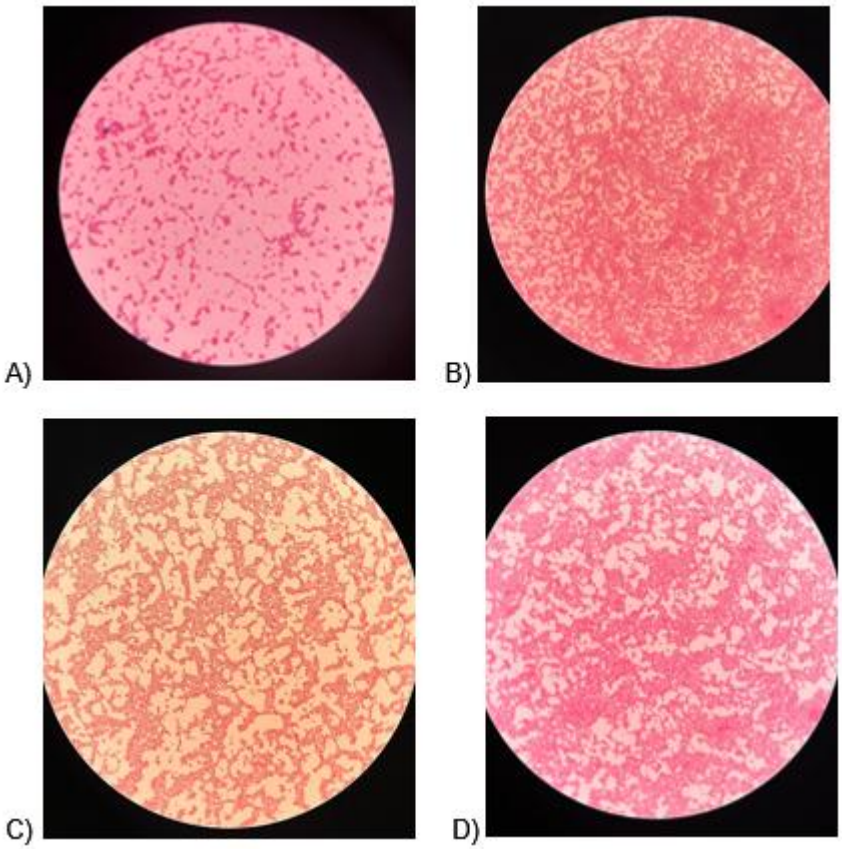


Şekil 3.1.1. İzolatların çizgi ekim görselleri: A) Z1 izolatı; B) Z2 izolatı; C) Z3 izolatı; D) Z4 izolatı

3.2. Fenotipik Karakterizasyon



Şekil 3.2.1. İzolatların katalaz testi sonuçları hepsi katalaz +



Şekil 3.2.2. İzolatların Gram reaksiyonları: A) Z1 izolatı Gram -; B) Z3 izolatı Gram -; C) Z5 izolatı Gram -; D) Z8 izolatı Gram –

3.3. Moleküler İdentifikasyon

İlk olarak izolatlardan total DNA ekstraksiyonu gerçekleştirilmiştir. Ardından 27F-1492R universal primer çifti kullanılarak 16S rRNA bölgesi PCR ile çoğaltılmıştır. PCR ürünleri agaroz jel elektroforezinde görüntülendikten sonra yaklaşık 1500 bp

uzunluğunda görünen diziler, sanger sekanslama için analize gönderilmiştir. Elde edilen diziler NCBI-Blast veritabanında taranmıştır.

Çizelge 3.3.1. 16S rRNA Sonuçları

İzolat kodu	En yakın tür (Blast/NCBI)	Benzerlik	Accession number
Z3	Acetobacter ghanensis strain HWW115	99.56%	MH424870.1
Z5	Acetobacter ghanensis strain KACC 22434	99.82%	ON746639.1
Z8	Acetobacter ghanensis strain 22368	99.82%	ON746607.1

Çizelge 3.3.2. İzolatların Referans Suş ile Dizi Hizalaması

```
CLUSTAL 2.1 multiple sequence alignment


DQ887338.1      --TGCAAGTCGCACGAACCTTTCGGGGTTAGTGGCGGACGGGTGAGTAACGCGTAGGAAT
Z8_27F          CATGCAAGTCGCACGAACCTTTCGGGGTTAGTGGCGGACGGGTGAGTAACGCGTAGGAAT
Z5_27F          --TGCAAGTCGCACGAACCTTTCGGGGTTAGTGGCGGACGGGTGAGTAACGCGTAGGAAT
Z3_27F          --TGCA-GTCGCACGAACCTTTCGGGGTTAGTGGCGGACGGGTGAGTAACGCGTAGGAAT
                  **** **************************************************

DQ887338.1      CTGTCCATGGGTGGGGGATAACTCTGGGAAACTGGAGCTAATACCGCATGATACCTGAGG
Z8_27F          CTGTCCATGGGTGGGGGATAACTCTGGGAAACTGGAGCTAATACCGCATGATACCTGAGG
Z5_27F          CTGTCCATGGGTGGGGGATAACTCTGGGAAACTGGAGCTAATACCGCATGATACCTGAGG
Z3_27F          CTGTCCATGGGTGGGGGATAACTCTGGGAAACTGGAGCTAATACCGCATGATACCTGAGG
                ************************************************************

DQ887338.1      GTCAAAGGCGCAAGTCGCCTGTGGAGGAGCCTGCGTTCGATTAGCTAGTTGGTGGGGTAA
Z8_27F          GTCAAAGGCGCAAGTCGCCTGTGGAGGAGCCTGCGTTCGATTAGCTAGTTGGTGGGGTAA
Z5_27F          GTCAAAGGCGCAAGTCGCCTGTGGAGGAGCCTGCGTTCGATTAGCTAGTTGGTGGGGTAA
Z3_27F          GTCAAAGGCGCAAGTCGCCTGTGGAGGAGCCTGCGTTCGATTAGCTAGTTGGTGGGGTAA
                ************************************************************

DQ887338.1      AGGCCTACCAAGGCGATGATCGATAGCTGGTTTGAGAGGATGATCAGCCACACTGGGACT
Z8_27F          AGGCCTACCAAGGCGATGATCGATAGCTGGTTTGAGAGGATGATCAGCCACACTGGGACT
Z5_27F          AGGCCTACCAAGGCGATGATCGATAGCTGGTTTGAGAGGATGATCAGCCACACTGGGACT
Z3_27F          AGGCCTACCAAGGCGATGATCGATAGCTGGTTTGAGAGGATGATCAGCCACACTGGGACT
                ************************************************************

DQ887338.1      GAGACACGGCCCAGACTCCTACGGGAGGCAGCAGTGGGGAATATTGGACAATGGGGGCAA
Z8_27F          GAGACACGGCCCAGACTCCTACGGGAGGCAGCAGTGGGGAATATTGGACAATGGGGGCAA
Z5_27F          GAGACACGGCCCAGACTCCTACGGGAGGCAGCAGTGGGGAATATTGGACAATGGGGGCAA
Z3_27F          GAGACACGGCCCAGACTCCTACGGGAGGCAGCAGTGGGGAATATTGGACAATGGGGGCAA
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DQ887338.1      CCCTGATCCAGCAATGCCGCGTGTGTGAAGAAGGTCTTCGGATTGTAAAGCACTTTCGAC
Z8_27F          CCCTGATCCAGCAATGCCGCGTGTGTGAAGAAGGTCTTCGGATTGTAAAGCACTTTCGAC
Z5_27F          CCCTGATCCAGCAATGCCGCGTGTGTGAAGAAGGTCTTCGGATTGTAAAGCACTTTCGAC
Z3_27F          CCCTGATCCAGCAATGCCGCGTGTGTGAAGAAGGTCTTCGGATTGTAAAGCACTTTCGAC
                ************************************************************

DQ887338.1      GGGGACGATGATGACGGTACCCGTAGAAGAAGCCCCGGCTAACTTCGTGCCAGCAGCCGC
Z8_27F          GGGGACGATGATGACGGTACCCGTAGAAGAAGCCCCGGCTAACTTCGTGCCAGCAGCCGC
Z5_27F          GGGGACGATGATGACGGTACCCGTAGAAGAAGCCCCGGCTAACTTCGTGCCAGCAGCCGC
Z3_27F          GGGGACGATGATGACGGTACCCGTAGAAGAAGCCCCGGCTAACTTCGTGCCAGCAGCCGC
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DQ887338.1      GGTAATACGAAGGGGGCTAGCGTTGCTCGGAATGACTGGGCGTAAAGGGCGTGTAGGCGG
Z8_27F          GGTAATACGAAGGGGGCTAGCGTTGCTCGGAATGACTGGGCGTAAAGGGCGTGTAGGCGG
Z5_27F          GGTAATACGAAGGGGGCTAGCGTTGCTCGGAATGACTGGGCGTAAAGGGCGTGTAGGCGG
Z3_27F          GGTAATACGAAGGGGGCTAGCGTTGCTCGGAATGACTGGGCGTAAAGGGCGTGTAGGCGG
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DQ887338.1      TTTGTACAGTCAGATGTGAAATCCCCGGGCTTAACCTGGGAGCTGCATTTGATACGTGCA
Z8_27F          TTTGTACAGTCAGATGTGAAATCCCCGGGCTTAACCTGGGAGCTGCATTTGATACGTGCA
Z5_27F          TTTGTACAGTCAGATGTGAAATCCCCGGGCTTAACCTGGGAGCTGCATTTGATACGTGCA
Z3_27F          TTTGTACAGTCAGATGTGAAATCCCCGGGCTTAACCTGGGAGCTGCATTTGATACGTGCA
                ************************************************************

DQ887338.1      GACTAGAGTGTGAGAGAGGGTTGTGGAATTCCCAGTGTAGAGGTGAAATTCGTAGATATT
Z8_27F          GACTAGAGTGTGAGAGAGGGTTGTGGAATTCCCAGTGTAGAGGTGAAATTCGTAGATATT
Z5_27F          GACTAGAGTGTGAGAGAGGGTTGTGGAATTCCCAGTGTAGAGGTGAAATTCGTAGATATT
Z3_27F          GACTAGAGTGTGAGAGAGGGTTGTGGAATTCCCAGTGTAGAGGTGAAATTCGTAGATATT
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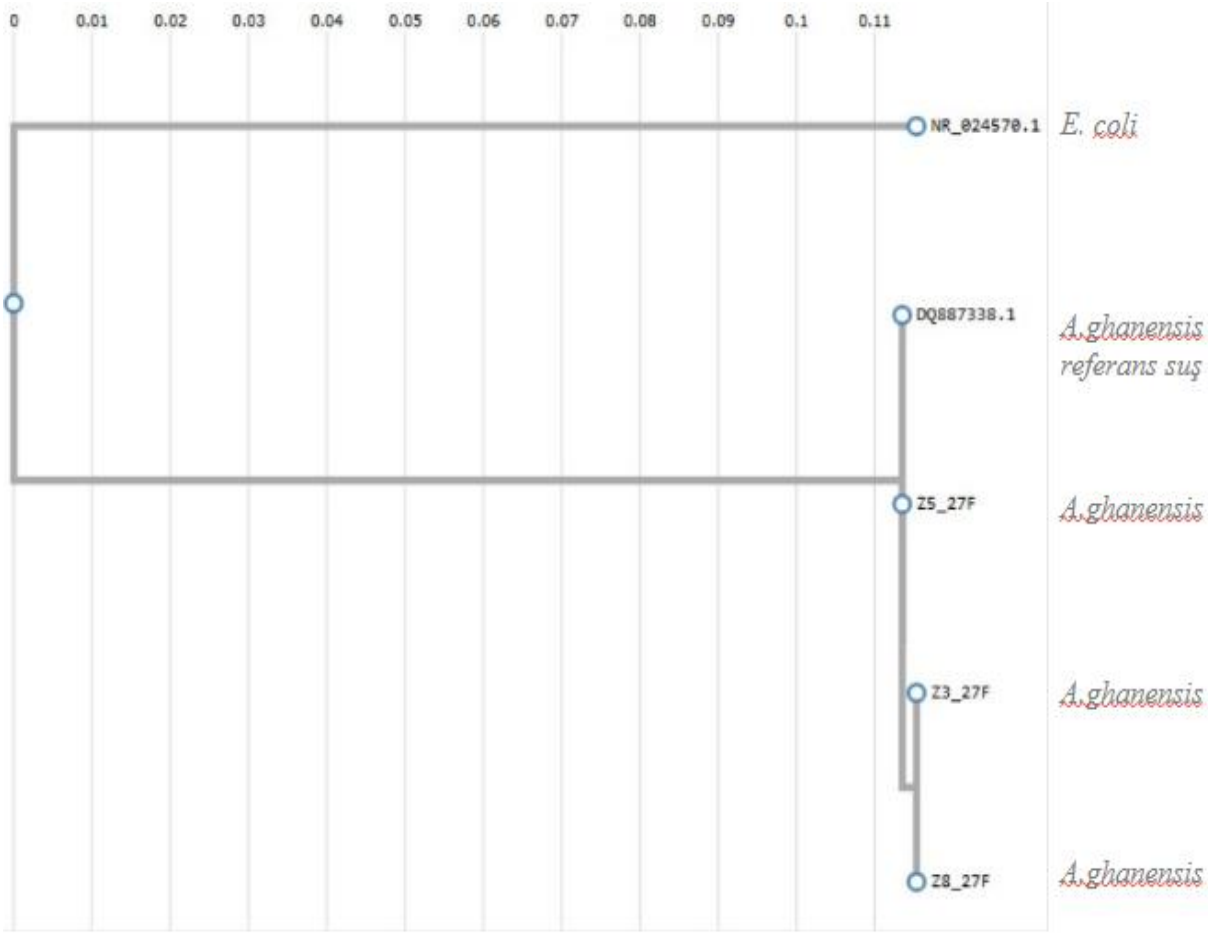
DQ887338.1      GGGAAGAACACCGGTGGCGAAGGCGGCAACCTGGCTCATTACTGACGCTGAGGCGCGAAA
Z8_27F          GGGAAGAACACCGGTGGCGAAGGCGGCAACCTGGCTCATTACTGACGCTGAGGCGCGAAA
Z5_27F          GGGAAGAACACCGGTGGCGAAGGCGGCAACCTGGCTCATTACTGACGCTGAGGCGCGAAA
Z3_27F          GGGAAGAACACCGGTGGCGAAGGCGGCAACCTGGCTCATTACTGACGCTGAGGCGCGAAA
                ************************************************************

DQ887338.1      GCGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCTGTAAACGATGTGTGCTA
Z8_27F          GCGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCTGTAAACGATGTGTGCTA
Z5_27F          GCGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCTGTAAACGATGTGTGCTA
Z3_27F          GCGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCTGTAAACGATGTGTGCTA
                ************************************************************

DQ887338.1      GATGTTGGGTAACTTTGTTATTCAGTGTCGCAGTTAACGCGTTAAGCACACCGCCTGGGG
Z8_27F          GATGTTGGGTAACTTTGTTATTCAGTGTCGCAGTTAACGCGTTAAGCACACCGCCTGGGG
Z5_27F          GATGTTGGGTAACTTTGTTATTCAGTGTCGCAGTTAACGCGTTAAGCACACCGCCTGGGG
Z3_27F          GATGTTGGGTAACTTTGTTATTCAGTGTCGCAGTTAACGCGTTAAGCACACCGCCTGGGG
                ************************************************************

DQ887338.1      AGTACGGCCGCAAGGTTGAAACTCAAAGGAATTGACGGGGGCCCGCACAAGCGGTGGAGC
Z8_27F          AGTACGGCCGCAAGGTTGAAACTCAAAGGAATTGACGGGGGCCCGCACAAGCGGTGGAGC
Z5_27F          AGTACGGCCGCAAGGTTGAAACTCAAAGGAATTGACGGGGGCCCGCACAAGCGGTGGAGC
Z3_27F          AGTACGGCCGCAAGGTTGAAACTCAAAGGAATTGACGGGGGCCCGCACAAGCGGTGGAGC
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Yapılan çoklu dizi hizalaması (multiple sequence alignment) sonucunda, test edilen izolatların (Z3, Z5 ve Z8) 16S rRNA sekanslarının, referans asetik asit bakterisi suşu (DQ887338.1) ile yüksek derecede homoloji gösterdiği belirlenmiştir. Hizalama analizinde, dizilerin başlangıç bölgelerindeki çok düşük sayıdaki nükleotit varyasyonları dışında, tüm bölgelerde %99'un üzerinde benzerlik saptanmıştır. Özellikle korunmuş bölgelerdeki tam eşleşme (konsensus), izolatların referans suş ile filogenetik olarak çok yakın bir ilişki içerisinde olduğunu doğrulamaktadır.



UPGMA yöntemi kullanılarak oluşturulan ağaçta, Z3, Z5 ve Z8 izolatlarının referans suş (DQ887338.1) ile aynı filogenetik grupta yer aldığı görülmektedir. *E. coli* 16S rRNA dizisi dış grup (outgroup) olarak kullanılmış olup, izolatların asetik asit bakterileri grubu içerisindeki yerleşimi doğrulanmıştır.

4. GENEL DEĞERLENDİRME VE SONUÇLAR

Bu çalışmada, doğal fermentasyon sürecinde bulunan farklı meyve örneklerinden izole edilen etanol dirençli asetik asit bakterilerinin (AAB) fenotipik ve moleküler özelliklerinin belirlenmesi amaçlanmıştır. Fermente meyvelerin, yüksek şeker içeriği ve etanol oluşumuna elverişli ortam koşulları sayesinde asetik asit bakterileri için uygun bir ekolojik niş oluşturduğu bilinmektedir. Bu bağlamda elde edilen bulgular, fermente meyvelerin AAB izolasyonu açısından önemli ve güvenilir bir kaynak olduğunu bir kez daha ortaya koymuştur.

İzolasyon çalışmaları sonucunda, seçici besiyerlerinde gelişim gösteren kolonilerden saf kültürler başarıyla elde edilmiş ve izolatlar temel fenotipik testlerle ön değerlendirmeye tabi tutulmuştur. Tüm izolatların Gram-negatif ve katalaz pozitif özellik göstermesi, bu mikroorganizmaların asetik asit bakterilerine özgü temel fenotipik karakterlerle uyumlu olduğunu göstermiştir. Fenotipik veriler, izolatların AAB grubuna ait olduğuna dair güçlü ön bulgular sunmakla birlikte, tür düzeyinde kesin tanımlama için moleküler analizlerin gerekliliğini de ortaya koymuştur.

Bu doğrultuda gerçekleştirilen 16S rRNA gen dizileme analizleri, izolatların büyük çoğunluğunun %99'un üzerinde benzerlik oranlarıyla *Acetobacter ghanensis* türü ile eşleştiğini göstermiştir. Elde edilen dizi verilerinin BLAST analizleri, çoklu dizi hizalamaları ve filogenetik ağaç sonuçları, izolatların referans suşlarla yüksek derecede filogenetik yakınlık sergilediğini doğrulamıştır. Bu sonuçlar, moleküler karakterizasyonun, özellikle yakın akraba türlerin ayrımında fenotipik yöntemlere kıyasla daha güvenilir ve ayırt edici olduğunu desteklemektedir.

Çalışmada elde edilen veriler, fermente meyve ortamlarında *Acetobacter* türlerinin baskın mikroorganizma gruplarından biri olduğunu ve bu bakterilerin etanol varlığında metabolik aktivitelerini sürdürebilme yeteneğine sahip olduğunu göstermektedir. Bu özellikler, söz konusu izolatların sirke üretimi ve diğer fermentatif biyoteknolojik uygulamalar açısından potansiyel adaylar olduğunu düşündürmektedir. Ancak, izolatların endüstriyel kullanım potansiyelinin tam olarak ortaya konabilmesi için etanol ve asetik asit tolerans düzeylerinin nicel olarak belirlenmesi, asetik asit üretim kapasitelerinin değerlendirilmesi ve genomik düzeyde daha ayrıntılı analizlerin yapılması gerekmektedir.

Sonuç olarak, bu çalışma fermente meyvelerden izole edilen asetik asit bakterilerinin fenotipik ve moleküler karakterizasyonuna ilişkin önemli veriler sunmakta; doğal fermentasyon kaynaklarının, endüstriyel açıdan değerli mikroorganizma suşlarının elde edilmesi açısından taşıdığı önemi vurgulamaktadır. Elde edilen bulguların, hem doğal fermentasyon mikrobiyotasının anlaşılmasına katkı sağlayacağı hem de ileride gerçekleştirilecek uygulamalı ve endüstriyel çalışmalara temel oluşturacağı düşünülmektedir.

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AN EVALUATION ON THE EXTERNAL MORPHOLOGY OF THE SPECIES *KARSCHIA (KARSCHIA) MASTIGOPHORA* BIRULA, 1890 (SOLIFUGAE, KARSCHIIDAE)

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ABSTRACT

The male specimen of *Karschia (Karschia) mastigophora* Birula, 1890 was investigated for specific morphological features using scanning electron microscopy. Cheliceral setal complexes and pedipalpal papillae were surveyed in detail. The types of sensilla (microtrichia, sensilla ampullacea, sensilla chaetica, sensilla styloconica, and sensilla trichodea) were described, and their possible functions were interpreted as mechanoreceptors and chemoreceptors.

Key words: *Karschia*, sensilla, chemoreceptor, mechanoreceptor, Hakkari.

1. INTRODUCTION

The sensory systems of arthropods are composed of organized organs featuring cuticular and cellular specializations aligned with their sensory functions. In arachnids, sensory organs are densely distributed on the extremities and primarily function as mechanoreceptors and chemoreceptors. Mechanical stimuli—including air currents, tactile input, and substrate-borne vibrations—constitute the primary sensory modalities in arachnids. The most prominent chemoreceptive structures are contact chemoreceptors (taste hairs) and olfactory receptors (pegs), predominantly located on the distal segments of the pedipalps, legs, and chelicerae. (Altner & Prillinger 1980, Keil & Steinbrecht 1984, Zacharuk 1980, Foelix 1985, Punzo 1998). Bauchhenss (1983) conducted the pioneering investigation into sensillar structures in solifuges, detailing the morphology and ultrastructure of sensilla ampullacea in *Oparba* sp., *Galeodes barbarus* (Galeodidae), and *Biton tunetanus* (Daesidae), and proposing their potential role as contact chemoreceptors. Cushing and Casto (2012) examined the setal and sensory structures on the pedipalp surface in representative species from each of 12 spider families. Cushing et al.(2014) studied the detailed morphology of the papillae located on the pedipalp metatarsus, especially in male individuals of 10 species belonging to 3 families (Eremobatidae, Karschiidae, Solpugidae). As a result of SEM, TEM and electrophysiological studies, they stated that it can function as a chemoreceptor as well as a mechanoreceptor. Erdek and Gharakhloo (2020) proposed that various types of setae, sensilla, and epicuticular protrusions in male specimens of *Rhagodes eylandti* and *Rhagodes caucasicus* serve functional roles as mechanoreceptors and contact chemoreceptors. Baran and Erdek (2022) interpreted that the external morphological evaluation concerning sensilla types and cuticular structures in *Galeodes araneoides* (Pallas, 1772).

Karschia (Karschia) mastigophora Birula, 1890 has a narrow distribution in the Palearctic, including Armenia, Georgia, and Türkiye (Harvey, 2003). In addition to being one of the type localities of Kars province, Türkiye, Koç (2007) also recorded this species from Hakkari, Iğdır, and Van provinces. The specimen used in this study is the first specimen recorded from the highest elevation in Turkey, at 2967 m.

2. MATERIAL AND METHOD

Adult male specimens of *Karschia (K.) mastigiphora* were obtained from under stones in the daytime period with forceps from Berçelan Plateu (37°38′12″N, 43°44′58″E, 2967 m, 04.07.2025) and Boybeyi Village, Dikilitaş Hamlet (37°47′16″N, 44°05′04″E, 1762 m, 16.07.2022) of Hakkari Province, Turkey. Specimens were photographed and documented using a Leica DFC295 digital camera. For scanning electron microscopy (SEM), chelicerae and pedipalps were dissected and immersed overnight in absolute ethanol. Following dehydration, samples were gold-coated using a Quorum SC7620 sputter coater. SEM imaging was performed at an accelerating voltage of 10 kV using a ZEISS Sigma 300 microscope housed at the Science Application and Research Center of Van Yüzüncü Yıl University. All examined material is deposited in the Arachnida collection of the Zoology Museum, Hakkari University.

Abbreviation: fcp — flagellar plumose spiniform setae, fcs — flagellar complex subspiniform to spiniform setae, flg — flagellum, , pdp — prodorsal proximal seta, pp — palpal papillae, pvd — proventral distal setae, pp — palpal papillae, pvsd — proventral subdistal setae, sp — stridulatory plate,

3. RESULTS

The general view of the dorsal and ventral parts of the species is as in Fig.1. The fixed finger of the chelicerae straightens and protrudes distally in the dorsal part, then curves downwards (Figs. 2A-B). Following its dorsal coiling from the socket, the flagellum ascends slightly and extends toward the immobile fingertip. Distally, from the ventral side beyond the coil, it gradually tapers and gives rise to comb-like microtrichia (Figs. 3A, C-F). There is two flagellar complex spiniform setae. The one close to socket marginal elevation of the flagellum is drop-shaped, being swollen proximally at the base and progressively tapering toward the apex. The other structure is conical, tapering uniformly from the base to the apex. In their robust and immovable condition, they assume the morphology of basiconic sensilla. Both exhibit longitudinal groove-like indentations and surface protrusions (Figs. 2B-D; 3A, C-D). On the ventral side of the flagellum, there are four flagellar complex plumose setae, which are not coiled like the flagellum. These branch out distally from approximately the middle, forming a comb-like structure resembling microtrichia of varying sizes (Figs. 2C; 3C). Two proventral distal setae are located immediately posterior to the flagellum, while setal comb (as eight proventral subdistal seta) are positioned directly beneath it (Figs. 2B, D; 3A, C). There are also five proventral distal setae on the dorsal side of the stridulatory plate (Fig. 2B). Each is aligned parallel to the cheliceral surface, with their apices oriented toward the cheliceral tip. The surface

of the stridulatory plate is generally smooth, and only two spindly setae in the form of trichodea sensilla were seen on the ventral part (Figs. 2B; 3B).

There are 5 setae on the prolateral side of the pedipalp tarsus and 9 setae on the metatarsus (Figs. 2E-F; 4A-B). It is the basiconic sensilla located in the middle part; it is short, swollen at the base, thinning towards the tip and its surface is smooth (Figs. 4A-B). n addition, certain setae are distinctly longer than the surrounding ones, oriented approximately at a right angle to the surface, and are classified as movable, aporous tactile setae (Figs. 2E-F;4A-B). A cluster of papillae is present in the middle and proximal part of the palp metatarsus (Figs. 2E; 4A-C). The papillae display branches emanating from the base of a central shaft. The apical portion of this shaft is elongated, projecting beyond the branches and terminating in a filiform tip (Figs.4C-E). Each papilla arises from a bulge of cuticle, with a flexible socket (Figs. 4C-D). This well-developed socket structure resembles some special sensilla chaetica and sensilla styloconica. In addition, on the metatarsus surface, there are thin setae resembling sensilla trichodae, which are non-socketed and immovable and positioned at an angle of approximately 35-45 degrees to the cuticle surface. In addition, these sensilla show bifurcation in places at the base. (Fig. 4F).

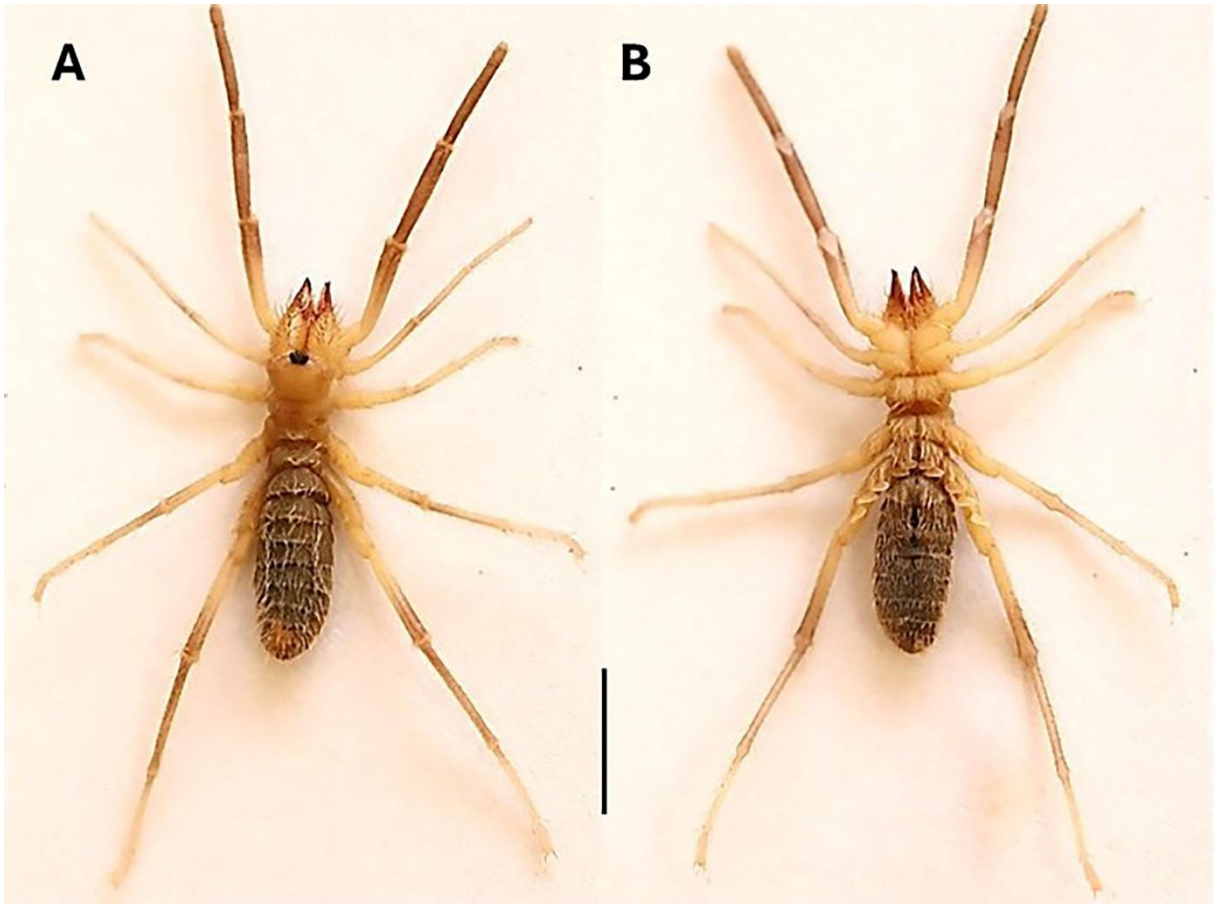


Figure 1. The general appearance of *Karcshia mastigophora* Birula, 1890. A. Dorsal view, B. Ventral view (Scale Bars: 1 cm)

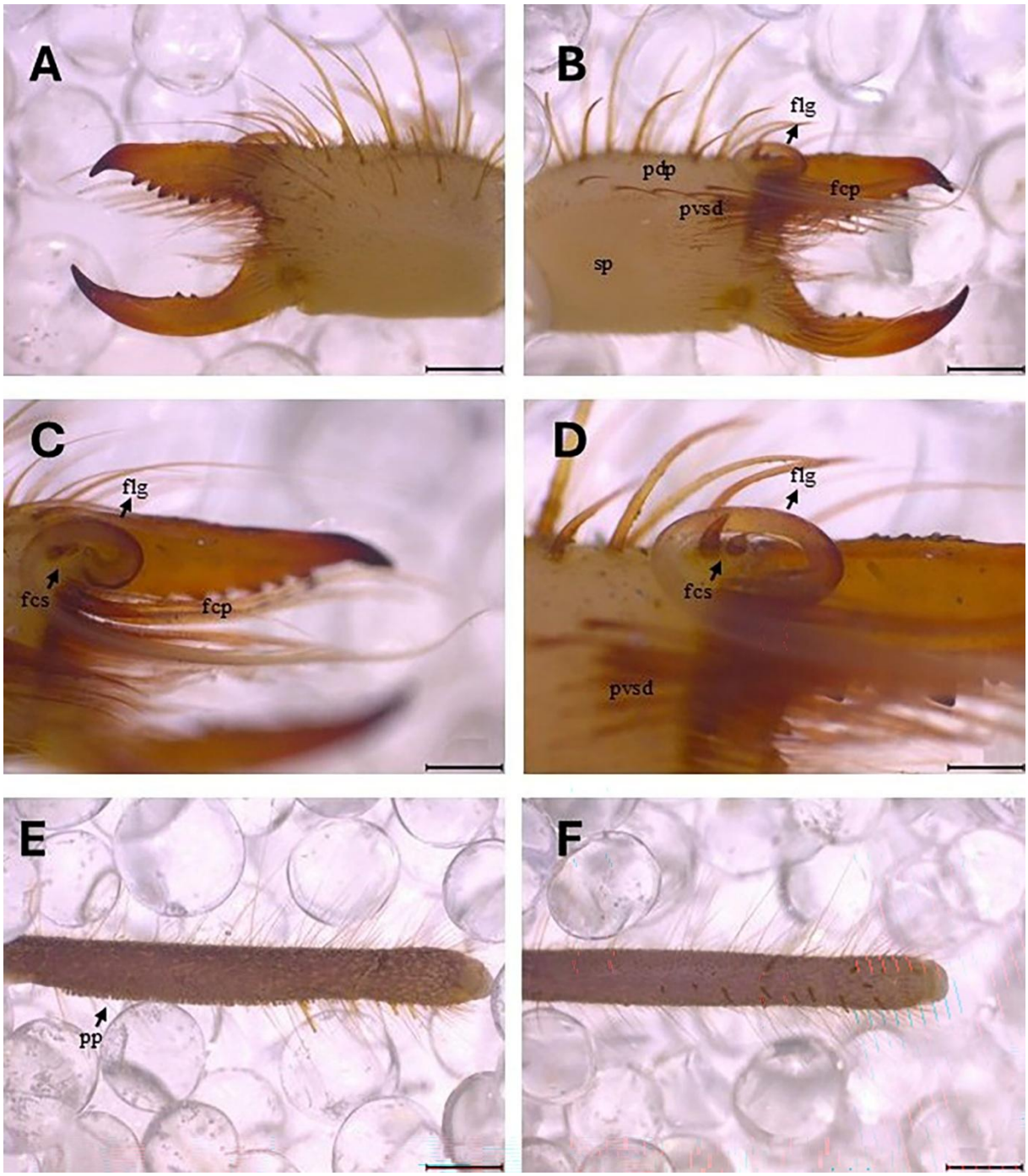


Figure 2. *Karcshia mastigophora* Birula, 1890, male. A.Sinistral chelicera in retrolateral view, B. Sinistral chelicera in prolateral view, C. Flagellum and flagellar setal complex. D. Basally coiled part of flagellum and flagellar complex spiniform setae. E. Sinistral pedipalp, tarsus and metatarsus, prolateral view, F. Sinistral pedipalp, tarsus and metatarsus, ventral view

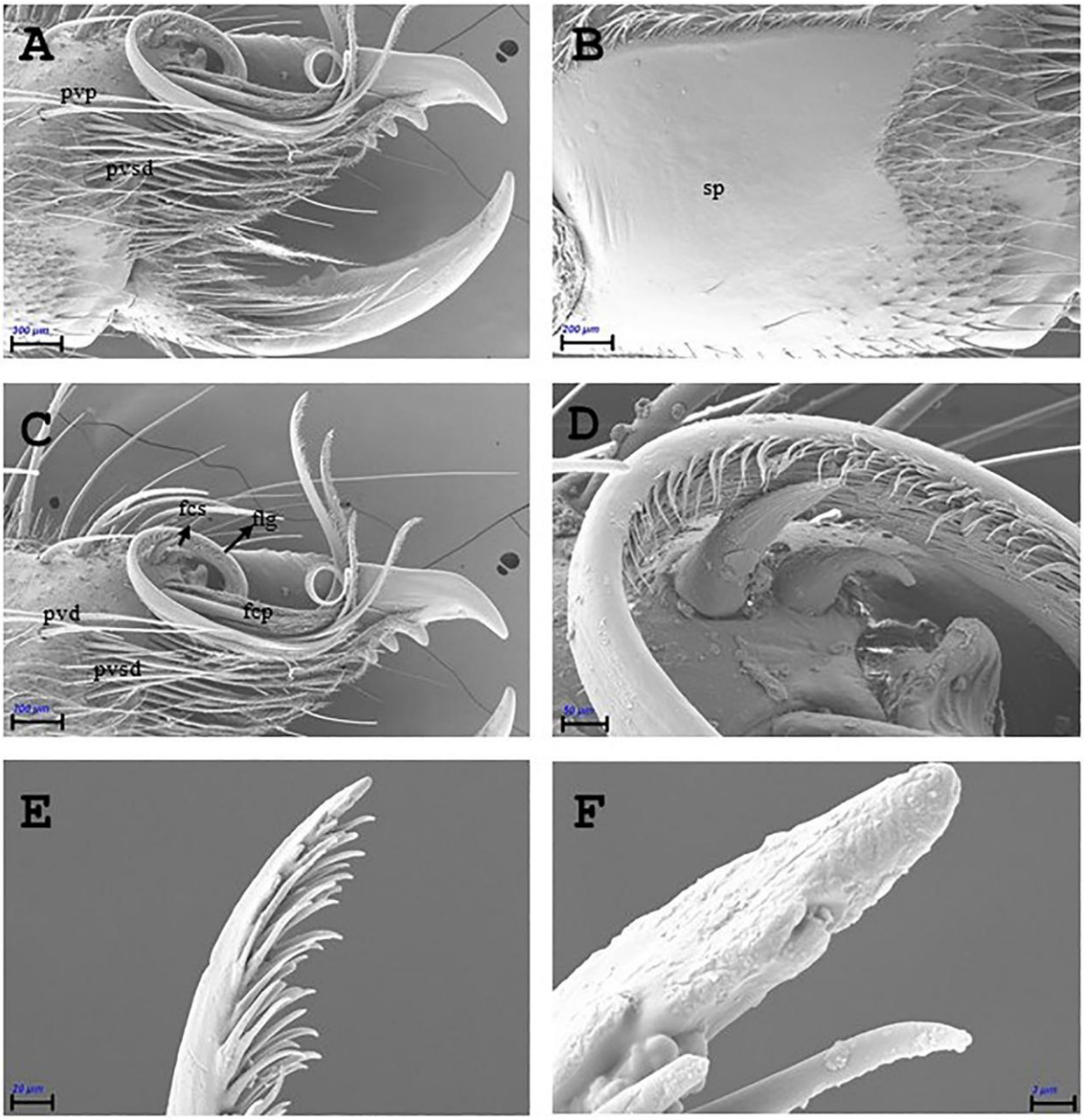


Figure 3. *Karcshia mastigophora* Birula, 1890, male. A.Sinistral chelicera in prolateral view, distal part B. Sinistral chelicera in prolateral view, proximal part C. Flagellum and flagellar setal complex. D. Basally coiled part of flagellum and flagellar complex spiniform setae. E. The distal part of flagellum, microtrichia. F. Tip of flagellum with ventral pore.

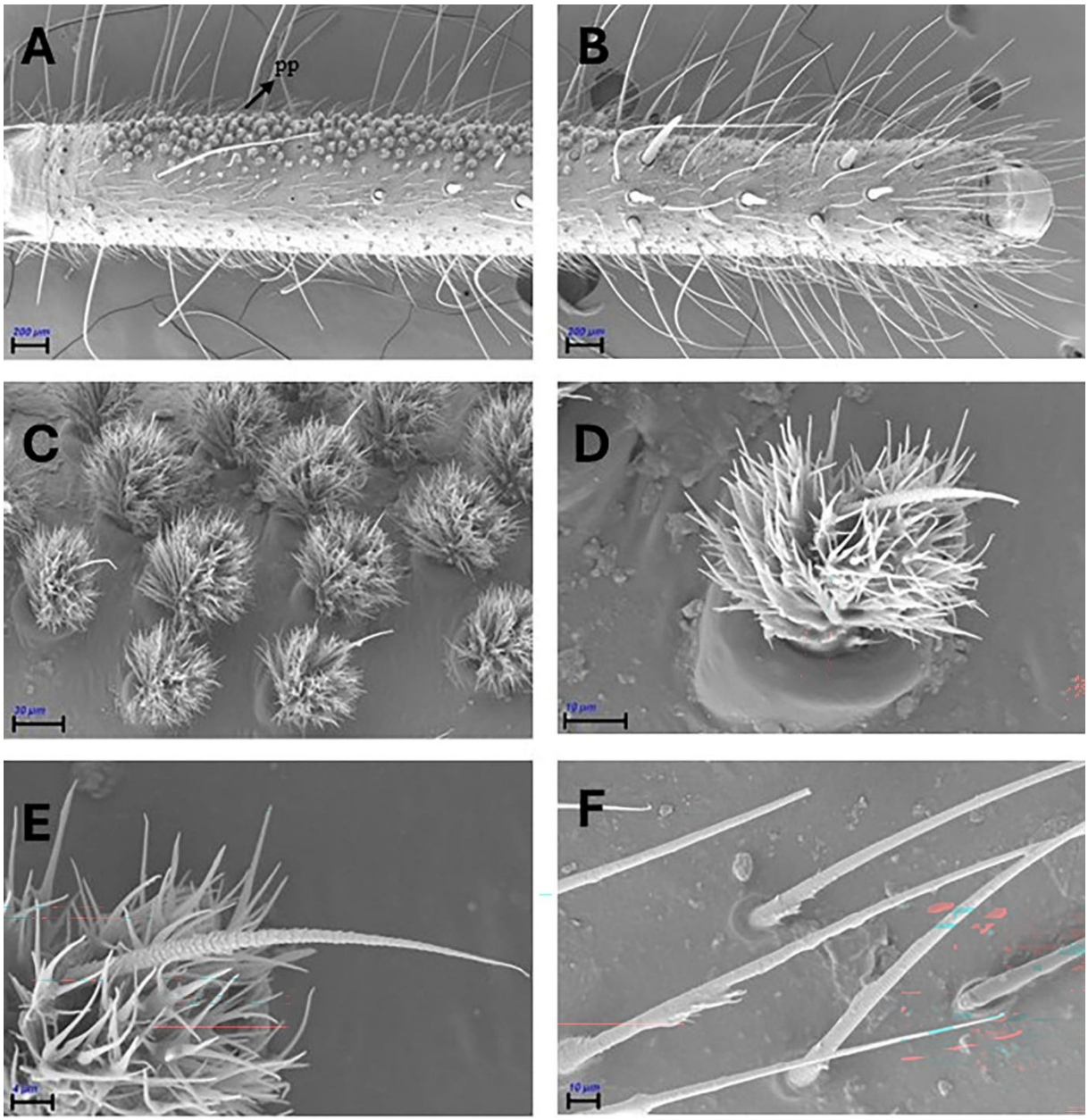


Figure 4. *Karcshia mastigophora* Birula, 1890, sinistral pedipalp in male. A. Proximal part of pedipalp metatarsus with the field of papillae, in prolateral view, B. Pedipalp tarsus and distal part of the metatarsus in prolateral view, C. Field of papillae. D. Single papillae. E. Papilla branches and single elongated-imbricated sensilla part. F. Non-socketed sensilla.

4. DISCUSSION

This study presents an assessment of the external morphology of sensillar types and selected cuticular structures on the chelicerae and pedipalps of male *K. (K.) mastigofera*.

While Kars is the type locality for our country, it has also been identified in Hakkari, Iğdır, and Van provinces Koç, 2007, Erdek, 2014). The locality included in this study is the highest known locality for the species. While the species mostly prefers steppe and herbaceous vegetation, it can also occur in dense alpine meadows, depending on the elevation, as reported in this study.

Five distinct types of sensilla, along with their respective subtypes, were identified across the chelicerae and pedipalps of male *K. mastigophora*; *Sensilla ampullacea* (SA)*, Sensilla chaetica* (SC)*, Sensilla styloconica* (SS), *Sensilla trichodea* (ST) and *Microtrichia*. Previous researches (McIver, 1975; Altner & Prillinger, 1980) have demonstrated that aporous sensilla act as mechanoreceptors. In line with this, the four sensillar types observed are considered to function predominantly as mechanoreceptors, characterized by the absence of pores or openings on the sensillar walls. The *pvsd* and *pvd* exhibit a hard and minimally movable morphology, corresponding to the SC type. Owing to their aporous nature, they are interpreted as mechanoreceptors. Considering the location of plumose setae on the chelicerae surface, they are structures that reduce food loss and are believed to be contact chemoreceptors responsible for gustation (Baran & Erdek, 2022).

The pedipalps possess SB, SS and ST. The SB is characterized by a broad basal region that gradually tapers into a conical apex. As this structure is present exclusively in males, it is presumed to serve a sexual function. Behavioral observations indicate that during the initial attack phase of mating, the first physical contact occurs, wherein the male employs his palps to tape and clasp the female's abdomen during the contact phase (Muma, 1966; Baran & Erdek, 2022). According to Cushing et al. (2014), SEM and electrophysiological analyses supported the hypothesis that papillae act as mechanoreceptors, while providing no evidence for chemoreceptive, thermoregulatory, or hygroreceptive functions. Nevertheless, the authors noted that their findings also suggest a potential chemoreceptive role for papillae in addition to mechanoreception. The SS were likewise documented in insects (Gelostocoridae) by Nowinska et al. (2023), with evidence suggesting their role in mechanoreception or gustation. Cushing et al. (2014) proposed that papillae located on the pedipalps (those categorized as SS in this study) of certain male solifuges may play a role in courtship or copulation. They suggested that the extensive branching of these specialized setae could constitute a distinctive mechanism for the transduction of mechanical stimuli during mating, potentially stimulating the female or eliciting her acceptance of the male. This represents a well-founded and plausible assumption. Beyond the aforementioned functions, this study further indicates a potential role as a contact chemoreceptor, particularly in relation to prey and female conspecifics.The longest subtype of ST, the tactile hairs, are considered to be involved in prey and mate detection in both sexes (Baran & Erdek, 2022) According to Erdek & Gharakhloo (2020), ST situated on the tarsus and metatarsus of the pedipalps probably function in hygroreception and thermoreception.

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Tilia tomentosa (GÜMÜŞİ IHLAMUR)'UN POTANSİYEL ANTİBİYOFİLM AKTİVİTESİNİN ARAŞTIRILMASI

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ÖZET

Biyofilm, bir yüzeye tutunan ve hücre dışı polimerik bir madde (EPS) ile çevrili mikrobiyal bir hücre topluluğudur. Bu yerleşik toplulukların oluşumu ve antimikrobiyal ajanlara karşı doğal dirençleri, birçok kalıcı ve kronik enfeksiyonun temel nedenidir. Biyofilm üreten bakterilerin neden olduğu mikrobiyal enfeksiyonların çoğu, geleneksel tedaviye direnç gösterdiğinden araştırmacılar, bu tür enfeksiyonların tedavisi için alternatif yöntemler belirlemeye yönelmiştir. Hastanelerde, öncelikle tıbbi ekipmanlarda biyofilm oluşumu, mikropların antibiyotiklere direnç göstermek için kullandığı bir taktiktir ve bunun kalıcı olmasına ve hastalara kolayca yayılmasına, bağışıklık savunmalarını yok etmesine ve çoğu kronik ve tekrarlayan enfeksiyona neden olmasına olanak tanır. Bu bağlamda, biyofilmlerle ilişkili enfeksiyonları ortadan kaldırabilecek veya önleyebilecek orjinal, yenilikçi ve daha ekonomik stratejiler tasarlamak önemlidir. Bitkilerin ham özütlerinin ya da içeriklerinin bakteriyel biyofilm oluşumu üzerinde engelleyici etkilere sahip olduğu geçmiş çalışmalarla kanıtlanmıştır. Sunulan bu çalışmada, *Tilia tomentosa*'nın sulu ekstrelerinin antibiyofilm aktivite yüzdesinin *Pseudomonas aeruginosa* (ATCC 27853) ve *Staphylococcus aureus* (ATCC 29213) kullanılarak değerlendirilmesi hedeflenmiştir. Elde edilen sonuçlara göre bitki ekstresinin µg/mL oranında kullanımı ile *S. aureus* için % 28.59 inhibisyon oranı gösterirken, *P. aeruginosa* için bu oran %51.46 olarak tespit edilmiştir. Bu sonuçlar alternatif bir antibiyofilm ajanı olarak *T. tomentosa* ekstresinin ilerleyen zamanlar için bir aday olabileceğini göstermektedir.

Anahtar Kelimeler: *Tilia tomentosa,* Antibiyofilm aktivite, *Pseudomonas aeruginosa, Staphylococcus aureus,*.

1. GİRİŞ

Biyofilm, hücrelerin birbirine bağlandığı ve biyotik veya abiyotik yüzeye tutunduğu karmaşık bir mikroorganizma matrisidir (Costerton vd. 1999, Mah ve O'Toole 2001). Biyofilmler genellikle klinik ve endüstriyel, gıda işleme ortamları ve içme suyu dağıtım sistemleri dahil olmak üzere farklı ortamlarda bulunan ıslak bir yüzey üzerinde polisakkaritler, proteinler ve diğer organik bileşenlerden oluşan yapışkan bir jel oluşturur (Oral vd. 2010, Kavanaugh ve Ribbeck 2012). Biyofilmlerdeki bakteriler, süspansiyondaki planktonik hücrelere göre antibiyotiklere ve kimyasal ajanlara daha dirençlidir (Stewart ve Costerton 2001). Biyofilm matrisine nüfuz eden kimyasal ajanlar daha az etkilidir, çünkü kimyasalların çoğu yalnızca bağlanmamış mikroorganizmalara karşı etkilidir. Antibiyotik dirençli mikroorganizmaların ortaya çıkışı, dünya çapında artan morbidite ve mortaliteye yol açan ve ciddi bir halk sağlığı sorunu olarak kabul edilen hastane enfeksiyonlarının önde gelen nedenidir (Samuel vd. 2010, Liu vd. 2015). Günümüzde büyük bir endişe haline gelen bakteri direncinin dünya çapındaki artışı nedeniyle, bu sorunla başa çıkmak için yöntem ve stratejileri iyileştirme ve geliştirme konusunda acil bir ihtiyaç vardır.

Hastanelerde, öncelikle tıbbi ekipmanlarda biyofilm oluşumu, mikropların antibiyotiklere direnç göstermek için kullandığı bir taktiktir ve bunun kalıcı olmasına ve hastalara kolayca yayılmasına, bağışıklık savunmalarını yok etmesine ve çoğu kronik ve tekrarlayan enfeksiyona neden olmasına olanak tanır (Stewart ve Costerton 2001, Høiby vd. 2011). Biyofilmlere nüfuz etmek ve onları parçalamak için biyofilm matrisini hidrolize etmek gerekir. *S.aureus* ve *Escherichia coli* gibi gıda kaynaklı ve hastane kaynaklı patojenlerin büyümesini ve gelişimini sınırlamak çok önemlidir, ancak bu organizmaların yok edilmesi her zaman başarılı değildir çünkü çeşitli yüzeylerde biyofilm oluşturma yetenekleri vardır (Nostro vd. 2007, Oral vd. 2010). Bu bağlamda, biyofilmlerle ilişkili enfeksiyonları ortadan kaldırabilecek veya önleyebilecek orijinal, yenilikçi ve uygun maliyetli stratejiler tasarlamak esastır (Lebeaux vd. 2014, Akhil vd. 2016).

Bitki özleri ve bitkilerden izole edilen diğer biyolojik olarak aktif bileşikler, eski çağlardan beri hastalıkları tedavi etmek için kullanıldığından bu konuda yaygın ilgi görmüştür (Maki ve Mermel 1998). Modern bilim ve teknolojik gelişmeler, bitkilerden elde edilen, iyileştirilmiş terapötik aktiviteye ve azaltılmış yan etkilere sahip yenilikçi ilaçların keşfini ve geliştirilmesini hızlandırmaktadır. Bitki bileşikleri, güvenli oldukları algısı nedeniyle yaygın olarak kabul görmektedir ve halk tıbbında bağışıklık güçlendirici olarak ve çeşitli hastalıkların önlenmesi ve tedavisi için uzun bir kullanım geçmişine sahiptir (Jones 1997). Yıllar geçtikçe, geleneksel tıbbın omurgasını oluşturan tıbbi bitkilerin kullanımı artmıştır ve çoğunlukla gelişmekte olan ülkelerde nüfusun yaklaşık %80'i, birincil sağlık hizmetleri için geleneksel ilaçlara güvenmektedir (Namasivayam ve Avimanyu 2011). İlaç endüstrisinde olası uygulamalar için yoğun araştırmalar altında olan bitki kaynaklı maddeler arasında yaprakların, köklerin, gövdelerin ham özütleri ve bunlardan izole edilen bireysel bileşikler, uçucu yağlar ve uçucu yağ bileşenleri yer almaktadır (Bookstaver vd. 2009). Bitkiler ve aktif bileşenler üzerine şu anda birçok araştırma devam etmekte olsa da, odak noktası esas olarak plankton veya biyofilm

oluşturan bakterilere karşı antimikrobiyal özelliklerdir (Knetsch ve Koole 2011). Bitki özleri, antimikrobiyal özelliklere sahip çeşitli biyoaktif bileşikler içerdiğinden, ilaç endüstrisinde yaygın olarak kullanılmaktadır. Bitki özlerinin (çözücü özleri ve fraksiyonları) biyofilm engelleyici etkisinin *E. coli* (Agrawal 2011, Vacheva vd. 2011), *Listeria monocytogenes* (Sandasi vd. 2010), *S. aureus* (Quave vd. 2008, Agrawal 2011) ve *Candida albicans*'a (Polaquini vd. 2006) karşı rapor edildiği bildirilmiştir.

T. tomentosa bitkisinin yaprakları ve çiçekleri yüzyıllardır Türkiye'de bitki çayı hazırlamak için kullanılmaktadır. Yatıştırıcı özelliklere sahip açık sarı renktedir ve soğuk algınlığı, ateş, baş ağrısı, boğaz ağrısı, yüksek tansiyon gibi rahatsızlıklara karşı çok etkili olduğu kanıtlanmıştır (Naika 2015). Bu bağlamda, bu çalışmada biyofilmlerle ilişkili enfeksiyonları ortadan kaldırabilecek daha yenilikçi bir strateji tasarlamak adına *T. tomentosa*'nın yaprak sulu ekstrelerinin iki farklı bakteri suşu üzerinde biyofilm oluşumunu engelleyici etkileri araştırılmıştır.

2. MATERYAL METOD

2.1 Bakteri suşları

Çalışmada kullanılan *S. aureus* (ATCC 29213) ve *P. aeruginosa* (ATCC 27853) suşları Afyon Kocatepe Üniversitesi Fen Edebiyat Fakültesi Moleküler Biyoloji ve Genetik Bölümünde yer alan Moleküler Biyoloji ve Genetik Laboratuvarında stokundan temin edilmiş ve çalışmadan önce gecelik taze kültürleri hazırlanmıştır.

2.2 Bitki Ekstrelerinin Hazırlanması

Bu çalışmada, Afyon Kocatepe Üniversitesi Fen Edebiyat Fakültesi Moleküler Biyoloji ve Genetik Bölümünde yer alan Moleküler Biyoloji ve Genetik Laboratuvarında hazır olarak bulunan *T. tomentosa* bitki örnekleri kullanılmıştır. Bitkiden elde edilen kuru yapraklar blenderdan geçirilip havanda dövülmüş ve toz haline getirilmiştir. Tartılan örnekler distile su ile muamele edilip karışım hazırlanmış ve daha sonra bu karışım mikrodalga fırında 1 dakika (1200W, 50Hz) boyunca tutulduktan sonra filtre kağıdından süzülerek bitki ekstreleri elde edilmiş ve çalışmada kullanılacak dozlar hazırlanmıştır.

2.3 Biyofilm inhibisyon aktivitesi

Tilia tomentosa'nın biyofilm önleme kapasitesini değerlendirirken, Farajzadeh vd. (2022) tarafından belirtilen yöntemde küçük değişiklikler yapılarak aynı yöntem kullanıldı. Birçok mikroorganizma türünün biyofilm oluşturduğu bilinmesine rağmen, bu çalışmada model mikroorganizma olarak *S. aureus* ve *P. aeruginosa* tercih edildi. *S. aureus* ve *P. aeruginosa* tarafından biyofilm oluşumunu engelleme yeteneğini test etmek için 96 kuyucuklu plakalar kullanıldı. Her bir bakteri türünün taze süspansiyonları ve bitki ekstresi besin ortamı içeren kuyucuklara eklendi. Daha sonra plaka 72 saat süreyle 37° C'de inkübasyona bırakıldı. Süre sonunda plakanın biyofilm kaplı kuyucukları fosfat tamponlu salin (PBS) ile iki kez iyice yıkandı ve oda sıcaklığında yarım saat kurumaya bırakıldı. Bu işlemlerin ardından, biyofilm oluşumunu değerlendirmek için her bir plaka kuyucuğuna %1'lik kristal viyole çözeltisi eklendi ve bir saat süreyle renk değiştirmeye bırakıldı. Daha sonra plakalar yeniden PBS ile yıkanarak

kristal viyole plakalardan uzaklaştırıldı. Kuyucuklara emilen kristal viyoleyi geri kazanmak için etanol eklendi ve plakaların on beş dakika boyunca oda sıcaklığında bekletilmesine izin verildi. Biyofilm inhibisyonu bir spektrofotometre kullanılarak 595 nm'de ölçüldü. Biyofilm inhibisyonu aşağıdaki formül (X)'e göre hesaplandı.

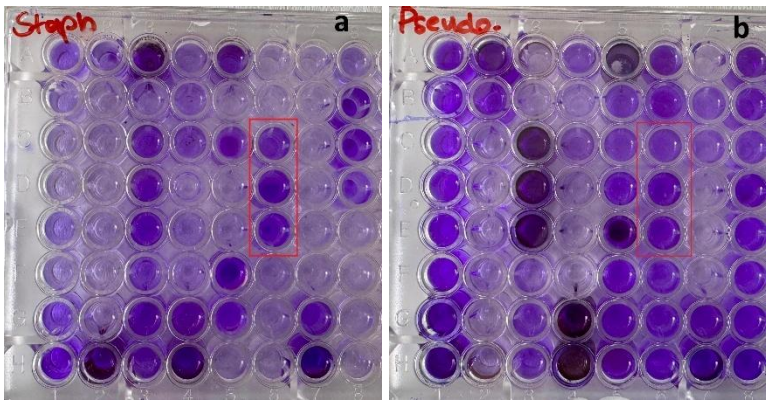
$$\%\text{Biyofilm İnhibisyonu}=(\text{Absorbans}_{\text{kontrol}} - \text{Absorbans}_{\text{örnek}}/\text{Absorbans}_{\text{kontrol}}) \times 100$$

$\text{Absorbans}_{\text{kontrol}}$, test numunesi içermeyen çözelti ve ayrıca $\text{Absorbans}_{\text{örnek}}$ test numuneleri içeren test tüplerinin absorbansı

3. SONUÇLAR VE DEĞERLENDİRME

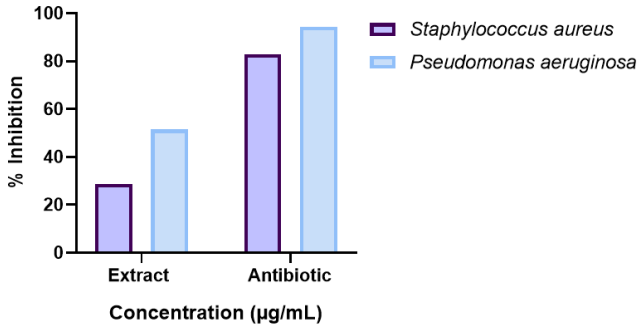
Biyofilm, çeşitli mikroorganizmalar tarafından oluşturulan yapılardan biridir ve bazı bakteriyel enfeksiyonlardan sorumludur. Biyofilm oluşumuna neden olan mikroorganizma toplulukları, bazen antibiyotiklerle kolayca tedavi edilemeyen bir biyofilm tabakası oluşturabilir. Bu dirençli yapılar sayesinde, mikroorganizmalar bazı antibiyotiklere karşı direnç geliştirebilir ve bakteriyel enfeksiyonların tedavisini zorlaştırabilir. Günümüzde, biyofilm oluşumuna neden olan mikroorganizmaların tedavisi için alternatif yöntemlere acilen ihtiyaç duyulmakta olup bu kapsamda çoğunlukla bitki özleri yaygın olarak kullanılmaktadır. Bu nedenle, çalışmada, *T. tomentosa* bitki ekstresinin antibiyofilm yetenekleri kristal viyole bağlanma testi kullanılarak araştırılmıştır. Gümüşi ıhlamur tıbbi bitkiler arasında yaygın kullanılan ve Türkiye'de dört farklı türle temsil edilen bir bitki olup bitkinin çiçekleri nezle, bronşit ve öksürük gibi sağlık problemlerine karşı dünyanın her yerinde yaygın olarak kullanılmaktadır (Gruenwald vd. 2000, Anonymous 2012, Chinou 2012).

Kristal viyole, mikroorganizmalar tarafından sentezlenen biyofilm tabakasına bağlanma özelliğine sahiptir. Biyofilm tabaka sayısı ne kadar fazla olursa, mikrobiyal biyofilm tabakasına o kadar fazla kristal viyole bağlanır. Biyofilm tabakasına bağlanan kristal viyole, etanol ile geri kazanılır. Geri kazanım sonucunda, daha koyu renk biyofilm tabakasının yüksek olduğunu, daha açık renk ise biyofilm tabakasının düşük olduğunu gösterir. Uygulanan bitki ekstresinin antibiyofilm aktivitesinin belirlenmesi sırasında kristal viyolenin geri kazanım aşaması Görsel 1'de verilmiştir.



Görsel 1: *Tilia tomentosa*'nın antibiyofilm etkisi, a: *S. aureus* b: *P. aeruginosa*

Bu çalışma sonuçları değerlendirildiğinde kullanılan bitki ekstresinin her iki suş için de antibiyofilm özelliğine sahip olduğu saptanmıştır. Suşlar kendi için de karşılaştırıldığında bitki ekstresine karşı *P. aeruginosa*'nın *S. aureus*'a kıyasla daha duyarlı olduğu görülmektedir. Elde edilen sonuçlar her ne kadar bitki ekstresinin antibiyofilm kapasitesine sahip olduğunu gösterse de pozitif kontrol grubu olarak kullanılan antibiyotik uygulaması kadar inhibisyon oranına sahip olmadığı görülmektedir. Çalışmamızda bitki ekstresi, *S. aureus* için % 28.59 inhibisyon oranı gösterirken, *P. aeruginosa* için bu oran % 51.46 olarak tespit edilmiş ve Çizelge 1'de verilmiştir.



Çizelge 1. *T. tomentosa* bitki ekstresinin *S. aureus* ve *P. aeruginosa* üzerindeki antibiyofilm etkisi

Mikrobiyal enfeksiyonların çoğunun karmaşıklığının artması ve geleneksel tedaviye karşı direnç nedeniyle, araştırmacılar enfeksiyonların tedavisi için alternatifler belirlemeye yönelmişlerdir. Bitki özleri ve bitkilerden izole edilen diğer biyolojik olarak aktif bileşikler, eski çağlardan beri hastalıkları iyileştirdiği bilindiğinden bu konuda yaygın ilgi görmüştür (Tamilvanan vd. 2008). Quaralleh vd. (2021) yaptıkları bir çalışmada *Althaea officinalis, Tilia cordata* ve *Psidium guaja* bitkilerinin tek tek ve kombinasyon halinde, solunum yolu enfeksiyonlarına neden olan patojenlere karşı antibakteriyel ve antibiyofilm etkilerini incelemişler ve bu bitki ekstraktları ve fraksiyonlarının eşit oranlarda birleştirilmesinin tek tek kullanımlarına göre daha güçlü antibiyofilm etki gösterdiğini bulmuşlardır. *T. cordata*'nın sulu ve metanolik özütlerinin, özellikle solunum yolu enfeksiyonlarına neden olan klinik açıdan önemli bakteri izolatlarına karşı antibakteriyel ve antibiyofilm özellikler gösterip göstermediğini belirlemek amacıyla yapılan çalışmada ise, çiçeğin metanolik özütünün izolatlarda biyofilm oluşumunu çalışmamıza paralel olarak güçlü bir şekilde engelleyebildiğini göstermiştir (İsmail vd. 2019). *Azadirachta indica, Vitex negundu, Tridax procumbens* ve *Ocimum tenuiflorumi*'nin hem sulu hem de kitosan kaplı özütlerinin, klinik bir *E.coli* izolatının biyofilm gelişimine karşı antibiyofilm etkisinin değerlendirildiği çalışmada tüm bitki özleri, doz bağımlı bir şekilde biyofilmi inhibe etmiştir (Namasivayam ve Roy 2013). Çeşitli bitki özlerinin insan patojenik bakterilerinin biyofilmine karşı antibiyofilm etkileri de farklı araştırmacılar tarafından rapor edilmiştir (Essawi ve Srour 2000, Carneiro vd. 2011, Karlapudi vd. 2012). Bu literatürlerden de anlaşılacağı üzere bitkiler ve çeşitli deniz organizmaları, biyofilm önleyici maddeler için paha biçilmez bir kaynak oluşturmaktadır. Bu bileşiklere örnek olarak: *Helichrysum italicum'un* polar özütünden elde edilen stirilpironlar ve kinik asit türevleri

P. aeruginosa'ya karşı aktiftir (D'Abrosca vd. 2013), florretin (özellikle enterohemorajik *Escherichia coli* O157:H7 (EHEC) biyofilm oluşumunu azaltır (Lee vd. 2011) veya deniz süngerlerinden elde edilen alkaloidler gram pozitif ve gram negatif bakterilere karşı aktiftir (Stowe vd. 2010).

P. aeruginosa, hastane kaynaklı ve ventilatörle ilişkili pnömoni, kistik fibrozis (KF), menenjit, apse, yumuşak doku ve idrar yolu enfeksiyonları, kornea enfeksiyonu ve konjonktiva eritemi gibi durumlarda en sık görülen patojenlerden biridir. Ayrıca, bağışıklık sistemi baskılanmış hastalarda kateterle ilişkili ve kronik akciğer enfeksiyonlarına da neden olabilir (Chatterjee vd. 2016). Tıbbi cihazlarda biyofilm oluşturma ve geniş spektrumlu antibiyotiklerin uygulanması nedeniyle normal florası değişmiş konakçıdan faydalanma yeteneği göz önüne alındığında, *P. aeruginosa* araştırmacıları yeni tedavi stratejileri geliştirmeye ve incelemeye yöneltmiştir. Öte yandan, *S. aureus*, MRSA (Metisiline Dirençli *S. aureus*) gibi çoklu ilaca dirençli suşların ortaya çıkması nedeniyle yüksek morbidite ve mortalite ile ilişkili hem toplum kaynaklı hem de hastane kaynaklı enfeksiyonların önde gelen nedenidir (Liu vd. 2016). Çevrede bulunmasına ve normal insan florasının bir parçası olabilmesine (en sağlıklı bireylerin derisini ve mukoz zarlarını kolonize etmesine) rağmen, kan dolaşımına veya iç dokulara girme koşullarını bulursa, farklı, potansiyel olarak ciddi enfeksiyonlardan sorumlu olabilir. Kistik fibrozis, otitis media, periodontitis, idrar yolu enfeksiyonları ve osteomiyelit, hepsi polimikrobiyaldir (Ibberson ve Whiteley 2020). Örneğin, *P. aeruginosa* ve *S. aureus*'un sıklıkla CF'li hastaların akciğerlerinde birlikte enfeksiyon oluşturduğu görülmektedir ve aljinat aşırı üretimi, *P. aeruginosa*'nın *S. aureus* ile birlikte enfeksiyonunu tetikleyen önemli bir faktör olabilmektedir (Limoli vd. 2017, Limoli vd. 2019).

Mikroorganizmalarda antibiyotiklere karşı kazanılmış direnç oluşmasına yol açan mekanizmalar çok çeşitli ve karmaşıktır. Bunlar arasında, hücre zarı yoluyla geçirgenliğin azalması, moleküler hedefin modifikasyonu, artmış dışa atım pompası ekspresyonu ve antibiyotiklerin parçalanması, serbest planktonik hücrelerde ilaç etkinliğini azaltan önemli faktörlerdir. Ek olarak, bakteriyel biyofilmde, azalmış büyüme hızları ve metabolizma gibi diğer modifikasyonlar ve kalıcı hücreler olarak bilinen hücre biyofilmine özgü fenotiplerin indüklenmesi meydana gelir (Borges vd. 2016). Sonuç olarak, planktonik hücrelere karşı aktif olan antibiyotikler, yerleşik/uyku halindeki hücrelerde etkisiz hale gelebilir. Birçok çalışma, yerleşik bakterilerde antibiyotik etkisizliğinin altında yatan moleküler mekanizmayı anlamaya çalışmıştır. Antibiyotiklerin pervasız kullanımı, hayatta kalabilirliklerine uygulanan seçici baskı nedeniyle çoklu ilaç dirençli mikroorganizmaların gelişmesine yol açmıştır; bu nedenle, mikroorganizmaların öldürülmesinden ziyade, mikroorganizma virülans faktörlerinin gen ekspresyon modülasyonu yaygın olarak araştırılmıştır. Doğal ürünler esas olarak bakteriyel büyümeyi engellemeye veya patojenitelerini azaltmaya yöneliktir ve önemli virülans faktörlerini kontrol eden belirli genler üzerinde etki gösterir (Shaw ve Wuest 2020).

4. SONUÇ

Biyofilmler, bakterilerin antibiyotiklere ve antimikrobiyal ajanlara karşı dirençlerini artırmak için kullandıkları en başarılı stratejilerden birini temsil eder. Biyofilm oluşturan mikroorganizmalar büyük bir zorluk teşkil ederken, *S. aureus* ve *P. aeruginosa* gibi çoklu mikroorganizma içeren biyofilmlerle mücadele daha da karmaşıktır. Bu nedenle, yeni antibiyofilm kimyasalları bulmak çok önemlidir. Bu bağlamda, bitkiler, antimikrobiyal ve antibiyofilm özellikleri de dahil olmak üzere çeşitli biyolojik aktivitelere sahip bileşikler açısından son derece zengin bir kaynaktır. Bu bileşikler genellikle hâlihazırda kullanılan antibiyotiklerden farklı etki mekanizmalarıyla hareket eder ve böylece antibiyotik direncine karşı mücadele için de bir araç sunar.

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Thymus serpyllum (YABANİ KEKİK) BİTKİSİNİN SULU EKTRAKTININ *Staphylococcus aureus* ve *Pseudomonas aeruginosa* ÜZERİNDE ANTİBİYOFİLM AKTİVİTESİNİN BELİRLENMESİ

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ÖZET

Yabani kekik olarak bilinen *Thymus serpyllum(T. serpyllum)*, Lamiaceae familyasına ait bir türdür ve hem resmi hem de geleneksel tedavilerde kullanım alanı bulan değerli bir bitkidir. Günümüzde mikroorganizmalar tarafından oluşturulan enfeksiyonların tedavisinde kullanılan antibiyotiklere karşı başlayan direnç olgusu yeni antibakteriyel ajan arayışlarını hızlandırmıştır. Bakteriler tarafından oluşturulan biyofilm hastalıkların tedavisinde işleri daha da zorlaştırmaktadır. Biyofilm mikroorganizmaya tutunma alanı sağlamasının yanı sıra, onları antimikrobiyal ajanlardan ve bağışıklık sisteminin elemanlarından koruyarak kronik enfeksiyonların ortaya çıkmasına, tedaviye dirence bu bağlamda da istenmeyen etkilere neden olmaktadır. *Staphylococcus aureus (S. aureus)* gram-pozitif patojenik bir bakteridir ve insan ya da hayvanlarda çeşitli hastalıklar oluşturmaktadır. *Pseudomonas aeruginosa (P. aeruginosa)* gram negatif bir mikroorganizma olup yine farklı hastalıklara yol açmaktadır. Bu iki bakteri türünün oluşturduğu biyofilm ise bu mikroorganizmalar tarafından oluşturulan hastalıklarda tedaviyi zorlaştırmakta ve bu türlerin virülanslarını arttırmaktadır. Günümüzde oldukça önemli bir sorun teşkil eden biyofilm oluşumunu engellemek için bilim insanları yeni ajanlar keşfetmek için çaba göstermekte ve bunun için farklı doğal bileşikleri araştırmaktadır. Bu çalışma ile *T. serpyllum* bitkisinin sulu ekstraktının *S. aureus* (ATCC 29213) ve *P. aeruginosa* (ATCC 27853) bakteri suşlarının oluşturduğu biyofilme karşı etkinliğinin araştırılması hedeflenmiştir. Elde edilen sonuçlara göre bitki ekstraktının µg/mL oranında kullanımı ile *S. aureus* için % 14.25 inhibisyon oranı gösterirken, *P. aeruginosa* için bu oran % 8.59 olarak tespit edilmiştir. Bu sonuçlar alternatif bir antibiyofilm ajanı olarak *T. serpyllum* ekstresinin bir aday olabileceğini göstermektedir.

Anahtar Kelimeler: Biyofilm; *Staphylococcus aureus*; *Pseudomonas aeruginosa*; *Thymus serpyllum*

1. GİRİŞ

Thymus cinsi, Lamiaceae familyasının bir üyesidir ve dünya genelinde yaklaşık 214 tür ve 36 alt tür ile temsil edilmektedir (Dall'Acqua ve ark. 2017). Bu cins, taksonomik ve sistematik bakış açılarından oldukça karmaşıktır ve yalnızca morfolojik özelliklerinde değil aynı zamanda eterik yağların bileşiminde de önemli polimorfizm göstermektedir (Harley ve ark. 2004). Thymus cinsinin kökeni Akdeniz bölgesi, özellikle İber Yarımadası ve Kuzeybatı Afrika'dır; buradan Avrupa, Grönland, Kuzey Amerika ve Habeşistan'a, ayrıca Asya'ya yayılmıştır (Stahl-Biskup ve ark. 2012; Dall'Acqua ve ark. 2017). Hoş tadı, besleyici ve tıbbi değerleri nedeniyle Thymus cinsi bitkiler gıda, kozmetik, parfüm ve ilaç endüstrilerinde yaygın olarak kullanılmaktadır (Salehi ve ark. 2019). Thymus cinsine ait türler arasında özellikle *T. vulgaris* L. (adi kekik) en önemli türdür ve uzun bir geçmişe sahiptir. *T. zygis* L. (İspanyol kekiği), *T. serpyllum* L. (yabani kekik) ve *T. pulegioides* L. (büyük kekik) dahil olmak üzere diğer türler de bu cinsin dünyadaki başlıca ticari çeşitleridir (Dall'Acqua ve ark. 2017). *T. serpyllum,* kuzey ve orta Avrupa bölgelerine özgü çok yıllık bir çalıdır. Breckland kekiği, yabani kekik veya sürünen kekik olarak bilinir; ancak tür adı olan "serpillum", yabani kekiğin sürünme özelliğinden dolayı Yunanca "sürünmek" anlamına gelen kelimeden türetilmiştir (Salehi ve ark. 2019).

Yabani kekik bitkisinin tıbbi özellikleri, resmi ve geleneksel tıpta yüzyıllardır yaygın olarak kullanılmaktadır. Özellikle bitkinin çiçek açtığı dönemde toplanan, toprak üstü kısmının üst bölümü olmak üzere, taze ve kurutulmuş otlar, önemli miktarda uçucu yağ içermesi nedeniyle belirli iyileştirici özelliklere sahiptir. Tüm bu özellikleri sebebiyle son yıllarda, ilaç ve kimya endüstrilerinde birçok farklı formülasyonu hazırlanan *T. serpyllum* türünün tıbbi özelliklerine yönelik etnobotanik, fitokimyasal ve farmakolojik araştırmalara olan ilgi artmıştır. Bitki; şuruplar, tentürler, infüzyonlar, çay ve yağ gibi doğal bitkisel ilaçların hazırlanmasında kullanılmaktadır. Ayrıca patojenik mikroorganizmaların çoklu ilaç dirençli suşlarının artması, antioksidan, antimikrobiyal, antitümör ve sitotoksik özelliklere sahip tıbbi maddelerin önemli bir kaynağı olarak *T. serpyllum*'un kapsamlı fitokimyasal ve farmakolojik çalışmalarına ve bunların etkili tıbbi uygulamalarına ve yine ilaç, gıda ve kozmetik endüstrilerinde kullanımına olanak sağlamaktadır (Li ve ark. 2019).

Bakteriyel biyofilm enfeksiyonları, kalıcı enfeksiyonların ve belirli veya çoklu antibiyotiklere karşı direncin yaygınlığının temel nedenidir. Biyofilmler, çeşitli stres koşulları altında bakteriler için koruyucu bir ortam sağlayan ve kronik enfeksiyonların patogenezine önemli ölçüde katkıda bulunan benzersiz özelliklere sahiptir. Bakteri hücreleri kendi ürettikleri hücre

dışı polimerik bir matrisle kendi etraflarını kaplayarak, bu hücreleri etkili bir şekilde gizlerler (Upadhyay ve ark. 2025). Böylelikle biyofilmler, antibiyotik etkileri, konak bağışıklık etkileri, beslenme kısıtlamaları ve çevresel kısıtlamalar gibi olumsuz koşullar altında hayatta kalma desteği sağlayan, bakteri hücreleri üzerinde karmaşık bir örtü olarak görev yaparlar. Biyofilm, bakteri hücresinin kendisi tarafından sentezlenen ve düzenlenen karbonhidratlar, lipitler ve proteinler gibi çeşitli biyolojik moleküllerden oluşmakta olup bu örtü hücre dışı polimerik madde (EPS, extracellular polymeric substances) olarak bilinmektedir (Rather ve ark., 2021). Hücre sayısı arttıkça, EPS de büyümekte ve olgun bir biyofilmin gelişmesine yol açmaktadır (Sauer ve ark. 2022). Böylece, bakteri hücreleri birbirleriyle daha güçlü bir şekilde iletişim kurmakta ve koordinasyon sağlamaktadır. Sonuç olarak, bakteri hücreleri herhangi bir stresli ortamda kolayca hayatta kalabilmektedirler. Aynı zamanda, biyofilmler karmaşık yapısı nedeniyle ilaç molekülünün hücre içine girmesine karşı önemli bir bariyer görevi de görmektedir. Sonuç olarak, antibiyotik ilaçlar istenen terapötik sonucu göstermemekte ve tekli veya çoklu ilaç direnci (MDR) gelişmektedir (Halawa ve ark. 2024).

Ancak biyofilmin teşkil ettiği sorun, antibiyotik direnciyle sınırlı değildir, aynı zamanda kanser ve tekrarlayan bakteriyel enfeksiyonlar gibi kronik hastalıklarla da dolaylı bağlantılar göstermektedir. Yapılan önceki çalışmalar, biyofilmin poliamin gibi bazı biyolojik molekülleri saldığını, bunun da bakteriyel hücre duvarı oluşumunu ve hücre büyümesini artırdığını, toksin molekülleri ve karnitin oluşumuna sebep olduğunu ve kanser oluşumunu teşvik ettiğini öne sürmektedir. Bu nedenle, bakteriyel biyofilm oluşumu, sağlık açısından insanlarda ciddi bir sorundur. Mevcut senaryoda, mevcut tüm antibiyotik ilaçlar biyofilme karşı etkili terapötik sonuçlar göstermemiştir. Bu nedenle, biyofilm enfeksiyonunu kontrol altına almak gereklidir. Dolayısıyla, biyofilm enfeksiyonlarıyla mücadele etmek ve antibiyotik direncini kontrol altına almak için acilen yeni potansiyel tedavilere ihtiyaç duyulmaktadır (Upadhyay ve ark. 2023). Gerek gram negatif gerekse gram pozitif farklı bakteri türleri biyofilm oluşturma potansiyeline sahiptir. Ve bakteriyal biyofilmlerin eşlik ettiği enfeksiyonlarda bilim insanları tedavi noktasında zorlanmakta ve yeni tedavi arayışları içine girmektedir.

S. aureus gram-pozitif patojenik bir bakteridir ve insanlarda ve hayvanlarda çeşitli bulaşıcı hastalıkların başlıca nedenidir (Schaumburg ve ark., 2015). Bu hastalıklar, basit deri ve yumuşak doku enfeksiyonlarından kan enfeksiyonları (bakteriyemi/septisemi) gibi daha ciddi ve yaşamı tehdit eden durumlara kadar değişebilmektedir (Kobayashi ve ark. 2015). *S. aureus* antibakteriyel ilaçlara direnmesine ve etkilerini en aza indirmesine yardımcı olan biyofilm olarak bilinen EPS salgılama potansiyeline sahip önemli bir mikroorganizmadır (Kaplan ve ark. 2018; Idrees ve ark. 2021). Yine *P. aeruginosa*, kanser hastaları, ameliyat sonrası hastalar, ciddi yanıklar veya insan immün yetmezlik virüsü (HIV) ile enfekte olanlar gibi bağışıklık sistemi baskılanmış bireylerde ölümcül enfeksiyonların yanı sıra hastane enfeksiyonlarına da neden olan yaygın bir gram negatif bakteridir (Gomila ve ark. 2018). Ek olarak, bu enfeksiyonların tedavisi, *P. aeruginosa*'nın onları çevreleyen çevresel streslerden koruyan, fagositozu önleyen ve böylece kolonizasyon ve uzun süreli kalıcılık kapasitesi kazandıran biyofilm oluşturma yeteneği tarafından da engellenmektedir (Moradali ve ark. 2017). Tüm bu nedenlerle *P. aeruginosa*, 2017 yılında, yaşamı tehdit eden önemli bakterilerden biri olarak tanınmış ve

Dünya Sağlık Örgütü tarafından yeni antibiyotiklerin Araştırma ve Geliştirmesi için öncelikli patojen olarak listelenmiştir (WHO, 2017).

Tüm bu bilgiler ışığında biyofilm oluşturan mikroorganizmalara karşı yeni tedavi arayışları devam etmekte olup, günümüzde önemli bir araştırma alanını oluşturmaktadır. Doğada bulunan pek çok bitki türü keşfedilmeyi bekleyen antimikrobiyal özellikler sunmaktadır. Bu çalışma ile, *T. serpyllum* bitkisinden elde edilen sulu ektraktın *S. aureus* (ATCC 29213) ve *P. aeruginosa* (ATCC 27853) suşlarına karşı antibiyofilm aktivitesinin değerlendirilmesi amaçlanmıştır.

2. DENEYSEL ÇALIŞMALAR

2.1 Bakteri Suşları

Çalışmada kullanılan *S. aureus* (ATCC 29213) ve *P. aeruginosa* (ATCC 27853) suşları Afyon Kocatepe Üniversitesi Fen Edebiyat Fakültesi Moleküler Biyoloji ve Genetik Bölümünde yer alan Moleküler Biyoloji ve Genetik Laboratuvarının stoğundan temin edilmiş ve çalışmadan önce gecelik taze kültürleri hazırlanmıştır.

2.2 Bitki Ekstraktının Hazırlanması

Bu çalışmada, Afyon Kocatepe Üniversitesi Fen Edebiyat Fakültesi Moleküler Biyoloji ve Genetik Bölümünde yer alan Moleküler Biyoloji ve Genetik Laboratuvarında hazır olarak bulunan *Thymus serpyllum* bitki örnekleri kullanılmıştır. Bitkiden elde edilen kuru yapraklar blenderdan geçirilip havanda dövülmüş ve toz haline getirilmiştir. Tartılan örnekler distile su ile muamele edilip karışım hazırlanmış ve daha sonra bu karışım mikrodalga fırında 1 dakika (1200W, 50Hz) boyunca tutulduktan sonra filtre kağıdından süzülerek bitki özütleri elde edilmiş ve çalışmada kullanılacak doz hazırlanmıştır.

2.3 Biyofilm Engelleme Aktivitesi

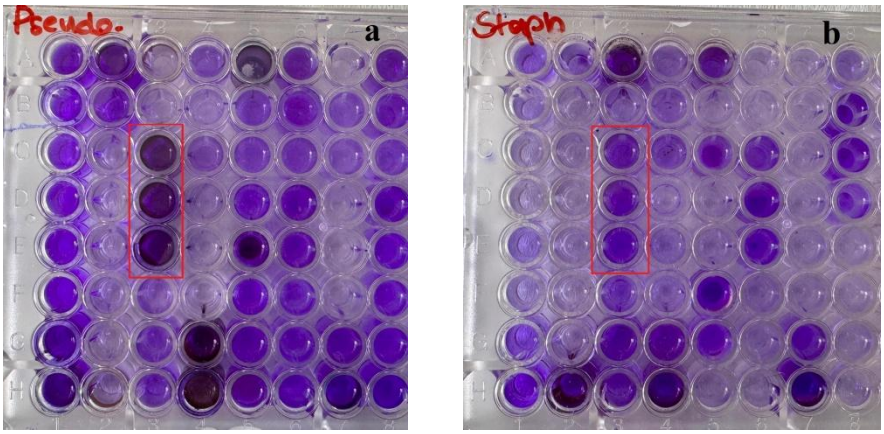
T. serpyllum bitki ektresinin, *S. aureus* ve *P. aeruginosa* tarafından oluşturulan biyofilmi engelleme yeteneğini test etmek için 96 kuyucuklu plakalar kullanıldı. Her bir bakteri türünün taze süspansiyonları ve bitki ekstraktı besin ortamı içeren kuyucuklara eklendi. Daha sonra plaka 72 saat süreyle 37°C'de inkübasyona bırakıldı. Süre sonunda plakanın biyofilm kaplı kuyucukları fosfat tamponlu salin (PBS) ile iki kez iyice yıkandı ve oda sıcaklığında yarım saat kurumaya bırakıldı. Bu işlemlerin ardından, biyofilm oluşumunu değerlendirmek için her bir plaka kuyucuğuna %1'lik kristal viyole çözeltisi eklendi ve bir saat süreyle renk değiştirmeye bırakıldı. Daha sonra plakalar yeniden PBS ile yıkanarak kristal viyole plakalardan uzaklaştırıldı. Kuyucuklara emilen kristal viyoleyi geri kazanmak için etanol eklendi ve plakaların on beş dakika boyunca oda sıcaklığında bekletilmesine izin verildi. Biyofilm inhibisyonu bir spektrofotometre kullanılarak 595 nm'de ölçüldü.

Biyofilm inhibisyonu aşağıdaki denklem kullanılarak hesaplanmıştır:

Biyofilm İnhibisyonu (%) = (Absorbans kontrol-Absorbans örnek/Absorbans kontrol)×100

3. SONUÇLAR VE DEĞERLENDİRME

Antimikrobiyal ajanlara karşı direncin küresel olarak artması, halk sağlığı için önemli bir tehdit oluşturmakta ve alternatif tedavi seçeneklerini gerektirmektedir. Kritik zorluklardan biri, özellikle geleneksel antibiyotiklere dirençli olan biyofilm oluşturan bakterilerin neden olduğu enfeksiyonların tedavisidir (Barbarossa ve ark. 2025). Biyofilm tabakasını ortadan kaldırabilecek yeni ajanların geliştirilmesi antimikrobiyal direnç noktasında tedavi başarısını arttıracak bir yaklaşımdır. Bu sebeple biyofilm oluşumunu engellemek için yeni ajan arayılşarı devam etmekte ve konu güncel önemini korumaktadır. Deneysel olarak mikroorganizmaların sentezlediği biyofilm tabakasının belirlenmesinde bu tabakaya bağlanma özelliği olan kristal viyole kullanılmaktadır. Biyofilm tabakaları arttıkça bu tabakalara bağlanan kristal viyole miktarı da artış göstermektedir. Bu tabakaya bağlanan kristal viyole, deney basamaklarında yer alan etanol uygulaması ile geri kazanılır. Görsel olarak değerlendirildiğinde kuyucuklarda koyu renk oluşumu biyofilm tabakasının yoğunluğunu gösterirken daha açık renk ise geri kazanım sonucunda biyofilm tabakasının daha zayıf olduğunu göstermektedir. Spektrofotometre ile değişken kristal viyole oranları tespit edilerek uygulanan herhangi bir maddenin antibiyofilm özelliği yüzde inhibisyon oranlarıyla belirlenebilir. Çalışmamızda uygulanan bitki ekstraktının antibiyofilm aktivitesinin belirlenmesi sırasında kristal viyolenin geri kazanım aşaması Görsel 1'de verilmiştir.



Görsel 1. *T. serpyllum*'un antibiyofilm etkisi, a: *P. aeruginosa*, b: *S. aureus*

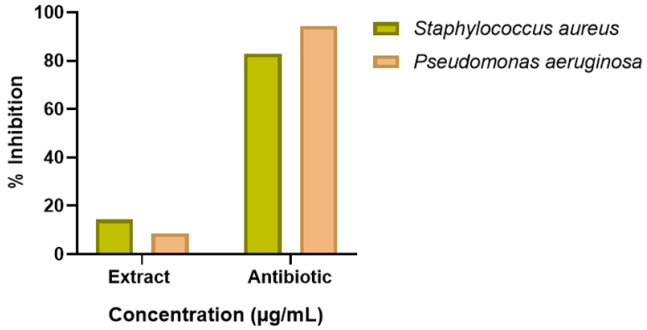
S. aureus'un neden olduğu enfeksiyonlar, bakteriyemi (Tătaru ve ark. 2023), sepsis (Chen ve ark. 2022), enfektif endokardit (Thomer ve ark. 2016) ve osteomiyelit (Widaa ve ark. 2012) gibi hafiften şiddetliye ve potansiyel olarak ölümcül hastalıklara kadar değişmektedir (Ahmad-Mansour ve ark. 2021). Metisiline dirençli *S. aureus* (MRSA) suşları, biyofilmle ilişkili enfeksiyonlarda önemli bir patojendir ve tedaviyi zorlaştırarak kronik vakalara yol açmaktadır (Barbarossa ve ark. 2025). Buna ek olarak, MRSA gibi çoklu ilaca dirençli antibiyotik suşlarının yaygınlığındaki önemli artışın halk sağlığı açısından büyük endişelere yol açtığı

bilinmektedir (Ahmad-Mansour ve ark. 2021). Biyofilm oluşumu sadece bakterinin antibiyotiklere karşı direncini artırmakla kalmamakta, aynı zamanda tedavi edilmesi özellikle zor olan ve sıklıkla kronik enfeksiyonlara yol açan hastalıklara da neden olmaktadır (Tigabu ve ark. 2021). Yine *P. aeruginosa*, AIDS (Edinilmiş Bağışıklık Yetmezliği Sendromu) ve kanser gibi bağışıklık sistemi zayıflamış hastalarda, idrar yolu enfeksiyonlarında (İYE), yanık vakalarında ve solunum cihazına bağlı hastalarda hastane kaynaklı pnömonide yaşamı ciddi tehdit eden enfeksiyonların kaynağı olarak bilinmektedir; nadiren de bağışıklık sistemi sağlam olan organizmaları hedef almaktadır. *P. aeruginosa* biyofilmleri, bakteriyel keratit, otitis eksterna, İYE, ventilatörle ilişkili pnömoni ve yanık enfeksiyonlarının patogenezinde önemli bir rol oynamaktadır. Ek olarak İYE, kateter enfeksiyonları ve diş plağı oluşumu, biyofilmden kaynaklanan yaygın enfeksiyonlardır ve bunların dışında kistik fibrozis de biyofilmle ilişkili bir diğer hastalık olup en ölümcül enfeksiyonlardan biri olarak belgelenmiştir (Parsek ve Singh 2003). Biyofilmler, kistik fibrozis hastalarında ölüm oranının en önemli kök nedenidir (%40-60). Akciğerlerin hasar görmüş hava yolu epitellerini kolonize ederler, ortadan kaldırılmaları neredeyse imkansızdır ve akciğer yetmezliğine dahası ölüme yol açabilirler. Ayrıca tüm hastane enfeksiyonlarının yaklaşık %10-20'sinin *P. aeruginosa'*dan kaynaklandığı bildirilmiştir (Hirakawa ve Tomita 2013). *S. aureus* ve *P. aeruginosa* görüldüğü gibi oluşturdukları hastalıklar nedeniyle ciddi sorunlar ortaya çıkarabililen mikroorganizma suşlarıdır. Bu bakterilerin biyofilm oluşturabilme kapasiteleri, virülanslarını arttırmakta dolayısıyla onlarla savaşmayı daha da zorlaştırmaktadır. Biyofilm oluşturma potansiyelleri bu iki mikroorganizmanın oluşturduğu enfeksiyonların önüne geçilmesini engellemekte, standart terapi metotlarını yetersiz bırakmaktadır.

Umut vadeden alternatiflerden biri, biyofilm oluşumunu engelleyebilen bitki kökenli doğal bileşiklerin araştırılmasıdır (Liziana ve ark. 2013). Tarihsel olarak, bitki özleri ve bunların biyolojik olarak aktif bileşikleri, hastalıkların önlenmesinde ve tedavisinde merkezi bir rol oynayan ve insan sağlığının korunmasına yardımcı olan değerli bir doğal ürün kaynağı olmuştur (Karuppiah ve Mustaffa 2013). Dahası, güvenli oldukları algısı ve eski çağlardan beri halk tıbbında hastalıkları tedavi etmek için uzun bir kullanım geçmişine sahip olmaları nedeniyle yaygın olarak kabul görmektedirler (Rasamiravaka ve ark. 2015). Pek çok hastalığın çaresi aslında doğada bulunmayı beklemektedir. Bu sebeple bitki ekstraktlarının farklı hastalıkların tedavisinde kullanılma potansiyellerinin belirlendiği çalışmalar oldukça önemli bilgiler sunmaktadır. Yaptığımız çalışma ile *T. serpyllum* bitki özütünün biyofilm oluşturma yeteneği yüksek olan ve bu sebeple ciddi enfeksiyonlarda rol oynayan iki bakteri türü üzerindeki antibiyofilm etkinliğinin belirlenmesi amaçlanmıştır.

Yapılan çalışma sonuçları değerlendirildiğinde kullanılan bitki özütünün her iki suş için de antibiyofilm özelliğine sahip olduğu tespit edilmiştir. Suşlar kendi içinde karşılaştırıldığında bitki ekstresine karşı *S. aureus*'un *P. aeruginosa*'ya kıyasla daha duyarlı olduğu görülmektedir. Elde edilen sonuçlar her ne kadar bitki ekstresinin antibiyofilm kapasitesine sahip olduğunu gösterse de pozitif kontrol grubu olarak kullanılan antibiyotik uygulaması kadar yükse inhibisyon oranına sahip olmadığı da görülmektedir. Bu çalışmada kullanılan *T. serpyllum* bitki

ekstraktı *S. aureus* için % 14.25 inhibisyon oranı gösterirken, *P. aeruginosa* için bu oran % 8.59 olarak tespit edilmiştir (Çizelge 1).



Çizelge 1. *T. serpyllum* bitki ekstresinin *S. aureus* ve *P. aeruginosa* üzerindeki antibiyofilm etkisi

Galgano ve ark. (2025) *S. aureus*'un -1'i bu çalışmada kullandığımız suş olmak üzere- 3 referans suşu (*S. aureus* 25923 ve 11623 ve *S. epidermidis* 12228) ve 12 klinik izolat üzerinde aynı cinse ait başka bir tür olan *T. vulgaris* bitki özütünün antibiyofilm etkinliğini araştırmış ve tüm test edilen konsantrasyonlarda biyofilm oluşumunda belirgin bir inhibisyon gözlemlemişlerdir. Artan bitki dozları ile birlikte yüksek inhibisyon oranları elde edilmiştir. Yaptığımız çalışmada inhibisyon oranı yaklaşık %14 civarında seyretmiştir. Dolayısıyla çalışma sonuçlarımız bu çalışma ile paralellik göstermektedir. Çalışmamızda kullanılan bitki ekstrakt dozu "µg/mL" olarak uygulanmıştır, bu doz uygulamasında görülen bu inhibisyon oranının %14 gibi azımsanamayacak bir oran olduğu ve artan dozla birlikte daha fazla inhibisyon orana ulaşılabileceği düşünülmektedir. Çeşitli bitki özlerinin *S. aureus* dahil olmak üzere farklı mikroorganizmalarda biyofilm oluşumunu önlemedeki etkinliği daha önce pek çok farklı yapılan çalışma ile gösterilmiştir (Galgano ve ark. 2022; Canessci ve ark. 2023; Ünlü ve ark. 2023; Galgano ve ark. 2025). Tüm bu çalışmalar çalışmamıza benzer şekilde sonuçlar sergilemiştir.

P. aeruginosa için yapılan literatür taramalarında Thymus cinsine ait herhangi bir türün herhangi bir ekstraksiyonun antibiyofilm özelliği ile ilgili yapılmış çalışmaya rastlanmamış olup bu konudaki bilgilerin sınırlı olduğu gözlemlenmiştir. Ancak Varposhti ve ark. (2013) yaptıkları çalışmada, *P. aeruginosa* 214 suşunun biyofilm oluşturma potansiyeli üzerinde, *Cyclamen coum, Dianthus orieltalis* ve *Origanum majorana* olmak üzere üç farklı bitki özütü ve *Zataria multiflora* bio uçucu yağının etkinliğini değerlendirmişlerdir. *C. coam* özütü ve *Z. multiflora* bio uçucu yağı, sırasıyla <0.062 mg/ml ve 4.7 mg/ml konsantrasyonlarında biyofilm oluşumunu tamamen inhibe etmiştir. Ancak *D. orientalis* ve *O. majorana* özleri, kullanılan konsantrasyonlarda (0.003-8 mg/ml) biyofilm oluşumunu inhibe etmemiştir. Bu çalışmanın sonuçları, bazı bitki özlerinin düşük konsantrasyonlarda bile biyofilmle ilişkili enfeksiyonlar için alternatif bir ilaç oluşturabileceğini göstermektedir. Yaptığımız çalışmada *P. aeruginosa*

için yaklaşık %8 oranında biyofilm inhibisyonu tespit edilmiştir ve artan bitki ekstraktı konsantrasyonlarına bağlı olarak antibiyofilm özelliğinin de artış göstermesi öngörülmektedir.

4. GENEL DEĞERLENDİRME VE SONUÇLAR

Mikroorganizmalar tarafından salgılanan biyofilm çok karmaşık bir mimariye sahiptir ve mikroorganizmalar için eşşiz bir savunma bariyeri oluştururlar. Sonuç olarak, biyofilm içerisinde gizlenmiş olan mikroorganizmalar, hem virulans faktörlerini kuvvetlendirmiş olurlar hem de besin kullanımı ve bir yere tutunma üstünlüğü açısından avantajlı hale geçerler. Tüm bu özellikler mikroorganizmaların, olumsuz ortamlarda hayatta kalmalarını sağlarken, aynı zamanda antimikrobiyal bileşiklere karşı direnç ve konak bağışıklığından kaçınmalarına da olanak tanımaktadır. Bu açıdan da insanoğlu için gerek enfeksiyon hastalıklarında gerekse pek çok endüstriyel alanda biyofilm oluşumu istenmeyen bir durumu oluşturmaktadır. Artan antibiyotik direncine sağladığı katkı da düşünülürse bilim insanlarının yeni antibiyofilm maddelerini tespit etmeleri elzem bir durum haline gelmiştir. Bu bağlamda bitkiler geleneksel tıp uygulamalarında uzun yıllar öncesine dayanan önemlerini, çağdaş toplumlarda ortaya çıkan ve büyük bir sorun haline gelen antimikrobiyal ajan direncinin ortadan kaldırılmasında da devam ettirmektedirler. Bu çalışma ile alternatif olarak antibiyofilm özellikleri için *T. serpyllum* bitkisinin önemli hastalıklara yol açan iki mikroorganizma türü üzerinde etkinliği araştırılmış ve elde edilen inhibisyon oranlarının artan bitki konsantrasyonları ile antibiyofilm ajan olarak kullanılabileceği öngörülmüştür.

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Cydonia Oblonga (AYVA) SULU EKSTRAKTININ ANTİBİYOFİLM AKTİVİTESİ

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ÖZET

Bakteriyel enfeksiyonlar dünya genelinde önemli bir halk sağlığı sorunu oluşturmaktadır ve antibiyotiklerin yaygın ve yanlış kullanımı, antibiyotik direncinin hızla artmasına yol açmaktadır. Özellikle biyofilm oluşturan bakteriler, antimikrobiyal ajanlara karşı yüksek direnç göstermekte ve hastane enfeksiyonlarının başlıca nedenleri arasında yer almaktadır. Bakteriyel enfeksiyonların büyük bir kısmının biyofilm yapılarıyla ilişkili olduğu göz önüne alındığında, antibiyofilm özelliklere sahip yeni ve doğal ajanların araştırılması kritik önem taşımaktadır.

Doğal ürünler ve bitkisel kökenli fitokimyasallar, antimikrobiyal ve antibiyofilm potansiyelleri nedeniyle son yıllarda artan bir ilgi odağı olmuştur. Bu bağlamda, Rosaceae familyasına ait olan *Cydonia oblonga* (*C. oblonga*), zengin fitokimyasal içeriği ve geleneksel tıptaki kullanımı nedeniyle dikkat çekmektedir. Ayvanın farklı bitki kısımlarından elde edilen ekstraktların antibakteriyel, antioksidan ve terapötik özelliklere sahip olduğu çeşitli çalışmalarla gösterilmiştir. Mevcut çalışma, *C. oblonga* yaprağından elde edilen sulu ekstraktın, klinik açıdan önemli iki insan patojeni olan *Staphylococcus aureus* ve *Pseudomonas aeruginosa* üzerindeki antibiyofilm etkisini değerlendirmeyi amaçlamıştır. Yaprak ekstraktı Afyon ilinden temin edilmiş, standart yöntemlerle hazırlanmış ve biyofilm inhibisyonu kristal viyole testi kullanılarak belirlenmiştir. Elde edilen verilere göre, *C. oblonga* yaprağı sulu ekstraktı *S. aureus* suşunda %3,96, *P. aeruginosa* suşunda ise %35,29 oranında biyofilm inhibisyonu göstermiştir ($p<0,001$). *P. aeruginosa*'nın ekstrakta daha duyarlı olduğu belirlenmiştir. Her ne kadar antibiyotik pozitif kontrol grubuna kıyasla daha düşük inhibisyon oranları gözlemlense de sonuçlar *C. oblonga* yaprağı sulu ekstraktının antibiyofilm potansiyele sahip olduğunu ve ileri çalışmalarla desteklenmesi halinde alternatif veya tamamlayıcı bir ajan olarak değerlendirilebileceğini göstermektedir.

Anahtar Kelimeler: Antibiyofilm aktivite, *Cydonia oblonga*, Sulu ekstrakt.

1. GİRİŞ

Her yıl dünya çapında milyonlarca insan bakteriyel enfeksiyonlardan kaynaklanan hastalıklardan muzdarip olmaktadır (Samreen, Malak & Abulreesh, 2021). Geleneksel antibiyotikler, bakteriyel enfeksiyonların tedavisi için ilk seçenektir ve yaygın ve yanlış kullanımları antibiyotik direncinin ortaya çıkmasına neden olmaktadır (Kandi, & Kandi, 2015; Ansari ve ark., 2020; Samreen ve ark., 2021). Antibiyotiğe dirençli mikroorganizmaların artışı, dünya çapında artan mortalite ve morbiditeye neden olan önemli bir halk sağlığı sorunu olarak kabul edilen hastane enfeksiyonlarının ana kaynağıdır (Samuel ve ark., 2010; Liu ve ark., 2015). Günümüzde, bakteriyel direncin küresel artışı nedeniyle, bu zorlu durumu yönetmek için yöntemler ve yaklaşımlar geliştirmek kritik bir gerekliliktir.

Ulusal Sağlık Enstitüsü'nün (NIH) raporuna göre, bakteriyel enfeksiyonların yaklaşık %80'i bakteriyel biyofilmler tarafından oluşturulmakta ve yayılmaktadır (Donlan, 2001; Schachter, 2003). Biyofilm, besin arayışında biyolojik veya biyolojik olmayan yüzeylere planktonik bakterilerin yapışması sonucu hücre dışı polimerik bir matristen oluşan kompleks bir yapıdır (Garrett ve ark., 2008). Bakterilerin kolonizasyona başlamasıyla bakteri kolonilerini çevreleyen ve dış streslerden koruyucu bir ortam sağlayan hücre dışı polimerik maddelerden (EPS) oluşan bir matris salgılanmaktadır (López ve ark., 2010). Yani temelde biyofilm, bakteri kolonilerinden ve içlerindeki EPS'den oluşan kompleks, çok katmanlı 3 boyutlu bir yapıdır (Flemming, 2020). Bu kompleks ağ, bakterilerin çeşitli yüzeylere yapışmasını sağlamaktadır ve onları fiziksel veya kimyasal tedaviler gibi koşullardan korumaktadır (O'gara & Humphreys, 2001; Hassanı, Nakhaeı & Forghanifard, 2015). Biyofilmle ilişkili enfeksiyonların tedavisi kaçınılmaz olarak yüksek dozlarda ve uzun süreli antimikrobiyal ajan kürlerini içerir; bu nedenle, antimikrobiyal direnç (AMR) gelişme riski vardır. AMR'nin yüksek yaygınlığı ve biyofilm oluşumuyla ilişkisi nedeniyle, daha etkili antibiyofilm ajanlarının araştırılması gerekmektedir (Jang & Mosolygó, 2020). Aynı şekilde, gram pozitif ve gram negatif bakteriler, endotrakeal tüpler, kalp kapakları, kateterler, protez eklemler, orto-diş aletleri ve kontakt lensler gibi tıbbi yüzeylerde biyofilm oluşturma kapasitesine sahiptir (Ashajyothi ve ark., 2016). Bu bağlamda, *Staphylococcus aureus* (S. *aureus*) ve *Pseudomonas aeruginosa* (*P. aeruginosa*), biyofilm oluşumu için en iyi incelenen modellerdendir ve tıbbi cihazlarda biyofilm oluşturabilen ve kas-iskelet, solunum yolu ve idrar yolu enfeksiyonları gibi biyofilmle ilişkili ciddi enfeksiyonlara neden olabilen iki tipik patojendir (Banin, Brady & Greenberg, 2006; Yakandawala ve ark., 2007; Lee ve ark., 2017). Özellikle, *S. aureus*, çeşitli insan enfeksiyonlarına neden olabilen iyi bilinen bir patojendir. *S. aureus*'un çok sayıda ekolojik nişi vardır ve sıklıkla ön burun deliklerini, cildi, perineyi ve farenksi kolonize edebilmektedir (Raafat ve ark., 2019). Bu gram-pozitif bakteri, yumuşak doku ve hafif deri enfeksiyonları, osteomiyelit, bakteriyemi ve endokardit gibi akut ve kronik enfeksiyonlara neden olabilir (Guo ve ark., 2020). Dahası, *S. aureus* cerrahi yaraları, kanı veya implant çevresini enfekte edebilmektedir (Tong ve ark., 2015). *P. aeruginosa* ise Gram-negatif, aerobik bir bakteridir ve insanların derisinin ve gastrointestinal sisteminin normal florasıdır (Jabalameli ve ark., 2011; Jabalameli ve ark., 2012). Bu bakteri, fırsatçı bir patojen olarak, maligniteler, kistik fibroz ve

yanıklar gibi bağışıklık sistemi zayıflamış hastalarda hastane enfeksiyonlarında en önemli mikroorganizmalardan biridir; çoklu patojenik faktörlere ve çoğu antibiyotiğe karşı yüksek direnç oranına sahiptir. Hücre zarındaki glikokaliks varlığı, bakterinin konak hücreye kolayca bağlanmasından, biyofilm oluşumundan ve bakterilerin antimikrobiyal ajanların ve fagositoz sisteminin penetrasyonuna karşı korunmasından sorumludur (Russell & Gacesa, 1988). Ayrıca, *S. aureus* 'un daha yüksek dozda antibiyotiklere dirençli olduğu gösterilmiştir, bu da antibiyotik dirençli duyarsız suşların gelişmesine katkıda bulunmaktadır (Miklasińska-Majdanik ve ark., 2018). Bakteriyel enfeksiyonların yanı sıra, biyofilmlerin tıbbi bakım üniteleri, membran atık su arıtma, denizcilik endüstrisi, su taşıma sistemleri ve daha birçok alanda birçok dezavantajı vardır (Flemming, 2020). Bakteriyel biyofilmlerin kontrolü ve bozulması için geleneksel tedavi yöntemleri daha az etkili, maliyetli ve atık üreten hale gelmiştir. Su jeti püskürtme, yüksek basınçlı su, ultrasonikasyon vb. gibi kimyasal ve mekanik tedavi yöntemleri her zaman uygulanabilir değildir ve daha fazla atık ve su kıtlığına neden olmaktadır (Boudarel ve ark., 2018; Yu ve ark 2020). Ayrıca, bakterilerin ilaç direnci ve bileşiklerin maliyeti, antibiyotiklerin ve diğer biyositlerin kullanımını en aza indirgemektedir. Bu nedenle, ilaç dirençli bakterilere karşı yeni antimikrobiyal ajanların eksikliği ve biyofilmlerin tedavisi için alternatif bir ajana ciddi bir ihtiyaç vardır.

Eski çağlardan beri doğal ürünler, hastalıkların tedavisinde terapötik ajanlar olarak kullanılmıştır (Ahmed ve ark., 2022). Dünya Sağlık Örgütü, dünya nüfusunun %80'inden fazlasının bitkisel ilaç kullandığını tahmin etmektedir (Katiyar, Singh & Ali, 2016). Bitkisel tıp, geleneksel ilaçlarla değiştirilmesine rağmen, temel sağlık sistemine hala entegre edilmemiştir. Fitokimyasalların potansiyel sağlık ve farmakolojik faydaları, antioksidan, antibakteriyel, antikanser, kardiyoprotektif, bağışıklık sistemini güçlendirici, UV radyasyonuna karşı koruyucu ve antiinflamatuar özellikleri de dahil olmak üzere vurgulanmıştır (Tungmunnithum ve ark., 2018; Muhammad ve ark., 2021). Ayrıca eski çağlarda bitkiler ve baharatlar gıdaları korumak için kullanılmıştır ve antimikrobiyal, antibiyofilm ve anti-quorum sensing özellikleri iyi bilinmektedir. Dahası, fitokimyasallar, dirençli bakterilerin ortaya çıkmasına olanak sağlamadan veya konakçı mikrobiyotasına zarar vermeden, sub-inhibitory konsantrasyonlarda antibiyofilm özellik göstermektedir. Doğal fitoterapötik ajanlara yönelik artan bilimsel ilgiyle birlikte, son yıllarda çok sayıda deneysel araştırma yapılmıştır (Jang & Mosolygó, 2020).

Cydonia oblonga (*C. oblonga*), geleneksel olarak tıbbi, besleyici ve süs bitkisi olarak kullanılan Rosaceae familyasına aittir (Shemchuk ve ark., 2020). Ayva, 4-5 m genişliğinde ve 5-8 m yüksekliğinde küçük bir bitki veya çalıdır. 7-12 cm uzunluğunda ve 6-9 cm genişliğinde parlak sarı bir meyve vermektedir. Ayva meyvesi, buruk bir tada ve karakteristik bir kokuya sahiptir (Gholgholab, 1961). Bununla birlikte, yaprakları 6-11 cm uzunluğunda ve yüzeyinde beyaz tüyler bulunan elips şeklindedir (Yildirim, Oktay & Bilaloğlu, 2001; Evans, 2009). Ayva meyvesi çeşitli ülkelerde gıda, ilaç, parfüm ve tarım amaçlı kullanılmaktadır (Rop ve ark., 2011). Bu nedenle, bu bitki ekonomik değeri nedeniyle önemli bir ilgi görmektedir. Ayva meyvelerinde büyük miktarlarda ikincil metabolitler (fenolik bileşikler ve uçucu yağlar), mineraller ve vitaminler bulunmaktadır (Erdoğan ve ark., 2012). Çeşitli çalışmalar, ayva posasının kardiyovasküler hastalıklar, kanser, kolon sorunları ve böbrek sorunları gibi

hastalıkların riskini azalttığını ortaya koymuştur Yamanaka, Oda & Nagao, 1997; Nomoto ve ark., 2004; Carvalho ve ark., 2010). Ayva tanenleri, bakteri, mantar ve virüslere karşı aktivite gösterdikleri için akciğer enfeksiyonlarında antiseptik ajan olarak kullanılmaktadır (Adel ve ark., 2010). Ayrıca, ayva tohumu öksürük, ishal, kabızlık, dizanteri ve bronşit tedavisinde kullanılmaktadır. Ayva meyvelerinin fitokimyasal taramasında çok sayıda ikincil metabolit tanımlanmıştır (Benahmed Djilali ve ark., 2021). Ayva yaprağı özütünün diyabet, kanser ve hemolize karşı etkili olduğu bulunmuştur (Costa ve ark., 2009 ; Aslan ve ark., 2010 ; Carvalho ve ark., 2010 ; Jouyban ve ark., 2011). Bitki ayrıca, endüstriyel atık sudaki kanserojen aromatik boyaları renksizleştiren bir enzim olan fenol peroksidaz içermektedir (Nandi ve ark., 2009 ; Arabaci ve Usluoglu, 2014). Ayvanın farklı kısımlarında uçucu yağlar, fenolik bileşikler, organik asitler, tetrasiklik sesterterpenler ve iyonon glikozitler bulunmaktadır (De Tommasi ve ark., 1996; Lutz-Roder ve ark., 2002; Oliveira ve ark., 2007; Oliveira ve ark., 2008; Osman ve ark., 2010 ; Erdogan ve ark., 2012). Alizadeh ve ark., tarafından yapılan bir çalışmada (2013) *C. oblonga* meyvesi ve çekirdeğinden elde edilen (etanolik, asetonik ve sulu) ekstraktların E. coli, K. pneumoniae ve E. aerogenes üzerindeki antibakteriyel etkileri rapor edilmiştir. Çekirdeğin etanolik özütü en etkili sonuçları göstermiştir, E. coli en hassas bakteri olarak belirlenmiştir. Abed ve ark., (2022) tarafından yapılan bir çalışmada, *C. oblonga* kabuğunun metanolik özütünün fitokimyasal içeriği ile antibakteriyel, antioksidan ve antidiyabetik potansiyeli değerlendirilmiştir. Metanolik özüt HPLC ile yedi fraksiyona ayrılmış (F1–F7) ve bileşenler GC-MS ve HPLC analizleriyle tanımlanmıştır. Ekstrakt ve fraksiyonların tamamı antibakteriyel aktivite göstermiştir, en yüksek etki *Staphylococcus aureus* ve *Streptococcus pneumoniae*'ye karşı metanolik özütte gözlemlenmiştir. Antioksidan analizlerde metanolik özüt güçlü DPPH inhibisyonu sergilemiştir, ayrıca α-glukozidaz ve α-amilaz enzimlerini önemli düzeyde inhibe ederek antidiyabetik potansiyel göstermiştir. Bu biyolojik aktivitelerin, özütlerin fenolik ve flavonoid bileşiklerce zengin olmasından kaynaklandığı belirlenmiştir. Dalkılıç (2024) tarafından yapılan bir çalışmada, *C. oblonga* yaprağının metanol ve hekzan ekstraktının antimikrobiyal aktivite açısından, en iyi zon çapının E. coli bakterisinde, en düşük zon çapı ise da B. megaterium'da gözlemlenmiştir.

Mevcut çalışma, *C. oblonga* yaprağının sulu ekstraktının insan patojenleri *S. aureus* ve *P. aeruginosa*'ya karşı biyofilm oluşumunun inhibisyonuna odaklanmaktadır. *C. oblonga* yaprağının sulu ekstraktının biyofilm oluşumu üzerindeki etkisi kristal viyole testi kullanılarak incelendi.

2. MATERYAL METOD

2. 1. Bitki Materyali Temini ve Ekstrakt Hazırlanması

C. oblonga yaprağı örneği Afyon ilinde bulunan yerel satıcılarından temin edildi. Bitki örnekleri distile su ile yıkandı ve karanlık ortamda kurutuldu. Kuruyan bitki örnekleri havan ile dövülerek öğütüldü. Hassas terazide öğütülen bitkiden 1 g tartılarak 20 mL distile su içerisinde homojen hale getirildi. Bu işlemi takiben bitkinin sulu ekstraktını elde etmek için karışım 60°C sıcaklıktaki su banyosuna konuldu ve 10 dakika aralıklarla yavaşça karıştırılarak 1 saat inkübasyona bırakıldı. Süre sonunda su banyosundan çıkartılan ekstrakt, filtre kâğıdı (Whatman

Filtre Kâğıdı No.1) ile süzülerek posasından ayrıldı. Berrak süpernatant amber şişelerde hava ile teması kesilerek kullanılmak üzere +4°C'de muhafaza edildi.

2. 2. Biyofilm İnhibisyon Testi

C. oblonga yaprak ekstraktının, *S. aureus* (ATCC 29213) ve *P. aeruginosa* (ATCC 27853) suşları üzerindeki biyofilm oluşumunu engelleme yeteneğini test etmek için 96 well plate ile Kristal viyole (CV) testi yapıldı. Her bir bakteri türünün taze süspansiyonları, *C. oblonga* yaprak ekstraktı ve antibiyotik ayrı ayrı eklendikten sonra Nutrient Broth (NB) içeren 96 well plate'e ekildi. Hücrelerin yüzeye yapışmasını sağlamak için daha sonra 37,5 °C'de 72 saat inkübe edildi. İnkübasyondan sonra, 96 well plate'in biyofilm kaplı kuyucukları 200 µL fosfat tamponlu salin (PBS) ile iki kez iyice yıkandı. Yarım saat boyunca havada kurumaya bırakıldı. Bu işlemlerin ardından, biyofilm oluşumunu değerlendirmek için her bir plaka kuyucuğuna 200 µL %1'lik sulu CV çözeltisi uygulandı. Biyofilm bir saat boyunca renk değiştirmeye bırakıldı. Daha sonra CV, plakalar PBS ile yıkanarak plakalardan uzaklaştırıldı. Emilen CV'yi geri kazanmak için etanol eklendi ve plakalar on beş dakika boyunca oda sıcaklığında bekletildi. Aşağıdaki Denklem kullanılarak, biyofilm inhibisyonu bir spektrofotometre kullanılarak 595 nm'de ölçüldü.

$$\text{Biyofilm İnhibisyonu (\%)} = (A_{\text{kontrol}} - A_{\text{örnek}}/A_{\text{kontrol}}) \times 100$$

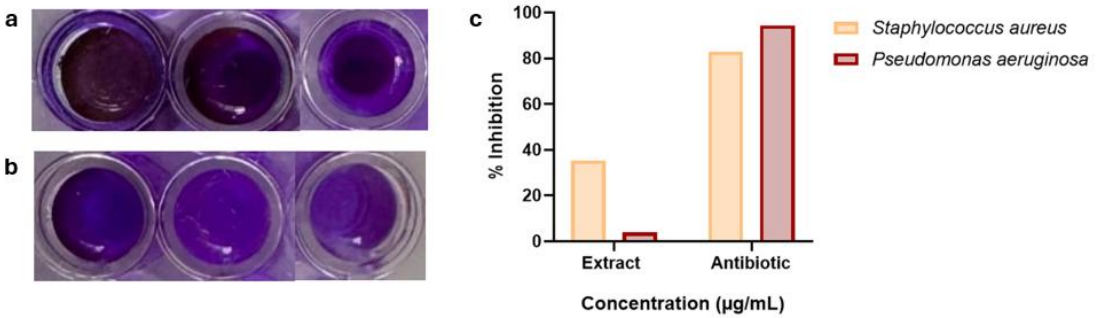
3. SONUÇLAR VE DEĞERLENDİRME

Biyofilmler, bakterilerin nemli biyotik ya da abiyotik bir yüzeye tutunup hücre dışı matriste birlikte çoğalıp uyum içinde yaşadığı mikroorganizma toplulukları olarak bilinmektedir (Ceyhan, 2008; Kokare ve ark., 2009). Biyofilm oluşumuyla birlikte bakterilerin antibiyotiklere karşı direnci artmaya başlamaktadır ve araştırmacılar bakterilerin antibiyotik direncine karşı yeni alternatif yöntemler bulmaya yönelmişlerdir (Ceyhan, 2008). Bilim insanlarının, ticari amaçlarla kullanılan antimikrobiyal ajanlara dirençli bakterileri ortadan kaldırmak için yeni antimikrobiyal ajanların karakterizasyonu üzerinde çalışmaları çok önemlidir (Altuner ve ark., 2018).

Tıbbi bitkiler eski çağlardan bu yana hastalıkların tedavisinde kullanılmaktadır ve belirli kısımlarından elde edilen biyoaktif maddeler önem arz etmektedir (Yaldiz ve Kulak, 2014). Dünya Sağlık Örgütü (WHO) tarafından yapılan önceki çalışmalar, yaklaşık 20.000 tıbbi bitki olduğunu göstermektedir Ulgen, Bulbul & Ceylan, 2020). Tedavide kullanılan bitkiler zamanla mikrobiyologların dikkatini çekmiştir ve bitkilerin antimikrobiyal aktiviteleri üzerine çalışmalar yoğunlaşmaya başlamıştır (Erdoğrul, 2002; Altuner ve Çetin, 2018; Bülbül ve ark., 2018). Bitkilerden elde edilen etken maddeler, mikroorganizmaların neden olduğu hastalıkların tedavisinde kullanılmaktadır. Bitkiler üzerinde yapılan araştırmalarda, bitkilerin kimyasal bileşiminin ve dozaj düzeyinin belirlenmesiyle hastalıkların tedavisinin, antimikrobiyal mekanizmanın çözünürlüğüne bağlı olduğu gözlemlenmiştir (Erdoğan ve Everest, 2012).

Günümüzde ayva meyvesi, antioksidan, antimikrobiyal ve ülser önleyici özellikleriyle bilinen biyolojik olarak aktif bileşenleri nedeniyle, sağlığı destekleyici bileşiklerin iyi, ucuz ve önemli bir diyet kaynağı olarak kabul edilmektedir (Rivas-Gonzalo ve ark., 2003; Fattouch ve ark., 2007; Hamauzu ve ark., 2005 , Hamauzu ve ark., 2006 , ve ark.,, Silva, Andrade, Valentão ve ark., 2004 , Wang ve ark., 2006 , Yildirim, 2006). *C. oblonga* yaprakları, halk tıbbında yatıştırıcı, ateş düşürücü, ishal giderici ve öksürük kesici özellikleri ve çeşitli cilt hastalıklarının tedavisinde, kaynatma veya infüzyon yoluyla kullanılmıştır (De Tommasi, De Simone, Pizza ve ark., 1996; Oliveira ve ark., 2007). Ayrıca, çay yapraklarında belirlenen içeriğe göre daha yüksek değerlere sahip polifenoller açısından zengin olmaları nedeniyle, ayva yaprağı türevleri, statinlerle hiperkolesterolemi tedavisine, kansere yol açan oksidatif stres kaynaklı hasarı durdurmaya veya azaltmaya yönelik farmasötik yaklaşımlara ve solunum yollarının Gram-pozitif bakteriyel enfeksiyonlarına karşı antimikrobiyal tedavilere güvenli ve düşük maliyetli bir alternatif olabileceği gözlemlenmiştir (Ferreira ve ark., 2022).

Özetle, mevcut çalışmada, *C. oblonga* yaprağının sulu ekstraktının antibiyofilm aktivitesini rapor etmektedir. *C. oblonga* yaprak sulu ekstraktı antibiyofilm aktivitesi sergileyerek, *S. aureus* suşunda %3,96, *P. aeruginosa* suşunda ise %35,29 oranında biyofilm oluşumunu inhibe etmiştir (Görsel 1) ($p<0,001$). Bulgulara göre *P. aeruginosa* suşunun *S. aureus* suşuna kıyasla *C. oblonga* yaprağının sulu ekstraktına karşı daha duyarlı olduğu gözlemlenmiştir. Elde edilen bulgular, bitki ekstraktının anlamlı düzeyde antibiyofilm aktivite sergilediğini ortaya koymakla birlikte, bu etkinin pozitif kontrol grubu olarak kullanılan standart antibiyotik (*S. aureus* suşunda %94,30, *P. aeruginosa* suşunda ise %82,95) uygulamasına kıyasla daha düşük düzeyde kaldığını göstermektedir. Bununla birlikte, ekstraktın biyofilm oluşumunu belirli bir oranda inhibe edebilmesi, doğal kaynaklı bileşiklerin antibiyofilm potansiyelini desteklemekte ve söz konusu ekstraktın tek başına ya da antibiyotiklerle kombine kullanımı açısından ileri çalışmalar için umut vadeden bir aday olabileceğine işaret etmektedir.



Görsel 1. *C. oblonga* yaprağının sulu ekstraktının antibiyofilm aktivitesi. **a.** Sta *Staphylococcus aureus* suşunun kristal viyole ile boyama sonrası görüntüsü. **b.** *Pseudomonas aeruginosa* suşunun

kristal viyole ile boyama sonrası görüntüsü. **c.** *C. oblonga* yaprağının sulu ekstraktının antibiyofilm aktivitesi % grafiği.

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AYDIN İLİ'NDEN TOPLANAN KESTANE YAPRAKLARIYLA İLİŞKİLİ MİKOBİYOTA

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ÖZET

Bitkilerin toprak üstü yüzeyleri (fillosfer), çeşitli mikroorganizmalara ev sahipliği yapmaktadır. Fillosfer mikrobiyomu, çeşitli bakteri ve mantarlardan oluşmakta ve konakçı bitkinin sağlığında, gelişmesinde ve çevresel sitreslere tolerans geliştirmesinde önemli katkılar sunmaktadırlar. Aynı zamanda filosferik mantarlar, ilginç biyolojik aktiviteler ve yüksek düzeyde kimyasal çeşitlilik gösteren yeni sekonder metabolitlerin zengin bir kaynağı oldukları da bilinmektedir. Yeni sekonder metabolitlerin tespiti için farklı bitkilerin filosfer mikobiyomları oldukça önemlidir. Bu çalışmada kestane yapraklarının filosferik fungal mikrobiyom çeşitliliğinin incelenmesi amaçlandı. Bu nedenle de Aydın ili kestane üretim alanları gezildi ve sağlıklı kestane yaprakları toplandı. Laboratuvara getirilen kestane yaprakları morfolojik farklılıklarına göre guruplandırıldı ve farklı morfolojideki yapraklardan standart mikolojik yöntemler kullanılarak fungal izolasyonlar yapıldı. Yapılan çalışmalar sonucunda yedi farklı fungal cinse (*Geotrichum* spp., *Aspergillus* spp., *Penicillium* spp. *Aureobasidium spp. Alternaria* spp. *Cladosporium* spp. *Trichoderma* sp) ait izolatlar elde edildi. Bu çalışmanın sonuçları yeni sekonder metabolitlerin araştırılmasında kestane yapraklarının iyi bir kaynak olabileceğini göstermiştir.

Anahtar Kelimeler : Kestane, Mikobiyota, Fungus, Fillosfer.

MYCOBIOTA ASSOCIATED OF CHESTNUT LEAVES COLLECTED FROM AYDIN PROVINCE

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The above-ground surfaces of plants (phyllosphere) host a variety of microorganisms. The phyllosphere microbiome is composed of various bacteria and fungi, which make significant contributions to the health, development, and environmental stress tolerance of the host plant. It is also known that fungal microbiome, especially in the phyllosphere are a rich source of interesting biological activities and new secondary metabolites exhibiting a high degree of chemical diversity. The phyllosphere microbiomes of different plants are quite important for the detection of new secondary metabolites. This study aimed to investigate the diversity of the phyllospheric fungal microbiome of chestnut leaves. Therefore, chestnut production areas in Aydın province were visited and healthy chestnut leaves were collected. The chestnut leaves brought to the laboratory were grouped according to their morphological differences, and fungal isolations were made from leaves with different morphologies using standard mycological methods. As a result of the studies conducted, isolates belonging to seven different fungal genera (*Geotrichum* spp., *Aspergillus* spp., *Penicillium* spp. *Aureobasidium spp. Alternaria* spp. *Cladosporium* spp. *Trichoderma* sp) were obtained. The results of this study indicate that chestnut leaves could be a good source for the investigation of new secondary metabolites.

Keywords: Chestnut, Mycobiota, Fungus, Phyllosphere

1.GİRİŞ

Bitkiler, kök, gövde ve yaprak gibi farklı dokularında çok çeşitli mikroorganizmalardan oluşan karmaşık mikrobiyal topluluklara ev sahipliği yapmaktadır. Bu mikrobiyota, bitki büyümesi ve gelişimi, stres toleransı ve patojenlere karşı direnç gibi pek çok ekolojik ve fizyolojik süreçte önemli bir rol oynar (Terhonen E., vd. 2019). Özellikle yaprak yüzeyinde ve yaprak dokularında bulunan mikroorganizmalar, çevresel koşullara doğrudan maruz kalması nedeniyle yüksek çeşitlilik göstermekte ve bitki-mikroorganizma etkileşimlerinin anlaşılmasında kritik bir araştırma alanı oluşturmaktadır (Sivakumar, N., vd. 2020).

Kestane (*Castanea sativa* Mill.) Türkiye'de başta Ege ve Akdeniz Bölgeleri olmak üzere geniş bir yayılışa sahiptir. Odun üretimi ve meyve verimi açıdan önemli bir tür olan kestane ağaçları, aynı zamanda zengin bir mikrobiyal ve kimyasal çeşitliliğe sahiptir (Wall, J., vd. 2025). Son yıllarda kestane ekosistemleri kanser, dal ve meyve çürüklükleri gibi çeşitli fizyolojik bozukluklar dahil olmak üzere çok sayıda biyolojik stres etmeni ile karşı karşıya kalmaktadır (Nicoletti, R., vd. 2021). Bu stres faktörlerinin bazıları farklı bitki dokuları ile ilişkili zengin ve karmaşık fungal toplulukların bir parçası olarak ortaya çıkmaktadır. Öte yandan kestanede endofitik veya antagonistik özellikler gösteren bazı türlerin biyokontrol potansiyeli taşıdığı, özellikle meyve çürüklüğü etmenine karşı koruyucu rol oynayabildiği de gösterilmiştir (Wen, Y., vd. 2024).

Kestane endofitik mantarlarının ikincil metabolit üretimine ilişkin bugüne kadar herhangi bir çalışma yapılmamış olup, tek istisna olarak *G. castanea*'nın bir suşunun absisik asit ve muhtemelen patojenitede rol oynayan diol türevini ürettiğini rapor etmişlerdir (Nicoletti, R., vd. 2021).

Bu çalışmada Aydın ilinde yetişen kestane ağaçlarının yapraklarının yüzeyindeki mikobiyotanın ortaya konması amaçlanmıştır. Elde edilen bulguların, kestane ekosisteminin mikobiyal çeşitliliğine katkı sağlaması, gelecekte yapılacak yeni sekonder metabolit araştırmalarına zemin oluşturulması hedeflenmiştir.

2.MATERYAL ve YÖNTEM

2.1.MATERYAL

Filosferik mikobiyom tespiti için kestane yaprak örnekleri kullanıldı. Öncelikle Aydın'ın Efeler ilçesine bağlı Eğrikavak Yaylası'nda bulunan kestane bahçeleri ve Karacasu ilçesinde kestane ağaçlarının bulunduğu ormanlık alan gezildi. Bu alanlardan fungal enfeksiyon belirtisi göstermeyen sağlıklı yapraklar toplandı. Her bir örnek 10 yaprak içerecek şekilde hazırlandı. Yaprakların benzer morfolojide olanları bir araya getirildi. Her yaprak örneği steril bir plastik torbaya konulup, hemen işleme tabi tutulmak üzere buz üzerinde laboratuvara taşındı.

2.2.YÖNTEM

2.2.1.Fungal İzolatların Elde Edilmesi

Kestane yapraklarından fungus izolasyon aşamasında, araziden toplanarak laboratuvara getirilen yapraklar öncelikle şekil, renk ve boyutlarına göre guruplara ayrılmıştır. Daha önce içerisine 90 ml fizyolojik tuzlu su (FTS) konularak otoklavda steril edilen beherlere, her bir gruptan 10 g yaprak örneği tartılarak eklenmiştir. Beherler çalkalayıcıya yerleştirilmiş ve 7 dakika çalkalanmıştır. Çalkalama işleminin ardından elde edilen süspansiyonun 10 lu sulandırımları hazırlanmış ve Malt Extract Agar (MEA) üzerine yayma ekim yöntemi ile ekim yapılmıştır. Besiyerleri 28 °C'de 72 ila 96 saat inkibasyona bırakılmıştır. İnkübasyon sonrası görülen fungus kolonilerinden alınan konidiler yeni bir besiyerine transfer edilmiştir. Saflaştırılmış izolatlar buzdolabında +4, -20 ve -80ºC'de daha sonraki çalışmalar için muhafaza edilmiştir.

2.2.2.Fungusların Mofolojik Karakterizasyonu

Elde edilen saf kültürlerin petrideki makroskobik görüntüsü ve rengi ile mikroskobik görüntüleri birlikte değerlendirileren tür tanılaması yapılmıştır. Mikroskobik inceleme için her bir fungal izolat laktofenol blue ile boyanarak ışık mikroskobu altında incelenmiştir. Mikroskop altında incelenen hiflerin özelliği, fruktifikasyon organlarının gelişimi, konidiyoforların yapısı, çap ve boylarının ölçüleri, sporların ölçüleri ve renkleri incelenip çeşitli kaynaklar kullanılarak tür tayini gerçekleştirilmiştir (Tsuneo, 1999).

3.SONUÇLAR ve TARTIŞMA

Aydın İli'nin iki farklı ilçesinden toplanan üç farklı morfolojik özellik taşıyan yapraklardan fungus izolasyonu ve tanısı yapılmıştır. Yapılan çalışmalar sonucunda 15 fungus elde

edilmiştir. Elde edilen fungusların petride oluşturdukları kolonilerin morfolojileri ile mikroskop görüntüleri birlikte değerlendirilerek karakterizasyonları yapılmıştır. Yapılan çalışmalar sonrasında yedi farklı fungal cinse (*Geotrichum* spp., *Aspergillus* spp., *Penicillium* spp. *Aureobasidium spp. Alternaria* spp. *Cladosporium* spp. *Trichoderma* sp) ait izolatlar elde edilmiştir (Çizelge 1). *Aspergillus* spp ve *Cladosporium* spp. nin diğer funguslara göre daha yaygın olduğu görülmüştür. Efeler ilçesinden toplanan örneklerden izole edilen *Trichoderma* spp.'nin antifungal etkinliği üzerine yaptığımız çalışmalar başarılı sonuçlar vermiştir (Burada o çalışmaya ait veriler paylaşılmayacaktır.)

Çizelge 1. Kestane yapraklarından izole edilen ve tanılanan funguslar

Yaprak Örneklerinin Toplandığı İlçe	**Yaprak Morfolojisi**	**Fungus**
Efeler (Eğrikavak Yaylası)	Dalgalı Uzun	***Trichoderma* spp.**
	Dalgalı	***Cladosporium* spp.** ***Alternaria alternata***
Karacasu	Koyu	***Geotrichum candidum*** ***Cladosporium* spp.** ***Aspergillus* spp.**
	Dalgalı Uzun	***Aspergillus flavus***
	Dalgalı	***Aureobasidium pullulans*** ***Cladosporium* spp.** ***Penicillium cheresanum*** ***Aspergillus flavus***

Karacasu ilçesinden toplanan yaprak örneklerinden izole edilen FÇKD/1 kodlu izolat PDA besiyerinde düz, beyaz–krem renkli ve tebeşirimsi koloni oluştururken; mikroskobik

incelemede hiflerin artrosporlara parçalanması nedeniyle *Aureobasidium pullulans* spp. olduğu değerlendirilmiştir. *Aureobasidium*, dünya genelinde çok çeşitli habitatlarla ilişkili olarak bulunabilen, maya benzeri bir mantar olarak bilinir. Bu mantar, özellikle pullulan olmak üzere çeşitli enzimlerin ve polisakkaritlerin ticari üretimi için potansiyel olarak kullanılmaktadır. Türkiye'de Armutlarda ateş yanıklığına karşı kullanılması tavsiye edilen ruhsatlı bitki koruma ürünün içeriğini oluşturmaktadır (TAGEM, 2025).

Petrideki koloni morfolojileri ve laktofenol mavisi ile boyanarak mikroskobik inceleme sonucu FKSD-2 kodlu izolatın *Penicillium cheresanum* olduğu tespit edilmiştir. Petride koloniler karakteristik mavi rengi oluşturuken, mikroskopda septat hifler, penicilli adı verilen karakteristik fırça benzeri yapılarla sonlanan konidioforlar ve küresel uzun zincir oluşturan konidiler gözlenmiştir.

P. chrysogenum alkaloidler, poliketidler, terpenoidler, pironlar, komarinler ve steroidler de dahil olmak üzere çok çeşitli metabolit sentezi gerçekleştirebilir (Nie vd. 2021). Lu vd. (2024) yaptıkları çalışmada *Penicillium cheresanum*'un 15 farklı bileşik sentezleyebildiğini ve patojen bakteriler üzerinde güçlü antibakteriyal etki gösterdiklerini rapor etmişlerdir.

Funguslar, biyometabolitlerin en zengin kaynaklarından biri olarak kabul edilir. Parazitik, saprofitik ve endofitik türleri içeren *Alternaria*, antibakteriyel, antitümör, antioksidatif, fitotoksik ve enzim inhibitör özellikleri ile karakterize edilen 216 yeni tanılanmış mükemmel sekonder metabolit üreticisidir. Bu nedenle, *Alternaria* türlerinin biyometabolitleri biyoteknoloji uygulamalar için oldukça önemlidir (Zhao, 2023).

Suş sayısının az olmasına rağmen, 1971'de *Cladosporium* spp.'nin bulunmasıyla başlayan çalışmalar sonucunda 244 adet kimyasal olarak tanılanan metabolit sentezleyebildiği tespit edilmiştir (Salvatore, 2021).

Literatür taramaları ve çalışma içerisinde elde edilen veriler birlikte değerlendirildiğinde kestane yapraklarının çok değerli fungus kaynağı olduğu görülmektedir. Mikroorganizmaların farklı stres koşulları ve konukçu bitki ile etkileşimi sonucunda farklı metabolit sentezleyebileceği bilgileri doğrultusunda, kestane yapraklarının gelecekte yeni metabolit çalışmalarında kullanılabilecek çok önemli kaynak olacağı öngörülmektedir.

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FARKLI *Trichoderma* spp. İZOLATLARININ BAZI BİTKİ PATOJENİ FUNGUSLARA KARŞI *In vitro* ANTAGONİSTİK ETKİLERİNİN BELİRLENMESİ

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ÖZET

Beslenmenin temelini oluşturan gıda ürünleri, bitkisel ve hayvansal kaynaklı olarak sınıflandırılmaktadır. Türkiye'de tarımsal üretimde bitkisel üretim, hayvansal üretime kıyasla daha baskındır. Stratejik öneme sahip bitkisel ürünler, üretim sürecinde çeşitli biyotik ve abiyotik stres faktörlerine maruz kalmakta olup, bu faktörler arasında kontrolü en zor ve epidemik yayılma potansiyeli en yüksek olanlar mikrobiyolojik hastalıklardır. Mikrobiyolojik hastalıklarla mücadelede kimyasal yöntemlerin sınırlı etkinliği ve çevresel etkileri, biyolojik kontrol stratejilerini ön plana çıkarmaktadır. Bu kapsamda *Trichoderma* türleri, geniş etki spektrumları ve çevre dostu özellikleri nedeniyle yaygın olarak kullanılmaktadır. Bu bilgiler ışığında yapılan çalışmada *Trichoderma* izolatlarının (ÜA/3 ve Acarlar) bazı önemli patojen funguslara [*Fusarium oxysporum* f. sp. radicis-lycopersici (FORL), *Rhizoctonia solani* (RS-AG-4) ve *Fusarium solani* (AK-1)] karşı *in vitro* antagonistik etkileri ve siderofor üretim potansiyelleri incelendi. Sonuç olarak, özellikle FORL üzerinde ÜA/3 izolatının %67 oranında, Acarlar izolatının ise %70,54 oranında yüksek inhibisyon etkisi gösterdiğini ve her iki izolatında siderofor üretebilme yeteneğine sahip olduğu belirlendi. Bu çalışma sonucunda, *Trichoderma* izolatlarının biyolojik kontrol ajanı olarak potansiyel özellik taşıdığını ortaya koymaktadır. Bu doğrultuda, *Trichoderma* izolatlarının tarla koşullarında etkinliklerinin değerlendirilmesine yönelik ileri düzey çalışmaların yapılması önerilmektedir.

Anahtar Kelimeler: *Trichoderma*, patojen funguslar, *in vitro* antagonizma, biyolojik kontrol

DETERMINATION OF THE IN VITRO ANTAGONISTIC EFFECTS OF DIFFERENT *Trichoderma* spp. ISOLATES AGAINST SPECIFIC PLANT PATHOGENIC FUNGI

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Food products that form the basis of nutrition are classified as plant-based and animal-based. Plant production in Turkey is more dominant than animal production. Plant products of strategic importance are exposed to various biotic and abiotic stress factors during the production process; among these factors, the most difficult to control and those with the highest potential for epidemic spread are microbial diseases.The limited effectiveness and environmental impacts of chemical methods in combating microbiological diseases have brought biological control strategies to the forefront. In this context, Trichoderma species are widely used due to their broad spectrum of activity and environmentally friendly properties. In light of this information, the study examined the in vitro antagonistic effects and siderophore production potential of Trichoderma isolates (ÜA/3 and Acarlar) against some important pathogenic fungi (*Fusarium oxysporum f. sp. radicis-lycopersici* (FORL), *Rhizoctonia solani* (RS-AG-4), and *Fusarium solani* (AK-1)). As a result, it was determined that the ÜA/3 isolate showed a high inhibition effect of 67% and the Acarlar isolate showed a high inhibition effect of 70.54%, especially on FORL, and that both isolates had the ability to produce siderophores. This study demonstrates that Trichoderma isolates have potential properties as biological control agents. In this context, it is recommended that advanced studies be conducted to evaluate the effectiveness of Trichoderma isolates under field conditions.

Keywords: *Trichoderma*, pathogenic fungi, *in vitro* antagonism, biological control

1. GİRİŞ

Beslenme, insanlığın en temel ihtiyaçlarından biri olup bu ihtiyacın karşılanmasında gıda ürünleri temel unsurları oluşturmaktadır. Gıda ürünleri bitkisel (sebzeler, meyveler, tahıllar vb.) ve hayvansal (et ve et ürünleri, süt ve süt ürünleri, yumurta, bal ve arı ürünleri) olmak üzere iki ana gruba ayrılabilir (Sipahi, 2024).

Türkiye coğrafyasında tarımsal üretim deseninde bitkisel üretim, ekim alanları ve üretim miktarı açısından hayvansal üretime kıyasla daha baskındır (T.C. Tarım ve Orman Bakanlığı, 2025). Türkiye'de ihracat ve ithalat bakımından stratejik öneme sahip bitkisel ürünler, üretim sürecinde verim ve kalite kayıplarına neden olabilen çeşitli biyotik ve abiyotik stres faktörlerine maruz kalmaktadır (Öztürk ve Sefaoğlu, 2022). Bu faktörler içerisinde kontrolü en zor ve epidemik yayılma potansiyeli en yüksek olanlar mikrobiyolojik (fungal, bakteriyel ve viral etmenler) hastalıklardır (Degani, 2024; Tatineni ve Hein, 2023; Rai & Rai, 2025).

Mikrobiyolojik hastalıkların kontrolünde kimyasal mücadele yöntemlerin sınırlı etkinliği ve çevresel etkileri göz önünde bulundurulduğunda, antagonistik mikroorganizmaların kullanımına dayalı biyolojik kontrol stratejileri önem kazanmaktadır (Kılınç ve Dinler, 2021). Bu mikroorganizmalar arasında *Trichoderma* türleri, geniş etki spektrumları ve çevre dostu özellikleri nedeniyle öne çıkmaktadır (Aydin, 2015). Ayrıca *Trichoderma* spp. parazitlik, antibiyöz, sekonder metabolit üretimi ve bitki savunma sistemi indüksiyonu gibi çeşitli biyolojik mücadele özelliği taşımalarından dolayı biyolojik kontrol ajanı olarak en çok kullanılan mikroorganizmalar arasındadır (Guzmán-Guzmán ve diğerleri, 2023).

Trichoderma spp, saprofitik olmaları nedeniyle 25°C ile 30°C arasında değişen sıcaklıklarda gelişebilen, tüm iklim bölgelerindeki tarım bölgelerinde yaygın olarak dağıldığı belirtilmiştir (Singh vd., 2024). Çok geniş bir pH aralığında (2,0 ile 13,0 pH) yaşayabilirler (Al-Ani, 2018). Genel olarak *Trichoderma* türlerinin konidi renk morfolojisi yeşildir ancak türe bağlı olarak gri, beyaz ve sarı da olabileceği bildirilmiştir (Chaverri et al., 2015). *Trichoderma* türleri bitkilerin rizosferinde bulunmaktadır. Saprofit rekabetçi özellikleri sayesinde bitkilerin hastalıklara karşı sistemik direnç oluşturmasını sağladığı ve bitki gelişimini arttırdığı bilinmektedir (Schuster ve Schmoll, 2010).

Trichoderma türleri biyolojik kontrolde, patojenlere doğrudan saldırı veya konak çevresinde patojen çoğalmasını baskılama yoluyla etki gösterir. Bu süreçte litik ve proteolitik

enzimler, taşıyıcı proteinler, uçucu ve difüz metabolitler kullanılarak funguslar ve nematodlar kontrol altına alınır. Biyolojik kontrol etkinliği; hücre duvarı yıkımı, hif gelişimi, stres toleransı ve parazitizmle ilişkili çok sayıda gen tarafından düzenlenir. Bu genlerin ekspresyonu cAMP ve MAPK gibi sinyal iletim yolları aracılığıyla kontrol edilirken, TVK1, TGA1, TGA3 ve VELVET gibi düzenleyici proteinler mikoparazitizm ve antifungal aktivite için kritik rol oynar (Schuster ve Schmoll, 2010; Sharma vd., 2011; Zeilinger ve Omann, 2007; Mendoza-Mendoza vd., 2007; Reithner vd., 2005; Mukherjee ve Kenerley, 2010).

Trichoderma türleri, klasik biyolojik kontrol uygulamalarına ek olarak; faydalı bakteriler ve arbusküler mikorizal mantarlarla birlikte aşılanarak sinerjik etki oluşturmak, rizofosfer ve endofitik mikrobiyomu yeniden şekillendirerek bitkilerin patojenlere karşı direncini artırmak ve nanopartiküllerin yeşil biyosentezinde kullanılmak gibi yenilikçi stratejilerle biyolojik mücadelede değerlendirilmektedir. Bu yaklaşımlar, bitki büyümesini teşvik ederken fungus ve zararlılara karşı etkili kontrol sağlamakta ve kimyasal fungisitlere çevre dostu alternatifler sunmaktadır (Metwally, 2020; Poromarto ve Indriani, 2021; Consolo vd., 2020; Abd-Elsalam vd., 2017).

Bu yenilikçi biyolojik mücadele yaklaşımlarının tarımsal üretim sistemlerine etkin biçimde entegre edilebilmesi, *Trichoderma* türlerinin uygun taşıyıcılar ve formülasyon teknikleri ile stabilize edilerek ticari biyoformülasyonlar hâline getirilmesini gerekli kılmaktadır.

Trichoderma bazlı biyolojik formülasyonlar, tarımda bitki büyümesini teşvik etme ve hastalıklara karşı direnç sağlama açısından sera ve tarla koşullarında etkili sonuçlar vermektedir (Awad-Allah et al., 2022). Ayrıca ticari *Trichoderma* ürünleri, bitkilerde sistemik direnç oluşturmak, patojen mantarların gelişimini baskılamak ve mikotoksin üretimini azaltmak gibi çok yönlü etkilere sahiptir (Martinez vd., 2023). Yerel suşların ve canlı mikroorganizma içermeyen uyarıcı bileşiklerin kullanımı, çevresel riskleri azaltmaya yönelik alternatif stratejiler olarak öne çıkmakta; bu bulgular *Trichoderma* bazlı biyolojik formülasyonların kimyasal girdilere sürdürülebilir ve çevre dostu bir alternatif olduğunu göstermektedir.

Aynı türün farklı suşlarının farklı antifungal aktiviteye sahip olabileceği bilinen bir gerçektir. O nedenle yeni *Trichoderma* spp. suşları biyolojik mücadelede başarı oranını arttırabilir. Bu çalışmada antifungal aktivitesi yüksek *Trichoderma* spp. suşlarını izole etmek ve tarımda büyük ekonomik kayıplara neden olan üç farklı fungal patojenle [*Fusarium*

oxysporum f. sp. radicis-lycopersici (FORL), *Rhizoctonia solani* (RS-AG-4), and *Fusarium solani* (AK-1)] mücadele yeteneğini testlemeyi hedefledik.

2. MATERYAL VE YÖNTEM

2.1. Materyal

Çalışmada kullanılan patojen funguslar [*Fusarium oxysporum f. sp. radicis-lycopersici* (FORL), *Rhizoctonia solani* (RS-AG-4), and *Fusarium solani* (AK-1)] Isparta Uygulamalı Bilimler Üniversitesi, Ziraat Fakültesi, Tarımsal Biyoteknoloji Bölümü, Enzim ve mikrobiyal biyoteknoloji laboratuvarından temin edildi. Çalışmada kullanılacak *Trichoderma* spp. izolasyonu için Aydın İli domates tarım arazilerinden alınan topraklar kullanılmıştır.

2.2. Yöntem

2.2.1. *Trichoderma* spp.'nin izolasyonu ve Morfolojik karakterizasyonu

ÜA/3 kodlu *Trichoderma* spp. suşu laboratuvarımızda kestane yapraklarından fungus izolasyonu yaptığımız bir çalışmada elde edildi. Acarlar kodlu *Trichoderma* spp. suşunun izolasyonu için domates rizosferinden alınan toprak numuneleri kullanılmıştır. Örnekleme yöntemine uygun olarak domates kök bölgesinin 5-20 cm derinliğine kadar olan bölgeden topraklar alınıp steril ve soğuk zincir kurallarına uyularak laboratuvara getirildi. Laboratuvarda elekle elenip homojen hale getirilen topraklardan 10g tartılıp 90 ml fizyolojik tuzlu su içerisine transfer edildi. Çalkalayıcıda 30 dk çalkalama sonrasında sulu toprak numunesinin 10 lu sulandırımları hazırlandı ve her bir sulandırım oranından 100µl Malt Extract Agar (MEA) besiyerine transfer edildi. Yayma ekim yöntemi ile ekildikten sonra MEA petrileri 28°C'de 7 gün inkübasyona bırakıldı.

İnkübasyon sonrasında farklı morfolojilerdeki funguslar tek konidi transformasyonu ile yeni steril MEA besiyerine transfer edilerek izolasyonları yapıldı. MEA petrisinde yeşil spor oluşturan funguslar laktofenol mavisi ile boyanarak mikroskobik görüntüleri elde edildi. Dallanmış konidiofor, şişkin fiyalid, tek hücreli konidi görüntüsü ile petrideki koloni morfolojisi birlikte değerlendirilerek morfolojik karakterizasyonları tamamlanmıştır (Rifai, 1969).

2.2.2. *Trichoderma* spp.'izolatlarının Siderefor Üretimi

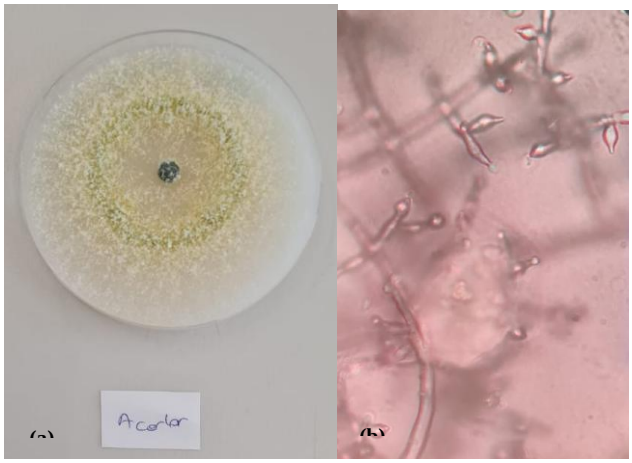
Siderofor üretimini tespit etmek için krom azurol S (CAS) agarlı petriler kullanılmıştır (Milagres vd., 1999). Taze kültürden alınan bir fungus miselyum diski (6 mm) CAS Agar'a aktarılmış ve mavi renkli kolonilerin etrafındaki turuncu halkalar siderofor üretimini göstermiştir.

2.2.3. *Trichoderma* spp.'izolatlarının Antifungal Etkinliklerinin Tespiti

Bu çalışmada *Trichoderma* spp. izolatlarının antifungal aktivitesinin tespiti için patojen *Fusarium oxysporum f. sp. radicis-lycopersici* (FORL), *Rhizoctonia solani* (RS-AG-4), ve *Fusarium solani* (AK-1) suşları kullanılmıştır. *Trichoderma* spp. izolatlarının *in-vitro* da antifungal aktivite tespitinde ikili kültür yöntemi kullanılmıştır. İnkübasyon süresinin sonunda patojen fungusun, *Trichoderma* spp. izolatı varlığında oluşturduğu zon çapı ile kontrol petrisinde oluşturduğu zon çapları mm cinsinden ölçülerek kaydedilmiştir. Formül aşağıda verildiği gibidir. % Engelleme= (1-(Muamelenin gelişimi/Kontrol gelişimi)) x100 formülü kullanılmıştır (Tariq vd., 2010)

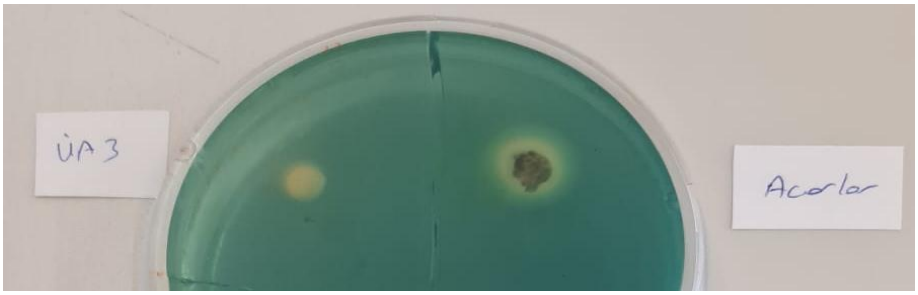
SONUÇLAR VE TARTIŞMA

Domates rizosferik topraklarından birkaç fungal izolat elde edildi ve bunlardan sadece biri *Trichoderma* spp. (Acarlar) olarak tanımlandı. 28 °C'de 7 gün inkübasyondan koloni çapı 86 mm idi ve koloni yüzeyinde yeşil spor alanları görülebiliyordu (Şekil 1a), bu da Samuels vd. (1999)'nın morfolojik tanımlamasıyla tutarlıydı. Konidiofor dallanmaları 90°'den daha küçük açılarda meydana geldi. Fialidler düzdü ve ortada hafifçe şişkin olma eğilimindeydi (Şekil 1b).



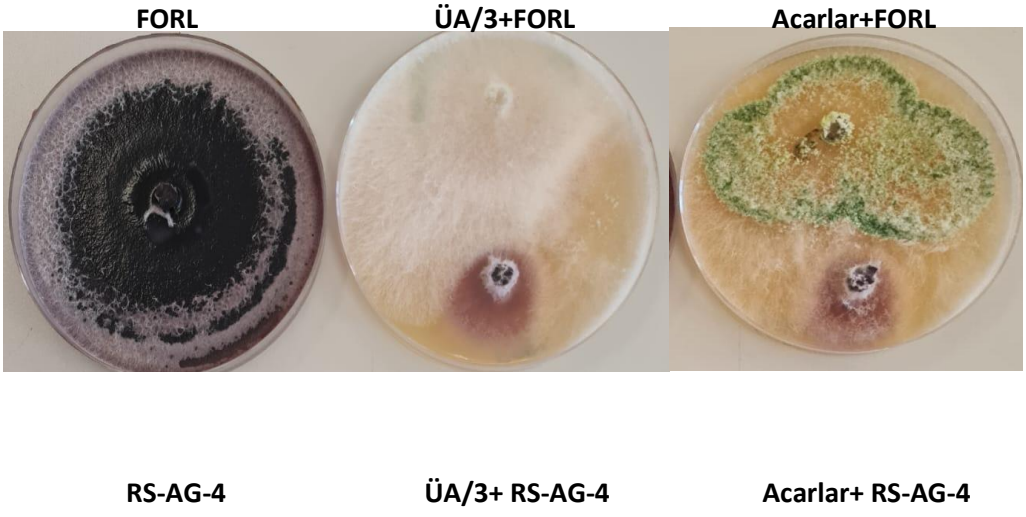
Şekil 1. Domates rizosferik toprağından izole edilen *Trichoderma* spp. (a): MEA'de, 28 °C de 7 gün inkübasyon sonrası koloni morfolojisi, (b):Mikroskopda konidiafor ve fiyalidler

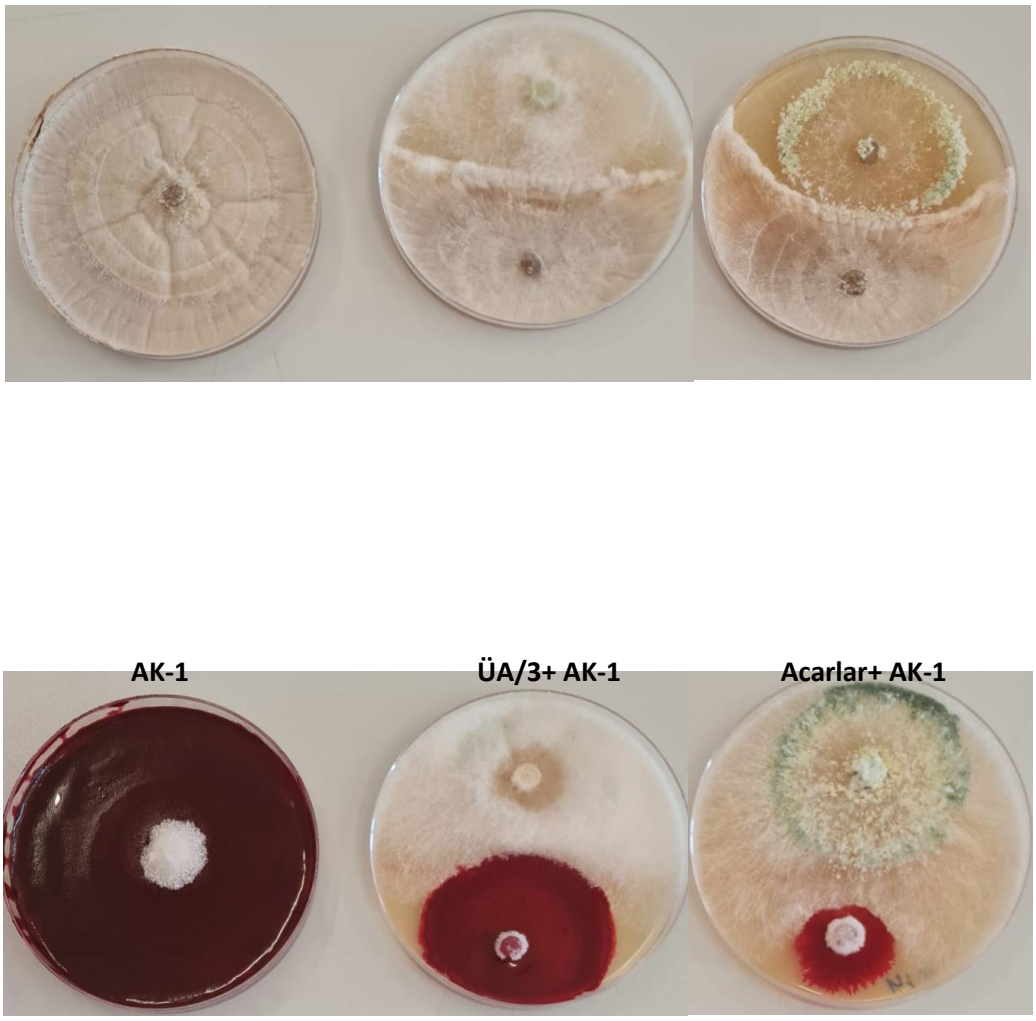
Kestane çalışmasından elde edilen ÜA/3 kodlu izolat ile Acarlar kodlu izolatın CAS agarda siderofor ürerim yetenekleri incelendi (Şekil 2). Acarların siderofor üretim kapasitesinin ÜA/3 izolatından daha yüksek olduğu görüldü.



Şekil 2. ÜA/3 ve Acarlar izolatlarının siderofor ürettim yetenekleri

Trichoderma spp. izolatlarının antifungal aktivite denemelerinin sonuçlarına bakıldığında ÜA/3 kodlu izolatın FORL üzerinde %67, RS-AG-4 üzerinde %43 ve AK-1 üzerinde ise %31,7 oranında inhibisyon etkisi olduğu görülmektedir (Şekil 3). Bu oranlar Acarlar izolatı için sırası ile %70.5, 50.3 ve 71.3 olduğu hesaplanmıştır. Şekil 2'de görüldüğü üzere Acarlar izolatının siderofor üretiminin daha fazla olması antifungal aktivitesinin ÜA/3'den yüksek olmasını açıklar niteliktedir.





Şekil 3. *Trichoderma* spp. izolatlarının *in vitro* anti fungal aktivite sonuçları

Çağlar vd. (2025), yapmış oldukları çalışmada *Trichoderma harzianum* izolatları FORL miselyal gelişimini %35,34-%72,56 oranlarında sınırlandırdığını rapor etmişlerdir. Yaptığımız çalışmada bu oranlar %67-70.5 arasında değişmektedir. Boakye vd. (2022), *Fusaium solani* üzerine *Trichoderma* spp.'nin antifungal aktivitesini incelemişlerdir. TL6 kodlu izolatlarının *Fusarium solani*'nin konidilerinin uzamasını in vitro da %54.58 oranında inhibe ettiğini rapor etmişlerdir. Yaptığımız çalışmada Acarlar izolatı %71.3 inhibisyon oranına ulaşmıştır.

Rhizoctonia solani dünya çapında birçok ekonomik açıdan önemli tarım ve bahçecilik ürünlerine ve ağaçlara ciddi zarar veren 100'den fazla türden oluşan karmaşık bir gruptur. Geniş bir konakçı yelpazesine ve dağılımına sahiptir (Druzhinina, 2005). *Rhizoctonia solani* kontrolü oldukça zordur. Sklerotiyum gibi yüksek hayatta kalma oranına sahip yapılar oluşturabilir, son derece geniş konakçı yelpazesine sahiptir ve toprakta uzun süreler canlı kalabilir. Bu nedenle, *Rhizoctonia solani*'yi kontrol etmek için stratejiler sınırlıdır, çünkü tam dirençli hiçbir kültür

çeşidi bulunmamaktadır. Hastalıkla mücadelede ekim nöbeti gibi agronomik kontroller büyük ölçüde kullanılmaktadır. Geniş spektrumlu fungisitler de mevcuttur, ancak bunlar yüksek toksisiteye sahiptir ve çevre dostu değildir. Bu nedenle Acarlar izolatı *Rhizoctonia solani* enfeksiyonları ile mücadelede alternatif olabilir.

Yaptığımız çalışmada veriler topluca değerlendirildiğinde Acarlar izolatının ÜA/3 kodlu izolata göre hem siderofor üretimi hem de in vitro antifungal aktivitesi daha yüksektir. Ayrıca *Fusarium oxysporum* ve *Fusairum solani* üzerine inhibisyon etkisi literatürle karşılaştırıldığında benzer ya da daha yüksek olduğu görülmektedir. Elle ettiğimiz Acarlar kodlu izolat tarımda büyük ekonomik kayıplara sebep olan fungal hastalıklarla mücadelede kullanılmaya adaydır.

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An Application Of The Theorem On Absolute Matrix summability

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ABSTRACT

In (A new class of matrices and its applications to absolute summability factor theorems, Math. Comput. Modelling 57 (2013) 401-412) Yu and Zhou introduced $S(\beta_n, \gamma_n)$ class of matrices.

In our study, we have a general theorem dealing with quasi-monotone sequences by taking lower triangular matrix which are widely used in summability theory and applications and $S(\beta_n, \gamma_n)$ class of matrices.

Key words: Absolute summability, Infinite series, Hölder and Minkowski inequalities.

1. INTRODUCTION

Let $A = (a_{nk})$ be a lower triangular matrix and $\{s_n\}$ partial sums of $\sum a_n$ and also $\{\beta_n\}$ be a non negative sequence. If (see [2])

$$\sum_{n=1}^{\infty} \beta_n |A_n - A_{n-1}|^k < \infty$$

where $A_n = \sum_{v=1}^{n} a_{nv}\, s_v$, then the series $\sum a_n$ is said to be summable $|A, \beta_n|_k$, $k \geq 1$.

As specially if we take $\beta_n = n^{k-1}$, then $|A, \beta_n|_k$ summability reduces to the $|A|_k$ summability (see [5]).

Let $\{\beta_n\}$ and $\{\gamma_n\}$ be sequences of positive numbers. It is defined as a lower triangular matrix $A = (a_{nk}) \in S(\beta_n, \gamma_n)$, if (see [1]) A satisfies the following conditions:

$\sum_{v=0}^{n-1} |\Delta_v \hat{a}_{nv}| = O(\gamma_n)$,

$|\hat{a}_{nv}| = O(\gamma_n),\ v = 0,1,\ldots,n,$

$\sum_{n=v+1}^{\infty} \beta_n {\gamma_n}^{k-1} |\Delta_v \hat{a}_{nv}| = O(\beta_v {\gamma_v}^{k})$,

$\sum_{n=v+1}^{\infty} \beta_n {\gamma_n}^{k-1} |\hat{a}_{nv+1}| = O(\beta_v {\gamma_v}^{k-1})$.

For any sequence (μ_n), we see that $\Delta\mu_n = \mu_n - \mu_{n+1}$. If $\sum_{n=1}^{\infty} |\Delta\mu_n| < \infty$, the sequence (μ_n), is said to be of bounded variation an denoted by $(\mu_n) \in BV$.

A sequence (c_n) is said to be δ-quasi monotone, if $c_n \to 0$, $c_n > 0$ ultimately, and $\Delta c_n \geq -\delta_n$, where $\Delta c_n = c_n - c_{n+1}$ and $\delta = (\delta_n)$ is a sequence of positive numbers (see [6]).

Bor obtained two general theorems dealing with some applications of δ- quasi-monotone sequences to the factored infinite series and trigonometric Fourier series (see [3]). And also we generalized these theorems to absolute matrix summability by using lower triangular matrices (see [7]). In this paper we generalize these results by using $S(\beta_n, \gamma_n)$ class of matrices.

Teorem 1.1:

Let $\{\beta_n\}$ and $\{\gamma_n\}$ be sequences of positive numbers and $\mu_n \to 0 \;\; n \to \infty$ and also

$Z_n = \sum_{v=0}^{n} a_{vv}$ for $n \geq 0$.

Suppose that there exists a sequence of (ε_n) which is δ-quasi monotone with $\sum n Z_n \delta_n < \infty$, $\sum \varepsilon_n Z_n$ is convergent, and $|\Delta\mu_n| \leq |\varepsilon_n|$ for all n.

If $A \in S(\beta_n, \gamma_n)$ satisfies

$$\sum_{v=1}^{n-1} \frac{|\widehat{a}_{n,v+1}|}{v} = O(\gamma_n)$$

$$\sum_{n=1}^{m} \beta_n \gamma_n{}^{k} \frac{|t_n|^k}{Z_n^{k-1}} = O(Z_m), \quad m \to \infty,$$

$$\sum_{n=1}^{m} \beta_n \gamma_n{}^{k-1} \frac{|t_n|^k}{n Z_n{}^{k-1}} = O(Z_m), \quad m \to \infty,$$

then the series $\sum a_n \mu_n$ is summable $|A, \beta_n|_k$ for $k \geq 1$.

2. Application to Fourier series:

Let f be a periodic function with period 2π and Lebesgue integrable over $(-\pi, \pi)$. The Fourier series of f is defined as $f(x) \sim \frac{1}{2} a_0 + \sum_{n=1}^{\infty} (a_n \cos nx + b_n \sin nx) = \sum_{n=0}^{\infty} C_n(x)$.

Write $\emptyset(t) = \frac{1}{2}\{f(x+t) + f(x-t)\}$ and $\emptyset_\alpha(t) = \frac{\alpha}{t^\alpha} \int_0^t (t-u)^{\alpha-1} \emptyset(u) du, \quad (\alpha > 0)$.

If $\emptyset_1(t) \epsilon BV(0, \pi)$, then $t_n(x) = O(1)$, where $t_n(x)$ is the $(C, 1)$ mean of the sequence $(nC_n(x))$ (see [4]). By taking this fact, we have the following theorem.

Theorem 2.1 Let $A \in S(\beta_n, \gamma_n)$. If $\emptyset_1(t) \in BV(0, \pi)$, the sequences (ε_n) , (μ_n), (Z_n) satisfy the conditions of Theorem 1.1, then the series $\sum C_n(x) \mu_n$ is summable $|A, \beta_n|_k$ for $k \geq 1$.

Remark: Let $\gamma_n = a_{nn}$ and $\beta_n = \theta_n^{k-1}$. If the matrix A satisfies the conditions of Theorem 3.1 in [7], then we have that $A \in S(\beta_n, \gamma_n)$ so the Theorem 3.1 can be given as a result of Theorem 1.1.

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ANALYTICAL OR SEMI-ANALYTICAL SOLUTIONS TO NONLINEAR TIME FRACTIONAL DIFFERENTIAL EQUATIONS THROUGH A HYBRID METHOD

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ABSTRACT

The contribution of this work is to solve the initial value problems, including fractional differential equations, with the Caputo derivative. The Laplace Iterative Method (LIM) is employed to acquire analytical or semi-analytical solutions of the fractional initial value problems. First, to overcome the difficulties in the nonlinear nature of fractional derivatives, we progressively used the Laplace transform, and then the inverse Laplace transform. The next step of the process is to employ an effective iterative approach to obtain an analytical or semi-analytical solution in the series form. The novelty of this work is that the proposed method yields convergent solutions with higher speed and has less computational complexity. The confirmation of the accuracy and effectiveness of the proposed method is provided by an example.

Keywords: Caputo Derivative, Fractional Differential Equations, Laplace Transform, Iterative method

1. INTRODUCTION

In the modeling of scientific processes, the fractional differential equations are more effective compared to the classical differential equations because of long-range dependencies and their memory effect. Therefore, having rational numbers as the order of the derivative leads to better accuracy and perspective for the problems in various fields such as quantum physics, hydrogeology, population science, fluid dynamics, etc. [1]. Based on physical context, various fractional derivatives have been defined and classified [2]. Even though classical differential equations are utilized to model simple systems, complex scientific processes can be modeled

better by fractional differential equations, which provide a significant depth to the analysis of the processes.

For the semi-analytical or analytical solution of the fractional differential equations, various iterative methods such as the variational iteration method (VIM) [3], the homotopy analysis method [4], the Green-Picard iterative technique [5], etc., have been utilized. These iterative methods provide convergent and steady solutions to fractional differential equations by using mathematical properties of fractional derivatives. Moreover, the solutions have higher accuracy as well as lower computational cost. As a result, iterative schemes have many applications for various problems, ranging from initial value problems to two-point boundary value problems, because of their great potential to deal with intricate problems such as fractional diffusion, Navier-Stokes equations, etc. As future work, the stability and convergence analysis of iterative methods can be considered.

The combination of the Laplace transform with various iterative methods gives rise to distinct hybrid methods to obtain rapidly convergent and more accurate solutions to fractional differential equations. In the literature, there are a great number of various hybrid methods such as the Fractional Laplace Differential Transform Method [7], the Variational Iterative Laplace Transform Technique [8], the Laplace-Composition Method [9], the Laplace Residual Power Series Algorithm [10], the Discrete Transformation Method, used in conjunction with the Adomian Decomposition Method [11], etc. However, in the solution of the process of intricate systems, the encountered problems imply the development of new hybrid methods, which lead to new directions for future work.

The primary goal of the current work is to provide analytical or semi-analytical solutions to nonlinear time fractional differential equations through LIM. The proposed method offers a wide range of applications.

The structure of the study can be summarized as follows: The second section provides preliminary information on the basic concepts and mathematical tools related to fractional calculus and the Laplace transform. In the following third section, the application procedure of LIM to nonlinear fractional differential equations is explained step by step, and the convergence characteristics of the method are examined. In section four, biological population model with Caputo fractional derivative is considered to present a detailed evaluation of its solutions. In the final section, the summary of obtained outcomes are presented.

2. PRELIMINARY RESULTS

In this section, a review of essential definitions and principles of fractional calculus is provided [12] [13].

Definition: The Riemann-Liouville fractional integral operator of fractional order $\alpha > 0$ for a function $\mu(\zeta)$ is defined as

$$I_{\zeta}^{\alpha}\mu(\zeta) = \frac{1}{\Gamma(\alpha)}\int_0^{\zeta}(\zeta - s)^{\alpha-1}\mu(s)ds.$$

Definition: Let $n = [\alpha]$. The α-order fractional derivative of a $\mu(\zeta)$ function in the Liouville-Caputo sense is expressed as follows for the interval $\zeta \in [\zeta_0, \zeta_0 + \mathrm{T}]$:

$$D_{\zeta}^{\alpha}\mu(\zeta) = \frac{1}{\Gamma(n-\alpha)}\int_{\zeta_0}^{\zeta}(\zeta - s)^{n-\alpha-1}\mu^{(n)}(s)ds,$$

where $\mu^{(n)}(\zeta)$ denotes the derivative of order n with respect to ζ. The fractional derivative becomes a classical derivative when the parameter α is an integer.

Definition: For the parameter range $0 < \alpha < 1$, the Liouville-Caputo fractional derivative of a $\mu(\zeta)$ function is defined by the following integral formulation:

$$D_{\zeta}^{\alpha}\mu(\zeta) = \frac{1}{\Gamma(1-\alpha)}\int_{\zeta_0}^{\zeta}(\zeta - s)^{-\alpha}\mu'(s)ds.$$

Here, $\zeta \in [\zeta_0, \zeta_0 + \mathrm{T}]$, and the expression $\mu'(s)$ represents the first-order ordinary derivative of the function.

Definition: For parameters $\alpha > 0, \beta > 0$, and $\lambda \in \mathbb{R}$, the two-parameter Mittag-Leffler function is expressed by the following power series [14]:

$$E_{\alpha,\beta}(\lambda(t - t_0)^{\alpha}) = \sum_{k=0}^{\infty}\frac{(\lambda(t-t_0)^{\alpha})^k}{\Gamma(\alpha k+\beta)}, \alpha, \beta > 0, \lambda \in R.$$

If $t_0 = 0$ and $\alpha = \beta = \mathrm{q}$ are taken, the above general definition is specialized to the following form:

$$E_{q,\mathrm{q}}(\lambda t^q) = \sum_{k=0}^{\infty}\frac{(\lambda t^q)^k}{\Gamma(qk+\mathrm{q})}. \quad (1)$$

Here, the condition $q > 0$ applies. The Mittag-Leffler function turns into an exponential function when q is equal to 1, i.e., $E_{1,1}(\lambda t) = e^{\lambda t}$. For more detailed information on this topic,

refer to source [14]. The functional structures given above were used in deriving the solution to the fundamental problem analyzed in this study.

The class of functions for which the Laplace transform is valid consists of functions satisfying the following conditions:

$$\{f(t)|\ \exists M, \tau_1, \tau_2 > 0,\ \ such\ that\ |f(x,t)| < Me^{|t|/\tau_j}\ \ if\ t \in (-1)^j \times [0,\infty)\}.$$

The Laplace transform of a function $f(t)$ is calculated using the integral given below:

$$\mathcal{L}[f(t)] = F(\omega) = \int_0^\infty e^{-\omega t} f(t)dt.$$

An important property of this transform is that it satisfies the following equality:

$$\mathcal{L}\left[\frac{t^{n\alpha}}{\Gamma(n\alpha+1)}\right] = \frac{1}{\omega^{n\alpha+1}},\ \alpha > 0.$$

The inverse Laplace transform of this expression is as follows:

$$\mathcal{L}^{-1}\left[\frac{1}{\omega^{n\alpha+1}}\right] = \frac{t^{n\alpha}}{\Gamma(n\alpha+1)},\ Re(\alpha) > 0,$$

where $n > 0$ is a parameter [12, 13].

Within the Liouville-Caputo definition, the Laplace transform of the time-dependent fractional derivative of a two-variable function such as $f(x,t)$ is given by the following formula [12] [13]:

$$\mathcal{L}\left[\frac{\partial^\alpha f(x,t)}{\partial t^\alpha}\right] = \omega^\alpha \mathcal{L}[f(x,t)] - \sum_{k=0}^{n-1}\left[\omega^{\alpha-k-1}\frac{\partial^k f(x,0)}{\partial t^k}\right],\ n-1 < \alpha \le n,\ n \in \mathbb{N}.$$

3. MAIN RESULTS

This section provides the algorithm of the proposed LIM to obtain semi-analytical or analytical solutions to boundary value problems including nonlinear fractional partial differential equations. The general problem form to be examined is as follows:

$$ {}_0^C D_\delta^\alpha\big(p(\sigma,\varsigma,\delta)\big) + Rp(\sigma,\varsigma,\delta) + Np(\sigma,\varsigma,\delta) = g(\sigma,\varsigma,\delta),\ m-1 < \alpha \le m,\ m \in \mathbb{N}, \qquad (2)$$

$$\frac{\partial^k}{\partial \varsigma^k} p(\sigma,\varsigma,0) = h_k(\sigma,\varsigma),\ k = 0,1,2,\dots,m-1,$$

where ${}_0^C D_\delta^\alpha\big(p(\sigma,\varsigma,\delta)\big), R, N$ and $g(\sigma,\varsigma,\delta)$ represent the fractional derivative of $p(\sigma,\varsigma,\delta)$, a linear operator, a nonlinear term, and the source function, respectively. The function $p(\sigma,\varsigma,\delta)$

is considered to be continuously differentiable up to M with respect to δ for the Laplace transform. In other words, the function $p(\sigma, \varsigma, \delta)$ must belong to the Banach space $W_2^m[0, \mathrm{T}]$, which is defined as follows:

$$W_2^m[0, \mathrm{T}] = \{p = p(.,.,\zeta): p, p^{(1)}, \ldots, p^{(m-1)} \in AC[0, \mathrm{T}]\}.$$

Without loss of generality, assuming $p = p(\sigma, \varsigma, \delta)$, applying the Laplace transform to both sides of Equation (2) yields the following result:

$$\mathcal{L}[{}_0^C D_\delta^\alpha p](s) + \mathcal{L}[Rp + Np](s) = \mathcal{L}[g(\sigma, \varsigma, \delta)](s).$$

By applying the fundamental theorems of the Laplace transform, the previous expression can be transformed into the following form:

$$\mathcal{L}[p](s) = \frac{1}{s^\alpha}\sum_{k=0}^{m-1} \frac{\partial^k}{\partial \delta^k} p(\sigma, \varsigma, 0) s^{\alpha-k-1} - \frac{1}{s^\alpha}\mathcal{L}[Rp + Np](s) + \frac{1}{s^\alpha}\mathcal{L}[g(\sigma, \varsigma, \delta)](s).$$

Subsequently, the inverse Laplace transform is applied, and the following equation is written for the solution function:

$$p = \mathcal{L}^{-1}\left[\frac{1}{s^\alpha}\left[\sum_{k=0}^{m-1} \frac{\partial^k}{\partial \delta^k} p(\sigma, \varsigma, 0) s^{\alpha-k-1} + \mathcal{L}[g(\sigma, \varsigma, \delta)](s)\right]\right] - \mathcal{L}^{-1}\left[\frac{1}{s^\alpha}[\mathcal{L}[Rp + Np](s)]\right]. \quad (3)$$

As a result of the iterative method, the solution function p is acquired in the series form:

$$p = \sum_{i=0}^{\infty} p_i. \quad (4)$$

The following is a result of the linearity of the operator R:

$$R\left(\sum_{i=0}^{\infty} p_i\right) = \sum_{i=0}^{\infty} R(p_i). \quad (5)$$

In contrast, the nonlinear operator N is decomposed as follows:

$$N\left(\sum_{i=0}^{\infty} p_i\right) = N(p_0) + \sum_{i=0}^{\infty}\left\{N\left(\sum_{k=0}^{i} p_k\right) - N\left(\sum_{k=0}^{i-1} p_k\right)\right\}. \quad (6)$$

If the expansions given in Equations (4), (5), and (6) are used for the expressions p, Rp, and Np in equation (3), the following equality is obtained:

$$\sum_{i=0}^{\infty} p_i = \mathcal{L}^{-1}\left[\frac{1}{s^\alpha}\left[\sum_{k=0}^{m-1} \frac{\partial^k}{\partial \delta^k} p(\sigma, \varsigma, 0) s^{\alpha-k-1} + \mathcal{L}[g(\sigma, \varsigma, \delta)](s)\right]\right] - \mathcal{L}^{-1}\left[\frac{1}{s^\alpha}\left[\mathcal{L}\left[R(p_i) + N(p_0) + \sum_{i=1}^{\infty}\left\{N\left(\sum_{k=0}^{i} p_k\right) - N\left(\sum_{k=0}^{i-1} p_k\right)\right\}\right](s)\right]\right].$$

Based on this result, the iterative solution scheme is defined by the following relations:

$$p_0 = \mathcal{L}^{-1}\left[\frac{1}{s^\alpha}\left[\sum_{k=0}^{m-1}\frac{\partial^k}{\partial\delta^k}p(\sigma,\varsigma,0)s^{\alpha-k-1} + \mathcal{L}[g(\sigma,\varsigma,\delta)](s)\right]\right],$$

$$p_1 = -\mathcal{L}^{-1}\left[\frac{1}{s^\alpha}[\mathcal{L}[R(p_0)+N(p_0)](s)]\right],$$

$$p_{m+1} = \mathcal{L}^{-1}\left[\frac{1}{s^\alpha}[\mathcal{L}[R(p_m)-\{N(\sum_{k=0}^{m}p_k)-N(\sum_{k=0}^{m-1}p_k)\}](s)]\right], m \geq 1. \quad (7)$$

Therefore, the approximate solution formed using m terms is given as follows:

$$p(\sigma,\varsigma,\delta) \cong \mu_0 + \mu_1 + \mu_2 + \ldots + \mu_m, m = 1,2,\ldots.$$

4. ILLUSTRATIVE EXAMPLE

To illustrate the application process of the proposed method, this section will address a nonlinear fractional-order initial value problem describing biological population dynamics.

Example: The following fractional-time biological population model constitutes the application example of this study:

$${}_0^C D_\delta^\alpha p = \frac{\partial^2}{\partial\sigma^2}p^2 + \frac{\partial^2}{\partial\varsigma^2}p^2 + hp(1-rp), \quad (9)$$

The initial condition of the equation is as follows:

$$p(\sigma,\varsigma,0) = e^{\sqrt{\frac{hr}{8}}(\sigma+\varsigma)}. \quad (10)$$

Here, $p = p(\sigma,\varsigma,\delta), 0 < \alpha \leq 1, (\sigma,\varsigma) \in \mathbb{R}^2, \delta > 0.$

Considering the initial condition (10), taking the Laplace transform of both sides of equation (9) yields the following expression:

$$\mathcal{L}[p](s) = \frac{1}{s}e^{\sqrt{\frac{hr}{8}}(\sigma+\varsigma)} + \frac{1}{s^\alpha}\mathcal{L}\left[\frac{\partial^2}{\partial\sigma^2}p^2 + \frac{\partial^2}{\partial\varsigma^2}p^2 + hp(1-rp)\right](s). \quad (11)$$

Applying the inverse Laplace transform to equation (11) yields the following integral equation formulation for the solution:

$$p = e^{\sqrt{\frac{hr}{8}}(\sigma+\varsigma)} + \mathcal{L}^{-1}\left[\frac{1}{s^{\alpha}}\left[\mathcal{L}\left[\frac{\partial^2}{\partial\sigma^2}p^2 + \frac{\partial^2}{\partial\varsigma^2}p^2 + hp(1-rp)\right](s)\right]\right]. \quad (12)$$

Solving equation (12) using the previously given expressions (4)-(6) and the recurrence relation (7) yields the following components of the solution:

$$p_0 = p(\sigma,\varsigma,0) = e^{\sqrt{\frac{hr}{8}}(\sigma+\varsigma)},$$

$$p_1 = h\frac{\delta^{\alpha}}{\Gamma(\alpha+1)}e^{\sqrt{\frac{hr}{8}}(\sigma+\varsigma)},$$

$$p_2 = h^2\frac{\delta^{2\alpha}}{\Gamma(2\alpha+1)}e^{\sqrt{\frac{hr}{8}}(\sigma+\varsigma)},$$

$$p_3 = h^3\frac{\delta^{3\alpha}}{\Gamma(3\alpha+1)}e^{\sqrt{\frac{hr}{8}}(\sigma+\varsigma)},$$

$\vdots$.

Based on this, the m −term approximate solution to the problem is written as follows:

$$p \cong p_0 + p_1 + p_2 + \ldots + p_m.$$

$$p \cong \left(1 + h\frac{\delta^{\alpha}}{\Gamma(\alpha+1)} + h^2\frac{\delta^{2\alpha}}{\Gamma(2\alpha+1)} + h^3\frac{\delta^{3\alpha}}{\Gamma(3\alpha+1)} + \ldots + h^m\frac{\delta^{m\alpha}}{\Gamma(m\alpha+1)}\right)e^{\sqrt{\frac{hr}{8}}(\sigma+\varsigma)}.$$

As the parameter m approaches infinity, this series expansion converges to the closed-form analytical solution:

$$p(\sigma,\varsigma,\delta) = E_{\alpha,1}(h\delta^{\alpha})e^{\sqrt{\frac{hr}{8}}(\sigma+\varsigma)}.$$

For the special case $\alpha = 1$, this analytical solution is given in the literature [15] as follows:

$$p(\sigma,\varsigma,\delta) = e^{\sqrt{\frac{hr}{8}}(\sigma+\varsigma)+h\delta}.$$

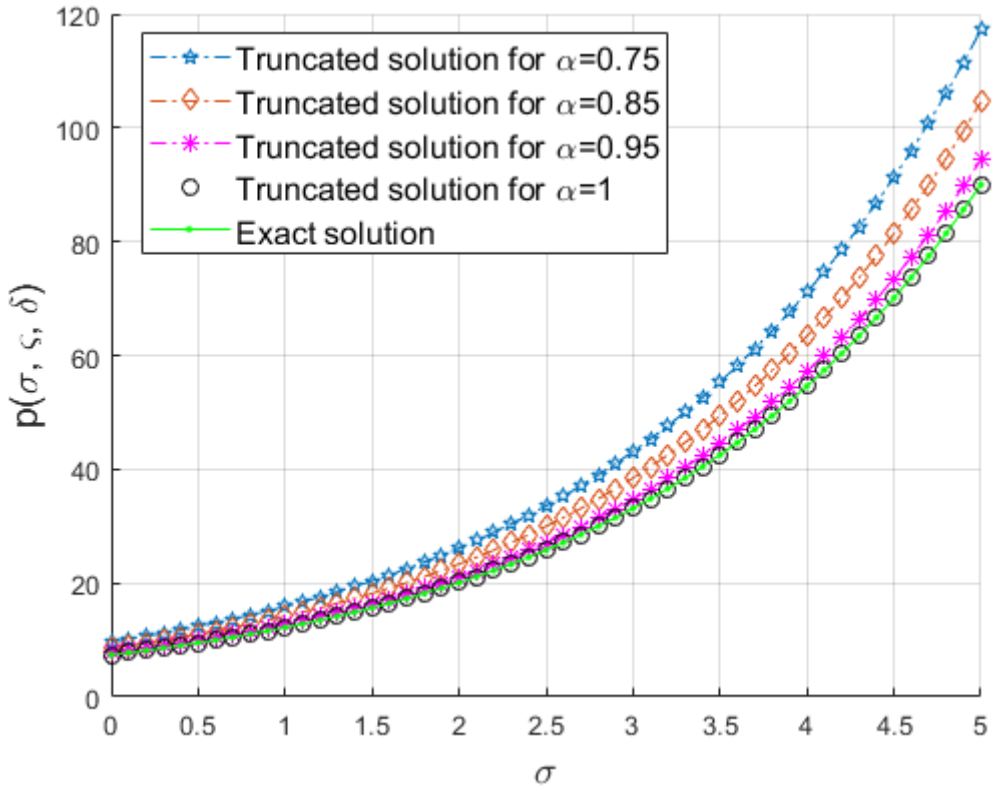


Figure 1. Graphical analysis of LIM solutions (exact and p_7) for different values of the parameter α, with $\delta = 1.5$, $r = 2$, and $\varsigma = h = 1$ fixed.

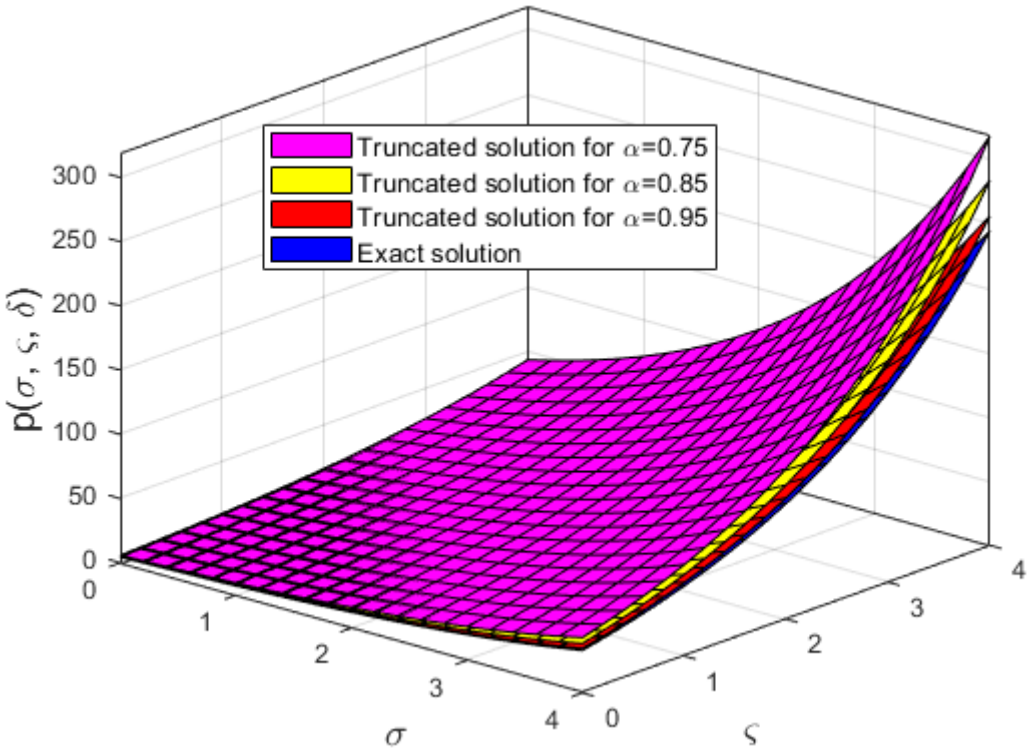


Figure 2. 3D comparison of LIM solutions for the Example model: Exact and seventh-order approximations (p_7) at different α values with $\delta = 1.5$, $r = 2$, and $h = 1$ fixed.

Table 1. Numerical values of absolute errors between the seventh-order LIM approximation (p_7) and the exact solution for $\alpha = 1$.

$(\sigma, \varsigma, \delta)$	$h = 1, r = 2$
(0.1,0.1,0.1)	$2.771116669464391\times 10^{-13}$
(0.2,0.2,0.2)	$7.930767154107343\times 10^{-11}$
(0.3,0.3,0.3)	$2,27200946945061\times 10^{-9}$
(0.4,0.4,0.4)	$2.537049281770010\times 10^{-8}$
(0.5,0.5,0.5)	$1.690687270183844\times 10^{-7}$

Table 1 presents the numerical breakdown of the absolute differences between the exact result calculated using the $\alpha = 1$ parameter in Example and the seventh-order approximation (p_7). The figures in Figure 1 and Figure 2 visually demonstrate that the approximate solutions obtained using the Laplace Iterative Method (LIM) converge regularly to the true solution as the α value approaches 1. The near-perfect overlap of the exact and p_7 approximate solution curves plotted in two- and three-dimensional space support this result. Additionally, a significant increase in the accuracy of the approximate solutions has been observed as the iteration step increases.

5. CONCLUSION

This study focuses on the development and detailed analysis of a numerical method (Laplace Iterative Method - LIM) that combines the Laplace transform with an iterative technique for solving initial value problems of nonlinear fractional differential equations. The presented example of a time fractional biological population problem exhibits the potential of the proposed method for various applications. The obtained outcomes imply the high accuracy and great effectiveness of the proposed method. Future research plans include investigating more complex nonlinear systems through the integration of the variational iteration method of the Laplace transform with other numerical methods, such as the homotopy analysis method and Adomian decomposition.

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NUMERICAL SOLUTION OF TIME FRACTIONAL DIFFERENTIAL EQUATION THROUGH A NUMERICAL METHOD

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ABSTRACT

The primary aim of the current research is to construct a numerical solution to a time differential equation with the Atangana-Baleanu-Caputo (ABC) derivative by utilizing the Adams-Bashforth type approach. The properties of the ABC derivative, such as memory effect and having a nonsingular kernel, make the considered problem more valuable since it has various applications in science. The obtained numerical solution can yield a closed-form solution, which can be expressed by Mittag-Leffler functions. Therefore, it can be concluded that the proposed method provides us with highly accurate numerical solutions.

Keywords: Fractional Adams-Bashforth Type Approach, Atangana-Baleanu-Caputo Derivative, Time Fractional Differential Equations, Mittag-Leffler Functions

1. INTRODUCTION

Since intricate processes in science have memory, in their mathematical modeling, fractional derivatives play a key role, which allows us to investigate them in detail and better [1] [2] [3]. Therefore, in many applications such as viscoelasticity and material science [4], financial modeling [5], anomalous diffusion in biology and physics [6], and system control engineering [7], etc., fractional differential equations have been employed. However, the complexity of computing solutions of fractional differential equations leads to some challenges [8] [9] [10].

We consider the following fractional initial value problem:

$$\begin{cases} {}^{ABC}_{0}D_t^{\alpha}\big(y(t)\big) = F\big(t, y(t)\big) \\ y(0) = y_0 \end{cases}, B(\alpha) = 1 - \alpha + \frac{\alpha}{\Gamma(\alpha)},$$

which contains a linear fractional differential equation with the ABC fractional derivative. The mathematical models, including fractional differential equations in the ABC sense, have been numerically solved by various methods such as spectral methods [11], and predictor-corrector algorithms [12].

The novelty of the current work is that a numerical scheme is proposed to obtain a numerical solution to fractional differential equations with the ABC fractional derivative.

The organization of the rest of the paper is listed as follows. Fundamental definitions and properties are given in Section 2. In section 3, error analysis and the flowchart of the proposed approach are presented. A numerical test is provided to exhibit the proof of the outcomes in Section 4. In the final section, a summary of the current work and new directions for future studies are provided.

2. PRELIMINARY RESULTS

This section provides the essential definitions and significant concepts used throughout this research.

Definition (Sobolev Space)

The Sobolev space $H^p(\Omega)$ where Ω is an open subset of $\mathbb{R}$ and $p \in [1, \infty)$ is defined as

$$H^p(\Omega) = \{f \in L^2(\Omega): D^\beta f \in L^2(\Omega) \; for \; all \; |\beta| \leq p\}.$$

Here, $D^\beta f$ is β^{th} order of the weak (or distributional) partial derivative of f.

Definition (Left Atangana-Baleanu Fractional Derivative in the Caputo Sense)

The left Atangana-Baleanu fractional derivative of $h \in H^1(0,1)$ in the Caputo sense is defined as

$${}^{ABC}_{0}D^{\alpha}_{x}\big(h(x)\big) = \frac{B(\alpha)}{(1-\alpha)} \int_0^x h'(s)\, E_\alpha \left[-\frac{\alpha}{1-\alpha}(x-s)^\alpha\right] ds,$$

where $B(\alpha)$ is a normalization function for $0 < \alpha < 1$ satisfying $B(0) = B(1) = 1$ and $B(\alpha) > 0$, and $E_\alpha(.)$ is the Mittag-Leffler function.

The relation between this and the fractional integral operator is given as

$${}^{ABC}_{0}I_x^{\alpha}\big(h(x)\big) = \frac{B(\alpha)}{(1-\alpha)}h(x) + \frac{\alpha}{B(\alpha)\Gamma(\alpha)}\int_0^x h(s)\,(x-s)^{\alpha-1}ds.$$

For the details of the Atangana-Baleanu fractional operators, readers are referred to [9].

3. MAIN RESULTS AND DISCUSSION

In this section, the ABC scheme and its implementation are provided. The fractional Adams-Bashforth-type approach is proposed to acquire numerical solutions iteratively. The proposed discretized scheme for the numerical solution to the Problem (*) is formulated as

$$y_{n+1} = y_0 + \frac{1-\alpha}{B(\alpha)}F(t_{n+1}, y_n) + \frac{\alpha}{B(\alpha)}\frac{h^{\alpha}}{\Gamma(\alpha+1)}\sum_{k=0}^{n}[(n-k+1)^{\alpha} - (n-k)^{\alpha}]\,F(t_k, y_k),$$

where

$y_0 = f(0)$ is the initial value,

y_{n+1} denotes the approximate solution at the step $n+1$,

$F(t, y) = y + 1$ is the right-hand side function of the differential equation,

$B(\alpha) = 1 - \alpha + \frac{\alpha}{\Gamma(\alpha)}$ represents the standard normalization function for the Atangana-Baleanu fractional derivative.

The memory term comes from the component $\frac{\alpha}{B(\alpha)}\frac{h^{\alpha}}{\Gamma(\alpha+1)}\sum_{k=0}^{n}[(n-k+1)^{\alpha} - (n-k)^{\alpha}]\,F(t_k, y_k)$, which can also be considered as the convolution sum. The memory of the system's dynamics is encoded by this component.

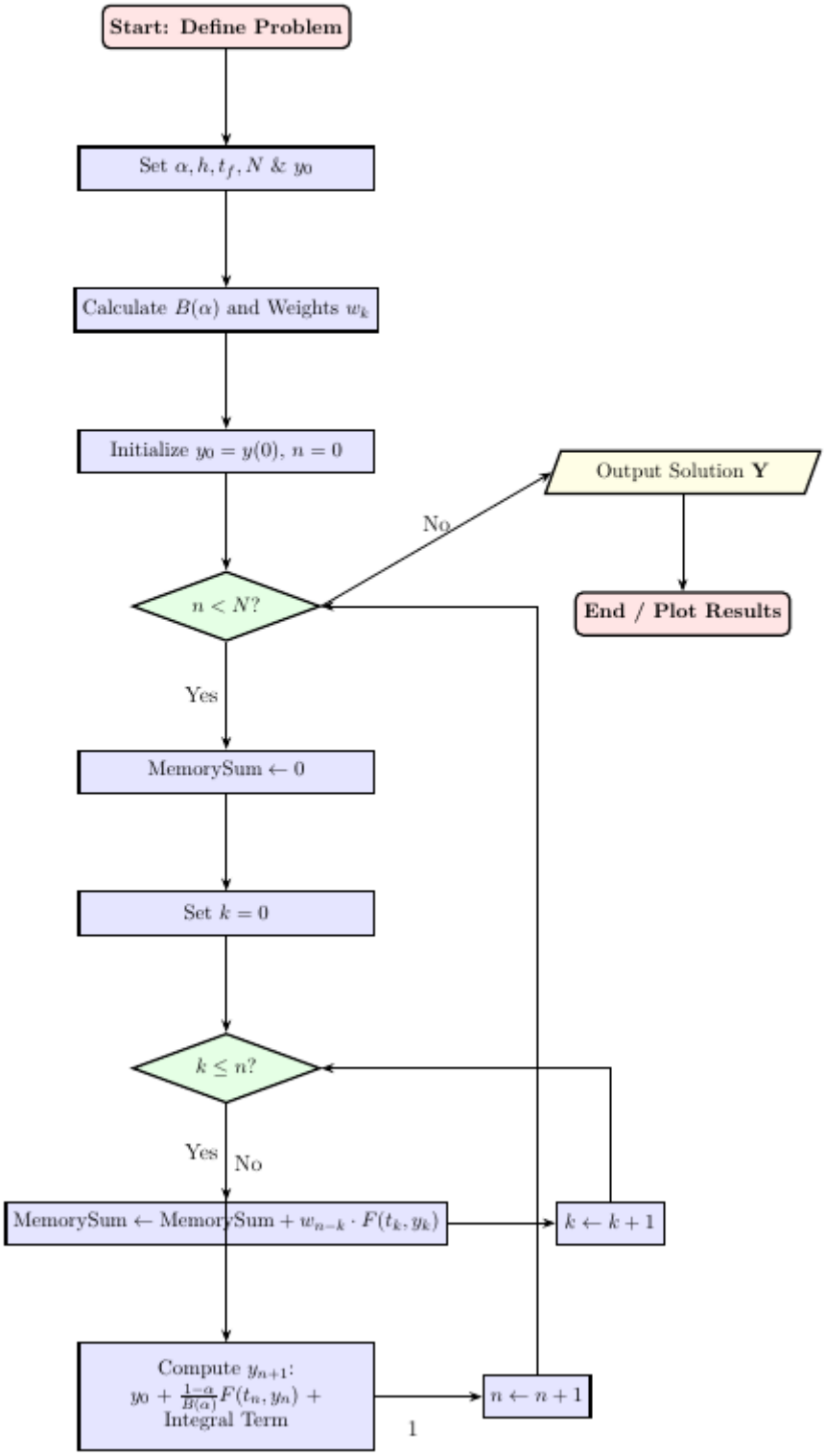


Figure 1. The flowchart of the proposed numerical approach for time FDEs with ABC fractional derivative.

The absolute error of the numerical solution is computed by the formulae

$$E(t) = \left|y_{analytical}(t) - y_{numerical}(t)\right|,$$

which is utilized to demonstrate the accuracy of the current scheme.

4. ELUCIDATED TEST

This section provides a test to confirm the results of the current approach. Let us consider the following linear fractional initial value problem

$${}^{ABC}_{0}D_t^{\alpha} f(t) = t,\ 0 < \alpha \leq 1,$$

$$f(0) = f_0,\ f_0 \in \mathbb{R},$$

whose analytical solution is

$$f(t) = \frac{\alpha(\alpha(\alpha+1)f_0 + t^{\alpha+1}) - (\alpha-1)\Gamma(\alpha+2)(f_0+t)}{\alpha(\alpha+1)(\alpha - \alpha\Gamma(\alpha) + \Gamma(\alpha))},\ f_0 \in \mathbb{R}.$$

For $\alpha = 1$, the analytical solution becomes [13]

$$f(t) = \frac{t^2}{2} + f_0.$$

The numerical solution is computed by the following discretized scheme:

$$y_{n+1} = y_0 + \frac{1-\alpha}{B(\alpha)} F(t_{n+1}, y_n) + \frac{\alpha}{B(\alpha)} \frac{h^{\alpha}}{\Gamma(\alpha+1)} \sum_{k=0}^{n} \left[(n-k+1)^{\alpha} - (n-k)^{\alpha}\right] F(t_k, y_k),$$

y_{n+1} is the approximate solution at the step $n+1$,

$$y_0 = f_0,$$

$$F(t, y) = t,$$

$$B(\alpha) = 1 - \alpha + \frac{\alpha}{\Gamma(\alpha)}.$$

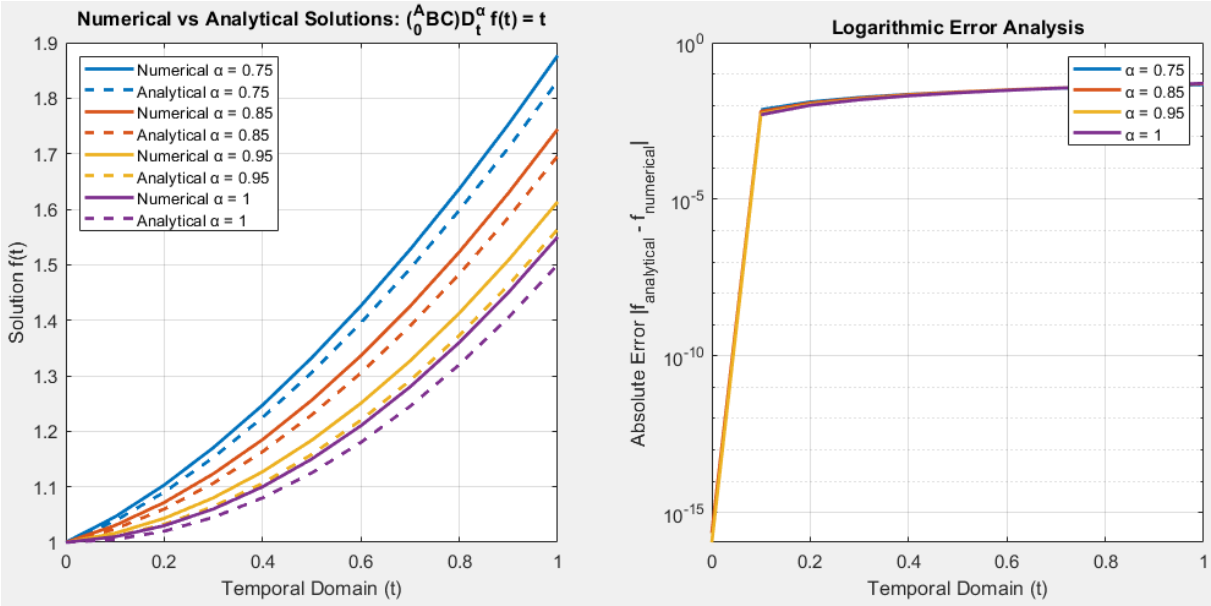


Figure 2. The 2D graphs of the analytical, numerical solutions, and the graphs of their absolute errors with a uniform temporal step size $h = 0.1$ for different fractional orders α and $f_0 = 1$.

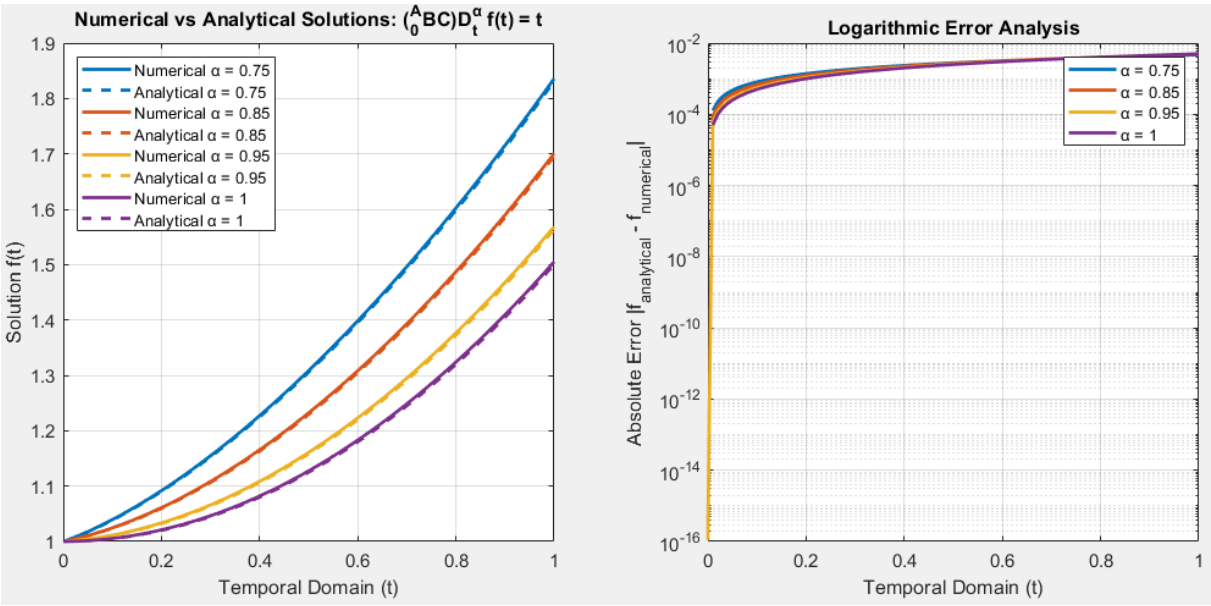


Figure 3. The 2D graphs of the analytical, numerical solutions, and the graphs of their absolute errors with a uniform temporal step size $h = 0.01$ for different fractional orders α and $f_0 = 1$.

Table 1. The values of absolute error and elapsed time with various uniform temporal step sizes h at $t = 1$ for various values of α and $f_0 = 1$.

	$\alpha = 0.75$	$\alpha = 0.85$	$\alpha = 0.95$	$\alpha = 1$	Elapsed Time
$h = 0.1$	0.04567	0.04832	0.04968	0.05	0.220661 s.
$h = 0.01$	0.004699	0.004902	0.004988	0.005	0.488488 s.

$h = 0.001$	0.0004727	0.0004915	0.0004992	0.0005	0.569760 s.
$h = 0.0001$	0.00004732	0.00004917	0.00004992	0.00005	35.36943 s.

As Figures 2 and 3 indicate, numerical approximation gets close to the analytical solution as the values of α get close to 1. These results imply that the current method accurately yields approximate solutions to the systems with memory effect.

It is clear from Table 1 that the increment in α causes to decrease in the absolute error, but an increase in the computational cost. Moreover, keeping the temporal size constant leads to better accuracy.

As a result, it can be concluded that the proposed method allows us to deal with the challenges of the ABC derivative and yields a more accurate numerical solution. Therefore, in the computation of numerical solutions to diverse FDEs in science, the current approach can be confidently employed.

5. CONCLUSION

An FDE with the ABC fractional derivative is considered, and the fractional Adams-Bashforth type approach is utilized to acquire a numerical solution to it. Since the ABC fractional derivative has a nonsingular and nonlocal kernel, it is hard to deal with this kind of FDEs. However, it is observed that the proposed approach produces better numerical solutions to them. The algorithm and flowchart of the current method are presented and applied for various fractional orders α. It is observed that as α decreases, the memory effect of the ABC fractional derivative increases, and the effect of the source function decreases, which leads to some delay in the solution. The obtained results indicate that the current approach has the potential to tackle more intricate nonlinear fractional differential equations, playing a substantial role in the modeling of many processes in control theory, biological systems, etc..

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A CONSTRUCTION OF THE SHAPE OPERATOR OF A RULED HYPERSURFACE

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ABSTRACT

In this paper, we examine a hypersurface induced by quasi-type vector fields along with the quasi normal and second binormal vectors in four-dimensional Euclidean space. A parametric representation of the hypersurface is first established, after which its fundamental geometric properties are systematically analyzed. In particular, the first and second fundamental forms, the corresponding shape operator, and the Gaussian and mean curvatures are derived in order to investigate some geometric properties such as flatness and minimality. Finally, the results are illustrated with an example.

Keywords: Hypersurface, Ruled surface, Shape operator.

1. INTRODUCTION

To better comprehend the phenomena that occur in our environment, the investigation of surfaces is of fundamental importance. Therefore, establishing a well-defined approach to constructing surfaces is of significant relevance in differential geometry. Among these, ruled surfaces hold a distinguished position due to their structural efficiency and the relative ease of their geometric formation. A ruled surface is described as a particular type of surface produced by the continuous motion of a straight line, called a ruling, along a prescribed curve.

Within this context, the geometry of ruled surfaces has been extensively examined from different viewpoints in [3, 5, 7, 8, 9], resulting in a substantial body of work on both their intrinsic and extrinsic characteristics. In 2021, the authors investigated 2-ruled hypersurfaces in four-dimensional Euclidean space and analyzed their geometric features through the study of the Gauss map in [1]. Meanwhile, Wang explored them in complex space forms in terms of the Lie derivative of the shape operator in [10}, and subsequently extended this analysis to non-flat complex space forms in [11]. Additionally, surfaces in four-dimensional spaces were studied in [12]. More recently, ruled hypersurfaces in both Euclidean [4] and Minkowski [13] spaces have been investigated.

In this section, we investigate a hypersurface generated by quasi-type vector fields, namely the quasi-tangent and second binormal vectors, in four-dimensional Euclidean space. A parametric representation of the hypersurface is first introduced, and its fundamental geometric characteristics are subsequently examined. In particular, we derive the first and second

fundamental forms, the associated shape operator, and the Gaussian and mean curvatures, in order to determine whether the hypersurface is minimal and flat. To clarify these computations, an illustrative example is provided, in which a ruled quasi-hypersurface is constructed using quasi-frame vectors of a suitable space curve in four-dimensional Euclidean space. Furthermore, by employing the coefficients of the fundamental forms, the corresponding curvatures are explicitly obtained. Finally, the projections of this quasi ruled hypersurface in four-dimensional space are visualized in various projection spaces.

2. FUNDAMENTAL CONCEPT OF QUASI FRAME AND HYPERSURFACES IN E^4

Consider the four–dimensional Euclidean space E^4 and a curve $\alpha(s)$ defined in it. Associated with this curve is the quasi–frame $\{T_q, N_q, B_q, C_q\}$, consisting of the quasi–tangent, quasi–normal, first quasi–binormal, and second quasi–binormal vector fields, respectively. To simplify the notation, we shall denote $T_q(s)$, $N_q(s)$, $B_q(s)$, and $C_q(s)$ simply by T_q, N_q, B_q, and C_q, respectively. The explicit expressions of these quasi–frame vectors are obtained as follows

$$T_q = \frac{\alpha'(s)}{\| \alpha'(s) \|}$$

$$N_q = \frac{T_q(s) \wedge \aleph_x \wedge \aleph_y}{\| T_q(s) \wedge \aleph_x \wedge \aleph_y \|}$$

$$C_q = \frac{\alpha'(s) \wedge N_q(s) \wedge \alpha'''(s)}{\| \alpha'(s) \wedge N_q(s) \wedge \alpha'''(s) \|}$$

$$B_q = C_q(s) \wedge T_q(s) \wedge N_q(s)$$

where the q-curvatures are

$$\aleph_1 = \frac{\langle T_q', N_q \rangle}{\| \alpha' \|}$$

$$\aleph_2 = \frac{\langle T_q', B_q \rangle}{\| \alpha' \|}$$

$$\aleph_3 = \frac{\langle N_q', B_q \rangle}{\| \alpha' \|}$$

$$\aleph_4 = \frac{\langle B_q', C_q \rangle}{\| \alpha' \|}$$

and $\aleph_x$ and $\aleph_y$ are unit standard vectors in E^4 [2]. The derivation formula is written as

$$\begin{bmatrix} T_q' \\ N_q' \\ B_q' \\ C_q' \end{bmatrix} = \| \alpha'(s) \| \begin{bmatrix} 0 & \aleph_1 & \aleph_2 & 0 \\ -\aleph_1 & 0 & \aleph_3 & 0 \\ -\aleph_2 & -\aleph_3 & 0 & \aleph_4 \\ 0 & 0 & -\aleph_4 & 0 \end{bmatrix} \begin{bmatrix} T_q \\ N_q \\ B_q \\ C_q \end{bmatrix}.$$

Let $M \subset E^4$ be a hypersurface parametrized by

$$\phi: U \subset \mathbb{R}^3 \longrightarrow E^4$$

$$(\sigma, \mu, \eta) \longmapsto \phi(\sigma, \mu, \eta) = (\phi_1(\sigma, \mu, \eta), \phi_2(\sigma, \mu, \eta), \phi_3(\sigma, \mu, \eta), \phi_4(\sigma, \mu, \eta))$$

The image $\phi(U)$ forms a hypersurface in the Euclidean space E^4 if and only if the vectors $\{\phi_\sigma, \phi_\mu, \phi_\eta\}$ are linearly independent at every point of the domain. The unit normal vector field associated with this hypersurface is defined by

$$N = \frac{\phi_\sigma \wedge \phi_\mu \wedge \phi_\eta}{\| \phi_\sigma \wedge \phi_\mu \wedge \phi_\eta \|}.$$

The first fundamental form associated with the hypersurface is given by

$$I: \mathcal{X}(M) \times \mathcal{X}(M) \to C^\infty(M, \mathbb{R})$$

$$(X, Y) \to I(X, Y) = \langle X, Y \rangle$$

where $\mathcal{X}(M)$ represents the set of all smooth vector fields on M. The corresponding coefficients of the first fundamental form are

$$a_{ij} = \langle \phi_i, \phi_j \rangle, 1 \leq i, j \leq 3,$$

and the corresponding matrix representation is

$$I = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{12} & a_{22} & a_{23} \\ a_{13} & a_{23} & a_{33} \end{pmatrix}.$$

Let D be the Levi–Civita connection on $\mathbb{R}^4$. The shape operator of the hypersurface corresponding to the unit normal vector field N is defined by

$$S: \mathcal{X}(M) \to \mathcal{X}(M)$$

$$X \to S(X) = -D_X N$$

The second fundamental form is given by

$$II: \mathcal{X}(M) \times \mathcal{X}(M) \to C^\infty(M, \mathbb{R})$$

$$(X, Y) \to II(X, Y) = \langle S(X), Y \rangle$$

The matrix representation of the second fundamental form is

$$II = \begin{pmatrix} b_{11} & b_{12} & b_{13} \\ b_{12} & b_{22} & b_{23} \\ b_{13} & b_{23} & b_{33} \end{pmatrix}.$$

where the coefficients are

$$b_{ij} = \langle \phi_{ij}, N \rangle, 1 \leq i, j \leq 3.$$

The shape operator is determined by

$$S = I^{-1} II.$$

The Gauss curvature of the hypersurface is given as

$$K(p) = \det\ S(p).$$

The mean curvature is given by

$$H(p) = \frac{1}{3}\mathrm{tr}\ S(p).$$

Theorem 2.1 The ruled surface is flat if and only if $K = 0$ [6].

Theorem 2.2 The ruled surface is minimal if and only if $H = 0$ [6].

Ruled surfaces are the surfaces generated by curves and straight lines. Let $\alpha(s)$ be a space curve and $X(s)$ a director vector field. Then the ruled surface is given by the parametrization

$$\phi(s,\mu) = \alpha(s) + \mu X(s).$$

3. SHAPE OPERATOR OF THE RULED HYPERSURFACES GENERATED WITH N_q AND C_q

Consider the hypersurface $M \subset \mathbb{R}^4$ parametrized by

$$\mathcal{R}(\mu,\eta,w) = \alpha(\mu) + \eta N_q(\mu) + wC_q(\mu),$$

where $\alpha(\mu)$ is a regular curve endowed with the orthonormal quasi–frame $\{T_q(\mu), N_q(\mu), B_q(\mu), C_q(\mu)\}$.

Theorem 3.1 Let α be a unit speed curve and $\mathcal{R}(\mu,\eta,w)$ be the ruled hypersurface generated by N_q and C_q. The unit normal vector field of this hypersurface is given by

$$N_{\mathcal{R}} = \frac{1}{\sqrt{(w\varkappa_4 - \eta\varkappa_3)^2 + (1-\eta\varkappa_1)^2}}((w\varkappa_4 - \eta\varkappa_3)T_q + (1-\eta\varkappa_1)B_q).$$

Proof.
The tangent space of the hypersurface $\mathcal{R}(\mu,\eta,w)$ at each point is spanned by $\mathcal{R}_\mu$, $\mathcal{R}_\eta$ and $\mathcal{R}_w$ which direct differentiation of the parametrization yields

$$\begin{aligned}\mathcal{R}_\mu &= \alpha'(\mu) + \eta N_q' + wC_q' \\ &= (1-\eta\varkappa_1)T_q + (\eta\varkappa_3 - w\varkappa_4)B_q \\ \mathcal{R}_\eta &= N_q \\ \mathcal{R}_w &= C_q\end{aligned}$$

The vector $\mathcal{R}_\mu \wedge \mathcal{R}_\eta \wedge \mathcal{R}_w$ used in the computation of the unit normal vector field of the hypersurface is given as follows

$$\mathcal{R}_\mu \wedge \mathcal{R}_\eta \wedge \mathcal{R}_w = \begin{vmatrix} T_q & N_q & B_q & C_q \\ 1-\eta\varkappa_1 & 0 & \eta\varkappa_3 - w\varkappa_4 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{vmatrix}$$

$$= \begin{vmatrix} T_q & N_q & B_q \\ 1-\eta\tau_1 & \eta\tau_3 - w\tau_4 & 0 \\ 0 & 1 & 0 \end{vmatrix}$$

$$= (w\tau_4 - \eta\tau_3)T_q + (1-\eta\tau_1)B_q$$

The norm of $\mathcal{R}_\mu \wedge \mathcal{R}_\eta \wedge \mathcal{R}_w$is calculated as

$$\| \mathcal{R}_\mu \wedge \mathcal{R}_\eta \wedge \mathcal{R}_w \| = \sqrt{(w\tau_4 - \eta\tau_3)^2 + (1-\eta\tau_1)^2}.$$

For simplicity, let

$$W = \| \mathcal{R}_\mu \wedge \mathcal{R}_\eta \wedge \mathcal{R}_w \|,$$

which proves the theorem.

Theorem 3.2 The first fundamental form of the hypersurface is

$$I = E\, d\mu^2 + d\eta^2 + dw^2,$$

where $E = \langle \mathcal{R}_\mu, \mathcal{R}_\mu \rangle$and the mixed products vanish.

Proof.
The matrix of the first fundamental form of the hypersurface $\mathcal{H}(\mu, \eta, w)$ is written as

$$I = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{13} & a_{23} & a_{33} \end{bmatrix} = \begin{bmatrix} (1-\eta\tau_1)^2 + (\eta\tau_3 - w\tau_4)^2 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}.$$

where a_{ij} are the coefficients of the first fundamental form such that

$$a_{11} = \langle \mathcal{R}_\mu, \mathcal{R}_\mu \rangle = (1-\eta\tau_1)^2 + (\eta\tau_3 - w\tau_4)^2$$

$$a_{22} = \langle \mathcal{R}_\eta, \mathcal{R}_\eta \rangle = 1$$

$$a_{33} = \langle \mathcal{R}_w, \mathcal{R}_w \rangle = 1$$

And

$$a_{12} = a_{21} = \langle \mathcal{R}_\mu, \mathcal{R}_\eta \rangle = 0$$

$$a_{13} = a_{31} = \langle \mathcal{R}_\mu, \mathcal{R}_w \rangle = 0$$

$$a_{23} = a_{32} = \langle \mathcal{R}_\eta, \mathcal{R}_w \rangle = 0$$

This proves the stated form.

Theorem 3.3 The non–zero coefficients of the second fundamental form are

$$h_{\mu\mu} = \langle \mathcal{R}_{\mu\mu}, N_{\mathcal{R}} \rangle, h_{\mu\eta} = \frac{1}{W}(\tau_3 - w\tau_1\tau_4), h_{\mu w} = \frac{1}{W}\tau_4(\eta\tau_1 - 1),$$

and hence

$$II = h_{\mu\mu}\, d\mu^2 + 2h_{\mu\eta}\, d\mu\, d\eta + 2h_{\mu w}\, d\mu\, dw.$$

Proof.
Differentiating $\mathcal{R}_\mu$, $\mathcal{R}_\eta$ and $\mathcal{R}_w$ once more gives

$$\mathcal{R}_{\mu\mu} = (-\eta\mathfrak{r}_1' - \mathfrak{r}_2(\eta\mathfrak{r}_3 - w\mathfrak{r}_4))T_q + (\mathfrak{r}_1(1-\eta\mathfrak{r}_1) - \mathfrak{r}_3(\eta\mathfrak{r}_3 - w\mathfrak{r}_4))N_q$$
$$+(\mathfrak{r}_2(1-\eta\mathfrak{r}_1) + \eta\mathfrak{r}_3' - w\mathfrak{r}_4')B_q + \mathfrak{r}_4(\eta\mathfrak{r}_3 - w\mathfrak{r}_4)C_q$$
$$\mathcal{R}_{\mu\eta} = -\mathfrak{r}_1 T_q + \mathfrak{r}_3 B_q$$
$$\mathcal{R}_{\mu w} = -\mathfrak{r}_4 B_q$$

while second derivatives with respect to η and w vanish. Using the quasi–equations and taking inner products with the normal vector field $N_{\mathcal{R}}$ yields

$$II = \frac{1}{W}\begin{bmatrix} h_{\mu\mu} & \mathfrak{r}_3 - w\mathfrak{r}_1\mathfrak{r}_4 & \mathfrak{r}_4(\eta\mathfrak{r}_1 - 1) \\ \mathfrak{r}_3 - w\mathfrak{r}_1\mathfrak{r}_4 & 0 & 0 \\ \mathfrak{r}_4(\eta\mathfrak{r}_1 - 1) & 0 & 0 \end{bmatrix}.$$

Theorem 3.4 The shape operator of the quasi ruled hypersurface $\mathcal{R}(\mu,\eta,w) = \alpha(\mu) + \eta N_q(\mu) + wC_q(\mu)$ is

$$S_{\mathcal{R}} = \frac{1}{W}\begin{bmatrix} \frac{h_{\mu\mu}}{W^2} & \frac{\mathfrak{r}_3 - w\mathfrak{r}_1\mathfrak{r}_4}{W^2} & \frac{\mathfrak{r}_4(\eta\mathfrak{r}_1 - 1)}{W^2} \\ \mathfrak{r}_3 - w\mathfrak{r}_1\mathfrak{r}_4 & 0 & 0 \\ \mathfrak{r}_4(\eta\mathfrak{r}_1 - 1) & 0 & 0 \end{bmatrix}.$$

Proof.
Let I and II denote the first and second fundamental form matrices of the hypersurface, given respectively by

$$II = \frac{1}{W}\begin{bmatrix} h_{\mu\mu} & \mathfrak{r}_3 - w\mathfrak{r}_1\mathfrak{r}_4 & \mathfrak{r}_4(\eta\mathfrak{r}_1 - 1) \\ \mathfrak{r}_3 - w\mathfrak{r}_1\mathfrak{r}_4 & 0 & 0 \\ \mathfrak{r}_4(\eta\mathfrak{r}_1 - 1) & 0 & 0 \end{bmatrix}, I = \begin{bmatrix} W^2 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}.$$

Then the shape operator (Weingarten map) is $S_{\mathcal{R}} = I^{-1}II$, and since

$$I^{-1} = \begin{bmatrix} \frac{1}{W^2} & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix},$$

we obtain

$$S_{\mathcal{R}} = \frac{1}{W}\begin{bmatrix} \frac{h_{\mu\mu}}{W^2} & \frac{\mathfrak{r}_3 - w\mathfrak{r}_1\mathfrak{r}_4}{W^2} & \frac{\mathfrak{r}_4(\eta\mathfrak{r}_1 - 1)}{W^2} \\ \mathfrak{r}_3 - w\mathfrak{r}_1\mathfrak{r}_4 & 0 & 0 \\ \mathfrak{r}_4(\eta\mathfrak{r}_1 - 1) & 0 & 0 \end{bmatrix}.$$

Theorem 3.5 The hypersurface $\mathcal{R}$ is minimal if and only if

$$(w\mathfrak{r}_4 - \eta\mathfrak{r}_3)(-\eta\mathfrak{r}_1' - \mathfrak{r}_2(\eta\mathfrak{r}_3 - w\mathfrak{r}_4)) + (1-\eta\mathfrak{r}_1)(\mathfrak{r}_2(1-\eta\mathfrak{r}_1) + (\eta\mathfrak{r}_3' - w\mathfrak{r}_4')) = 0.$$

Proof. Since

$$H_{\mathcal{R}} = \frac{1}{3}\text{tr } S_{\mathcal{R}},$$

and two principal curvatures vanish, the mean curvature reduces to

$$H_{\mathcal{R}} = \frac{h_{\mu\mu}}{3W^3}.$$

Thus $H_{\mathcal{R}} = 0$ if and only if $h_{\mu\mu} = 0$, which gives the stated condition.

Theorem 3.6 The hypersurface $\mathcal{R}$ is developable at every point.

Proof. Since

$$K_{\mathcal{R}} = \det S_{\mathcal{R}},$$

and the Gauss curvature of the hypersurface $\mathcal{R}$ vanishes identically, the hypersurface is developable everywhere.

Example 3.7 We consider the curve

$$\alpha(s) = \left(\frac{1}{\sqrt{5}}\cos s, \frac{1}{\sqrt{5}}\sin s, \frac{1}{\sqrt{5}}\cos 2s, \frac{1}{\sqrt{5}}\sin 2s\right).$$

Since its velocity vector is written as

$$\alpha'(s) = \left(-\frac{1}{\sqrt{5}}\sin s, \frac{1}{\sqrt{5}}\cos s, -\frac{2}{\sqrt{5}}\sin 2s, \frac{2}{\sqrt{5}}\cos 2s\right),$$

its norm is

$$\| \alpha'(s) \| = 1.$$

Therefore, the unit tangent vector is calculated as

$$T_q = \frac{\alpha'(s)}{\| \alpha'(s) \|} = \left(-\frac{1}{\sqrt{5}}\sin s, \frac{1}{\sqrt{5}}\cos s, -\frac{2}{\sqrt{5}}\sin 2s, \frac{2}{\sqrt{5}}\cos 2s\right).$$

When we choose the standard base vectors $\mathfrak{r}_x = (1,0,0,0)$ and $\mathfrak{r}_y = (0,1,0,0)$, direct computation yields the quasi-normal, quasi-binormal, and second quasi-binormal vectors

$$N_q = (0,0,\cos 2s, \sin 2s),$$
$$B_q = \left(\frac{2}{\sqrt{5}}\sin s, -\frac{2}{\sqrt{5}}\cos s, -\frac{2}{\sqrt{5}}\sin s\cos s, \frac{1}{\sqrt{5}}(2\cos^2 s - 1)\right),$$
$$C_q = (-\cos s, -\sin s, 0,0),$$

respectively. Using the dot product of quasi-vectors, we have

$$\mathfrak{r}_1 = -\frac{4}{\sqrt{5}}, \mathfrak{r}_2 = 0, \mathfrak{r}_3 = \frac{2}{\sqrt{5}}, \mathfrak{r}_4 = -\frac{2}{\sqrt{5}}.$$

The parametrization of quasi-ruled hypersurfaces generated by N_q and C_q is written as

$$\mathcal{R}(s,\eta,\mu)=\left(\left(\frac{1}{\sqrt{5}}-\eta\right)\cos\ s,\left(\frac{1}{\sqrt{5}}-\eta\right)\sin\ s,\left(\frac{1}{\sqrt{5}}+\mu\right)\cos\ 2s,\left(\frac{1}{\sqrt{5}}+\mu\right)\sin\ 2s\right).$$

The first-order partial derivatives with respect to s,η,μ are

$$\mathcal{R}_s=\left(-\left(\frac{1}{\sqrt{5}}-\eta\right)\sin\ s,\ \left(\frac{1}{\sqrt{5}}-\eta\right)\cos\ s,\ -2\left(\frac{1}{\sqrt{5}}+\mu\right)\sin\ 2s,\ 2\left(\frac{1}{\sqrt{5}}+\mu\right)\cos\ 2s\right),$$
$$\mathcal{R}_\eta=(-\cos\ s,\ -\sin\ s,\ 0,\ 0),$$
$$\mathcal{R}_\mu=(0,\ 0,\ \cos\ 2s,\ \sin\ 2s).$$

We obtain the first fundamental form as

$$I=\begin{bmatrix}\left(\frac{1}{\sqrt{5}}-\eta\right)^2+4\left(\frac{1}{\sqrt{5}}+\mu\right)^2 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\end{bmatrix}.$$

The only non-zero component of the second fundamental form is

$$\langle\mathcal{R}_{ss},N\rangle=\frac{-2\left(\frac{1}{\sqrt{5}}-\eta\right)\left(\frac{1}{\sqrt{5}}+\mu\right)}{\sqrt{\left(\frac{1}{\sqrt{5}}-\eta\right)^2+4\left(\frac{1}{\sqrt{5}}+\mu\right)^2}}.$$

Thus

$$II=\begin{bmatrix}\frac{-2\left(\frac{1}{\sqrt{5}}-\eta\right)\left(\frac{1}{\sqrt{5}}+\mu\right)}{\sqrt{\left(\frac{1}{\sqrt{5}}-\eta\right)^2+4\left(\frac{1}{\sqrt{5}}+\mu\right)^2}} & 0 & 0\\ 0 & 0 & 0\\ 0 & 0 & 0\end{bmatrix}.$$

Since $S=I^{-1}II$, the shape operator of the quasi-ruled hypersurface is

$$S=\begin{bmatrix}\frac{-2\left(\frac{1}{\sqrt{5}}-\eta\right)\left(\frac{1}{\sqrt{5}}+\mu\right)}{\left(\left(\frac{1}{\sqrt{5}}-\eta\right)^2+4\left(\frac{1}{\sqrt{5}}+\mu\right)^2\right)^{\frac{3}{2}}} & 0 & 0\\ 0 & 0 & 0\\ 0 & 0 & 0\end{bmatrix}.$$

Since the shape operator is a diagonal matrix, the principal curvatures are the eigenvalues

$$\kappa_1=\frac{-2\left(\frac{1}{\sqrt{5}}-\eta\right)\left(\frac{1}{\sqrt{5}}+\mu\right)}{\left(\left(\frac{1}{\sqrt{5}}-\eta\right)^2+4\left(\frac{1}{\sqrt{5}}+\mu\right)^2\right)^{\frac{3}{2}}},\qquad \kappa_2=0,\qquad \kappa_3=0.$$

The Gaussian and mean curvatures are

$$K = \det(S) = 0$$

and

$$H = \frac{1}{3}\mathrm{tr}(S) = \frac{-2\left(\frac{1}{\sqrt{5}} - \eta\right)\left(\frac{1}{\sqrt{5}} + \mu\right)}{3\left(\left(\frac{1}{\sqrt{5}} - \eta\right)^2 + 4\left(\frac{1}{\sqrt{5}} + \mu\right)^2\right)^{\frac{3}{2}}},$$

respectively.

Corollary 3.8 The hypersurface generated by $\alpha(s)$ is flat.

Proof. Since the Gaussian curvature $K = \det(S) = 0$, the result is obvious. □

Corollary 3.9 The hypersurface generated by $\alpha(s)$ is not globally minimal.

To understand the geometry of this hypersurface, we consider projections. For $s = 0$,

$$\mathcal{R}(0, \mu, \eta) = \left(\frac{1}{\sqrt{5}} - \eta,\ 0,\ \frac{1}{\sqrt{5}} + \mu,\ 0\right).$$

In xyz-projection:

$$\mathcal{R}(\mu, \eta) = \left(\frac{1}{\sqrt{5}} - \eta,\ 0,\ \frac{1}{\sqrt{5}} + \mu\right).$$

In xyt-projection:

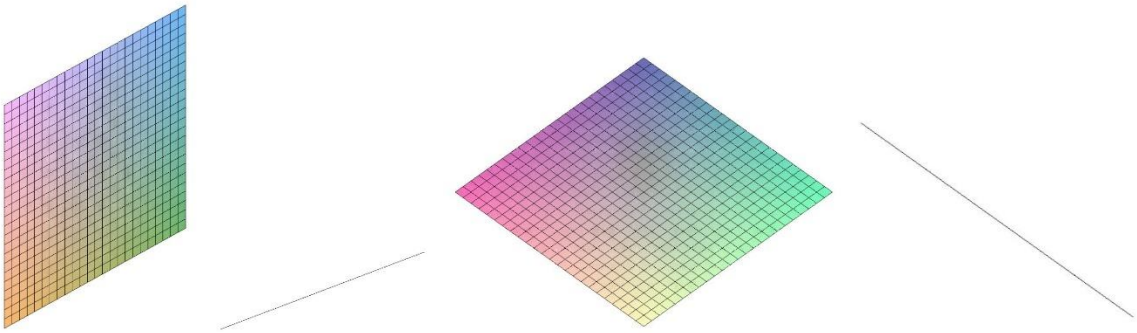
$$\mathcal{R}(\mu, \eta) = \left(\frac{1}{\sqrt{5}} - \eta,\ 0,\ 0\right).$$

In xzt-projection:

$$\mathcal{R}(\mu, \eta) = \left(\frac{1}{\sqrt{5}} - \eta,\ \frac{1}{\sqrt{5}} + \mu,\ 0\right).$$

In yzt-projection:

$$\mathcal{R}(\mu, \eta) = \left(0,\ \frac{1}{\sqrt{5}} + \mu,\ 0\right).$$



a) xyz-projection b) xyt-projection c) xzt-projection d) yzt-projection

Figure 1: The projections of the ruled hypersurface for $s = 0$ in xyz, xyt, xzt and yzt projection spaces.

For $\mu = 0$,we get

$$\mathcal{R}(s,0,\eta) = \left(\left(\frac{1}{\sqrt{5}} - \eta\right)\cos\, s,\ \left(\frac{1}{\sqrt{5}} - \eta\right)\sin\, s,\ \frac{1}{\sqrt{5}}\cos\, 2s,\ \frac{1}{\sqrt{5}}\sin\, 2s\right)$$

In xyz-projection:

$$\mathcal{R}(s,\eta) = \left(\left(\frac{1}{\sqrt{5}} - \eta\right)\cos\, s,\ \left(\frac{1}{\sqrt{5}} - \eta\right)\sin\, s,\ \frac{1}{\sqrt{5}}\cos\, 2s\right)$$

In xyt-projection:

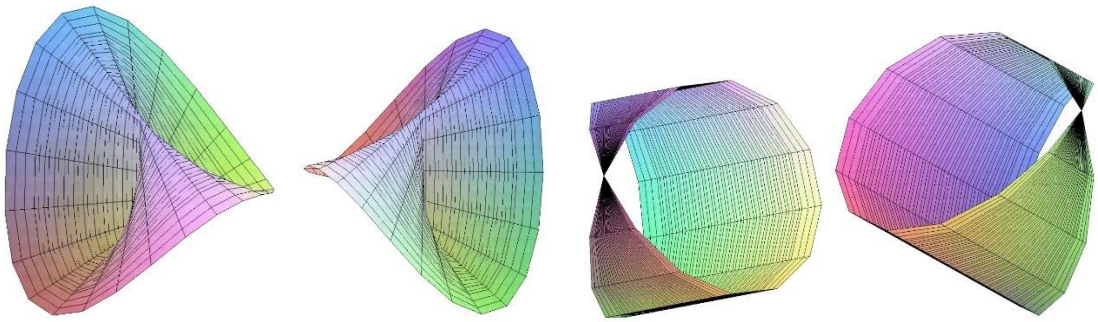
$$\mathcal{R}(s,\eta) = \left(\left(\frac{1}{\sqrt{5}} - \eta\right)\cos\, s,\ \left(\frac{1}{\sqrt{5}} - \eta\right)\sin\, s,\ \frac{1}{\sqrt{5}}\sin\, 2s\right)$$

In xzt-projection:

$$\mathcal{R}(s,\eta) = \left(\left(\frac{1}{\sqrt{5}} - \eta\right)\cos\, s,\ \frac{1}{\sqrt{5}}\cos\, 2s,\ \frac{1}{\sqrt{5}}\sin\, 2s\right)$$

In yzt-projection:

$$\mathcal{R}(s,\eta) = \left(\left(\frac{1}{\sqrt{5}} - \eta\right)\sin\, s,\ \frac{1}{\sqrt{5}}\cos\, 2s,\ \frac{1}{\sqrt{5}}\sin\, 2s\right)$$



a) xyz-projection b) xyt-projection c) xzt-projection d) yzt-projection

Figure 2: The projections of the ruled hypersurface for $\mu = 0$ in xyz, xyt, xzt and yzt projection spaces.

For $\eta = 0$, one have

$$\mathcal{R}(s,\mu,0) = \left(\frac{1}{\sqrt{5}}\cos\, s,\ \frac{1}{\sqrt{5}}\sin\, s,\ \left(\frac{1}{\sqrt{5}} + \mu\right)\cos\, 2s,\ \left(\frac{1}{\sqrt{5}} + \mu\right)\sin\, 2s\right)$$

In xyz-projection:

$$\mathcal{R}(s,\mu)=\left(\frac{1}{\sqrt{5}}\cos\ s,\ \frac{1}{\sqrt{5}}\sin\ s,\ \left(\frac{1}{\sqrt{5}}+\mu\right)\cos\ 2s\right)$$

In xyt-projection:

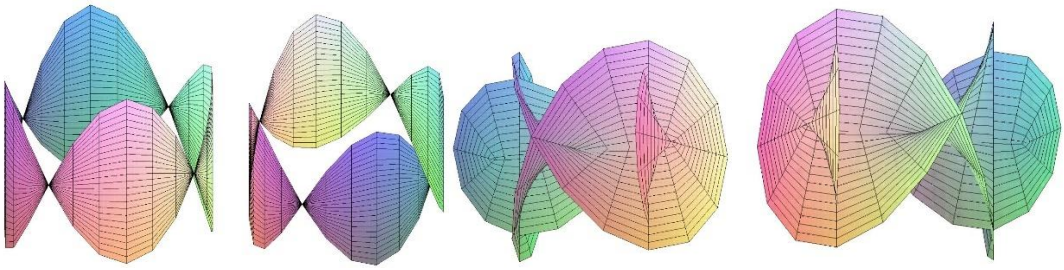
$$\mathcal{R}(s,\mu)=\left(\frac{1}{\sqrt{5}}\cos\ s,\ \frac{1}{\sqrt{5}}\sin\ s,\ \left(\frac{1}{\sqrt{5}}+\mu\right)\sin\ 2s\right)$$

In xzt-projection:

$$\mathcal{R}(s,\mu)=\left(\frac{1}{\sqrt{5}}\cos\ s,\ \left(\frac{1}{\sqrt{5}}+\mu\right)\cos\ 2s,\ \left(\frac{1}{\sqrt{5}}+\mu\right)\sin\ 2s\right)$$

In yzt-projection:

$$\mathcal{R}(s,\mu)=\left(\frac{1}{\sqrt{5}}\sin\ s,\ \left(\frac{1}{\sqrt{5}}+\mu\right)\cos\ 2s,\ \left(\frac{1}{\sqrt{5}}+\mu\right)\sin\ 2s\right)$$



a) xyz-projection b) xyt-projection c) xzt-projection d)yzt-projection

Figure 3: The projections of the ruled hypersurface for $\eta=0$ in xyz, xyt, xzt and yzt projection spaces.

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ABSOLUTE SUMMABILITY FACTORS RELATED TO THE SUMMABILITY $|C^q, \varphi|(\lambda)$

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ABSTRACT

The set of all sequences $\varepsilon = (\varepsilon_n)$ such that the series $\sum u_n \varepsilon_n$ is summable by the summability method Y whenever the series $\sum u_n$ is summable by the summability method X is denoted by (X, Y), and the sequence ε is called a summability factor type (X, Y). In the present study, we aim to establish general summability factor theorems associated with the absolute q-Cesáro summability $|C^q, \varphi|(\lambda)$ where φ is any sequence of positive numbers and λ is a bounded sequence of positive numbers.

Keywords: Absolute summability, summability factors, q-Cesáro matrix

1. INTRODUCTION

The foundation of the summability theory, which has held an important place in many fields of science from past to present, rests on the question “Is it possible to assign a sum to a divergent series?”. It has been seen with the progress of the process that a divergent series may still be assigned a value if an appropriate summation method is used. This idea forms the basis of summability theory. A classical illustration comes from Euler’s treatment of the geometric series. Although

$$\sum_{k=0}^{\infty} (-1)^k$$

is divergent in the usual Cauchy sense, applying the Cesàro mean to its partial sums b_m yields

$$t_k = \frac{1}{k+1}\sum_{j=0}^{k} b_j = \frac{1}{2} + \frac{1}{4(k+1)}(1 + (-1)^k),$$

and $t_k \to \frac{1}{2}$ as $k \to \infty$. Thus, the Cesàro method assigns the value $\frac{1}{2}$ to the alternating series. This simple example shows that under suitable transformations, even divergent series can be meaningfully summed, emphasizing the fundamental role of summability theory.

Moreover, summability theory remains important in various branches of pure and applied mathematics, with widespread utility in engineering disciplines, functional analysis, applied analysis, and Fourier analysis.

The literature on summability theory has principally evolved in two primary directions:

Classical Matrices and Sequence Spaces: In this regard, the construction, analysis, and characterization of new summability methods and their associated sequence spaces, based on classical matrices for example Hausdorff, Hölder, Cesàro, Nörlund, and Euler have been extensively studied.

Absolute Summability Methods: The development of novel absolute summability methods which are described by classical matrices for example Hausdorff, Hölder, Cesàro, Nörlund, and Euler and also the sequence spaces derived from this absolute summability methods are another important branch.

Recently, absolute summability methods have gained significant prominence, leading to the development of new summability methods and sequence spaces that expand the scope of the field. Consequently, summability theory continues to be a dynamic and influential area, making substantial contributions to contemporary mathematical and engineering research.
At the heart of this work lies another fundamental concept alongside absolute summability: the q-analogue of the mathematical expression, which is a generalization obtained by adding a parameter q. It should be noted that as $q \to 1$, the q-analog transforms to its classical form. Although its origins lie in Euler's work, q -calculus has recently become a vibrant and active area of research. It has attracted considerable interest due to its wide range of applications in mathematics, physics, and engineering, particularly in approximation theory, combinatorics, quantum algebra, operator theory, and hypergeometric functions. In line with this framework, the q-Cesáro matrix $C^q = \left(c_{jv}^q\right)$, which is one of the fundamental concept of the study, was described by Aktuğlu and Bekar (2011) as follows:

$$c_{jv}^q = \begin{cases} \dfrac{q^v}{[j+1]_q}, & 0 \le v \le j \\ 0, & v > j. \end{cases}$$

Here $[j]_q$ determines the q-analogue of a non-negative number j and identified by

$$[j]_q = \begin{cases} \dfrac{1-q^j}{1-q}, & q \epsilon R^+ - \{1\} \\ j, & q = 1. \end{cases}$$

For a review of some other studies dealing with the q-Cesáro matrix, see (Erdem,2022; Yaying et al, 2025).
To highlight the distinction between q-analogue summability and its classical counterparts, consider the sequence

$$x_n = (-1)^n. \qquad (1)$$

Beyond theoretical aspects, the q-Cesàro methods demonstrate significant practical importance through applications in Fourier series and q-difference equations. These methods offer a refined tool for capturing subtle forms of convergence, including weak or statistical types. In engineering applications, such as signal processing and data compression, the need to suppress noise or smooth irregular fluctuations is common. While traditional Cesàro means use uniform mean, which may be insufficient for highly variable data, the q-Cesàro methods provide

enhanced versatility. The adjustable q-parameter allows researchers to strategically balance smoothing with the preservation of local details. The sequence given by (1) is a good example that for $q < 1$, q-Cesàro smoothing often outperforms the classical scheme, especially when dealing with rapid oscillations. Nevertheless it must be noted that some limitations must be acknowledged. Calculations based on q-calculus such as q-differences or q-summability operators are typically more complicated than classical formulations, and proofs involving q-Cesàro matrices often require considerable technical effort. Furthermore, the selection of the q-parameter is non-trivial; its choice critically influences the outcome and must be carefully determined based on the nature of the specific application.

The space defined by

$$l(\lambda) = \left\{ y = (y_n) : \sum_{n=0}^{\infty} |y_n|^{\lambda_n} < \infty \right\}$$

has been called Maddox's space. It should be noted that this space is an FK space and therefore occupies a significant position in the summability theory. Also, the paranorm on this space is defined as

$$g(y) = \left(\sum_{k=0}^{\infty} |y_k|^{\lambda_k} \right)^{1\backslash M}$$

where $M = \max\{1; \sup_k \lambda_k\}$.

Assume that $b = (b_j)$ is the sequence of partial sums of the series $\sum u_i$, $\varphi = (\varphi_j)$ is any sequence of positive real components and $\lambda = (\lambda_j)$ is any bounded sequence of positive real components. Following Gökçe & Sarıgöl, (2018), the series $\sum u_i$ is said to be summable by $|\mathrm{U}, \varphi|(\lambda)$, whenever

$$\sum_{j=1}^{\infty} \varphi_j^{\lambda_n - 1} \left| \mathrm{U}_j(b) - \mathrm{U}_{j-1}(b) \right|^{\lambda_n} < \infty.$$

The summability method $|\mathrm{U}, \varphi|(\lambda)$ is highly general and encompasses many well-known absolute summability methods as special cases, depending on the choice of the sequences φ, λ and the matrix $U = (u_{ji})$ (see Gökçe, 2022; Gökçe and Sarıgöl, 2019; Gökçe, 2019; Gökçe and Sarıgöl, 2018; Sarıgöl, 2016).

Assume that $\varepsilon = (\varepsilon_n)$ is a sequence and X and Y are two summability methods. The sequence ε is called a summability factor of type (X, Y), written as $\varepsilon\epsilon(X, Y)$, if the following implication holds: whenever the series $\sum u_n$ is summable by the summability method X, the series $\sum \varepsilon_n u_n$ is summable by the method Y.

To summarize briefly, the theory of summability, in its classical and modern forms, continues to develop through the introduction of new summability methods, the examination of their inclusion relations, and the investigation of summability factors. As the field has advanced, attention has increasingly shifted to the structure of the sequence spaces constructed by these methods and the study of the matrix transformations acting on them. These developments have

naturally led to deeper analyses of the algebraic and topological structures of these spaces. This broad framework provides a foundation for deeper investigation of more refined concepts such as absolute summability and q −analogues. This study essentially aims to provide an initial study that brings together powerful concepts such as q-Cesàro matrix and the absolute summability method.

Before moving on to the main theorems, let us recall the lemmas that will be used in the proofs:

Lemma 1. (Grosse – Erdmann, 1993) Assume that $\mu = (\mu_v)$ is arbitrary bounded sequence of strictly positive components.

(i) If $\mu_j > 1$ for each j, then, $U \in (l(\mu), l)$ iff there exists an integer $C > 1$ satisfying the condition

$$\sup\left\{\sum_{j=0}^{\infty}\left|\sum_{n\in N} u_{nj}C^{-1}\right|^{\mu_j^*} : N \subset \mathbb{N} \text{ finite}\right\} < \infty.$$

(ii) If $\mu_j \leq 1,\ \lambda_j \geq 1$ for all $j \in \mathbb{N}$, then $U \in \left(l(\mu), l(\lambda)\right)$ iff there exists some C such that

$$\sup_j \sum_{n=0}^{\infty}\left|u_{nj}C^{-1/\mu_j}\right|^{\lambda_n} < \infty.$$

Lemma 2. (Sarıgöl, 2013) Assume that $U = \left(u_{nj}\right)$ is an infinite matrix with complex components, $\mu = \left(\mu_j\right)$ is a bounded sequence of positive numbers,

$$\mathcal{U}_\mu[U] = \sum_{j=0}^{\infty}\left(\sum_{n=0}^{\infty}\left|u_{nj}\right|\right)^{\mu_j}$$

and

$$\mathcal{L}_\mu[U] = \sup\left\{\sum_{j=0}^{\infty}\left|\sum_{n\in N} u_{nj}\right|^{\mu_j} : N \subset \mathbb{N} \text{ finite}\right\}.$$

If $\mathcal{U}_\mu[U] < \infty$ or $\mathcal{L}_\mu[U] < \infty$, then

$$(2M)^{-2}\mathcal{U}_\mu[U] \leq \mathcal{L}_\mu[U] \leq \mathcal{U}_\mu[U],$$

where $M = max\{1,\ 2^{H-1}\}, H = \sup_j \mu_j$.

2. MAIN RESULTS

In this section of the paper, we introduce the absolute q-Cesàro summability method which combines the notion of absolute summability with the transformation matrix generated by the

q-Cesàro matrix. Then, the theorems expressing the necessary and sufficient conditions for $\varepsilon\epsilon\left(|C^q,\varphi|(\lambda),|C^p,\delta|(\mu)\right)$ will be stated and proven. To explain the method, consider the sequence $\sum u_i$ with its partial sums b_m. Then, it is easily written that

$$U_n(b)=\sum_{i=0}^{n}c_{ni}^{q}b_i=\sum_{m=0}^{n}u_m\sum_{i=m}^{n}\frac{q^i}{[n+1]_q}$$
$$=\sum_{m=0}^{n}u_m\left(1-\frac{[m]_q}{[n+1]_q}\right)$$

and so,

$$\Delta U_n(b)=\sum_{m=0}^{n}u_m\left(1-\frac{[m]_q}{[n+1]_q}\right)-\sum_{m=0}^{n-1}u_m\left(1-\frac{[m]_q}{[n]_q}\right)$$
$$=\sum_{m=1}^{n}\frac{q^n[m]_q}{[n]_q[n+1]_q}u_m,\quad n>0,$$
$$\Delta U_0(b)=u_0.$$

If

$$\sum_{n=0}^{\infty}\varphi_n^{\lambda_n-1}\,|\,\Delta U_n(b)|^{\lambda_n}<\infty,$$

it is said that the series $\sum u_i$ is summable by the summability method $|C^q,\varphi|(\lambda)$. Also, considering the transformation sequence (T_n), it can be seen immediately that the series $\sum u_i$ is summable by $|C^q,\varphi|(\lambda)$ if and only if $(T_n)\epsilon\, l(\lambda)$. Here

$$T_n=\varphi_n^{1/\lambda_n^*}\sum_{m=1}^{n}\frac{q^n[m]_q}{[n]_q[n+1]_q}u_m,\quad n>0,$$
$$T_0=\varphi_0^{1/\lambda_0^*}u_0.$$

By making a few calculations, it can be seen that the inverse transformation of the transformation sequence (T_n) is as follows:

$$u_n=T_n\frac{[n+1]_q}{\varphi_n^{1/\lambda_n^*}q^n}-T_{n-1}\frac{[n-1]_q}{\varphi_{n-1}^{1/\lambda_{n-1}^*}q^{n-1}},n>0,$$
$$u_0=\varphi_0^{-1/\lambda_0^*}T_0.$$

Throughout the article, it is noted that (φ_j) and (δ_j) represent any sequences of positive components, (μ_j) and (λ_j) represent arbitrary bounded sequences of positive components, and also λ_j^* indicates the conjugate of λ_j that is $1/\lambda_j+1/\lambda_j^*=1$ for $\lambda_j>0$, $1/\lambda_j^*=0$ for $\lambda_j=1$ for all $j\epsilon\mathbb{N}$.

With its specific selections of $\varphi_n=n$, $q=1$ and $\lambda_n=s$ for all $n\epsilon\mathbb{N}$, $|C^q,\varphi|(\lambda)$, the fundamental summability method used in this study, transforms into the well-known $|C,1|_s$

classical absolute Cesàro method provided by Rhoades (1988), which holds an important place in the literature.

For simplicity, throughout the rest of the article, it will be used that

$$[n]_p[n+1]_q - [n+1]_p[n]_q = \Delta_{pq}(n).$$

Theorem 1. Assume that $\lambda_v > 1$ for each $v \in \mathbb{N}$. Then, $\lambda\epsilon(|C^q, \varphi|(\lambda), |C^p, \delta|)$ if and only if

$$\sum_{m=0}^{\infty}\left(\left|\varphi_m^{\frac{-1}{\lambda_m^*}}\frac{p^m[m+1]_q}{q^m[m+1]_p}\varepsilon_m\right| + \sum_{n=m+1}^{\infty}\left|\frac{\sigma_{m+1}^{(p)}}{\varphi_m^{-1/\lambda_m^*}q^m}\left(\varepsilon_m\Delta_{pq}(m) + \Delta\varepsilon_m[m+1]_p[m]_q\right)\right|\right)^{\lambda_m^*} < \infty$$

where

$$\sigma_{m+1}^{(p)} = \begin{cases} \dfrac{1}{m+1}, & p = 1 \\ \dfrac{p^{m+1}}{[m+1]_p}, & p < 1 \\ \dfrac{1}{[m+1]_p}, & p > 1. \end{cases}$$

Proof.

Let us define T_n and t_n as the transformations sequences of $|C^q, \varphi|(\lambda)$ and $|C^p, \delta|$ means of series $\sum u_n$ and $\sum \varepsilon_n u_n$ respectively, that is

$$T_n = \varphi_n^{1/\lambda_n^*}\sum_{m=1}^{n}\frac{q^n[m]_q}{[n]_q[n+1]_q}u_m, t_n = \sum_{m=1}^{n}\frac{p^n[m]_p}{[n]_p[n+1]_p}\varepsilon_m u_m.$$

If the inverse transformation of T_n is taken into account, it can be immediately written that

$$t_n = \sum_{m=1}^{n}\frac{p^n[m]_p}{[n]_p[n+1]_p}\varepsilon_m u_m$$

$$= \sum_{m=1}^{n}\frac{p^n[m]_p\varepsilon_m}{[n]_p[n+1]_p}\left(T_m\frac{[m+1]_q}{\varphi_m^{1/\lambda_m^*}q^m} - T_{m-1}\frac{[m-1]_q}{\varphi_{m-1}^{1/\lambda_{m-1}^*}q^{m-1}}\right)$$

$$= \sum_{m=1}^{n}\frac{p^n[m]_p\varepsilon_m}{[n]_p[n+1]_p}\frac{[m+1]_q}{\varphi_m^{1/\lambda_m^*}q^m}T_m - \sum_{m=0}^{n-1}\frac{p^n[m+1]_p\varepsilon_{m+1}}{[n]_p[n+1]_p}\frac{[m]_q}{\varphi_m^{1/\lambda_m^*}q^m}T_m$$

$$= \varphi_n^{-1/\lambda_n^*}\frac{p^n[n+1]_q}{q^n[n+1]_p}\varepsilon_n T_n + \sum_{m=1}^{n-1}\frac{\varphi_m^{\frac{-1}{\lambda_m^*}}p^n\Delta_{pq}^{\varepsilon}(m)}{q^m[n]_p[n+1]_p}T_m,$$

$$t_0 = \varphi_j^{-1/\lambda_0^*}\varepsilon_0 T_0$$

where

$$\Delta_{pq}^{\varepsilon}(m) = \left(\varepsilon_m [m]_p [m+1]_q - \varepsilon_{m+1}[m+1]_p [m]_q\right).$$

Hence, we obtain

$$t_n = \sum_{m=0}^{n} K_{nm}\, T_m$$

where

$$k_{nm} = \begin{cases} \varphi_n^{-1/\lambda_n^*} \dfrac{p^n [n+1]_q}{q^n [n+1]_p} \varepsilon_n, & m = n \\ \dfrac{\varphi_m^{-1/\lambda_m^*} p^n}{q^m [n]_p [n+1]_p} \left(\varepsilon_m \Delta_{pq}(m) + \Delta\varepsilon_m [m+1]_p [m]_q\right), & 1 \le m \le n-1 \\ 0, & m > n. \end{cases}$$

So, it is clear that $(t_n) \in l$ whenever $(T_n) \in l(\lambda)$ if and only if the matrix $K \in (l(\lambda), l)$. It follows from Lemma 1(i) that the condition

$$\sup\left\{ \sum_{m=0}^{\infty} \left| \sum_{n \in N} k_{nm} M^{-1} \right|^{\lambda_m^*} : N \subset \mathbb{N} \text{ finite} \right\} < \infty, \exists M > 1,$$

holds. At this stage, if Lemma 2 is considered, the last condition is reduced the following condition:

$$\sum_{m=0}^{\infty} \left(\left| \varphi_m^{\frac{1}{\lambda_m^*}} \frac{p^m [m+1]_q}{q^m [m+1]_p} \varepsilon_m \right| + \sum_{n=m+1}^{\infty} \left| \frac{\varphi_m^{1/\lambda_m^*} p^n}{q^m [n]_p [n+1]_p} \left(\varepsilon_m \Delta_{pq}(m) + \Delta\varepsilon_m [m+1]_p [m]_q\right) \right| \right)^{\lambda_m^*} < \infty . \quad (2)$$

On the other hand, it is clear that the sum $\sum_{n=m+1}^{\infty} \frac{p^n}{[n]_p [n+1]_p}$ can be written as follows

$$\sum_{n=m+1}^{\infty} \frac{p^n}{[n]_p [n+1]_p} = \begin{cases} \sum_{n=m+1}^{\infty} \left(\frac{1}{n} - \frac{1}{n+1}\right), & p = 1 \\ \sum_{n=m+1}^{\infty} \left(\frac{1}{1-p^n} - \frac{1}{1-p^{n+1}}\right), & p < 1 \text{ or } p > 1. \end{cases}$$

One can immediately see that the sum of the series is obtained as follows for each value of p:

$$\sigma_{m+1}^{(p)} = \begin{cases} \dfrac{1}{m+1}, & p = 1 \\ \dfrac{p^{m+1}}{[m+1]_p}, & p < 1 \\ \dfrac{1}{[m+1]_p}, & p > 1. \end{cases}$$

Thus, with this information, the condition (2) becomes the following condition:

$$\sum_{m=0}^{\infty}\left(\left|\varphi_m^{-1/\lambda_m^*}\frac{p^m[m+1]_q}{q^m[m+1]_p}\varepsilon_m\right| + \sum_{n=m+1}^{\infty}\left|\frac{\sigma_{m+1}^{(p)}}{\varphi_m^{\frac{-1}{\lambda_m^*}}q^m}\left(\varepsilon_m\Delta_{pq}(m) + \Delta\varepsilon_m[m+1]_p[m]_q\right)\right|\right)^{\lambda_m^*} < \infty,$$

which concludes the proof.

Theorem 2. Let $\mu_\nu \le 1,\ \lambda_\nu \ge 1$ for each $\nu \in \mathbb{N}$. The necessary and sufficient conditions for $\varepsilon\epsilon\left(|C^p,\delta|(\mu),|C^q,\varphi|(\lambda)\right)$ is that there exists some M such that

$$\sup_m\left\{\left|\frac{\varphi_m^{1/\lambda_m^*}}{\delta_m^{1/\mu_m^*}}\frac{q^m[m+1]_p}{p^m[m+1]_q}\varepsilon_m M^{\frac{-1}{\mu_m}}\right|^{\lambda_m} + \sum_{n=m+1}^{\infty}\left|\frac{\varphi_n^{1/\lambda_n^*}}{\delta_m^{1/\mu_m^*}}\frac{q^n M^{-1/\mu_m}}{p^m[n]_q[n+1]_q}\left(\varepsilon_m\Delta_{qp}(m) + \Delta\varepsilon_m[m+1]_q[m]_p\right)\right|^{\lambda_n}\right\} < \infty. \quad (3)$$

Proof.

Let define $\hat{T}_n$ and $\hat{t}_n$ as the transformations sequences of $|C^q,\varphi|(\lambda)$ and $|C^p,\delta|(\mu)$ means of the series $\sum\varepsilon_n u_n$ and $\sum u_n$, respectively. If we use the inverse transformation of $\hat{t}_n$, it is obtained that for all $n \ge 1$:

$$\hat{T}_n = \sum_{m=1}^{n}\frac{\varphi_n^{1/\lambda_n^*}q^n[m]_q}{[n]_q[n+1]_q}\varepsilon_m u_m$$

$$= \sum_{m=1}^{n}\frac{\varphi_n^{1/\lambda_n^*}q^n[m]_q}{[n]_q[n+1]_q}\varepsilon_m\left(\hat{t}_m\frac{[m+1]_p}{\delta_m^{1/\mu_m^*}p^m} - \hat{t}_{m-1}\frac{[m-1]_p}{\delta_{m-1}^{1/\mu_{m-1}^*}p^{m-1}}\right)$$

$$= \varphi_n^{1/\lambda_n^*}\frac{q^n[n+1]_p}{p^n[n+1]_q}\delta_n^{-1/\mu_n^*}\varepsilon_n\hat{t}_n + \varphi_n^{\frac{1}{\lambda_n^*}}\frac{q^n\delta_m^{-1/\mu_m^*}\Delta_{qp}^{\varepsilon}(m)}{p^m[n]_q[n+1]_q}$$

where

$$\Delta_{qp}^{\varepsilon}(m) = \left(\varepsilon_m[m]_q[m+1]_p - \varepsilon_{m+1}[m+1]_q[m]_p\right),$$

$$\hat{T}_0 = \varphi_0^{1/\lambda_0^*}\delta_0^{-1/\mu_0^*}\varepsilon_0\hat{t}_0.$$

So, it can be written that

$$\hat{T}_n = \sum_{m=0}^{n}s_{nm}\,\hat{t}_m.$$

Here the matrix $S = (s_{nm})$ is defined as

$$s_{nm} = \begin{cases} \varphi_n^{1/\lambda_n^*} \delta_n^{-1/\mu_n^*} \dfrac{q^n [n+1]_p}{p^n [n+1]_q} \varepsilon_n, & m = n \\ \varphi_n^{1/\lambda_n^*} \dfrac{q^n \delta_m^{-1/\mu_m^*}}{p^m [n]_q [n+1]_q} \left(\varepsilon_m \Delta_{qp}(m) + \Delta \varepsilon_m [m+1]_q [m]_p \right), & 1 \le m \le n-1 \\ 0, & m > n. \end{cases}$$

It can be written immediately that $(\hat{T}_n) \in l(\lambda)$ whenever $(\hat{t}_n) \in l(\mu)$ if and only if the matrix $S \in \left(l(\mu), l(\lambda)\right)$. It follows from Lemma 1(ii) that the condition (3) is immediately obtained which completes the proof.

3. CONCLUSION

The summability factor theorems of various summability methods constitute one of the central topics in summability theory. In this study, we investigated the class $\varepsilon\epsilon\left(|C^q, \varphi|(\lambda), |C^p, \delta|(\mu)\right)$. In contemporary research, matrix transformations between the sequence spaces generated by the new summability methods provide a broader and more informative setting for such theorems. Hence, a natural extension of the present work is to identify the matrix transformations between the sequence spaces derived from the two summability methods considered here.

Afterward, the resulting matrix classes can be analyzed in detail. To guide the reader more clearly, it may also be noted that, when these matrix classes are restricted to diagonal matrices, the obtained conditions reduce to explicit criteria for the summability factor.

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SOME COMPARISON RELATIONSHIPS IN ABSOLUTE q-CESÀRO METHODS

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ABSTRACT

In this article, we introduce an absolute summability method derived from a transformation matrix obtained by the q-Cesàro matrix. Then, we establish the necessary and sufficient conditions for $|C^q, \varphi|(\lambda) \Rightarrow |C^p, \delta|(\mu)$ and $|C^q, \varphi|(\lambda) \Rightarrow |C^p, \delta|$ where $\varphi = (\varphi_j)$ and $\delta = (\delta_j)$ are any sequences of positive real numbers, $\lambda = (\lambda_j)$ and $\mu = (\mu_j)$ are any bounded sequences of positive real numbers.

Keywords: Absolute summability, summability methods, q-Cesáro matrix

1. INTRODUCTION

Summability theory has continued to develop rapidly from past to present, particularly through summability and absolute summability methods generated by well-known matrices such as the Gauss, Euler, Cesàro, and Fibonacci matrices, as well as through the study of sequence and series spaces associated with these methods and their corresponding matrix transformations. While the literature in this direction continues to expand, the concept of the q −analogue which has recently become highly active in various engineering applications, has also begun to be incorporated into summability theory. The q-analogue also forms one of the central ideas of the present study. The q-analogue of the mathematical expression is a generalization obtained by adding a parameter q. It should be noted that as $q \to 1$, the q-analoge transforms to its classical form. Although its origins lie in Euler's work, q -calculus has recently become a vibrant and active area of research. It has attracted considerable interest due to its wide range of applications in especially mathematics, physics, and engineering, particularly in approximation theory, combinatorics, quantum algebra, operator theory, and hypergeometric functions. In this context, the q-Cesáro matrix $C^q = (c_{mv}^q)$ which is also examined in this paper, was described by Aktuğlu and Bekar (2011) as follows:

$$c_{mj}^q = \begin{cases} \dfrac{q^j}{[m+1]_q}, & 0 \le j \le m \\ 0, & j > m \end{cases}$$

where $[m]_q$ represents the q-analogue of a non-negative number m and described by

$$[m]_q = \begin{cases} \dfrac{1-q^m}{1-q}, & q \epsilon R^+ - \{1\} \\ m, & q = 1. \end{cases}$$

Now, consider the sequence

$$x_m = (-1)^m. \quad (1)$$

This sequence is a useful and straightforward example for comparing the absolute q-Cesàro summability method with other methods. It is easily seen that this sequence is not convergent in the classical sense. However, for a suitable choice q-parameter, it becomes summable by absolutely q-Cesàro summability method.

It should be noted that beyond theoretical role, the q-Cesàro methods also have practical value in areas such as Fourier analysis and q-difference equations. They provide a flexible framework for identifying sensitive convergence behaviors, including weak and statistical types. In engineering contexts like signal processing and data compression, reducing noise or smoothing sharp fluctuations is often necessary. While classical Cesàro methods rely on uniform mean, which may fail for highly irregular data, q-Cesàro methods are more adaptable. By adjusting the q- parameter, one can control the degree of smoothing without losing essential local information. Thus, q-Cesàro methods perform better when rapid oscillations are present.

However, some challenges should be recognized. Calculations involving q-calculus -such as q-differences and q-summability operators- are often more complex than their classical counterparts, and the proofs related to q-Cesàro matrices can demand substantial technical work. Moreover, selecting an appropriate q-parameter is not straightforward; the chosen parameter strongly affects the results and must be determined carefully depending on the specific context.

Let $\mathrm{U} = (u_{ji})$ be any infinite matrix of complex entries and Y, X be two subspaces of ω. For each $j \epsilon \mathbb{N}$, if the series

$$\mathrm{U}_j(y) = \sum_{i=0}^{\infty} u_{ji} y_i$$

converges, then, the sequence $\mathrm{U}(y) = \left(\mathrm{U}_j(y)\right)$ is called the U-transform of the sequence $y = (y_i)$. Moreover, U is said to define a matrix transformation from Y into another space X, and the collection of all such infinite matrices $\mathrm{U} : Y \to X$ is denoted by (Y, X).
Let $b = \left(b_j\right)$ be the sequence of partial sum of the series $\sum y_i$. Also, let $\varphi = \left(\varphi_j\right)$ denote any sequence of positive real entries, $\lambda = \left(\lambda_j\right)$ be any bounded sequence of positive real entries. It follows from Gökçe & Sarıgöl, (2018) that the series $\sum y_i$ is said to be summable $|\mathrm{U}, \varphi|(\lambda)$ whenever

$$\sum_{j=1}^{\infty} \varphi_j^{\lambda_m - 1} \left|\mathrm{U}_j(b) - \mathrm{U}_{j-1}(b)\right|^{\lambda_m} < \infty.$$

The scope of the concept of summability method $|\mathrm{U}, \varphi|(\lambda)$ is quite broad. That is, this method can be reduced to many well-established summability methods with specific choices of the matrix $U = \left(u_{ji}\right)$ and the sequences φ and λ. For example, choosing the Euler matrix instead

of U with $\lambda_m = s$ for all m, the method yields the summability methods $|E^r, \varphi|_s$ satisfying the condition

$$\sum_{m=1}^{\infty} \varphi_n^{s-1} \left| \sum_{j=1}^{m} \binom{m-1}{j-1} (1-r)^{m-j} r^j y_j \right|^s < \infty,$$

(Gökçe & Sarıgöl, 2020), if we chose the weighted mean matrix instead of U, the summability method $|\mathrm{U}, \varphi|(\lambda)$ is reduced to the $|\bar{N}, p_m, \varphi_m|(\lambda)$ satisfying the condition

$$\sum_{m=1}^{\infty} \varphi_m^{\lambda_m - 1} \left| \frac{p_m}{P_m P_{m-1}} \sum_{j=1}^{m} P_{j-1} y_j \right|^{\lambda_m} < \infty,$$

(Gökçe & Sarıgöl, (2018)), if we decide on the Cesàro matrix instead of U with $\lambda_m = m$ for each m, the method is reduced to $|C, \alpha, \beta|(\lambda)$ and the set of all series summable by the method is given by:

$$\sum_{m=1}^{\infty} m^{\lambda_m - 1} \left| \sum_{j=0}^{m} \left(\frac{A_{m-j}^{\alpha-1}}{A_m^{\alpha+\beta}} - \frac{A_{m-1}^{\alpha-1}}{A_{m-1}^{\alpha+\beta}} \right) A_j^{\beta} b_j \right|^{\lambda_m} < \infty,$$

(Gökçe & Sarıgöl, (2019)). In addition to the last choosing above, if $\beta = 0$ and $\lambda_m = s$ for all m is selected, the method $|C, \alpha|_s$ given by the condition

$$\sum_{m=1}^{\infty} \frac{1}{m} \left| \sum_{j=0}^{m} \frac{A_{m-j}^{\alpha-1}}{A_m^{\alpha}} j y_j \right|^s < \infty$$

is obtained in (Sarıgöl, 2016).

For more information on the summability theory, see also (Erdem, 2024; Sarıgöl, 2023; Yaying et al., 2025; Yaying et al., 2021)

Throughout the whole article it is noted that (φ_j) and (δ_j) represent any sequences of positive entries, (μ_j) and (λ_j) are arbitrary bounded sequences of positive entries, and also λ_j^* indicates the conjugate of λ_j that is $1/\lambda_j + 1/\lambda_j^* = 1$ for $\lambda_j > 0$, $1/\lambda_j^* = 0$ for $\lambda_j = 1$ for each $j \epsilon \mathbb{N}$. Moreover, $l(\mu), l(\lambda)$ represent the Maddox's spaces.

Before moving on to the main theorems, let us recall the lemmas that will be used in the proofs:

Lemma 1. (Grosse – Erdmann, 1993) Assume that $\lambda = (\lambda_j)$ is arbitrary bounded sequence of strictly positive entries.

(i) If $\mu_j > 1$ for each j, then, $U \in (l(\mu), l)$ iff there exists an integer $\rho > 1$ such that

$$\sup\left\{\sum_{j=0}^{\infty}\left|\sum_{m\in K}u_{mj}\rho^{-1}\right|^{\mu_j^*}:K\subset\mathbb{N}\text{ finite}\right\}<\infty.$$

(ii) If $\mu_j\leq 1$ and $\lambda_j\geq 1$ for each $j\in\mathbb{N}$, then $U\in\left(l(\mu),l(\lambda)\right)$ if and only if there exists some ρ satisfying

$$\sup_j\sum_{m=0}^{\infty}\left|u_{mj}\rho^{-1/\mu_j}\right|^{\lambda_n}<\infty.$$

Lemma 2. (Sarıgöl, 2013) Assume that $U=\left(u_{mj}\right)$ is an infinite matrix with complex entries, $\lambda=\left(\lambda_j\right)$ is a bounded sequence of positive entries,

$$\mathcal{U}_\lambda[U]=\sum_{j=0}^{\infty}\left(\sum_{m=0}^{\infty}\left|u_{mj}\right|\right)^{\lambda_j}$$

and

$$\mathcal{L}_\lambda[U]=\sup\left\{\sum_{j=0}^{\infty}\left|\sum_{m\in K}u_{mj}\right|^{\lambda_j}:K\subset\mathbb{N}\text{ finite}\right\}.$$

If $\mathcal{U}_\lambda[U]<\infty$ or $\mathcal{L}_\lambda[U]<\infty$, then

$$(2\sigma)^{-2}\mathcal{U}_\lambda[U]\leq\mathcal{L}_\lambda[U]\leq\mathcal{U}_\lambda[U],$$

where $\sigma=max\{1,\ 2^{H-1}\}, H=\sup_j\lambda_j$.

In this paper, firstly, the absolute summability method $|C^q,\varphi|(\lambda)$ derived by transformation matrix obtained by the q-Cesàro matrix is introduced and then, the necessary and sufficient conditions for $|C^q,\varphi|(\lambda)\Rightarrow|C^p,\delta|(\mu),|C^q,\varphi|(\lambda)\Rightarrow|C^p,\delta|$ are established where $\varphi=\left(\varphi_j\right)$ is any sequence of positive real entries, $\lambda=\left(\lambda_j\right)$ is any bounded sequence of positive real entries.

2. MAIN RESULTS

In this part of the paper, we present the absolute q-Cesàro summability method which combines the notion of absolute summability with the transformation matrix generated by the q-Cesàro matrix. Then, the theorems expressing the necessary and sufficient conditions for $|C^q,\varphi|(\lambda)\Rightarrow|C^p,\delta|(\mu),|C^q,\varphi|(\lambda)\Rightarrow|C^p,\delta|$ will be stated and proven.

To introduce the method $|C^q,\varphi|(\lambda)$, let us take the sequence $\sum y_i$ and its partial sums b_j. Then, we get

$$U_m(b)=\sum_{i=0}^{m}c_{mi}^q b_i=\sum_{j=0}^{m}y_j\left(1-\frac{[j]_q}{[m+1]_q}\right)$$

and so,

$$\Delta U_m(b) = \sum_{j=0}^{m} y_j \left(1 - \frac{[j]_q}{[m+1]_q}\right) - \sum_{j=0}^{m-1} y_j \left(1 - \frac{[j]_q}{[m]_q}\right)$$

$$= \sum_{j=1}^{m} \frac{q^m [j]_q}{[m]_q [m+1]_q} y_j, \quad m > 0,$$

$$\Delta U_0(b) = y_0.$$

If

$$\sum_{m=0}^{\infty} \varphi_m^{\lambda_m - 1} \, |\Delta U_m(b)|^{\lambda_m} < \infty,$$

it is said that the series $\sum y_i$ is summable by the method $|C^q, \varphi|(\lambda)$. Also, considering the transformation sequence (T_m), it can be written that the series $\sum y_j$ is summable by $|C^q, \varphi|(\lambda)$ if and only if $(T_m) \epsilon\, l(\lambda)$. Here

$$T_m = \varphi_m^{1/\lambda_m^*} \sum_{j=1}^{m} \frac{q^m [j]_q}{[m]_q [m+1]_q} y_j, \quad m > 0,$$

$$T_0 = \varphi_0^{1/\lambda_0^*} y_0.$$

It can be easily seen that in case of $q = 1$, $\varphi_m = m$ and $\lambda_m = s$ for each $m \epsilon \mathbb{N}$, the summability method $|C^q, \varphi|(\lambda)$ transforms to the classical absolute Cesàro method $|C, 1|_s$, (Rhoades,1998).

For the brevity and simplicity of the presentation, let us assume that

$$[j]_p [j+1]_q - [j+1]_p [j]_q = \Delta_{pq}(j),$$

$$\sigma_{j+1}^{(p)} = \begin{cases} \dfrac{1}{j+1}, & p = 1 \\ \dfrac{p^{j+1}}{[j+1]_p}, & p < 1 \\ \dfrac{1}{[j+1]_p}, & p > 1 \end{cases}$$

in the remainder of the work.

Theorem 1. Assume that $\lambda_j > 1$ for each $j \in \mathbb{N}$. Then, $|C^q, \varphi|(\lambda) \Longrightarrow |C^p, \delta|$ if and only if

$$\sum_{j=0}^{\infty} \left(\left| \varphi_j^{-1/\lambda_j^*} \frac{p^j [j+1]_q}{q^j [j+1]_p} \varepsilon_j \right| + \left| \frac{\sigma_{j+1}^{(p)} \Delta_{pq}(j)}{\varphi_j^{-1/\lambda_j^*} q^j} \right| \right)^{\lambda_j^*} < \infty.$$

Proof.

Let us define T_m and t_m as the transformations sequences of $|C^q, \varphi|(\lambda)$ and $|C^p, \delta|$ means of the series, respectively, that is

$$T_m = \varphi_m^{1/\lambda_m^*} \sum_{j=1}^{m} \frac{q^m [j]_q}{[m]_q [m+1]_q} y_j,$$

$$t_m = \sum_{j=1}^{m} \frac{p^m [j]_p}{[m]_p [m+1]_p} y_j.$$

By making a few calculations, the inverse transformation of T_m can be obtained as follows:

$$y_m = T_m \frac{[m+1]_q}{\varphi_m^{1/\lambda_m^*} q^m} - T_{m-1} \frac{[m-1]_q}{\varphi_{m-1}^{1/\lambda_{m-1}^*} q^{m-1}}, m > 0,$$

$$y_0 = \varphi_0^{-1/\lambda_0^*} T_0.$$

Taking into consideration y_m, it can be immediately written that

$$t_m = \sum_{j=1}^{n} \frac{p^m [j]_p}{[m]_p [m+1]_p} u_j$$

$$= \varphi_m^{-1/\lambda_m^*} \frac{p^m [m+1]_q}{q^m [m+1]_p} T_m + \sum_{j=1}^{m-1} \frac{\varphi_j^{-1/\lambda_j^*} p^m}{q^j [m]_p [m+1]_p} \Delta_{pq}(j)\, T_j,$$

$$t_0 = \varphi_j^{-1/\lambda_0^*} T_0.$$

So, it is written that

$$t_m = \sum_{j=0}^{\infty} s_{mj}\, T_j$$

where

$$s_{mj} = \begin{cases} \varphi_m^{-1/\lambda_m^*} \dfrac{p^m [m+1]_q}{q^m [m+1]_p}, & j = m \\ \dfrac{\varphi_j^{-1/\lambda_j^*} p^m}{q^j [m]_p [m+1]_p} \Delta_{pq}(j), & 1 \le j \le m-1 \\ 0, & j > m. \end{cases}$$

So, it is obtained that $(t_m) \in l$ whenever $(T_m) \in l(\lambda)$ or equivalent the matrix $S \in (l(\lambda), l)$. It follows from Lemma 1(i) the condition

$$\sup \left\{ \sum_{j=0}^{\infty} \left| \sum_{m \in K} s_{mj} C^{-1} \right|^{\lambda_j^*} : K \subset \mathbb{N} \text{ finite} \right\} < \infty, \exists C > 1,$$

holds. Again, with Lemma 2, the following condition is immediately obtained :

$$\sum_{j=0}^{\infty}\left(\left|\varphi_m^{-1/\lambda_m^*}\frac{p^m[m+1]_q}{q^m[m+1]_p}\varepsilon_j\right| + \sum_{m=j+1}^{\infty}\left|\frac{\varphi_j^{-1/\lambda_j^*}p^m\Delta_{pq}(j)}{q^j[m]_p[m+1]_p}\right|\right)^{\lambda_j^*} < \infty\,. (2)$$

It is clear that the sum $\sum_{m=j+1}^{\infty}\frac{p^m}{[m]_p[m+1]_p}$ can be written as follows

$$\sum_{m=j+1}^{\infty}\frac{p^m}{[m]_p[m+1]_p} = \begin{cases}\sum_{n=j+1}^{\infty}\left(\frac{1}{m}-\frac{1}{m+1}\right), & p=1\\ \sum_{m=j+1}^{\infty}\left(\frac{1}{1-p^m}-\frac{1}{1-p^{m+1}}\right), & p<1 \text{ or } p>1\end{cases}$$

$$= \sigma_{j+1}^{(p)}.$$

Thus, with this information, the condition (2) becomes the following condition:

$$\sum_{j=0}^{\infty}\left(\left|\varphi_j^{-1/\lambda_j^*}\frac{p^j[j+1]_q}{q^j[j+1]_p}\varepsilon_j\right| + \left|\frac{\sigma_{j+1}^{(p)}\Delta_{pq}(j)}{\varphi_j^{1/\lambda_j^*}q^j}\right|\right)^{\lambda_j^*} < \infty,$$

which concludes the proof.

Theorem 2. Let $\mu_j \le 1$ and $\lambda_j \ge 1$ for each $j \in \mathbb{N}$. Every series summable by the method $|C^p,\delta|(\mu)$ is also summable by the method $|C^q,\varphi|(\lambda)$, i.e., $|C^p,\delta|(\mu) \Rightarrow |C^q,\varphi|(\lambda)$, if and only if there exists some $C>1$ such that

$$\sup_j\left\{\left|\varphi_j^{1/\lambda_j^*}\delta_j^{-1/\mu_j^*}\frac{q^j[j+1]_p}{p^j[j+1]_q}C^{-1/\mu_j}\right|^{\lambda_j} + \sum_{n=j+1}^{\infty}\left|\varphi_n^{1/\lambda_n^*}\frac{q^n\delta_j^{-1/\mu_j^*}C^{-1/\mu_j}}{p^j[n]_q[n+1]_q}\Delta_{qp}(j)\right|^{\lambda_n}\right\} < \infty. \quad (3)$$

Proof.

Let define $\hat{T}_m$ and $\hat{t}_m$ as the transformations sequences of $|C^q,\varphi|(\lambda)$ and $|C^p,\delta|(\mu)$ means of series $\sum y_j$, respectively. If we use the inverse transformation of $\hat{t}_m$, it is obtained that for all $m \ge 1$:

$$\hat{T}_m = \sum_{j=1}^{m}\frac{\varphi_m^{1/\lambda_n^*}q^m[j]_q}{[m]_q[m+1]_q}y_j$$

$$= \varphi_m^{1/\lambda_m^*} \sum_{j=1}^{m} \frac{q^m [j]_q}{[m]_q [m+1]_q} \hat{t}_j \frac{[j+1]_p}{\delta_j^{1/\mu_j^*} p^j} - \varphi_m^{1/\lambda_m^*} \sum_{j=0}^{m-1} \frac{q^m [j+1]_q}{[m]_q [m+1]_q} \hat{t}_j \frac{[j]_p}{\delta_j^{1/\mu_j^*} p^j}$$

$$= \frac{\varphi_m^{1/\lambda_m^*}}{\delta_m^{1/\mu_m^*}} \frac{q^m [m+1]_p}{p^m [m+1]_q} \hat{t}_n + \sum_{j=1}^{m-1} \frac{\varphi_m^{1/\lambda_m^*} q^m \delta_j^{-1/\mu_j^*}}{p^j [m]_q [m+1]_q} \Delta_{qp}(j)\, \hat{t}_j,$$

$$\hat{T}_0 = \varphi_0^{1/\lambda_0^*} \delta_0^{-1/\mu_0^*} \hat{t}_0.$$

So, it can be written that

$$\hat{T}_m = \sum_{j=0}^{n} s_{mj}\, \hat{t}_j.$$

Here the matrix $S = (s_{mj})$ is defined as

$$s_{mj} = \begin{cases} \dfrac{\varphi_m^{1/\lambda_m^*}}{\delta_m^{1/\mu_m^*}} \dfrac{q^m [m+1]_p}{p^m [m+1]_q}, & j = m \\ \dfrac{\varphi_m^{1/\lambda_m^*} q^m \delta_j^{-1/\mu_j^*}}{p^j [m]_q [m+1]_q} \Delta_{qp}(j), & 1 \le j \le m-1 \\ 0, & j > m. \end{cases}$$

It can be written that $(\hat{T}_m) \in l(\lambda)$ whenever $(\hat{t}_m) \in l(\mu)$ if and only if the matrix $S \in (l(\mu), l(\lambda))$. It follows from Lemma 1(ii) that the condition (3) is immediately obtained which completes the proof.

3.CONCLUSION

The comparison of two summability methods is one of the most fundamental problems in summability theory. In this study, we have examined the comparison of the two methods using the absolute q-Cesàro summability method. However, in modern developments, matrix transformations between the sequence spaces generated by these summability methods provide a more comprehensive framework for understanding such comparisons. Therefore, a natural continuation of this study would be to characterize the matrix transformations between the sequence spaces induced by the two methods under consideration.

For this purpose, the mentioned summability method together with the Maddox space defined by

$$l(\lambda) = \left\{ y = (y_n) : \sum_{n=0}^{\infty} |y_n|^{\lambda_n} < \infty \right\}$$

with the its natural paranorm

$$\|y\| = \left(\sum_{k=0}^{\infty} |y_k|^{\lambda_k} \right)^{1\backslash M}$$

where $M = \max\{1; \sup_k \lambda_k\}$, can be used to form a new series space. Subsequently, the matrix characterizations formed between the spaces can be examined.

To offer a clearer roadmap for the reader, it can also be emphasized that, when the characterization of these matrix classes is restricted to a unit matrix, the resulting conditions yield direct criteria for comparing the two summability methods themselves.

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SONSUZ ARALIKTA İKİNCİ MERTEBEDEN IMPULSIVE SINIR DEĞER PROBLEMLERİ

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ÖZET

Diferansiyel denklemlerin teorik çalışmaları, gerçek hayatta karşılaşılan problemlerin analizinde oldukça önemli bir araç olarak karşımıza çıkmaktadır. Ancak bazı problemlerde modelleme kısmında adi diferansiyel denklemler yetersiz kalmaktadır (Dönmez, F. 2017).

Ani değişiklik gösteren süreçleri impulsive diferansiyel denklemler ifade etmiştir. Bu çalışmada sonsuz aralıkta impulsive sınır değer problemi ele alınmıştır. Sonsuz aralıkta impulsive diferansiyel denklem çalışmaları oldukça azdır (Liu,1998;Chen ve Sun,2010: Chen and Zhang,2011). Bu, çalışmadaki konuyu seçmemizde etkili olmuştur. İlk çalışmalar Pavlidis tarafından yapılmıştır (Pavlidis ve Jury,1965;Pavlidis,1966).

Bu çalışmada sonsuz aralıkta ikinci mertebeden impulsive sınır değer problemi ele alınmıştır. Bu problemin çözümü, uygun koşullar altında yapılmış olup sürekli operatör olduğu ispatlanmıştır. Daha sonra Banach uzayında uygun koşullar altında Krasnoselskii sabit teoremi ile en az bir pozitif çözümün varlığı, Avery-Henderson sabit nokta teoremi ile en az 2 pozitif çözümün varlığı, 5 fonksiyonelli sabit nokta teoremi ile en az 3 pozitif çözümün varlığı gösterilmiştir.

Anahtar Kelimeler : Sınır değer problemi, pozitif çözüm, sabit nokta teoremi

NEW GENERALIZED CONTRACTIONS ON S-METRIC SPACES

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ABSTRACT

Fixed point theory is an important area of study that mathematicians have been working on for many years. Research in this field is evaluated from various perspectives and continues with different approaches. In the metric sense, fixed point theory began during the time of Stefan Banach with the “Banach Fixed Point Theorem”, and studies have continued in the literature with various generalizations of this theorem. We encounter examples of functions that possess a unique fixed point but do not satisfy the conditions of the “Banach Fixed Point Theorem”. At this point, the investigation of new generalized fixed point theorems gains importance. While working on these generalizations, sometimes the contraction condition is generalized, and at other times, the structure of the metric space being studied is generalized. In this study, we present three different contraction conditions of Ciric type on S-metric spaces, which are a generalized type of metric space. A list of some open problems that can be derived using these contraction condition definitions are also provided.

Keywords : S-metric space, fixed point, contraction condition.

1. INTRODUCTION AND PRELIMANIRIES

Fixed point theory has become one of the central themes in nonlinear analysis due to its powerful ability to unify and generalize diverse mathematical problems. Many fundamental questions in differential equations, optimization, dynamical systems, and geometric analysis can be reformulated as fixed point problems for suitable self-mappings on metric or generalized metric spaces. Over time, the classical Banach contraction principle has inspired a wide spectrum of new contractive conditions and structural extensions, allowing fixed point techniques to flourish

in increasingly abstract settings. These developments not only deepen the theoretical foundations of the field but also open pathways to new applications across both pure and applied mathematics.

We now present some necessary definitions and fundamental concepts.

Let $\mathcal{F}$ be the family of all functions $F:\mathbb{R}^{+}\to\mathbb{R}$ satisfying the following conditions:

(F1) F is strictly increasing,

(F2) For each sequence $\{x_n\}$ of positive numbers, $\lim_{n\to\infty} x_n = 0 \Leftrightarrow \lim_{n\to\infty} F(x_n) = -\infty$,

(F3) There exists $k\in(0,1)$ such that $\lim_{n\to\infty}(x_n)^k F(x_n) = 0$ [1].

Definition 1.1. [1] Let (X,d) be a metric space and $T:X\to X$ be an operator. Then T is called an F-contraction if there exists a positive real number τ such that for all $x,y\in X$

$$d(Tx,Ty)>0 \Rightarrow \tau + F(d(Tx,Ty)) \le F(d(x,y)).$$

Definition 1.2. [2] Let A and B be two nonempty subsets of a set X. Then a mapping $T:X\times X\to X$ is called cyclic mapping if

(1) $T(x,y)\in B$ when $x\in A$ and $y\in B$.
(2) $T(x,y)\in A$ when $x\in B$ and $y\in A$.

Definition 1.3. [3] An element $(x,y)\in X\times X$ is called a coupled fixed point of the mapping $T:X\times X\to X$ if $T(x,y)=x$ and $T(y,x)=y$. If $T(x,x)=x$, then x is called strong coupled fixed point.

Definition 1.4. [4] Let A and B be two nonempty subsets of a metric space (X,d). Then a mapping $T:X\times X\to X$ is called cyclic coupled Ciric type mapping with reference to the sets A and B if T is cyclic with reference to the sets A and B such that for some $k\in\left(0,\frac{1}{2}\right)$, the following inequality holds:

For $b,x\in A$ and $a,y\in B$,

$$d(T(a,b),T(x,y)) \le k\mathcal{M}(a,x),$$

where

$$M(a,x)=\max\left\{d(a,x),\frac{d(a,T(a,b))+d(x,T(x,y))}{2},\frac{d(b,T(x,y))}{2},\frac{d(x,T(a,b))}{2}\right\}.$$

Definition 1.5. [5] Let A and B be two nonempty subsets of a metric space (X,d). Then a mapping $T:X\times X\to X$ is called cyclic F-contraction if

(1) $T(x,y)\in B$ for all $x\in A$ and $y\in B$; $T(y,x)\in B$ for all $x\in A$ and $y\in B$;
(2) there exist a positive real number τ and a function $F\in \digamma$ such that for all $(x,y),(a,b)\in X\times X$,

$$d(T(a,b),T(x,y))>0\Rightarrow \tau+F(d(Tx,Ty))\le F(d(b,y)).$$

Definition 1.6. [6] Let A and B be two nonempty closed subsets of a metric space (X,d) and $C=A\cup B$. Let $T:C\to C$ be an operator. Then T is called cyclic F-contraction of generalized Ciric type if

(1) T is cyclic with respect to A and B,
(2) There exist a positive real number τ and a function $F\in \digamma$ such that for all $x\in A$ and $y\in B$,

$$d(Tx,Ty)>0\Rightarrow \tau+F(d(x,y))\le F(M(x,y)),$$

where

$$M(x,y)=\max\left\{d(x,y),d(x,Tx),d(y,Ty),\frac{d(x,Ty)}{2},\frac{d(y,Tx)}{2}\right\}.$$

Definition 1.7. [6] Let A and B be two nonempty closed subsets of a metric space (X,d) and $T:X\times X\to X$ be a mapping. Then T is called cyclic coupled F-contractive mapping of generalized Ciric type if

(1) $T(x,y)\in B$ for all $x\in A$ and $y\in B$; $T(y,x)\in A$ for all $x\in A$ and $y\in B$,
(2) There exist a positive real number τ and a function $F\in \digamma$ such that for all $x,y,a,b\in X$

$$d(T(a,b),T(x,y))>0\Rightarrow \tau+F(d(T(a,b),T(x,y)))\le F(M_C(b,y)),$$

where

$$M_C(b,y)=\max\left\{d(b,y),d(b,T(a,b)),d(y,T(x,y)),\frac{d(b,T(x,y))}{2},\frac{d(y,T(a,b))}{2}\right\}.$$

Definition 1.8. [6] Let A and B be two nonempty closed subsets of a metric space (X,d). Let $h:X\to X$ be a mapping. Then the mapping $T:X\to X$ is called generalized Ciric type cyclic h-coupled F - contraction mapping if

(1) $T(x,y)\in h(B)$ for all $x\in A$ and $y\in B$; $T(y,x)\in h(A)$ for all $x\in A$ and $y\in B$,

(2) There exist a positive real number τ and a function $F\in \digamma$ such that for all $x,y,a,b\in X$

$$d(T(a,b),T(x,y))>0$$
$$\Rightarrow \tau+F\left(d(T(a,b),T(x,y))\right)\le F\left(M_{CC}(hb,hy)\right),$$

where

$$M_{CC}(b,y)=\max\left\{\begin{matrix} d(hb,hy),d(hb,T(a,b)),d(hy,T(x,y)),\\ \frac{d(hb,T(x,y))}{2},\frac{d(hy,T(a,b))}{2}\end{matrix}\right\}.$$

Definition 1.9. [7] Let X be a nonempty set and the mapping $S:X\times X\times X\to[0,\infty)$ satisfies the following conditions:

(S_1) $S(x,y,z)=0\Leftrightarrow x=y=z$ for all $x,y,z\in X$,

(S_2) $S(x,y,z)\le S(x,x,t)+S(y,y,t)+S(z,z,t)$ for all $x,y,z,t\in X$.

Then S is called an S-metric and the pair (X,S) is called an S-metric space.

Lemma 1.10. [7] Let (X,S) be an S-metric space and $x,y\in X$. Then we have

$$S(x,x,y)=S(y,y,x).$$

Definition 1.11. [8,9] Let (X,d) be a metric space. Then the function $S_d:X\times X\times X\to[0,\infty)$ defined by

$$S_d(x,y,z)=d(x,z)+d(y,z),$$

for all $x,y,z\in X$ is an S-metric on X. The S-metric S_d is called the S-metric generated by d.

In the literatüre, there exist some examples of an S-metric which is not generated by any metric d. For example, let X be the set of real numbers and the function $S:X\times X\times X\to[0,\infty)$ be defined as

$$S(x,y,z)=|x-z|+|x+z-2y|,$$

for all $x,y,z\in X$ [9]. Then the function S is an S-metric and it is not generated by any metric.

Remark 1.12. [10]

(1) It is shown that there exists a G-metric that is not an S-metric. Indeed, let $X=\{x,y\}$,

$$G(x,x,x)=G(y,y,y)=0,\ G(x,x,y)=1,\ G(x,y,y)=2$$

and extend G to all of $X\times X\times X$ by symmetry in the variables. Then, it is easy to proved that G is G-metric, but G is not an S-metric on X.

(2) There exists an example of an S-metric that is not a G-metric. For example, let $X=\mathbb{R}$ and

$$S(x,y,z)=|y+z-2x|+|y-z|$$

for all $x,y,z\in\mathbb{R}$ [7]. Then S is an S-metric but is not a G-metric.

2. MAIN RESULTS

In this section, we develop three Ciric type contraction conditions in the setting of S-metric spaces, a broader class that generalizes standard metric structures.

Definition 2.1. Let A and B be two nonempty closed subsets of an S-metric space (X,S) and $C=A\cup B$. Let $T:C\to C$ be an operator. Then T is called cyclic F_S-contraction of generalized Ciric type if

(i) T is cyclic with respect to A and B,
(ii) There exist a positive real number τ and a function $F\in\mathcal{F}$ such that for all $x\in A$ and $y\in B$,

$$S(Tx,Tx,Ty)>0\Rightarrow\tau+F\left(S(x,x,y)\right)\le F\left(M_S(x,y)\right),$$

where

$$M_S(x,y)=\max\left\{S(x,x,y),S(x,x,Tx),S(y,y,Ty),\frac{S(x,x,Ty)}{2},\frac{S(y,y,Tx)}{2}\right\}.$$

Remark 2.2. If the S-metric is generated by any metric d then the notion of cyclic F-contraction of generalized Ciric type and the notion of cyclic F_S-contraction of generalized Ciric type coincide.

Definition 2.3. Let A and B be two nonempty closed subsets of an S-metric space (X,S) and $T:X\times X\to X$ be a mapping. Then T is called cyclic coupled F_S-contractive mapping of generalized Ciric type if

(i) $T(x,y) \in B$ for all $x \in A$ and $y \in B$; $T(y,x) \in A$ for all $x \in A$ and $y \in B$,

(ii) There exist a positive real number τ and a function $F \in \mathcal{F}$ such that for all $x, y, a, b \in X$

$$S(T(a,b),T(a,b),T(x,y)) > 0$$
$$\Rightarrow \tau + F\left(S(T(a,b),T(a,b),T(x,y))\right) \leq F\left(M_S^C(b,y)\right),$$

where

$$M_S^C(b,y) = \max\left\{ S(b,b,y), S(b,b,T(a,b)), S(y,y,T(x,y)), \frac{S(b,b,T(x,y))}{2}, \frac{S(y,y,T(a,b))}{2} \right\}.$$

Remark 2.4. If the S-metric is generated by any metric *d* then the notion of cyclic coupled F -contractive mapping and the notion of cyclic coupled F_S - contractive mapping coincide.

Definition 2.5. Let A and B be two nonempty closed subsets of an S-metric space (X,S). Let $h: X \to X$ be a mapping. Then the mapping $T: X \to X$ is called generalized Ciric type cyclic h-coupled F_S - contraction mapping if

(i) $T(x,y) \in h(B)$ for all $x \in A$ and $y \in B$; $T(y,x) \in h(A)$ for all $x \in A$ and $y \in B$,

(ii) There exist a positive real number τ and a function $F \in \mathcal{F}$ such that for all $x, y, a, b \in X$

$$S(T(a,b),T(a,b),T(x,y)) > 0$$
$$\Rightarrow \tau + F\left(S(T(a,b),T(a,b),T(x,y))\right) \leq F\left(M_S^{CC}(hb,hy)\right),$$

where

$$M_S^{CC}(b,y) = \max\left\{ S(hb,hb,hy), S(hb,hb,T(a,b)), S(hy,hy,T(x,y)), \frac{S(hb,hb,T(x,y))}{2}, \frac{S(hy,hy,T(a,b))}{2} \right\}.$$

Remark 2.6. If the S-metric is generated by any metric *d* then the notion of generalized Ciric type cyclic h-coupled F -contraction mapping and the notion of generalized Ciric type cyclic h-coupled F_S - contraction mapping coincide.

3. CONCLUSION AND FUTURE WORKS

In this study, we introduce three distinct Ciric type contraction conditions formulated within the framework of S-metric spaces, a natural generalization of classical metric spaces. In

addition, we outline several open problems that naturally emerge from our results and may serve as potential directions for future research as follows:

Open Problem 1: Is it possible to obtain a fixed point theorem on complete S-metric spaces by employing Definition 2.1?

Open Problem 2: Is it possible to obtain a fixed point theorem on complete S-metric spaces by employing Definition 2.3?

Open Problem 3: Is it possible to obtain a fixed point theorem on complete S-metric spaces by employing Definition 2.5?

Open Problem 4: How can these newly obtained contraction conditions be formulated on G-metric spaces? If such formulations are possible, can various fixed point results be derived in that setting?

Open Problem 5: Can the contraction conditions defined on metric spaces as well as those introduced on S-metric spaces be suitably modified to obtain new solutions to the fixed-circle problem intoduced in [11]?

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C_G-KHAN TYPE FIXED-CIRCLE RESULTS ON G-METRIC SPACES

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ABSTRACT

Metric fixed point theory began with the Banach fixed point principle during the time of Stefan Banach, and its generalizations have been studied by various mathematicians through different approaches. In general, the research in this area can be categorized under three main themes. The first of these is the generalization of the contraction condition under consideration. The second approach involves modifying the conditions of the underlying metric space structure, leading to a generalization of the metric space itself. One of the most recent and actively studied approaches is the 'Fixed Circle Problem,' which arises in cases where the number of fixed points is greater than one. In this study, new fixed circle theorems are obtained on G-metric spaces, inspired by the concept of contraction conditions of the C_G-Khan type.

Keywords : G-metric space, fixed circle, C_G-Khan type contraction.

1. INTRODUCTION AND PRELIMINARIES

Fixed point theory has long been recognized as a central tool in nonlinear analysis, with deep connections to differential equations, optimization, dynamic systems, and geometric function theory. Classical fixed point results, such as those of Banach [1], Kannan [2], and Ćirić [3], typically guarantee the existence of a single point left invariant under a given self-mapping. In recent years, however, researchers have expanded this framework to study fixed geometric structures rather than fixed points alone. Among these developments, the fixed circle problem has emerged as a natural geometric counterpart to traditional fixed point results, aiming to identify entire circles that remain invariant under suitable self-maps [4]. This shift from fixed points to fixed sets not only enriches the qualitative behavior of mappings but also opens new pathways for applications in generalized metric spaces, such as S-metric [5] and G-metric spaces [6], where geometric notions can behave significantly differently from their classical counterparts. Motivated by these advancements, this study contributes to the ongoing

development of fixed circle theory and its interplay with modern generalizations of metric structures.

Now, we present the fundamental concepts that are essential for our study.

Let $\mathcal{F}$ be the family of all functions $F:\mathbb{R}^{+}\to\mathbb{R}$ satisfying the following conditions:

(F1) F is strictly increasing,

(F2) For each sequence $\{x_n\}$ of positive numbers, $\lim_{n\to\infty} x_n = 0 \Leftrightarrow \lim_{n\to\infty} F(x_n) = -\infty$,

(F3) There exists $k\in(0,1)$ such that $\lim_{n\to\infty}(x_n)^k F(x_n) = 0$ [7].

Definition 1.1. [6] A nonempty set X together with a function $G: X\times X\times X\to[0,\infty)$ is called a G-metric space, denoted by (X,G) if G satisfies

(G1) $G(x,y,z)=0 \Leftrightarrow x=y=z$,

(G2) $0<G(x,x,y)$ for all $x,y\in X$ with $x\neq y$,

(G3) $G(x,x,y)\le G(x,y,z)$ for all $x,y,z\in X$ with $y\neq z$,

(G4) $G(x,y,z)=G(x,z,y)=G(y,z,x)=\cdots$ (symmetry in all three variables),

(G5) $G(x,y,z)\le G(x,w,w)+G(w,y,z)$ for all $x,y,z,w\in X$ (rectangle inequality).

Then, the nonnegative real function G is called a G-metric on X. The set X together with such a generalized metric G is called a generalized metric space, or G-metric space and denoted by (X,G).

Definition 1.2. [5] Let X be a nonempty set and the mapping $S: X\times X\times X\to[0,\infty)$ satisfies the following conditions:

(S_1) $S(x,y,z)=0 \Leftrightarrow x=y=z$ for all $x,y,z\in X$,

(S_2) $S(x,y,z)\le S(x,x,t)+S(y,y,t)+S(z,z,t)$ for all $x,y,z,t\in X$.

Then S is called an S-metric and the pair (X,S) is called an S-metric space.

Lemma 1.3. [5] Let (X,S) be an S-metric space and $x,y\in X$. Then we have

$$S(x,x,y)=S(y,y,x).$$

Remark 1.4. [8]

(1) It is shown that there exists a G-metric that is not an S-metric. Indeed, let $X=\{x,y\}$,

$$G(x,x,x)=G(y,y,y)=0,\ G(x,x,y)=1,\ G(x,y,y)=2$$

and extend G to all of $X\times X\times X$ by symmetry in the variables. Then, it is easy to proved that G is G-metric, but G is not an S-metric on X.

(2) There exists an example of an S-metric that is not a G-metric. For example, let $X=\mathbb{R}$ and

$$S(x,y,z)=|y+z-2x|+|y-z|$$

for all $x,y,z\in\mathbb{R}$ [5]. Then S is an S-metric but is not a G-metric.

Definition 1.5. [9] Let (X,G) be a G-metric space. A circle of center $x_0\in X$ and radius $r\in(0,\infty)$ is defined as follows:

$$C_G(x_0,r)=\{x\in X: G(x_0,x,x)=r\}.$$

Definition 1.6. [10] Let (X,S) be an S-metric space and $T:X\to X$ be a self-mapping. Then T is called a generalized modified C-Khan type F-contraction if there exist $F\in\mathcal{F}$, a number $\tau>0$ and $x_0\in X$ such that

$$S(Tx,Tx,x)>0\Rightarrow$$
$$\tau+F(S(Tx,Tx,x))\le F\left(h\frac{S(Tx,Tx,x)S(x,x,Tx_0)+S(x_0,x_0,Tx_0)S(x_0,x_0,Tx)}{S(x,x,Tx_0)+S(Tx,Tx,x_0)}\right),$$

for all $x\in X$, where $h\in[0,1)$ is a constant.

2. MAIN RESULTS

In this section, we obtain new solutions to the fixed-circle problem on G-metric spaces.

Definition 2.1. Let (X,G) be a G-metric space and $T:X\to X$ be a self-mapping. Then T is called a modified C_G-Khan type contraction if there exists $x_0\in X$ such that

$$G(Tx,Tx,x) \le h\frac{G(Tx,Tx,x)G(x,x,Tx_0)+G(x_0,x_0,Tx_0)G(x_0,x_0,Tx)}{G(x,x,Tx_0)+G(Tx,Tx,x_0)},$$

for all $x \in X$, where $h \in [0,1)$ is a constant.

Theorem 2.2. Let (X,G) be a G-metric space, $T: X \to X$ be a self-mapping and $C_G(x_0,r)$ be a circle on X. If T is a modified C_G-Khan type contraction for all $x \in C_G(x_0,r)$ with $Tx_0 = x_0$, then T fixes the circle $C_G(x_0,r)$.

Proof. Let $x \in C_G(x_0,r)$ and $x \neq Tx$. Using the hypothesis, we obtain

$$G(Tx,Tx,x) \le h\frac{G(Tx,Tx,x)G(x,x,Tx_0)+G(x_0,x_0,Tx_0)G(x_0,x_0,Tx)}{G(x,x,Tx_0)+G(Tx,Tx,x_0)}$$

$$= \frac{hrG(Tx,Tx,x)}{r+G(Tx,Tx,x_0)}$$

and so we get the following cases:

Case 1: If $G(Tx,Tx,x_0) = r$ then we obtain

$$G(Tx,Tx,x) \le \frac{hrG(Tx,Tx,x)}{2r} = \frac{h}{2}G(Tx,Tx,x),$$

which implies

$$Tx = x,$$

since $h \in [0,1)$.

Case 2: If $G(Tx,Tx,x_0) > r$ then we have

$$G(Tx,Tx,x) \le \frac{hrG(Tx,Tx,x)}{2r} = \frac{h}{2}G(Tx,Tx,x),$$

which implies

$$Tx = x,$$

since $h \in [0,1)$. This is a contradiction with $x \in C_G(x_0,r)$.

Case 3: If $G(Tx,Tx,x_0) < r$ then we have

$$G(Tx,Tx,x) \le hG(Tx,Tx,x),$$

which implies

$$Tx = x,$$

since $h \in [0,1)$. This is a contradiction with $x \in C_G(x_0,r)$.

Consequently, $C_G(x_0,r)$ is a fixed circle of T. □

Example 2.3. Let $\mathbb{R}$ be the G-metric space with the G-metric defined as

$$G(x,y,z) = |x-y| + |x-z| + |y-z|,$$

for all $x,y,z \in \mathbb{R}$ [11]. Let us consider the circle $C_G(0,4)$ and define the self-mapping $T: \mathbb{R} \to \mathbb{R}$ by

$$Tx = \begin{cases} x & , \quad x \in C_G(0,4) \\ 0 & , \quad otherwise \end{cases}$$

for all $x \in \mathbb{R}$. Then T satisfies the conditions of Theorem 2.2. and so $C_G(0,4)$ is a fixed circle of T.

Definition 2.4. Let (X,G) be a G-metric space and $T: X \to X$ be a self-mapping. Then T is called a generalized modified C_G-Khan type F-contraction if there exist $F \in \mathcal{F}$, a number $\tau > 0$ and $x_0 \in X$ such that

$$G(Tx,Tx,x) > 0 \Rightarrow$$
$$\tau + F(G(Tx,Tx,x)) \le F\left(h \frac{G(Tx,Tx,x)G(x,x,Tx_0) + G(x_0,x_0,Tx_0)G(x_0,x_0,Tx)}{G(x,x,Tx_0) + G(Tx,Tx,x_0)} \right),$$

for all $x \in X$, where $h \in [0,1)$ is a constant.

Theorem 2.5. Let (X,G) be a G-metric space, $T: X \to X$ be a self-mapping and $C_G(x_0,r)$ be a circle on X. If T is a generalized modified C_G-Khan type F-contraction for all $x \in C_G(x_0,r)$ with $Tx_0 = x_0$, then T fixes the circle $C_G(x_0,r)$.

Proof. Let $x \in C_G(x_0,r)$ and $x \ne Tx$, that is, $G(Tx,Tx,x) > 0$. Using the hypothesis, we obtain

$$\tau + F\left(G\left(Tx,Tx,x\right)\right) \le F\left(h\frac{G\left(Tx,Tx,x\right)G\left(x,x,Tx_0\right)+G\left(x_0,x_0,Tx_0\right)G\left(x_0,x_0,Tx\right)}{G\left(x,x,Tx_0\right)+G\left(Tx,Tx,x_0\right)}\right)$$

$$= F\left(\frac{hrG\left(Tx,Tx,x\right)}{r+G\left(Tx,Tx,x_0\right)}\right)$$

and so we get the following cases:

Case 1: If $G\left(Tx,Tx,x_0\right)=r$ then we obtain

$$\tau + F\left(G\left(Tx,Tx,x\right)\right) \le F\left(\frac{hrG\left(Tx,Tx,x\right)}{2r}\right) = F\left(\frac{h}{2}G\left(Tx,Tx,x\right)\right).$$

Since F is strictly increasing, we have

$$G\left(Tx,Tx,x\right) < \frac{h}{2}G\left(Tx,Tx,x\right) < hG\left(Tx,Tx,x\right),$$

which is a contradiction since $h<1$. So we obtain

$$G\left(Tx,Tx,x\right)=0,$$

that is,

$$Tx = x.$$

Case 2: If $G\left(Tx,Tx,x_0\right)>r$ then we have

$$\tau + F\left(G\left(Tx,Tx,x\right)\right) \le F\left(\frac{h}{2}G\left(Tx,Tx,x\right)\right).$$

Using the strictly increasing property, we have

$$G\left(Tx,Tx,x\right) < hG\left(Tx,Tx,x\right),$$

which is a contradiction since $h<1$. It should be $Tx=x$ which is a contradiction with $x \in C_G\left(x_0,r\right)$.

Case 3: If $G\left(Tx,Tx,x_0\right)<r$ then we obtain

$$\frac{1}{G\left(Tx,Tx,x_0\right)} > \frac{1}{r},$$

$$\frac{1}{r+G\left(Tx,Tx,x_0\right)}>\frac{1}{2r}$$

and

$$F\left(\frac{hrG\left(Tx,Tx,x\right)}{r+G\left(Tx,Tx,x_0\right)}\right)>F\left(\frac{hrG\left(Tx,Tx,x\right)}{2r}\right)=F\left(\frac{h}{2}G\left(Tx,Tx,x\right)\right).$$

So, we have

$$\tau+F\left(G\left(Tx,Tx,x\right)\right)\leq F\left(\frac{hrG\left(Tx,Tx,x\right)}{r+G\left(Tx,Tx,x_0\right)}\right)>F\left(\frac{h}{2}G\left(Tx,Tx,x\right)\right).$$

In this case, we can not get any conclusion. Consequently, $C_G\left(x_0,r\right)$ is a fixed circle of T . □

3. CONCLUSION AND FUTURE WORKS

In this study, we established new fixed-circle results on G-metric spaces by employing a generalized modified Khan-type contraction. These results demonstrate that the fixed-circle framework can be meaningfully extended beyond classical metric settings and adapted to more sophisticated geometric environments such as G-metric spaces. The proposed contraction condition not only broadens the spectrum of admissible mappings but also provides a unified approach for obtaining fixed-circle theorems under weaker or more flexible assumptions. Our findings reveal the strength of the modified Khan-type structure in capturing geometric stability on circular subsets, highlighting its potential in both theoretical developments and applications involving generalized distance functions. Overall, the results contribute to the expanding landscape of fixed point geometry and emphasize how G-metric spaces offer a fertile ground for new fixed-set phenomena.

Several interesting directions arise from this investigation:

- Extension to best-proximity circles: One may study whether the generalized modified Khan-type contraction can be adapted to obtain best-proximity circle results between non-self mappings in G-metric spaces.
- Order-theoretic extensions: It would be worthwhile to examine fixed-circle theorems under the presence of partial orders or monotone structures on G-metric spaces.

- Broader contraction families: Future work may explore whether other contraction families (e.g., rational, Wardowski-type, or α–ψ–type contractions) admit fixed-circle analogues on G-metric spaces.
- Applications to nonlinear analysis: The established results could be applied to iterative methods, differential or integral equations, and neural-network activation models defined on generalized metric frameworks.
- Stability and data-dependent fixed circles: Another direction is the analysis of Ulam–Hyers stability or data-dependent versions of fixed-circle results under modified Khan-type contractions.

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SUSTAINABLE CONCRETE FROM WASTE: SYNERGISTIC USE OF SEWAGE SLUDGE ASH, SILICA FUME AND RECYCLED PLASTIC.

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ABSTRACT

The by-product of burning wastewater is sewage sludge ash (SSA), which has been shown to have promising application in the production of bricks, artificial aggregate, and cement substitutes for concrete. Plastics are widely accessible, affordable, lightweight, and versatile, but their growing waste production presents significant environmental problems. In order to improve sustainability while preserving performance, this study investigates the combined use of recycled plastic as a partial replacement for fine aggregate and silica fume with sewage sludge ash as cement replacements in concrete. Mechanical, durability, and environmental properties were investigated on eight different combinations. After 28 days, the results indicated that the control mix had the highest slump, while the mix containing 10% SF and 5% SSA (mix 3) performed the best, improving its compressive strength by 18% and its splitting tensile strength by 6%, respectively, in comparison to the control. Additionally, the same mixture showed better resilience to acid attack and a 33% reduction in water absorption. According to an environmental assessment, adding silica fume, sewage sludge ash, and recycled plastic reduced embodied carbon emissions by 13–14%.

Keywords: Recycled plastic, Sewage sludge ash, Supplementary cementitious material, Sustainable concrete.

Biochar-Enhanced Cement Mortar Using Pyrolyzed Posidonia Oceanica Leaves: Mechanical, and Durability Properties

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Abstract

Over the past two decades, growing sustainability concerns in cement production have driven the search for alternative materials. This study examines the use of Posidonia Oceanica leaf biochar (PBC), at dosages ranging from 1% to 6% as a partial replacement for cement in mortar. The research focuses on its impact on the rheological, mechanical, and durability attributes across curing times of 7 and 28 days in both wet and dry environments, while keeping a constant temperature of 20 °C and water to cement ratio at 0.35. The experimental result at 28 days, shoiws that every blend was higher compared to baseline mixture at 7 days. PBC reduces flowability and fresh density. PBC content (1–2%) of PBC slightly improve compressive and flexural strengths, while higher concentrations tend to decrease performance and increase shrinkage. Moreover, PBC enhances acid resistance and demonstrates superior fire resistance at elevated temperatures. The best overall results were observed at 2% PBC content, effectively balancing strength and durability. These findings highlight the potential of PBC to contribute to more sustainable and resilient cement-based materials. Flexural strength improved with moderate PBC content but declined at higher levels. However, PBC6 exhibits a 7.3% increase in water absorption due to the porous nature of the biochar, while mixes with 1–%2% PBC (14% and 14.5%) showed improved resistance to acid attack. Under fire exposure, all mixes experienced strength loss, but PBC6, with (88.4%), retained the highest residual strength at 600°C. Excessive PBC (5–6%) increased shrinkage and compromised durability, indicating that 1–2% PBC and combined PBC2WGP 15 and PBC2WG20 offer the best overall performance.

Keywords: Biochar; Cementitious materials; Fresh and hardened properties; Glass Powder; Posidonia Oceanic leaves; Sustainable waste

BREAST CANCER DETECTION USING DEEP LEARNING POWERED APPROACH

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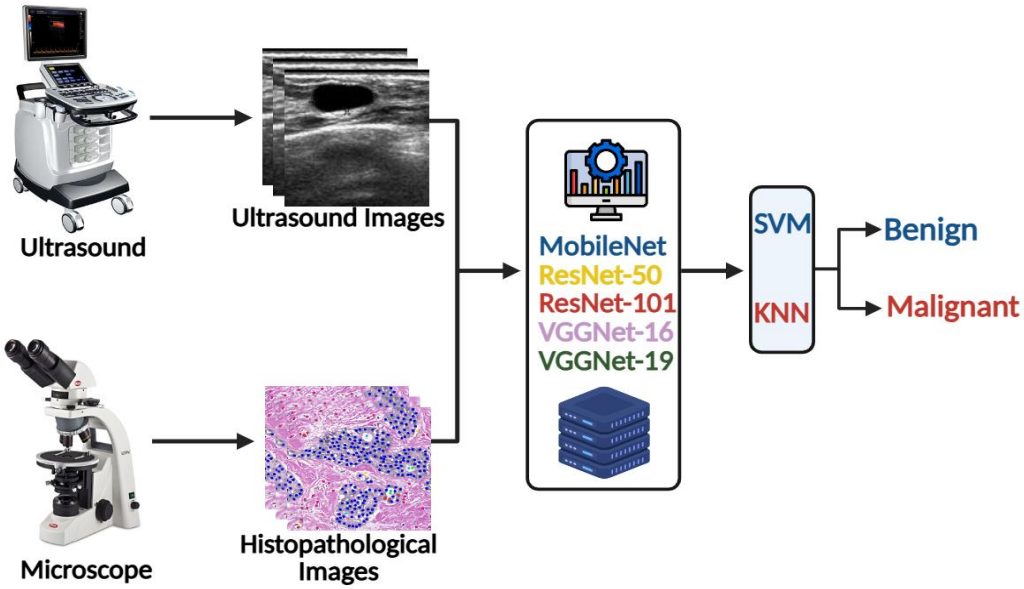
ABSTRACT

Breast cancer is one of the most common cancers worldwide. Early and accurate diagnosis of breast cancer is crucial for timely treatment. The medical experts rely on conventional methods of medical imaging and biopsy. These techniques are highly challenging. To address these challenges, scientists integrate machine learning techniques. This study aims to use a deep learning-powered approach to detect breast cancer from histopathological and ultrasound image data sets. In this study, we proposed using 5 pre-trained models fused with a Support Vector Machine (SVM) and K-nearest neighbor (KNN) for the binary classification of breast cancer. The study employed 5 datasets obtained from the Kaggle repository. The datasets include: (3 histopathological datasets of 7783 Breast Cancer datasets, 10000 Multi Cancer datasets and 400 BreakHis-histopathological images), and (2 ultrasound datasets of 9016 Ultrasound Breast Classification datasets and 1578 Ultrasound Breast Images datasets). The model's performance evaluation indicated that ResNet50-SVM achieved the best result for classifying Breast Cancer from multi-cancer Datasets with 99.25% accuracy. Residual Networks (ResNet) ResNet50-KNN achieved the best result for classifying the Breast Cancer Dataset with 94.22% accuracy.

ResNet101-SVM achieved the best result for classifying the BreaKHis 400X dataset with 93.2% accuracy. Visual Geometry Group Network (VGGNet) VGG19-SVM achieved the best result for classifying Ultrasound Breast Cancer Classification with 98.84% accuracy. The study provides the medical experts with an opportunity where real-time data can be processed and validated.

Keywords: Malignant Cancer; Benign Cancer; Histopathological images; Ultrasound Images; Deep Learning; Medical Image diagnosis

Graphical Abstract



1. INTRODUCTION

Breast cancer and skin cancer are two of the most common cancers in women. According to estimates, more than 1.6 million new cases of breast cancer were diagnosed in women worldwide in 2012, with women over the age of 55 accounting for the majority of these cases (Mammone, Alessia, Marco Turchi 2009). Uncontrolled growth of breast cells is the first step in the development of breast cancer. A tumor results from these cells growing together; it can be identified by X-ray or as a lump in the breast. When breast cancer cells proliferate and invade neighboring tissue and other body parts, the cancer may turn malignant (Abdollahi et al. 2022). Despite technological advancements and computer-aided detection methods, the causes of breast cancer and other cancers remain unknown or entirely unclear. Several factors, including genetics, age, female sex hormones, and predisposition, are important in the

development of breast cancer. Unknown is the mechanism by which these factors cause or facilitate the development of breast tumors (Al-Ejeh et al. 2014). Typical signs of breast cancer include swelling, redness, and an increase in body temperature in a portion or the entire breast, which are symptoms of inflammation of the breast. Nipple peeling, redness, and sore formation; persistent, widespread pain in one or both breasts; hard masses in one or two breast organs that are characterized by lump size, texture, shape, occurrence of smooth and rough edges, discharge of fluid other than breast milk, bleeding, nipple contraction and retraction, breast thickening and redness, and significant breast lymph node swelling (Bhatia 2010; Al-Ejeh et al. 2014). To diagnose and treat breast cancer, it is essential to comprehend the disease's stages and severity. Breast cancer can be categorized by grade and aggressiveness (invasive versus non-invasive). Breast cancer that spreads outside of the breast is known as invasive breast cancer. Cells or tissue in the ducts that carry milk to the nipples can harbor invasive ductal breast cancer, also known as ductal carcinoma, the most prevalent type of invasive breast cancer. Additional instances include invasive lobular breast cancer and inflammatory breast cancer. In situ carcinoma is a type of breast tumor that is non-invasive and is found in the breast. Breast palpation is difficult to detect this type of cancer, which can only be found in a mammogram. In addition, there are other forms of breast cancer, such as triple-negative breast cancer, metastatic breast cancer, and other uncommon forms (Mammone, Alessia, Marco Turchi 2009; Abdollahi et al. 2022).

Breast cancer can be classified based on its Grade, and this type of classification is among the common types of breast cancer classification, wherein the tissue under biopsy is evaluated based on the tumor's morphology about healthy or normal tissue, as well as the rate of the division of the cells. Cells that exhibit a slow rate of growth or division are referred to as being of a “lower grade.” When cells show rapid growth or division and tend to invade adjacent tissues or cells, this phenomenon is called “high grade.” Additional classifications of grades encompass the Nottingham grade, Elston-Ellis’s grade, Bloom Richardson grade, and Scarf Bloom Richardson grade (Al-Ejeh et al. 2014). This classification may also be indicated as follows:

• Grade 1: Cancer is designated as grade 1 when its appearance resembles normal cells but remains well differentiated.
• Grade 2: Cancer is classified as grade 2 when it exhibits moderate differentiation.
• Grade 3: Cancer is classified as grade 3 when it is significantly difficult to recognise the cells and proliferates or advances exceptionally rapidly.

A biopsy is among the initial diagnostic procedures for breast cancer, conducted when a physician has reason to suspect the existence of a tumor. The biopsy technique involves the acquisition of breast tissue samples, which are subsequently examined microscopically (Bhatia 2010). The diagnosis or screening of breast cancer can be effectively accomplished through the use of mammography, a method characterized by its simplicity, safety, and cost-effectiveness. This methodology can identify cancer cells at an incipient phase (stage zero and stages 1A-1B) when symptoms remain undetectable. Regular mammography has been demonstrated to mitigate or diminish the likelihood of developing malignant or chronic cancers that present significant challenges in terms of treatment (i.e., stages 3-A, 3-B, 3-C, and 4). This method employs X-ray technology to capture images of the breast's mammary glands, conducted within a designated space equipped with mammography machines (Bhavsar and And 2012) (Figure 1).

1.1 Challenges

Breast cancer is one of the leading causes of death among women in both developed and developing nations. Even though there are different diagnostic approaches ranging from biopsy, mammography, CT scan, etc, some of the drawbacks of biopsy include: It is highly challenging to differentiate histopathologic features into grade manually. It requires the use of chemicals and the experience of pathologists. At the same time, some of the limitations of medical imaging include the need for experienced medical professionals, high workload, or the tediousness of carrying thousands of diagnoses, which can lead to misgrading or misinterpretation.

o solve these issues, scientists adopted AI-based techniques, which have been shown to effectively classify images according to labels (i.e., supervised). Artificial intelligence is a field that seeks to study and design machines capable of human intelligence and decision-making. Artificial intelligence can be divided into machine learning and deep learning. DL is a subfield of ML that works similarly to the human brain by taking data and processing it through networks and neural network layers. DL, such as Convolutional Neural Networks (CNNs) and Artificial Neural Networks (ANNs), have revolutionized CAD technology. Currently, many AI-driven models perform better than medical experts in terms of the classification of diseases. Thus, the contribution of this study is outlined as follows:

- To train and validate several pre-trained models for the classification of Ultrasound images
- To train and validate several pre-trained models for the classification of biopsy images
- To fuse ML classifiers such as SVM and KNN with pre-trained CNNs
- To conduct an unbiased comparison between model performances with previous studies.

Related work

The research performed by Karthiga et al. (Karthiga et al. 2022) (Table 1) proposed the use of pretrained models for the binary classification of malignant and benign breast cancer using mammographic images. The experimental setup of the study is organized according to several phases, which include pre-processing, construction of CNNs, Contrast Limited Adaptive Histogram Equalisation (CLAHE), data augmentation to maximize the training set, segmentation using polynomial curve fitting, and cropping of the breast region. The study applied the proposed CNN (constructed using 3 convolution layers, 2 max-pooling layers, 5 ReLU layers, 3 batch normalization layers, and 3 fully-connected layers), and 2 pretrained models known as AlexNet and VGGNet for training and validation of mammographic images from 3 sources, which include Mammogram Image Analysis Society (MIAS) with 3816 images and Digital Dataset for Screening Mammography (DDSM) with 13128 images and the INbreast dataset with 7632 images (i.e., 24576 total images). The performance evaluation of the models has shown that the proposed model achieved 95.95% accuracy on the MIAS dataset, 99.39% accuracy on the DDSM dataset and 96.53% on the INbreast dataset, and 92.27% accuracy on (MIAS+DDSM+INbreast).

Abdolahi et al. (M. Abdolahi, M. Salehi, I.Shokatian 2020) Trained and validated 277524 image patches using CNN, the baseline model, and VGG16 to classify breast pathology images (Table 1). The study acquired a dataset made available on the Kaggle website, which contains images of patients diagnosed with Invasive Ductal Carcinoma (IDC) and control (i.e., 78786 images belong to "IDC (+) and 198738 images to “IDC (-)). The performance

evaluation of the model has shown that the baseline model achieved 85% accuracy, 86% precision, and 83% F1-Score, while pretrained VGG16 achieved 81% accuracy, 81% precision, and 81% F1-Score.

Abdolahi et al. (Abdollahi et al. 2022) Proposed a deep learning-based approach for automatically identifying metastatic breast cancer (Table 1). The study utilized 220025 whole-slide pictures from patients' lymph nodes (obtained from Kaggle titled Camelyon16 dataset), partitioned into 60:40 for training and testing, respectively. For identification of metastatic breast cancer, a hybrid CNN (VGG16, Resnet50) and two fully-trained ones (Google Net and Mobile Net). The performance evaluation of the models has shown that VGG-16 achieved the best result with an accuracy of 98.84%, a precision of 92.42%, and a recall of 91.25%.

Another study that utilized histopathological images was proposed by Mahmood et al. (Mahmood et al. 2020). The study applied deep CNNs and a Faster region convolutional neural network (Faster R-CNN for multistage mitotic-cell detection (Table 1). To train and validate the models, the study acquired datasets from 2 different sources, including ICPR 2014 (MITOS-ATYPIA-14) and the International Conference on Pattern Recognition (ICPR) 2012. By comparing the results on the 2 datasets, the proposed Faster R-CNN achieved a precision of 0.848, a recall of 0.583, an F1-measure of 0.691 using the ICPR 2014 dataset, and a precision of 0.876, a recall of 0.841, and an F1-measure of 0.858 F1 using the ICPR 2012 dataset.

On the other hand, Tsochatzidis et al. (Tsochatzidis et al. 2019) Applied several CNNs, including AlexNet, VGGNets, Inception, and ResNet, to detect breast cancer (Table 1). The study utilized 2 different datasets, including DDSM-400 (400 mass ROIs extracted from the Digital Database for Screening Mammography) and Curated Breast Imaging Subset-DDSM (CBIS-DDSM), which contain 10,239 mammographic images. The performance of deep neural networks was conducted based on (1) using the from-scratch training scenario and (2) initialized on pre-trained weights (fine-tuning). The performance evaluation and comparison of the models have shown that ResNet-101 achieved the best result with 78.5% accuracy on DDSM-400 and ResNet-152 with 75.5% accuracy on CBIS-DDSM.

han et al. (Khan et al. 2019) Used pretrained models for binary classification into benign and malignant images (Table 1). The study is designed according to several phases, which include data collection of microscopic images from 2 sources, which include a standard benchmark dataset and locally developed images at the LRH hospital in Peshawar, Pakistan. Data augmentation was conducted via color modeling, translation, and rotation to scale up the training set, leading to 8000 total images. The images were processed to remove noise and split into training (6000) and testing (2000), followed by feature extraction using pretrained models, which include Visual Geometry Group Network (VGGNet), GoogleNet and ResNet and the proposed framework (GoogleNet, VGGNet, and ResNet are used to share their properties on transfer learning and fine-tuning), which are fed into a fully connected layer for classification. The framework is evaluated based on computing the average accuracies of different Lens Magnification (100X, 140X, 200X, and 500X), which led to 93.5% accuracy using GoogleNet, 94.15% accuracy using VGGNet, 94.35% accuracy using ResNet and 97.525 % accuracy using the proposed framework.

Saber et al. (Saber et al. 2021) proposed using pretrained CNN architectures to classify mammographic images (Table 1). The study utilized a dataset called Mammographic Image Analysis- Society (MIAS), which contains 322 images (61 benign cases, 52 malignant cases, and 209 normal cases). Data augmentation was carried out via clockwise rotation and flipping to increase the input data. The classification of mammographic images revolves around extracting features using pre-trained VGG-16, VGG-19, ResNet, and Inception-V2. The pre-trained models were evaluated using an 80:20 data split and 10k cross-validation. The result

indicated that pretrained VGG16 achieved the best result with 98.96% overall accuracy, 97.83% sensitivity, 99.13% specificity, 97.35% precision, 97.66% F-score, and 0.995 AUC score based on 80:20 split and 98.87% overall accuracy, 97.27% sensitivity, 98.2% specificity, 98.84% precision, 98.04% F-score, and 0.993 AUC score based on 10k cross-validation.

Vaka et al. (Vaka et al. 2020) The Deep Neural Network with Support Value (DNNS) was introduced to classify histopathological images into benign and malignant (Table 1). The study acquired 8009 histopathology image samples (2580 benign and 5429 malignant) of over 683 patients of various magnification levels from the M. G Cancer Hospital & Research Institute, Visakhapatnam, India. Data augmentation was carried out via rotation (900, 1800, and 2700) to increase the input data. The performance evaluation of the proposed approach (Deep Neural Network with Support Value (DNNS)) achieved 97.21% accuracy,97.9% precision, and 97.01% recall.

Table 1. Summary of related work

REFERENCE	DATA SET	ML/DL MODEL	RESULTS
(Karthiga et al. 2022)	Mammogram Image Analysis Society [MIAS], Digital Dataset for Screening Mammography [DDSM] and the INbreast dataset	AlexNet and VGGNet	92.27% accuracy on (MIAS+DDSM+INbreast)
(M. Abdolahi, M. Salehi, I.Shokatian 2020)	The cancer institute of new jersey and Pennsylvania University Hospital	Baseline model and VGG-16	85% accuracy, 86% precision, and 83% F1-Score using a baseline model
(Mahmood et al. 2020)	International Conference on Pattern Recognition [ICPR] 2012 and 2014	Faster R-CNN	0.876 Precision and 0.841 Recall using ICPR 2012, and 0.848 Precision and 0.583 Recall using ICPR 2014
(Abdollahi et al. 2022)	Camelyon16 dataset	VGG-16	92.42% Precision and 91.25% Recall
(Tsochatzidis et al. 2019)	DDSM-400 & Curated Breast Imaging Subset-DDSM [CBIS-DDSM]	AlexNet, VGGNets, Inception, ResNet	ResNet-101 with 78.5% ACC on DDSM-400 & ResNet-152 with 75.5% ACC on CBIS-DDSM
(Khan et al. 2019)	Standard benchmark dataset and locally developed images at the LRH hospital in Peshawar, Pakistan	proposed framework (GoogleNet, VGGNet, and ResNet	97.525 % accuracy
(Saber et al. 2021)	Mammographic image analysis- society (MIAS)	pretrained VGG-16, VGG-19, ResNet and Inception-V2	98.96% overall accuracy, 97.83% sensitivity, 99.13% specificity, 97.35% precision, 97.66% F-score, and 0.995 AUC

(Vaka et al. 2020)	M. G Cancer Hospital & Research Institute, Visakhapatnam, India	Deep Neural Network with Support Value (DNNS)	97.21% accuracy, 97.9% precision, and 97.01% recall

2.1 Limitation of Existing Approaches

In the literature, most existing articles used pretrained networks such as ResNet, AlexNet, and VGGNet, using SoftMax as a Classifier. Secondly, most of the studies utilized a single dataset. Thirdly, some of the articles only use 1 or 2 pre-trained models. However, this study will use several classifiers, such as SVM and KNN and train models using several datasets (i.e., RSNA, Breast Ultrasound, Breast histopathological datasets, and MIAS mammography datasets).

2.2 Aim of the study

In this study, we proposed the use of 5 pre-trained models, which include ResNet-50, ResNet-101, VGGNet-16, VGGNet-19, and MobileNet, fused with SVM and KNN for the binary (benign and malignant) and multiclass classification of breast cancer into benign and malignant and normal. After a careful search of other literature, we discovered that few or no articles published in the past 10 to 20 years involved using or combining such pre-trained models for the classification of breast cancer into different grades.

Methodology

Medical data in texts, audio, and images drives medical diagnosis. These data help medical experts conduct accurate diagnoses, crucial for timely and appropriate treatment. Thus, the main aim of this study is to apply pretrained models fused with classifiers for accurate and automatic detection of breast cancer from histopathological and ultrasound images. Thus, several pretrained models selected due to their performance in computer vision application, namely, ResNet-101, ResNet-50, MobileNet, VGG16, and VGG19, are fused with 2 classifiers, which include SVM and KNN, for binary (benign and malignant) and ternary (normal, benign, and malignant) classification of histopathological and ultrasound images as summarized in Figure 1.

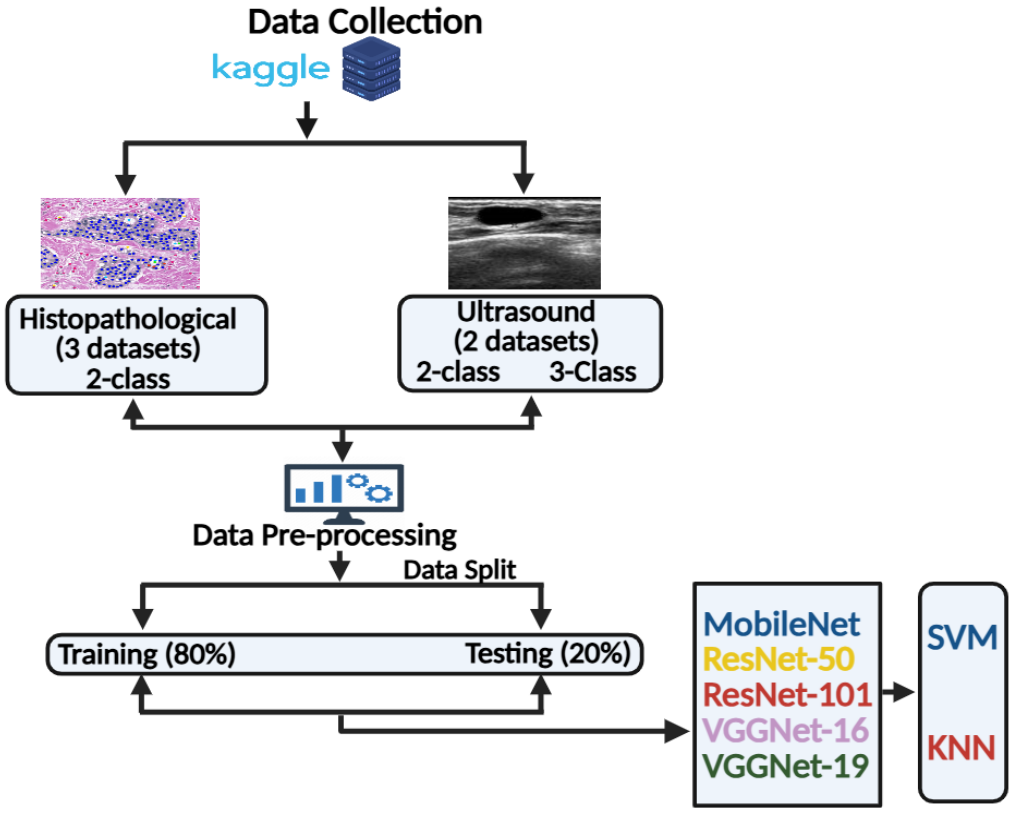


Figure 1: Overall Methodology from the Data collection of 5 datasets obtained from the Kaggle Repository, 3 of the datasets containing two classes (Benign and Malignant), while the remaining dataset includes 3 classes (Normal, Benign and Malignant). The remaining part of the methodology is Data pre-processing. Phase, Data split. Phase, Deployment of ensemble models, phase and SVM and KNN.

3.1 Dataset

The dataset to be employed in this study includes 5 different datasets curated from Kaggle:

3.1.1 Breast Cancer Dataset

The breast cancer dataset is a binary class dataset with histopathological images classified into benign (2,479) and malignant (5304) images (Table 2). The dataset can be accessed at https://www.kaggle.com/datasets/anaselmasry/breast-cancer-dataset.

3.1.2 Multi-Cancer Dataset

The multicancer dataset contains 8 different types of cancer, which include breast, brain, cervical, Acute Lymphoblastic leukemia, oral, Lung and Colon Cancer, kidney, and lymphoma. However, breast cancer was selected as the class of interest. The class is divided into 2 sub-classes, which include 5000 benign and 5000 malignant (Table

2). The dataset can be accessed at https://www.kaggle.com/datasets/obulisainaren/multi-cancer.

3.1.3 BreaKHis 400X dataset

The BreaKHis 400X dataset is a histopathology slide of breast cancer images classified into 2 folders: training and testing. Each folder has 547 benign (371 training and 176) and malignant classes with 1146 (777 training and 369 testing) (Table 2). The dataset can be accessed at https://www.kaggle.com/datasets/forderation/breakhis-400x.

3.1.4 Ultrasound Breast Classification Dataset

The ultrasound breast classification dataset contains 2 folders: train and validation. The binary folder dataset includes benign with 4574 ultrasound images (4074 training and 500 validation) and malignant with 4442 ultrasound images (4042 training and 400 validation) (Table 2). The dataset can be accessed at https://www.kaggle.com/datasets/vuppalaadithyasairam/ultrasound-breast-images-for-breast-cancer.

3.1.5 Breast Ultrasound Images Dataset

The breast ultrasound dataset comprises 3 folders, which include benign (891), malignant (421), and normal (266) (Table 2). The dataset can be accessed at (https://www.kaggle.com/datasets/aryashah2k/breast-ultrasound-images-dataset).

Table 2. Summary of the Dataset

Name	Type	Classes	Number of images
Breast Cancer Dataset	Histopathological	2	7783 (2479 BG and 5304 MG)
Multi-Cancer Dataset	Histopathological	2	10,000 (5000 BG and 5000MG)
BreaKHis 400X dataset	Histopathological	2	1693 (547 BG and 1146 MG)
Ultrasound Breast Classification Dataset	Ultrasound	2	9,016 (4574 BG and 4442 MG)
Breast Ultrasound Images Dataset	Ultrasound	3	1578 (266 NM, 891 BG and 421MG)

*BG: Benign; MG: Malignant; NM: Normal

3.2 Pretrained Models and Classifiers

In this study, 5 pretrained models are selected, which include 2 variants of ResNet (ResNet-101 and ResNet-50, 2 variants of VGGNet (VGG16 and VGG19) and MobileNet. These pretrained models are chosen based on their performance in several computer vision applications, even though several deep learning architectures include DenseNet, EfficientNet, Inception, Xception, AlexNet, etc. However, these pretrained models are adopted due to their moderate hidden layers (above 10 and less than 100), as in the case of ResNets and VGGNets, while MobileNet is selected due to its lightweight traits.

3.2.1 Visual Geometry Group Network (VGGNet)

VGGNets are CNN architectures developed by scientists from the VGG group in Oxford. The CNN architecture became runner-up in the 2014 ILSVRC competition with 92.7% accuracy. VGGNets are designed to improve AlexNet, where the large

kernel-sized filters in the first and second convolutional layers (i.e., 11x11 and 5x5) are replaced with multiple 3x3 kernel-sized filters. The main reason behind this replacement is that multiple stacked small-sized filters perform better than larger ones because multiple non-linear layers increase the depth of the architecture, which promotes the learning of complex features (Simonyan and Zisserman 2014; Jaderberg et al. 2016).
The most popular VGGNets are the VGG16 and VGG19. VGG16 comprises 13 convolutional layers followed by 3 fully connected layers, while VGG19 comprises 16 convolutional layers and 3 fully connected layers. VGGNets are designed using ReLu as an activation function and accept input images with a size of 224x224x3. The architecture uses SoftMax as a classifier and can classify up to 1000 classes. (Simonyan and Zisserman 2014).

3.2.2 Residual Networks (ResNets)

ResNets are a group of CNN architectures developed by He et al. (He et al. 2016). The network became top overall in 2015 ILSVRC with 95.51% accuracy. The CNN architecture is developed to solve the issue of vanishing gradients and prevent higher training errors (as a result of training deeper networks). Unlike the inception module in GoogleNet, ResNet is designed using residual blocks. There are several variations of ResNets, including ResNet18, ResNet35, ResNet50, ResNet101, ResNet152, and ResNeXT. ResNet uses several convolutional layers, and batch normalization is used after every convolution. Also, there is no dropout layer in the architecture. Like GoogleNet, ResNet also uses global average pooling followed by SoftMax classification. Thus, it lacks a fully connected layer and can classify up to 1000 classes. (H.C. Shin, H.R. Roth, M. Gao, L. Lu, Z. Xu, I. Nogues, J. Yao, D.J. Mollura 2016; Targ et al. 2016).

3.2.3 MobileNet

Most existing models are very heavy, with higher Computational parameters designed for high-performance computers with suitable graphics applications. To create a lighter and less Computational CNN architecture that can be used for mobile phone applications, the Google team developed MobileNet in 2017. The model is designed based on 2 different types of convolution, known as pointwise and depthwise. The primary function of the depthwise separable convolution is to minimize complexity and model size. (Howard et al. 2017).
The model uses 28 overall layers, including pointwise and depthwise separable convolution. The convolutional layers are designed to perform 3 primary operations: convolution, batch normalization, and ReLu, except the last FCL, equipped with SoftMax for classification. To downsample the output, a strider convolution is used in the first layer's pointwise and depthwise separable convolution. In the final convolutional layer, average pooling is applied to minimize the spatial resolution before feeding the output into the FCL.

3.2.4 Support Vector Machine (SVM)

SVM is one of the most popular ML algorithms for solving regression, linear and non-linear classification tasks, and outlier detection tasks. The ML algorithm is currently employed to solve tasks ranging from image and text classification, spam classification, face and anomaly detection, handwriting identification, etc. The

mechanism behind the application of SVM revolves around using hyperplanes, which separate different classes of input data. Moreover, the main objective of the SVM algorithm is to discover the optimal hyperplane in an N-dimensional space that can discriminate data points into different classes. The role of the hyperplane is to find the minimum margin between the closest points of the classes. Thus, the dimension of the margin relies upon the number of features. Therefore, for binary classification, the hyperplane is 1D or a single line, while for 3 input classes, the hyperplane is 2D. However, one of the drawbacks of SVM is that it is challenging to classify more than 3 classes. (Mammone, Alessia, Marco Turchi 2009; Bhavsar and And 2012).

3.2.5 K-Nearest Neighbour (KNN)

KNN is another supervised ML algorithm used to solve regression and classification problems. The algorithms take advantage of the "that similar data points tend to have similar values or labels." Like other SML algorithms, KNN algorithms undergo training in which the classifiers store the entire training input data as a reference. Thus, when making predictions, it estimates the distance between the input data point and the whole training example by employing Euclidean distance (distance metric) (Bhatia 2010; Zhang 2016).

3.3 Training

The histopathological and ultrasound images are trained using 80% of the dataset and validated using 20%. Both training and testing were conducted using MATLAB installed on a PC. The models were evaluated based on training and testing accuracies, sensitivities, specificities, AUC, F-1 score, and confusion matrix.

3.4 Performance Metrics

Training and testing the ML model is insufficient to generalize its performance and ascertain whether it will perform effectively on real-world data and whether it needs to be improved through optimization, fine-tuning, training with larger datasets, etc. Several evaluation metrics are used to evaluate the performance of ML models on classification tasks. These metrics include accuracy, precision, recall, AUC, F1-score, etc.

3.4.1 Accuracy

Accuracy is a simple evaluation metric that shows the ratio of correctly classified instances over total instances. Thus, accuracy in this context depicts the number of positive and negative tuberculosis cases classified accurately by the model over the total number of cases (Jordan and Mitchell 2015). This can be represented mathematically as:

$$\frac{\#\ of\ correctly\ classified\ cases\ (positive\ and\ negative)}{Total\ \#\ of\ cases} \quad (1)$$

Recall and Precision

Recall and precision are defined based on True Positive (TP), True Negative (TN), False Positive (FP), and False Negative (FN).

TP is the number of positive cases correctly classified as positive (i.e., the number of actual positive cases the model classifies).

TN is the number of negative cases correctly classified as negative (i.e., the number of actual negative cases the model classifies).
FP is defined as the number of actual negative cases that are incorrectly classified as positive cases.
FN is defined as the number of positive cases incorrectly classified as negative. (Jordan and Mitchell 2015).
Precision can be represented as

$$Precision = \frac{TP}{TP+FP} \quad (2)$$

Recall can be represented as

$$Recall = \frac{TP}{TP+FN} \quad (3)$$

F1-Score
F1-Score is another performance metric that combines precision and recall or harmonic mean of precision and recall. The F1 score is applied mainly for classification, especially when there is a class imbalance [29]. It can be represented as

$$F1 - Score = \frac{2}{{}^{1}/_{precision} + {}^{1}/_{recall}} \quad (4)$$

AUC/ROC
The ROC curve compares the True Positive Rate and False Positive Rate. AUC differentiates between classes (i.e., positive, negative/normal, and abnormal). A prediction outcome of closer to one shows that the model is competent. AUC is plotted based on TPR against FPR at various threshold values (Gong 2021).

2. Result and Discussion

Accurate and timely cancer screening is crucial for understanding the best treatment approach and increasing the life span of patients. Incorporating DL models in medical imaging diagnoses aids healthcare experts such as oncologists and radiologists in providing accurate, reliable, and fast diagnoses and minimizing misdiagnoses and misinterpretations. In line with the abovementioned statement, this study proposed applying DL models fused with 2 classifiers for the binary classification of 4 different datasets into benign and malignant.

4.1 Breast Cancer from Multi-Cancer Datasets

The results for the MobileNet-SVM model were as follows: 98.6% accuracy, 99.3% sensitivity, 97.9% specificity, 97.93% precision, 98.61%F1-Score, 97.2% Yonden Index, and 99.91% AUC. On the other hand, the MobileNet-KNN demonstrated 91%accuracy, 99.2% sensitivity, 82.8% specificity, 85.22% precision, 91.68%F1-Score, 82%Yonden Index, and 91%AUC (Table 3) (Figure 2). ResNet50-SVM achieved 99.25% accuracy, 99.5% sensitivity, 99.25% specificity, 99.25% precision, 99.25% F1-Score, 98.5% Yonden Index, and 99.92% AUC. 99.1%accuracy, 99.1% sensitivity, 99.1% specificity, 99.1% precision, 99.1% F1-Score, 99.1%Yonden Index, and 99.1% AUC were shown by ResNet50-KNN (Table 3) (Figure 2). The VGG19-SVM exhibited 98.65% accuracy, 99.8% sensitivity, 97.5% specificity, 97.56% precision, 98.67% F1-Score, 97.3% Yonden Index, and 99.61% AUC. Finally, VGG19-KNN achieved 90.35% accuracy, 100% sensitivity, 80.7% specificity, 83.82% precision, 91.2% F1-Score, 80.7% Yonden Index, and 90.35% AUC (Table 3)

(Figure 2). Training of images using ResNet101-SVM has resulted in 99.3% accuracy, 99.9% sensitivity, 98.7% specificity, 98.72% precision, 99.3% F1-Score, 98.6% Yonden Index, and 99.88% AUC. ResNet101-KNN achieved 98.95% accuracy, 99.3% sensitivity, 98.6% specificity, 98.61% precision, 98.95% F1-Score, 97.9% Yonden Index, and 98.95% AUC. The VGG16-SVM exhibited a 99.15% accuracy, 99.7% sensitivity, 98.6% specificity, 98.62% precision, 99.15% F1-Score, 98.3% Yonden Index, and 99.93% AUC. The performance of VGG16-KNN resulted in 91.32% F1-Score, 81.1% Yonden Index, 90.55% AUC, 99.9% sensitivity, 81.2% specificity, 84.16% precision, and 90.55% accuracy (Table 3) (Figure 2).

Table 3. Performance of the models on Breast Cancer from Multi cancer Datasets

Models	Accuracy	Sensitivity	Specificity	Precision	F1-Score	Yonden Index	AUC
MobileNet-SVM	0.986	0.993	0.979	0.9793	0.9861	0.972	0.9991
MobileNet-KNN	0.91	0.992	0.828	0.8522	0.9168	0.82	0.91
ResNet50-SVM	0.9925	0.995	0.99	0.99	0.9925	0.985	0.9992
ResNet50-KNN	0.991	0.991	0.991	0.991	0.991	0.991	0.991
ResNet101-SVM	0.993	0.999	0.987	0.9872	0.993	0.986	0.9988
ResNet101-KNN	0.9895	0.993	0.986	0.9861	0.9895	0.979	0.9895
VGG16-SVM	0.9915	0.997	0.986	0.9862	0.9915	0.983	0.9993
VGG16-KNN	0.9055	0.999	0.812	0.8416	0.9132	0.811	0.9055
VGG19-SVM	0.9865	0.998	0.975	0.9756	0.9867	0.973	0.9961
VGG19-KNN	0.9035	1	0.807	0.8382	0.912	0.807	0.9035

It was observed that in Table 3, the SVM classifier consistently performs better than the KNN classifier across all metrics when combined with different architectures. Among the models in this group, the ResNet101-SVM model has the best AUC and excellent sensitivity, indicating that it has the potential to be a very dependable tool for cancer detection with low false negatives. Although the VGG19-KNN model achieved an impressive sensitivity, its lower specificity and AUC suggest that it may mistakenly identify non-cancerous conditions as cancerous, which could cause patients to undergo needless medical treatments and stress.

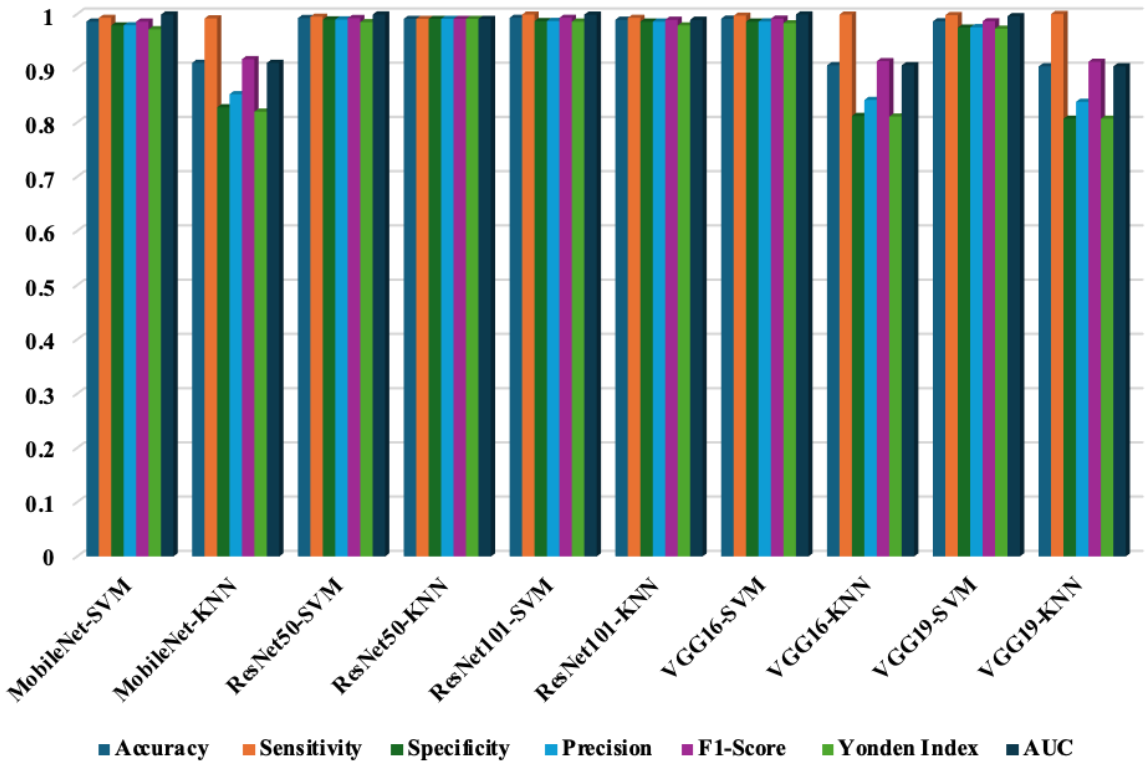


Figure 2: Performance of the models on Breast Cancer from Multi cancer Datasets

4.2 Breast Cancer Dataset

MobileNet-SVM achieved 83.43% accuracy, 87.75% sensitivity, 74.19% specificity, 87.83% precision, 87.83% F1-Score, 61.94% Yonden Index, and 89.54% AUC. The performance evaluation of MobileNet-KNN resulted in an F1-Score of 86.79%, Yonden Index of 50.93%, AUC of 75.46%, specificity of 59.88%, precision of 82.92%, sensitivity of 91.05%, and accuracy of 81.2%. ResNet50-SVM, on the other hand, achieved 92.81% accuracy, 95.98% sensitivity, 86.09% specificity, 93.65% precision, 94.79% F1-Score, 82.07% Yonden Index, and 95.47% AUC. ResNet50-KNN exhibited 94.22% accuracy, 95.57% sensitivity, 91.33% specificity, 95.93% precision, 95.75% F1-Score, 86.9% Yonden Index, and 93.45% AUC. ResNet101-SVM achieved 91.27% accuracy, 92.64% sensitivity, 88.306% specificity, 94.42% precision, 93.53% F1-Score, 80.95% Yonden Index, and 95.31% AUC. ResNet101-KNN achieved 93.26% accuracy, 95.19% sensitivity, 89.11% specificity, 94.92% precision, 95.06% F1-Score, 84.3% Yonden Index, and 92.15% AUC (Table 4) (Figure 3).

Evaluation of the performance of VGG16-SVM has resulted in an AUC score of 91.55%, Yonden Index of 69.55%, F1-Score of 90.65%, specificity of 78.23%, accuracy of 87.15%, and sensitivity of 91.33%. The VGG16-KNN demonstrated 76.81% accuracy, 85.01% sensitivity, 59.27% specificity, 81.7% precision, 83.33% F1-Score, 44.29% Yonden Index, and 72.14% AUC. The VGG19-SVM achieved 85.81% accuracy, 90.01% sensitivity, 76.81% specificity, 89.25% precision, 89.63% F1-Score, 62.28% Yonden Index, and 91.17% AUC. At the same time, VGG19-KNN, on the other hand, achieved 77.33% accuracy, 94.44% sensitivity, 40.73% specificity, 77.31% precision, 85.02% F1-Score, 35.17% Yonden Index, and 67.58% AUC (Table 4) (Figure 3).

Table 4. Performance of the models on the Breast Cancer Dataset

Models	Accuracy	Sensitivity	Specificity	Precision	F1-Score	Yonden Index	AUC
MobileNet-SVM	0.8343	0.8775	0.7419	0.8783	0.8783	0.6194	0.8954
MobileNet-KNN	0.812	0.9105	0.5988	0.8292	0.8679	0.5093	0.7546
ResNet50-SVM	0.9281	0.9598	0.8609	0.9365	0.9479	0.8204	0.9547
ResNet50-KNN	0.9422	0.9557	0.9133	0.9593	0.9575	0.869	0.9345
ResNet101-SVM	0.9127	0.9264	0.88306	0.9442	0.9353	0.8095	0.9531
ResNet101-KNN	0.9326	0.9519	0.8911	0.9492	0.9506	0.8431	0.9215
VGG16-SVM	0.8715	0.9133	0.7823	0.8997	0.9065	0.6955	0.9155
VGG16-KNN	0.7681	0.8501	0.5927	0.817	0.8333	0.4429	0.7214
VGG19-SVM	0.8581	0.9001	0.7681	0.8925	0.8963	0.6228	0.9117
VGG19-KNN	0.7733	0.9444	0.4073	0.7731	0.8502	0.3517	0.6758

In this case, the ResNet50-SVM model shows great promise as the top performer with the highest AUC and high sensitivity, indicating its usefulness for robust overall performance and fewer false negatives in detection. However, there may be a problem with the lower specificity of models like MobileNet-SVM and VGG19-KNN, as this could lead to more false positives, which could result in overtreatment in a clinical situation.

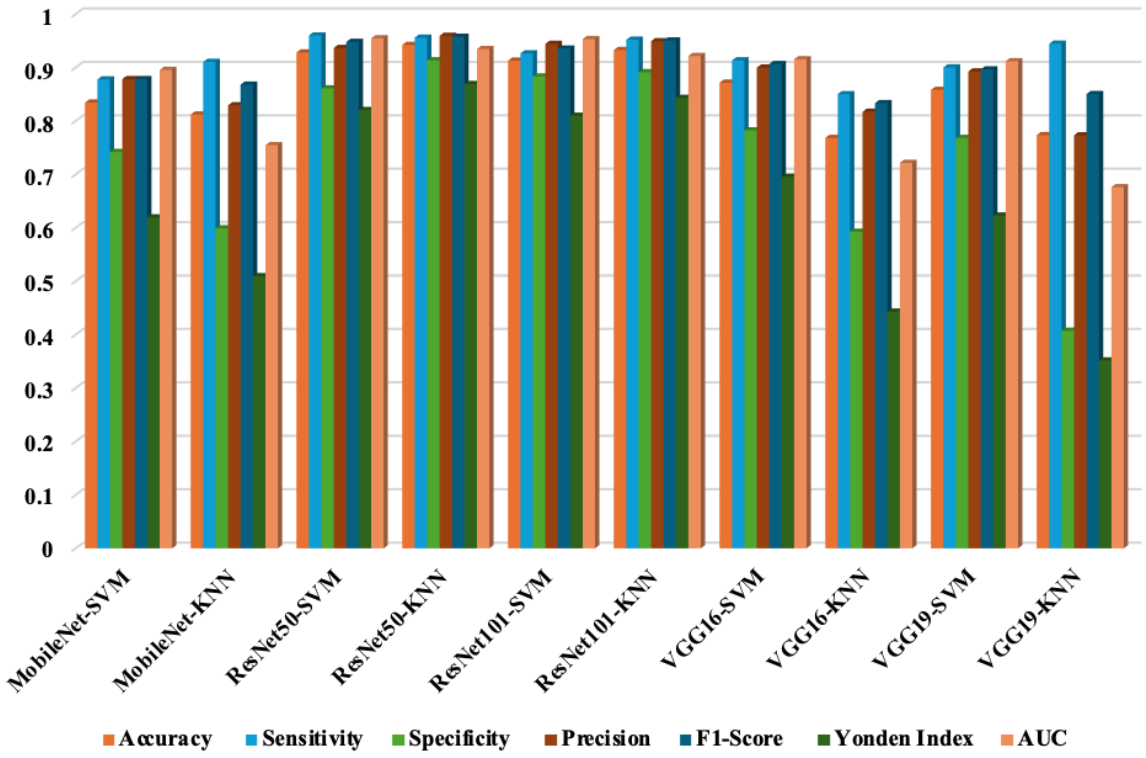


Figure 3: Performance of the models on the Breast Cancer Dataset

4.3 BreakHis 400X dataset

The evaluation of the model's performance has shown that MobileNet-SVM achieved 85.21% accuracy, 90.83% sensitivity, 73.39% specificity, 87.76% precision, 89.27% F1-Score, 64.22% Yonden Index, and 90.73% AUC. The results obtained using

MobileNet-KNN yielded 74.56% accuracy, 84.28% sensitivity, 54.13% specificity, 79.42% precision, 81.78% F1-Score, 38.41% Yonden Index, and 69.2% AUC. ResNet50-SVM displayed 91.72% accuracy, 96.07% sensitivity, 82.57% specificity, 92.05% precision, 94.02% F1-Score, 78.64% Yonden Index, and 96.64% AUC. ResNet50-KNN demonstrated a 93.2% accuracy, 93.89% sensitivity, 91.74% specificity, 95.89% precision, 94.92% F1-Score, 85.63% Yonden Index, and 92.81% AUC. ResNet101-SVM achieved 93.2% accuracy, 96.51% sensitivity, 86.24% specificity, 93.64% precision, 95.05% F1-Score, 82.75% Yonden Index, and 97.09% AUC. At the same time, ResNet101-KNN, on the other hand, recorded 91.72% accuracy, 93.45% sensitivity, 88.07% specificity, 94.27% precision, 93.86% F1-Score, 81.52% Yonden Index, and 90.76% AUC (Table 5) (Figure 4).

Evaluation of the model performance has revealed that VGG16-SVM achieved 88.46% accuracy, 92.14% sensitivity, 80.73% specificity, 90.95% precision, 91.54% F1-Score, 72.87% Yonden Index, and 90.23% AUC. The VGG16-KNN demonstrated 75.15% accuracy, 76.42% sensitivity, 72.84% specificity, 85.37% precision, 80.65% F1-Score, 48.9% Yonden Index, and 74.45% AUC. The results of the VGG19-SVM analysis showed 86.39% accuracy, 91.7% sensitivity, 75.23% specificity, 88.61% precision, 90.13% F1-Score, 66.93% Yonden Index, and 90.29% AUC. Meanwhile, VGG19-KNN achieved 76.92% accuracy, 88.21% sensitivity, 53.21% specificity, 79.82% precision, 83.82% F1-Score, 41.42% Yonden Index, and 70.71% AUC (Table 5) (Figure 4). The excellent accuracy and AUC of the ResNet101-SVM model confirm the potency of the ResNet architecture when paired with an SVM classifier. KNN classifiers, on the other hand, exhibit decreased AUC and accuracy, suggesting the classifier's possible limits for challenging cancer detection tasks.

Table 5. Performance of the models on the BreaKHis 400X dataset

Models	Accuracy	Sensitivity	Specificity	Precision	F1-Score	Yonden Index	AUC
MobileNet-SVM	0.8521	0.9083	0.7339	0.8776	0.8927	0.6422	0.9073
MobileNet-KNN	0.7456	0.8428	0.5413	0.7942	0.8178	0.3841	0.692
ResNet50-SVM	0.9172	0.9607	0.8257	0.9205	0.9402	0.7864	0.9664
ResNet50-KNN	0.932	0.9389	0.9174	0.9589	0.9492	0.8563	0.9281
ResNet101-SVM	0.932	0.9651	0.8624	0.9364	0.9505	0.8275	0.9709
ResNet101-KNN	0.9172	0.9345	0.8807	0.9427	0.9386	0.8152	0.9076
VGG16-SVM	0.8846	0.9214	0.8073	0.9095	0.9154	0.7287	0.9023
VGG16-KNN	0.7515	0.7642	0.7284	0.8537	0.8065	0.489	0.7445
VGG19-SVM	0.8639	0.917	0.7523	0.8861	0.9013	0.6693	0.9029
VGG19-KNN	0.7692	0.8821	0.5321	0.7982	0.8382	0.4142	0.7071

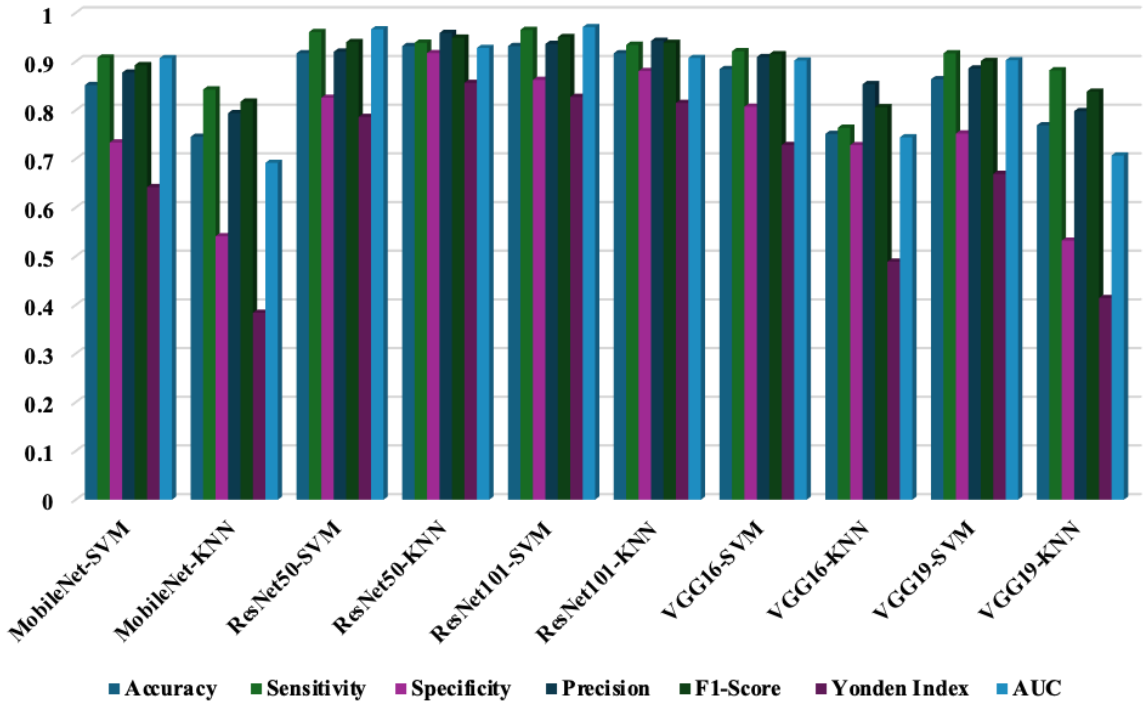


Figure 4: Performance of the models on BreaKHis 400X datasets

4.4 Ultrasound Breast Classification Dataset

Training and testing of pre-trained models using the ultrasound breast classification dataset have shown that MobileNet-SVM achieved 98.39% accuracy, 98.2% sensitivity, 98.58% specificity, 98.53% precision, 98.36% F1-Score, 96.78% Yonden Index, and 99.86% AUC. While MobileNet-KNN achieved 98.61% accuracy, 98.77% sensitivity, 98.36% specificity, 98.32% precision, 98.6% F1-Score, 97.23% Yonden Index, and 98.62% AUC. ResNet50-SVM displayed 96.12% accuracy, 97.18% sensitivity, 95.08% specificity, 95.04% precision, 96.1% F1-Score, 92.27% Yonden Index, and 98.89% AUC. The ResNet50-KNN model yielded the following results: 97.23% accuracy, 97.86% sensitivity, 96.61% specificity, 96.56% precision, 97.2% F1-Score, 94.47% Yonden Index, and 97.24% AUC. ResNet101-SVM obtained a 95.73% accuracy, 94.93% sensitivity, 96.5% specificity, 96.34% precision, 95.63% F1-Score, 91.44% Yonden Index, and 99% AUC. Meanwhile, ResNet101-KNN displayed 96.95% accuracy, 97.18% sensitivity, 96.72% specificity, 96.64% precision, 96.91% F1-Score, 93.91% Yonden Index, and 96.95% AUC (Table 6) (Figure 5). The use of VGG16-KNN demonstrated strong performance, leading to an F1-score of 97.49%, Yonden Index of 95.03%, AUC of 97.52%, specificity of 96.72%, precision of 96.68%, sensitivity of 98.31%, and accuracy of 97.5%. The VGG16-SVM achieved 98.06% accuracy, 99.21% sensitivity, 96.94% specificity, 96.92% precision, 98.05% F1-Score, 96.15% Yonden Index, and 99.81% AUC The VGG19-SVM displayed 98.84% accuracy, 99.32% sensitivity, 98.36% specificity, 98.33% precision, 98.82% F1-Score, 97.68% Yonden Index, and 99.76% AUC. The VGG19-KNN demonstrated 96.73% accuracy, 97.86% sensitivity, 95.63% specificity, 95.6% precision, 96.72% F1-Score, 93.49% Yonden Index, and 96.74% AUC (Table 6) (Figure 5).

Table 6. Performance of the models on the Ultrasound Breast Classification Dataset

Models	Accuracy	Sensitivity	Specificity	Precision	F1-Score	Yonden Index	AUC
MobileNet-SVM	0.9839	0.982	0.9858	0.9853	0.9836	0.9678	0.9986
MobileNet-KNN	0.9861	0.9877	0.9836	0.9832	0.986	0.9723	0.9862
ResNet50-SVM	0.9612	0.9718	0.9508	0.9504	0.961	0.9227	0.9889
ResNet50-KNN	0.9723	0.9786	0.9661	0.9656	0.972	0.9447	0.9724
ResNet101-SVM	0.9573	0.9493	0.965	0.9634	0.9563	0.9144	0.99
ResNet101-KNN	0.9695	0.9718	0.9672	0.9664	0.9691	0.9391	0.9695
VGG16-SVM	0.9806	0.9921	0.9694	0.9692	0.9805	0.9615	0.9981
VGG16-KNN	0.975	0.9831	0.9672	0.9668	0.9749	0.9503	0.9752
VGG19-SVM	0.9884	0.9932	0.9836	0.9833	0.9882	0.9768	0.9976
VGG19-KNN	0.9673	0.9786	0.9563	0.956	0.9672	0.9349	0.9674

High accuracy and AUC values are frequently exhibited by the models in Table 3's ultrasound image-based breast cancer diagnosis. With exceptional accuracy and AUC, the VGG19-SVM model stands out in particular. This indicates that the model is highly reliable and can accurately classify malignant or non-malignant. When combined with our machine learning models, ultrasound images have the potential to be a potent tool for breast cancer screening, as seen by the models' consistently high performance in this table.

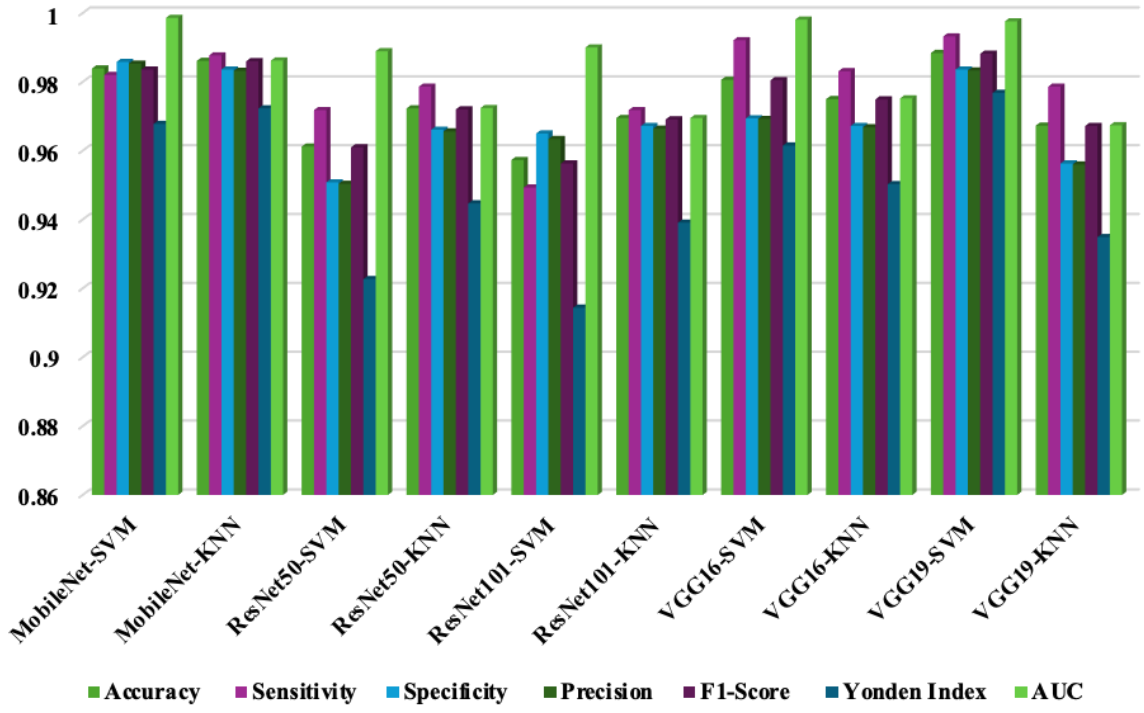


Figure 5: Performance of the models on the Ultrasound Breast Classification Dataset

4.5 Discussion

The dominance of SVM classifiers over other classifiers across all datasets indicates that SVMs are more proficient at handling the complexities involved in cancer identification from medical images (Table 7) (ResNet50-SVM, ResNet101-SVM, and VGG19-SVM). The potential of SVM classifiers in reducing false negatives is critical in cancer diagnosis since early identification is essential for effective therapy, as demonstrated by their high sensitivity. The models fused with SVM revealed their dependable ability to differentiate across classes (benign and malignant) as indicated

by the regularly high AUC values. Moreover, while evaluating the performance of models using the KNN classifier, it can be observed that both sensitivity and specificity do not match, which might result in more false-positive classifications. However, this could be resolved by adding more data for training or fine-tuning the models.

Table 7. Comparison between the performance of models/classifiers on Cancer Datasets

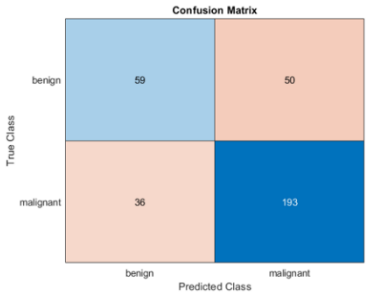
Dataset	Best performing model	Result
Breast Cancer from Multi-Cancer Datasets	ResNet50-SVM	0.9925 Ac, 0.995 Sv, 0.99 Sp, 0.99 Pr, 0.9925 F1 score, 0.985 YI and 0.9992 AUC
Breast Cancer Dataset	ResNet50-KNN	0.9422 Ac, 0.9557 Sv, 0.9133 Sp, 0.9593 Pr, 0.9575 F1 score, 0.869 YI and 0.9345 AUC
BreaKHis 400X dataset	ResNet101-SVM	0.932 Ac, 0.9651 Sv, 0.8624 Sp, 0.9364 Pr, 0.9505 F1 score, 0.8275 YI, 0.9709 AUC
Ultrasound Breast Cancer Classification	VGG19-SVM	0.9884 Ac, 0.9932 Sv, 0.9836 Sp, 0.9833 Pr, 0.9882 F1 score, 0.9768 YI, 0.9976 AUC

*Ac: Accuracy; Sv: Sensitivity; Sp: Specificity; Pr: Precision; YI: Yonden Index;

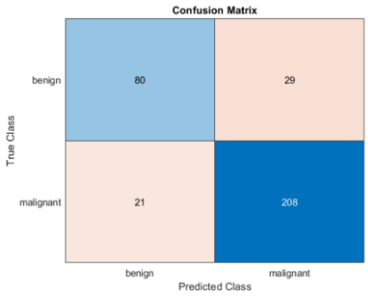
AUC: Area Under the Curve

These findings support the usefulness of deep learning models in medical diagnostics and emphasize how crucial it is to match the appropriate classifier with these architectures. The excellent result achieved using deep learning models fused with SVMs in this study may impact future SVM-related research and development, directing attention toward optimizing SVM-based models for clinical applications in cancer diagnosis.

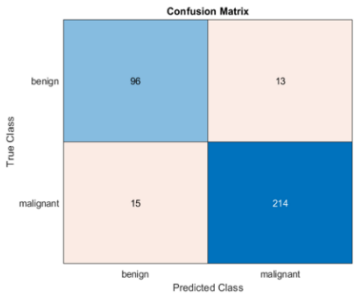
The system performance is also evaluated regarding the confusion matrix provided (Fig. 6a,7a and 8a) and ROC curve/AUC as provided (Fig. 6 b,7b and 8b). The breast cancer dataset was allotted for validation of the model data. The higher true positive (TP) and true negative (TN) values in the confusion matrix provide a better performance metric. The performance evaluation of the model indicated that ResNet50-SVM achieved the best result for classifying Breast Cancer from multi-cancer Datasets with 0.9925 accuracy and 0.9992 AUC. ResNet50-KNN achieved the best result for classifying the Breast Cancer Dataset with 0.9422 accuracy and 0.9345 AUC. ResNet101-SVM achieved the best result for classifying the BreaKHis 400X dataset with 0.932 accuracy and 0.9707 AUC. VGG19-SVM achieved the best result for classifying Ultrasound Breast Cancer Classification with 0.9884 accuracy and 0.9976 AUC.


Confusion Matrix
benign
malignant
True Class
59
50
36
193
benign
malignant
Predicted Class

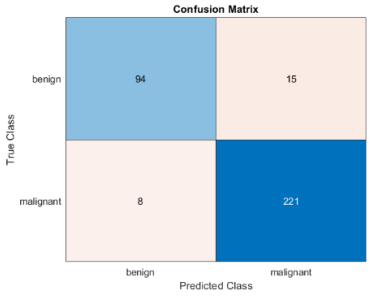
(a)


Confusion Matrix
benign
malignant
True Class
80
29
21
208
benign
malignant
Predicted Class

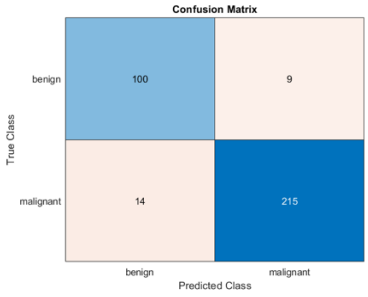
(b)


Confusion Matrix
benign
malignant
True Class
96
13
15
214
benign
malignant
Predicted Class

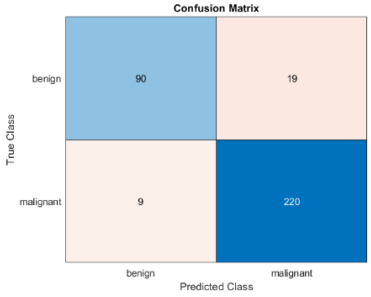
(c)


Confusion Matrix
benign
malignant
True Class
94
15
8
221
benign
malignant
Predicted Class

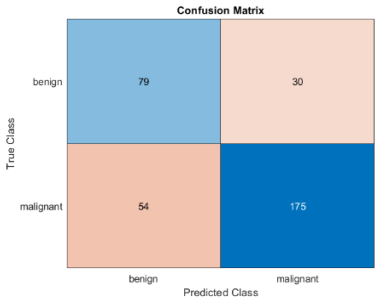
(d)

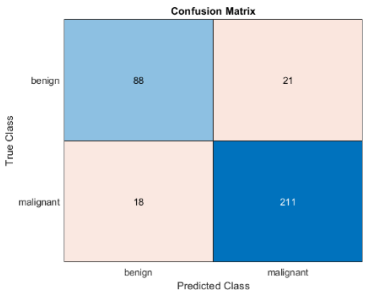

Confusion Matrix
benign
malignant
True Class
100
9
14
215
benign
malignant
Predicted Class

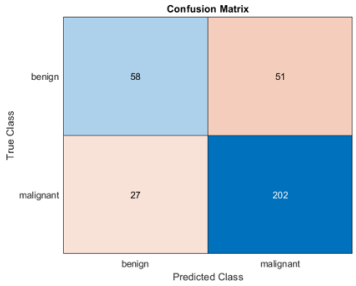
(e)


Confusion Matrix
benign
malignant
True Class
90
19
9
220
benign
malignant
Predicted Class

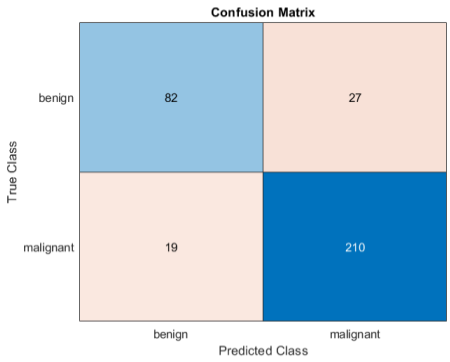
(f)





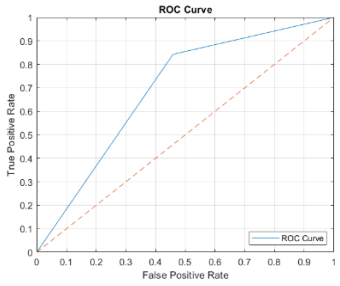


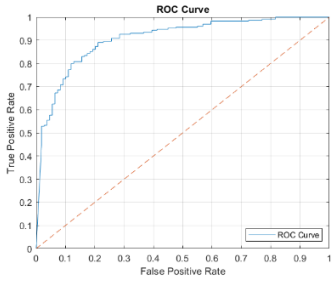
(g) (h) (i)

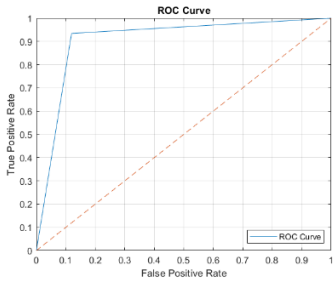


(j)

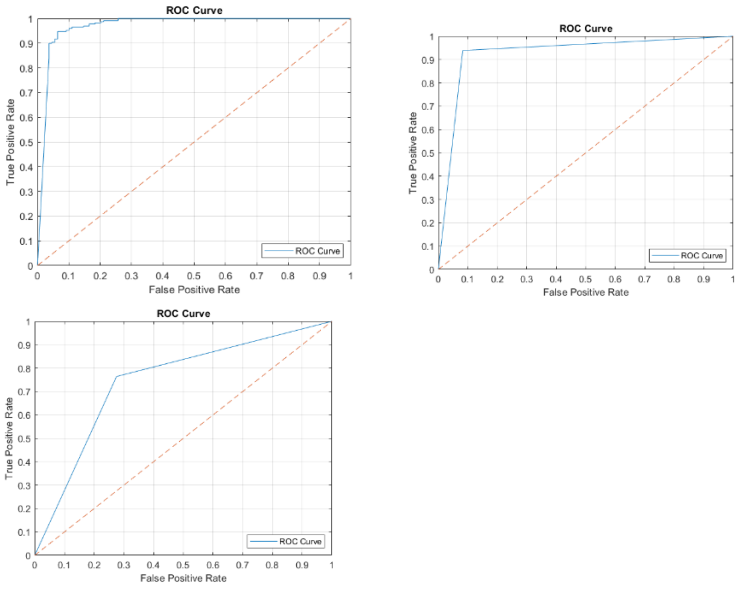
Figure 6a: Confusion Matrix (a) MobileNet-KNN (b) MobileNet-SVM (c)ResNet101-KNN (d)ResNet101-SVM (e) ResNet50-KNN (f) ResNet50-SVM (g) VGG16-KNN (h) VGG16-SVM (i) VGG16-KNN (j) VGG16-SVM



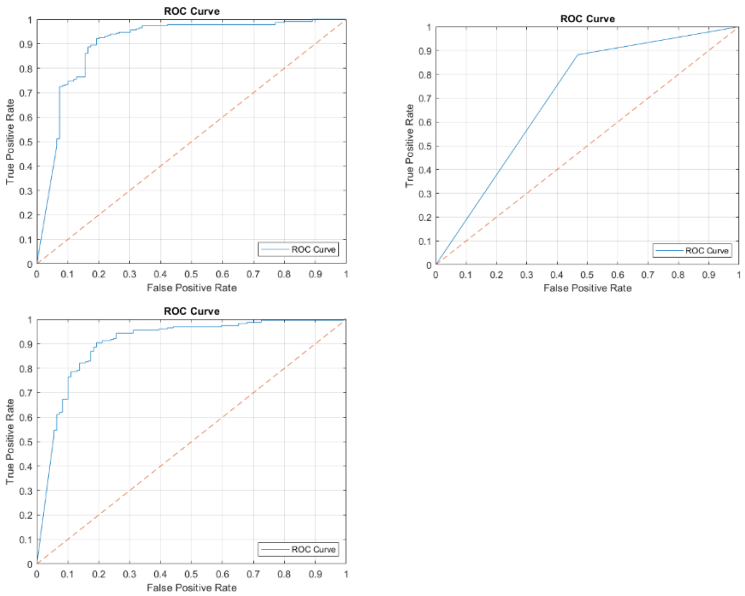




(a) (b) (c)

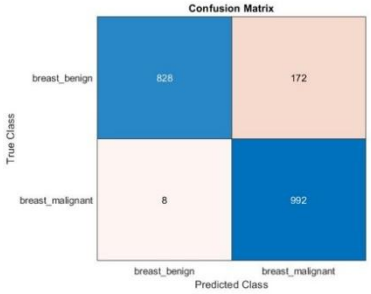


(d) (e) (g)

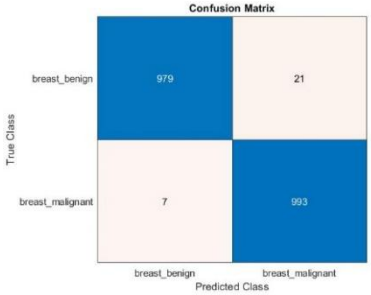


(h) (i) (j)

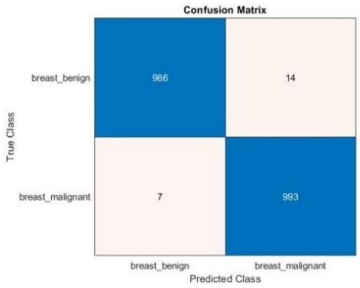
Figure 6b: ROC/AUC (a) MobileNet-KNN (b) MobileNet-SVM (c)ResNet101-KNN (d)ResNet101-SVM (e) ResNet50-KNN (f) ResNet50-SVM (g) VGG16-KNN (h) VGG16-SVM (i) VGG16-KNN (j) VGG16-SVM


Confusion Matrix
breast_benign
breast_malignant
828
172
8
992
True Class
breast_benign
breast_malignant
Predicted Class

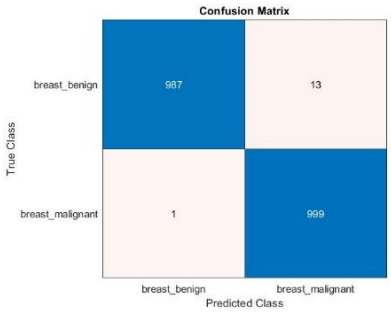
(a)


Confusion Matrix
breast_benign
breast_malignant
979
21
7
993
True Class
breast_benign
breast_malignant
Predicted Class

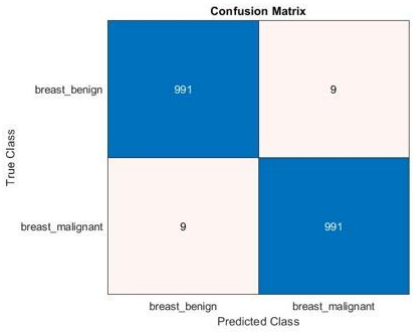
(b)


Confusion Matrix
breast_benign
breast_malignant
986
14
7
993
True Class
breast_benign
breast_malignant
Predicted Class

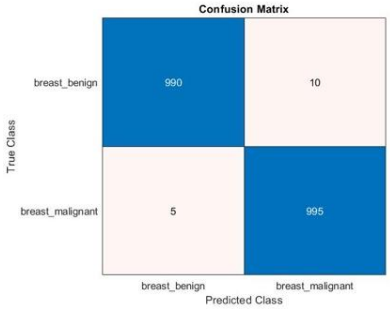
(c)


Confusion Matrix
breast_benign
breast_malignant
987
13
1
999
True Class
breast_benign
breast_malignant
Predicted Class

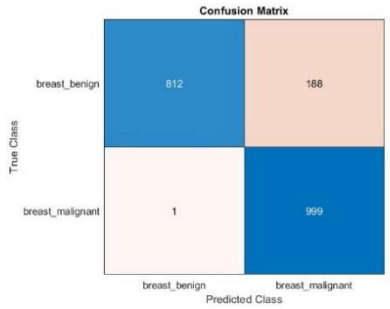
(d)

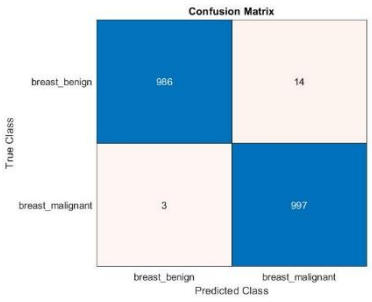

Confusion Matrix
breast_benign
breast_malignant
991
9
9
991
True Class
breast_benign
breast_malignant
Predicted Class

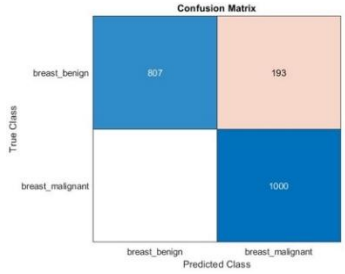
(e)


Confusion Matrix
breast_benign
breast_malignant
990
10
5
995
True Class
breast_benign
breast_malignant
Predicted Class

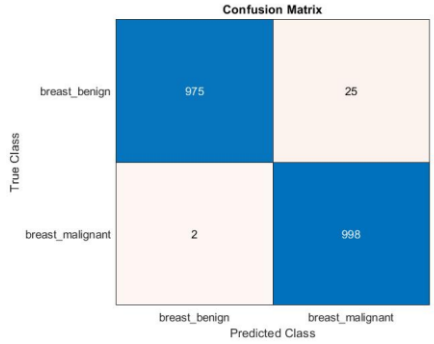
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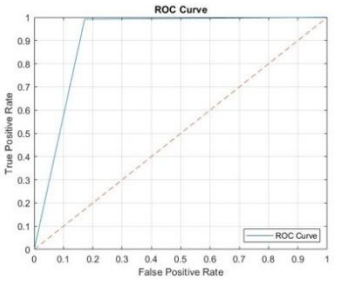


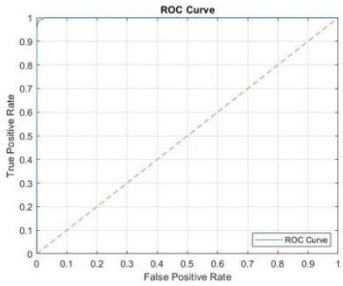
(g) (g) (h)

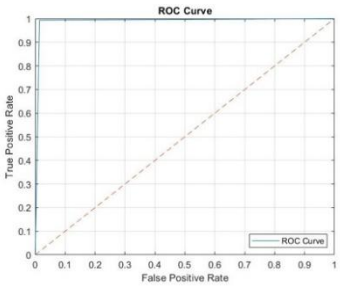


(i)

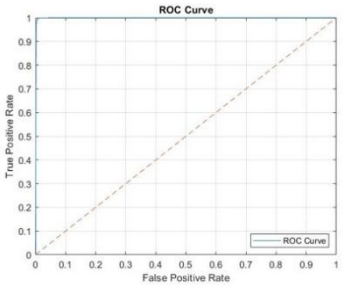
Figure 7a: Confusion Matrix (a) MobileNet-KNN (b) MobileNet-SVM (c)ResNet101-KNN (d)ResNet101-SVM (e) ResNet50-KNN (f) ResNet50-SVM (g) VGG16-KNN (h) VGG16-SVM (i) VGG16-KNN (j) VGG16-SVM

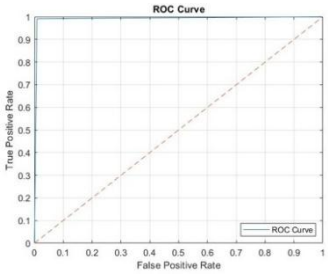

ROC Curve
True Positive Rate
False Positive Rate
ROC Curve

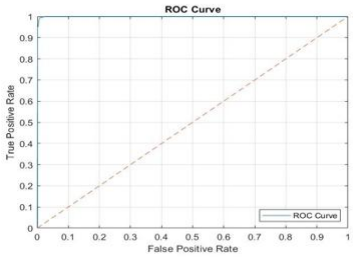

ROC Curve
True Positive Rate
False Positive Rate
ROC Curve


ROC Curve
True Positive Rate
False Positive Rate
ROC Curve

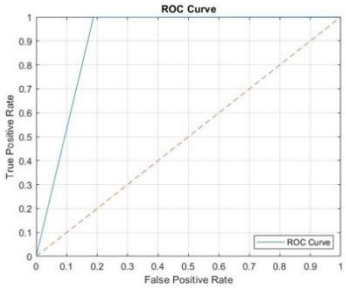
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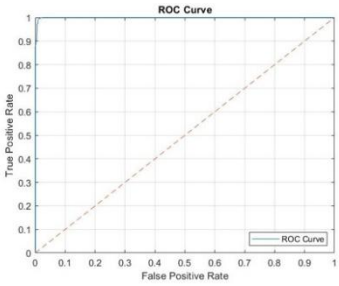

ROC Curve
True Positive Rate
False Positive Rate
ROC Curve

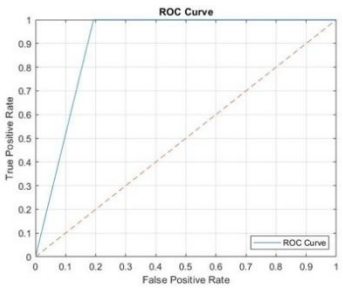

ROC Curve
True Positive Rate
False Positive Rate
ROC Curve


ROC Curve
True Positive Rate
False Positive Rate
ROC Curve

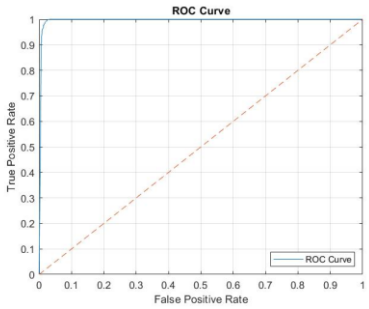
(d). (e) (f)


ROC Curve
True Positive Rate
False Positive Rate
ROC Curve


ROC Curve
True Positive Rate
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ROC Curve


ROC Curve
True Positive Rate
False Positive Rate
ROC Curve

(g) (h) (i)

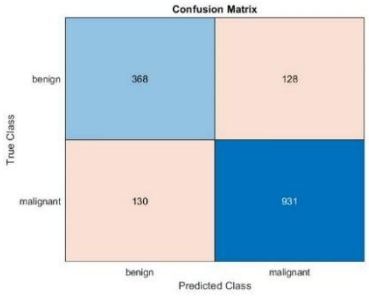


(j)

Figure 7b: ROC/AUC (a) MobileNet-KNN (b) MobileNet-SVM (c)ResNet101-KNN (d)ResNet101-SVM (e) ResNet50-KNN (f) ResNet50-SVM (g) VGG16-KNN (h) VGG16-SVM (i) VGG16-KNN (j) VGG16-SVM

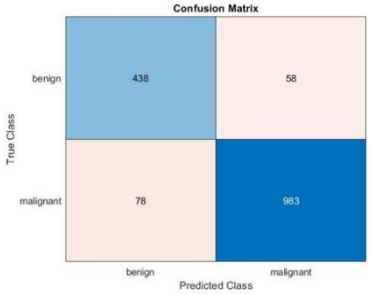


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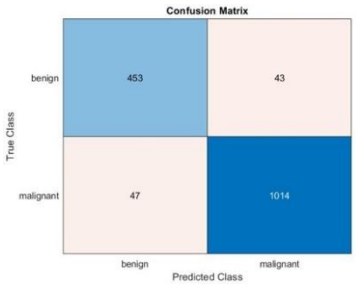


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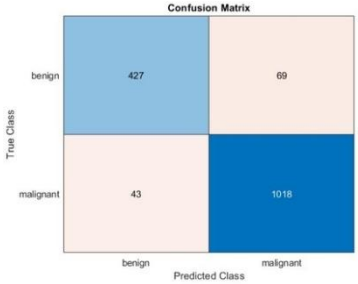
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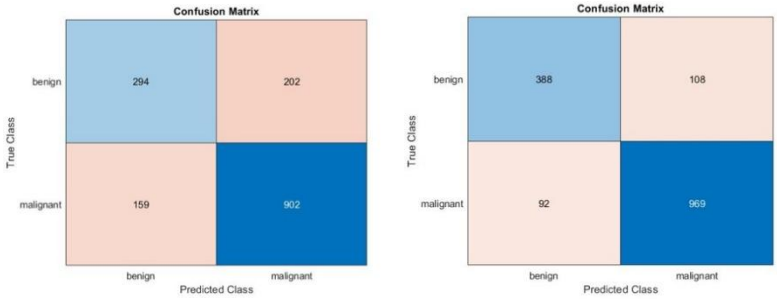
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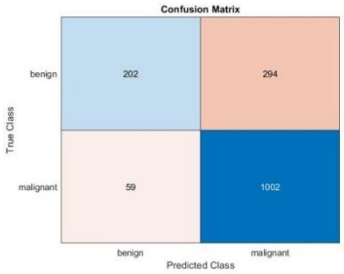


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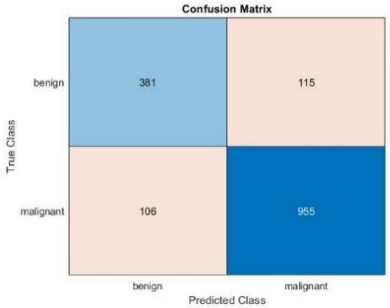


(f)



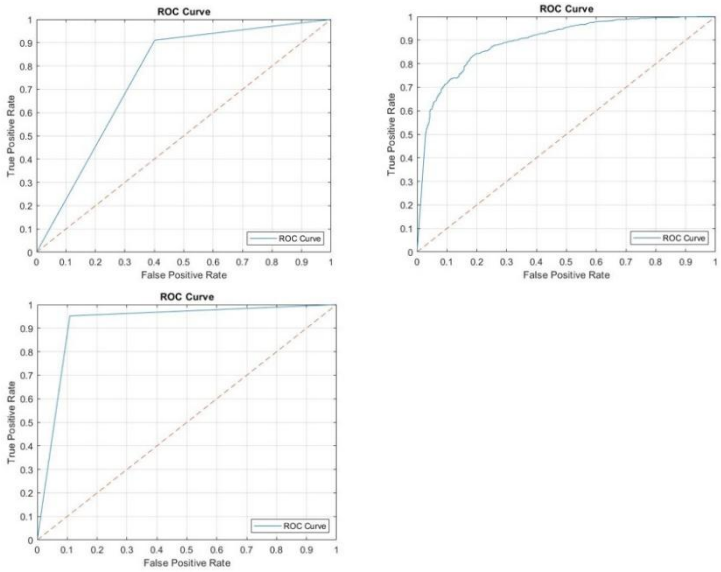


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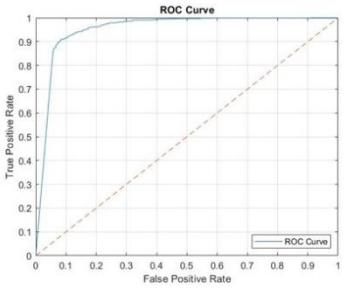


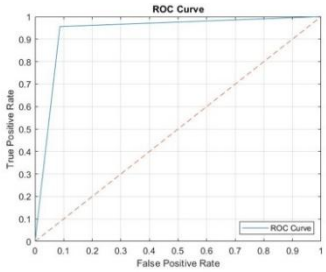
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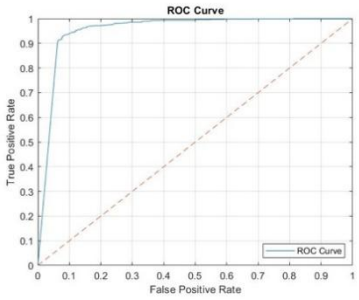
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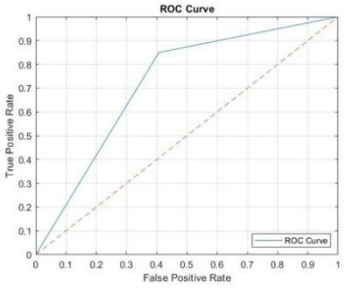
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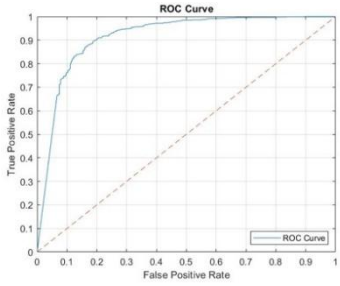


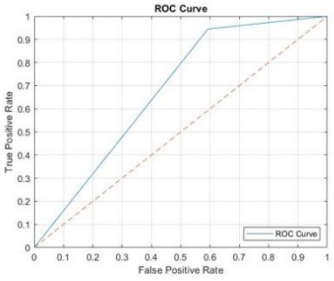




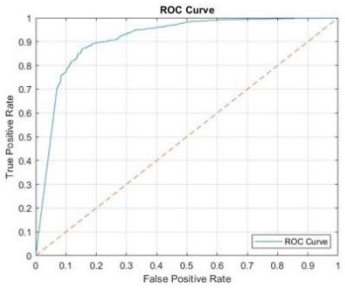
(d) (e) (f)







(g) (h) (i)



(j)

Figure 8b: ROC/AUC (a) MobileNet-KNN (b) MobileNet-SVM (c)ResNet101-KNN (d)ResNet101-SVM (e) ResNet50-KNN (f) ResNet50-SVM (g) VGG16-KNN (h) VGG16-SVM (i) VGG16-KNN (j) VGG16-SVM

Limitations and Future Studies

This study conducted both binary and 3-way classification of breast cancer from histopathological and ultrasound images using ensemble deep learning and machine learning models (as classifiers). However, despite achieving excellent results, the study can be improved using several approaches. For example, one of the limitations of this study is the curation of images from publicly accessible domains. The study can achieve more practicability when trained and tested using real-time clinical images. Moreover, acquiring more datasets can improve performance. Another technique that can be integral is data augmentation, which is conducted to maximize the training set. There are several data augmentation techniques which include rotation, color enhancement, shifting, zooming, shearing etc. Consequently, only 5 pre-trained models and 2 machine-learning classifiers are employed. Thus, future studies will include deeper models such as DenseNet Inception-ResNet and EfficientNet and classifiers such as decision tree, random forest, naïve Bayes etc.

5. Conclusions

The number of patients diagnosed with breast cancer continues to increase annually due to the continuous use of carcinogens, smoking, and drug abuse. Thus, in order to diagnose patients suspected of breast cancer, medical experts order several tests, which include biopsies, mammography, ultrasound, and other imaging tests. However, oncologists' and radiologists' diagnostic efficiency can be stretched due to high workload, leading to missed diagnoses or misinterpretations. Thus, developing or adopting an automated system that can minimize diagnostic errors, increase diagnostic accuracy, and save time is vital. In order to address these issues, pre-trained models were coupled with 2 distinct classifiers for screening cancer images (histopathological and ultrasound) into binary classes (benign and malignant).

Several datasets were curated from the Kaggle repository, and the acquired datasets were split 80:20 for training and testing, respectively.

The performance evaluation of the model indicated that ResNet50-SVM achieved the best result for classifying Breast Cancer from multi-cancer Datasets with 0.9925 accuracy and 0.9992 AUC. ResNet50-KNN achieved the best result for classifying the Breast Cancer Dataset with 0.9422 accuracy and 0.9345 AUC. ResNet101-SVM achieved the best result for classifying the BreaKHis 400X dataset with 0.932 accuracy and 0.9707 AUC. VGG19-SVM achieved the best result for classifying Ultrasound Breast Cancer Classification with 0.9884 accuracy and 0.9976 AUC. Despite the high performance obtained using these models, the result can be improved by employing ensemble and hybrid models, which combine features of different models and have been tested to perform better than single architectures. Moreover, performance can be improved by curating a more significant number of images. Consequently, the field of AI/IoT is growing exponentially due to increased biomedical data and the design of online platforms that provide healthcare experts with real-time cancer screening from different types of medical images.

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- All reports (Turkish and English) must follow these guidelines for report writing.
- Items such as photos, images, charts, etc. should be referred to as "**Figure**".
- Descriptions of **Tables and Figures** should be in **11**-point font.
- The **manuscript** should use 1.15 line spacing, 12-point font and Times New Roman typeface.
- Any photo included to the report should be in JPEG format (300dpi).

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INFLUENCE OF HEAT TREATMENT ON THE COMPRESSION STRENGTH OF PINE (*Pinus nigra* Arn.) AND BEECH (*Fagus sylvatica* L.)

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ABSTRACT

This study evaluates the effects of thermal modification on mass loss and compressive strength in pine (*Pinus nigra* Arn.) and beech (*Fagus sylvatica* L.) at temperatures of 130°C, 180°C, and 220°C for duration times of 2 and 8 hours. The mass loss increased with an increase in both time and intensity of treatment, varying from 0.5% to 11.37% for pine wood and 0.4% to 10.77% for beech wood. At 130°C, both wood species exhibited minimal mass loss and slight increases in compressive strength. At 180°C, the pine wood showed a maximum compression strength of 41.89 N/mm², and the beech wood showed 57.24 N/mm². Higher temperature treatment (220°C) resulted in clear strength reductions, with values decreasing to 31.15 N/mm² for pine and 44.26 N/mm² for beech. Overall, moderate thermal treatments (up to 180°C for 2 hours) enhanced compressive performance, whereas higher-intensity treatments significantly reduced strength in both species.

Keywords: Compression Strength, pine, beech, mass loss

1. INTRODUCTION

Wood is well known for being a very sustainable and low-carbon building material, and its application in modern construction systems and engineered wood products continues to grow (Hill, 2006). However, despite being such a good option, wood remains problematic in terms of being hygroscopic, unstable, and prone to biological degradation, among other factors. To overcome such shortcomings, several wood modification methods have evolved, with thermal-modified wood being a variant that gained popularity because of its chemical-free, thus environmentally friendly.

Heat treatment is a process in which wood is subjected to higher temperatures, usually in a range of 160°C to 240°C, in a controlled atmosphere. Additionally, characteristic physical and chemical transformations in wood occur in a controlled manner during this treatment. Moreover, these transformations affect wood in a positive way, increasing its service life and

thermal performance, turning wood into a sustainable high-performance material in building and design contexts. Heat treatment ensures wood is less susceptible to fungi, insects, and other biodegradation materials since thermal modifications in wood improve wood's resistance to these factors in a controlled manner. Moreover, wood with a reduced equilibrium moisture content performs better in terms of dimensional stability and swelling and shrinkage properties, ensuring wood is less prone to these factors in a controlled manner.

From a mechanical point of view, however, linear or predictable effects of thermal treatment on other wood properties, such as compression strength, do not exist. Some studies have indicated a minor gain with less aggressive treatment parameters, and a marked decrease in strength when temperature or treatment time exceeded a certain threshold. Godinho et al. in 2024 have observed that, despite an aesthetic gain in wood color and a reduction in wood moisture absorption, enhanced resistance to weathering is not necessarily gained.

Pine (Pinus nigra Arn.) and Beech (Fagus sylvatica L.) are two of the most widely used species in both construction and interior designs, primarily because of their preferred mechanical properties. Pine is light with good workability but shows marked changes in dimensions with varying moisture content. Several studies have demonstrated that thermal treatment can improve pine dimensional stability through reduced hygroscopicity and, in moderate treatment conditions, increased strength parameters in a controlled manner (Korkut & Budakçi, 2009; Yildiz et al., 2006; Esteves & Pereira, 2009). Beech is preferred for its high density, strength, and beauty, but shows marked sensitivity to swelling, shrinkage, and color variability. Research studies on thermally-treated beech wood have consistently indicated improvements in dimensional stability, reduced hygroscopicity, and associated modifications in treatment-dependent mechanical properties. Such studies include but are not limited to those presented in literature by Candelier et al. (2016); Bekhta & Niemz, 2003; Yildiz et al. (2006). Thermal treatment of these two species presents worthwhile effects, especially in terms of hygro/moisture-resistant performance, which can be adjusted to suit their usage in construction/solid wood materials (Hill, 2006; Esteves & Pereira, 2009; Cao, S et al 2022).

Although interest in thermal modification is increasing, very few studies have focused on thermal treatment factors and their impact on the compression strength of pine and beech.

The work presented in this paper focuses on studying the influence of varying heat treatment times and temperatures on the compression strength of pine and beech wood, to better enable a more efficient usage of these types of wood in the future.

This research aims to draw attention to the significance of interaction among heat treatment parameters and mechanical properties, with a focus on the latter being compressive strength. With increased understanding of these variables, this research aims to offer recommendations on improving wood with a focus on a high degree of structural integrity in a specific application and facilitating more widespread usage of thermally modified wood in construction industries.

2. EXPERIMENTAL RESEARCH (or METHODS)

2.1. Wood Material and Sample Preparation

Defect-free specimens of pine and beech were selected and prepared in accordance with the ISO 13910 standard. Air-dried pine and beech boards, randomly selected from a sawmill

lumberyard in the Librazhdi region, were used as raw material for sample preparation. Each sample was prepared into 20 × 20 × 40 mm dimensions and conditioned at 20°C and 65% relative humidity until equilibrium moisture content (EMC) was achieved. In total, 140 samples are prepared for the heat treatment process (20 samples in each group). All the samples were oven-dry at 103±2°C until the moisture content 0% before the heat treatment. Thus, the kiln-dried materials were divided into seven groups, six of which were to be heat-treated at six different regimes (later also called treated samples) and one of which was left untreated (later also called untreated control). The oven-dried samples were first weighed by a digital weight scale (accuracy 0.01 g), in order to calculate the mass loss. There were used three different temperatures (130°C, 180°C, and 220°C) were used at atmospheric pressure for the time duration of 2 and 8 hours. The mass loss that occurred by heat treatment was determined. Mass loss (%), ML was calculated according to the equation below:

$$ML = \frac{M_1 - M_2}{M_1} * 100\ (\%)$$

where: ML – mass loss of samples (%);

M_1 – the mass of oven-dried samples before treatment (g);

M_2 – the mass of samples after heat treatment (g).

Treated and untreated samples were conditioned until the moisture content of the untreated samples reached 12%.

Compressive strength testing was performed using a U*niversal Testing Machine*. The maximum compressive force at failure (F_{max}) was recorded, and compressive strength (CS) was calculated.

$$CS = F_{max} / A\ [N/mm^2]$$

Where: CS – compression strength [N/mm^2]

Fmax - maximum compressive force at failure [N]

A- Sample transversal area [mm^2]

The change, in terms of percentage, of the compressive strength was found using the formula below for each data point, relative to the control.

$$Change\ (\%) = ((CS_{treatment} - CS_{control}) / CS_{control}) * 100$$

Changes in physical properties were evaluated by comparing the measurements before and after the thermal treatment

3. RESULTS AND DISCUSSION

Mass Loss

The results demonstrate that both pine and beech undergo a progressive increase in mass loss with rising temperature and prolonged exposure during heat treatment, reflecting the gradual thermal degradation of wood polymers (Hill, 2006; Esteves & Pereira, 2009). At 130 °C, both species show negligible losses (<1 %), indicating that only moisture and volatile extractives are

removed, without significant chemical decomposition. As the temperature rises to 180 °C, mass loss becomes more evident (2.56–4.22 % for pine and 2.92–3.63 % for beech), corresponding to the onset of hemicellulose degradation and partial deacetylation (Esteves & Pereira, 2009). The highest temperature (220 °C) produces substantial weight reductions (11.37 % for pine and 10.77 % for beech after 8 h), signifying advanced decomposition of hemicelluloses and amorphous cellulose regions, as well as lignin condensation. Pine consistently shows slightly higher mass loss than beech, likely due to its higher extractive content and lower density, which facilitate faster heat penetration and volatilization. The results confirm that thermal modification intensity is strongly governed by temperature and time, with pine exhibiting greater sensitivity to prolonged heating than beech, and that moderate treatments (≤ 180 °C) remain optimal for improving durability while limiting structural degradation.

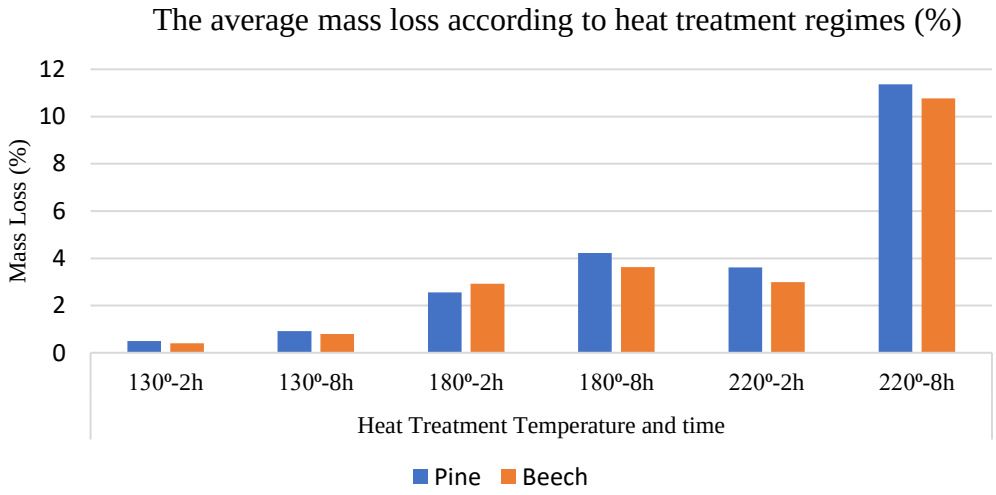


Figure 1. The average mass loss according to heat treatment regimes in %

Compression Strength

Compressive Strength (CS) tests performed on pine and beech wood samples undergo heat treatment at 130°C, 180°C, and 220°C for a total of 2 hours and 8 hours indicate a distinct effect of time and temperature on the mechanical properties of both wood species. While pine wood samples presented an average compressive strength of 38.96 N/mm² with a coefficient of variation (V%) of 3.98%, beech wood presented a higher average strength of 52.51 N/mm² with lower variability of 1.49% in control samples. Tests conducted at a lower temperature of 130°C recorded a marginal increase in CS to 39.5 N/mm² in pine wood samples after 8 hours of treatment, but beech wood presented a marginal increase in strength to 53.36 N/mm², indicating a possible minimal degradation or compacting of cell walls because of evaporation of sap and partial rearrangement of hemicelluloses in wood cell walls during a mild heating treatment, which matches with a study stating that less intensity of thermal degradation can lead to increased wood density attributable to partial degradation of hemicelluloses in wood cell walls (Hill, 2006; Yildiz et al., 2006). Moreover, with an increase in temperature to 180°C, both pine wood samples recorded peak strength of 41.89 N/mm² in 2 hours with 7.5% higher compressive

strength compared to control samples, along with a higher increase in beech wood samples up to 55.48 N/mm².

However, when the time factor was considered by increasing the heating time to 8 hours at 180°C, a decrease in pine strength to 36.71 N/mm² (9% decrease from control) occurred, with beech exhibiting a further increase to 57.24 N/mm², thus showing better resistance to prolonged heating of the hardwood over softwood in pine wood (Yildiz et al., 2006).

At 220°C, both kinds of wood showed a large decrease in their compressive strength. Compressive strength in pine reduced to 34.23 N/mm² after 2 h and 31.15 N/mm² after 8 h (decreasing by ~20% relative to the control). Beech reduced to 48.55 N/mm² after 2 h and 44.26 N/mm² after 8 h (decreasing by ~16%, which conforms to previous research indicating a rapid thermal degradation of cell-wall polymers at higher temperatures, Bekhta & Niemz, 2003). In contrast to these reductions in mechanical properties, both kinds of wood have low coefficients of variation, which remained below 3.94% for pine and below 2.72% for beech. Although both kinds of wood have reduced in their mechanical properties, they remained homogeneous with a low coefficient of variation. Moreover, this statistical analysis confirms coherent trends in these wood data. The standard deviations were small with a mean deviation of +/- s = 0.68-1.66 for both kinds of wood, which gives a strong indication of reliable experimental results. The experimental results clearly indicate a temporary increase in compressive strength with moderate heat treatment at 180°C for short-term exposure times of 2 h.

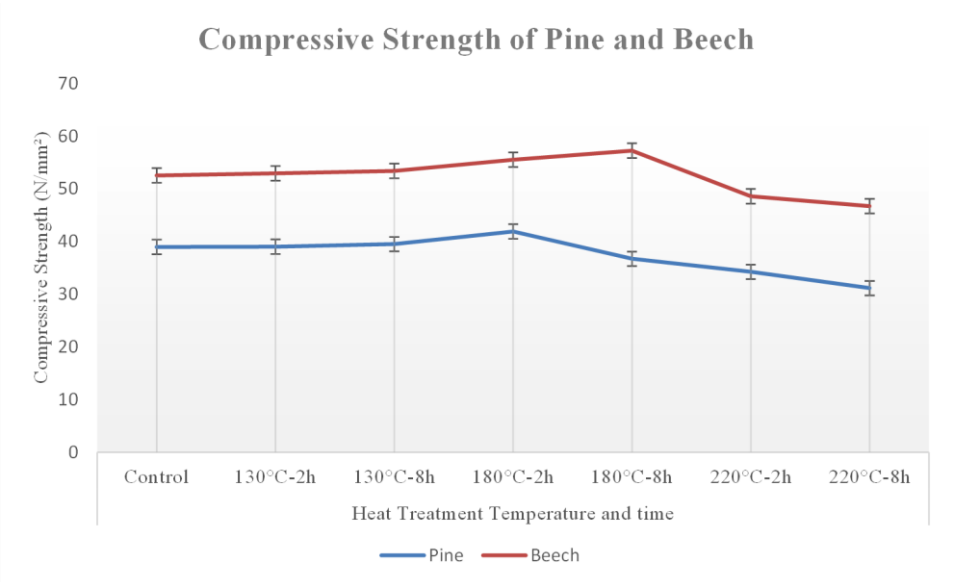


Figure 2. The CS according to the heat treatment regimes

Based on the plotted data, a clear negative correlation is observed between mass loss and compressive strength loss for both pine and beech wood (Figure 3). As mass loss increases, CS loss rises for both species, reflecting the progressive degradation of structural polymers during heat treatment. Pine shows a stronger correlation ($y = –0.8157x + 40.233$; $R^2 = 0.6848$), indicating that mass loss explains much of the mechanical reduction, while beech follows a similar trend with slightly higher CS losses overall ($y = –0.8876x + 55.154$; $R^2 = 0.4855$). These

results confirm that greater thermal degradation directly contributes to the reduction of compressive

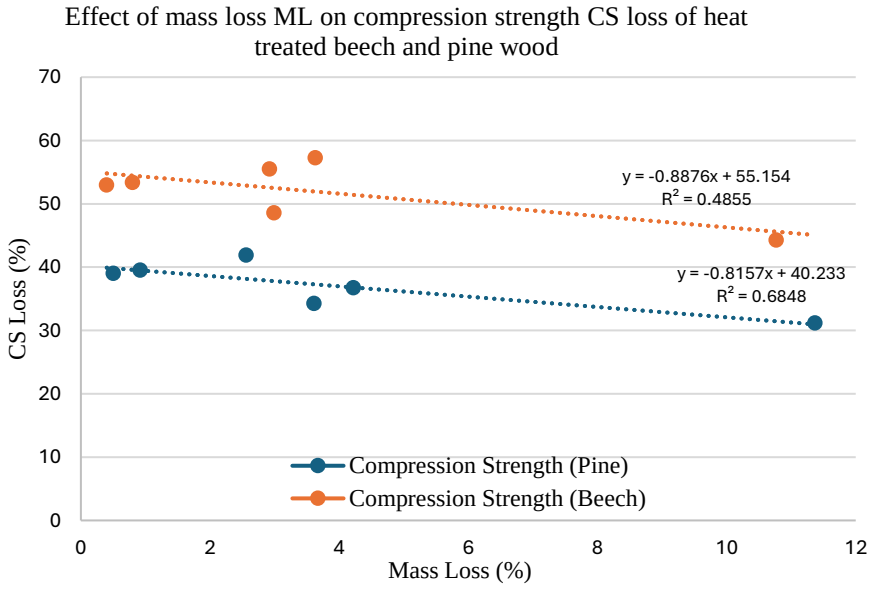


Figure 3. The effect of Mass Loss on Compression Strength

These findings confirm that treatment intensity is the key factor governing thermal degradation and that careful selection of temperature–time regimes is essential to balance durability improvements with mechanical integrity.

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THE PERCEPTIONS OF NURSING STUDENTS REGARDING ORGAN DONATION

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Abstract

The objective of this study is to ascertain the attitudes and willingness of students in the Bachelor of Nursing program regarding organ donation and whether the curriculum influences these perceptions. **Methodology** - This is a cross-sectional study, and a descriptive design was utilized for this study. The study data were collected from three-year students of the Bachelor of Nursing study programs, at the Faculty of Natural Sciences, University of Shkodra "Luigj Gurakuqi" Shkodra. The data were collected during the period January 15 – February 15, 2025, through an online questionnaire. Two tools and one session related to curricular formation were used in this study: the demographic questionnaire and the "Knowledge and Attitude Questionnaire" questionnaire used by Miranda, L. E. C and colleagues (2024). 191 participants participated, constituting 55.85% of the total number of students. The data were collected with an online questionnaire in Microsoft Forms. **Results and conclusions** - Students show a largely positive attitude towards organ donation after brain death, with a high percentage supporting this idea. The vast majority, 69%, stated that they would only donate to close relatives such as parents, children, brothers or sisters. This shows that a sense of responsibility and family love is a key factor in the willingness to undertake such an important action. 90% of students think that extracurricular training should be organized on this topic, suggesting that, despite being included in the curriculum, such additional activities can contribute to deepening knowledge and raising awareness of the importance of organ donation.

Keywords: donation, organs, students, nursing, paired organs, curriculum

1. INTRODUCTION

Organ donation and transplantation are widely recognized as foundational elements of contemporary health services, playing a pivotal role in the management of severe illnesses and the enhancement of quality of life (Kılavuz Ören, 2024). Organ transplantation is regarded as the optimal and sole life-saving treatment when an organ is no longer capable of functioning (Chen et al., 2024; Alizadeh & Takasi, 2024). Organ transplantation is an effective treatment for restoring organ function and preventing early death. In addition to its therapeutic benefits, it also provides the recipient with a better quality of life (Sengul & Sahin, 2022). Despite the increase in the number of donors, it is not possible to meet the requirements of the lists, as organ transplantation is the only therapeutic method for a significant number of patients suffering from terminal diseases (Miranda et al., 2023; Majeed., 2016). Moreover, in recent years, a global increase in demand for organ donation has been observed, attributable to the rising prevalence of organ failure (Chen et al., 2024). Research has demonstrated that the number of organ donations currently stands below the necessary threshold to satisfy the demand (Özkan et al., 2015). The procurement of organs for transplantation can be sourced from three potential donors: living relatives of the recipient, unrelated donors, or deceased donors (Taşdemir, 2024). The attitudes of individuals towards tissue and organ donation are closely associated with their sociocultural and socio-economic levels, as well as their religious beliefs (Tuncer & Gurses, 2024). Despite its widespread acceptance within the medical community, there remain significant controversies surrounding the topic, particularly among the general population (Rydzewska-Rosołowska et al., 2020). The debate surrounding human organ transplantation has been a subject of discourse within various social circles for an extended period, addressing a range of dimensions including scientific, moral, religious, political, and legal aspects. Currently, it is regarded as a life-saving procedure for patients experiencing end-stage organ failure (Hejazi et al., 2017). The majority of global religions permit organ transplantation, contingent upon the non-harming of the donor's life (Majeed, 2016). Organ donation, whether from a living or deceased individual, is defined as the donation of a human organ or tissue to a living person in need of transplantation (Ahmed et al., 2024). The majority of transplanted organs are derived from cadavers; however, kidney transplantation research has demonstrated that donation from living individuals is the optimal treatment (Alwesmi et al., 2023). Nevertheless, the ethical implications of endangering a healthy individual to extend or enhance the life of a patient have been a subject of debate. Consequently, organ donation after brain death remains the predominant source of organ transplants (Alwesmi et al., 2023). A deceased donor is an individual who is medically certified as deceased, with their cells and organs deemed suitable for utilization, akin to those from living donors (Alizadeh & Takasi, 2024). In the context of organ transplantation, the donation of organs is a critical component of treatment for patients who have suffered fatal organ failure (Taşdemir, 2024). The organ donation process frequently hinges on the decision of the deceased's family. The primary impediment to this process is often the family's refusal to consent to organ donation (Hejazi et al., 2017). In the United Kingdom, nurses play a pivotal role in the organ donation system. They are responsible for identifying potential donors and preparing the family for the possibility of organ donation. Nurses also explain the process and obtain consent from the donor's family (Sayin & Dağci, 2022). The attitudes of health professionals have been shown to significantly impact the attitudes of transplant recipients, donor families, the approach to brain-dead patients, and the

decision-making process by families (Taşdemir, 2024). As future health professionals, medical students play an integral role in raising awareness about organ donation (Taşdemir, 2024). In order to inform knowledge about organ donation and shape attitudes towards transplantation, the optimal moment is during the process of medical education (Rydzewska-Rosołowska et al., 2020). A survey of medical students, and nurses revealed a lack of knowledge regarding organ donation and transplantation, coupled with negative attitudes towards these practices (Özkan et al., 2015). Additionally, the findings revealed that nursing students in Turkey exhibited a moderate level of knowledge about organ donation, while in Mexico, nursing students demonstrated an insufficient level of knowledge regarding this matter (Alizadeh & Takasi, 2024). Curricula in nursing programs leading to a bachelor's degree do not include courses or lectures on organ donation and transplantation (Özkan et al., 2015). To this end, it is imperative to enhance knowledge, raise awareness in society, and eliminate negative attitudes to increase the frequency of organ donation. Healthcare professionals play a pivotal role in this regard, as they communicate with patients and their relatives (Tuncer & Gurses, 2024). A study conducted in Poland revealed that 20% of medical and nursing students did not accept the definition of brain death and would be willing to protest against organ donation by their relatives (Rydzewska-Rosołowska et al., 2020). The dearth of reliable information concerning donation and transplantation programs constitutes a significant impediment to the willingness of individuals to consent to organ donation (Rydzewska-Rosołowska et al., 2020). Two categories that can be modified for organ donation are public education in society and the provision of optimal conditions at the time of request. These conditions should meet the supportive and informative needs of the family and should also include understanding of the patient's critical condition (Hejazi et al., 2017). Educational interventions have been demonstrated to effectively raise awareness among medical students regarding the subject of organ donation (Rydzewska-Rosołowska et al., 2020). It has been documented that the university education of students pursuing medical sciences is inadequate in altering and enhancing their attitudes regarding organ donation and transplantation (Kılavuz Ören, 2024). The training of health professionals to educate patients as integral members of the treatment team has been demonstrated to exert a positive influence on the organ donation process (Sengul & Sahin, 2022). Despite the variance in attitudes toward organ donation and transplantation, attributable to factors such as religion, culture, social values, and societal values, the predominant cause of negative attitudes toward organ donation is the presence of incomplete or inaccurate information regarding this subject. Consequently, the necessity for training to promote organ donation is underscored (Kılavuz Ören, 2024).

The objective of this study is to ascertain the attitudes and willingness of students in the Bachelor of Nursing program regarding organ donation and whether the curriculum influences these perceptions.

2. MATERIAL AND METHODOLOGY

2.1. Study Design

This is a cross-sectional study, and a descriptive design was utilized for this study. The data were collected from students enrolled in the Bachelor of Nursing program over the course of their three-year program of study.

2.2. Sample

The study's exclusive focus on students enrolled in the nursing program is a notable limitation. During the 2024–2025 academic year, the number of active students in this study program was 342, including 109 first-year students, 118 second-year students, and 115 third-year students. A total of 191 participants were included in this study, constituting 55.85% of the total number of students. A total of 63 students participated from the first year of study, constituting 57.80% of the total sample. A total of 60 students participated from the second year of study, constituting 50.85% of the total, while 68 students participated from the third year of study, constituting 59.13%. As is evident, there is a satisfactory representation of them.

2.3. Inclusion criteria

The present study is open to any student enrolled in the Bachelor's degree program in Nursing at the University of Shkodra "Luigj Gurakuqi" who attended the program during the 2024-2025 academic year.

2.4. Data collection

The data were collected from January 15, 2025, to February 15, 2025, through an online questionnaire administered via Microsoft Forms. The present study employed two instruments and a single session pertaining to curricular formation: the demographic questionnaire and the "Knowledge and Attitude Questionnaire" questionnaire utilized by Miranda et al., (2024).

The demographic questionnaire was designed to elicit information regarding the personal characteristics of the participants. The following data were collected: age, gender, place of residence, marital status, number of children, living arrangements, study program, year of study, and the question, "Do you know anyone who has donated an organ?" Have you ever engaged in discourse on the subject of organ donation in a meeting-like setting? .

The "Knowledge and Attitudes" questionnaire utilized in this study was developed by Miranda, L. E. C et al., 2024. The questionnaire is composed of 12 items, which are divided into two dimensions:

The initial dimension pertains to students' attitudes concerning organ donation and encompasses seven items, each of which is evaluated on a scale from 1 to 5 (1 = not at all, 2 = a little, 3 = average, 4 = a lot, 5 = completely).

1) How much do you think we should be organ donors in case of brain death?

2) How much do you think we should be paired organ donors?

3) How much do you think the family should be discussed about the attitude towards organ donation?

4) How much should the family know about the decision if the organ should be donated?

5) How much do you agree that if one of the family members were diagnosed with brain death, should organ donation be accepted?

6) How much do you think organ donation can cause any harmful effects/complications in living donors?

7) How much do you think organ donation can bring any material or emotional benefit to the donor's family?

The second dimension refers to students' willingness regarding organ donation and consists of 5 items and each item has response alternatives (yes; no; no answer) and only the item “What do you think about donating tissues or organs during your lifetime?” has response alternatives

(I would not be a donor under any circumstances; I would only donate to a close relative such as parents, children or siblings; I would be a donor for anyone I knew who needed an organ; I would be a donor for anyone who needed an organ, even if I did not know them);

1) Have you ever considered the possibility of being an organ donor in case of brain death?;

2) What do you think about donating tissues or organs during your lifetime?;

3) Have you talked to your family about your attitude towards organ donation?;

4) Does your family know about your decision (yes or no)?;

5) If one of your family members were diagnosed with brain death, would you agree to donate organs?

The third part of the questionnaire refers to curricular formation by posing six items and each item is rated from 1 to 5 (1= not at all, 2= a little, 3= average, 4= a lot, 5= completely) and only the question “Do you think that extracurricular training on organ donation should be organized?” has answer alternatives (yes; no; no answer)

1. To what extent do you think that organ donation is included in the curriculum of the study program?

2. To what extent do you think that topics on organ donation should be included in the teaching curriculum?

3. Do you think that extracurricular training on organ donation should be organized?

4. To what extent do you think that extracurricular training on organ donation should be organized?

5. How interested would you be in creating educational classes on organ donation readiness?

6. To what extent do you think that the research literature on organ donation readiness is understandable?

2.5. Statistical analysis

Data analysis was performed using the Microsoft Forms platform and the Excel package.

2.6. Ethical considerations

Ethics approval was obtained from the Board of the Department of Preclinical Studies at the University of Shkodra "Luigj Gurakuqi." The de-identification of the participants' data was imperative to safeguard the confidentiality of the subjects. During the data collection period, the research team contacted the interest group and provided a thorough explanation of the study's rationale to all participants. The completion of the questionnaire indicated their agreement with the study's objectives and their consent to participate.

3. RESULTS AND DISCUSSIONS

Table 1. Distribution of participants by age and gender

Participant Data	Number of Students	Percentage
Gender	**191**	**100%**
Mala	39	20%
Female	152	80%
Age	**191**	**100%**
18-19 years old	55	29%
19-20 years old	43	23%
20-21 years old	39	20%
21-22 years old	23	12%
22-23 years old	19	10%
23-24 years old	4	2%
24-25 years old	1	1%
Over 25 years old	7	4%

As indicated in Table 1, the majority of the study participants are female, constituting 80% of the sample, while the remaining 20% are male. This finding aligns with the predominance of female students in the Bachelor of Nursing program, mirroring global trends in the workforce, where males comprise 9-12% of the workforce, as well as with the results of studies conducted within the same program (Kraja et al., 2022: Kraja & Shabani, 2022).

An analysis of the age demographics of the study participants reveals that the majority, constituting 29% of the sample, fall within the 18-19 age range. Following the 19-20 age group, which accounted for 23% of the sample, the 20-21 age group (20%), the 21-22 age group (12%), and the age group over 22 (17%) constituted the subsequent categories.

Table 2. Distribution of participants according to knowledge about donation

Participant Data	Number of Students	Percentage
Do you know anyone who has donated an organ?	**191**	**100%**
Yes	55	29%
No	136	71%
Have you ever participated in meetings that discussed organ donation?	**191**	**100%**
Yes	29	15%
No	162	85%

As indicated in Table No. 2, 71% of students reported no knowledge of individuals who have donated organs, while 29% reported knowledge of such individuals. With respect to participation in meetings at which the subject of organ donation was discussed, a significant percentage of the student body—85%, to be precise—have never participated in such meetings, while a mere 15% of students claim to have done so. In light of the findings, it is reasonable to hypothesize that educational initiatives concerning organ donation, complemented by comprehensive information about this subject, should be incorporated into the pre-university education curriculum. This assertion is substantiated by the data obtained from the study's participants, which revealed a conspicuous dearth of knowledge regarding organ donation. It has been demonstrated that a high level of knowledge and a favorable attitude towards organ

donation are associated with an increased propensity to donate (Alwesmi et al., 2023; Ahmed et al., 2024; Chen et al., 2024).

Table 3. Students' attitudes towards organ donation

Students' attitudes towards organ donation	No.	%
How many of us do you think should be organ donors in the event of brain death?	**191**	**100%**
Not at all	18	9.42%
A little	21	10.99%
Average	61	31.94%
A lot	62	32.46%
Completely	29	15.18%
How many of us do you think should be organ donors?	**191**	**100%**
Not at all	34	17.80%
A little	35	18.32%
Average	45	23.56%
A lot	54	28.27%
Completely	23	12.05%
How much do you agree that if one of your family members were to be diagnosed with brain death, should organ donation be accepted?	**191**	**100%**
Not at all	30	15.71%
A little	20	10.46%
Average	41	21.47%
A lot	50	26.18%
Completely	50	26.18%
To what extent do you think organ donation can cause any harmful effects/complications in living donors?	**191**	**100%**
Not at all	26	13.62%
A little	43	22.51%
Average	62	32.46%
A lot	48	25.13%
Completely	12	6.28%

The data presented in the table indicates that the majority of students in the Bachelor of Nursing program are in favor of organ donation in cases of brain death. As indicated by the findings of Alwesmi et al. (2023), the results of our study demonstrate that students also endorse the concept of organ donation in the event of brain death. However, an increase in the willingness to donate organs after brain death has been observed to be concomitant with an increase in information about brain death (Ahmed et al., 2024; Tuncer & Gurses, 2024). According to Sayin & Dağci (2022), the reluctance of nursing students to donate organs is attributable to their limited awareness regarding brain death and organ donation.

The data demonstrate that the attitudes of students regarding organ donation in the event of brain death of a family member are average. This phenomenon is influenced by a multitude of factors, including culture, information, and religious beliefs.

A survey revealed that 31% of respondents expressed concerns about potential health complications associated with organ donation. The apprehension surrounding the potential

challenges associated with brain death has been identified as a contributing factor to students' skepticism regarding organ donation (Miranda et al., 2023).

Table 4. Information from curricula on organ donation

Information from curricula on organ donation	No.	%
To what extent do you think organ donation is included in the curriculum of the study program?	**191**	**100%**
Not at all	37	19%
A little	54	28%
Average	24	13%
A lot	52	27%
Completely	24	13%
To what extent do you think topics about organ donation should be included in the curriculum?	**191**	**100%**
Not at all	8	4%
A little	12	6%
Average	32	17%
A lot	90	47%
Completely	49	26%
Do you think that extracurricular training on organ donation should be organized?	**191**	**100%**
Yes	172	90%
No	19	10%
How interested would you be in studying educational classes on organ donation readiness?	**191**	**100%**
Not at all	7	4%
A little	21	10%
Average	49	26%
A lot	68	36%
Completely	46	24%

The data presented in the table indicate that 28% of students perceive the inclusion of this topic to be inadequate, while 19% consider it to be entirely absent. An additional 13% regard the level of inclusion as being merely average. Consequently, the prevailing perspective among the majority is that the curricular training is deemed inadequate. Consistent with the conclusions of Miranda et al. (2024), the findings of this study also indicate a need to enhance the existing curricula. Additionally, Majeed, (2016) underscores that nursing students' knowledge regarding organ donation is limited to moderate levels. Alwesmi et al. (2023) further argue that, despite the positive attitudes exhibited by nursing students, their limited knowledge is attributable to the absence of structured education on the subject of organ donation.

While 40% of the study participants expressed satisfaction with the current curriculum's adequacy in addressing organ donation, a significant majority of 71% advocated for the incorporation of additional information on this subject. A significant proportion of the respondents, specifically 90%, advocate for the organization of extracurricular training programs focused on organ donation. Additionally, 60% of respondents express a strong belief in the necessity of establishing educational classes to promote awareness about organ donation.

Organ donation training is imperative to cultivate students' knowledge and positive attitudes towards this critical issue. These educational interventions have the potential to enhance the number of prospective donors among future healthcare providers (Alwesmi et al., 2023).

4. CONCLUSIONS

This cross-sectional comparative study aimed to assess the knowledge and attitudes of nursing students at the University of Shkodra “Luigj Gurakuqi” towards organ donation.

The predominant belief among participants is that organs should be donated by the individual to close relatives, such as parents, children, brothers, or sisters. This finding suggests that a strong sense of responsibility and profound family affection play a pivotal role in determining the propensity to engage in such significant actions.

The predominant belief among participants is that the donation of an organ is associated with a significant risk of adverse complications for the donor.

The participants consider the presence of extracurricular training on organ donation to be necessary, suggesting that, despite being included in the curriculum, such additional activities can contribute to deepening knowledge and raising awareness of the importance of organ donation.

Additionally, they have expressed concerns regarding the paucity of information regarding organ donation in the curriculum of the study program. In light of these observations, they have put forward a recommendation to incorporate the subject into the curriculum.

LIMITATIONS

The participants in this study are exclusively enrolled in the Bachelor of Nursing program at the University of Shkodra "Luigj Gurakuqi" for the entirety of their three-year program. Consequently, the findings of this study do not necessarily reflect the views of all nursing students nationally or regionally. Despite the predominance of females, with 80% of the sample, the statistical significance of this observation is negligible. A comprehensive analysis of data from various countries reveals that this ratio remains consistent across different geographical regions (Kraja et al., 2024; Kraja et al., 2022).

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DIAGNOSIS OF PINWORM INFECTION BY USING SCOTCH-TEST: A CROSS SECTION-BASED EPIDEMIOLOGICAL SURVEY

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ABSTRACT

Introduction: *Enterobius vermicularis*, also known as pinworms, is considered the most common nematode in the human intestine, as they are its only natural host. The prevalence of this parasite at a global level is estimated to be more than 20% of cases, but it is more common in children.

Aim: The study aims to demonstrate the detection of pinworm eggs by using perianal swab method (Scotch-test strip) as well as the detection of their epidemiological characteristics.

Methods: This cross-sectional study is based on data obtained from 83 young patients (3-6 years old) over a 12-month period. Microscopic examination constituted the fundamental method of analysis employed in the investigation of the *E vermicularis* parasite egg forms. The test employed was the Scotch-tape test (cellophane adhesive tape test). The data were analyzed using the SPSS test, where a value less than 5% was considered significant.

Results: The prevalence of this infection in the child population resulted in 24.09%, with the highest prevalence found in males 60%. In fact, 93.7% of children are enrolled in kindergartens, with the majority of these being enrolled in public kindergartens. The use of shared spaces, as well as having an older sibling were seen as predominant factors of this infection (OR 1.07; CI 95%: 0.36–1.93; p = 0.04 and OR 1.5; CI 95% 0.87-3.05; p=0.03 respectively). It should be noted that the symptoms in most cases were alternating. Anal itching was the most common complaint at 55.6%, discomfort mainly during the evening hours at 52.4%, insomnia, anxiety 34.9%,18.2%, abdominal pain and diarrhea 15.9% and 9.5% respectively.

Conclusions: *E vermicularis* remains a prevalent parasitic infection, especially among children attending kindergartens, who often lack the personal hygiene practices necessary to prevent such infections. The symptoms that were most commonly reported in this study included pruritus and discomfort. In order to prevent the spread of this infection to other children attending the kindergarten, efforts are needed to ensure the availability of treatment for these children. Parents and educators should be advised to reinforce hygienic behavior both in the environments where these children grow up and in the personal hygiene of the children.

Keywords: *Enterobius vermicularis*, cellophane adhesive tape test epidemiological data, preschool children

Introduction

The nematode parasite *Enterobius vermicularis* (*E vermicularis*) is one of the most widespread intestinal helminths worldwide and the infection it causes is also known as Pinworm infection, Oxyuriasis or Enterobiasis [1,2]. This infection is a cosmopolitan parasite and one of the most common parasitic infections in many countries, but it is most commonly found in children and their family members [3]. The global prevalence of parasitic infections in humans in developing countries is mainly high, while the prevalence of enterobiasis is generally underestimated. According to a report by the World Health Organization, the prevalence of enterobiasis in children is estimated to be from 4% to 28% [4]. According to Ali, (2022), about 200 million people are infected worldwide with pinworm infection, of which more than 29% of cases are children aged 5 - 10 years [5].

This parasite has a fairly simple life cycle, and its transmission occurs mainly through the fecal-oral route, autoinfection, or indirect contact with contaminated surfaces [1]. According to Kuang-Yao et al., 2018. Another route of spread of this parasite is through retroinfection of larvae through the anus [6], while reinfection is common in overcrowded environments such as kindergartens, schools, orphanages, etc. Or it can also be found in environments with irregular sanitation that facilitate continuous transmission [7]. Some patients with enterobiasis are asymptomatic, while others, especially children, may exhibit symptoms such as perianal itching, discomfort, loss of appetite, malnutrition, anemia, insomnia, and irritability. Severe cases of ectopic enterobiasis, which can invade the kidneys and fallopian tubes, leading to serious health problems and even death, should not be excluded [8,9].

Identification and prevention of pinworm transmission in children can promote infection control and bring benefits to the health of children and the community [9,10]. According to several studies, the appropriate choice of diagnostic method for *E vermicularis* is essential. The use of a cellophane tape test or Scotch-test is more advisable when compared to stool examinations, as eggs can only be detected in about 5% of fecal samples [12-14]. In other words, the prevalence of intestinal worm infection is generally underestimated due to the difficulty of detecting intestinal worm eggs by stool examinations. Furthermore, the detection of eggs in the perianal area is still a very important reference point and tool in assessing the epidemiological characteristics of pinworm infection in a community and in the clinical diagnosis of infected individuals, because there are no other approaches currently available [15]. Given this fact, we undertook this study to demonstrate the detection of pinworm eggs by using perianal swab method (Scotch-test strip) as well as the detection of their epidemiological characteristics.

Methods

The present study is based on data obtained from 83 young patients (3-6 years old) over a 12-month period. Microscopic examination constituted the fundamental method of analysis employed in the investigation of the *E vermicularis* parasite egg forms. Samples were brought to the parasitology laboratory for the purpose of detecting pinworm eggs (*Enterobius vermicularis*) among kindergarten children aged between three and six years old. The test employed was the Scotch-tape test (adhesive slides). This test method is a particular diagnostic technique employed in the identification of Oxyuresis, otherwise classified as *Enterobius vermicularis*.

All parents were instructed on the method of sample collection using perianal swabs, and the laboratory provided the material for each case. Parents were also advised to take the sample in the morning and deliver it directly to the laboratory. In addition to the collection of adhesive

slides, a range of data was collected on various factors for each patient. These factors included age, gender, reason for testing, and child's medical history.

The analysis was conducted using SPSS version 26.0. Descriptive statistics were computed in order to determine the prevalence of parasitosis, while inferential statistics (Chi-square tests) were utilised to identify significant associations between parasitosis and potential risk factors. For the purposes of statistical analysis, a significance level of $p < 0.05$ is widely accepted as the benchmark for statistical significance.

Results and Discussion

Numerous reports have documented the prevalence of *E vermicularis* infection in children, yet there is a paucity of comprehensive studies that comprehensively describe the global status of enterobiasis infection in children. As asserted by Wang et al., the infection caused by *E vermicularis* is ubiquitous across the globe, including within developed countries. It is estimated that 4–28% of children worldwide are infected [16, 17]. The detection of *E vermicularis* eggs by cellophane tape test or Scotch-test is still a benchmark and a very important tool in assessing the epidemiological characteristics of intestinal worm infection in a community and in the clinical diagnosis of infected individuals. Conversely, the presence of eggs in the perianal region does not necessarily indicate the existence of the worm or worms in the host's intestine [18]. As previously stated, the present study comprised a total of 83 kindergarten-age children, ranging in age from 3 to 6 years. In view of the fact that the Schott test method was the sole diagnostic approach employed in suspected cases of the *Enterobius vermicularis* parasite, the prevalence of this infection resulted in an overall figure of 24.09% among the pediatric population.

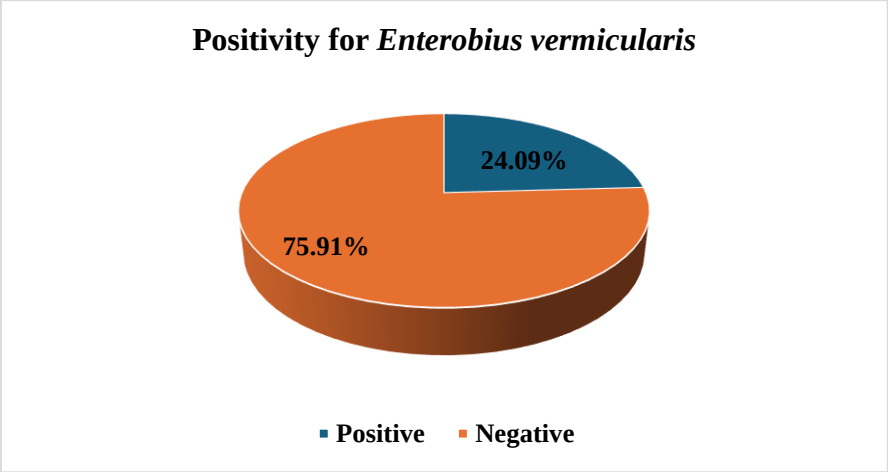


Figure 1. Prevalence of *Enterobius vermicularis* among young children

Table 1 presents the epidemiological data manifesting among young children. The findings indicate that a significant proportion of the child population falls within the 3-4 age bracket, exhibiting a 45% prevalence rate. This is in comparison to the 5- to 6-year-old age group, which demonstrates a prevalence of 55%. The prevalence of *E vermicularis* infection was found to be significantly higher in children over the age of five in comparison to those below five years of age. This finding is consistent with the results observed in other studies [16]. This may be related to the activities that can be performed in different environments, such as playing with each other, etc., for children >5 years of age that differ little from those of younger children aged ≤5 years.

This suggests that these children have increased opportunities for direct physical contact with their peers and a higher frequency of interaction with dirt compared to younger children, thereby increasing their susceptibility to infection [19].

The observed frequency of male-to-female transmission is 2:1, however a predominance of female-to-male infection is evident among the 5–14 age group [19,20]. The observed gender disparity may be attributed to the tendency of girls to prioritise personal hygiene more rigorously than boys, thereby reducing their susceptibility to infection [20]. In this study, a higher percentage of male subjects were tested, with 63.5% of cases being male. This is in comparison to the percentage of female subjects who were tested, which was 36.5%. The prevalence of the condition was found to be higher in males, with a percentage of 60%. It is estimated that 93.7% of children are enrolled in kindergartens, with the majority of these being enrolled in public kindergartens.

The infection rate is observed to be highest among children living in the community, in comparison to those living under the care of parents or relatives. While the majority of children reside in apartments, the prevalence of infection caused by *E vermicularis* in this demographic was found to be comparable to that of children residing in private homes, with a proportion of 50% in each group. In addition, a higher positivity is observed in the cases of children who have siblings, as well as in children who do not have pets. A notable finding was the observation that children with a sibling exhibited a significantly higher prevalence of the condition. This finding was consistent with another study [21], suggesting that transmission of infection can occur within families through siblings. A lack of a significant correlation between the various variables and pinworm infection was identified ($p > 0.05$) (Table 1).

Table 1. The epidemiological data for young children's participants of this study

Variables	Categories	Total (83)		Negative (63)		Positive (20)	
		No	%	No	%	No	%
Age groups	3-4 years old	47	56.6	36	57.1	9	45
	5-6 years old	36	43.4	27	42.9	11	55
Gender	Female	31	37.3	23	36.5	8	40
	Male	52	62.7	40	63.5	12	60
Attends kindergartens or stay in house	Yes	75	90.4	59	93.7	16	80
	No	8	9.6	4	6.3	4	20
Type of kindergarten that the children attend (75 cases)	Public	60	80	46	83.6	14	70
	Private	15	20	9	16.4	6	30
The kind of house you live in	Apartment	54	65.06	44	69.8	10	50
	Private house	29	34.94	19	30.2	10	50
Do they have brothers or sisters?	Yes	48	57.83	33	52.4	15	75
	No	35	42.17	30	47.6	5	25
Do they have any pets at home?	Yes	24	28.92	17	27	7	35
	No	59	71.08	46	73	13	65

Approximately one-third of patients with *Enterobius vermicularis* are asymptomatic, the most common symptom being perianal itching. Conversely, persistent pruritus can result in sleep disturbances and insomnia. Furthermore, symptoms such as diarrhoea and abdominal pain have

been reported in some patients [22]. Conversely, the presence of diminutive thread-like worms, observable without the use of magnification, in the perianal region or during defecation, has also been documented [18]. As demonstrated in Figure 2, the medical information concerning patients who were tested for *Enterobius vermicularis* as suspected cases in the laboratories is presented. Clinicians and pediatricians referred the children due to clinical signs. It is important to note that the signs most concerning to parents were specified; however, numerous children presented with combinations of different signs (Figure 2).

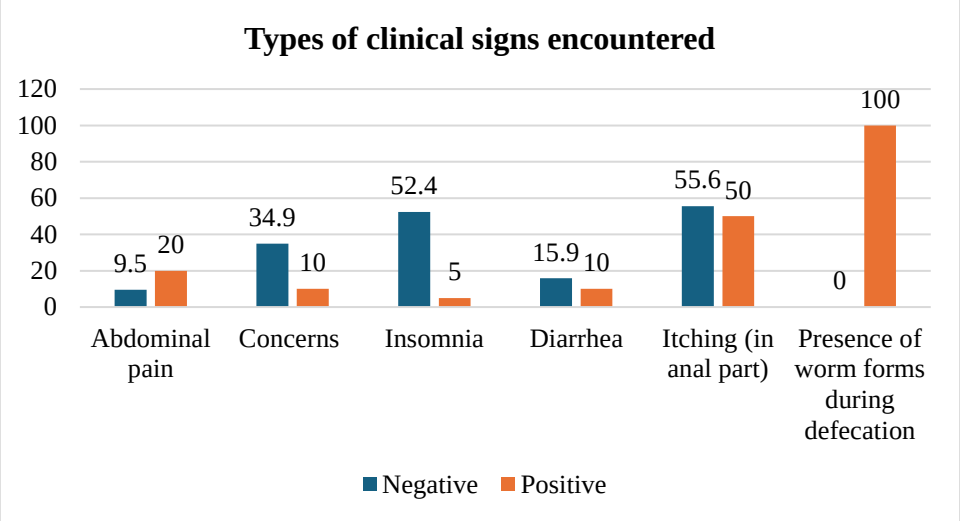


Figure 2. Types of clinical sign encountered

Conclusion

E vermicularis remains a prevalent parasitic infection, especially among children attending kindergartens, who often lack the personal hygiene practices necessary to prevent such infections. The symptoms that were most commonly reported in this study included pruritus and discomfort during the nighttime hours, which resulted in insomnia. In view of the presence of the parasite in children who attend shared environments, such as kindergartens, there is a requirement to ensure the availability of treatment for these children, in order to prevent the spread of infection in childcare centres. It is recommended that parents and educators adopt a proactive approach to promote hygienic practices among children, encompassing both their immediate environments and personal hygiene routines.

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PREVALENCE OF HEALTHCARE-ASSOCIATED INFECTIONS IN "MOTHER TERESA" UNIVERSITY HOSPITAL AND REGIONAL DURRESHOSPITAL

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Abstract

A healthcare-associated infection (HAI) is defined as an infection that occurs in a patient during the care process in a hospital or other healthcare facility that was not present or incubating at the time of admission. It is important to note that HAI has the capacity to affect patients in any type of healthcare setting. Furthermore, it should be noted that such infections can also occur after discharge from hospital. Healthcare-associated infection is the most prevalent adverse event in healthcare provision, and no institution or country can claim to have solved this problem. It is estimated that hundreds of millions of patients worldwide are infected with HAI each year, a figure based on data from a variety of countries. The prevalence of HAI is found to be significantly higher in low- and middle-income countries compared to high-income countries. The daily presence of HAIs has been demonstrated to result in prolonged hospital stays, long-term disability, and increased resistance of microorganisms to antimicrobials. Furthermore, the presence of HAIs has been shown to result in significant additional costs to health systems, high costs to patients and their families, and unnecessary deaths.

Keywords: healthcare-associated infection, hospital, patients, prevalence, epidemiological data

Introduction

The European Centre for Disease Prevention and Control (ECDC) coordinated the inaugural European Union (EU) country-wide point prevalence (PPS) surveillance of healthcare-associated infections (HAIs) and antimicrobial use in hospitals during the 2011–2012 period.The survey confirmed that HAIs represent a major public health problem. ECDC estimates that approximately 80,000 patients per day are affected by at least one HAI, indicating that one in 18 patients in a European hospital has a healthcare-associated HAI. In 2016–2017, the European Centre for Disease Prevention and Control (ECDC) organised a second Public Health Programme (PHS) in all Member States.

The results of the 2016–2017 survey corroborated earlier trends. Such infections, including pneumonia, surgical site infections and bloodstream infections, are often severe and have a significant impact. It is estimated that in excess of 50% of all identified HAIs are considered to be preventable.

In addition, hospitals have established "packages" of care in infection prevention and patient safety. These packages consist of simple, evidence-based sets of practices that have been shown to enhance patient safety and outcomes.

Despite the prevalence of healthcare-associated infection as the most common adverse event in healthcare, the true global burden remains uncertain due to the challenges in collecting reliable data. The majority of countries lack surveillance systems for healthcare-associated infection, and those that do have them encounter difficulties with the intricacy and lack of uniformity of criteria for its diagnosis.

Aim and Methodology

The objectives of the point prevalence study of healthcare-associated infections and antimicrobial use in acute care hospitals are as follows:

1) The objective of this study is to estimate the total burden (prevalence) of HAI and antimicrobial use in acute care hospitals and,
2) To provide a comprehensive description of the main structures and processes for the prevention of HAI and antimicrobial resistance at the hospital and ward level.

A pilot study of the prevalence of healthcare-associated infections and antimicrobial use was conducted in selected hospitals in Albania [Mother Teresa University Hospital Center (MTUHC) and Durrës Regional Hospital (DRH)]. The pilot study of the PPS was conducted in accordance with the ECDC prevalence survey protocol for healthcare-associated infections and antimicrobial use in hospitals in the country. The inclusion criteria encompass hospitals and wards, as well as patients.

1). The present study encompassed two hospitals, namely MTUHC and DRH. 2). Wards. The study encompassed wards believed to have the highest risk of HAI and where antimicrobial use was most prevalent.

A distinct document was generated for each patient admitted to each hospital, with this documentation being based on the hospitalised service. The file provides a synopsis of the data relating to the nature of the intervention, the duration of stay, the antibiotics administered, and the occurrence of nosocomial infections during the patients' hospitalisation, etc.

Results

The present study comprised two hospitals, categorised into two distinct types: a tertiary hospital (MTUHC) and a secondary hospital (DRH). In both hospitals, only wards that presented a higher risk of HAI or for greater use of antimicrobials were included according to the standard protocol. The total number of beds included in the study for both hospitals is 954 (714 at MTUHC and 240 at DRH). During the period in which the study was conducted, a total of 648 patients were present, with 511 of these patients being admitted to the MTUHC hospital and 137 to the DRH hospital. The mean length of stay was 5.5 days for both hospitals, and respectively 5.6 days for MTUHC and 4.8 days for DRH.

Table 1. Patient characteristics by hospital included in this study

Variables	MTUHC		DRH		Total	
	N	%	N	%	N	%
Age group						
<1 Years old	21	4.1%	3	2.2%	24	3.7%
1-4 Years old	31	6.1%	5	3.6%	36	5.6%
5-14 Years old	48	9.4%	3	2.2%	51	7.9%
15-24 Years old	11	2.2%	7	5.1%	18	2.8%
25-34 Years old	22	4.3%	21	15.3%	43	6.6%
35-44 Years old	24	4.7%	8	5.8%	32	4.9%
45-54 Years old	58	11.4%	18	13.1%	76	11.7%
55-64 Years old	118	23.1%	18	13.1%	136	21.0%
65-74 Years old	102	20.0%	24	17.5%	126	19.4%
75-84 Years old	68	13.3%	25	18.2%	93	14.4%
>=85 Years old	8	1.6%	5	3.6%	13	2.0%
Gender						
Female	221	43.2%	81	59.1%	302	46.6%
Male	290	56.8%	56	40.9%	346	53.4%
Days of hospitalization (7)						
1-3 days	174	34.1%	71	51.8%	245	37.8%
4-7 days	132	25.8%	40	29.2%	172	26.5%
8-14 days	121	23.7%	19	13.9%	140	21.6%
>=3 weeks	84	16.4%	7	5.1%	91	14.0%
McCabe score						
Non-fatal disease	386	75.5%	112	81.8%	498	76.9%
Fatal disease	102	20.0%	7	5.1%	109	16.8%
Rapidly fatal disease	17	3.3%	18	13.1%	35	5.4%
Missing/Unk	6	1.2%	0	0.0%	6	0.9%
Central vascular catheter	36	7.0%	0	0.0%	36	5.6%
Peripheral vascular catheter	424	83.0%	119	86.9%	543	83.8%
Urinary catheter	129	25.2%	11	8.0%	140	21.6%
Intubation	10	2.0%	1	0.7%	11	1.7%

The median age of the total population is 59 years, respectively 59 years for MTUHC and 8:0.1 for the hospital, and respectively 0.7:1 for MTUHC and 1.4:1 for DRH. The average length of stay of patients until the day of the study is 5 days, respectively 5.6 days for MTUHC and 4.8

days for DRH. Table 1 presents the distribution of patients according to age group, both for individual hospitals and on aggregate.

On the day of the study, 24% of the patients had undergone surgical interventions since their admission to the hospital. In accordance with the McCabe classification, it was ascertained that 76% of the patients did not have fatal diseases, 5.4% had rapidly fatal diseases, and 16.8% had fatal diseases. For 0.9% of the patients, however, this classification was not reported (it was not completed by the interviewers who did not deem it necessary to make the classification).

The evaluation of the prevalence of catheters revealed that 83.8% of patients exhibited the presence of peripheral vascular catheters. Furthermore, 21.6% of patients were found to have urinary catheters, 5.6% exhibited central catheters, and only 1.7% were intubated. The consumption and utilisation of alcohol for the purpose of hand hygiene constitutes a significant indicator of the hygiene standards within a hospital setting. An analysis of the data obtained from the hospitals reveals that the consumption levels are 8.1 litres per 1,000 patient days. The MTUHC hospital has consumed 6.6 litres per 1,000 patient days, while the DRH hospital has consumed 19.5 litres per 1,000 patient days (for each patient).

Of the 47 instances of nosocomial infection identified during the course of the study, the microbiological aetiology was ascertained for a mere 12.8% of these, amounting to just six cases. A total of eight microorganisms were isolated. In the group of gram-negative non-enterobacteriaceae, only one isolate was identified (12.5% of the total number of isolated microorganisms), namely Acinetobacter baumannii. A total of 50% of the isolated microorganisms were identified as belonging to the Enterobacteriaceae group, while 37.5% were classified as Gram-positive cocci. With regard to the nature of the infection, 33.3% of the isolated microorganisms were identified in cases of urinary tract infections or surgical wound infections, while 16.7% were isolated in cases of pneumonia or lower respiratory tract infection, and in blood infections.

In the present study, a total of 41 identified IS were analysed, of which only 5 were isolated in MTUHC. The five microorganisms in question are as follows: The distribution of the isolates is as follows: one isolate was identified in the Gram-negative non-Enterobacter group, three were identified in the Enterobacteriaceae group, and one was identified in the Gram-positive cocci group. In the present study, DRH was identified in 7 out of the total number of isolates examined. Of these, the microorganism was isolated in only one instance. In this particular isolate, two were classified as gram-negative non-Enterobacteriaceae, and one was identified as a gram-negative Enterobacteriaceae.

The establishment of a hospital infection control unit and an infection control committee is a pivotal component of effective hospital infection control and antimicrobial resistance strategies. As demonstrated in Table 2, only MTUHC has an infection control unit and an infection control committee. By contrast, DRH has only an infection control committee. However, the organisation of work and the transparency of decision-making at DRH are inadequate.

Table 2. Type of microorganism and resistance to antimicrobials

Microorganism /Resistance	N isol.	N test.	N NS	% NS
GRAM-POSITIVE COCCI	**4**	**4**	**1**	**25%**
Staphylococcus aureus, OXA-R (MRSA)	1	1	1	100%

Staphylococcus aureus, GLY-R	1	1	0	0%
Enterococci, GLY-R (VRE)	1	1	0	0%
Enterococcus faecalis	1	1	0	0%
Enterococcus faecium	0	0	0	.
Enterobacteriaceae, 3GC-NS	**3**	**3**	**3**	**100%**
Escherichia coli, 3GC-NS	1	1	1	100%
Klebsiella spp., 3GC-NS	1	1	1	100%
Enterobacter spp., 3GC-NS	1	1	1	100%
Enterobacteriaceae, CAR-NS	**3**	**3**	**0**	**0%**
Escherichia coli, CAR-NS	1	1	0	0%
Klebsiella spp., CAR-NS	1	1	0	0%
Enterobacter spp., CAR-NS	1	1	0	0%
Other Gram- Negative Bacteria, CAR-NS	**1**	**0**	**0**	
Pseudomonas aeruginosa, CAR-NS	0	0	0	
Acinetobacter baumannii, CAR-NS	1	0	0	

Discussion

A total of eight microorganisms were isolated. In the gram-negative non-enterobacteriaceae group, Acinetobacter baumani was the sole isolate (12.5% of the isolated microorganisms). The results of the study indicate that 50% of the isolated microorganisms belong to the Enterobacteriaceae group, while 37.5% belong to the Gram-positive cocci group. With regard to the nature of the infection, 33.3% of the isolated microorganisms were identified in cases of urinary tract infections or surgical wound infections, while 16.7% were isolated in cases of pneumonia or lower respiratory tract infections, and in blood infections. Hospital infections (HI). On the day of the study, 41 out of 648 patients presented with at least one healthcare-associated infection. The prevalence of HI is 6.3% (95% CI 4.4-8.1%). The observed prevalence of the condition varies between the two hospitals. The prevalence of hospital infections (HI) in MTUHC was found to be 6.7% (95% CI 4.5-8.8%), while in DRH it was 5.1% (95% CI 1.4-8.7%). Of the 41 patients with hospital infections, 36 had only one HI, 4 had two HI, and only one had three HI. The presence of HI at the time of hospitalization was observed in 12 patients, representing 26% of the total number of patients with HI. In the present study, 8.5% of patients (4 patients) acquired HI in the same hospital, i.e. in the hospital where they were admitted. 12.8% of patients (6 patients) had an HI origin from another hospital, i.e. they had previously been admitted to a different hospital. Finally, 2 patients (4.3%) had an untimely HI origin on admission. In MTUHC, only 5 out of 41 identified microorganisms were isolated. The following five microorganisms are of particular interest: The distribution of the isolates is as follows: one isolate was identified in the Gram-negative non-Enterobacter group, three were identified in the Enterobacteriaceae group, and one was identified in the Gram-positive cocci group. In the DRH 7 sample, the presence of the microorganism was documented, yet the isolation of the microorganism was successful in only one instance. Of the isolated microorganism, two were classified as gram-negative non-Enterobacteriaceae, and one was identified as a gram-negative Enterobacteriaceae.

Conclusion

The results of the study will inform national policies and procedures aimed at reducing HAIs, supporting policies for the appropriate use of antimicrobial drugs, enhancing methods for collecting HAI data, and facilitating the implementation of essential components of the Infection Prevention and Control (IPC) program at both the national and local levels. This includes the identification of a set of priorities for the prevention of HAIs and antimicrobial resistance in selected hospitals.

Recommendations

1. It is recommended that surveillance and data analysis be strengthened through the conducting of prevalence studies at intervals of between three and six months in order to identify the sources and most common types of infection.

2. In the identification of healthcare-associated infections, the establishment of performance indicators in wound infections and ventilator-associated pneumonitis is of paramount importance.

3. It is imperative that the requirements and implementation of hand hygiene standards and the use of alcohol-based disinfectant solutions are increased.

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IMPACT OF PROBIOTICS, PREBIOTICS, AND THE GUT MICROBIOME ON SPORTS PERFORMANCE IN ADOLESCENTS: A STRUCTURED PRISMA-STYLE REVIEW

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Abstract

Background: The gut microbiome modulates metabolism, immune function, and inflammation pathways relevant to athletic performance and recovery. Probiotics and prebiotics are nutritional strategies proposed to beneficially modify the gut microbiota and thereby improve sports performance. Most evidence comes from adult athletes and animal models; adolescent-specific evidence is unclear.

Objective: To perform a structured review of the literature on the effects of probiotics, prebiotics, and gut microbiome composition on sports performance and recovery in adolescents (≈10–19 years), summarizing current evidence, mechanisms, and research gaps.

Methods: Structured literature searches were conducted in PubMed/MEDLINE, Scopus, Web of Science, and Google Scholar (2000–2025) using keywords related to probiotics, prebiotics, microbiome, sports performance, and adolescents. Inclusion prioritized RCTs, systematic reviews, and cohort studies with athletic outcomes. Data extraction included study design, population, intervention, outcomes, and adverse events. Narrative synthesis was applied due to heterogeneity.

Results: Adult studies indicate probiotics reduce URTI and some GI illnesses, improve some inflammatory markers, and modestly enhance endurance metrics (VO_2max, time-to-exhaustion), but strength/power outcomes are inconsistent. Adolescent-targeted studies are scarce; small trials in swimmers and other youth athletes showed modest VO_2max improvements and reduced URTI incidence with multi-strain probiotic interventions. Prebiotic-specific performance data are very limited.

Conclusions: Probiotics may support endurance and recovery via illness reduction and microbiome modulation, but adolescent-specific, adequately powered RCTs are needed. Prebiotics require further study. Standardized outcome sets and mechanistic trials are recommended.

Keywords: probiotics, prebiotics, gut microbiome, adolescent athletes, sports performance, systematic review

Introduction

The human gut microbiome interacts with host metabolism, immunity, and inflammation systems integral to athletic performance and recovery (1-3). Exercise itself shapes the gut microbiome, -producing bidirectional effects between training and microbial ecology. Interest has grown in targeted nutritional modulation using probiotics and prebiotics to enhance athlete health and performance (PMC) (4-8).

Adolescence (≈12–18 years) is a distinct developmental window physiological growth, hormonal changes, maturation of immune function, and evolving diet patterns may shape microbiome–host interactions differently than in adults (9-13). Youth athletes are important because training loads, development, and vulnerability to illness/injury affect long-term performance trajectories (14). Despite growing adult evidence, translation to adolescent athletes has been limited. This review synthesizes evidence (RCTs, systematic reviews, cohorts) on probiotics, prebiotics, and gut microbiome composition in relation to sports performance and recovery in adolescents and identifies research gaps (15-17).

Methods

Review design

Structured PRISMA-style literature review focusing on probiotics, prebiotics, and gut microbiome effects on athletic performance and recovery in adolescents. Adult studies and systematic reviews were included where adolescent evidence was sparse but mechanistic inference was useful.

Search strategy

PubMed/MEDLINE, Scopus, Web of Science, and Google Scholar were searched (database inception–October 2025) using: (probiotic* OR prebiotic* OR "gut microbiome" OR "gut microbiota" OR microbiota*). AND (sport* OR athlete* OR exercise OR performance OR endurance OR strength OR VO2max). AND (adolescent* OR teen* OR youth OR pediatric OR child*). Hand-searching of references from recent reviews and major position statements (e.g., ISSN) was also performed.

Inclusion/Exclusion criteria

Inclusion: RCTs, quasi-RCTs, cohort studies, case-control studies, systematic reviews/meta-analyses reporting probiotics, prebiotics, synbiotics, or gut microbiome composition with objective, subjective, or physiological performance-related outcomes in adolescents or extractable adolescent data. Exclusion: Animal-only studies (except for mechanistic discussion), case reports, conference abstracts without full data, studies without performance- or recovery-related outcomes.

Data extraction and synthesis

Extracted: study design, population (age, sex, sport), intervention (strain(s), dose, duration), outcomes, main results, and adverse events. Narrative synthesis highlighted RCTs and high-quality systematic reviews. Risk of bias assessed qualitatively.

Results

General landscape

Systematic reviews and meta-analyses indicate probiotics reduce URTI and GI illness in athletes and modestly improve endurance metrics; strength/power effects are inconsistent. Heterogeneity is high across strains, doses ($10^{8–10}$11 CFU/day), duration, athlete status, and outcomes ((PMC, MDPI)).

Probiotics — adult RCTs & reviews: Mixed but promising results for aerobic capacity and illness reduction. McDermott et al. (2024) reported endurance improvements in non-elite adult athletes after probiotic supplementation. Meta-analyses show small-to-moderate VO_2max/time-to-exhaustion benefits, with inconsistent strength/power improvements.

Probiotics — adolescent evidence: Few small trials (multi-strain probiotic yogurt in adolescent swimmers) reported improved VO_2max and reduced URTI incidence. Trials often include multiple bioactive components, limiting strain-specific conclusions. Adequately powered adolescent RCTs are scarce.

Prebiotics and synbiotics: Limited direct evidence for prebiotic interventions on performance; mechanistic animal studies suggest SCFA-mediated energy and anti-inflammatory effects may support recovery. Synbiotic data are minimal in adolescents.

Gut microbiome composition: Cohort/cross-sectional studies show sport-specific microbiome signatures; SCFA-producing taxa associated with endurance and recovery. Translational mouse studies suggest metabolic benefits, but human causal evidence is limited.

Safety and tolerability: Generally, well tolerated; mild, transient GI effects reported. Immunocompromised individuals often excluded. Quality control of commercial probiotic products is variable.

Discussion

Adult evidence: probiotics reduce URTI/GI illness and modestly improve endurance; strength/power effects inconsistent. Adolescent evidence: limited, small trials suggest VO_2max improvements and reduced illness with multi-strain probiotics; prebiotics understudied. Mechanisms: immune modulation, SCFA production, nutrient absorption, gut–brain axis effects (18-20). Reduced illness may mediate endurance benefits via fewer training interruptions. Direct ergogenic effects remain speculative. For adolescents, indirect benefits may still enhance performance (21-24). Strengths: structured search, emphasis on adolescent data. Limitations: no registered systematic review, heterogeneous studies, few adolescent RCTs, narrative synthesis.

Well-powered adolescent RCTs by age, sex, sport type, maturation stage. Standardized interventions: strains, CFU counts, duration, matrices. Core outcome set: VO_2max, time-to-exhaustion, recovery, URTI/GI incidence, fatigue/recovery scales, biomarkers, microbiome sequencing. Mechanistic sub-studies: SCFA, metabolomics, mucosal immunity. Prebiotic and synbiotic trials in youth. Longitudinal studies across growth and training phases.

Probiotics generally safe in adolescents; may reduce illness and indirectly improve endurance. Prebiotics and targeted microbiome modulation remain investigational. Clinicians should use well-characterized, tested products and counsel about variability (25-28).

Conclusions

Probiotics show potential for endurance and recovery benefits. Adolescent evidence is limited; prebiotic effects unproven. Future research should focus on adolescent-specific, adequately powered RCTs, mechanistic studies, and standardized outcomes.

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LEVEL OF STRESS, AND BURNOUT AMONG NURSING STAFF IN THE WORKPLACE: A CORRELATIONAL STUDY IN A REGIONAL HOSPITAL

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Abstract

Introduction

Nowadays, nursing staff are experiencing excessive fatigue, which has often resulted in low performance, delayed health services and a frequent staff shortage. On the other hand, the presence of stress in the workplace is further exacerbating the problems that are being observed in nursing staff. For this reason, we undertook this study to determine the relationship between these two variables in the context of healthcare professionals such as nurses.

Methods

Methods: This cross-sectional, observational study was conducted over a period of six months and involved 110 nursing professionals from a regional hospital. The prevalence of stress and burnout was evaluated using the standardized Perceived Stress Scale (PSS-10) and Maslach Burnout Inventory (MBI) questionnaires. The data were collated in Excel and exported to SPSS version 26.0 for analysis. In the context of statistical analysis, a p-value of less than 0.05 was designated as statistically significant, with a confidence level of 95%.

Results

Overall, 110 analyzed nursing 31.5% fell into the 25-35 age bracket, indicating a high proportion of nurses in this age group. The mean age of the subjects was found to be 32.41 years (±5.89), with a minimum age of 24 years and a maximum of 64 years. The prevalence of burnout among nurses was found to be 42.3% (95% CI: 32.9 to 54.7). The prevalence of "Emotional Exhaustion" was found to be 37.6%, "Depersonalization" 45.3%, and "Personal Achievement" 50.1%, while, the most predominant level of stress among nursing staff resulted in level of moderate 45.6% and 25% in high perceived stress. Factors associated with burnout were long hours, work regimens, night shifts, number of patients receiving support, lack of rest hours, environmental working conditions, and poor social support, while for stress we found (OR = 2.43, 95% CI = 0.98 to 4.65).

Conclusion

A high prevalence of moderate stress and burnout was identified among nurses. Those phenomena can be attributed to a combination of factors, including excessive workloads, insufficient social support and other work-related pressures. The work regime moderates the relationship between 'work-related stress' and burnout, having a direct impact on the performance of these staff. Given the current work regimes, it can be concluded that, among the dimensions of work-related stress, there is a strong correlation with work-related burnout. In order to ensure the efficacy of nursing staff and their contribution to patient care, it is recommended that optimal support and its subsequent evaluation be provided.

Keywords: burnout; stress level, nursing, performance, prevalence

Introduction

Stress can be defined as a state of mental distress or tension caused by a difficult situation [1], while work-related stress (WRS) can be defined as stress caused or exacerbated by work. This stress can occur when a person perceives their work environment in a way that makes them feel unable to cope. It can also be caused by perceived or real pressures, anxieties in the workplace, pressure to perform the workload in real time, and in some cases threats from colleagues or managers [2].

Work-related stress can affect workers in all professions and nurses are no exception as they are subjected to a large amount of stress due to the nature of the work environment (3). The highest reported level of stress in the healthcare industry, such that in nursing practice it is associated with constant contact of care between patients together with their intensive demands for recovery [4]. The negative impact that comes as a result of the stressful situation that employees experience, at work in nurses, can greatly affect the quality and safety of care, absenteeism, increased intention to leave work, etc. [5]. High work pressure and demands in the face of unfavorable job characteristics, namely shift changes, experience of violence, low staffing levels and high expectations of patients and their families, are identified as important stress factors [6].

While on the one hand there are a number of studies that evidence work-related stress mainly in nursing staff, on the other hand there is a notable lack of research on the effects of work-related stress and Burnout on nursing performance [7]. Burnout in the workplace is not the daily, short-term stress or pressure that we may feel from time to time, but something chronic, intense and continuous. According to the World Health Organization, Burnout is a syndrome that results from chronic stress in the workplace that is not successfully managed [8,9].

According to Qattan, (2017), work-related stress can affect job satisfaction and can also lead to Burnout, which can consequently affect job performance and satisfaction [7]. A recent study of

Iranian and Turkish nurses respectively confirmed that Burnout is caused by prolonged exposure to stress [10].

Also, this chronic exposure to stress makes it difficult to have enough time for recovery both physically and mentally [11]. The hallmark symptoms of Burnout are emotional exhaustion, depersonalization and reduced professional development. The personal impact of excessive fatigue can be explained by its impact on physical and mental health, along with significant declines in quality of life domains [12]. Given these facts, it is essential to study work-related stress in relation to fatigue in comparison to performance and job satisfaction. Since increased stress has been strongly associated with Burnout, determining the relationship between these two variables in the context of healthcare professionals such as nurses was the main objective of this study.

Methodology

The study aimed to identify levels of stress and burnout, determining the causal link and relationship between these variables among nursing staff. This is a descriptive correlational study. The study included 110 nurses from a regional hospital. The inclusion criteria are: (1) all nurses regardless of gender, aged 22-65 years, who are part of the staff of this hospital with a full-time contract; (2) have at least 6 months of work experience; and (3) agree to be part of this study voluntarily. Prior to participation, all individuals were provided with comprehensive information regarding the objectives and methodological characteristics of the study, and their involvement was voluntary and informed consent was obtained. The collection of data was achieved through the use of an online survey, employing the Google form format. The initial section of the study includes inquiries pertaining to sociodemographic, occupational, and health-related information, in addition to job satisfaction. While to measure the level of stress and burnout among the nursing staff, two instruments were used, known as: Perceived Stress Scale with 10 questions (PSS-10) and a three-dimensional model, the MBI (Maslach Burnout Inventory) comprises the following subscales: emotional exhaustion, depersonalization, and professional accomplishment. To calculate the scores for the PSS-10 items with 5-point Likert-type rating scale from 0 (never) to 4 (very often), firstly, we had to reverse each score for questions 4, 5, 7, and 8. On these 4 questions, we had changed the scores like this: 0 = 4, 1 = 3, 2 = 2, 3 = 1, 4 = 0. After these steps, the scores for each participant on the PSS-10 test can range from 0 to 40, where the higher scores indicate higher perceived stress. Meantime, the total scores that ranged from 0-13 were considered as low stress; Scores ranging from 14-26 were considered moderate stress; and Scores ranging from 27-40 were considered high perceived stress. The Perceived Stress Scale is interesting and important because nursing perception of what is happening in their workplace is most important.

Additionally, MBI is further characterized by the incorporation of 22 items and a 7-point Likert-type rating scale. The items are expressed in the form of statements regarding personal sentiments or outlooks. The frequency scale is labeled at each point, ranging from 0 (never) to 6 (every day). The maximum score that can be achieved on the total burnout scale is 132. Cronbach's alpha, a statistical technique used to evaluate reliability, was employed to assess the validity of the questionnaire. The result of the analysis was a reliability coefficient of 0.82.

The collected data underwent meticulous organization in Excel, followed by transfer to the statistical software SPSS version 26.0 for systematic scrutiny. The numerical data were presented as the mean and the standard deviation (SD). Categorical data were presented as

numbers and percentages, and the chi-squared test was used for the statistical analysis. In the context of statistical analysis, a p-value of less than 0.05 was designated as statistically significant, with a confidence level of 95%.

Results and Discussion

Nurses are on the front lines of patient care in hospitals and other settings, often present when physicians are not present and tasked with making important decisions related to patient care [15]. Due to the critical role of nurses in providing and, in some cases, supervising patient care, burnout and perceived stress among nursing staff may be associated with multiple dimensions of patient outcomes [4]. This study argues that there is a correlation between increased levels of workplace stress and burnout among the nursing profession in the Shkodra Regional Hospital. A total of 110 nurses were analyzed in this study, of whom 31.5% fell into the 25-35 age bracket, indicating a high proportion of nurses in this age group. The mean age of the subjects was found to be 32.41 years (±5.89), with a minimum age of 24 years and a maximum of 64 years. The demographic is predominantly comprised of women, constituting 68.2% of all cases, and approximately 71.8% of the population residing within urban environments. Furthermore, the majority of participants (80%) were married, and 92.7% had higher education (Bachelor's in nursing Diploma). Related to family income, a significant proportion of the respondents, amounting to 74.6%, reported that their income fluctuated within the range of more than 60,001 lek. The Body Mass Index (BMI) of the majority of participants in this study ranges from overweight (45.5%) (Table 1).

Table 1. Socio-demographic data of the nursing staff in the study

Variables	Categories	Frequency	Percentage
Age group (years)	≤25 years old	25	22.7
	26-35 years old	33	30
	36-45 years old	23	20.9
	46-55 years old	20	18.2
	56-65 years old	9	8.2
Sex	Male	35	31.8
	Female	75	68.2
Place of Residence	Rural area	31	28.2
	Urban area	79	71.8
Status of Family	Single	27	24.6
	Married	80	72.7
	Widow/divorced	3	2.7
Level of Education	Higher education	102	92.7
	Secondary education	8	7.3
Monthly income (per family)	Less than 40,000 lek	3	2.7
	40,001-60,000 lek	25	22.7
	More than 60,001 lek	82	74.6
Body Mass Index (BMI)	Underweight <18	3	2.7
	Normal, 18.5 - 25	42	38.2
	Overweight 25 - 30	50	45.5
	Obese Class I-III, >30	15	13.6

According to Maslach & Leiter (2016), burnout has a major impact on employee performance and the organizational environment, causing decreased productivity and reduced decision-making skills (16). In cases where employees experience burnout, they are unable to concentrate, and the work they perform results in delays or frequent errors, which can lead to a decrease in both their accuracy and quality (17). In this study, we found a high prevalence of burnout among nursing staff, with the prevalence of high burnout in "Emotional Exhaustion" at 37.6%, high burnout in "Depersonalization" at 45.3%, and low burnout in "Personal Achievement" at 50.1% (Figure 1). Factors associated with burnout were long hours, night shifts, number of patients receiving support, lack of rest hours, while for environmental working conditions, and poor social support we found (OR = 2.7, 95% CI = 1.13 to 4.31) and (OR = 2.09, 95% CI = 0.87 to 3.45) respectively.

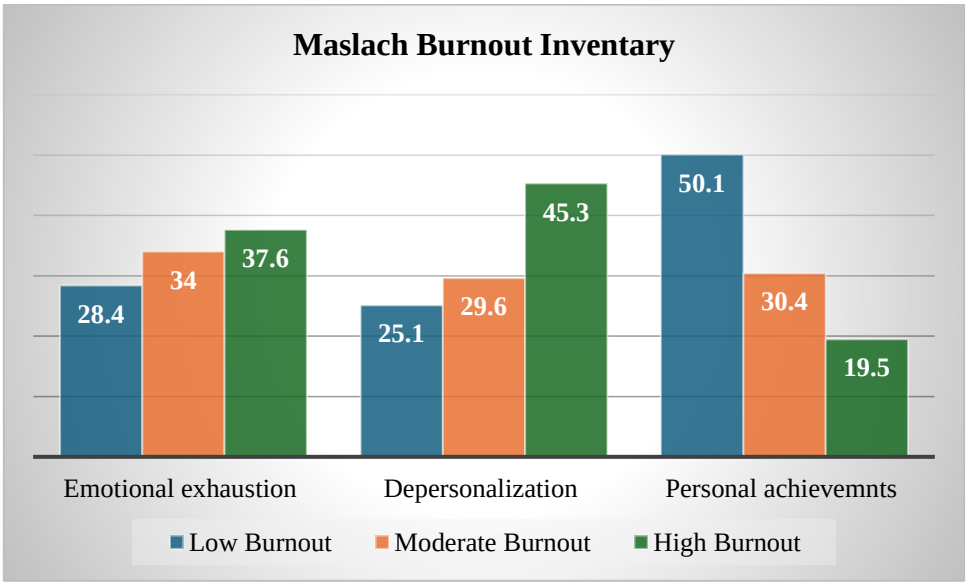


Figure 1. Prevalence of Maslach Burnout Inventory for each domen

On the other hand, nursing staff employees, as a result of continuous stress at work, have a rapid fatigue. If this stress continues to a certain extent, these employees face constant problems in meeting deadlines and achieving expected goals, exhibit a lack of autonomy, which can then lead to extreme fatigue, which translates into a high level of demotivation and carelessness (17,18). Stress at work contributes to the onset of burnout syndrome, which in turn exacerbates the effects of stress on perceived performance. Freitas et al. (2023) in their study, reported a positive and significant relationship between stress at work and levels of burnout from work (19). Given that employees are more susceptible to burnout and emotional exhaustion, excessive fatigue impairs the relationship between stress and performance, leading to reduced productivity, increased employee turnover and a negative impact on job performance (20).
According to W. B. Schaufeli (2017), burnout is the mechanism that explains the relationship between job stress and perceived performance (21). This is also observed in our study. Where we find a correlative relationship between Burnout and persistent job stress (OR = 2.43, 95% CI = 0.98 to 4.65). The following table presents the average values obtained for each question raised in the Perceived Stress Scale assessment.

Table 2. The Perceived Stress Scale among nursing

Statements		Mean	Sdt (±)
In the last month, how often have you….	been upset because of something that happened unexpectedly?	0.81	0.752
	felt that you were unable to control the important things in your life?	0.85	0.891
	felt nervous and "stressed"?	0.80	0.759
	felt confident about your ability to handle your personal problems?	0.88	0.648
	felt that things were going your way?	0.92	0.842
	found that you could not cope with all the things that you had to do?	0.81	0.709
	been able to control irritations in your life?	0.79	0.670
	felt that you were on top of things?	0.89	0.734
	been angered because of things that were outside of your control?	0.82	0.810
	felt difficulties were piling up so high that you could not overcome them?	0.83	0.643
Total scores		16.29	8.45

It is quite essential to take care of the staff of employees. This helps you not only to be present, but also to assess their concerns, as well as to increase their performance at work. Therefore, assessing the level of Perceived Stress is interesting because the perception of nurses about what is happening in their workplace is the most important in achieving positive results at work, as well as protecting the employees and the patients they care for in their daily lives (22). We found a high level of moderate stress (45.6%) among nursing staff (figure 2).

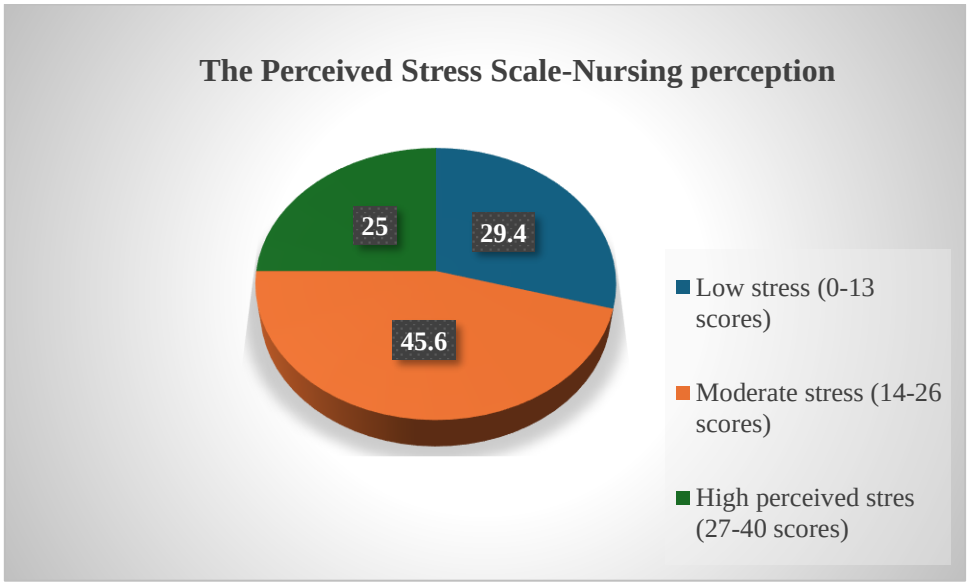


Figure 2. The Perceived Stress workplace prevalence among nursing

Conclusion

This study found a correlation between work-related stress and burnout among nursing staff. Workplace stress has shown a profound and significant impact on employee performance,

affecting both individual and organizational factors. Furthermore, work-related stress and burnout have shown a negative effect on nurses' job satisfaction and job performance. The high prevalence of burnout and high levels of moderate stress raise the alarm for immediate interventions that should provide mechanisms to reduce excessive fatigue in nursing staff, reduce workload, increase employee health care, and provide psychological and social support. In essence, measures should be taken to help alleviate work-related stress and fatigue levels in nurses. Managing professional practices in a supportive environment favors highly resilient individuals who are less likely to experience burnout. Further studies by specialists in the field are recommended regarding the relevant factors that directly or indirectly influence stress and burnout. Furthermore, the findings should be addressed and bridges should be created through the development of open communication, strong interpersonal relationships, availability of resources, and inclusion in policy decision-making. These should also include a systematic approach to the prevention and treatment of burnout.

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SUPPLEMENTS IN ATHLETES; TRENDS AND AWARENESS IN IMPLICATION WITH MICROBIOTIA

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Abstract

Introduction: Nutritional supplements have become a prevalent practice among physically active individuals, particularly athletes and sports science students. However, awareness of their impact on the gut microbiota, which is recognised as a regulator of the immune and metabolic systems, remains limited. The objective of this study is to assess the use of supplements and the level of knowledge about their impact on the gut microbiota among students of the University of Sports of Tirana and athletes registered in different disciplines in Tirana.

Methodology: This descriptive, cross-sectional study was conducted from January to May 2025 via a structured electronic questionnaire distributed using Google Forms. The questionnaire encompassed demographic data, supplement utilisation, physical activity, and awareness of the microbiota. The data set, which comprised information from 115 participants, was analysed in SPSS 27 using descriptive statistics and correlational analysis.

Results: This study revealed that 80.9% of respondents reported using at least one supplement, with protein (75.3%) and creatine (54.8%) being the most prevalent, followed by multivitamins (50.5%) The survey found that only 55.7% of respondents had heard about microbiota, while 18.3% of them felt informed. A positive and significant correlation was identified between the utilisation of probiotics and the belief in their positive effects (rho = 0.41, $p < 0.001$). Those who participated in training on a more regular basis demonstrated a heightened level of interest in acquiring knowledge regarding the microbiota.

Conclusions: The utilisation of supplements is pervasive and methodical, yet the understanding of the intestinal microbiota remains deficient and disorganised.

Keywords: supplements, microbiome, students, sportiest, foods

Introduction

Protein metabolism can be defined as the various biochemical processes responsible for the synthesis of proteins and amino acids (anabolism) and the breakdown of proteins (catabolism). The process of protein digestion begins with the breakdown of dietary proteins into individual amino acids by various enzymes and hydrochloric acid present in the gastrointestinal tract. These amino acids are absorbed into the bloodstream, where they are transported to the liver. From there, they are distributed to the rest of the body. The utilisation of absorbed amino acids typically occurs in the production of functional proteins. However, these molecules can also be employed for the generation of energy. Furthermore, these molecules can be converted into glucose. Subsequently, this glucose can be converted into triglycerides and stored in adipocytes (1). Furthermore, in humans, the synthesis of certain amino acids is possible through the utilisation of pre-existing intermediates. These amino acids are classified as non-essential amino acids. It is an established fact that essential amino acids require intermediates that are not present in the human body (2).

Conversely, the microbiota has been demonstrated to contribute to protein nutrition and intestinal well-being in individuals engaging in high levels of physical activity. The application of high-protein diets to athletes is somewhat paradoxical. Despite the augmented physiological requirements for dietary protein in athletes, the ingestion of high-protein diets has been demonstrated to exert an influence on the composition of the gut microbiota and the levels of protein fermentation, which may potentially engender adverse health consequences.

It has been demonstrated that elevated protein intake results in an increased presence of peptides within the systemic circulation and the distal segments of the gastrointestinal tract. This phenomenon can give rise to proteolytic fermentation, a process that has been observed to potentially intensify gastrointestinal symptoms, induce immune system disturbances, and stimulate inflammation, damage, and even dysfunction of the gastrointestinal tract (3). As colonic luminal nitrogen levels increase during periods of intense exercise due to the processes of protein catabolism and exercise-induced stress, greater amounts of nitrogen become available for metabolism and proliferation of the gut microbiota. This, in turn, can lead to alterations in microbiota composition. However, research has also demonstrated a positive correlation between microbial diversity and protein intake, as well as exercise, in both these individuals and others. This suggests that exercise may contribute to the maintenance of a healthy and balanced gut microbiota, as well as muscle mass and function. Nonetheless, it is imperative to acknowledge that elite athletes constitute a distinct demographic, with a considerable proportion of them seeking counsel on nutrition from both nutritionists and professional physicians (4).

In the context of personalised nutrition plans for athletes, it is imperative to consider the impact of diet on the gut microbiota, in conjunction with the utilisation of specific probiotic and prebiotic formulations. The microbiota has been demonstrated to facilitate the absorption and synthesis of amino acids, in addition to contributing to the regulation of the energy pathway in skeletal muscle. The absorption of microbially produced amino acids, which occurs primarily in the small intestine, may be of significance to the plasma amino acid pool. The quality of dietary proteins and the presence of a robust microbiota remain of significant importance for athletes. It is for this reason that this study was initiated, with two primary objectives. Firstly, to assess the use of supplements in physically active individuals; and secondly, to assess the level of awareness of the impact of supplements on the intestinal microbiota among students of the University of Sports of Tirana and athletes registered in various sports disciplines in Tirana.

Methods

This descriptive cross-sectional study has been designed to analyse trends in supplement use and awareness of their impact on the intestinal microbiota. The data were collected between January and May 2025 through an electronic questionnaire distributed with Google Forms. The instrument utilised for the aggregation of data in this study was a structured questionnaire, which was designed and adapted based on internationally validated instruments employed in analogous studies, such as that of El Khoury et al. (2019), which appraised the utilisation of supplements in athletes and sports students (5). The questionnaire is divided into five sections. The first section collects demographic data and information on physical activity. The second section queries the use of supplements. The third section explores respondents' knowledge and awareness of the intestinal microbiota. The fourth section poses questions regarding respondents' attitudes and goals regarding the use of supplements. The final section comprises open-ended questions that delve deeper into respondents' perceptions. The population of this study consists of students of the University of Sports of Tirana and athletes registered in various sports disciplines in the city of Tirana, who are physically active and use nutritional supplements.

The analysis exclusively incorporated data from students who had correctly completed the questionnaire. A total of 115 questionnaires were analysed. The study was conducted in accordance with the ethical principles of confidentiality, and the data were used exclusively for research purposes. The final data were analysed with the SPSS version 27 programme. Initially, a descriptive analysis was performed to present the percentages, frequencies, means and standard deviations for all variables. Further, to assess the relationships between the type of sport, the use of supplements and awareness of the microbiota, appropriate statistical tests such as the Chi-Square (χ^2) test, the t-test for independent groups and Pearson or Spearman correlation analysis were used, according to the nature of the data. The level of statistical significance was set at $p < 0.05$.

Results and Discussion

First, demographic data regarding the study participants were analyzed, such as age group, gender, and status (student/athlete) (table 1).

Table 1. Demographic data of study participants

Variables	Characteristics	Frequency (No)	Percentage (%)
Age groups	18–20 years old	33	28.7
	21–23 years old	45	39.1
	24–26 years old	22	19.1
	>26 years old	15	13.1
Gender	Male	100	87
	Female	15	13
University status	Student at the University of Sports	70	60.9
	Registered athlete	45	39.1

The data demonstrate that the participants in this study are predominantly young, with a substantial proportion falling within the 21–23 age bracket (39.1%), followed by the 18–20 age group (28.7%). This distribution is consistent with the typical profile of first-year university students and young athletes actively engaged in intensive training and pursuit of performance goals.

The majority of respondents were male (100 participants), constituting 87% of the sample, while females represented a mere 13%. The gender imbalance observed in studies related to

supplement use and high-intensity sports is a common phenomenon. This is primarily due to the fact that males constitute a larger proportion of regular practitioners of strength and endurance sports. In addition, they are more likely to experiment with the use of supplements for performance enhancement, recovery, and aesthetic benefits (6, 7).

The demographic composition of the participants is also of interest. A total of 60.9% of the participants were students of the Sports University of Tirana, while the remaining 39.1% were athletes registered in sports federations or associations. This distribution is indicative of the prevailing involvement of a university group with a focus on physical education and sports sciences, where the utilisation of supplements is an integral component of the daily training regimen. Registered athletes also represent a category of particular interest, as they are potentially more exposed to pressures for higher performance, and consequently may have different levels of awareness and education about the impact of supplements on intestinal health and microbiota (table 1).

In the subsequent phase of the study, an analysis was conducted on the utilisation of nutritional supplements by the participants

Table 2. Use of nutritional supplements by participants

Variables	Characteristics	Frequence (No)	Percentage (%)
Current supplement use	User	93	80.9
	Non-user	22	19.1
Types of supplements used	Protein	70	75.3
	Creatine	51	54.8
	Vitamin D	34	36.6
	Probiotics	28	30.1
	Omega-3	21	22.6
	BCAA	39	41.9
	Multivitamins	47	50.5
	Other	17	18.3
Frequency of use	Daily	56	60.2
	3–5 times a week	27	29.0
	Less often	10	10.8
Purpose of use	Performance enhancement	68	73.1
	Recovery enhancement	55	59.1
	Health support	40	43.0
	Digestion / microbiota	22	23.7
	Don't know exactly	12	12.9
Current supplement use	Self-determination	41	44.1
	Coach	29	31.2
	Doctor	10	10.8
	Society / social influence	7	7.5
	Media / Internet	6	6.4

The results of this study clearly show that the use of nutritional supplements is a widespread practice among physically active individuals, especially students of the Sports University of

Tirana and registered athletes. With a prevalence of 80.9% of current supplement users, this high percentage is consistent with the literature, which highlights that individuals engaged in intense physical activities often rely on supplements to improve performance, facilitate recovery, or support overall health (8).

The literature highlights that supplement use is more prevalent in athletic populations compared to the general population, especially in younger age groups that engage in intensive training and have performance-related goals (8). Among supplement users, protein is the most commonly used supplement with 70% of participants (75.3%), followed by creatine (54.8%) and multivitamins (50.5%). This result is consistent with the profile of the participants, with the majority engaged in sports that require increased muscle mass and rapid recovery. Meanwhile, the use of probiotics (30.1%) and omega-3 (22.6%) signals a growing awareness of their gastrointestinal health and anti-inflammatory components. Regarding frequency of use, the vast majority of participants who use supplements (60.2%) take them daily, indicating a continuous and integrated approach to their sports routine. This distribution suggests that supplement use is well-structured and often tailored to the weekly training load. The high frequency of use is particularly characteristic of supplements such as proteins, multivitamins and probiotics, which require consistency for optimal effect (9-13).

The main motivation for supplement use was performance enhancement, stated by 73.1% of participants, which is expected given the athletic nature of the sample. Post-workout recovery was the second most reported goal (59.1%), followed by health support (43.0%). A particular element of this study is that 23.7% of respondents linked supplement use to digestion and microbiota, indicating a growing awareness of the impact that nutritional supplements can have on intestinal health. Regarding the source of recommendation, self-determination is the most common way of choosing supplements (44.1%), followed by recommendation from trainers (31.2%). This suggests that athletes often make decisions independently or rely on the opinion of coaches, who are not always qualified in the field of sports nutrition (table 2).

Only 10.8% received a recommendation from doctors, while society/social influences (7.5%) and media/internet (6.4%) remain smaller but present sources. This result highlights the importance of creating educational programs to increase awareness of the appropriate use of supplements and to minimize unfounded self-experimentation (table 2).

Finally, data were analyzed regarding the awareness of athletes taking supplements about their impact on the microbiota

Table 3. Assessment of knowledge and awareness on intestinal microbiota

Response scale: 1 = I completely disagree | 5 = I completely agree					
Statements	**Frequency (No)**			**Percentage (%)**	
Have you ever heard of the gut microbiota?					
Yes	64			55.7	
No	51			44.3	
Statement	1 (no/%)	2 (no/%)	3 (no/%)	4 (no/%)	5 (no/%)
The gut microbiota influences the immune system.	5 (4.3%)	9 (7.8%)	31 (27.0%)	36 (31.3%)	34 (29.6%)
Probiotics positively influence the gut microbiota.	10 (8.7%)	19 (16.5%)	25 (21.7%)	27 (23.5%)	14 (12.2%)
Supplements without information can harm the microbiota.	7 (6.1%)	13 (11.3%)	29 (25.2%)	34 (29.6%)	22 (19.1%)
I have enough information about the microbiota.	29 (25.2%)	33 (28.7%)	32 (27.8%)	13 (11.3%)	8 (7.0%)

I would like to know more about this topic.	2 (1.7%)	6 (5.2%)	30 (26.1%)	39 (33.9%)	38 (33.0%)

Of those who constituted the sample population of the study (N = 115), 64 participants (55.7%) indicated that they had previously encountered the notion of the gut microbiota, while 51 (44.3%) reported an absence of prior familiarity with the subject. This finding suggests that awareness of the microbiota is limited to less than half of the population, indicating a substantial gap in the fundamental education of athletes and sports science students concerning this critical component of gastrointestinal health. The majority of participants acknowledge the impact of the microbiota on the immune system. The results of the study indicate that 70 participants (60.9%) expressed strong agreement (at levels 4 and 5), while only 14 participants (12.1%) disagreed (at levels 1 and 2).

The remaining 27% remained neutral. These findings are in line with the scientific literature, where the intestinal microbiota has been shown to be one of the main regulators of the immune system through the production of metabolites such as short-chain fatty acids (SCFA) and interaction with immunocompetent cells. Therefore, this level of knowledge can be considered good, although there is still room for further education. Probiotics positively affect the microbiota. In this question, the level of awareness was lower: only 43 participants (35.7%) gave a high rating (scale 4–5), while 29 participants (25.2%) disagreed and a large percentage (21.7%) remained neutral. This distribution shows that the concept of probiotics and their impact on the composition and function of the microbiota is not yet fully understood. The literature highlights that probiotics, when used consistently and in a personalized manner, can help regenerate the microbiota after antibiotic use or during chronic physical fatigue, so promoting education on their role is essential.

Supplements without information can harm the microbiota. This question resulted in a significant level of awareness, with 56 participants (48.7%) giving a high rating (scale 4–5), and only 17.4% disagreeing. Meanwhile, 25.2% remained neutral, suggesting that a significant proportion of athletes are aware of the risks associated with uncontrolled use of supplements, including the negative impact on the intestinal bacterial flora. This is a positive finding and is consistent with the literature that highlights that non-certified supplements, taken without professional consultation, may contain substances that negatively affect microbial balance. Correlational analysis conducted between variables related to supplement use and level of knowledge about the gut microbiota showed some significant, but also some non-significant relationships, reflecting a partial link between usage practices and awareness. A moderate and statistically significant positive correlation was observed between probiotic use and agreement with the question “Probiotics positively affect the microbiota” ($rho = 0.388$; $p < 0.01$). This is in line with the literature that emphasizes that individuals who use supplements directly related to gut health are more aware of their function (14-19). There was also a slight positive correlation between the number of weekly workouts and the desire to learn more about the microbiota ($rho = 0.251$; $p = 0.008$), suggesting that more engaged athletes are more likely to be interested in topics related to gut health.

On the other hand, the correlations between general use of supplements and feeling of being sufficiently informed about the microbiota were weak and statistically insignificant ($rho = 0.162$; $p = 0.089$), indicating that the use of supplements alone does not automatically guarantee education or awareness about their impact on the gastrointestinal system. Also, no significant correlations were found between gender or age group with knowledge about the microbiota, suggesting that these demographic factors do not significantly influence awareness on this topic. The results support the idea that the use of specialized supplements (such as probiotics)

is more strongly associated with awareness about the microbiota than the general use of sports supplements. These findings highlight the need for targeted education and awareness among athletes about the effects of supplements on intestinal health.

Conclusion

The use of nutritional supplementation is pervasive among physically active athletes and students, with over 80% of participants using at least one such supplement. The most commonly used supplements are proteins, creatine and multivitamins, followed by probiotics and vitamin D, which have seen a surge in interest in relation to performance, recovery and overall health. The level of awareness regarding the gut microbiota is limited, as evidenced by the fact that only half of the participants had heard of it, and only 18% of them felt informed. The absence of structured education regarding supplements and the microbiota has been demonstrated to increase the risk of self-experimentation and misuse. It is recommended that educational programmes and training dedicated to athletes and sports students be developed on the role of the gut microbiota and the impact of supplements on it. It is recommended that sports professionals, including coaches and instructors, possess fundamental knowledge regarding supplements and the microbiota, enabling them to offer precise and secure counsel. It is recommended that future studies include larger samples with a more balanced gender distribution in order to assess the impact of these factors on the level of knowledge.

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Ekstremiteler ve Abdominal Bölgeyi Tutan Yaygın Lipomatozis: Olgu Sunumu

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Lipomlar, yağ dokusundan köken alan benign tümörler olup lipomatozis tablosunun en sık bileşenini oluştururlar. Genel popülasyonda görülme sıklığının yaklaşık binde iki civarında olduğu bildirilmektedir; ancak çoğu olgu asemptomatik seyrettiğinden gerçek insidansın daha yüksek olabileceği düşünülmektedir. Genellikle baş, boyun, sırt ve ekstremitelerin deri altı yağ dokusunda yerleşim gösterirler. Bu bildiride, dört ekstremitesinde ve abdominal bölgede yaygın lipomları bulunan bir olgu sunulmaktadır.

Daha önce lokal anestezi altında ekstremitelerinden lipom eksizyonları yapılan hasta vücudunda yeni oluşan ve önceden mevcut olup büyüyen lipomları nedeniyle polikliniğe başvurdu. Yapılan MR görüntülemelerinde multipl lipomlar tespit edildi. Preoperatif planlamada hastanın görsel ve boyutsal olarak rahatsız olduğu lipomlar işaretlendi. Genel anestezi altında ortopedi ve genel cerrahi uzmanı tarafından vakaya alınarak lipomlar eksize edildi. Boyutları 1 cm ile 5 cm arasında değişen spesmenler patolojiye gönderildi. (lipom olarak raporlandı) Hastanın postoperatif kontrolleri yapıldıktan sonra 1.gün sorunsuz şekilde taburcu edildi.

Bu olguda, dört ekstremite ve abdominal bölgede multipl lipomları bulunan hastaya multidisipliner yaklaşımla başarılı bir cerrahi tedavi uygulanmıştır. Preoperatif görüntüleme ve dikkatli cerrahi planlama sayesinde operasyon etkinliği artırılmış, postoperatif dönemde sorunsuz bir iyileşme süreci sağlanmıştır. Bu olgu, yaygın lipomatozisli hastalarda bireyselleştirilmiş cerrahi stratejilerin ve disiplinler arası iş birliğinin tedavi başarısı açısından önemini vurgulamaktadır.

Anahtar kelimeler: yaygın lipomatozis, ekstremite, abdominal, cerrahi eksizyon

SİGARA İÇEN BİREYLERDE SPELEOTERAPİNİN SOLUNUM FONKSİYONLARINA ETKİSİ

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ÖZET

Bu çalışma, sigara tüketen bireylerde farklı coğrafi özelliklere sahip tuz mağaralarında uygulanan speleoterapinin terapötik etkilerini incelemeyi amaçlamaktadır. Araştırmaya 18–65 yaş aralığında toplam 60 birey dâhil edilmiş ve katılımcılar rastgele yöntemle kontrol grubu ve speleoterapi grubu olmak üzere iki gruba ayrılmıştır. Speleoterapi grubunun uygulamaları Iğdır Tuzluca Tuz Terapi Merkezi'nde, kontrol grubunun uygulamaları ise Iğdır Fizyodinamik Wellness Merkezi'nde 6 haftalık süre boyunca yürütülmüştür. Katılımcıların değerlendirmeleri uygulama öncesinde (T0), üçüncü haftada (T1) ve altıncı haftada (T2) gerçekleştirilmiştir. Speleoterapi grubunda bulunan 30 birey (13 kadın, 17 erkek) ile kontrol grubunda yer alan 30 bireyin (16 kadın, 14 erkek) tamamı planlanan solunum egzersizleri programını başarıyla tamamlamıştır. İstatistiksel analizlerde anlamlılık düzeyi $p<0,05$ olarak kabul edilmiştir. Her iki grupta da FEV_1, FVC, PEF ve FEV_1/FVC parametreleri, ıpaq test puanı, yaşam kalitesi ölçeğinin tüm alt boyutları ile altı dakikalık yürüme testi fark puanlarında artış gözlenmiştir. Gruplar arası değerlendirmelerde; FEV_1, altı dakikalık yürüme testi değişim puanı ile yaşam kalitesi ölçeğinin fiziksel sağlık, psikolojik durum, sosyal ilişkiler ve çevresel alan alt boyutlarında istatistiksel açıdan anlamlı farklılıklar olduğu görülmüş, bu parametrelerde speleoterapi uygulanan grubun kontrol grubuna göre daha iyi sonuçlar verdiği saptanmıştır.

Anahtar Kelimeler : Pranayama, Speleoterapi, Spirometri

EVALUATION OF HUMAN PAPILLOMAVIRUS (HPV) KNOWLEDGE LEVELS AMONG UŞAK UNIVERSITY STUDENTS

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ABSTRACT

Human papillomavirus (HPV) is one of the most common sexually transmitted infections worldwide and is associated with several benign and malign diseases, including cervical, anogenital and oropharyngeal cancers. University students represent a high-risk age group for HPV transmission; therefore, evaluating their level of knowledge is crucial for effective prevention strategies. This study aimed to assess HPV-related knowledge among university students. This cross-sectional study was conducted between March-May 2025 among 358 students at Uşak University (1 Eylül Campus). Data were collected using a 25-item questionnaire developed from the literature and a reference scale, with permission obtained from the original scale owner. The questionnaire included three sections: general HPV knowledge, HPV screening test knowledge, and HPV vaccine knowledge. Each correct response was scored as one point, yielding a maximum score of 50. The survey was administered digitally via Google Forms using a QR code on a voluntary basis. Ethical approval was obtained from the Uşak University Non-Interventional Clinical Research Ethics Committee. Of the participants, 70% were female and 61% were aged 17–20 years. The mean total knowledge score was 22.7 out of 50 (45.4%), indicating insufficient HPV knowledge. Mean scores were 10.71/27 (39.6%) for general HPV knowledge, 8.17/12 (68.1%) for HPV screening knowledge, and 5.23/11 (47.5%) for HPV vaccine knowledge. Knowledge levels didn't differ significantly by gender ($p<0.05$). Awareness of HPV vaccination and preventive measures was particularly low. HPV-related knowledge among university students was inadequate, emphasizing the urgent need for structured educational and awareness programs on HPV transmission, prevention, and vaccination.

Key Words : Human Papilloma Virus, University students, Knowledge levels.

1. INTRODUCTION

Human papillomavirus (HPV), a double-stranded DNA virus belonging to the *Papillomaviridae* family, infects basal epithelial cells of the skin and mucosal surfaces and is one of the most common sexually transmitted infections worldwide (1). More than 200 HPV types have been identified to date (1). Low-risk types such as HPV 6 and 11 typically cause anogenital warts and benign lesions, whereas high-risk types—particularly HPV 16 and 18—are responsible for malignancies of the cervix, vulva, vagina, penis, anus, and oropharynx (1–3). Persistent infection with high-risk HPV is detected in more than 90–95% of cervical cancer cases globally (3,4). Cervical cancer remains the fourth most common cancer among women worldwide, with an estimated 660,000 new cases and nearly 350,000 deaths in 2022 (5).

Prophylactic HPV vaccines are the most effective strategy for preventing HPV-related cervical cancer and may prevent up to 90% of cases when administered at the recommended age (3,5,6). To accelerate cervical cancer elimination, the World Health Organization introduced the global "90-70-90" targets—vaccinating 90% of girls by age 15, screening 70% of women at ages 35 and 45, and ensuring 90% access to appropriate treatment for precancerous lesions and invasive cancer (6). Despite increasing global implementation of HPV vaccines, vaccination coverage remains suboptimal. As of 2023, only around 27% of girls aged 9–14 worldwide had received at least one dose of HPV vaccine, with even lower full-dose completion rates (7,8). Concerns about costs, vaccine safety, misinformation, and hesitancy remain major barriers to vaccine uptake (3,7,8).

University students represent an important at-risk population due to increasing sexual activity and the formation of long-term health behaviors during this developmental stage. Multi-center studies and meta-analyses have consistently shown that HPV knowledge among university students is limited, with actual HPV vaccination rates remaining low despite moderate willingness to be vaccinated (9–11). Lack of awareness, safety concerns, financial barriers, social stigma, and insufficient healthcare counseling are among the most frequently reported reasons for low vaccination uptake (9–11).

Studies conducted in Türkiye similarly reveal insufficient knowledge regarding HPV, cervical cancer, and HPV vaccination among adolescents and university students (12). Several investigations report that many students have never heard of HPV, are unaware of the causal link between HPV and cervical cancer, and possess limited knowledge about the HPV vaccine (13–15). In one study among female university students, mean HPV knowledge scores were low, and only about one-third correctly recognized HPV as a risk factor for cervical cancer (13). Recent studies from various Turkish universities report HPV vaccination rates between <1% and 7%, despite higher self-reported willingness to be vaccinated (16–18). Although female students tend to demonstrate slightly higher awareness than male students, vaccination rates remain insufficient in both groups; even health-science students continue to exhibit hesitancy and stigma toward HPV vaccination (16–20). Factors such as e-health literacy, gender, academic field, and receiving information from family or healthcare providers significantly influence HPV awareness and vaccine acceptance (18,19).

In Türkiye, absence of the HPV vaccine from the national immunization program, out-of-pocket costs, concerns about safety and side effects, and fear of social stigma are major contributors to low vaccination rates among university students (12,16–18). Therefore, evaluating knowledge and awareness regarding HPV infection, cervical cancer, screening tests, and HPV vaccination in this population is critical for developing targeted and culturally sensitive educational interventions.

The aim of this study is to assess university students' knowledge levels regarding HPV and its associated health risks, determine existing awareness, and identify educational needs. Findings are expected to contribute to the development of effective educational strategies that address misconceptions and improve health literacy. The study will be conducted in accordance with ethical principles; participation will be voluntary, data will be anonymized, and results will be used solely for scientific purposes.

2. METHODS

This cross-sectional study was conducted between March and May 2025 and included 358 students enrolled at Uşak University, 1 Eylül Campus. In order to evaluate the level of HPV knowledge and associated preventive practices among university students, a structured questionnaire was developed based on current literature and an existing validated scale, for which permission was obtained from the original author (21).

The final questionnaire consisted of 25 items grouped into three domains assessing different dimensions of HPV-related knowledge:

1. General HPV Knowledge,
2. Knowledge of HPV Screening Tests, and
3. Knowledge of HPV Vaccination.

In addition to knowledge items, the questionnaire collected detailed sociodemographic and educational characteristics, including age, faculty and year of study, place of residence, type of high school attended, parental education and employment status, family structure, household income, and current living arrangement. Variables previously shown to influence HPV knowledge—such as voluntarily choosing the current academic department, prior awareness of HPV, prior awareness of the HPV vaccine, and history of HPV vaccination—were also included (21,22).

The survey was administered digitally via Google Forms using a QR code to facilitate accessibility and voluntary participation. Prior to data collection, students were informed about the purpose, procedures, and confidentiality of the study. Some items contained more than one correct response; therefore, knowledge scoring was performed by assigning one point per correct answer. The maximum achievable score was 50 points. All personal data were anonymized, and no identifiable information was collected. The study adhered to ethical principles of the Declaration of Helsinki.

Data were exported to Microsoft Excel for preprocessing and descriptive statistical analysis. Categorical variables were summarized using frequency and percentage distributions. Ethical approval for the study was obtained from the Uşak University Non-Interventional Clinical Research Ethics Committee (Decision No: 592-592-05; Date: 20 March 2025).

3. RESULTS

A total of 358 students completed the 25-item questionnaire assessing HPV-related knowledge. The largest age group was 17–20 years, comprising 61% of all respondents (Figure 1).

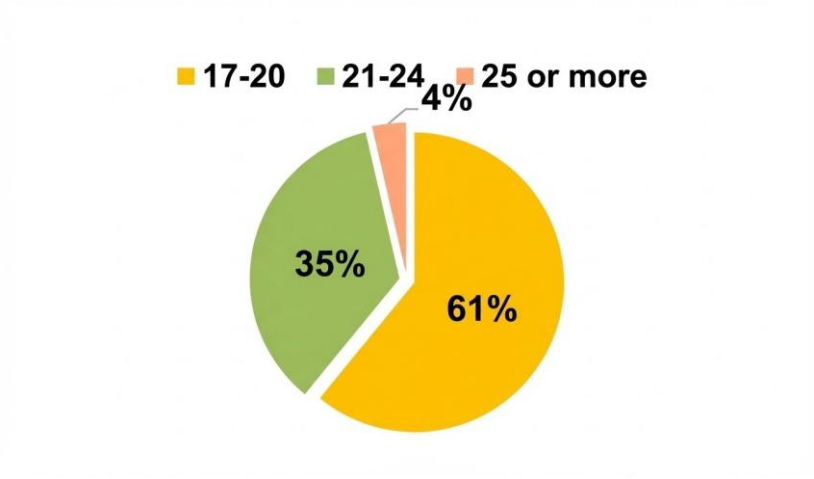


Figure 1. Age distribution of participants

Of the participants, 70% were female and 30% were male (Figure 2).

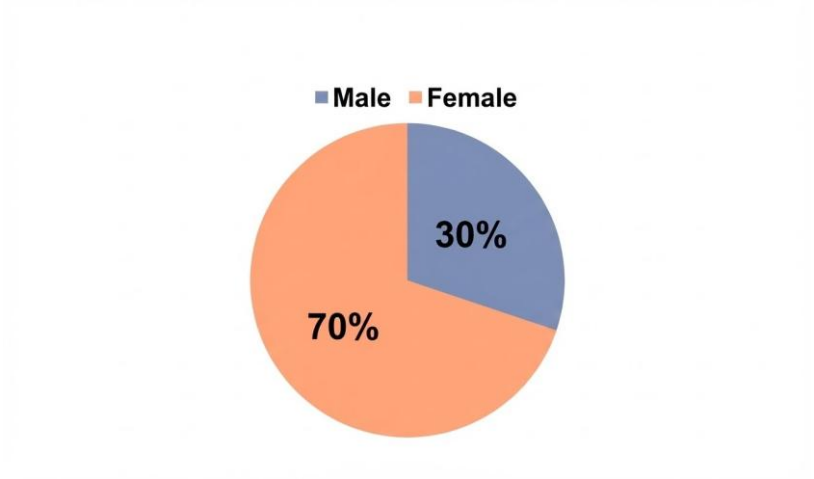


Figure 2. Gender distribution of participants

Regarding academic distribution, 33% of participants were enrolled in health-related programs, whereas 67% were studying in non-health fields. The Faculty of Engineering and Natural Sciences represented the highest proportion of participants, accounting for 16% of the sample (Figure 3).

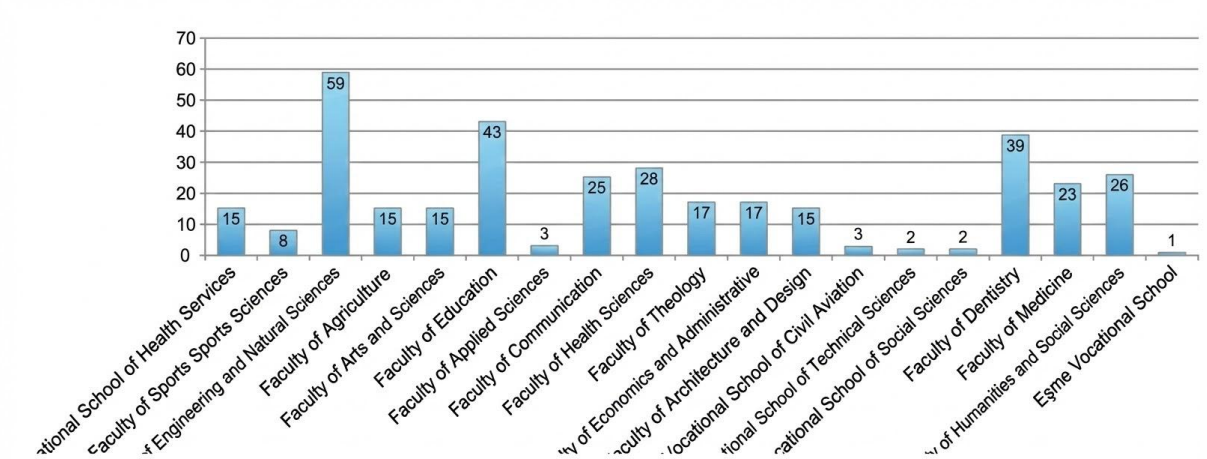


Figure 3. Faculties where participants received education

Most respondents (97%) reported being single. Regionally, participation was highest from the Aegean Region (53.6%), while Manisa was the most represented province with 50 participants (14%) (Figure 4).

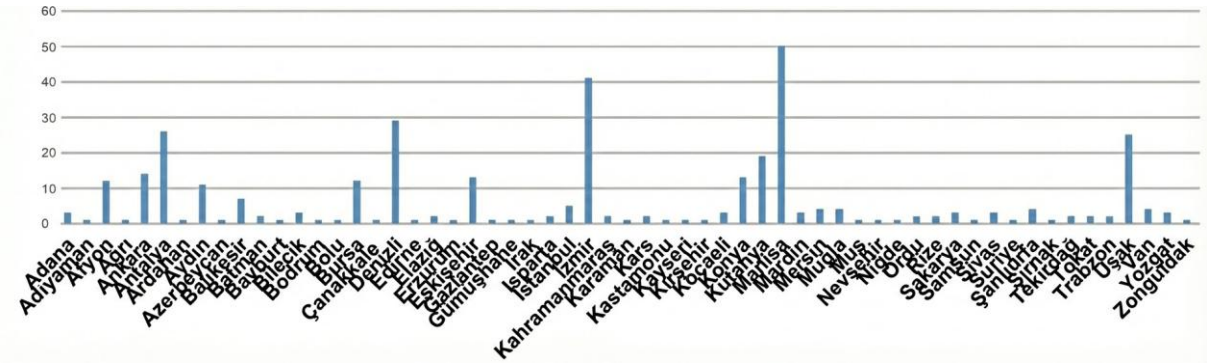


Figure 4. Participants' hometown distribution

With respect to sexual behavior, 5.6% of female students and 16.6% of male students reported experiencing their first sexual intercourse between ages 12 and 18 (Figure 5). A chi-square test demonstrated a statistically significant association between gender and early sexual debut (χ^2, $p<0.05$), indicating that male students were significantly more likely to report early sexual intercourse compared with female students.

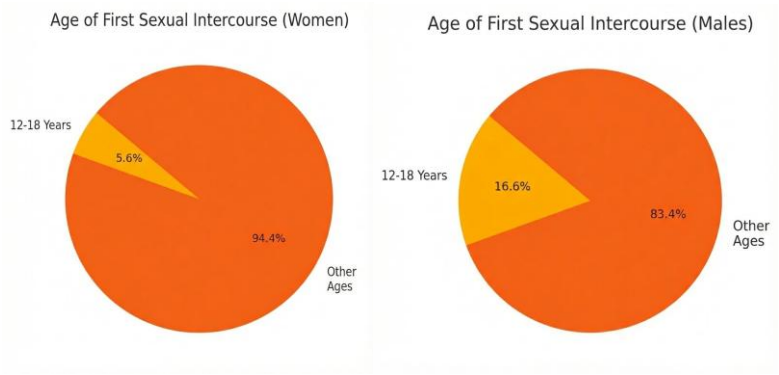


Figure 5. Age distribution of first sexual intercourse among female and male participants

Additionally, no significant association was observed between age group and faculty type (health vs. non-health programs) (χ^2, $p>0.05$). Similarly, marital status did not show any statistically significant relationship with academic field or demographic variables (χ^2, $p>0.05$).

Thirty-four percent of the participants reported having previously received education on sexually transmitted infections (STIs) (Figure 6).

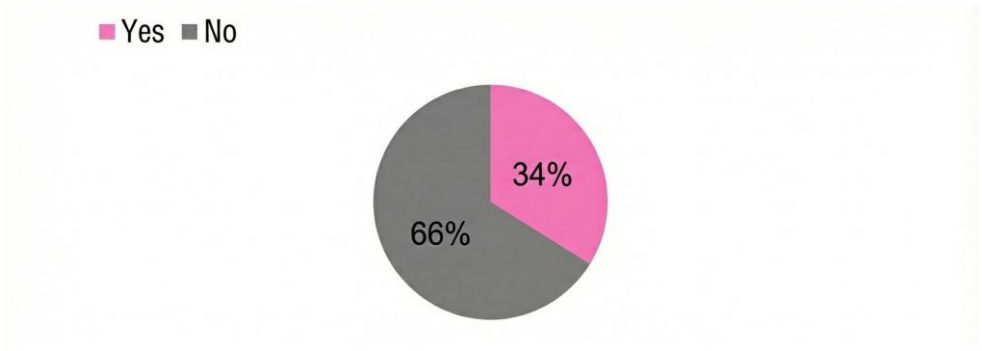


Figure 6. Participants' status of receiving education about sexually transmitted diseases

Among male respondents, 8.3% (n=30) indicated that they used a condom during a sexual encounter they perceived as risky. Based on the correct responses given by the participants to the items assessing HPV and HPV vaccine knowledge, the following mean scores were obtained (Figures 7a, 7b, 7c):

7a **7b** **7c**

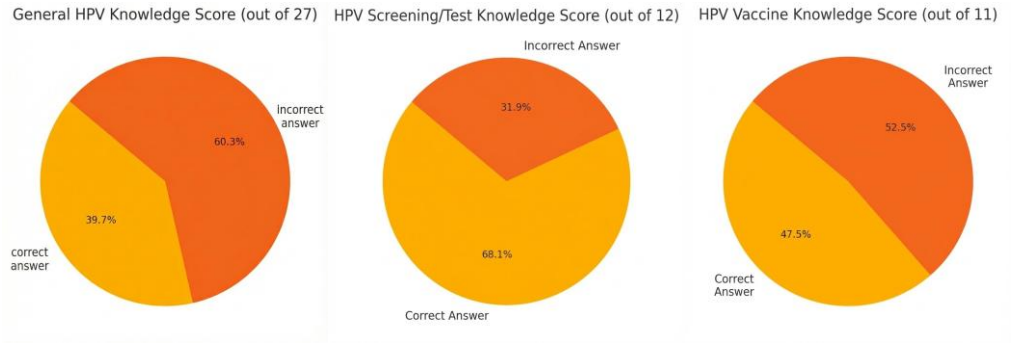


Figure 7. Distribution of participants' scores according to the sections of the HPV knowledge level questionnaire

The mean score for the "General HPV Knowledge" section was 10.71 out of 27 (Figure 7a). The mean score for the "HPV Screening Test Knowledge" section was 8.17 out of 12 (Figure 7b). The mean score for the "General HPV Vaccine Knowledge" section was 5.23 out of 11 (Figure 7c). The overall mean knowledge score was calculated as 22.7 out of 50 points. A comparison of mean scores by gender revealed no statistically significant difference in HPV knowledge levels (χ^2 test, $p > 0.05$). Among the participants, the rate of women who had undergone Pap smear testing for HPV screening was found to be 64.5% (Figure 8).

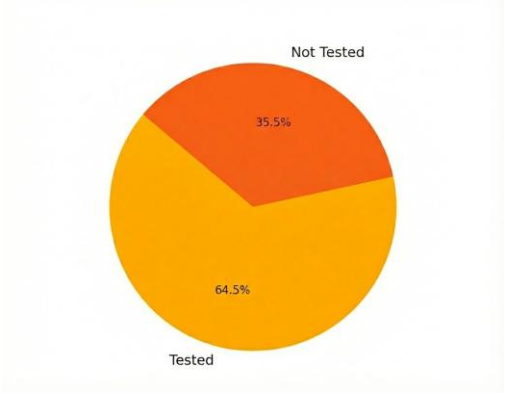


Figure 8. Distribution of woman participants' Pap smear testing for HPV screening

4. DISCUSSION

The findings of this study demonstrate that university students possess insufficient knowledge regarding HPV, HPV-related cancers, screening tests, and HPV vaccination. This aligns with a substantial body of international and national research consistently reporting low awareness and knowledge levels among adolescents and young adults (9,12–15). Despite the well-established causal link between high-risk HPV types and cervical cancer (1–3) and strong epidemiological evidence that nearly all cervical cancer cases are attributable to persistent HPV infection (3,4), awareness among young populations remains alarmingly low. Our study's overall mean score of 22.7/50 reflects this continuing deficiency and mirrors the findings of earlier Turkish studies showing similar knowledge gaps among college and university students (12–15,19).

Globally, HPV remains one of the most important vaccine-preventable oncogenic infections, and HPV vaccination has been shown to substantially reduce the incidence of cervical and other anogenital cancers (5–7). Nevertheless, vaccine uptake remains suboptimal worldwide (7,8) and is particularly challenging in regions where cost barriers, misinformation, and cultural hesitancy restrict access, as reported in Türkiye (12,16,18). Similar to previous literature, our findings showed limited prior knowledge of HPV and low exposure to STI-related education, consistent with research demonstrating that inadequate educational exposure is one of the strongest predictors of low vaccine acceptance (18,19).

Interestingly, our study found no statistically significant difference in HPV knowledge scores between genders, despite several studies reporting higher awareness among females (13,16). This deviation may be attributable to institutional differences, unequal access to educational opportunities, or variability in participants' fields of study. Considering that 67% of our sample consisted of students from non-health faculties, it is plausible that limited curricular exposure contributed to the overall low knowledge levels. This pattern underscores an important public health concern, as young adults—particularly university students—fall within the age group at greatest risk for acquiring HPV (1,3,9) and represent a critical population for prevention-based interventions.

Education-based strategies have repeatedly proven effective in increasing HPV knowledge and vaccine intention among youth (10,17,18). Evidence also suggests that improving eHealth literacy—another factor strongly associated with HPV awareness (18)—can significantly enhance students' ability to interpret reliable online health information, a particularly relevant aspect in the digital era. Therefore, structured, culturally sensitive educational initiatives on HPV transmission, screening, and vaccination may play a transformative role for students at our institution.

Given Türkiye's ongoing challenges related to HPV vaccine acceptance (12,16) and the global call for cervical cancer elimination through the WHO's strategic framework (6), strengthening student awareness is not only necessary but urgent. University-based educational interventions—seminars, workshops, curriculum-integrated content, and digital awareness campaigns—may serve as effective tools to bridge the substantial knowledge gap identified in our study.

This study has several limitations that should be considered when interpreting the results. First, the cross-sectional design prevents the identification of causal relationships between demographic factors and HPV knowledge (standard methodological limitation). Second, data were collected through self-reported questionnaires, which may be subject to recall bias and social desirability bias. Third, the study sample was restricted to a single university, which may limit the generalizability of the findings to all university students in Türkiye. Fourth, although the questionnaire was adapted from validated measurement tools (21,22), the inclusion of multiple-answer questions may have influenced scoring variations. Finally, advanced statistical analyses such as multivariate regression were not performed; thus,

potential confounding variables—including socioeconomic status, STI education exposure, or faculty type—could not be fully evaluated.

Despite these limitations, the study provides valuable insight into HPV knowledge levels among a large and diverse university student population and highlights critical areas for targeted educational interventions.

5. CONCLUSION

In conclusion, despite HPV being a highly preventable cause of cancer, knowledge levels among university students remain strikingly inadequate, consistent with both national and global evidence (9,12–16,19). Strengthening awareness through structured, evidence-based education is therefore essential. Implementing comprehensive HPV-focused programs—including training on transmission, screening, and vaccination—has the potential to transform students' protective behaviors and substantially reduce the future burden of HPV-related diseases on both individual and public health.

Ultimately, unless we close the knowledge gap today, the preventable cancers of tomorrow will continue to rise—a reality that makes effective HPV education not merely beneficial, but imperative.

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BEYİN KAYNAKLI NÖROTROFİK FAKTÖR VE BEYİN SAĞLIĞINDAKİ ÖNEMİ

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ÖZET

Beyin kaynaklı nörotrofik faktör (BDNF), hem merkezi hem de çevresel sinir sisteminde önemli roller üstlenen bir proteindir. BDNF; serebellum, hipokampus, omurilik, prefrontal korteks, hipotalamus ve amigdala gibi beynin birçok bölgesinde bulunmaktadır. Sinir sisteminde oldukça çeşitli biyolojik süreçleri düzenleyen BDNF'nin düzeylerinin, hem normal fizyolojik koşullarda hem de çeşitli patolojik durumlarda değişiklik gösterdiği belirlenmiştir.

Nöronların yaşamsal fonksiyonları ve hayatta kalması açısından kritik bir öneme sahip olan BDNF, fetal gelişim sürecinde de nörogenez, rejenerasyon ve nöroplastisiteyi destekleyerek nöronal iletimin artırılmasında rol oynar. BDNF düzeylerindeki azalmanın depresyon ile ilişkili olduğu, buna karşılık BDNF düzeylerinin artırılmasının antidepresan etki gösterdiği ortaya konmuştur. Ayrıca, nörodejeneratif hastalıkların tedavisinde potansiyel bir hedef olarak değerlendirilmesi nedeniyle BDNF giderek artan bir araştırma konusu hâline gelmiştir.

Bu bildiri, beyin kaynaklı nörotrofik faktörün (BDNF) sinir sistemi üzerindeki etkilerini ve beyin sağlığı açısından taşıdığı potansiyel önemi ortaya koymayı amaçlamaktadır.

Anahtar Kelimeler : Beyin, Demans, Alzeimer,Nörotrofik Faktör, Sağlık

SUMMARY

Brain-derived neurotrophic factor (BDNF) is a protein that plays important roles in both the central and peripheral nervous systems. BDNF is found in many regions of the brain, including the cerebellum, hippocampus, spinal cord, prefrontal cortex, hypothalamus, and amygdala. It has been determined that BDNF levels, which regulate a wide variety of biological processes in the nervous system, change under both normal physiological conditions and various pathological conditions.

Critical for the vital functions and survival of neurons, BDNF also plays a role in enhancing neuronal transmission by supporting neurogenesis, regeneration, and neuroplasticity during

fetal development. It has been demonstrated that decreased BDNF levels are associated with depression, whereas increased BDNF levels exhibit antidepressant effects. Furthermore, BDNF has become an increasingly popular research topic due to its potential as a target in the treatment of neurodegenerative diseases.

This paper aims to highlight the effects of brain-derived neurotrophic factor (BDNF) on the nervous system and its potential importance for brain health.

Key Words : Alzheimer's, Brain, Dementia, Health, Neurotrophic Factor

1. GİRİŞ

Beyin kaynaklı nörotrofik faktör (BDNF), merkezi ve çevresel sinir sisteminde nöronların hayatta kalmasını, büyümesini ve işlevlerini destekleyen bir proteindir. Ayrıca sinapsların stabilitesini korur, sinaptik iletişimi düzenler ve akson ile dendritlerin dallanmasını kontrol eder (Yarım ve Kazak, 2015). Merkezi sinir sisteminde BDNF, nöronların gelişim süreçlerini ve kendilerini onarma yeteneklerini desteklerken, nörotransmitterlerin görev yaptığı önemli sinir yollarının yapısal bütünlüğünün korunmasına ve işlevlerini sürdürmesine de katkıda bulunur (Yarım ve Kazak, 2015). BDNF'nin sinaptik plastisite ve nörogenez üzerindeki etkileri, öğrenme ve hafıza süreçlerinin nörobiyolojik temellerini açıklamada önemli bir rol oynamaktadır (Bath ve Lee, 2006; Phillips, 2017).

Stres, egzersiz, beslenme ve yaş gibi çevresel ve fizyolojik faktörlerin BDNF düzeyleri üzerinde doğrudan etkisi olduğu belirlenmiştir (Bath ve Lee, 2006; Zuccato ve Cattaneo, 2009). BDNF düzeylerinin azalması depresyon, Alzheimer ve Parkinson gibi nörodejeneratif ve psikiyatrik bozukluklarla ilişkilendirilmiştir (Zuccato ve Cattaneo, 2009; Erickson ve ark., 2011).

1.1 Beyin Kaynaklı Nörotrofik Faktör (BDNF)

Beyin Kaynaklı Nörotrofik Faktör (BDNF), nörotrofin ailesine ait, yaklaşık 247 amino asitten oluşan bir proteindir ve sinir sistemi gelişimi ile nöronal bütünlüğün korunmasında kritik bir rol üstlenir (Binder ve Scharfman, 2004). BDNF, hücrelerde başlangıçta pre-pro-BDNF formunda sentezlenmekte, ardından hücre içi proteolitik işlemlerle önce pro-BDNF, daha sonra biyolojik olarak aktif olgun (matür) BDNF formuna dönüştürülmektedir. Bu farklı moleküler formlar, farklı reseptörler üzerinden etki göstererek BDNF sinyalizasyonuna işlevsel çeşitlilik kazandırmaktadır (Binder ve Scharfman, 2004; Park ve Poo, 2013; Colucci-D'Amato ve ark., 2020; Kowiański ve ark., 2020).

BDNF sentezi ağırlıklı olarak merkezi sinir sisteminde gerçekleşmekle birlikte yalnızca beyinle sınırlı değildir. Özellikle hipokampus, serebral korteks, amigdala ve serebellum gibi öğrenme, hafıza, duygudurum düzenlenmesi ve motor kontrol ile ilişkili beyin bölgelerinde yüksek düzeyde ekspresyon gösterir (Huang ve Reichardt, 2003; Park ve Poo, 2013; Miranda ve ark., 2019). BDNF'nin temel üretici hücreleri nöronlar olmakla birlikte, astrositler ve mikroglial hücreler de bu faktörün sentezine katkı sağlayarak sinaptik mikroçevrenin düzenlenmesinde önemli rol oynar (Colucci-D'Amato ve ark., 2020).

Merkezi sinir sistemi dışında da BDNF sentezi gerçekleşmektedir. Periferik sinir sistemi, iskelet kası dokusu, endotel hücreleri ve bazı immün hücreler BDNF üretebilen yapılar arasında yer almaktadır. Özellikle trombositlerde depolanan BDNF, uygun fizyolojik koşullarda kana salınmakta ve serum düzeyleri plazmaya göre 20–50 kat daha yüksek olabilmektedir (Shafiee ve ark., 2023; Colucci-D'Amato ve ark., 2020). Bu durum, serum BDNF'nin çeşitli nörolojik ve psikiyatrik hastalıkların değerlendirilmesinde dolaylı bir biyobelirteç olarak kullanılmasına olanak sağlar. Egzersiz gibi çevresel uyaranların periferik BDNF üretimini artırdığı ve merkezi sinir sistemi ile perifer arasında işlevsel etkileşim oluşturduğu da bildirilmiştir (Rico-González ve ark., 2020; Colucci-D'Amato ve ark., 2020).

Olgun BDNF'nin biyolojik etkileri, yüksek afiniteye sahip TrkB (tropomiyozin ilişkili kinaz B) reseptörünün aktivasyonu aracılığıyla ortaya çıkar. TrkB reseptörüne bağlanmayı takiben PI3K/Akt, MAPK/ERK ve PLCγ gibi hücre içi sinyal yolakları aktive edilmekte; bu yolaklar nöronal sağkalımın desteklenmesi, dendritik dallanmanın artırılması ve sinaptik iletimin güçlendirilmesine katkı sağlamaktadır (Huang ve Reichardt, 2003; Lu ve ark., 2013; Kowiański ve ark., 2020). Buna karşılık pro-BDNF, düşük afiniteye sahip p75NTR reseptörü ile etkileşime girerek hücre ölümü ve sinaptik gerileme ile ilişkili mekanizmaların aktive edilmesine yol açabilir. Bu çift yönlü etki modeli, BDNF'nin sinir sistemindeki düzenleyici rolünün moleküler forma ve bağlama bağımlı olduğunu göstermektedir (Colucci-D'Amato ve ark., 2020).

Fonksiyonel açıdan BDNF, sinir hücrelerinin büyümesini, gelişimini ve hayatta kalmasını destekleyen temel bir düzenleyicidir. Özellikle öğrenme ve hafıza süreçlerinde merkezi bir rol oynayarak sinaptik plastisiteyi artırmakta ve nöronlar arasındaki bağlantıların güçlenmesini sağlamaktadır (Binder ve Scharfman, 2004; Park ve Poo, 2013; Miranda ve ark., 2019). Nöronal aktiviteye bağlı olarak salınan BDNF, uzun süreli

sinaptik değişikliklerin oluşumuna katkıda bulunarak nöroplastisiteyi destekler. Ayrıca stres, çevresel koşullar ve yaşam tarzı faktörlerinin BDNF ekspresyonu üzerinde belirleyici olduğu bildirilmektedir (Lu ve ark., 2013; Colucci-D'Amato ve ark., 2020; Rico-González ve ark., 2020).

BDNF'nin merkezi ve periferik düzeylerdeki değişimleri, nörodejeneratif hastalıklar ve depresyon gibi durumlarda bilişsel ve duygusal işlevlerle doğrudan ilişkilidir. Alzheimer, Parkinson ve diğer nörodejeneratif hastalıklarda BDNF eksikliği bilişsel bozulmayla bağlantılıdır; depresyonda ise düşük BDNF seviyeleri duygu durumunu etkiler ve antidepresan tedavi ile normale dönebilir (Azman & Zakaria, 2023; Thornton, 2023; Wang ve ark., 2024). Fiziksel aktivite ve egzersiz gibi yaşam tarzı müdahaleleri, BDNF seviyelerini artırarak sinaptik plastisiteyi ve öğrenme kapasitelerini desteklemektedir (Rico-González ve ark., 2020).

Yeni şeyler öğrenmek, zihinsel egzersiz yapmak ve bilişsel uyarılma gibi aktiviteler de BDNF seviyelerini yükselterek beynin rezerv kapasitesini artırır (Voss ve ark., 2013). BDNF'nin sinir sistemi boyunca yaygın dağılımı ve çok yönlü biyolojik etkileri, onun nörolojik sağlığın korunmasında merkezi bir molekül olduğunu göstermektedir. Bu nedenle BDNF, hem temel nörobiyolojik süreçlerin anlaşılmasında hem de hastalık mekanizmalarının aydınlatılmasında önemli bir araştırma odağı olmaya devam etmektedir (Park ve Poo, 2013; Lu ve ark., 2013; Kowiański ve ark., 2020)

BDNF'nin terapötik potansiyelini inceleyen deneysel çalışmalarda, molekülü hedef bölgeye ulaştırmak için çeşitli invaziv ve non-invaziv yöntemler kullanılır. Bu yöntemlerin her biri, BDNF'nin spesifik etkilerini ve zaman içindeki sürekliliğini incelemek amacıyla farklı avantajlar ve sınırlılıklar sunar.

BDNF uygulama yöntemleri farklı stratejilerle incelenmektedir. Genetik yolla yapılan çalışmalarda, Nagahara ve arkadaşları (2009, 2011) adenovirüs gibi viral vektörlerle BDNF geninin beyin bölgelerine aktarılmasının uzun süreli ve lokal ekspresyon sağladığını göstermiştir; Alzheimer fare modellerinde hipokampusa yapılan Adenovirus ve BDNF enjeksiyonları sinaptik kayıp ve hafıza bozukluklarını azaltmıştır. Rekombinant protein enjeksiyonu yönteminde, Altar ve DiStefano (1998) ile Hyman ve ark. (1991) saflaştırılmış BDNF proteininin doğrudan beyin dokusuna veya omurilik sıvısına uygulanmasının davranışsal testlerde hızlı yanıt ve kısa süreli etki sağladığını belirtmişlerdir; Parkinson modeli farelerde striatuma yapılan BDNF enjeksiyonları dopaminerjik hücreleri korumuş ve motor fonksiyonu iyileştirmiştir. Sistemik uygulama

veya salınmayı artıran yöntemlerde ise Cotman ve Berchtold (2002) ile Voss ve ark. (2013), egzersiz, diyet modifikasyonları ve antidepresan kullanımı ile BDNF seviyelerinin sistemik olarak artırılabileceğini ve bu artışın sinaptik ve davranışsal etkilerinin gözlenebileceğini göstermiştir; örneğin, kronik egzersiz yapılan farelerde hipokampal BDNF artışı ve öğrenme performansındaki iyileşme gözlenmiştir. Transgenik modellerde ise Lyons ve ark. (1999) ile Patterson ve ark. (1996), hayvanların genomuna ek BDNF genleri eklemenin veya mevcut BDNF geninin aşırı ekspresyon gösterecek şekilde modifiye edilmesinin uzun vadeli nöroplastisite ve gelişimsel süreçleri incelemeye olanak tanıdığını göstermiştir; örneğin, BDNF geni aşırı eksprese edilen farelerde uzun süreli potansiyon (LTP) artmış ve öğrenme kapasitesi güçlenmiştir. Genel olarak, viral vektör veya rekombinant protein uygulamaları lokal ve hızlı etkiler sağlarken, egzersiz veya farmakolojik yöntemler BDNF'yi sistemik ve doğal yollarla artırmakta; transgenik modeller ise gelişimsel ve kronik etkilerin araştırılmasına imkân tanımaktadır **(**Patterson ve ark., 1996; Lyons ve ark., 1999**).**

1.2 Beyin Kaynaklı Nörotrofik Faktör'ün Salgılandığı Yerler

Beyin kaynaklı nörotrofik faktör (BDNF), sinir hücrelerinin gelişimi, sağkalımı ve sinaptik plastisite için kritik öneme sahip bir nörotrofik faktör olup, bu özellikleri nedeniyle pek çok nörolojik ve psikiyatrik çalışmada önemli bir biyolojik belirteç olarak incelenmektedir. BDNF'nin özellikle öğrenme, hafıza ve nöroplastisite süreçlerindeki merkezi rolü, bu molekülün hem deneysel hem de klinik araştırmalarda yaygın olarak değerlendirilmesine yol açmıştır. Ancak insanlarda beyin dokusundan doğrudan örnek alınmasının etik ve teknik nedenlerle mümkün olmaması, BDNF ölçümlerinin çoğunlukla periferik biyolojik örnekler üzerinden yapılmasına neden olmaktadır **(**Tiwari ve ark., 2022; Liberona ve ark., 2024**)**.

Bu nedenle insan çalışmalarında BDNF düzeyleri genellikle serum veya plazma örneklerinden ölçülmektedir. BDNF ölçümlerinin santral BDNF düzeylerini yalnızca kısmen ve dolaylı biçimde temsil edebileceği düşünülmektedir **(**Tiwari ve ark., 2022; Liberona ve ark., 2024). Kan BDNF düzeyi bu molekülün yalnızca merkezi sinir sisteminden kaynaklanmadığını, birçok farklı doku tarafından üretilen ve salınan periferik dolaşımdaki BDNF'nin de etkili olduğu belirlenmiştir. Bu dokular arasında trombositler en büyük BDNF deposu olarak öne çıkmakta; bunun yanı sıra iskelet kası,

endotel hücreleri ve bağışıklık sistemi hücreleri de periferik BDNF üretimine katkıda bulunmaktadır **(**Tiwari ve ark., 2022).

Bu çoklu periferik kaynaklar nedeniyle, kanda ölçülen BDNF düzeylerindeki değişimlerin hangi dokudan kaynaklandığını ayırt etmek mümkün değildir. Bu durum, periferik BDNF ölçümlerinin yorumlanmasını güçleştirmekte ve santral BDNF aktivitesi ile birebir ilişkilendirilmesini sınırlandırmaktadır. Nitekim Tiwari ve ark. (2022), periferik BDNF düzeylerinin merkezi sinir sistemindeki BDNF ekspresyonunu doğrudan temsil etmediğini özellikle vurgulamıştır. Benzer şekilde Liberona ve ark. (2024), periferik ölçümlerin biyolojik anlamının dikkatle değerlendirilmesi gerektiğini belirtmiştir **(**Tiwari ve ark., 2022; Liberona ve ark., 2024**).**

Merkezi sinir sistemi açısından değerlendirildiğinde ise BDNF'nin başlıca nöronlar tarafından sentezlendiği ve sinaptik aktiviteye bağımlı olarak salındığı bilinmektedir. Bu santral üretim, öğrenme ve deneyime bağlı nöroplastisite süreçleriyle yakından ilişkilidir. Ancak periferik dolaşımdaki BDNF'nin, bu santral üretimi ne ölçüde yansıttığı net değildir. Bu nedenle serum veya plazma BDNF düzeyleri, beyin BDNF aktivitesinin doğrudan bir göstergesi olarak değil, daha çok dolaylı ve sınırlı bir biyobelirteç olarak değerlendirilmelidir (Tiwari ve ark., 2022; Liberona ve ark., 2024).

BDNF'nin büyük kısmı trombositlerde depolandığı için kanın pıhtılaşması sırasında hızla salınır (Tiwari ve ark., 2022). Bu durumun bir sonucu olarak serum BDNF düzeyleri, plazma BDNF düzeylerinden 20–50 kat daha yüksek bulunurken (Tiwari ve ark., 2022), plazma BDNF daha düşük olmasına rağmen daha stabildir (Tiwari ve ark., 2022). Ölçüm sonuçları tüpteki katkı maddeleri, pıhtılaşma süresi, santrifüj koşulları ve saklama sıcaklığı gibi pre-analitik faktörlere oldukça duyarlıdır (Tiwari ve ark., 2022; Liberona ve ark., 2024). Bu nedenle farklı çalışmalar arasında önemli tutarsızlıklar gözlemlenmektedir (Tiwari ve ark., 2022).

İnsan beyninden doğrudan BDNF ölçümü yaşayan bireylerde mümkün değildir; bu nedenle araştırmacılar dolaylı yöntemlere başvurur (Liberona ve ark., 2024; Rico-González ve ark., 2025). Bu yöntemler arasında beyin-omurilik sıvısı (BOS) analizi gibi invaziv yaklaşımlar, hayvan modelleri ve nörogörüntüleme teknikleri yer almaktadır (Liberona ve ark., 2024). Literatür, periferik BDNF'nin santral BDNF düzeylerini birebir

yansıtmadığını net bir şekilde göstermektedir (Tiwari ve ark., 2022; Liberona ve ark., 2024). Bununla birlikte depresyon, egzersiz, yaşlanma ve nörodejeneratif hastalıklar gibi durumlarda, periferik ve merkezi BDNF değişimlerinin paralel olabileceğine dair bazı çalışmalar mevcuttur (Tiwari ve ark., 2022; Rico-González ve ark., 2025). Örneğin, egzersiz hem kanda hem de hayvan modellerinde hipokampal BDNF artışıyla ilişkilendirilmiştir (Rico-González ve ark., 2025).

Periferik BDNF ölçümleri insan çalışmalarında pratik ve erişilebilir bir yöntem sunmakla birlikte, bu ölçümlerin santral BDNF düzeylerini birebir temsil etmediği kabul edilmelidir. Bu durum, BDNF ile ilişkili bulguların yorumlanmasında dikkatli olunmasını ve sonuçların biyolojik bağlam içerisinde ele alınmasını zorunlu kılmaktadır **(**Tiwari ve ark., 2022; Liberona ve ark., 2024**).**

1.3 Beyin Kaynaklı Nörotrofik Faktörü Etkileyen Faktörler

BDNF, beynin sağlıklı çalışması için kritik bir moleküldür ve sinir hücrelerinin büyümesini, bağlantılarını güçlendirmesini sağlar. Ancak, BDNF seviyeleri birçok iç ve dış faktöre bağlı olarak değişebilir. Bu değişiklikler, beyin fonksiyonlarını doğrudan etkileyerek öğrenme, hafıza ve duygudurum üzerinde önemli rol oynar. BDNF seviyelerini etkileyen faktörler aşağıda verilmiştir:

1.3.1 Genetik Faktörler

Genetik faktörler, beyin kaynaklı nörotrofik faktörün (BDNF) sentezi, salınımı ve biyolojik işlevleri üzerinde belirleyici bir role sahiptir. BDNF geninde bulunan tek nükleotid polimorfizmleri (SNP'ler), bireyler arasında BDNF ekspresyonu ve nöroplastisite kapasitesinde önemli farklılıklara yol açabilmektedir. Bu genetik varyasyonlar, öğrenme, hafıza, bilişsel esneklik ve duygu durum düzenlenmesi gibi süreçleri doğrudan etkileyebilir (Bath ve Lee, 2006; Binder ve Scharfman, 2004).

BDNF geni ile ilişkili en iyi tanımlanmış genetik varyant Val66Met (rs6265) polimorfizmidir. Bu polimorfizm, BDNF proteininin pro-domen bölgesinde valin (Val) yerine metiyonin (Met) bulunmasıyla karakterizedir ve aktiviteye bağlı BDNF salınımını anlamlı düzeyde azaltmaktadır. Val66Met taşıyıcılarında özellikle hipokampus ve

prefrontal kortekste BDNF'nin sinaptik bölgelere taşınmasının bozulduğu, bunun sonucunda sinaptik plastisite ve uzun süreli potansiyasyon (LTP) mekanizmalarının zayıfladığı gösterilmiştir (Bath ve Lee, 2006; Lu ve ark., 2013).

Fonksiyonel ve yapısal nörogörüntüleme çalışmaları, Val66Met polimorfizmine sahip bireylerde hipokampal hacmin daha küçük olabildiğini ve bellek performansının Val/Val genotipine sahip bireylere kıyasla daha düşük olabileceğini ortaya koymuştur. Ayrıca bu genetik varyantın, stres duyarlılığını artırarak depresyon, anksiyete ve travma sonrası stres bozukluğu gibi psikiyatrik hastalıklara yatkınlığı artırabileceği bildirilmektedir (Bath ve Lee, 2006; Duman ve ark., 2006; Thornton, 2023).

Genetik faktörlerin etkisi yalnızca tek bir polimorfizmle sınırlı değildir. BDNF geninin promotör bölgesindeki epigenetik düzenlemeler (DNA metilasyonu ve histon modifikasyonları), çevresel faktörlerle etkileşime girerek BDNF ekspresyonunu dinamik biçimde değiştirebilir. Özellikle erken yaşam stresi, travma ve kronik stres maruziyetinin BDNF gen metilasyonunu artırarak gen ekspresyonunu baskıladığı ve bunun yaşam boyu süren nöroplastisite değişikliklerine yol açtığı bildirilmiştir (Duman ve Monteggia, 2006; Colucci-D'Amato ve ark., 2020).

Bununla birlikte, genetik yatkınlığa rağmen çevresel müdahalelerin BDNF düzeyleri üzerinde telafi edici etkiler gösterebildiği de vurgulanmaktadır. Düzenli fiziksel egzersiz, bilişsel uyarım ve sağlıklı yaşam tarzı faktörlerinin, Val66Met polimorfizmi taşıyıcılarında dahi BDNF düzeylerini artırabildiği ve sinaptik plastisiteyi desteklediği gösterilmiştir (Cotman ve Berchtold, 2002; Erickson ve ark., 2011; Rico-González ve ark., 2020).

1.3.2 Hormonal Değişiklikler

Hormonlar, beyin kaynaklı nörotrofik faktörün (BDNF) sentezi ve sinyalizasyonu üzerinde önemli düzenleyici etkilere sahiptir. Özellikle östrojen ve testosteron gibi seks steroid hormonları, BDNF ekspresyonunu doğrudan etkileyerek sinaptik plastisite, nörogenez ve bilişsel işlevlerin sürdürülmesinde rol oynar (Spencer ve ark., 2008; Lu ve ark., 2013).

Östrojen ve testosteron gibi hormonlar, BDNF seviyelerini düzenler. Örneğin, östrojen seviyelerinin yüksek olduğu dönemlerde BDNF üretimi artabilir; bu durum,

kadınlarda belirli dönemlerde bilişsel fonksiyonların güçlenmesini sağlar (Spencer ve ark., 2008).

Menopoz döneminde östrojen seviyelerinde meydana gelen belirgin azalma, BDNF üretiminde düşüş ile ilişkilendirilmiştir. Östrojenin hipokampus ve prefrontal kortekste BDNF ve TrkB reseptör ekspresyonunu artırdığı bilinmektedir. Bu nedenle menopozla birlikte azalan östrojen düzeyleri, BDNF sinyalizasyonunun zayıflamasına yol açarak sinaptik plastisite ve nöroplastisite süreçlerini olumsuz etkileyebilir (Spencer ve ark., 2008; Binder ve Scharfman, 2004). Klinik ve deneysel çalışmalar, menopoz sonrası kadınlarda bilişsel performansta görülen gerileme, duygu durum değişiklikleri ve depresif belirtilerin kısmen BDNF azalmasıyla ilişkili olabileceğini göstermektedir (Yarım ve Kazak, 2015; Thornton, 2023).

Benzer şekilde, erkeklerde yaşlanmayla birlikte görülen andropoz sürecinde testosteron düzeylerinin azalması da BDNF üzerinde olumsuz etkilere neden olabilir. Testosteronun ve onun aromatizasyon yoluyla oluşturduğu östrojenin, nöronal sağkalım ve BDNF ekspresyonunu desteklediği bildirilmiştir. Andropoz döneminde azalan testosteron seviyeleri, hipokampal BDNF üretiminde düşüşe yol açarak bilişsel işlevlerde zayıflama ve depresif semptom riskinde artış ile ilişkilendirilmektedir (Lu ve ark., 2013; Colucci-D'Amato ve ark., 2020).

Menopoz ve andropoz dönemlerinde BDNF düzeylerindeki bu hormonal kaynaklı azalma, yaşlanma ile birlikte görülen bilişsel gerileme ve nörodejeneratif süreçlerin hızlanmasına katkıda bulunabilir. Bununla birlikte, düzenli fiziksel aktivite, zihinsel uyarım ve uygun yaşam tarzı müdahalelerinin bu dönemlerde BDNF seviyelerini artırabildiği ve hormonal düşüşün olumsuz etkilerini kısmen dengeleyebildiği gösterilmiştir (Cotman ve ark., 2002; Erickson ve ark., 2011; Rico-González ve ark., 2020).

1.3.3 Enflamasyon ve Bağışıklık Sistemi

Enflamasyon ve bağışıklık sistemi aktivitesi, beyin kaynaklı nörotrofik faktörün (BDNF) sentezi ve sinyalizasyonu üzerinde önemli düzenleyici etkilere sahiptir. Akut ve kontrol altındaki bağışıklık yanıtları, doku onarımı ve nöroprotektif mekanizmaları destekleyebilirken; kronik ve sistemik enflamasyon**,** BDNF ekspresyonunda azalma ile ilişkilendirilmektedir (Dantzer ve ark., 2008; Colucci-D'Amato ve ark., 2020).

Kronik enflamatuar durumlarda artan pro-enflamatuar sitokinler (özellikle interlökin-1β (IL- 1β), interlökin-6 (IL-6) ve tümör nekroz faktör-α (TNF-α), BDNF gen ekspresyonunu baskılayarak TrkB aracılı sinyal yolaklarını olumsuz etkiler. Bu durum sinaptik plastisiteyi zayıflatır, nörogenezi azaltır ve nöronal sağkalımı tehlikeye sokar (Dantzer ve ark., 2008; Lu ve ark., 2013). Özellikle hipokampus ve prefrontal korteks gibi bilişsel ve duygusal işlevlerle ilişkili beyin bölgeleri, enflamatuar süreçlere karşı daha duyarlıdır (Dantzer ve ark., 2008; Lu ve ark., 2013**).**

Bağışıklık sistemi hücreleri ile merkezi sinir sistemi arasındaki etkileşimler, mikroglia aracılığıyla gerçekleşir. Mikroglial hücrelerin kronik aktivasyonu, reaktif oksijen türlerinin ve sitokinlerin artışına yol açarak BDNF üretimini azaltabilir ve sinaptik bütünlüğü bozabilir (Block ve ark., 2009; Colucci-D'Amato ve ark., 2020). Bu mekanizma, depresyon, Alzheimer ve Parkinson hastalığı gibi nörodejeneratif ve psikiyatrik bozuklukların patofizyolojisinde önemli bir rol oynamaktadır. **(**Block ve ark., 2009; Colucci-D'Amato ve ark., 2020**).**

Klinik çalışmalarda, depresyon ve kronik stres durumlarında sistemik enflamasyon belirteçleri (CRP, IL-6) ile düşük periferik BDNF düzeyleri arasında ters yönlü bir ilişki olduğu gösterilmiştir. Bu bulgular, enflamasyon-BDNF hipotezini desteklemekte ve bağışıklık sistemi aktivitesinin nöroplastisite üzerinde belirleyici olduğunu ortaya koymaktadır (Dantzer ve ark., 2008; Thornton, 2023).

Öte yandan, anti-enflamatuar etkileri bilinen düzenli fiziksel aktivite**,** sağlıklı beslenme ve bazı farmakolojik yaklaşımların, sitokin düzeylerini azaltarak BDNF ekspresyonunu artırabildiği bildirilmiştir. Özellikle egzersizin, hem periferik hem de santral enflamasyonu baskılayarak BDNF aracılı sinaptik plastisiteyi desteklediği gösterilmiştir (Cotman ve ark., 2002; Rico-González ve ark., 2020).

1.3.4 İlaçlar, Kimyasal Maddeler, Çevresel Toksinler ve Kirleticiler

İlaçlar, endüstriyel kimyasal maddeler, çevresel toksinler ve hava–su–toprak kirleticileri, beyin kaynaklı nörotrofik faktörün (BDNF) sentezi, salınımı ve sinyalizasyonu üzerinde doğrudan ve dolaylı etkilere sahiptir. Bu etkenler, özellikle oksidatif stres, mitokondriyal disfonksiyon, nöroenflamasyon ve epigenetik mekanizmalar yoluyla BDNF ekspresyonunu modüle edebilmektedir (Colucci-D'Amato ve ark., 2020; Thornton, 2023).

Farmakolojik ajanlar arasında antidepresan ilaçlar (özellikle SSRI ve SNRI grubu), BDNF ekspresyonunu artıran en iyi tanımlanmış ilaçlardır. Bu ilaçların uzun süreli kullanımı, hipokampus ve prefrontal kortekste BDNF düzeylerini yükselterek sinaptik plastisiteyi ve nörogenezi desteklemektedir. Bu durum, antidepresanların terapötik etkilerinin yalnızca monoamin düzeyleriyle değil, aynı zamanda BDNF aracılı nöroplastik mekanizmalarla da ilişkili olduğunu göstermektedir (Duman ve ark., 2006; Lu ve ark., 2013). Buna karşılık, bazı antipsikotikler, glukokortikoidler ve kemoterapötik ajanların BDNF ekspresyonunu baskılayabildiği bildirilmiştir.

Endüstriyel ve çevresel kimyasallar arasında yer alan ağır metaller (kurşun, cıva, kadmiyum) ve pestisitler**,** merkezi sinir sisteminde oksidatif stres ve mikroglial aktivasyonu artırarak BDNF üretimini azaltabilmektedir. Özellikle erken yaşam döneminde bu maddelere maruziyetin, BDNF düzeylerinde kalıcı düşüşlere ve bilişsel gelişimde bozulmalara yol açtığı gösterilmiştir (Block ve Calderón-Garcidueñas, 2009; Colucci-D'Amato ve ark., 2020).

Çevresel kirleticiler, özellikle hava kirliliği bileşenleri (ince partikül maddeler – PM2.5, azot dioksit, ozon), sistemik ve santral enflamasyonu tetikleyerek BDNF ekspresyonunu dolaylı olarak baskılamaktadır. Uzun süreli hava kirliliğine maruziyetin, düşük serum BDNF düzeyleri, bilişsel gerileme ve nörodejeneratif hastalık riskinde artış ile ilişkili olduğu bildirilmektedir (Block ve ark., 2009; Thornton, 2023).

Ayrıca endokrin bozucu kimyasallar (bisfenol A, ftalatlar), hormon reseptörleri üzerinden etki göstererek östrojen–BDNF etkileşimini bozabilmekte ve sinaptik plastisiteyi olumsuz etkileyebilmektedir. Bu maddelerin özellikle gelişimsel dönemlerde BDNF sinyalizasyonu üzerinde uzun vadeli etkiler oluşturduğu düşünülmektedir (Colucci-D'Amato ve ark., 2020).

1.3.5 Egzersiz

Hem akut (tek seans) hem de kronik (≥8–12 hafta düzenli) egzersizler, birçok çalışma ve meta-analize göre dolaşımdaki BDNF düzeylerini artırma eğilimindedir; etki büyüklüğü, egzersiz tipi, yoğunluğu, süresi, ölçüm yöntemi ve örnekleme zamanına göre değişiklik göstermektedir (Rico-González ve ark., 2025).

Tek bir egzersiz oturumundan sonra, özellikle orta-yüksek yoğunlukta yapılan aerobik aktiviteler sonrasında dolaşımdaki BDNF seviyeleri hızlı bir şekilde artmaktadır.

Bu artış, egzersizi izleyen dakikalar ve saatler içinde ölçülmüş olup, sağlıklı bireylerin yanı sıra obez ve nörolojik hastalığı olan farklı popülasyonlarda da gözlemlenmiştir. Bu hızlı artışın, BDNF'nin periferik kaynaklardan, özellikle trombositler ve kaslardan salınmasına bağlı olduğu düşünülmektedir (Rico-González ve ark., 2025). Öte yandan, kronik ve düzenli egzersiz programları bazal BDNF düzeylerini kalıcı olarak artırabilmektedir. Haftalık düzenli egzersiz, sinaptik plastisiteyi destekleyerek uzun vadede bilişsel fonksiyonların iyileşmesine ve nörodejeneratif süreçlerin yavaşlamasına katkıda bulunur (Ruiz-González ve ark., 2021).

Çocuklarda egzersizin BDNF seviyeleri üzerindeki etkisi, yalnızca egzersizin türüne değil, çocuğun yaşına ve gelişimsel evresine de bağlıdır. Erken çocukluk döneminde (6-10 yaş) beyin hâlâ yüksek nöroplastisiteye sahip olduğundan, egzersiz BDNF düzeylerini artırarak sinaptik bağlantıların güçlenmesini ve öğrenme kapasitesinin artmasını destekler. Ergenlik öncesi ve ergenlik döneminde ise hormon seviyelerindeki değişimler (özellikle östrojen ve testosteron) BDNF yanıtını etkileyebilir; bu dönemde bazı bireylerde BDNF artışı daha belirgin olurken, bazılarında daha sınırlı kalabilir. Ayrıca beynin farklı bölgelerinin olgunlaşma hızındaki farklılıklar, aynı egzersiz programının yaşa bağlı olarak farklı bölgelerde farklı derecede BDNF artışına yol açmasına neden olur. Bu nedenle, çocuklarda egzersizin nörobilişsel etkilerini değerlendirirken, yaş ve gelişimsel dönem önemli bir belirleyici faktördür (Rico-González ve ark., 2023).

Düzenli ve özellikle aerobik türdeki egzersiz, beyindeki BDNF üretimini artıran en güçlü fizyolojik faktörlerden biridir. Egzersizin sinaptik plastisiteyi ve öğrenme kapasitesini desteklediği, özellikle hipokampus hacmini artırarak bilişsel fonksiyonları iyileştirdiği gösterilmiştir (Erickson ve ark., 2011; Park ve Poo, 2013).

Aerobik egzersizler (koşu, bisiklet, yürüyüş) BDNF düzeyleri üzerindeki etkileri en ayrıntılı biçimde incelenmiş fiziksel aktivite türleri arasında yer almaktadır. Yapılan çalışmalar, özellikle orta–yüksek yoğunlukta ve görece uzun süreli aerobik egzersiz seanslarının BDNF artışı açısından en güçlü uyarımı sağladığını göstermektedir (Ruiz-González ve ark., 2021). Bunun yanı sıra, direnç (strength) antrenmanlarının da BDNF düzeylerini artırabildiği bildirilmekle birlikte, bu etkinin uygulanan egzersiz protokolü, yoğunluk ve süreye bağlı olarak değişkenlik gösterdiği rapor edilmiştir (Kaagman ve ark., 2024). Aerobik ve direnç egzersizlerinin birlikte uygulandığı kombinasyon

programlarının (concurrent training) ise genellikle daha belirgin ve tutarlı BDNF artışları sağladığı bildirilmektedir (Kaagman ve ark., 2024).

Yüksek yoğunluklu interval antrenman (HIIT) protokolleri, kısa süreli yüksek efor periyotlarının kısa dinlenme aralıkları ile ardışık olarak uygulanmasıyla karakterize olup, özellikle akut BDNF artışları ile ilişkilendirilmiştir (The Times ve ark., 2025). Bu artışın, egzersiz sırasında ortaya çıkan yüksek laktat düzeyleri ve bunun tetiklediği nörotrofik sinyalizasyon mekanizmaları ile ilişkili olabileceği öne sürülmektedir. Klinik popülasyonlarda (örneğin obezite) yapılan çalışmalarda da aerobik egzersiz ile aerobik ve direnç antrenmanının kombinasyonundan oluşan programların BDNF düzeylerini artırdığı, buna ek olarak motor ve fonksiyonel kazanımlar sağladığı gösterilmiştir (Kaagman ve ark., 2024). Bununla birlikte, farklı popülasyonlar ve egzersiz protokolleri arasında BDNF yanıtının büyüklüğü açısından heterojenlik bulunduğu ve sonuçların bu değişkenlere bağlı olarak farklılık gösterebildiği bildirilmektedir (Kaagman ve ark., 2024).

1.3.6 Beslenme

Beslenme, beyin kaynaklı nörotrofik faktörün (BDNF) düzeyleri ve biyolojik işlevleri üzerinde önemli bir çevresel düzenleyici faktördür. Diyetin içeriği; oksidatif stres, enflamasyon, insülin duyarlılığı ve bağırsak–beyin ekseni üzerinden etki göstererek BDNF ekspresyonunu ve sinaptik plastisiteyi doğrudan modüle edebilmektedir (Gómez-Pinilla, 2008; Lu ve ark., 2013).

Bu bağlamda, beslenme yoluyla alınan bazı besin öğeleri ve biyoaktif bileşikler, bilişsel işlevleri destekleyici özellikleri nedeniyle besin kökenli nootropikler olarak değerlendirilmektedir. Bu bileşenlerin, antioksidan ve anti-enflamatuar etkileri aracılığıyla BDNF aracılı nöroplastisite üzerinde olumlu etkiler oluşturduğu bildirilmektedir. (Gómez-Pinilla, 2008; Lu ve ark., 2013).

Omega-3 yağ asitleri, özellikle dokosahekzaenoik asit (DHA), nöronal membran bütünlüğünü destekleyerek BDNF sinyalizasyonunu artırmaktadır. Hayvan ve insan çalışmalarında, omega-3 açısından zengin diyetlerin hipokampal BDNF düzeylerini yükselttiği ve öğrenme–hafıza performansını iyileştirdiği gösterilmiştir (Gómez-Pinilla, 2008).

Benzer şekilde, polifenoller (flavonoidler, resveratrol) ve diğer antioksidan bileşikler, oksidatif stresi ve enflamasyonu azaltarak BDNF ekspresyonunu dolaylı yoldan desteklemektedir. Bu etkiler, özellikle sebze, meyve ve bitkisel kaynaklardan zengin beslenme modellerinde daha belirgin olarak ortaya çıkmaktadır.

Beslenme ile alınan antioksidan bileşikler, reaktif oksijen türlerinin (ROS) neden olduğu oksidatif stresi azaltarak nöronal hasarı sınırlandırmakta ve BDNF ekspresyonunun korunmasına katkı sağlamaktadır. Oksidatif stresin sinaptik plastisiteyi bozduğu ve BDNF sentezini baskıladığı göz önüne alındığında, antioksidanlardan zengin beslenmenin beyin sağlığı açısından kritik öneme sahip olduğu belirtilmektedir. C ve E vitaminleri, karotenoidler ve polifenoller gibi antioksidan bileşiklerin, mitokondriyal fonksiyonları destekleyerek ve hücresel sinyal yolaklarını modüle ederek BDNF-aracılı nöroplastik süreçleri güçlendirdiği bildirilmektedir (Gómez-Pinilla, 2008; Lu ve ark., 2013). Bu etkilerin, özellikle sebze, meyve, kuruyemiş ve bitkisel kaynaklardan zengin beslenme modellerinde daha belirgin olduğu vurgulanmaktadır. **(**Gómez-Pinilla, 2008; Lu ve ark., 2013).

Akdeniz tipi beslenme gibi sebze, meyve, tam tahıl, balık ve zeytinyağı ağırlıklı diyet modellerinin; düşük enflamasyon düzeyi ve artmış BDNF konsantrasyonları ile ilişkili olduğu bildirilmektedir. Bu beslenme modelinin bilişsel gerilemeyi yavaşlatıcı ve depresyon riskini azaltıcı etkilerinin, kısmen BDNF aracılı nöroplastik mekanizmalar üzerinden gerçekleştiği düşünülmektedir (Gómez-Pinilla, 2008; Thornton, 2023).

Bu bileşiklerin antioksidan ve anti-enflamatuar özellikleri, nöronal enerji metabolizmasını desteklemeleri ve sinaptik iletimi güçlendirmeleri yoluyla BDNF ekspresyonu ve BDNF-aracılı nöroplastisite üzerinde olumlu etkiler oluşturduğu bildirilmektedir (Gómez-Pinilla, 2008; Lu ve ark., 2013). Özellikle omega-3 yağ asitleri, polifenoller, flavonoidler ve bazı mikrobesinlerin nootropik etkilerinin, hipokampal BDNF düzeylerinde artış, sinaptik plastisitenin güçlenmesi ve öğrenme-hafıza süreçlerinin desteklenmesi ile ilişkili olduğu bildirilmektedir. Bu nedenle besin kökenli nootropikler, beslenmenin beyin sağlığı üzerindeki düzenleyici rolünü açıklayan temel mekanizmalardan biri olarak değerlendirilmektedir. **(**Gómez-Pinilla, 2008; Lu ve ark., 2013).

Buna karşılık, yüksek yağlı ve yüksek şekerli Batı tipi beslenme modelleri, insülin direnci ve sistemik enflamasyonu artırarak BDNF ekspresyonunu baskılamaktadır. Özellikle rafine karbonhidratlar ve doymuş yağ asitlerinin aşırı tüketiminin, hipokampal

BDNF düzeylerinde azalma ve bilişsel işlevlerde bozulma ile ilişkili olduğu bildirilmektedir (Gómez-Pinilla, 2008; Lu ve ark., 2013).

Meta-analiz çalışması yapan Shafiee ve ark. (2023), alkol tüketiminin BDNF kan düzeylerini anlamlı şekilde azalttığını ortaya koymuştur. Bu bulgu, alkolün sinaptik plastisite, nörogenez ve bilişsel işlevler üzerindeki olumsuz etkilerini moleküler düzeyde desteklemektedir. Kronik alkol kullanımı, özellikle öğrenme ve hafıza süreçlerinden sorumlu olan hipokampus ve prefrontal korteks gibi beyin bölgelerinde BDNF azalmasına bağlı yapısal ve işlevsel bozulmalara yol açabilir. Dolayısıyla, alkol tüketimi BDNF'yi düşürerek bilişsel performans ve nöronal sağkalım üzerinde olumsuz etkilere neden olabilmektedir. (Shafiee ve ark., 2023).

Son olarak, B grubu vitaminleri (B6, B9, B12), D vitamini, çinko, magnezyum ve demir gibi mikrobesinlerin; nöronal metabolizma, nörotransmitter sentezi ve hücresel enerji dengesi üzerinden BDNF ekspresyonunu destekleyici etki gösterdiği, bu mikrobesinlerin yetersizliğinin ise BDNF düzeylerinde düşüş ve duygu durum bozuklukları ile ilişkili olduğu belirtilmektedir. Ayrıca kalori kısıtlaması ve aralıklı oruç gibi beslenme yaklaşımlarının, metabolik stres yanıtlarını aktive ederek BDNF üretimini artırabildiği ve sinaptik plastisiteyi desteklediği, bu etkinin keton cisimleri ve artmış mitokondriyal verimlilik yoluyla gerçekleştiği bildirilmektedir (Colucci-D'Amato ve ark., 2020; Gómez-Pinilla, 2008; Lu ve ark., 2013).

1.3.7 Stres

Stres, organizmanın iç veya dış çevreden gelen fiziksel, psikolojik ya da biyolojik tehditlere karşı homeostatik dengeyi korumak amacıyla geliştirdiği fizyolojik ve davranışsal yanıtların bütünüdür. Akut stres durumları kısa süreli adaptif yanıtlar oluşturarak organizmanın hayatta kalmasına katkı sağlarken, kronik stres maruziyeti merkezi sinir sistemi üzerinde yapısal ve fonksiyonel bozulmalara yol açabilmektedir. Özellikle uzun süreli stres, nöroplastisiteyi olumsuz etkileyerek bilişsel işlevler ve duygu durum düzenlenmesinde önemli rol oynayan beyin bölgelerinde değişikliklere neden olmaktadır (McEwen, 2007; Dantzer ve ark., 2008).

Stres yanıtının temel biyolojik düzenleyicisi hipotalamus–hipofiz–adrenal (HHA) aksıdır. Stresörlere yanıt olarak hipotalamustan kortikotropin salgılatıcı hormon (CRH) salınmakta, bunu takiben hipofizden adrenokortikotropik hormon (ACTH) ve adrenal

bezlerden glukokortikoidler (kortizol) salınmaktadır. Akut stres sırasında glukokortikoidlerin kısa süreli artışı nöronal adaptasyonu destekleyebilirken, kronik stres koşullarında sürekli yüksek kortizol düzeyleri BDNF gen ekspresyonunu baskılamakta ve TrkB aracılı sinyal yolaklarını olumsuz etkilemektedir (McEwen, 2007; Lu ve ark., 2013).

Kronik stresin BDNF üzerindeki baskılayıcı etkileri özellikle hipokampus ve prefrontal korteks gibi öğrenme, hafıza ve duygu durum düzenlenmesiyle ilişkili beyin bölgelerinde belirgin olarak gözlenmektedir. Deneysel ve klinik çalışmalar, uzun süreli stres maruziyetinin hipokampal BDNF düzeylerinde azalmaya, dendritik dallanmanın gerilemesine ve sinaptik plastisitenin zayıflamasına yol açtığını göstermektedir. Bu değişiklikler, stresle ilişkili bilişsel bozulmalar ve depresif belirtilerin ortaya çıkmasında önemli bir mekanizma olarak değerlendirilmektedir (Duman ve ark., 2006; Lu ve ark., 2013).

Ayrıca stres, enflamatuar yanıtları da tetikleyerek BDNF düzenlenmesini dolaylı yoldan etkilemektedir. Kronik stres durumlarında artan pro-enflamatuar sitokinler, mikroglial aktivasyonu artırmakta ve nörotrofik destek mekanizmalarını baskılamaktadır. Bu süreç, BDNF üretiminde azalma ve sinaptik bütünlüğün bozulması ile sonuçlanarak nörodejeneratif ve psikiyatrik hastalıkların patofizyolojisine katkıda bulunmaktadır (Dantzer ve ark., 2008; Block ve ark., 2009).

Stresin süresi ve şiddeti BDNF düzeyleri üzerinde belirleyici bir rol oynamaktadır. Akut stres sınırlı ve geçici etkiler oluştururken, kronik stres BDNF ekspresyonunu baskılayarak nöroplastisiteyi zayıflatmakta ve beyin sağlığını olumsuz yönde etkilemektedir. Bu nedenle stres yönetimi, BDNF aracılı nöroplastik mekanizmaların korunması ve ruhsal hastalık riskinin azaltılması açısından kritik bir çevresel düzenleyici faktör olarak değerlendirilmektedir (McEwen, 2007; Lu ve ark., 2013).

Ayrıca, depresyon tedavisinde kullanılan bazı antidepresanlar (özellikle SSRI'lar) BDNF düzeylerini yükseltir; bu durum, antidepresanların nöronal sağkalımı ve plastisiteyi artırıcı etkileri üzerinden çalıştığını gösteren nörotrofik hipotezin temelini oluşturur (Duman ve ark., 2006).

BDNF düzeylerindeki azalma genellikle patolojik veya olumsuz fizyolojik durumlarla ilişkilidir. Uzun süreli ve kronik stres, hipotalamik-hipofiz-adrenal (HPA) aksisinin aktivasyonu ve yüksek kortizol salınımı BDNF seviyelerini düşürür; bu durum

sinir hücrelerinde hasara, dendritik büzülmeye ve bilişsel işlevlerde bozulmaya yol açabilir (Bath ve ark., 2006, McEwen, 2007). Depresyon ve anksiyete gibi psikiyatrik hastalıklarda BDNF seviyeleri belirgin şekilde azalır; bu azalma hipokampus ve korteksteki yapısal küçülmelerle ilişkilidir ve hastalığın patogenezinde merkezi bir rol oynar (Bath ve ark., 2006, Duman ve ark., 2006).

1.4 Yaşın Beyin Kaynaklı Nörotrotik Faktör Üzerindeki Etkisi

Yaşlanma ile birlikte sinir sisteminde birçok yapısal ve işlevsel değişiklik meydana gelir. Bu değişiklikler; sinaptik bağlantıların zayıflaması, nöronların sağkalımında azalma ve öğrenme-hafıza gibi bilişsel işlevlerin gerilemesi şeklinde kendini gösterebilir. Beyin kaynaklı nörotrofik faktör (BDNF), bu süreçte beyin sağlığını koruyucu bir rol üstlenmektedir (Binder ve ark., 2004).

Nörotrofik faktörler arasında özellikle önemli bir yere sahip olan BDNF, yaşlanmayla birlikte doğal olarak azalma eğilimindedir. Bu azalma, özellikle hipokampus gibi öğrenme ve bellekten sorumlu bölgelerde nöronların işlevselliğini olumsuz etkileyebilir. BDNF seviyelerindeki düşüş, hem bilişsel performansın zayıflaması hem de yaşlı bireylerde görülen depresif belirtilerle ilişkilendirilmiştir (Yarım ve ark., 2015).

Bilişsel gerilemenin önlenmesi açısından yaşam tarzı faktörleri büyük önem taşır. Özellikle fiziksel egzersiz gibi aktivitelerin, yaşlılık döneminde BDNF düzeylerini artırabildiği, böylece hipokampus hacmini koruduğu ve bellek kapasitesini geliştirdiği gösterilmiştir.. Bu durum, yaşlı bireylerde düzenli egzersizin sadece fiziksel sağlığı değil, zihinsel işlevleri de destekleyebileceğini göstermektedir (Cotman ve ark., 2002; Erickson ve ark., 2011).

BDNF, depresyon, anksiyete, Alzheimer, Parkinson ve travmatik beyin hasarı gibi çeşitli klinik durumlarda önemli bir biyobelirteç olarak değerlendirilmektedir (Tiwari ve ark., 2022; Liberona ve ark., 2024). Ancak elde edilen sonuçlar sıklıkla tutarsızdır ve bunun başlıca nedenleri arasında ölçüm tekniklerinin standardize edilmemesi, laboratuvarlar arası metodolojik farklılıklar ve yaş, cinsiyet, stres, uyku, sigara kullanımı ve metabolik durum gibi bireysel faktörlerin etkisi yer almaktadır (Tiwari ve ark., 2022; Liberona ve ark., 2024; Rico-González ve ark., 2025). Ayrıca, proBDNF ve mBDNF ayrımının çoğu çalışmada yapılmamış olması, verilerin yorumlanmasını daha da

karmaşık hâle getirmektedir (Rico-González ve ark., 2025). Bu nedenle güncel literatürde BDNF'nin tek başına güvenilir bir biyobelirteç olmadığı yaygın olarak kabul edilmektedir (Liberona ve ark., 2024).

Bununla birlikte, yaşlılık döneminde yaygın olarak görülen uyku bozukluklarının da BDNF düzeyleriyle ilişkili olduğu ortaya konmuştur. Uyku kalitesinin düşmesi, sinaptik plastisiteyi azaltarak öğrenme ve duygu durumu üzerinde olumsuz etkiler yaratabilir. Yapılan bir çalışmada, insomnia tanısı konmuş yaşlı bireylerde BDNF seviyelerinin anlamlı biçimde azaldığı ve bunun bilişsel zayıflamayı etkileyebileceği gösterilmiştir (PubMed, 2023).

Alzheimer, Parkinson ve Huntington gibi nörodejeneratif hastalıklarda BDNF üretimi de düşer; bu eksiklik nöron kaybını hızlandırarak hastalığın ilerlemesini destekleyebilir ve bu nedenle BDNF, bu hastalıklarda potansiyel bir tedavi hedefi olarak değerlendirilmektedir (Erickson ve ark., 2011). Meta-analiz çalışması yapan Son olarak, yaşlanma süreciyle birlikte BDNF seviyesi doğal olarak azalır; bu azalma, öğrenme, hafıza ve bilişsel kapasitede düşüşe yol açan nöroplastisite eksikliğinin temel moleküler nedenlerinden biri olarak kabul edilir (Cotman ve ark., 2002).

Dolayısıyla, BDNF yaşlılık döneminde hem zihinsel sağlığın sürdürülmesinde hem de nörodejeneratif süreçlerin yavaşlatılmasında merkezi bir role sahiptir (Binder ve ark., 2004; Yarım ve ark., 2015).

1.5 Beyin Kaynaklı Nörotrotik Faktör'ün Beyin Sağlığı Üzerindeki Etkileri

Depresyon ve BDNF ilişkisi üzerine yapılan çalışmalar, bu nörotrofik faktörün ruh sağlığındaki önemini açıkça ortaya koymaktadır. Thornton (2023) tarafından bildirildiği üzere, depresyonlu bireylerde BDNF seviyeleri genellikle düşüktür ve bu düşüş hipokampus ve prefrontal korteks gibi duygudurum ile ilişkili beyin bölgelerindeki yapısal ve fonksiyonel değişikliklerle paralellik göstermektedir. Düşük BDNF düzeyleri, sinaptik plastisiteyi ve nöroplastisiteyi olumsuz etkileyerek öğrenme, hafıza ve duygu durum süreçlerinde bozulmalara yol açabilir (Thornton, 2023).

Antidepresan tedavileri ve yaşam tarzı müdahaleleri, BDNF düzeylerini artırarak bu olumsuz etkileri telafi edebilmektedir. Özellikle SSRI tipi ilaçların uzun süreli kullanımı,

hipokampal BDNF ekspresyonunu artırarak sinaptik bağlantıları güçlendirmekte ve depresif semptomların azalmasına katkı sağlamaktadır (Duman ve ark., 2006). Benzer şekilde, düzenli fiziksel egzersiz ve zihinsel aktiviteler de BDNF seviyelerini yükselterek sinaptik plastisiteyi desteklemekte ve bilişsel işlevleri iyileştirmektedir (Rico-González , 2020)

Alzheimer hastalığı modellerinde Götz ve ark. (2018) farelerde yaptıkları çalışmada, amiloid β transgenik fareler ve yaşlı sıçanlarda BDNF geninin viral vektörlerle iletilmesinin sinaptik kayıpları azalttığını ve özellikle öğrenme ile hafıza performansını geliştirdiğini göstermiştir. Depresyon ve stres modellerinde Duman ve ark. (2000) kronik stres uygulanan farelerde hipokampal BDNF düzeylerinin belirgin şekilde azaldığını ve bunun depresif davranışlarla ilişkili olduğunu bulmuş, antidepresan tedavisi uygulanan gruplarda ise BDNF seviyelerinin yükseldiğini ve davranışsal iyileşmenin sağlandığını rapor etmiştir. Nöroplastisite ve öğrenme modellerinde Lu ve ark. (2005) BDNF eksikliği olan farelerde uzun süreli potansiyonun bozulduğunu ve öğrenme kapasitesinin düştüğünü, ancak genetik veya rekombinant BDNF uygulamalarının bu eksikliği telafi ettiğini ve hipokampal BDNF düzeyinin artırılmasının öğrenme, hafıza ve sinaptik plastisiteyi güçlendirdiğini göstermiştir. Parkinson hastalığı modellerinde ise Kells ve ark. (2012) 6-hidroksidopamin ile dopaminerjik nöron kaybı oluşturulan farelerde BDNF uygulamasının motor performansı iyileştirdiğini ve substantia nigra bölgesindeki dopamin nöronlarının sağkalımını artırdığını bildirmiştir. Bu çalışmalar, BDNF'nin sinaptik bütünlüğün korunmasında, öğrenme ve hafıza süreçlerinin desteklenmesinde, depresif davranışların azaltılmasında ve dopaminerjik nöron sağ kalımında merkezi bir rol oynadığını ortaya koymaktadır. **Çizelge 1. '**de olan çalışmalar, BDNF'nin genetik, protein temelli ve davranışsal yollarla artırılmasının sinaptik plastisite, öğrenme-hafıza ve nöronal sağkalım üzerinde belirgin olumlu etkiler oluşturduğunu göstermektedir (Nagahara ve ark., 2009; Duman ve ark. 2006; Patterson ve ark., 1996).

Çizelge 1. BDNF ile ilgili deney hayavanları ile yapılan bilimsel çalışmalar

Uygulama Yöntemi	**Hayvan Modeli / Bölge**	**Uygulama Şekli**	**Gözlenen Etkiler**
Viral vektör (AAV, adenovirüs)	Alzheimer fare modeli / hipokampus	BDNF geni lokal olarak enjekte edilir	Sinaptik kayıp azalır, hafıza ve öğrenme performansı artar
Rekombinant BDNF proteini	Parkinson fare modeli / striatum	Saf BDNF proteini direkt enjekte edilir	Dopaminerjik nöronlar korunur, motor performans artar
Sistemik yöntem (egzersiz / farmakoloji)	Farelerde kronik stres / hipokampus	Egzersiz veya antidepresan tedavisi	Hipokampal BDNF artışı, depresif davranışlar azalır, öğrenme iyileşir
Transgenik fareler (overexpression)	Hipokampus, korteks	BDNF geni aşırı eksprese edilir	LTP ve öğrenme kapasitesi artar, nöroplastisite güçlenir

BDNF'nin sinaptik plastisite ve nörogenez üzerinde önemli etkilerinin yanı sıra bazı durumlarda beyin tümörlerinin büyümesini destekleyebileceğini belirtmektedir. Özellikle glioblastom gibi agresif tümörlerde BDNF, hücre proliferasyonu ve hayatta kalmayı artırarak tümör ilerlemesine katkıda bulunabilir. Bu nedenle BDNF'nin beyin sağlığındaki yararlı etkileri ile kanser gibi patolojik süreçlerdeki potansiyel olumsuz etkileri arasında dikkatli bir denge kurulması gerekmektedir. (Colucci-D'Amato ve ark.,2020).

2. SONUÇLAR VE DEĞERLENDİRME

BDNF, nöronal gelişim, sağkalım, sinaptik plastisite ve bilişsel fonksiyonlar için kritik bir nörotrofindir. Yapılan deneysel ve klinik çalışmalar, BDNF'nin hem merkezi sinir sistemi gelişiminde hem de yaşam boyu devam eden nöroplastisite süreçlerinde temel bir düzenleyici

rol üstlendiğini göstermektedir. BDNF seviyesindeki değişikliklerin stres, depresyon, Alzheimer ve Parkinson gibi nörodejeneratif hastalıklarda belirgin şekilde ortaya çıktığı görülmektedir. Bu bulgular, BDNF'nin hem hastalık mekanizmalarının anlaşılmasında hem de tedavi stratejilerinin geliştirilmesinde önemli bir biyobelirteç olduğunu ortaya koymaktadır. (Binder ve ark. 2004; Bath ve ark. 2006; Duman ark., 2006; Zuccato ark., 2009,Erickson 2011;).

Deney hayvanlarında yapılan araştırmalar, viral vektörler, rekombinant protein uygulamaları, sistemik farmakolojik yaklaşımlar ve transgenik modeller aracılığıyla BDNF düzeylerinin modüle edilebildiğini göstermiştir. Bu uygulamalar, özellikle Alzheimer ve Parkinson modellerinde sinaptik bütünlüğün korunması, davranışsal performansın artması ve nörodejenerasyonun yavaşlatılması gibi olumlu sonuçlar vermiştir (Lu 2005, Nagahara., 2009,Kells 2012,Götz 2018). Ayrıca düzenli fiziksel egzersizin hem akut hem de kronik olarak BDNF düzeylerini artırdığı; bunun da öğrenme, hafıza ve duygu durum düzenlenmesine katkı sağladığı güçlü bir şekilde desteklenmektedir. (Cotman ve ark. 2002; Erickson 2011 Rico-González 2020).

Özetle; BDNF; nörogenez, sinaptik plastisite ve davranışsal iyilik hali üzerindeki etkileri nedeniyle beyin sağlığının korunmasında merkezi bir rol oynamaktadır. Bu nedenle, BDNF temelli yaklaşımlar günümüzde nörodejeneratif ve psikiyatrik hastalıkların tedavisinde umut verici bir hedef olarak değerlendirilmektedir.

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UNUSUAL ONSET OF SACROTUBEROUS LIGAMENT

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Abstract

This case involves the topographic and morphometric characterization of the sacrotuberous ligament (STL) originating from the gluteus maximus muscle. In our case, the pudendal nerve was observed to be in close proximity and contact with the LST. Considering the various clinical problems that cause pudendal neuralgia, it may be useful to know that anatomical variations of the STL, similar to those in this case, may play a role in the etiopathogenesis.

Keywords: pudendal neuralgia, pudendal nerve compression, ligamentum sacrotuberale, nervus pudendus, musculus gluteus maximus

Introduction

The sacrotuberous ligament originates as a broad band from the posterior inferior iliac spine, sacrum, and coccyx; it extends in an antero-inferior direction while narrowing, then broadens again to attach to the ischial tuberosity.[1] Sometimes, a portion of the sacrotuberous ligament (STL) fibers extends to the medial aspect of the ischial tuberosity, and this extension is called the falciform process.[2] The upper margin of the STL bounds the greater sciatic foramen posteriorly and inferiorly, while its lower margin bounds the lesser sciatic foramen superiorly.[1] Consequently, it is in close proximity to important neurovascular structures, such as the pudendal nerve, that pass through these foramina.[3]

The pudendal nerve is formed by the union of the ventral rami of the S2-4 nerve roots. It carries sensory, motor, and autonomic fibers.[4] It passes between the coccygeus muscle and the piriformis muscle. Proceeding ventral to the STL, it leaves the pelvis through the infrapiriform foramen. It then passes through the lesser sciatic foramen and travels within the pudendal canal (Alcock's canal) to reach the perineal region. It divides into its terminal branches: the inferior anal (rectal) nerves, the perineal nerves, and the dorsal nerve of the penis/clitoris.[5]

Pudendal neuralgia, which can result from the compression (entrapment) of the pudendal nerve, is a neuropathy that negatively affects quality of life. Pudendal neuralgia is characterized by perineal pain that is aggravated by sitting and usually relieved by standing or lying down.[3] Urinary and sexual dysfunction may accompany these symptoms.[6]

Three potential sites where the pudendal nerve can be entrapped during its course have been identified: between the sacrospinous ligament (SSL) and the sacrotuberous ligament (STL), in Alcock's canal, while crossing the falciform process. It has been reported that entrapment occurs most commonly as the nerve passes between the SSL and the STL.[3]

In our case, the presence of a unilateral (left) sacrotuberous ligament (STL) originating from the gluteus maximus muscle—a variation we could not find described in the literature—was observed. It was noted that the nerves and vessels coursing within the pudendal canal were in very close proximity to and in contact with this variational STL, in a manner predisposing them to entrapment.

Materials and Methods

The variation in question was identified during a routine dissection of an adult female cadaver, fixed in 10% formalin solution and placed in the prone position, at the Department of Anatomy, Ege University Faculty of Medicine. Prior to the preparation of this case report, approval was obtained from the Medical Research Ethics Committee of Ege University Faculty of Medicine.

In the dissection performed using a standard set, following the removal of the skin and subcutaneous superficial fascia in the gluteal region, a detailed dissection of the ischioanal fossa

was performed, and the gluteus maximus muscle was reflected near its origin to proceed deeper (Figure 1a-b).

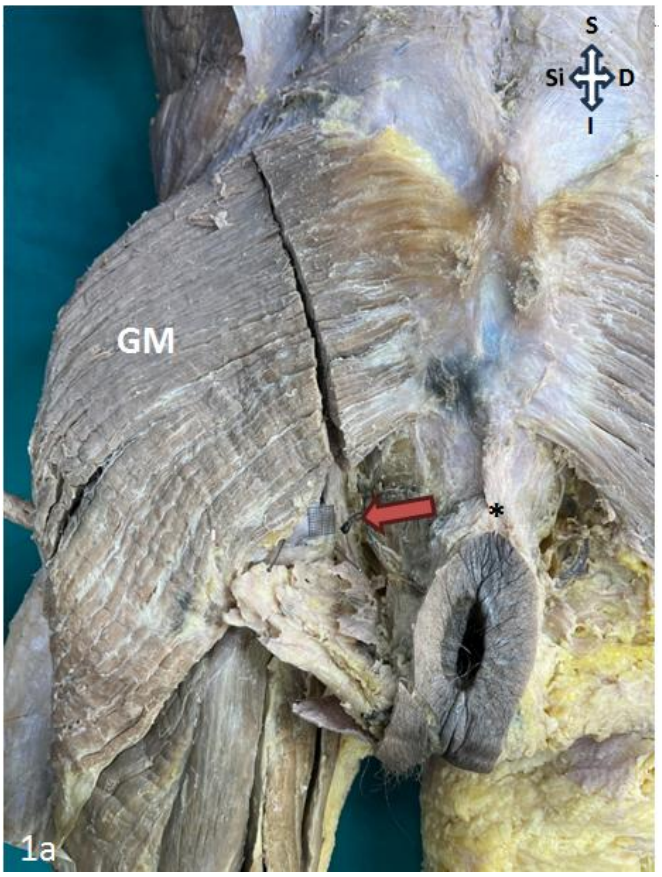


Figure 1a - Posterior view of the left gluteal region



Figure 1b – A portion of the gluteus maximus muscle (GM) was reflected to reveal the STL (arrow). Gm: gluteus medius muscle, *: anococcygeal ligament, P: piriformis muscle, S: sciatic nerve

Findings

In the case, during the detailed dissection of the ischioanal fossa and when attempting to proceed deeper by reflecting the gluteus maximus muscle near its origin, a strong, hard fibrous band was observed extending from the anterior fibers of the inferomedial part of the muscle to the ischial tuberosity. Considering this band might be the STL, dissection was continued in a manner that left one portion of the ligament on the reflected muscle side and the other portion in place to allow for full identification. When the gluteus maximus muscle was reflected laterally, a hematoma spreading into the infrapiriform fossa and onto the deep surface of the muscle was observed. After cleaning the hematoma, it was seen that the STL originated entirely from the gluteus maximus muscle instead of its normal origin and extended towards the ischial tuberosity. Its length was measured as 35.91 mm, its thickness at the thickest point as 6.94 mm, its thickness at the midpoint as 4.86 mm, and its width at the attachment site on the ischial tuberosity as 20.49 mm (Figure 2a-b).

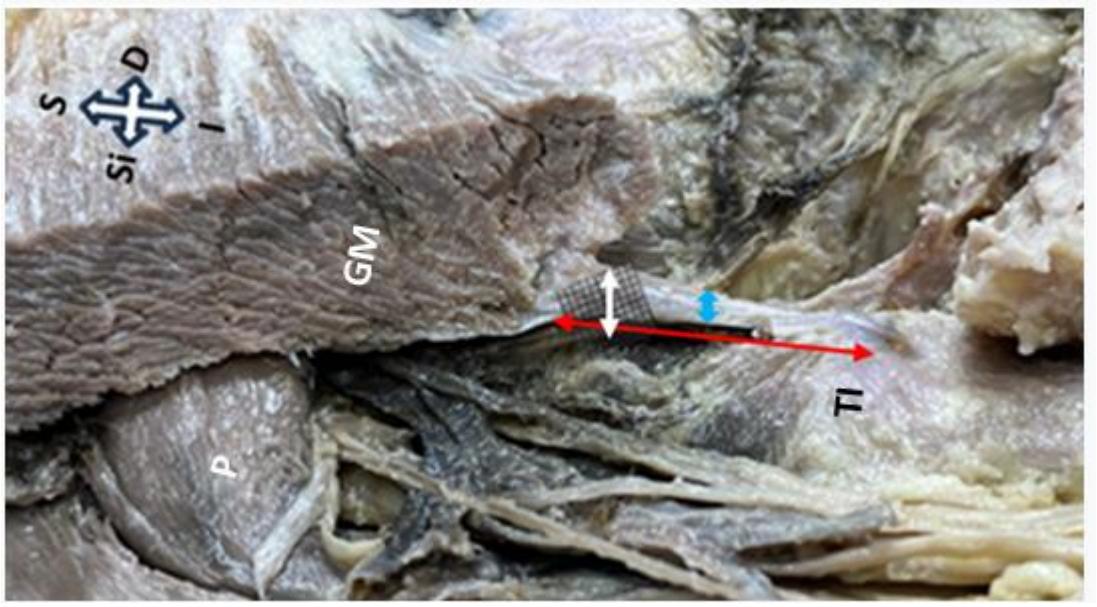


Figure 2a – Red arrow: Length, White arrow: Thickness at the thickest point, Blue arrow: Thickness at the midpoint.

GM: gluteus maximus muscle, TI: ischial tuberosity, P: piriformis muscle

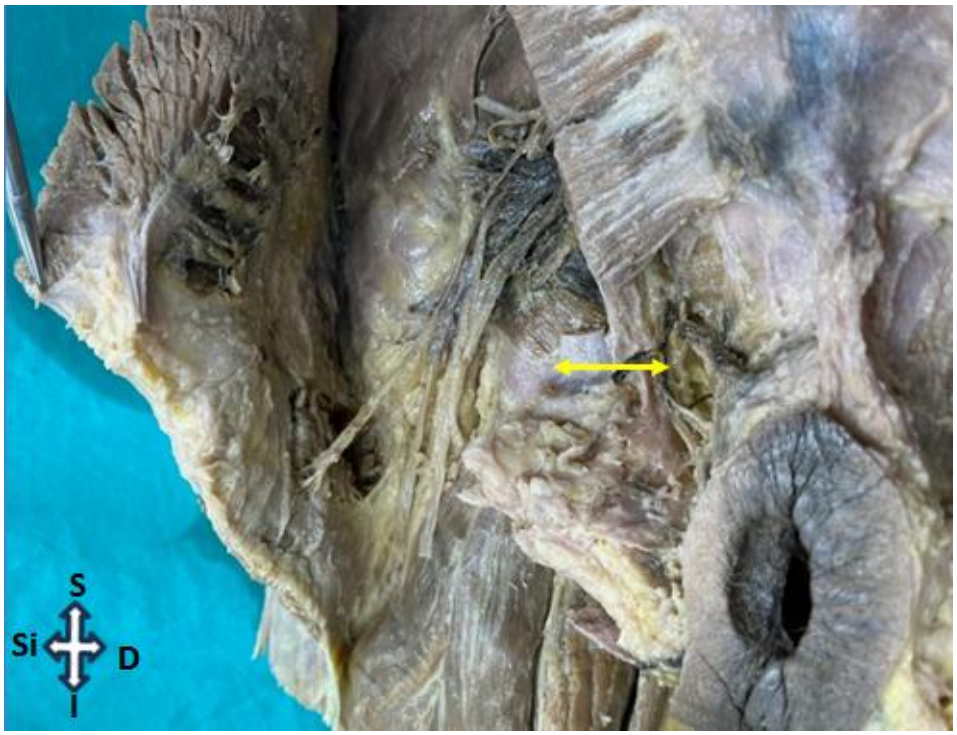


Figure 2b – Yellow arrow: Width at the attachment site on the ischial tuberosity.

It was observed that the nerves and vessels coursing into the pudendal canal were in very close proximity to the STL, and that the pudendal nerve was in contact with the ligament near the ischial tuberosity (Figure 3a, 3b).

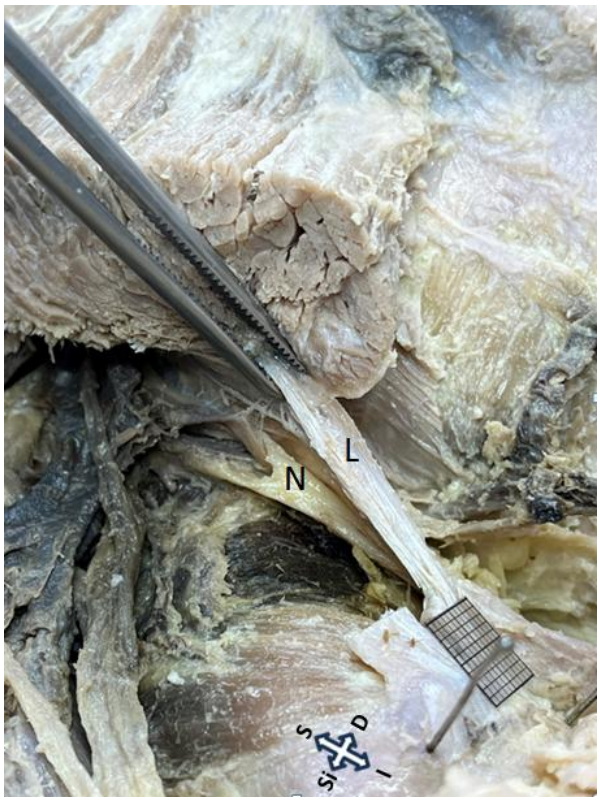


Figure 3a – STL (L), pudendal nerve (N).

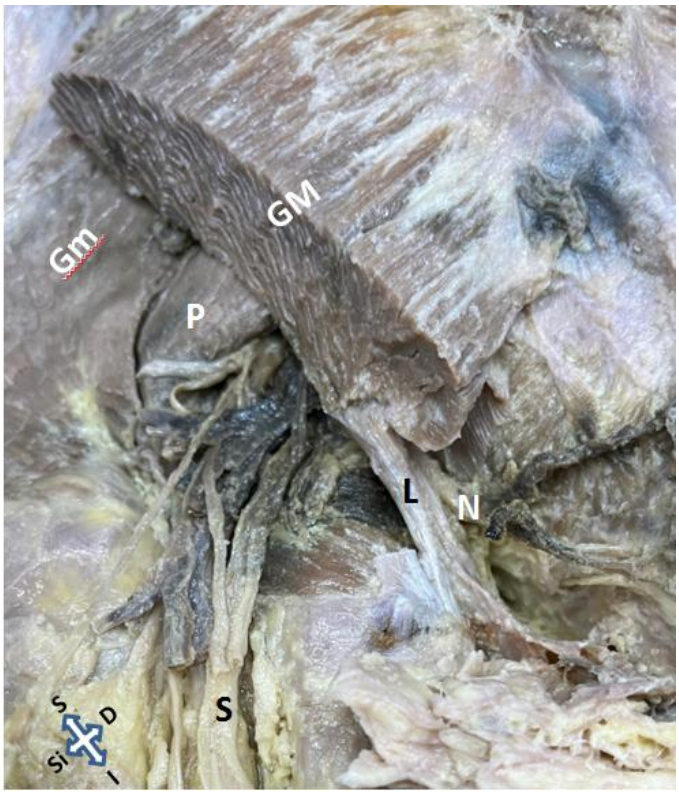


Figure 3b – GM: gluteus maximus muscle, Gm: gluteus medius muscle, P: piriformis muscle, S: sciatic nerve, L: sacrotuberous ligament, N: pudendal nerve

Conclusion

Pudendal neuralgia is a chronic pain syndrome that can be seen in both sexes, usually resulting from pudendal nerve entrapment. It has devastating effects on patients' quality of life and causes severe limitations in performing usual daily activities. The anatomical course of the pudendal nerve and its relationship with adjacent structures may predispose it to compression in a manner similar to that observed in this case. Therefore, it should be kept in mind that variations of the STL may play a role in the etiopathogenesis of diseases affecting the perineal region, such as pudendal neuralgia.

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SIRADIŞI BAŞLANGIÇLI LIGAMENTUM SACROTUBERALE

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Özet

Bu olgu musculus gluteus maximus başlangıçlı ligamentum sacrotuberale'nin (LST) topografik ve morfometrik tanımlamasını içermektedir. Olgumuzda nervus pudendus'un LST ile yakın komşulukta ve temas halinde olduğu gözlenmiştir. Pudendal nevraljiye sebep olan çeşitli klinik sorunlar göz önüne alındığında, bu olgudakine benzer şekilde, LST'nin anatomik varyasyonlarının etiyopatogenezde yer alabileceğinin bilinmesi faydalı olabilir.

Anahtar kelimeler: pudendal nevralji, pudendal sinir sıkışması, ligamentum sacrotuberale, nervus pudendus, musculus gluteus maximus

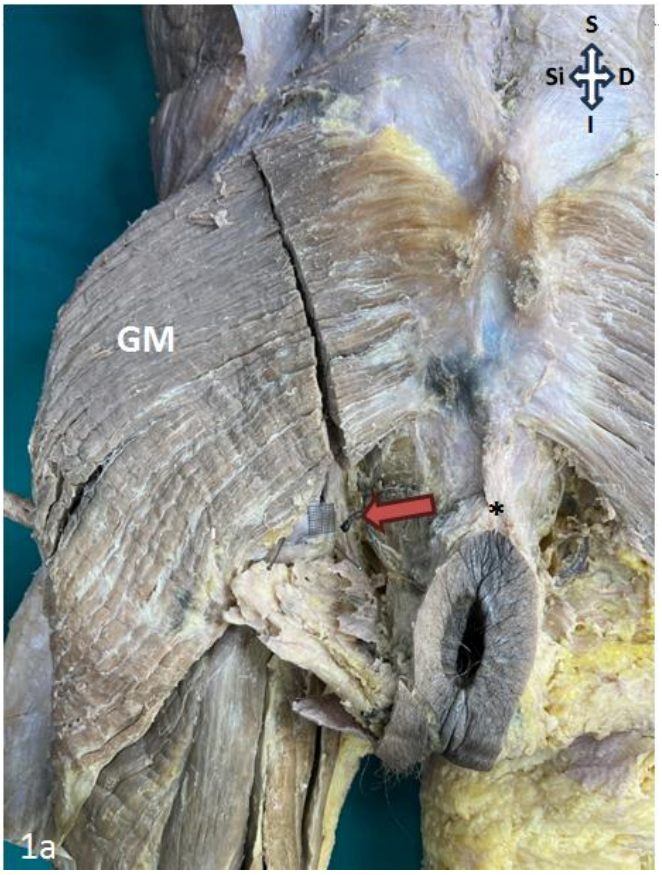
Giriş

Ligamentum sacrotuberale, spina iliaca posterior inferior, os sacrum ve coccyx'ten geniş bir bant halinde başlar, daralarak antero-inferior yönde uzanır. Tekrar genişleyerek tuber ischiadicum'a tutunur.[1] Bazen LST liflerinin bir kısmı tuber ishiadicum'un medialine uzanır ve bu uzantıya processus falciformis adı verilir.[2] LST'nin üst kenarı foramen ischiadicum majus'u arkadan ve alttan, alt kenarı ise foramen ischiadicum minus'u üstten sınırlar.[1] Bu sebeple foramenlerden geçen nervus pudendus gibi önemli nörovasküler yapılar ile yakın komşuluğu bulunmaktadır.[3] Nervus pudendus; S2-4 sinir köklerinin ramus ventralis'lerinin birleşmesiyle oluşur. Duyusal, motor ve otonom lifler taşır.[4] Musculus coccygeus ile musculus piriformis arasından geçer. LST'nin ventralinden ilerleyerek pelvisi foramen infrapiriforme'den terk eder. Foramen ischiadicum minus'tan geçip canalis pudendalis (Alcock kanalı) içinde seyrederek perineal bölgeye gelir. Terminal dalları olan nn. anales (rectales) inferiores, nn. perineales ve n. dorsalis penis/clitoridis'e ayrılır.[5] Nervus pudendus'un sıkışmasından kaynaklanabilen pudendal nevralji; yaşam kalitesini olumsuz yönde etkileyen bir nöropatidir. Pudendal nevralji; oturmakla şiddetlenen, genellikle ayakta durmakla ve yatmakla azalan perineal ağrı ile karakterizedir.[3] Bu semptomlara üriner ve seksüel disfonksiyon eşlik edebilir.[6] Nervus pudendus'un seyri sırasında tuzaklanabileceği üç muhtemel alan belirtilmiştir; LSS ve LST arasında, Alcock kanalında, proccessus falciformis'i geçerken. Tuzaklanmanın en yaygın LSS ve LST arasından geçerken olduğu bildirilmiştir.[3]

Olgumuzda literatürde tarifine rastlayamadığımız, tek taraflı (sol) m. gluteus maximus'tan köken alan LST varlığı söz konusudur. Canalis pudendalis'te uzanan sinir ve damarların, tuzaklanmaya uygun şekilde, varyatif başlangıçlı LST ile çok yakın komşulukta ve temas halinde oldukları gözlenmiştir.

Gereç ve Yöntem

Söz konusu varyasyon Ege Üniversitesi Tıp Fakültesi Anatomi Anabilim Dalı'nda, %10 formalin solüsyonu ile fikse edilmiş erişkin kadın kadavranın yüzüstü pozisyonda gerçekleştirilen rutin diseksiyon sırasında tespit edilmiştir. Olgu sunumu şeklinde hazırlanmadan önce Ege Üniversitesi Tıp Fakültesi Tıbbi Çalışmalar Etik Kurul'undan onay alınmıştır. Standart set ile gerçekleştirilen diseksiyonda, gluteal bölgede deri, derialtı yüzeyel fasya kaldırılmasını takiben, fossa ischioanalis'in detay diseksiyonu ve m. gluteus maximus'un origosu yakınından kaldırılarak derinine ilerlenilmiştir (Şekil 1a-b).



Şekil 1a - Sol gluteal bölgenin posterior görünümü



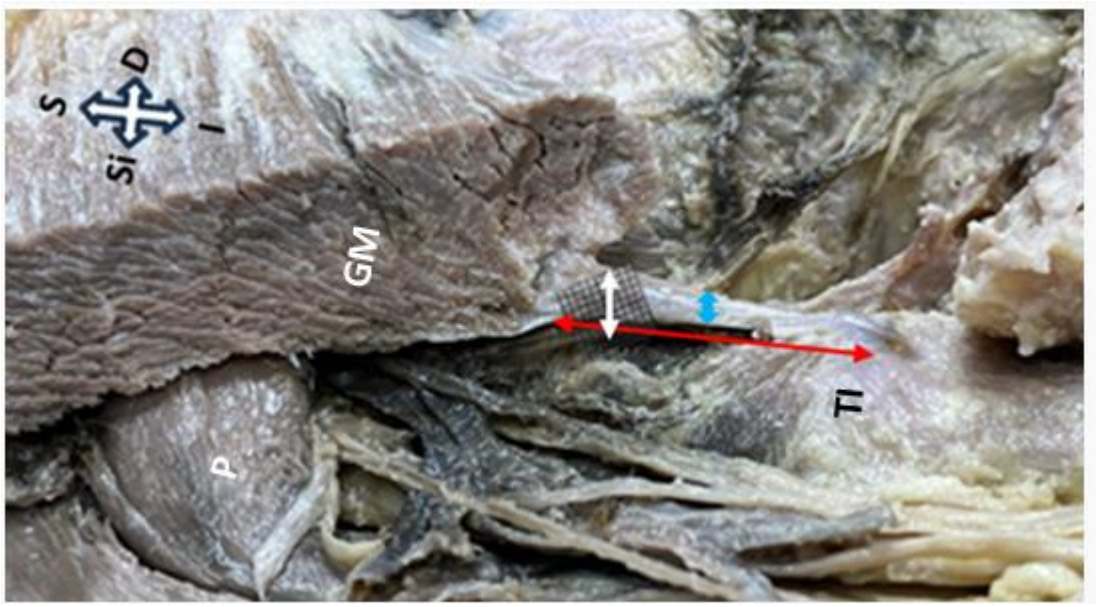
Şekil 1b – Musculus gluteus maximus'un (GM) bir kısmı LST'yi (ok) ortaya çıkarmak için uzaklaştırıldı. Gm: musculus gluteus medius, *: Lig. anococcygeum, P: musculus piriformis, S: nervus ischiadicus

Diseksiyon aşamaları fotoğraflanırken milimetrik ölçek kullanıldı ve ölçümlemeler ImageJ programı ile fotogrametrik olarak gerçekleştirildi. Fotogrametrik ölçümün uygun olmadığı yerlerde dijital kumpas kullanılarak ölçümler yapıldı.

Bulgular

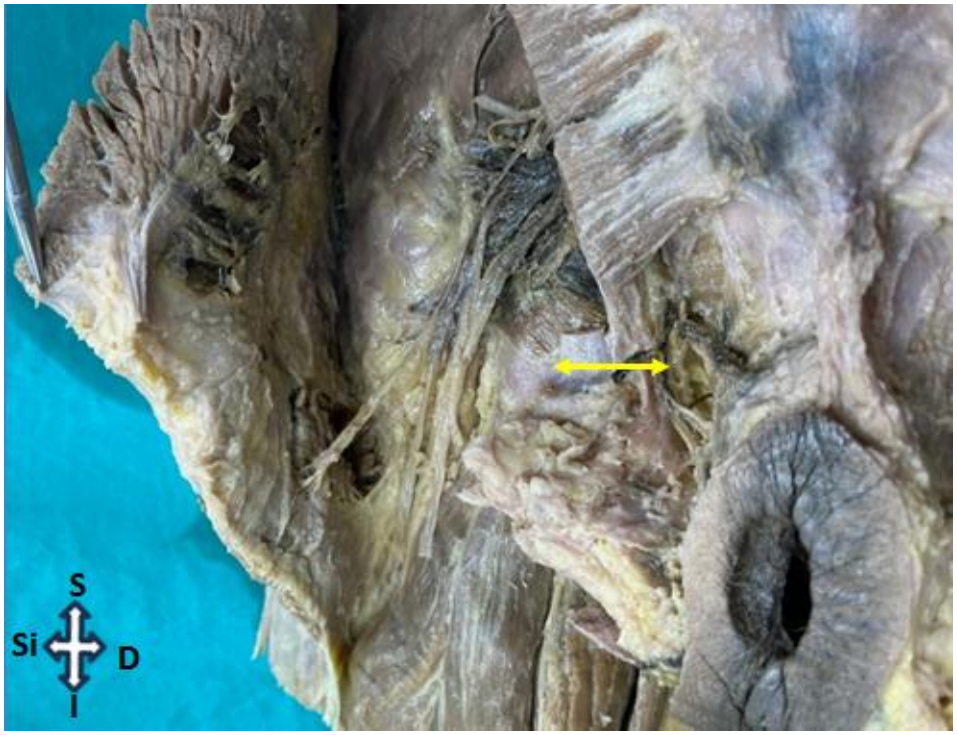
Olguda fossa ischioanalis'in detaylı diseksiyonu ve m. gluteus maximus'un origosu yakınından kaldırılarak derinine ilerlenmek istendiğinde kasın inferomedial bölümündeki ön liflerinden başlayarak tuber ischiadicum'a uzanan sağlam, sert fibröz bant gözlendi. Bu bantın LST olabileceği düşünülerek, tam tanımlama yapılabilmesi için ligamentin bir bölümü kaldırılan kas tarafında, diğer bölümü yerinde bırakılacak şekilde diseksiyona devam edildi. Musculus gluteus maximus laterale doğru kaldırıldığında fossa infrapiriformis'e ve kasın derin yüzeyine yayılmış hematom varlığı gözlendi. Hematomun temizlenmesinin ardından LST'nin normal origosu yerine tamamının m. gluteus maximus'tan köken aldığı ve tuber ischiadicum'a doğru uzandığı

görüldü. Uzunluğu 35,91 mm, en kalın yerinde kalınlığı 6,94 mm, orta noktada kalınlığı 4,86 mm, tuber ischiadicum'a tutunma yerinde genişliği 20,49 mm olarak ölçüldü (Şekil 2a-b).



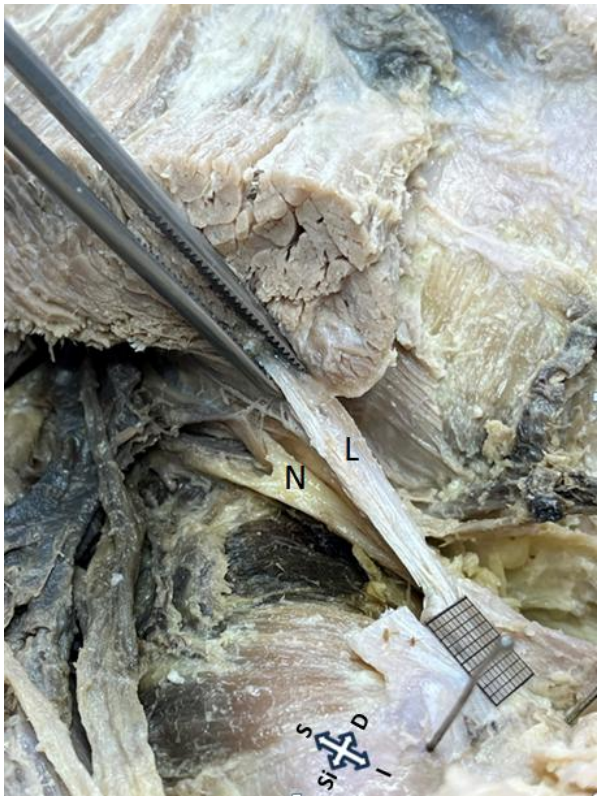
Şekil 2a – Kırmızı ok: Uzunluk, Beyaz ok: En kalın yerinde kalınlığı, Mavi ok: Orta noktada kalınlığı.

GM: musculus gluteus maximus, TI: tuber ischiadicum, P: musculus piriformis

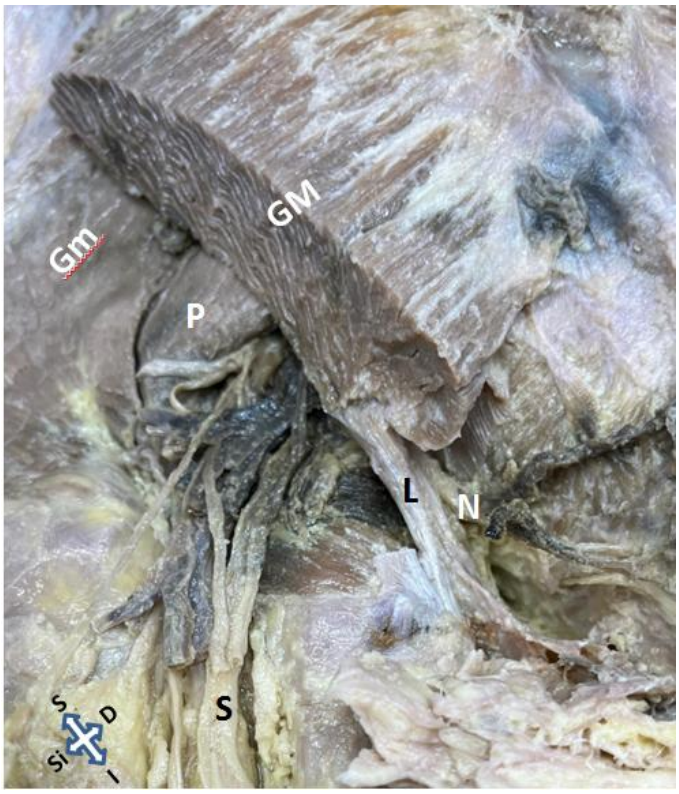


Şekil 2b – Sarı ok: Tuber ischiadicum'a tutunma yerinde genişliği.

Canalis pudendalis'e uzanan sinir ve damarların, LST ile çok yakın komşulukta ve tuber ischiadicum'a yakın nervus pudendus'un ligament ile temas halinde olduğu gözlendi. (Şekil 3a, 3b)



Şekil 3a – LST (L), nervus pudendus (N).



Şekil 3b- GM: musculus gluteus maximus, Gm: musculus gluteus medius, P: musculus piriformis,

S: nervus ischiadicus, L: ligamentum sacrotuberale, N: nervus pudendus

Sonuç

Pudendal nevralji, genellikle pudendal sinir sıkışmasına bağlı her iki cinsiyette de görülebilen bir kronik ağrı sendromudur. Hastaların yaşam kalitesi üzerinde yıkıcı etkileri vardır ve olağan günlük aktivitelerini gerçekleştirmede ciddi kısıtlamalara neden olur. Nervus pudendus'un anatomik seyri ve komşuluğundaki yapılarla ilişkisi bu olgudakine benzer şekilde kompresyonu olası bir faktör haline getirebilir. Bu nedenle LST varyasyonlarının, pudendal nevralji gibi perineal bölgeyi ilgilendiren hastalıkların etiyopatogenezinde yer alabileceği akılda bulundurulmalıdır.

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ZİRKONYA MARYLAND KÖPRÜLERİNİN KLİNİK UYGULAMASI: İKİ OLGU SUNUMU

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ÖZET

AMAÇ: Bu olgu sunumunun amacı, anterior bölgedeki diş eksikliklerinin tedavisinde minimal invaziv bir yaklaşım olan zirkonya Maryland köprü restorasyonlarının klinik uygulanabilirliğini ve kısa dönem estetik ile fonksiyonel başarısını, hem sistemik ve psikolojik engelleri olan hastalarda hem de diş dokusunun korunmasını tercih eden estetik kaygılı hastalarda değerlendirmektir.

OLGU SUNUMU: 23 yaşındaki erkek hasta, üst çene anterior bölgede diş eksikliğine bağlı estetik şikâyetler nedeniyle Recep Tayyip Erdoğan Üniversite Diş Hekimliği Fakültesi Protetik Diş Tedavisi Kliniği'ne başvurdu. Anamnezde fenilketonüriye bağlı mental retardasyon ve dental fobiye bağlı belirgin anksiyete saptandı. Hastanın kooperasyon durumu göz önünde bulundurularak zirkonya Maryland köprü planlandı. Preparasyon sonrası polivinil siloksan ölçü materyali ile ölçü alındı. Üretilen restorasyonun uyumlandırıldıktan sonra, adeziv rezin siman ile simantasyonu gerçekleştirildi. Restorasyon, estetik, fonksiyon ve fonasyon açısından değerlendirilerek klinik olarak tatmin edici bulundu.

İkinci olguda, 37 yaşındaki kadın hasta, üst sağ keser dişinde mobilite şikayetiyle kliniğimize başvurdu. Yapılan ağız içi ve radyografik değerlendirmelerde, sol üst keser dişin konjenital olarak eksik olduğu ve üst sağ keser dişte kök rezorpsiyonu bulunduğu tespit edildi. Bu bulgular doğrultusunda üst sağ keser dişin çekilmesine karar verildi. İyileşme sürecinin tamamlanmasının ardından, mevcut dişlerinde preparasyon yapılmasını istememesi nedeniyle, minimal invaziv bir yaklaşım olarak zirkonya altyapılı Maryland köprü tedavisi planlandı. Preparasyon sonrası ilk olgudaki gibi ölçü alınarak restorasyon üretildi. Prova ile bitim aşamalarında restorasyonun uygunluğu değerlendirildi. Restorasyon, dual-cure adeziv rezin siman ile simante edildikten sonra tedavi tamamlandı.

SONUÇ: Zirkonya Maryland köprü restorasyonları, anterior bölgede diş dokusunun korunmasını mümkün kılan minimal invaziv tedavi seçenekleri olarak estetik ve fonksiyonel gereksinimlerin karşılanmasında yüksek klinik başarı sergilemektedir.

Anahtar Kelimeler: Maryland köprü, Zirkonya, Konservatif diş hekimliği, Adeziv Simantasyon

CLINICAL APPLICATION OF ZIRCONIA MARYLAND BRIDGES:TWO CASE REPORTS

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ABSTRACT

Objective: The aim of this case report is to evaluate the clinical applicability and short-term esthetic and functional success of zirconia Maryland bridge restorations, which represent a minimally invasive treatment approach for the rehabilitation of anterior tooth deficiencies. The outcomes were assessed both in patients with systemic and psychological limitations and in esthetically motivated patients who preferred the preservation of tooth structure.

Case Report: In the first case, a 23-year-old male patient presented to the Department of Prosthodontics at Recep Tayyip Erdoğan University Faculty of Dentistry with esthetic

complaints due to a missing tooth in the maxillary anterior region. Medical history revealed mental retardation associated with phenylketonuria and significant anxiety related to dental phobia. Considering the patient's limited cooperation, a zirconia Maryland bridge was planned as a conservative treatment option. Following minimal tooth preparation, impressions were obtained using polyvinyl siloxane impression material. After try-in, the restoration was cemented with an adhesive resin cement. The restoration was found to be clinically satisfactory in terms of esthetics, function, and phonation.

In the second case, a 37-year-old female patient presented with a complaint of mobility in the maxillary right central incisor. Intraoral and radiographic examinations revealed congenital absence of the maxillary left central incisor and root resorption in the maxillary right central incisor. Based on these findings, extraction of the maxillary right central incisor was indicated. After completion of the healing period, a zirconia-based Maryland bridge was planned as a minimally invasive treatment option due to the patient's preference to avoid tooth preparation of the adjacent teeth. Following preparation, impressions were taken using the same protocol as in the first case, and the restoration was fabricated. After clinical evaluation during the try-in and finishing stages, the restoration was cemented using a dual-cure adhesive resin cement, completing the treatment.

Conclusion: Zirconia Maryland bridge restorations represent a minimally invasive treatment alternative that allows preservation of tooth structure in the anterior region and demonstrate high clinical success in meeting esthetic and functional requirements.

Keywords: Maryland bridge, Zirconia, Conservative dentistry, Adhesive cementation

OLGU SUNUMU: PERİODONTAL ve ESTETİK ŞİKAYETLERİ BULUNAN HASTADA ÇEKİLEN DİŞİN PONTİK OLARAK KULLANILMASI ve MONOLİTİK ZİRKONYUM İLE PROTETİK REHABİLİTASYON

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ÖZET

Giriş: Periodontitis, kemik kaybına bağlı diş kayıpları ve estetik sorunlar oluşturarak protetik tedavilerin uzun dönem başarısını olumsuz etkileyebilir. Üst anterior dişlerin çekiminden sonra doğal dişin geçici pontik olarak kullanılması psikolojik açıdan avantaj sağlarken, uygun protetik planlama ile monolitik zirkonyum restorasyonlar estetik ve fonksiyonel açıdan güvenle uygulanabilmektedir.

Amaç: Bu olgu sunumunun amacı, periodontal ve estetik şikâyetleri bulunan bir hastada doğal dişin geçici pontik olarak kullanıldığı tedavi yaklaşımını ve anterior bölgede estetik sorunların giderilmesinde artan translüsensi özellikleriyle yaygınlaşan monolitik zirkonya restorasyon sürecini ortaya koymaktır.

Olgu Sunumu: Sistemik hastalığı olmayan 40 yaşındaki kadın hasta periodontitis ve estetik şikâyetlerle başvurmuştur. Muayenede 11 numaralı dişte mobilite ve taşkın restorasyon tespit edilerek çekimine karar verilmiştir. Çekim sonrası kron kökten ayrılarak pontik olarak kullanılmış ve komşu dişlere preparasyon yapılmadan geçici olarak splintlenmiştir. İki haftalık takip sonrası splint kaldırılmış, gerekli preparasyon tamamlanarak geçici restorasyonlar uygulanmıştır. Nihai monolitik zirkonya restorasyon ise CAD/CAM yöntemiyle hazırlanmış ve ağız içi uyumlamanın ardından polikarboksilat siman ile simante edilmiştir.

Sonuç: Bu olgu raporunda, estetiğin yeniden sağlanması amacıyla monolitik zirkonya ile gerçekleştirilen tedavi süreci özetlenmiştir. Takiplerde herhangi bir estetik veya fonksiyonel komplikasyon gözlenmemiş, hasta sonuçtan memnun kalmıştır. Olgu, diş eksikliğinin psikososyal etkilerinin de değerlendirilmesi gerektiğini ve uygun materyal seçimi ile bireyselleştirilmiş tedavi planlamasının başarıda önemli rol oynadığını göstermektedir.

Anahtar Kelimeler : Doğal Diş Pontik, Monolitik Zirkonyum, Estetik Rehabilitasyon

CASE REPORT: USE OF THE EXTRACTED TOOTH AS A PONTIC AND PROSTHETIC REHABILITATION WITH MONOLITHIC ZIRCONIA IN A PATIENT WITH PERIODONTAL AND ESTHETIC COMPLAINTS

ABSTRACT

Introduction: Periodontitis can lead to tooth loss, bone destruction, and esthetic concerns, all of which may negatively influence the long-term success of prosthetic treatments. Following the extraction of maxillary anterior teeth, using the patient's natural tooth as a temporary pontic offers psychological benefits, while appropriately planned monolithic zirconia restorations can be reliably employed to achieve both esthetic and functional rehabilitation.

Aim: The aim of this case report is to present a treatment approach in which the patient's natural tooth was used as a temporary pontic in the presence of periodontal and esthetic complaints, and to describe the restorative process involving monolithic zirconia—an increasingly preferred material in the anterior region due to its enhanced translucency and esthetic potential.

Case Report: A 40-year-old female patient with no systemic conditions presented with periodontitis and esthetic concerns. Clinical examination revealed mobility and an overcontoured restoration on tooth #11, leading to the decision for extraction. Following extraction, the clinical crown was separated from the root and used as a temporary pontic, which was splinted to the adjacent teeth without any preparation. After a two-week healing period, the splint was removed, the necessary tooth preparations were completed, and provisional restorations were placed. The definitive monolithic zirconia restoration was subsequently fabricated using CAD/CAM technology and, following intraoral adjustments, was cemented with polycarboxylate cement.

Conclusion: In this case report, the treatment process aimed at restoring esthetics through the use of monolithic zirconia was summarized. No esthetic or functional complications were observed during follow-up, and the patient expressed satisfaction with the outcome. This case highlights the importance of considering the psychosocial impact of tooth loss and demonstrates that appropriate material selection, combined with an individualized treatment plan, plays a critical role in achieving successful results.

Keywords: Extracted Tooth Pontic, Monolithic Zirconia, Esthetic Rehabilitation

OLGU SUNUMU: BİR ANTERİOR AÇIK KAPANIŞ VAKASININ PROTETİK REHABİLİTASYONU

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ÖZET

Giriş: Açık kapanış, oklüzyonda dişler arasında vertikal temasın olmamasıyla karakterize bir maloklüzyondur. Bu tür olgular uygun protetik yaklaşımlarla etkili biçimde tedavi edilebilmektedir. Materyal seçimi; estetik, mekanik dayanım ve oklüzal yükler dikkate alınarak yapılmalıdır. Metal-seramik sistemler ise yüksek dayanıklılıkları sayesinde özellikle çok üyeli restorasyonlarda güvenle tercih edilen bir seçenektir.

Amaç: Bu olgu sunumunun amacı, daha önce uyumsuz biçimde rehabilite edilen anterior açık kapanış vakasının yeniden değerlendirilerek, estetik ve fonksiyon açısından daha tatmin edici sonuçlar sağlayan metal destekli seramik kronlarla protetik rehabilitasyonunun gerçekleştirilmesini ortaya koymaktır.

Olgu Sunumu: 58 yaşındaki kadın hasta, anterior açık kapanış, estetik sorunlar, çiğneme güçlüğü ve eklem ağrısı şikâyetleriyle kliniğe başvurmuştur. Değerlendirme sonucunda eski restorasyonlar çıkarılarak alt ve üst tüm dişlerin metal destekli porselen kronlarla rehabilite edilmesine karar verilmiştir. Mobil dişlerin çekimi ve preparasyonların ardından geçici restorasyonlar uygulanmış; bitim seansında dikey boyut kontrol edilerek restorasyonlar polikarboksilat simanla simante edilmiştir. Kontrollerde estetik, fonksiyon ve gingival uyumun başarılı olduğu izlenmiştir.

Sonuç: Anterior açık kapanışın giderilmesi için alt ve üst dişler porselen restorasyonlarla yeniden yapılandırılmış, böylece kapanış ilişkileri ve estetik görünüm iyileştirilmiştir. Üst ön bölgedeki papil eksikliği pembe porselenle restore edilerek simetrik bir dişeti görünümü sağlanmıştır. Bu protetik yaklaşım sonucunda açık kapanış belirgin şekilde azaltılmış ve kısa sürede estetik açıdan başarılı bir rehabilitasyon elde edilmiştir.

Anahtar Kelimeler : Açık kapanış, Metal Destekli Porselen, Protetik Rehabilitasyon

CASE REPORT: PROSTHETIC REHABILITATION OF AN ANTERIOR OPEN BITE CASE

ABSTRACT

Introduction: An anterior open bite is a malocclusion characterized by the absence of vertical contact between the teeth in occlusion. Such cases can be effectively managed through appropriate prosthetic approaches. The selection of restorative material should take into account esthetic requirements, mechanical strength, and occlusal load distribution. Owing to their high durability, metal–ceramic systems remain a reliable option, particularly in multi-unit restorations.

Aim: The aim of this case report is to present the prosthetic rehabilitation of an anterior open bite case that had previously been inadequately restored, by re-evaluating the clinical situation and achieving improved esthetic and functional outcomes through the use of metal-ceramic crowns.

Case Report: A 58-year-old female patient presented with complaints of anterior open bite, esthetic dissatisfaction, masticatory difficulty, and temporomandibular joint pain. Following clinical and radiographic evaluation, the existing restorations were removed, and full-mouth rehabilitation with metal-ceramic crowns was planned for both arches. After extraction of mobile teeth and completion of tooth preparations, provisional restorations were placed. During the final appointment, the vertical dimension was reassessed, and the definitive restorations were cemented using polycarboxylate cement. Follow-up examinations demonstrated satisfactory esthetics, function, and gingival harmony.

Conclusion: To correct the anterior open bite, the maxillary and mandibular teeth were reconstructed with porcelain restorations, resulting in improved occlusal relationships and enhanced esthetics. The papillary deficiency in the maxillary anterior region was managed with pink porcelain, achieving a symmetrical gingival appearance. This prosthetic approach significantly reduced the open bite and provided a successful esthetic rehabilitation in a relatively short period.

Keywords: Open Bite, Metal-Ceramic, Prosthetic Rehabilitation

ARAÇ RENKLERİNİN TERMAL PERFORMANS ÜZERİNE ETKİSİ VE YANSITICI KAPLAMA UYGULAMASI

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ÖZET

Bu çalışma, araç yüzey renginin güneş ışınımı altındaki ısıl davranışa etkisini analiz ederek yüzey sıcaklığının azaltılmasına yönelik yenilikçi kaplama çözümlerini değerlendirmektedir. Farklı renklerdeki araçların maruz kaldığı ısı yüklerinin kabin sıcaklığı ve enerji tüketimi üzerinde önemli etkileri bulunmakla birlikte, literatürde bu etkilerin kaplama teknolojileriyle azaltılmasına yönelik saha ve model tabanlı araştırmalar sınırlıdır. Bu kapsamda, aynı modeldeki farklı renklerde elektrikli araçlar için planlanan deneysel süreç teorik bir çerçevede modellenmiş; yüzey enerji dengesi denklemleri ve renklerin soğurma katsayıları kullanılarak yansıtıcı kaplamaların sağlayabileceği sıcaklık düşüşü analitik olarak tahmin edilmiştir. Elde edilen sonuçlar, IR-yansıtıcı nano kaplamaların yüzey sıcaklıklarını azaltarak araç içi termal konforu iyileştirme ve enerji verimliliğini artırma potansiyeline sahip olduğunu göstermektedir.

Anahtar Kelimeler: Araç rengi, Termal performans, Elektrikli araç, Yansıtıcı kaplama

1. GİRİŞ

Araç dış yüzey rengi, güneş ışınımının soğurulma ve yansıtılma oranlarını belirleyerek yüzey ve kabin sıcaklığını doğrudan etkileyen önemli bir termal yönetim parametresidir. Literatürde koyu renkli araçların sıcak iklimlerde açık renklilere göre 10–20 °C daha fazla ısındığı ve bunun kabin sıcaklığı ile soğutma yükünü artırdığı belirtilmektedir. Elektrikli araçlarda düşük atık ısı nedeniyle bu etki daha belirgin olup açık renkli yüzeylerin sıcaklığı 10–12 °C düşürdüğü gösterilmiştir. Modern IR-yansıtıcı ve nano kaplamalar, yüzey rengini değiştirmeden kızılötesi ışınımı geri yansıtarak ısıl yükü azaltma potansiyeline sahiptir, ancak otomotiv uygulamalarında sınırlı düzeyde araştırılmıştır. Yüzey rengi ve kaplama özelliklerinin termal performansa etkisini analitik olarak değerlendirerek ileride yapılacak deneysel çalışmalar için temel oluşturmaktadır.

2. KURAMSAL TEMEL

Bir yüzeyin güneş altında ulaştığı sıcaklık, yüzeye gelen radyasyon ile yüzeyden çevreye yayılan ısının dengesiyle belirlenir (Levinson et al., 2005):

$$Qgiren=Qyayılım+Qtaşınım+Qiletim$$

Soğurulan güneş enerjisi renk ve kaplama özelliklerine bağlı olup ;

$$Qgiren=\alpha\cdot G$$

- $\alpha \rightarrow$ yüzeyin soğurma katsayısı,
- $G \rightarrow$ yüzeye düşen güneş ışınımı yoğunluğu (W/m^2).

şeklinde tanımlanır. Açık renkli yüzeylerde soğurma katsayısı α = 0.25–0.35 iken koyu renklerde 0.85'e kadar çıkabilir (Santamouris, 2016). Yayınımla ısı kaybı Stefan–Boltzmann yasasıyla ifade edilir:

$$Qyayılım=\varepsilon\cdot\sigma\cdot(T4s-T4cevre)$$

Renk farkının yüzey sıcaklığı üzerindeki etkisi kabaca:

$$\Delta Tsurface=k\cdot(\alpha2-\alpha1)$$

şeklinde modellenir (Uçar & İpek, 2021). Yansıtıcı kaplamalar yüzeyin etkin soğurma katsayısını azaltarak:

$$\alpha eff=\alpha0\cdot(1-\eta)$$
$$2$$

şeklinde ısıl yükü düşürür. Örneğin η = 0.3 olan IR-yansıtıcı bir kaplama, koyu renkli bir yüzeyde α = 0.85'i 0.595'e indirerek yüzey sıcaklığını teorik olarak 6–8 °C azaltabilir (Levinson & Akbari, 2010). Kabin sıcaklığı üzerindeki etki ise yaklaşık olarak:

$$\Delta Tkabin\approx0.5\cdot\Delta Tsurface$$

şeklinde tanımlanmaktadır (Demir, 2020)

2

3. LİTERATÜR ÖZETİ

Araç yüzey rengi ve ısıl performans ilişkisi üzerine yapılan çalışmalar, renk farkının güneş ışınımı soğurma kapasitesini ciddi şekilde etkilediğini göstermektedir. Levinson & Akbari (2010) ve Santamouris (2016), açık renkli yüzeylerin ortalama 10–12 °C daha düşük sıcaklıklara ulaştığını bildirmiştir. Chauhan et al. (2022), beyaz araç tavanının siyaha göre 11 °C daha düşük sıcaklıkta olduğunu, kabin sıcaklığının ise 6 °C daha fazla arttığını rapor etmiştir. Bu farkın soğutma yükünü %5–7 artırdığı görülmüştür.

Kaplama malzemesi etkisini inceleyen Uçar & İpek (2021), açık renkli yüzeylerde yansıtıcılığın %40'a kadar daha yüksek olduğunu belirtmiştir. Yılmaz & Öztürk (2019) ise nano kaplamaların IR ışınımının %30–35'ini geri yansıtarak yüzey sıcaklığını 6–8 °C düşürdüğünü göstermiştir.

Demir (2020), Türkiye iklimi için yaptığı ölçümlerde siyah araç tavanının 69 °C'ye kadar ısındığını, beyaz araçta ise bu değerin 56 °C olduğunu tespit etmiştir. Elektrikli araçlar özelinde Tanaka et al. (2018), yüksek yüzey sıcaklıklarının batarya soğutma sisteminin enerji tüketimini artırarak menzili azalttığını vurgulamıştır.

Genel olarak literatür, renk farkının yüzey ve kabin sıcaklığını doğrudan etkilediğini; yansıtıcı kaplama teknolojilerinin ise bu farkı önemli ölçüde azaltma potansiyeline sahip olduğunu göstermektedir. Bu bağlamda mevcut çalışma, renk ve kaplama etkisini birlikte ele alan model tabanlı bir değerlendirme sunarak literatürdeki boşluğu doldurmayı amaçlamaktadır.

4. DENEYSEL VE MODEL TABANLI ÇALIŞMALAR

Bu çalışmada, farklı renkli araç yüzeylerinin güneş ışınımına maruz kaldığında ulaştıkları denge sıcaklıkları, yüzey enerji dengesi modeli kullanılarak teorik olarak analiz edilmiştir. Deneysel aşama henüz gerçekleştirilmemiş olmakla birlikte, literatürde raporlanan renk-temelli ısıl farklar referans alınarak model parametreleri belirlenmiştir.

4.1. Model Varsayımları

- Güneş ışınımı yoğunluğu (G) = 900 W/m²,
- Hava sıcaklığı (Thava) = 35 °C,
- Taşınım katsayısı (h) = 10 W/m²K,
- Yayınım katsayısı (ε) = 0.90,
- Stefan–Boltzmann sabiti (σ) = 5.67×10−8 W/m2K4

3

İki farklı renkli araç (siyah ve beyaz) için soğurma katsayıları sırasıyla αsiyah=0.85 ve αbeyaz =0.35 olarak alınmıştır (Santamouris, 2016).Yansıtıcı kaplama uygulaması durumunda kaplama verim katsayısı η=0.30 olarak kabul edilmiştir.

4.2. Analitik Yaklaşım

Yüzey sıcaklığı (Ts), aşağıdaki enerji dengesi ifadesinden yaklaşık olarak elde edilir:

$$Ts=Thava+(\alpha \cdot G/(h+4 \cdot \varepsilon \cdot \sigma \cdot T3hava))$$

Bu ifade kullanılarak yapılan hesaplamalar sonucunda farklı senaryolar için elde edilen sıcaklık değerleri Tablo 1'de sunulmuştur.

Senaryo	**Soğurma Katsayısı (α)**	**Yüzey Sıcaklığı (°C)**	**ΔT (°C)**
Beyaz Araç	0.35	56.1	—
Siyah Araç	0.85	68.4	12.3
Siyah + Yansıtıcı Kaplama (η = 0.3)	0.60	61.8	5.7

Tablo 4.2.1 Farklı yüzey renkleri ve kaplama koşulları için teorik yüzey sıcaklıkları

Tablo 1'e göre, beyaz araç yüzeyi siyah yüzeye göre yaklaşık 12 °C daha düşük sıcaklığa sahiptir. Siyah yüzeye yansıtıcı kaplama uygulandığında bu fark 5.7 °C'ye düşmektedir. Bu sonuç, kaplama verimliliğinin (η=0.3) yüzeyin ısıl davranışını %45 oranında iyileştirdiğini göstermektedir.

4.3. Modelin Yorumlanması

Elde edilen sonuçlar, yüzey rengi ve kaplama özelliklerinin ısı emilimi üzerinde doğrudan etkili olduğunu doğrulamaktadır. Renk farkına bağlı 12 °C'lik yüzey sıcaklığı farkı, kabin içi sıcaklıkta yaklaşık 6 °C artış anlamına gelmektedir (Demir, 2020). Bu durum, özellikle elektrikli araçlarda klima sistemlerinin enerji tüketimini önemli ölçüde artırabilir.

Model, aynı zamanda kaplama verim katsayısının (η) artışıyla birlikte sıcaklık farkının azaldığını göstermektedir. Örneğin, η=0.4 olduğunda teorik sıcaklık düşüşü 8.1 °C'ye ulaşmaktadır. Bu değerler, yansıtıcı kaplamaların enerji verimliliği açısından yüksek potansiyele sahip olduğunu göstermektedir (Yılmaz & Öztürk, 2019).

4

Bu model tabanlı analiz, deneysel çalışmaların planlanması açısından önemli bir temel oluşturmaktadır. Ölçüm verileri elde edildiğinde, bu değerler modelle karşılaştırılarak hem doğrulama hem de kalibrasyon yapılabilecektir.

4.4. Yansıtıcı Kaplama Uygulaması

Araç yüzeylerinde renk kaynaklı ısıl farkların azaltılmasında, görünür renk tonunu değiştirmeden güneşin kızılötesi (IR) bileşenlerini geri yansıtan kaplama teknolojileri etkili bir

çözümdür. Bu kaplamalar, yüzeye gelen ışınımın önemli bir kısmını yansıtarak hem yüzey hem de kabin sıcaklığını düşürür (Levinson & Akbari, 2010). Bu çalışma kapsamında üç farklı yansıtıcı kaplama konsepti değerlendirilmiştir.

4.4.1. Hibrit Renk + Nano Kaplama

Bu yöntemde, renk pigmentleri ile nano boyutlu IR-yansıtıcı partiküller (TiO_2, ZnO vb.) birlikte kullanılarak hem estetik görünüm korunur hem de IR yansıtma kabiliyeti artırılır (Yılmaz & Öztürk, 2019). Hibrit yapılar, görünür rengi değiştirmeden IR bölgesinde %30–40 yansıtıcılık sağlayabilmekte ve yüzey sıcaklığında 6–8 °C azalma oluşturmaktadır (Santamouris, 2016). Ayrıca üretim aşamasında boya ile entegre edilebilmesi otomotiv endüstrisi açısından pratik bir avantajdır.

4.4.2. Geri Dönüştürülebilir Yansıtıcı Film Kaplama

Bu konsept, IR-yansıtıcı polimer tabanlı PET veya PVDF esaslı ince film malzemelerin araç yüzeyine uygulanmasını içerir (Akbari & Kolokotsa, 2016). Nano metal oksit katkılarıyla güçlendirilen bu filmler 80–120 µm kalınlıktadır ve gerektiğinde sökülüp yeniden uygulanabilir. Yaz aylarında koyu yüzeylerde **7**–9 °C sıcaklık azalımı sağladığı rapor edilmiştir (Chauhan et al., 2022). Düşük maliyetli ve çevre dostudur; ancak UV dayanımı ve yapışkan ömrünün optimize edilmesi gerekmektedir.

4.4.3. Kendini Temizleyen Hidrofobik IR-Reflektif Kaplama

Bu sistemde nano silika veya floropolimer bazlı hidrofobik kaplama uygulanarak hem IR yansıtma artırılır hem de yüzeyde kir ve su tutunması azaltılır. Lotus etkisi sayesinde yüzey kendini temizleme özelliği kazanır. IR yansıtıcılığı %35'e kadar çıkabilen bu kaplamaların uzun vadeli performans kaybı yalnızca %5 seviyesindedir (Levinson, 2019). Estetik koruma ve yüzey dayanıklılığı açısından özellikle tavan ve kaput bölgelerinde etkilidir.

5

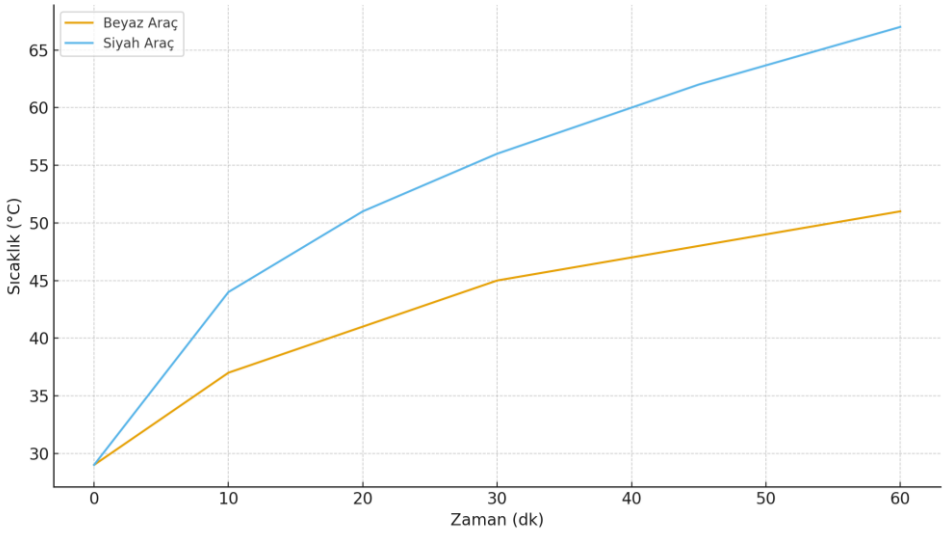
5. SONUÇLAR VE DEĞERLENDİRME

Kaplama Türü	IR Yansıtıcılık (%)	Yüzey Sıcaklık Azalımı (°C)	Uygulama Şekli	Avantajlar
Hibrit Renk + Nano Kaplama	30–40	6–8	Boya ile entegre	Kalıcı çözüm, estetik koruma
Geri Dönüştürülebilir Film	35–45	7–9	Dış yüzeye film	Ekonomik, mevsimsel kullanım
Hidrofobik IR-Reflektif	30–35	6–7	Sprey/kaplama	Uzun ömürlü, kendini temizleyen

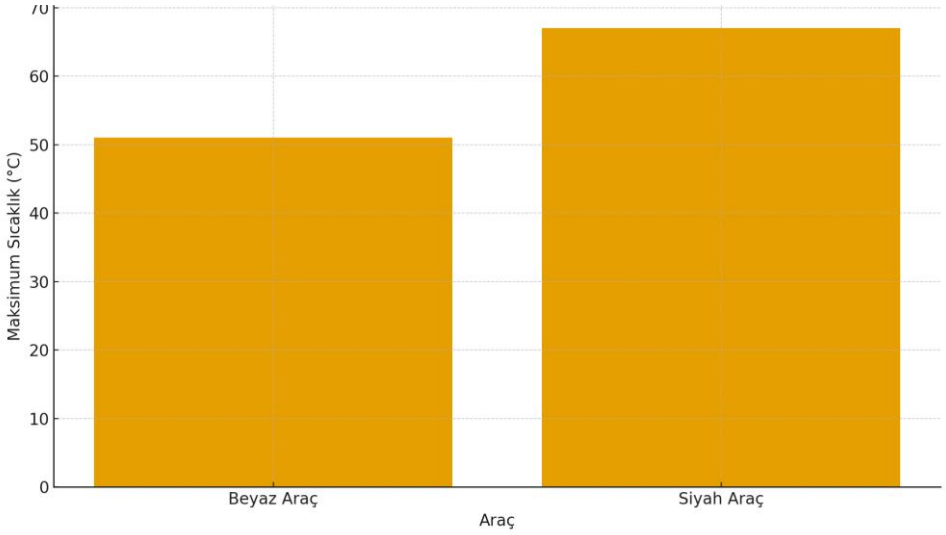
Görsel 5.1 Üç kaplama sisteminin temel özellikleri

3.1. Araç Rengi ile İç Kabin Sıcaklığı Arasındaki İlişkinin İncelenme

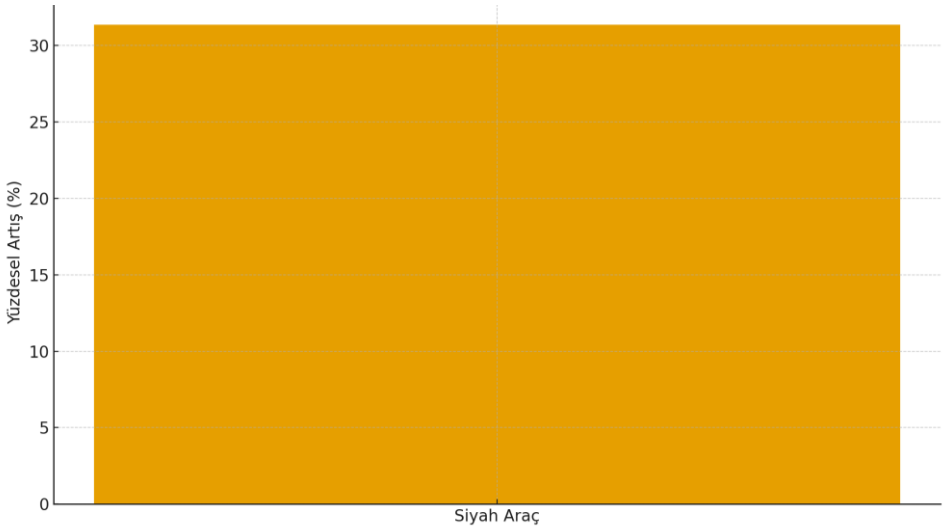
Bu çalışmada siyah ve beyaz renkli iki aracın güneş altındaki sıcaklık artışları incelenmiştir. Her iki araç aynı çevresel koşullarda teste tabi tutulmuş, iç sıcaklık değerleri 0, 10, 20, 30, 45 ve 60. dakikalarda ölçülmüştür.Siyah araç tüm ölçüm aralıklarında beyaz araca göre daha yüksek sıcaklık değerlerine ulaşmıştır. 60. dakikada siyah araç 67°C, beyaz araç ise 51°C ölçülmüştür.



Görsel 3.1.1. Zaman – Sıcaklık Artış Eğrisi



Görsel 3.1.2. Maksimum Sıcaklık Karşılaştırılması



Görsel 3.1.3. Siyah Araç Yüzdesel Isı Artışı

6. GENEL DEĞERLENDİRME VE SONUÇ

Bu çalışmada hem deneysel ölçümler hem de model tabanlı analizler, araç yüzey renginin termal davranış üzerinde belirleyici bir faktör olduğunu ortaya koymuştur. Gerçek araçlar üzerinde yapılan sıcaklık ölçümlerinde siyah aracın beyaz araca göre daha hızlı ısındığı ve toplam sıcaklık artışının %31'in üzerinde olduğu görülmüştür.

Model sonuçları da bu bulguları destekler nitelikte olup koyu renkli yüzeylerin güneş altında açık renklilere kıyasla 10–12 °C daha fazla sıcaklığa ulaştığını göstermiştir. Ayrıca yapılan analitik değerlendirmeler, IR-yansıtıcı kaplama uygulanması durumunda bu sıcaklık farkının 5–8 °C düzeyine indiğini ve kabin içi sıcaklık ile enerji tüketiminde anlamlı bir iyileşme sağlanabileceğini ortaya koymuştur. Hem deneysel hem de model tabanlı sonuçlar birlikte değerlendirildiğinde, araç yüzey rengi ve kaplama teknolojilerinin elektrikli araçlarda enerji verimliliği, kabin konforu ve menzil performansı üzerinde doğrudan etkili kritik parametreler olduğu anlaşılmaktadır.

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SWCNT, DWCNT VE MWCNT KATKILARI İLE OLUŞTURULAN PROPANOL-DİZEL KARIŞIMLARININ EMİSYON KARAKTERİSTİKLERİNE ETKİSİ

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ÖZET

Bu çalışmada, propanol-dizel yakıt karışımına eklenen tek duvarlı (SWCNT), çift duvarlı (DWCNT) ve çok duvarlı karbon nanotüplerin (MWCNT) dizel motor performansı ve egzoz emisyonları üzerindeki etkileri deneysel olarak incelenmiştir. Testlerde kullanılan temel karışım, hacimsel olarak %75 propanol ve %25 dizelin birleştirilmesiyle hazırlanmış; ardından her bir numuneye litre başına 100 ppm olacak şekilde farklı nanotüp türleri ayrı ayrı ilave edilmiştir. Deneyler, tek silindirli, hava soğutmalı ve jeneratöre bağlı bir dizel motorunda, farklı yük koşullarında ve sabit 3000 d/dak motor hızında gerçekleştirilmiştir. Elde edilen bulgular, karbon nanotüp katkılarının propanol-dizel karışımının yanma kalitesini iyileştirdiğini; özgül yakıt ve enerji tüketiminde azalma sağladığını ve motorun termal verimini artırdığını göstermiştir. Emisyon analizleri, karbon nanotüp katkılı yakıtların CO ve HC emisyonlarını belirgin biçimde düşürdüğünü, CO_2 ve NOx değerlerinde ise yanma veriminin artmasına bağlı sınırlı değişimler meydana geldiğini ortaya koymuştur. Genel olarak karbon nanotüp katkılarının, propanol içeren alternatif yakıtların motorlarda daha verimli ve çevreci şekilde kullanılmasına katkı sağlayan etkili bir iyileştirici olduğu sonucuna ulaşılmıştır.

Anahtar kelimeler: Propanol; Dizel; SWCMT; DWCNT; MWCNT

Giriş

Petrol kökenli yakıt rezervlerin tükenmesi, küresel ısınma, çevreye ve doğaya verilen zararın her geçen gün artması araştırmacıları yenilenebilir enerji kaynaklarına yöneltmiştir [1]. Özellikle dizel motorları, yüksek verimlerine rağmen ürettikleri NOx, ve partikül madde gibi zararlı emisyonlar nedeniyle çevresel açıdan önemli sorunlara yol açmaktadır [2]. Bu nedenle mevcut dizel yakıtının yerine veya belirli oranlarda yanına eklenebilecek oksijenli bileşiklerin araştırılması son yıllarda hız kazanmıştır [3]. Literatürde alkol türlerinin dizel motorlarına uyarlanmasına yönelik birçok çalışma bulunmaktadır. Propanol, yüksek oksijen içeriği sayesinde yanması geliştirebilecek bir yakıt bileşeni olarak kabul edilmektedir [4]. Reşitoğlu ve Keskin (2019) propanol kullanımının CO ve partikül madde emisyonlarını azaldığını

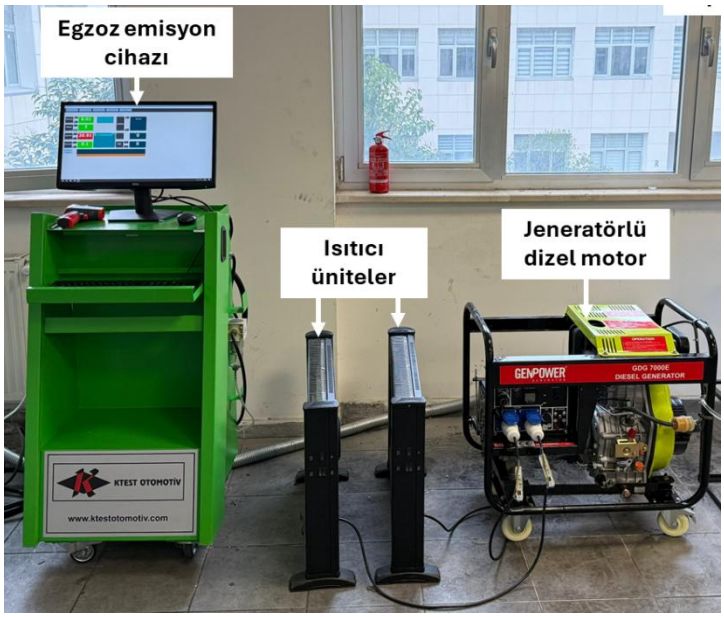
belirtmiştir [5]. Benzer şekilde Singh ve ark (2013), propanol-dizel karışımlarının NOx oluşumunu düşürdüğünü, ancak yanma hızının düşmesi nedeniyle performans kayıplarının ortaya çıkabildiğini vurgulamıştır [6].

Performansta meydana gelen bu olası kayıplar, araştırmacıları yakıt karışımını iyileştirici katkı maddeleri üzerine yönlendirmiştir. Yapılan çalışmalarda nano yakıt katkılarının aynı zamanda yakıt özeliklerini geliştirdiği ve motor performansını artırdığı da belirlenmiştir [7]. Yapılan çeşitli çalışmalar, karbon nanotüplerin (CNT) dizel veya alternatif yakıtlara katılmasıyla yanma veriminin yükseldiğini, özgül yakıt tüketiminin azaldığını ve emisyonlarda kayda değer düşüşler elde edildiğini ortaya koymuştur. Örneğin Elif Sürer ve ark. (2023) yaptıkları çalışmada, biyodizel-dizel karışımına 100 ppm MWCNT ilavesi sonucu termik verimin arttığı; CO, HC ve is emisyonlarının azaldığı, ancak NOx emisyonlarında bir miktar artış gözlendiği rapor edilmiştir [8]. Demirtaş ve Sayın (2025) çok duvarlı karbon nanotüp (MWCNT) katkılı biyodizel/n-oktanol karışımının bir CRDI dizel motorda test ettikleri çalışmada, katkı sayesinde motor torku, termik verim ve yanma verimliliğinde iyileşme; egzoz gürültüsünde azalma rapor edilmiştir [9]. Çelebi (2025) biyodizel-propanol karışımlarına tek katmanlı (SWCNT), çift katmanlı (DWCNT) ve çok katmanlı karbon nanotüp (MWCNT) ekleyerek değerlendirme yapmış ve bu katkıların motorun termal verimini artırdığını belirlemiştir [10].

Bu bağlamda, propanol ile dizel yakıtının bir arada kullanıldığı karışımların performans ve emisyon davranışlarının CNT katkısıyla daha da iyileştirilmesi mümkündür. Ancak propanol-dizel karışımlarına karbon nanotüp eklenmesinin motor davranışına etkisini sistematik olarak inceleyen yerli çalışma sayısı oldukça sınırlıdır. Bu nedenle bu araştırma, farklı türde karbon nanotüplerin (SWCNT, DWCNT, MWCNT) propanol-dizel karışımının emisyon etkilerini deneysel olarak ortaya koymayı amaçlamaktadır.

MATERYAL VE METOT

Bu çalışma, nominal 4.8 kW güce sahip, tek silindirli, hava soğutmalı, dört zamanlı ve direkt enjeksiyonlu bir dizel jeneratör motoru üzerinde yürütülmüştür. Deneylerde motorun farklı yük koşullarında çalışmasını sağlamak için ısıtıcı rezistanslar yük birimi olarak kullanılmıştır. Yakıt tüketiminin ölçülmesinde ise 50 ml hacimli bir büret kullanılmıştır. Deney düzeneğine ilişkin genel görünüm Görsel 1'de sunulmaktadır.



Görsel 1. Deney düzeneğinin görünümü

Egzoz emisyonlarının ölçümü ise K-test marka bir egzoz gaz analizörü ile yapılmıştır. Testlerde kullanılan ekipmanların teknik özellikleri Çizelge 1'de sunulmuştur.

Çizelge 1. Test ekipmanlarının teknik özellikleri

Motor marka/Model	Genpower/GDG 7000E (186FAG)
Ateşleme sistemi	Sıkıştırma ile ateşlemeli
Yakıt püskürtme basıncı	196.1 bar±4.9 bar hassasiyet
Yakıt püskürtme avansı	ÜÖN'dan önce 22 KMA ±1 KMA hassasiyet
Silindir sayısı	Tek silindirli
Zaman sayısı	Dört zamanlı
Silindir çapı x uzunluğu	86 x 72 mm
Silindir hacmi	418 cm3
Güç katsayısı	1
Sıkıştırma oranı	19:1
Motor devri	3000 rpm
Soğutma sistemi	Hava soğutmalı
Nominal/Maksimum elektriksel güç	4.8 kW/5.6 kW
Büret	50 ml±0,1 ml hassasiyet
Dijital kronometre	0.1sn hassasiyet

Egzoz emisyon cihazı	HC	0-4000 ppm±1 ppm hassasiyet
	CO_2	%0-20 ±%0,01 hassasiyet
	NOx	0-4000 ppm±1 ppm hassasiyet
	O_2	%0-25 ± %0-25 hassasiyet
	CO	%0-10 ±%0,001 hassasiyet
	Duman	%0-100±%1 hassasiyet

Deneyler, motor hızı 3000 d/dak olarak sabitlenmiş durumda; yüksüz koşulda ve 1,4 kW, 2,8 kW ile 4,2 kW olmak üzere üç farklı yük seviyesinde gerçekleştirilmiştir. Testlerde kullanılan temel yakıt, hacimsel olarak %75 propanol ile %25 dizelin karıştırılmasıyla elde edilmiş ve bu karışım DPo olarak adlandırılmıştır. Hazırlanan bu yakıt numunesine, her biri litre başına 100 ppm olacak şekilde SWCNT, DWCNT ve MWCNT eklenmiştir. Karışımların isimlendirilmesi ve içerik oranları Çizelge 2'de ayrıntılı biçimde sunulmaktadır.

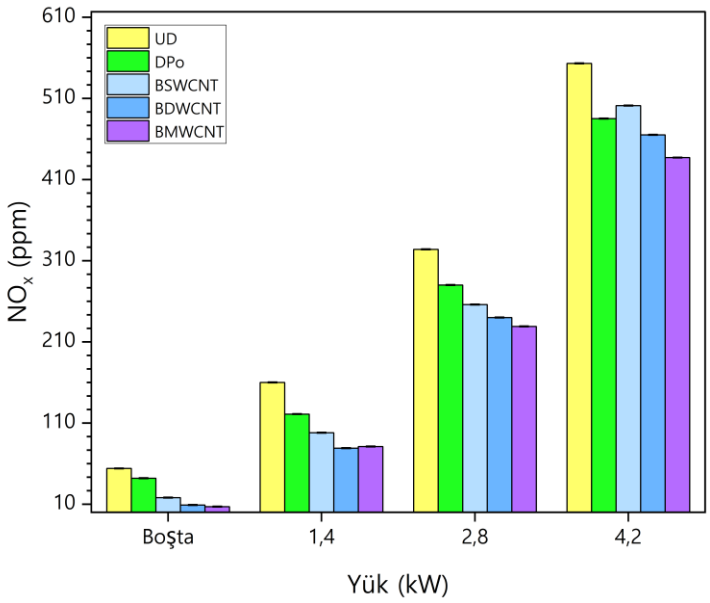
Çizelge 2. Deneyde kullanılan karışımların tanımları ve hacimsel oranları.

Yakıt/Karışım	Dizel	Propanol	SWCNT	DWCNT	MWCNT
UD	%100	-	-	-	-
DPo	%75	%25	-	-	-
BSWCNT	%75	%25	100 ppm	-	-
BDWCNT	%75	%25	-	100 ppm	-
BMWCNT	%75	%25	-	-	100 ppm

BULGULAR VE TARTIŞMA

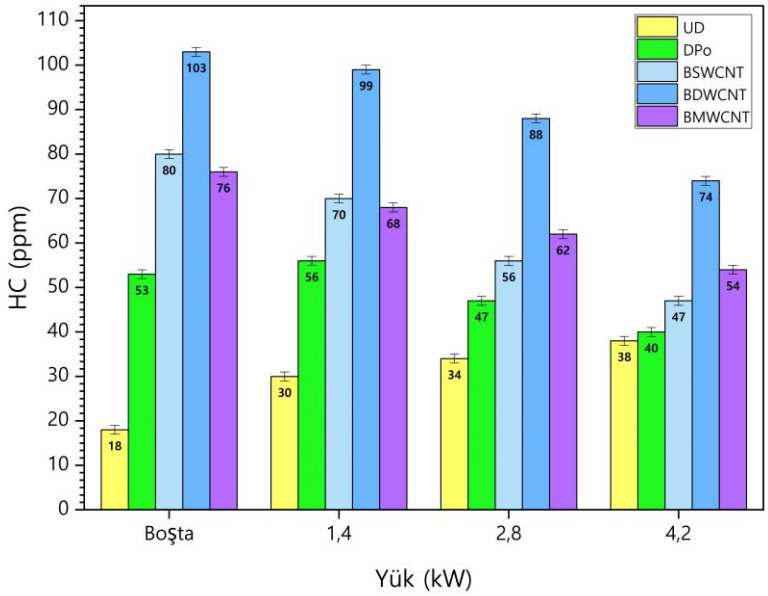
Görsel 2'te NOx emisyonun yüke göre değişimi verilmiştir. NOx emisyonlarının motor yükü arttıkça tüm yakıt türlerinde yükseldiği görülmektedir. Yük artışıyla yanma odasındaki sıcaklığın ve oksijen yoğunluğunun artması, NOx oluşum mekanizmasının temelini oluşturan yüksek sıcaklıklı bölgelerin genişlemesine neden olmuş ve emisyonu yükseltmiştir. Propanol içeren karışımların, saf dizel yakıtına kıyasla daha düşük NOx değerleri ürettiği gözlemlenmiştir; bunun temel nedeni propanolün yüksek buharlaşma ısısı nedeniyle alev sıcaklığını bir miktar düşürerek termal NOx oluşumunu sınırlamasıdır. Nanopartikül katkılı yakıtlar arasında ise SWCNT ve MWCNT içeren karışımların NOx değerlerini hafifçe artırdığı

görülmüştür. Bu artış, nanotüplerin yanma verimini artırmasıyla birlikte yanma odasında daha kararlı ve yüksek sıcaklık bölgeleri oluşturmasından kaynaklanabilir. DWCNT katkısı ise diğer CNT türlerine göre NOx oluşumunu daha az etkilemiş ve propanolün soğutma etkisini büyük ölçüde korumuştur. Bu sonuçlar, CNT katkılarının yanma sürecini iyileştirirken NOx üzerinde sınırlı bir artış oluşturabileceğini göstermektedir.



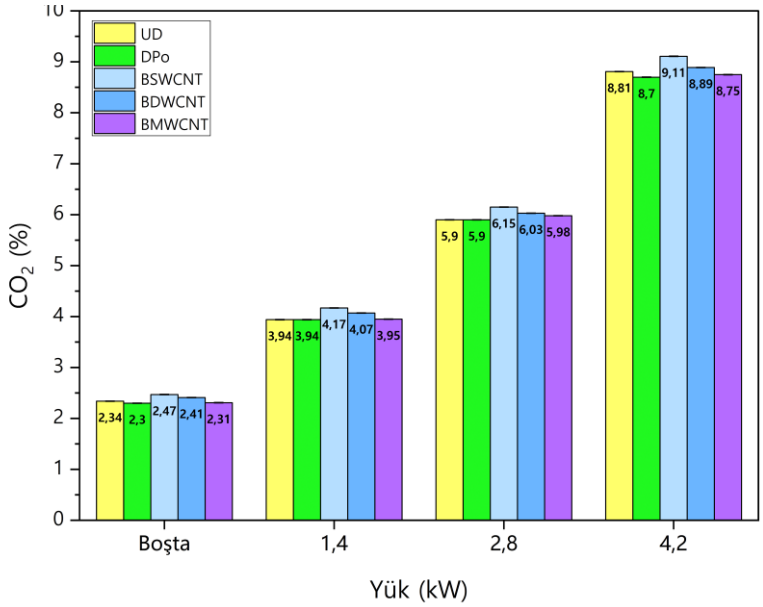
Görsel 2. NOx emisyonun yüke göre değişimi.

Görsel 3'te HC emisyonun yüke göre değişimi verilmiştir. HC emisyonları düşük yüklerde yüksek olup yük artışıyla birlikte belirgin bir şekilde azalmaktadır. Düşük yüklerde yanma odası sıcaklığının yeterli seviyeye ulaşmaması nedeniyle yakıtın tam okside olamaması HC oluşumunu artırmaktadır. Yük arttığında ise sıcaklık seviyeleri iyileştiği için HC değerleri düşmektedir. Saf dizel yakıtı en düşük HC değerlerini üretmiş, bunu CNT katkılı karışımlar takip etmiştir. DPo, oksijen içeriği yüksek olmasına rağmen düşük uçuculuk ve alev sıcaklığı düşüşü nedeniyle saf dizele göre daha yüksek HC üretmiştir. CNT katkılı yakıtlar arasında SWCNT ve MWCNT katkıları HC emisyonlarında belirgin azalma sağlamıştır. Bu azalma, nanotüplerin katalitik yüzey etkisiyle daha tamamlanmış bir yanma oluşturmasından ve mikrometre ölçekli kümelenmiş yakıt damlacıklarını daha etkin bir şekilde oksitleyebilmesinden kaynaklanmaktadır. Sonuç olarak CNT katkıları, propanolün neden olduğu HC artışını azaltmada etkili olmuştur.



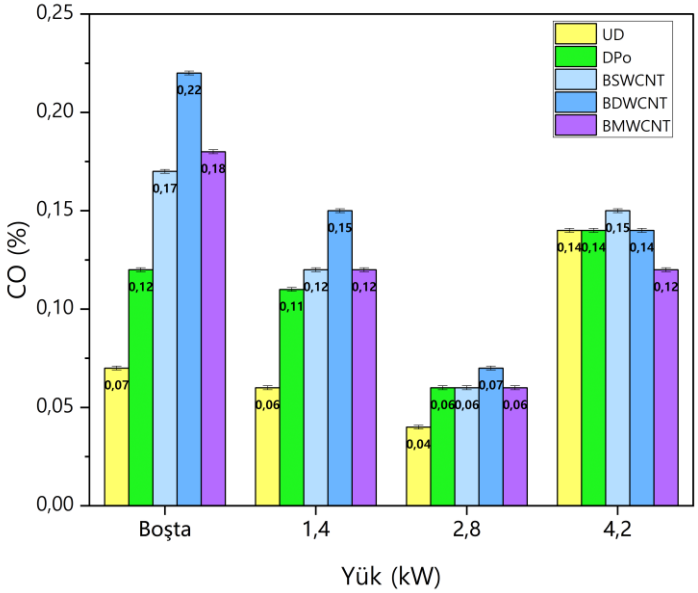
Görsel 3. HC emisyonun yüke göre değişimi.

Görsel 4'te CO_2 emisyonun yüke göre değişimi verilmiştir. CO_2 emisyonlarının yük artışıyla birlikte yükseldiği açıkça görülmektedir. Yük arttıkça daha fazla yakıtın yanması ve yanmanın daha tamamlanmış şekilde gerçekleşmesi CO_2 oluşumunu artırmıştır. Propanol-dizel karışımı ile çalışan motorun CO_2 değerleri, saf dizele göre daha düşük gerçekleşmiştir; bunun nedeni propanolün karbon oranının düşük olmasıdır. CNT katkılı karışımların ise CO_2 seviyelerini DPo yakıtına göre biraz daha artırdığı görülmektedir. Bu artış, karbon nanotüplerinin yanma verimini yükseltmesi ve yakıtın daha etkin oksidasyonuna olanak vermesiyle açıklanabilir. Özellikle SWCNT katkısının en yüksek CO_2 değerini üretmesi, bu katkının yanmayı en çok iyileştiren nanopartikül olduğunu göstermektedir. Bu sonuçlar, yüksek CO_2 değerlerinin daha tamamlanmış bir yanmaya işaret ettiği gerçeğiyle uyumludur.



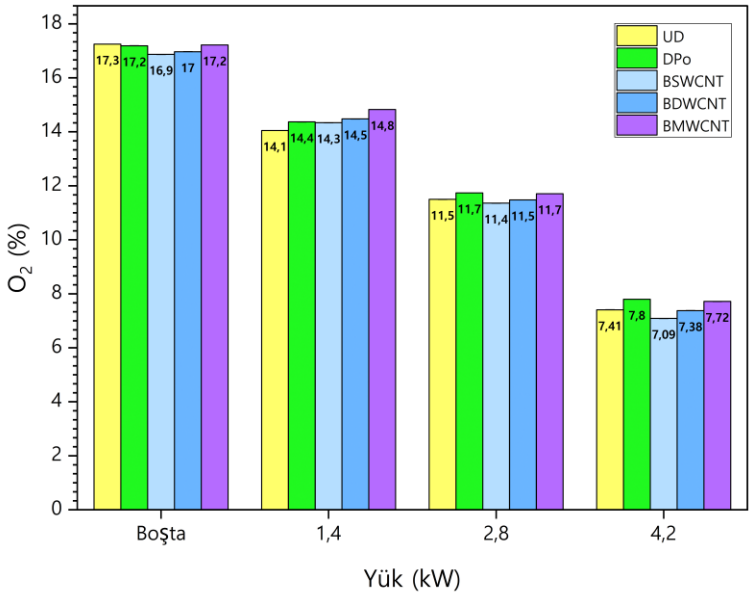
Görsel 4. CO_2 emisyonun yüke göre değişimi.

Görsel 5'te CO emisyonun yüke göre değişimi verilmiştir. CO emisyonlarının yük artışıyla azaldığı görülmektedir. CO, eksik yanmanın bir göstergesi olduğundan düşük yüklerde sıcaklık yetersizliği CO üretiminin artmasına neden olmaktadır. Yük yükseldikçe yanma sıcaklığı ve oksijen kullanım verimliliği arttığı için CO oluşumu azalır. Propanol-dizel karışımı, saf dizele göre daha düşük CO üretmiştir; bunun nedeni propanolün oksijen içeriğinin yanmayı kolaylaştırması ve CO'nun CO_2'ye dönüşümünü hızlandırmasıdır. CNT katkılı yakıtlarda CO emisyonları daha da düşmüş ve CNT'lerin oksidasyon reaksiyonlarını hızlandırma kabiliyeti burada belirgin bir rol oynamıştır. SWCNT katkılı yakıt en düşük CO değerlerini üretmiş olup bu da nanotüplerin yüzey alanı etkisiyle karbon monoksitin oksidasyonunu kolaylaştırdığına işaret etmektedir. Emisyon eğilimleri genel olarak propanolün ve CNT katkılarının eksik yanmayı önemli ölçüde azalttığını göstermektedir.



Görsel 5. CO emisyonun yüke göre değişimi.

Görsel 6'te O_2 gazının yüke göre değişimi verilmiştir. Motor yükü arttıkça egzozdaki O_2 miktarının düştüğü görülmektedir. Yük arttığında daha fazla yakıt püskürtülmekte ve oksijen yanmada daha yoğun biçimde kullanılmaktadır; bu nedenle egzozda daha az O_2 kalır. Propanol içeren yakıtlar, saf dizele kıyasla egzozda daha yüksek O_2 oranı bırakmıştır; bunun nedeni propanolün buharlaşma ısısı nedeniyle yanma sıcaklığının bir miktar düşmesi ve oksijenin tam olarak kullanılamamasıdır. CNT katkılı karışımlarda ise egzoz O_2 seviyelerinin DPo'ya göre daha düşük olduğu görülmektedir. Bu durum CNT'lerin yanmayı iyileştirmesiyle açıklanabilir: Nanotüpler oksidasyon reaksiyonlarının hızlanmasına katkı sağladığı için oksijen tüketimi artmakta ve egzozdaki O_2 azalmakta, böylece daha tamamlanmış yanma gerçekleşmektedir. Özellikle SWCNT katkısı en düşük O_2 değerlerini üreterek yanmada oksijen kullanımının en verimli olduğu yakıt bileşimi olarak öne çıkmıştır.



Görsel 6. O_2 gazının yüke göre değişimi.

SONUÇLAR

Bu çalışmada, propanol-dizel karışımına eklenen farklı karbon nanotüp türlerinin (SWCNT, DWCNT ve MWCNT) dizel motor emisyonları üzerindeki etkileri deneysel olarak incelenmiştir. Elde edilen bulgular, CNT katkılarının yanma kalitesini belirgin şekilde iyileştirdiğini ve emisyon karakteristiklerini olumlu yönde etkilediğini göstermektedir. NOx emisyonlarında, propanol içeriğinin yanma sıcaklığını düşürmesine bağlı olarak bir azalma eğilimi görülmüş; ancak SWCNT ve MWCNT katkılarında yanma kararlılığının artmasıyla hafif bir yükselme meydana gelmiştir. Buna karşın, HC ve CO emisyonları CNT katkısıyla belirgin biçimde azalmış, özellikle SWCNT katkısının eksik yanmayı en etkin şekilde azaltan nanopartikül olduğu tespit edilmiştir. CO_2 emisyonlarında ise yanma verimindeki iyileşmeye bağlı olarak CNT katkılı yakıtlarda bir miktar artış gözlenmiş, bu durum daha tamamlanmış bir oksidasyon sürecinin göstergesi olarak değerlendirilmiştir. Egzoz O_2 değerlerinin CNT katkılı karışımlarda daha düşük seyretmesi, oksijenin yanmada daha etkin şekilde kullanıldığını doğrulamaktadır.

Genel olarak sonuçlar, karbon nanotüplerin propanol-dizel karışımında oluşan yanma zorluklarını büyük ölçüde giderdiğini, yanma verimini artırarak CO ve HC gibi kirletici emisyonları önemli ölçüde azalttığını ortaya koymaktadır. Özellikle SWCNT katkısının gerek yanma verimi gerekse emisyon iyileştirme açısından en başarılı katkı türü olduğu belirlenmiştir. Bu bağlamda CNT katkılarının, propanol içeren alternatif yakıtların motorlarda daha verimli ve çevreci şekilde kullanılmasını mümkün kılan etkili bir katkı maddesi olduğu söylenebilir.

Teşekkür

Bu araştırma Şırnak Üniversitesi Bilimsel Araştırma Projeleri Koordinasyon Birimi Koordinatörlüğü'nce desteklenmiştir. Proje No: 2024.FNAP.17.08.01, 2024.

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TİTANYUM MALZEMELERDE ZAMANA BAĞLI OLARAK YÜZEY PÜRÜZLÜLÜĞÜ VE TAKIM AŞINMASININ İNCELENMESİ

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ÖZET

Talaşlı imalat ile işlenen makine parçaları için yüzey pürüzlülüğü ve takım aşınması en önemli faktörlerdendir. Kontrol edilemeyen takım aşınması ya da amacına uygun olmayan yüzey kalitesi talaşlı imalat sürecine büyük zararla verebilir. Bu çalışmada birçok endüstriyel sektör için oldukça önemli olan Titanyum alaşımlarından Ti6Al4V Eli malzemenin talaşlı imalatı araştırılmıştır. Bu amaçla 70 m/dk kesme hızı, 2 mm kesme derinliği, 0,2 mm yana kayma miktarı ve 223 mm/dk ilerleme değerleri kullanılarak toplam 8 paso ile talaşlı imalat deneyleri gerçekleştirilmiştir. Her paso sonrası yüzey pürüzlülüğü ölçümleri gerçekleştirilmiş ve talaşlı imalat işlemleri sonrası takım aşınması incelemiştir. Yapılan incelemeler sonrasında takım aşınmasının oldukça düşük olduğu anlaşılmıştır. Benzer şekilde yüzey pürüzlülüğü değerlerinin de kayda değer şekilde düşük ölçüldüğü anlaşılmış ve çok iyi bir yüzey kalitesine ulaşılmıştır. Her paso sonrası yapılan incelemelerde ise yüzey pürüzlülüğü değerlerinde ciddi bir değişim tespit edilememiştir.

Anahtar Kelimeler : Yüzey pürüzlülüğü, takım aşınması, Ti6Al4V Eli, talaşlı imalat

Abstract

Surface roughness and tool wear are the most prominent factors for machined parts. Uncontrolled tool wear or improper surface quality can cause significant damage to the machining process. In this study, the machining of Ti6Al4V Eli material, one of the titanium alloys that are very important for many industrial sectors, was investigated. For this purpose, machining experiments were performed with a total of eight passes at a cutting speed of 70 m/min, an axial depth of cut of 2 mm, a radial depth of cut of 0.2 mm, and a feed rate of 223 mm/min. Surface roughness measurements were performed after each pass, and tool wear was

examined after machining. After the examinations, it was concluded that the tool wear was relatively limited. The surface roughness values were quite low, and a high-quality surface finish was achieved. No considerable change in the surface roughness values was observed in the examinations carried out after each pass.

Keywords: Surface roughness, tool wear, Ti6Al4V Eli, machining

1. GİRİŞ

1.1. Materyal ve Metot

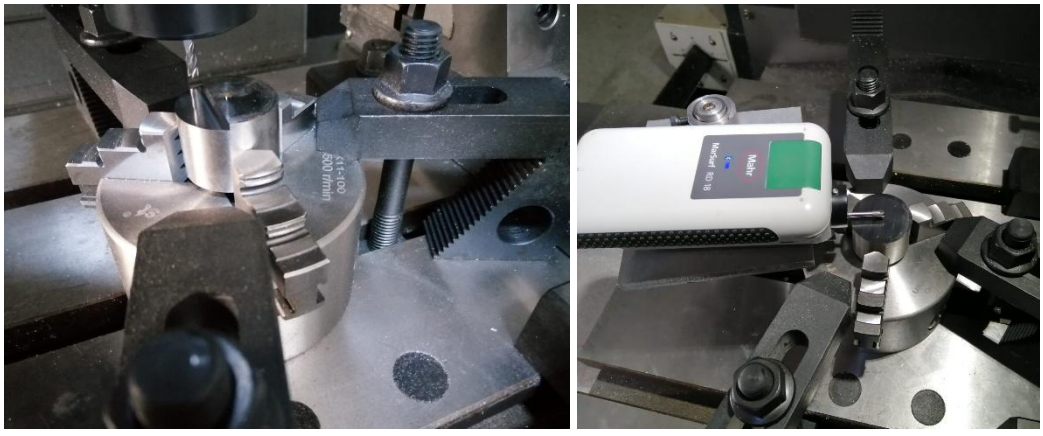
Bu çalışmada Ti6Al4V Eli (Grade 23) malzeme kullanılmıştır. Üstün mekanik özelliklere sahip bu malzemenin birçok sektörde kullanılmasına karşı düşük işlenebilirliği nedeniyle bu malzeme tercih edilmiştir [1–3]. Ti6Al4V Eli malzemeye ait kimyasal kompozisyon Çizelge 1'de verilmiştir.

Çizelge 1. Ti6Al4V Eli Titanyum alaşımına ait kimyasal kompozisyon [ASTM B348].

Element	Al	C	Fe	H	N	O	V	Ti
%	5.885	0.022	0.1	0.003	0.008	0.101	3.925	Kalan

Talaşlı imalat işlemlerinde Ø4 mm çapında AlCrN kaplamalı dört ağızlı genel amaçlı karbür parmak freze kullanılmıştır. Ti6Al4V Eli (Grade 23) malzeme Ø35 mm çapında çubuk şeklinde temin edilmiş ve 26 mm uzunlukta kesilerek frezeleme işlemlerine tabi tutulmuştur. Deneylerde 70 m/dk kesme hızı, 2 mm kesme derinliği, 0,2 mm yana kayma miktarı ve 223 mm/dk ilerleme kullanılmıştır. İş parçası X eksenine dik olarak dikey ilerleme ile işlenmiştir.

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(a) (b)

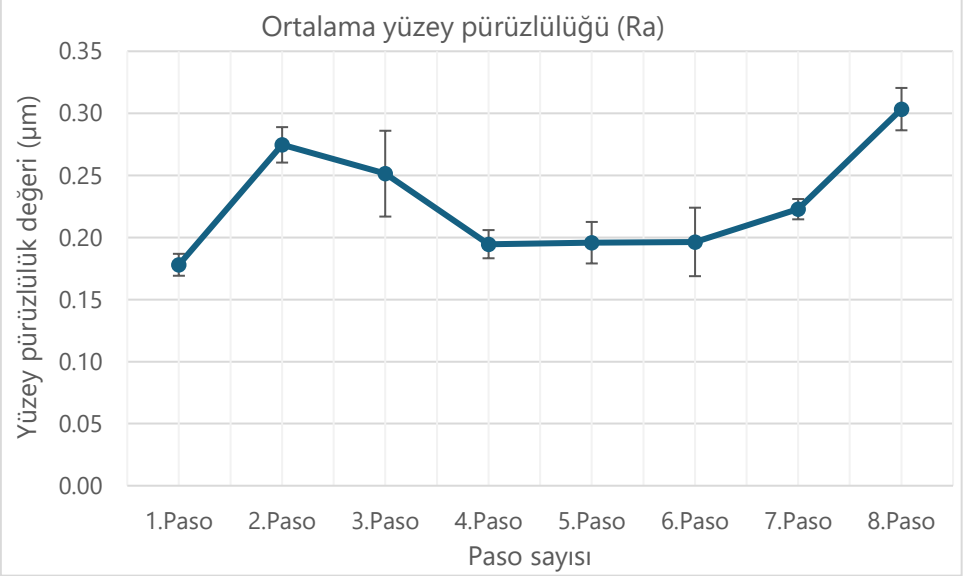
Görsel 1. Deney ve Ölçüm işlemleri a) Talaşlı imalat işlemi b) Yüzey pürüzlülüğü ölçme işlemi

Ti6Al4V Eli titanyum alaşımı her seferinde 2 mm talaş kaldırılarak (Görsel 1a) 8 paso halinde toplam 16 mm talaşlı imalat operasyonuna tabi tutulmuştur. Deneyler kuru işleme şartlarında gerçekleştirilmiştir. Her paso sonrası iş parçası yüzeyinden toplam beş adet yüzey pürüzlülüğü

ölçümü alınmıştır (Görsel 1b). Yüzey pürüzlülüğü ölçümlerinin üç tanesi işleme yönüne dik diğer ikisi işleme yönüne 45° ve 135° açı ile gerçekleştirilmiştir. Ayrıca talaşlı imalat deneyleri sonrası kullanılan karbür kesici takım, takımcı mikroskobu kullanılarak takım aşınması yönünden incelemiştir.

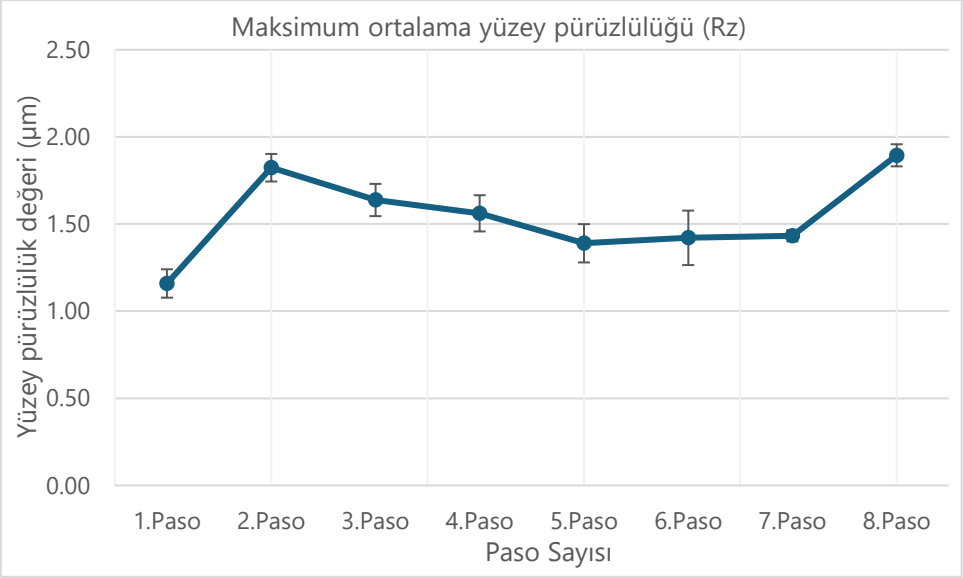
2. BULGULAR

Yüzey pürüzlülüğü talaşlı imalat işlemlerinin en önemli çıktılarından biridir. Yüzey pürüzlülüğü birçok faktörden etkilendiğinden talaşlı imalat sürecinin tamamında takip edilmesi gerekmektedir. Deneyler kapsamında yapılan ölçümlerde sonucunda elde edilen değerler temel alınarak oluşturulan Ortalama yüzey pürüzlülüğü (Ra) grafiği Görsel 2'de ortalama maksimum yüzey pürüzlülüğü grafiği Görsel 3'te sunulmuştur.



Görsel 2. Ortalama yüzey pürüzlük değerlerinin değişimi

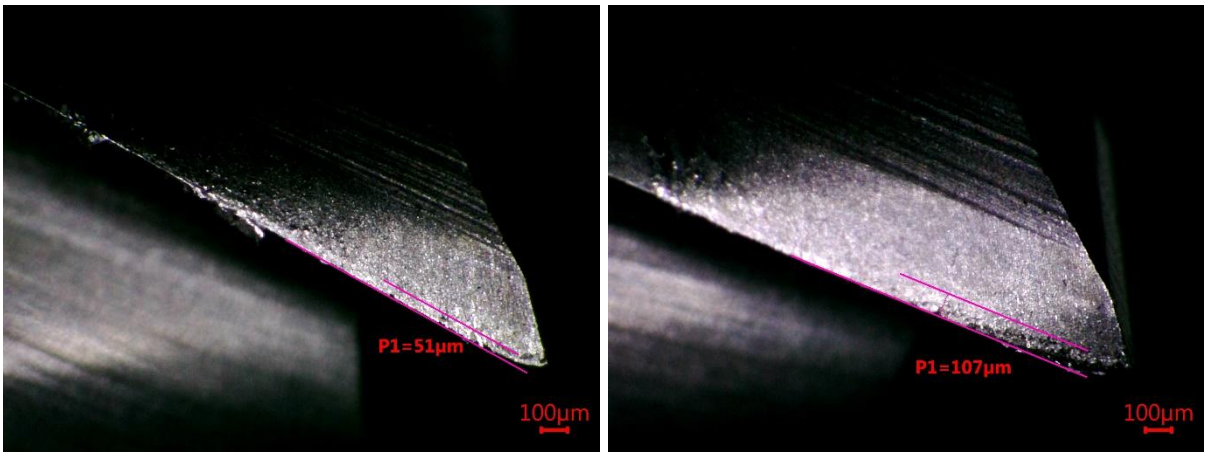
Ortalama yüzey pürüzlülüğü (Ra) makine parçalarının değerlendirilmesinde kullanılan en temel ölçüttür. Bu çalışma kapsamında yapılan ölçüm sonuçlarına göre (Görsel 2) yüzey pürüzlülüğü değerlerinin oldukça küçük olduğu görülmektedir. Yüzey pürüzlülüğünün etkileyen en önemli etkenlerin başında ilerleme ve yanal kayma miktarı gelmektedir [4]. Deneylerde kullanılan 223 mm/dk ilerleme ve 0,2 mm yanal kayma miktarı nedeniyle yüzey pürüzlülüğü değerlerinin oldukça düşük olduğu gözlenmiştir. Ayrıca birçok deneyde standart sapmanın da düşük çıkması ölçümler arasındaki farkın düşük olduğunu ve yüzeyin tamamının benzer özellikler taşıdığını göstermiştir.



Görsel 3. Ortalama maksimum yüzey pürüzlülüğü

Ortalama yüzey pürüzlülüğü (Ra) makine parçalarının yüzey pürüzlülük değerleri açısından genel bir fikir verse de makine parçalarının yüzeyi hakkında yeterli bilgiyi sunmamaktadır. Deneyler kapsamında gerçekleştirilen ortalama maksimum yüzey pürüzlülüğü değerleri (Rz) ile malzeme yüzeyinin daha detaylı incelenmesi amaçlanmıştır. Görsel 3'te görülen ortalama maksimum yüzey pürüzlülüğü (Rz) değerlerinin de oldukça düşük olduğu ve kararlı seviyelerde değişime uğradığı görülmüştür. Ra parametresine benzer Görselde Rz parametresi içinde düşük standart sapma değerleri gözlenmiştir [5,6]. Deneyler tek bir karbür parmak freze ile gerçekleştirilmiştir. Kesici takımlarının zaman içerisinde aşındığı bilinmektedir. Takım aşınmasına bağlı olarak ise yüzey pürüzlülüğü değerlerinde bozulmalar meydana geldiği birçok literatür kaynağında vurgulanmıştır

Gerek Ra gerek se Rz parametrelerinin deneyler boyunca ciddi değişime uğramaması takım aşınmasının belirgin olmadığını ortaya koymaktadır. Kullanılan karbür parmak frezenin dört ağzının tamamı takımcı mikroskobu ile incelenmiştir. Yapılan incelemelerde en az takım aşınmasının görüldüğü ölçüm Görsel 4a'da ve en fazla takım aşınmasının görüldüğü ölçüm Görsel 4b'de sunulmuştur.



(a) (b)

Görsel 4. Takım aşınması ölçümleri a) En az aşınan kesici kenar b) En fazla aşınan kesici kenar

Kesici takımlarda aşınma birçok faktörden etkilenmektedir [7]. Her ne kadar tüm talaşlı imalat faktörlerinin takım aşınması üzerinde etkisi olsa da en belirgin etki kesme hızına bağlıdır [8]. Genel olarak kesici takımlarda aşınma önce hızlıca gerçekleşmekte ardından sabit bir hızla artmakta ve son olarak aşınma tekrar hızla artarak takım ömrü tamamlanmaktadır [9].
Gerçekleştirilen deneylerde kesici takıma ait kenarlar için 51 µm, 61 µm, 87 µm ve 107 µm aşınma ölçülmüştür. Ortalama 77 µm olan takım aşınması oldukça düşüktür. Ayrıca kesici takımda aşınmanın düzenli gerçekleştiği görülmektedir. Parmak frezelerle için frezeleme işleminde takım aşınması analizlerinde ISO 8688-2 (Tool life testing in milling — Part 2: End milling) kullanılmaktadır [ISO 8688-2]. ISO 8688-2'ye göre kesici takım aşınması için sınır değerler belirlenmiştir. Düzenli aşınma durumunda ortalama aşınma değeri 250 µm sınır değer olarak belirlenmiştir. Deneylerde elde edilen 77 µm'lik aşınma değerinin ISO 8688-2'ye göre çok düşük olması aşınmanın henüz yeni başladığının bir göstergesidir. Kesici takım yeterince aşınmadığından yüzey pürüzlülüğü değerlerinde ciddi bir değişim görülmemiştir.

3. SONUÇ VE ÖNERİLER

Birçok endüstriyel alanda kullanılan ve işlenmesi zor malzeme grubunda yer alan Ti6Al4V ELI malzeme üzerinde yapılan talaşlı imalat deneyleri sonucunda aşağıdaki sonuçlar elde edilmiştir.

- Ti6Al4V ELI alaşımı Ø35 mm çubuk malzeme Ø4 mm çapında dört ağızlı genel amaçlı karbür parmak freze ile 70 m/dk kesme hızı, 2 mm kesme derinliği, 0,2 mm yanal kayma miktarı ve 223 mm/dk ilerleme ile 8 paso olacak şekilde işlenmiş ve değişken olarak birbirini takip eden pasolar dikkate alınmıştır. Uygulama sonrası parmak frezeye ait 4 ağızında aşınmaları mikroskop yardımı ile ölçülmüştür.

- İlk değerlendirme kriteri olarak Ra değerleri incelendiğinde; ilk pasoda 0,17 µm iken, son kademeye doğru genel olarak artış eğilimi göstermiş ve 8. ve son pasoda 0,30 µm'ye ulaşmıştır. Rz değerleri incelendiğinde ise ilk pasoda 1,1 µm iken, 2–4.

pasolarda dalgalanmış, 5–6. pasolarda 0,4 µm'ye düşmüş, son pasoda ise 1,9 µm'ye yükselmiştir. Ra ve Rz değerlerinindeki değişimin birbirine paralel geliştiriği ileri sürülebilir.

- Standartlara göre yapılan ölçümlerde takım aşınması dört ağızda 51–107 µm aralığında bulunmuş olup ortalama aşınma 77 µm olarak hesaplanmıştır.

- Kaldırılan talaş miktarının artması ile takımda ölçülen aşınmanın artışı özellikle son 2 pasoda (7. ve 8.) Ra ve Rz değerlerinin yükselmesi ile uyumludur. Yüzey kalitesi sınırlı bir sürede stabil gözlemlenirken işlemenin devam etmesi ile birlikte aşınmanın artması söz konusudur.

  Ti6Al4V ELI malzemesi yapısı gereği; yüksek reaktivite ve kesme bölgesindeki termal yük oluşturması söz konusudur. Yapılan çalışmada bu durumla paralel şekilde takım aşınması hızla artmış ve dolayısı ile yüzey kalitesi git gide bozulma eğilimindedir.

- Bu çalışmada sınırlı sayıda deney gerçekleştirildiği için bazı parametrelerinin gözlenmesi mümkün olmamıştır. Bu nedenle Çalışmanın devamı niteliğinde olabilecek çalışma önerileri ise;

  - Kullanılan karbür takım yerine farklı kaplama kullanılmış (AlTiN/TiAlN kaplamalı) karbür takımlar kullanılarak takım aşınmasının değişimi gözlemlenebilir.

  - Ø35 mm çubuk malzeme Ø4 mm çapında dört ağızlı genel amaçlı karbür parmak freze ile 70 m/dk kesme hızı, 2 mm kesme derinliği ile yapılan çalışmada 8. Pasodan itibaren takım aşınması gözlemlenmesi üretim aşamasında aynı malzemenin kullanımında ciddi takım sarfiyatına sebep olacaktır. Bu sebeple takım ömrünü arttırabilmek adına 70 m/dk yerine 50–60 m/dk aralığı kesme hızlarının denenmesi farklı sonuçların elde edilmesini sağlayabilir.

  - Diğer bir takım aşınmasını arttırması muhtemel parametrede 2mm olan kesme derinliğidir. Kesme derinliğinin 1-1,5mm arağında tutulması durumunda takım aşınmasının davranışı araştırılabilir.

  - Soğutma sistemi kullanılması kuru işlemeye göre birçok avantaj sunabilecektir. Bunlardan ilki talaş uzaklaştırmada ikincisi takım ile iş parçası arasındaki sürtünmeyi azaltma ve son olarak da takım ve iş parçasının ısınmasını azaltmadır. Sonraki çalışmalarda farklı soğutma sistemlerinin kullanılması ilgi çekici olabilir.

Teşekkür: Bu çalışma Manisa Celal Bayar Üniversitesi Bilimsel Araştırma Projeleri Koordinasyon Birimi tarafından desteklenmiştir. Proje Numarası: 2023-028

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CAM ELYAF TAKVİYELİ POLİPROPİLEN YÜZEY TABAKALI ALÜMİNYUM BAL PETEĞİ SANDVİÇ KOMPOZİTLERİN YARI STATİK PENETRASYON DAVRANIŞININ İNCELENMESİ

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ÖZET

Bu çalışmada, cam elyaf takviyeli termoplastik polipropilen granülleri sıcak pres yöntemi ile üretilerek yüzey tabakaları elde edilmiştir. Daha sonra elde edilen bu yüzey tabakaları alüminyum bal peteği çekirdek malzemeleri ile Henkel PU 7600 adlı yapıştırıcı kullanılarak birleştirilmiş ve sandviç kompozit haline getirilmiştir. Yüzey tabakalarının kalınlığı 3 mm olup, çekirdek malzemesinin kalınlığı ise 15 mm'dir. Üretilen sandviç kompozitlerin yarı statik delme kesme davranışı farklı hızlar altında (10 mm/dak ve 20 mm/dak) test edilmiştir. Yapılan deneyler sonucunda numunelere ait kuvvet – uzama diyagramları çizilmiştir. Elde edilen sonuçlara göre, hızın 10 mm/dak'dan 20 mm/dak'ya artırılması ile birlikte numunelerin maksimum temas kuvvetinde azalma gözlemlenmiştir.

Anahtar Kelimeler: Alüminyum Bal Peteği, Elyaf Takviyeli Polipropilen, Yarı-statik Delme Testi, Termoplastik Kompozit, Sıcak Pres

1. GİRİŞ

Malzemelerde artan performans beklentileri ve hafif yapı gereksinimi, mühendislik uygulamalarında malzeme seçimini belirleyici bir faktör haline getirmiştir. Bu gereksinimleri karşılamak için üretim teknikleri ve malzeme teknolojileri hızla gelişmektedir [1]. Bu doğrultuda, yüksek özgül dayanım ve tasarım serbestliği sunan kompozit malzemeler, mühendislik uygulamalarında ön plana çıkmaktadır [2]. Kompozit malzemeler, farklı fiziksel ve kimyasal özelliklere sahip en az iki malzemenin faz bütünlüğü korunarak tek bir yapı içerisinde birleşmesiyle elde edilmektedir [3]. Kompozit malzemeler, otomotiv, inşaat, denizcilik ve medikal gibi alanlarda yaygın olarak tercih edilmektedir [4]. Kompozit malzemeler matris malzeme ve takviye elamanı olmak üzere iki bileşenden oluşmaktadır. Matris malzemeleri kendi aralarında metal, seramik ve polimer olmak üzere ayrılırken takviye elemanları ise parçacık, elyaf vb. gibi yapılardan oluşabilmektedir [5].

Kompozit malzemeler sahip oldukları üstün mekanik ve yapısal performans özellikleri sunmaları nedeniyle mühendislik uygulamalarında ön plana çıkmaktadır. Son zamanlardaki gelişmeler ile birlikte kompozitlerin hafifliğini ön plana çıkarmak ve mekanik özelliklerini iyileştirmek için kompozit malzemeleri çekirdek malzemeler ile birleştirilerek sandviç kompozitlerin üretilmesi üzerine yoğunlaşılmıştır [6]. Sandviç kompozitler, iki taşıyıcı yüzey plakasının bir çekirdek katmanı ile birleştirilmesiyle oluşmaktadır. Yüzey plakaları ve çekirdek katmanı tasarım gereksinimlerine bağlı olarak farklı malzemelerden tercih edilebilmektedir [7]. Bu çalışmada çekirdek malzemesi olarak 15 mm kalınlığına sahip alüminyum bal peteği kullanılmıştır. Alt ve üst yüzey plakası olarak 3 mm kalınlığında cam elyaf takviyeli termoplastik polipropilen materyal kullanılmıştır. Cam elyaf takviye oranı ağırlıkça %20'dir. Polipropilen farklı endüstriyel alanlarda tekne, yat, hidrofobik özellik gerektiren uygulama alanlarında geri dönüştürülebilen ve uygulama kolaylığından dolayı yaygın şekilde kullanılmaktadır [8]. Polipropilen düşük maliyeti ve yüksek çekme mukavemeti gibi özellikleri nedeniyle teknik amaçlı kullanımlarda termoplastik malzeme olarak tercih edilmektedir [9].

2. DENEYSEL ÇALIŞMALAR

2.1 Malzemeler

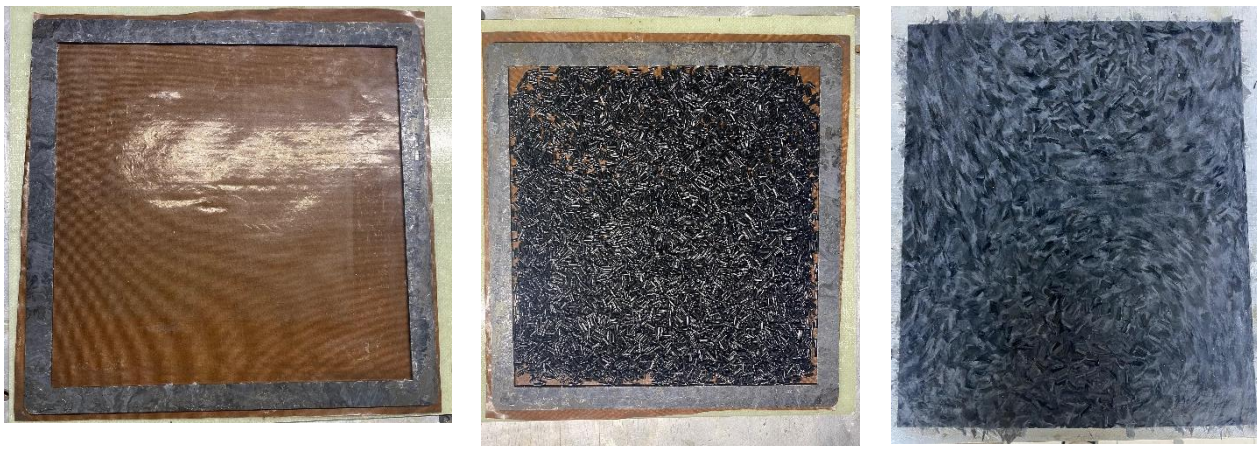
Sandviç kompozitlerin üretiminde alt ve üst yüzey tabakası olarak cam elyaf takviyeli siyah renkli polipropilen (DuraMax LFT PP 20) kullanılmıştır. Cam elyaf takviyeli termoplastik polipropilen granüllerin yüzey levhası haline getirilmesi için Dokuz Eylül Üniversitesi Makine Mühendisliği Bölümü Kompozit Üretim Laboratuvarında bulunan *FONTUNE PRESSES* sıcak pres cihazı kullanılmıştır. Sandviç kompozit üretimi için tercih edilen alüminyum bal peteği Dokuz Eylül Üniversitesi Makine Mühendisliği Bölümü'nden temin edilmiştir. Çekirdek malzemenin kalınlığı 15 mm'dir. Cam elyaf takviyeli termoplastik polipropilen levhaların alüminyum bal peteği ile birleştirilmesi için Henkel PU 7600 adlı yapıştırıcı kullanılmıştır.

2.2 Cam Elyaf Takviyeli Polipropilen Üretimi

Cam elyaf takviyeli polipropilen olarak DuraMax LFT PP 20 kullanılmıştır. Bu malzemenin fiziksel ve mekanik özellikleri aşağıda Çizelge 1'de verilmiştir. Polipropilenin sıcak prese alınabilmesi için hazırlık aşaması olarak alt yüzeye yapışmaması ve sonrasında tek bir parça olarak çıkarılabilmesi için teflon serilmiştir. Daha sonra üzerine iç ölçüsü 350x350 mm olan metal çerçeve yerleştirilmiştir ve çerçevenin iç hacmini dolduracak şekilde cam elyaf takviyeli polipropilen homojen şekilde dağıtılarak yerleştirilmiştir. Görsel 1'de üretim aşamaları gösterilmiştir. Bu şekilde sıcak presin içerisine yerleştirilen polipropilenin üzerine yine aynı teflon malzemesi yerleştirilmiştir. Sıcak preste polipropilene sıcak presin çeneleri aracılığıyla 100 kN'luk kuvvet uygulanmıştır. Presin hem alt hem de üst yüzeyinden olmak üzere malzemeye 60 dakika boyunca 180°C sıcaklık uygulanmıştır. Sonrasında 300 dakika oda sıcaklığına (24 C°) düşmesi için soğumaya bırakılmıştır. Pres makinesinden çıkarılan malzeme sulu testere yardımıyla 100x100 mm ölçüsünde kesilmiştir. Yüzey tabakalarının üretimi için kullanılan *FONTUNE PRESSES* sıcak pres makinesi Görsel 2'de gösterilmiştir.

Çizelge 1. DuraMax LFT PP 20'nin fiziksel ve mekanik özellikleri

Fiziksel/Mekanik Özellikler	Test Metodu	Değerler*	Birim
Cam Oranı	ISO 3451	20	%
Yoğunluk	ISO 1183	1,03	g/cm³
Çekme Dayanımı	ISO 527	92	Mpa
Çekme Dayanım Modülü	ISO 527	4750	MPa
Eğme Dayanımı	ISO 178	125	MPa
Eğme Dayanım Modülü	ISO 178	3875	kJ/m²
Izod Darbe, Çentiksiz	ISO 179	30	kJ/m²
HDT(0,45 Mpa)	ISO 75	154	°C



(a) **(b)** **(c)**

Görsel 1. a) Teflon üzerine yerleştirilmiş çerçeve b) Çerçeve içerisine homojen dağıtılmış cam elyaf takviyeli polipropilen c) Sıcak pres işlemi sonrası elde edilen cam elyaf takviyeli polipropilen yüzey tabakası



Görsel 2. *FONTUNE PRESSES* Sıcak Pres Makinesi

2.3 Sandviç Kompozit Üretimi

Sandviç kompozitlerin yüzey tabakası olarak belirlenen cam elyaf takviyeli termoplastik polipropilenlerin alüminyum bal peteği ile birleştirilmesi için Henkel PU7600 adlı yapıştırıcı homojen bir biçimde uygulanmıştır. Görsel 3.a'da bu işlem görülmektedir. Alüminyum bal peteği çekirdek malzeme, yapıştırıcının uygulandığı yüzeye oturtulup işkence yardımı ile birleştirilmesi sağlanmış ve oda sıcaklığında 48 saat süre ile bekletilmiştir. Görsel 3.b'de Henkel PU7600 adlı yapıştırıcının cam elyaf takviyeli termoplastik polipropilenlerin yüzeyine uygulanma biçimi gösterilmiştir. Daha sonra polipropilen üst yüzey tabakasının da bir yüzeyine de yapıştırıcı homojen olarak uygulanmış olup, yapıştırıcı bulunan yüzey, alüminyum bal peteğinin üzerine sabitlenmiştir.



(a) (b)

Görsel 3. a) Polipropilen İle Yapıştırılmış Alüminyum Bal Peteği a) Yapıştırıcı Uygulanmış Polipropilen

2.4 Yarı-statik Delme Kesme Deneyi

Üretilen sandviç kompozit malzemeye yarı-statik delme kesme testi uygulanmıştır. Test için *SHIMADZU AUTOGRAPH AG-IS 100 kN* adlı cihaz kullanılmıştır. Deney cihazı Görsel 3'te görülmektedir. Yarı statik kesme delme testi 10 mm/dak ve 20 mm/ dak olmak üzere iki farklı hızda uygulanmıştır.

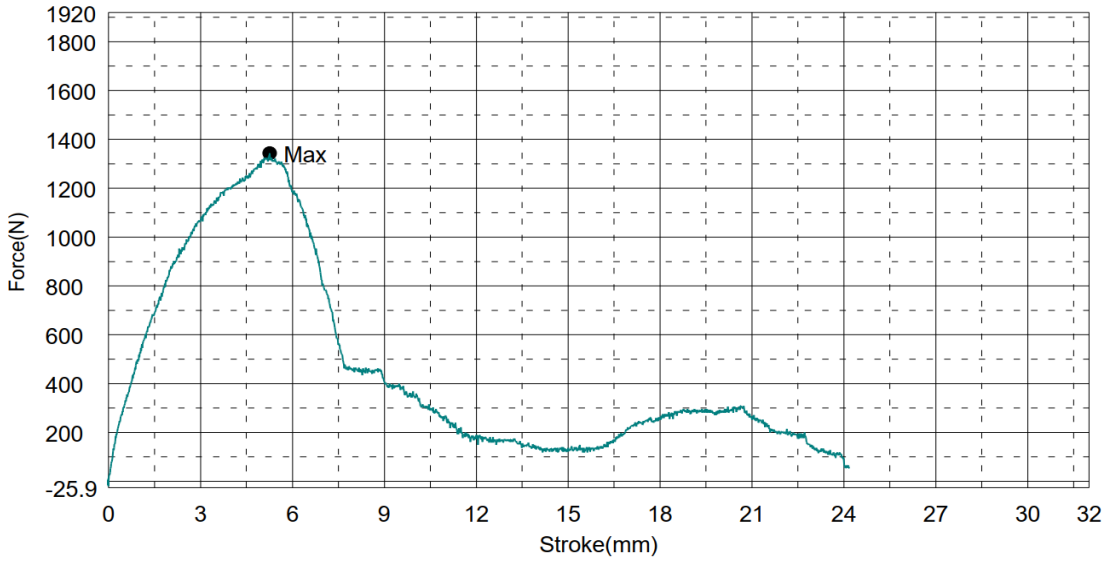


Görsel 4. SHIMADZU AUTOGRAPH AG-IS 100 kN Deney Cihazı

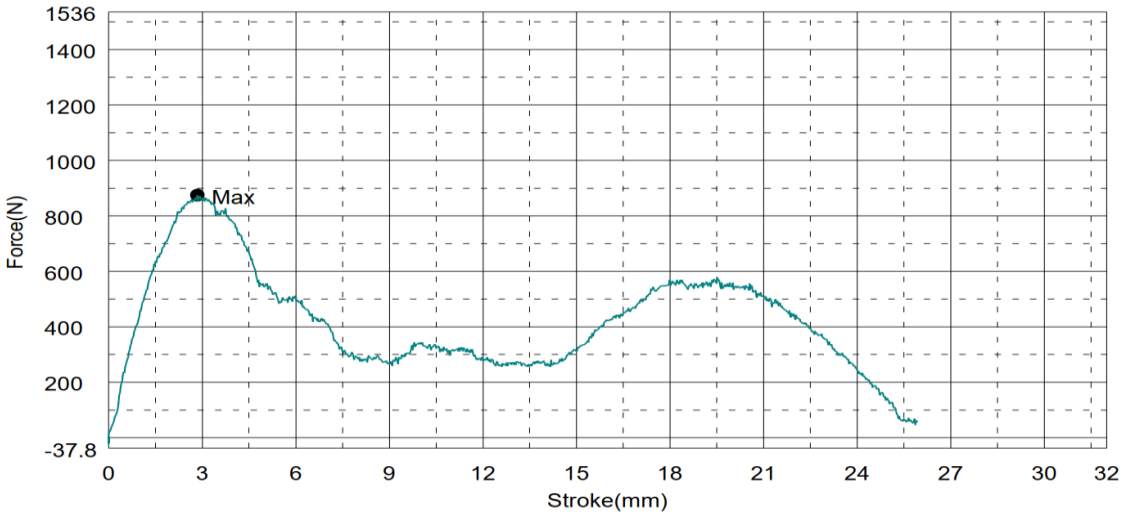
3. SONUÇ VE DEĞERLENDİRME

Alüminyum bal peteği çekirdekli cam elyaf takviyeli termoplastik polipropilen sandviç kompozitlerin yarı statik delme kesme testlerinin sonucunda mekanik özellikleri ve elde edilen kuvvet-uzama diyagramları Görsel 4'te verilmiştir. 15 mm kalınlığa sahip alüminyum bal peteği çekirdekli ve 3 mm kalınlığa sahip cam elyaf takviyeli termoplastik polipropilen sandviç kompozitlerin farklı hızlarda (10 mm/dak ve 20 mm/dak) yapılan yarı statik delme kesme testleri sonucunda yüzey temas kuvvetlerinin maksimum değerleri sırasıyla 1343,75 N ve 875 N olarak elde edilmiştir. Elde edilen yüzey temas kuvvetlerinin maksimum pik değerlerine göre yarı statik delme kesme testindeki hız artışının 10 mm/dak'dan 20mm/dak hıza arttırıldığında

mekanik özelliğinde yaklaşık olarak %34,88 oranında azalma meydana gelmiştir. Sandviç kompozitlerin arka yüzeyindeki bulunan cam elyaf takviyeli termoplastik polipropilen levhanın kuvvet-uzama diyagramındaki 10 mm/dak ve 20mm/dak hız ile yapılan deneylerin sonucunda 2. Tepe noktasındaki değerler sırasıyla 305 N ve 585 N olarak elde edilmiştir. 2.tepe noktasındaki hız farkının etkisi 1.tepe noktasında farklı bir sonuç göstererek hızın yükselmesiyle tepe noktası da artmıştır. Bunun nedeni olarak 20mm/dak hızında yapılan yarı statik delme kesme testinin sonucunda hızın arttıkça çekirdek malzemenin ezilmeden direk delindiği ve bundan dolayı çıkış yüzeyindeki cam elyaf takviyeli termoplastik polipropilen kuvvetini arttığı görülmüştür. Ancak 2.tepe noktasındaki değer 10mm/dak hızına göre artmış olsa da maksimum tepe noktasındaki (1. Tepe noktasındaki) değer 10 mm/dak da daha yüksek olduğu görülmüştür. Sandviç kompozitlerin 10 mm/dak ve 20 mm/dak hızındaki 1.tepe noktalarındaki ve 2.tepe noktalarındaki yüzey temas kuvvetleri bar grafiği şeklinde Görsel 5'te verilmiştir.



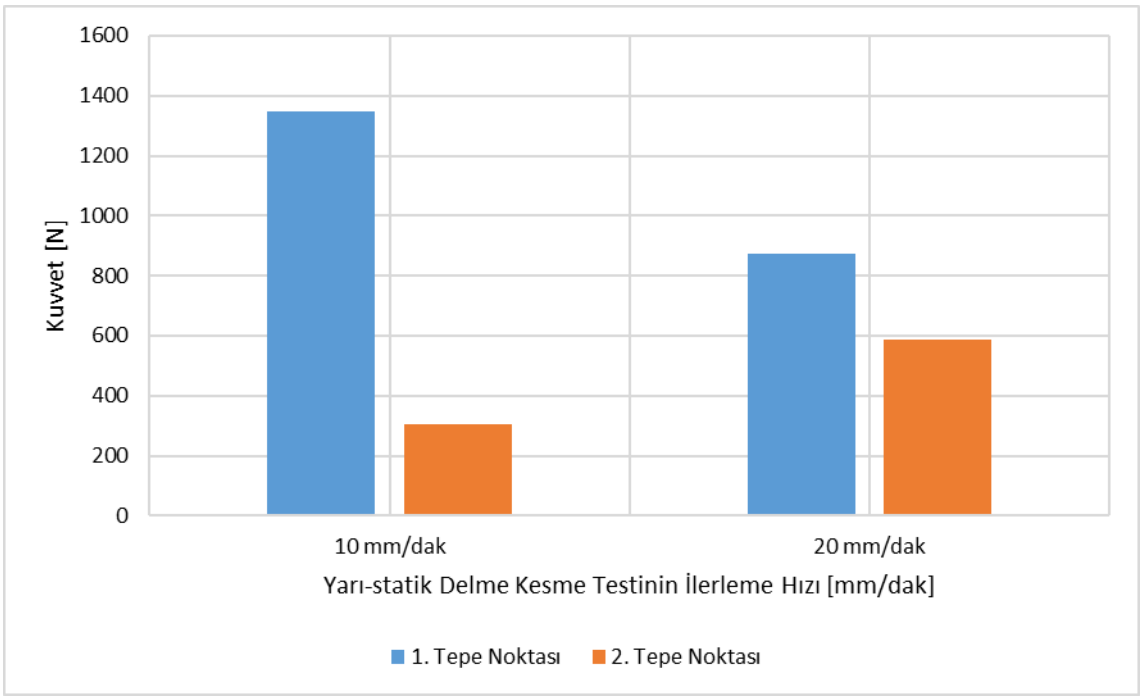
(a)



(b)

Görsel 4. Yarı Statik Delme Kesme Testi Kuvvet-Uzama Diyagramı

a) 10mm/dak hızında b) 20mm/dak hızında



Görsel 5. Yarı-Statik Delme Kesme Testi İlerleme Hızı Değişimine Göre Tepe Noktası Kuvveti Değişim Diyagramı

4. GENEL DEĞERLENDİRME VE SONUÇLAR

Alüminyum bal peteği çekirdekli cam elyaf takviyeli termoplastik polipropilen sandviç kompozitlerin yarı statik delme kesme testlerinde hız arttıkça mekanik özelliğinin azaldığı görülmüştür. 20 mm/dak hızda yapılan yarı-statik delme kesme testindeki 2. tepe noktasının 10 mm/dak hızı ile yapılan yarı-statik delme kesme testindeki 2. tepe noktasından yüksek olma nedeni 20 mm/dak ile yapılan testte delici ucun çekirdek malzemeyi ezmeden direkt delmesinden kaynaklanmaktadır. 10mm/dak hızdaki yarı-statik delme kesme testinde alüminyum bal peteği çekirdek malzemenin ezildiği gözlemlenmiştir. Yapılan yarı-statik delme kesme testi sonrasında hasara uğramış deney numunesinin alt ve üst yüzey tabakaları Görsel 6'da gösterilmiştir.



(a) (b)

Görsel 6. a) Hasara Uğramış Üst Yüzey Tabakası b) Hasara Uğramış Alt Yüzey Tabakası

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TAKVİYE KULLANIMININ ÇİFT BİNDİRMELİ YAPIŞTIRICI BAĞLANTILARIN MEKANİK DAVRANIŞINA ETKİSİ: SAYISAL BİR ÇALIŞMA

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ÖZET

Bu çalışmada, yapıştırıcı ile birleştirilen çift bindirmeli (double-lap) bağlantıların mekanik davranışı sonlu elemanlar yöntemi kullanılarak sayısal olarak incelenmiştir. Yapısal çelik levhalar ve Neoxil esaslı bir yapıştırıcıdan oluşan çift bindirmeli yapıştırıcı bağlantıların Uy=0 sınır şartı altındaki davranışı, yapıştırıcı kalınlığı, yapışan levha kalınlıkları, bindirme mesafesi ve takviye elemanı kullanımı gibi geometrik parametreler dikkate alınarak incelenmiştir. Hasar yüklerinin belirlenmesinde, yapıştırıcı tabakasında oluşan eşdeğer Von Mises gerilmelerinin yapıştırıcının çekme dayanımına ulaşması hasar başlangıcı olarak kabul edilmiştir. Sayısal analizler, ANSYS Workbench 2023 R1 yazılımı kullanılarak gerçekleştirilmiştir. Tüm analizler statik koşullar altında yapılmıştır. Sayısal sonuçlar, çift bindirmeli bağlantıların simetrik yük aktarım mekanizması sayesinde tek bindirmeli yapıştırıcı bağlantılara göre daha yüksek hasar yüklerine ulaştığını göstermektedir. Yapışan levha kalınlıklarının ve bindirme mesafesinin artırılmasının bağlantının taşıma kapasitesini artırdığı görülmüştür. Yapıştırıcı tabakası inceldikçe bağlantı rijitliğinin arttığı ve daha yüksek hasar yüklerinin elde edildiği belirlenmiştir. Takviye elemanı kullanımı ve takviye uzunluğunun artırılması bindirme bölgesinde yük aktarımını iyileştirerek bağlantı performansını olumlu yönde etkilemiştir. Bu çalışma, çift bindirmeli yapıştırıcı bağlantıların tasarımında geometrik parametrelerin ve takviye elemanı kullanımının bağlantının mekanik davranışı üzerindeki etkilerini ortaya koyarak, sayısal bir çalışma sunmaktadır.

Anahtar Kelimeler: Yapıştırıcı Birleştirme, Çift Bindirmeli Bağlantı, Sonlu Elemanlar Yöntemi, Gerilme Analizi

THE EFFECT OF REINFORCEMENT USAGE ON THE MECHANICAL BEHAVIOR OF DOUBLE-LAP ADHESIVE JOINTS: A NUMERICAL STUDY

ABSTRACT

In this study, the mechanical behavior of adhesively bonded double-lap joints was numerically investigated using the finite element method. The behavior of double-lap adhesive joints composed of structural steel plates and a Neoxil-based adhesive under the Uy=0 boundary condition was examined by considering geometric parameters such as adhesive thickness, adherend thicknesses, overlap length, and the use of reinforcement elements. The damage loads were determined by adopting the criterion that damage initiation occurs when the equivalent Von Mises stresses developed in the adhesive layer reach the tensile strength of the adhesive. Numerical analyses were carried out using ANSYS Workbench 2023 R1 software, and all analyses were performed under static loading conditions. The numerical results indicate that double-lap joints achieve higher damage loads compared to single-lap adhesive joints due to their symmetric load transfer mechanism. It was observed that increasing the adherend thicknesses and overlap length enhances the load-carrying capacity of the joint. Moreover, reducing the adhesive layer thickness leads to an increase in joint stiffness and results in higher damage loads. The use of reinforcement elements and the increase in reinforcement length were found to improve load transfer in the overlap region, thereby positively affecting the overall joint performance. This study presents a numerical investigation that reveals the effects of geometric parameters and reinforcement usage on the mechanical behavior of double-lap adhesive joints in joint design.

Keywords: Adhesive Bonding, Double-Lap Joint, Finite Element Method, Stress Analysis

1. GİRİŞ

Farklı malzemelerin mühendislik yapılarında güvenli ve etkin biçimde bir araya getirilmesi, üretim süreçleri ve yapısal performansın temel belirleyicilerinden biridir. Geleneksel birleştirme yöntemleri olan cıvata, perçin ve kaynak gibi teknikler uzun yıllardır yaygın olarak kullanılmasına rağmen, bu yöntemler özellikle hafif malzeme uygulamalarında, ince kesitli elemanlarda ve karma malzeme birleşimlerinde bazı sınırlamalara sahiptir. Mekanik bağlantılarda oluşan gerilme yığılmaları, ek ağırlık, yapısal süreksizlik ve imalat zorluğu gibi dezavantajlar, yapıştırıcı esaslı birleştirme tekniklerinin endüstride daha fazla tercih edilmesine yol açmıştır.

Yapıştırıcı birleştirmeler, geniş bir yüzey temas alanı üzerinden yük aktarabilmeleri, gerilmeleri daha homojen dağıtmaları, delik açma ihtiyacını ortadan kaldırmaları, farklı malzemeleri birlikte kullanma imkânı sunmaları nedeniyle özellikle havacılık, otomotiv, rüzgâr türbini ve kompozit yapı sektörlerinde stratejik bir öneme sahiptir. Yapıştırıcıların daha hafif, daha yüksek mukavemetli ve daha ekonomik tasarımlara olanak sağlaması, bu alandaki araştırmaların hızla artmasına katkıda bulunmaktadır. Ancak yapıştırıcı bağlantıların mekanik

davranışı; bağlantı geometrisi, yapıştırıcı özellikleri, yapışan levha kalınlıkları ve uygulanan sınır şartları gibi birçok parametreye bağlı olarak değişmektedir.

Yapıştırıcı birleştirmeler içerisinde çift bindirmeli (double-lap) bağlantılar, yükün birden fazla yapışan levha üzerinden aktarılabilmesinden dolayı tek bindirmeli (single-lap) bağlantılara kıyasla daha dengeli gerilme dağılımı sağlamalarıyla öne çıkmaktadır. Bu bağlantı tipi simetrik geometrisi sayesinde olumsuz mekanik etkileri azaltmakta ve çekme yükleri altında daha yüksek taşıma kapasitesi sunmaktadır. Bu nedenle, çift bindirmeli yapıştırıcı bağlantılar, yapısal uygulamalarda yaygın olarak tercih edilmektedir.

Hart-Smith (1973), yapıştırıcı ile birleştirilmiş çift bağlantılar için analitik çözümler geliştiren öncü çalışmalardan birini sunmuştur. Çalışmasında Volkersen'in elastik çözümünü genişleterek yapıştırıcının elastik-plastik davranışı, yapışan levhalar arasındaki rijitlik dengesizliği ve termal uyumsuzluk etkileri modele dahil edilmiştir. Analiz sonuçları, bağlantı dayanımının bindirme boyu arttıkça belirli bir sınıra kadar yükseldiğini, bu sınırdan sonra yük taşıma kapasitesinin doygunluğa ulaştığını göstermiştir. Maksimum bağ dayanımının yapıştırıcının birim alan başına kayma şekil değiştirme enerjisi ile tanımlanabildiğini vurgulamıştır.

Weißgraeber ve Becker (2012), yapıştırıcı bağlantıların kopma yüklerinin tahmin edilmesi amacıyla sonlu kırılma mekaniğine dayalı bir yaklaşım önermiştir. Çalışma, tek bindirmeli yapıştırıcı bağlantılar üzerine yoğunlaşmakla birlikte, geometrik parametrelerin (bindirme boyu, yapıştırıcı tabakası kalınlığı ve yapışan levha kalınlığı) kopma yükü üzerindeki etkilerini sistematik biçimde incelemiştir. Geliştirilen hibrit kriter, enerji temelli ve gerilme temelli yaklaşımları birleştirerek deneysel sonuçlarla uyumlu tahminler sunmuştur. Bu yöntem, daha sonraki sayısal çalışmalara teorik bir temel sağlaması açısından önemlidir.

Atay (2019), kompozit yapıştırıcı bağlantılarda hasar davranışını inceleyen kapsamlı bir yüksek lisans çalışması gerçekleştirmiştir. Çalışmada, tek bindirmeli kompozit bağlantılar için deneysel testler yapılmış ve aynı bağlantılar kohesif bölge modeli kullanılarak sonlu elemanlar yöntemiyle modellenmiştir. Bağlantı geometrisi, yapışan levha kalınlığı ve bindirme uzunluğunun mekanik performans üzerindeki etkileri araştırılmıştır. Sayısal analiz sonuçlarının deneysel bulgularla uyumlu olduğu gösterilmiş ve gerilme yığılmalarının hasar başlangıcındaki rolü ortaya konmuştur. Bu tez, yapıştırıcı bağlantıların sayısal olarak modellenmesine yönelik yöntemsel bir referans sunmaktadır.

Adole ve arkadaşları (2025), çift bindirmeli yapıştırıcı bağlantıların mekanik davranışını hem deneysel hem de sayısal olarak incelemiştir. Çalışmada, kenaf lif takviyeli polimer (KFRP) ve talaş takviyeli polimer (SDRP) malzemelerden oluşan doğal lif esaslı kompozitler kullanılmıştır. Farklı bindirme uzunlukları ve bağlantı geometrileri için basma yükü altında deneyler gerçekleştirilmiş, ardından sonlu elemanlar modeli ile sonuçlar doğrulanmıştır. Bulgular, bindirme uzunluğunun artmasının yük taşıma kapasitesini yükselttiğini ancak

ortalama kayma dayanımını azalttığını göstermiştir. Sayısal analizlerin deneysel verilerle uyumlu olduğu belirtilmiş ve doğal lif takviyeli kompozitlerin yapıştırıcı bağlantılarda kullanılabilirliği ortaya konmuştur.

Solmaz ve Topkaya (2011), yapıştırıcı ve perçin kullanılarak birleştirilmiş çift bindirmeli bağlantıların mekanik davranışını sonlu elemanlar yöntemiyle incelemiştir. Çalışmada, farklı bindirme mesafelerine sahip bağlantılar modellenmiş ve çekme yükü altında ilerlemeli hasar analizleri gerçekleştirilmiştir. Analiz sonuçları, hasarın perçin deliği çevresinden başlayıp uçlara doğru ilerlediğini ve yapıştırıcı tabakanın uç kısımlarından başlayıp iç kısımlara ilerleyip birleşerek bağlantı hasarı ile sonuçlandığını ve bindirme mesafesi arttıkça hasar kuvvetlerinin arttığını göstermiştir.

Adin (2016), farklı malzeme türüne ve geometrilere sahip çift takviyeli yapıştırma bağlantılarının mekanik davranışını deneysel olarak incelemiştir. Bindirme mesafesi, yama genişliği ve yama malzemesi türü gibi geometrik parametrelerin bağlantının taşıma kapasitesi üzerindeki etkilerini incelemiştir. Taguchi metodu ve ANOVA analizi ile yaptığı çalışmada çekme dayanımı üzerinde en etkili parametrenin bindirme mesafesi olduğunu belirlemiştir.

Sülü (2017), çift tesirli yapıştırma yöntemiyle birleştirilmiş farklı fiber oryantasyon açılarına sahip kompozit parçaların mekanik davranışı sonlu elemanlar yöntemi kullanarak incelemiştir. Çalışmada çift tesirli yapıştırma bağlantılarında bindirme mesafesi değiştikçe hasar yükünün değiştiğini ve oryantasyon açılarının bağlantı mukavemeti üzerinde kritik parametreler olduğunu ortaya koymuştur.

2. SAYISAL MODEL VE YÖNTEM

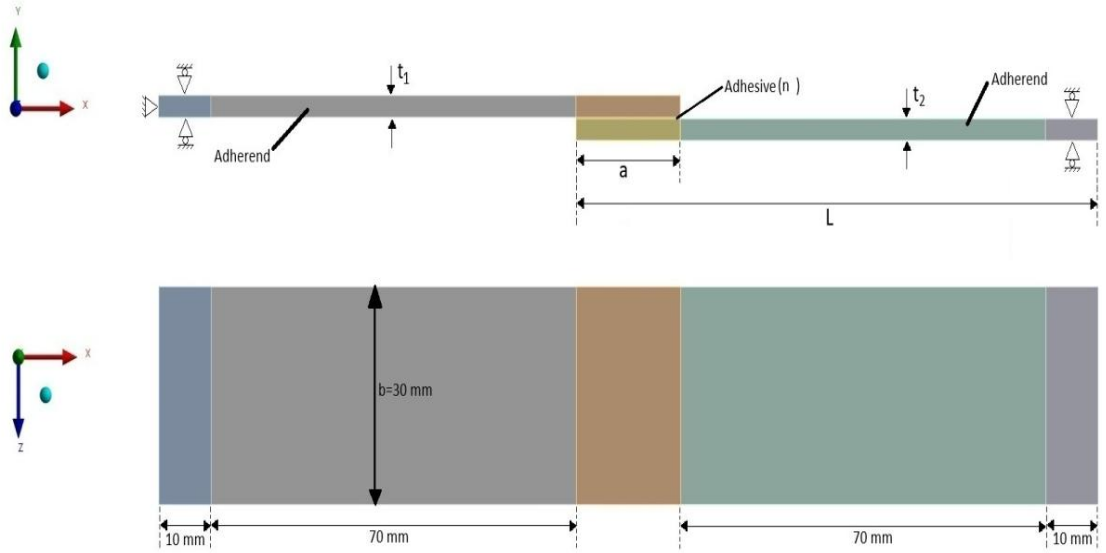
Bu çalışmada, yapıştırıcı ile birleştirilmiş çift bindirmeli bağlantıların mekanik davranışı sonlu elemanlar yöntemiyle incelenmiştir. Sayısal analizler, ANSYS Workbench 2023 R1 yazılımı kullanılarak gerçekleştirilmiştir.

Tek bindirmeli bağlantılar yalnızca karşılaştırma amacıyla değerlendirilmiş olup, detaylı parametre analizleri çift bindirmeli bağlantılar üzerinden gerçekleştirilmiştir.

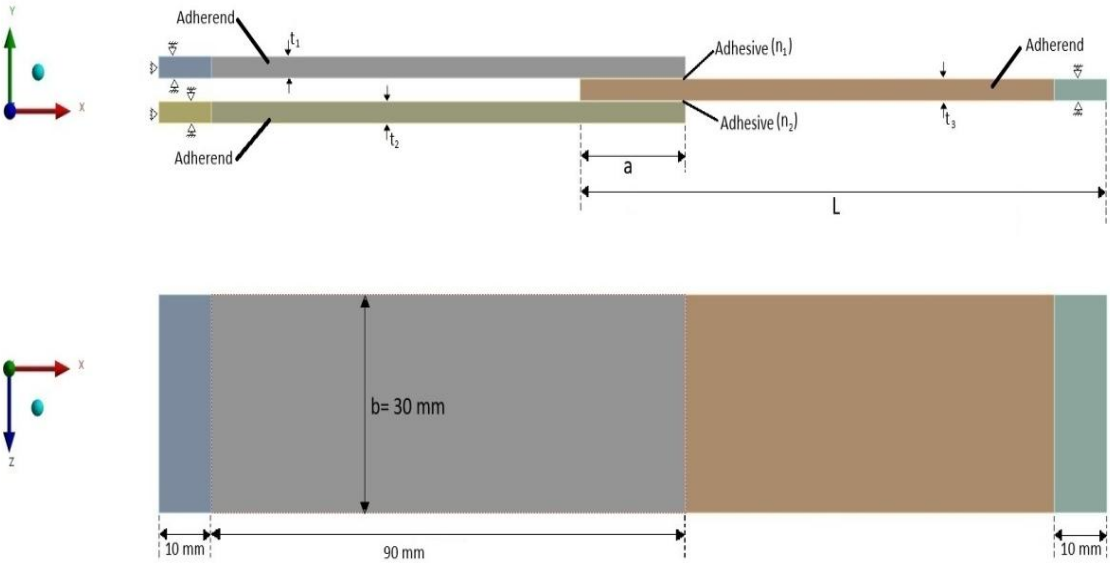
2.1. Bağlantı Geometrisi

Bu çalışmada ilk olarak yapıştırıcıyla birleştirilmiş çelik levhaların mekanik davranışını değerlendirmek amacıyla iki farklı bağlantı tipi modellenmiştir. Tek bindirmeli (SL) ve çift bindirmeli (DL) bağlantı tipleri incelenmiştir. Her iki model aynı malzeme özellikleri, aynı yükleme koşulları ve aynı geometrik parametreler kullanılarak oluşturulmuş ve böylece bağlantı tiplerinin performanslarının doğrudan karşılaştırılabilmesi sağlanmıştır. Görsel 1'de tek bindirmeli modelde yük, levhaların yalnızca bir yüzeyinden aktarılmış olup bu yapı eksen kaçıklığı nedeniyle eğilme momentine maruz kalmaktadır. Görsel 2'de çift bindirmeli modelde

ise yük iki yüzeyden simetrik olarak iletilmiş ve eksen kaçıklığı ortadan kaldırılarak daha dengeli bir yük aktarım mekanizması oluşturulmuştur.



Görsel 1. Tek Bindirmeli (SL) Bağlantı Tipi



Görsel 2. Çift Bindirmeli (DL) Bağlantı Tipi

Bu iki farklı geometrinin yapıştırıcı üzerindeki gerilme dağılımına ve bağlantı performansına etkilerini ortaya koymak için her iki model aynı şekilde analiz edilmiştir. Çizelge 1’ de tek bindirmeli bağlantının, Çizelge 2’ de çift bindirmeli bağlantının ölçüleri verilmiştir.

Çizelge 1. Tek Bindirmeli Bağlantı Ölçüleri

Özellikler	Ölçü (mm)
Yapışan Levha Kalınlıkları, $t_1=t_2$	3
Yapıştırıcı Kalınlığı, n	0,1
Yapışan Levha Uzunluğu, L	100
Bindirme Mesafesi, a	20

Çizelge 2. Çift Bindirmeli Bağlantı Ölçüleri

Özellikler	Ölçü (mm)
Yapışan Levha Kalınlıkları, $t_1=t_2=t_3$	3
Yapıştırıcı Kalınlığı, $n= n_1+n_2$	0,1
Yapışan Levha Uzunluğu, L	100
Bindirme Mesafesi, a	20

2.2. Malzeme Özellikleri

Bu çalışmada çift bindirmeli yapıştırıcı birleştirmelerin mekanik davranışını incelemek amacıyla oluşturulan modellerde, yapışan ve takviye elemanı olarak yapısal çelik levhalar kullanılmıştır. Birleştirme elemanı olarak ise çelik yüzeyler ile yüksek yapışma (aderans) sağlayan Neoxil CE92 N8 esaslı yapıştırıcı tercih edilmiştir. Yapısal çelik ve Neoxil CE92 N8 malzeme özellikleri Çizelge 3' te yer almaktadır.

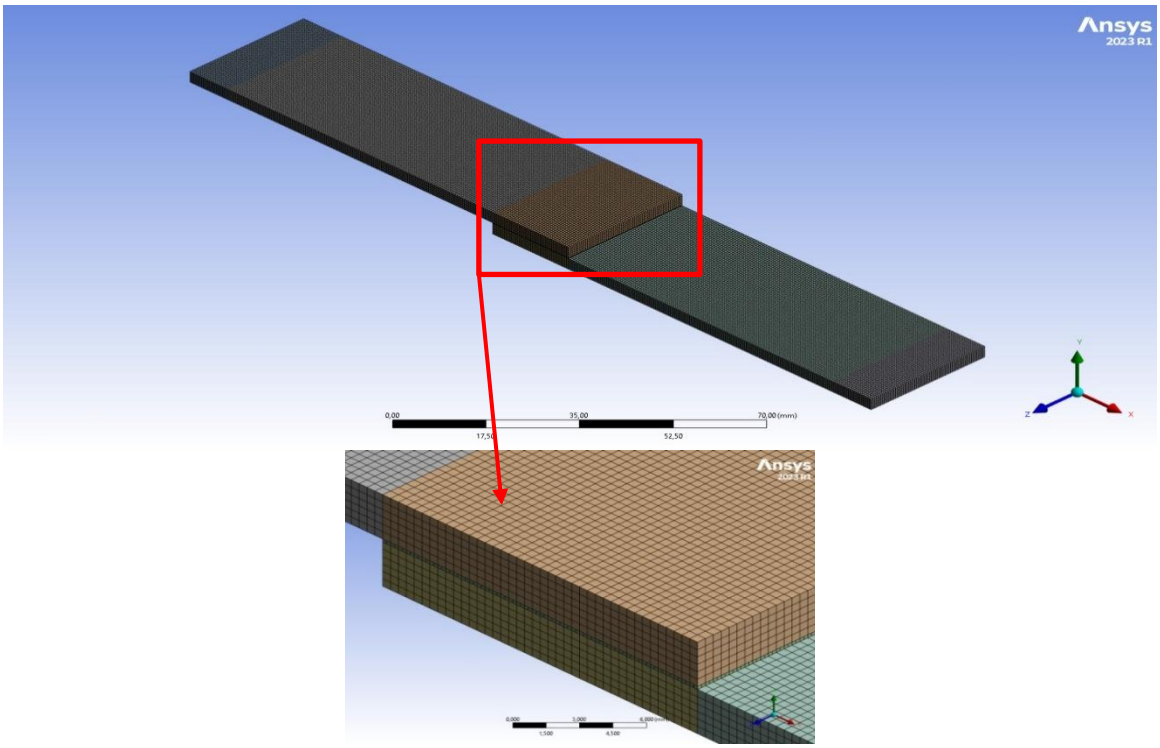
Çizelge 3. Kullanılan Malzemelere Ait Mekanik Özellikler

ÖZELLİKLER	MALZEME	
	Yapı Çeliği	**Neoxil CE92 N8**
Elastisite Modülü (MPa) - E	200000	4152
Çekme Mukavemeti (MPa) - σ_u	460	24,7
Akma Mukavemeti (MPa) - σ_y	250	-
Kayma Modülü (MPa) - G	76923	1540
Poisson oranı - υ	0,30	0,35

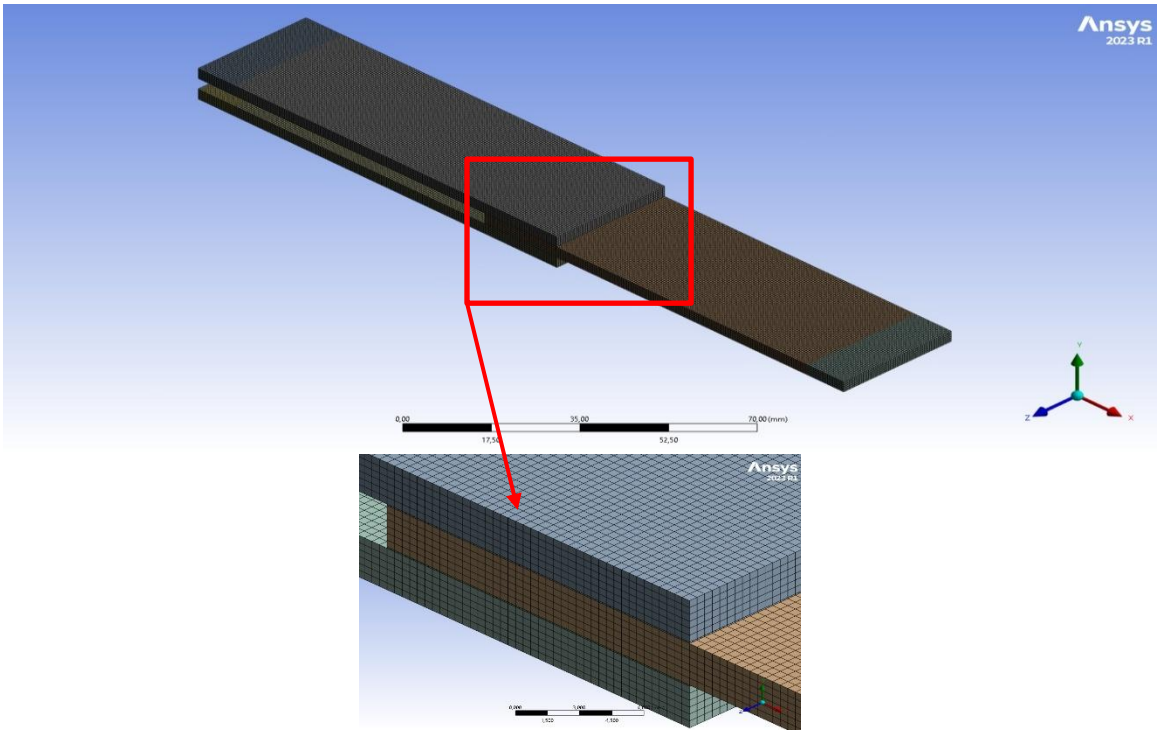
2.3. Sonlu Elemanlar Modeli

Sonlu elemanlar modeli, ANSYS Workbench 2023 R1 yazılımı kullanılarak oluşturulmuştur. Modelde kullanılan tüm bileşenler katı elemanlar ile temsil edilmiştir. Analizlerde karşılaştırılabilir sonuçlar elde edebilmek amacıyla tüm modellerde aynı ağ yapısı kullanılmıştır. Yapışan levhalar ve takviye elemanı için 0,5 mm, yapıştırıcı tabakası için 0,25 mm olarak seçilmiştir. Bu yaklaşım ile yapıştırıcı tabakasında oluşan gerilme dağılımlarının daha doğru şekilde sonuçlanması amaçlanmıştır. Görsel 3'te tek bindirmeli bağlantı ve Görsel

4’te çift bindirmeli bağlantı modelinin meshlenmiş görüntüsü yer almaktadır. Ağ yapısı, tüm analizlerde sabit tutularak diğer parametrelerdeki değişimlerin sonuçlar üzerindeki etkisinin doğrudan karşılaştırılabilir olması sağlanmıştır.



Görsel 3. Tek Bindirmeli Bağlantı Analizinin Mesh Yapısı

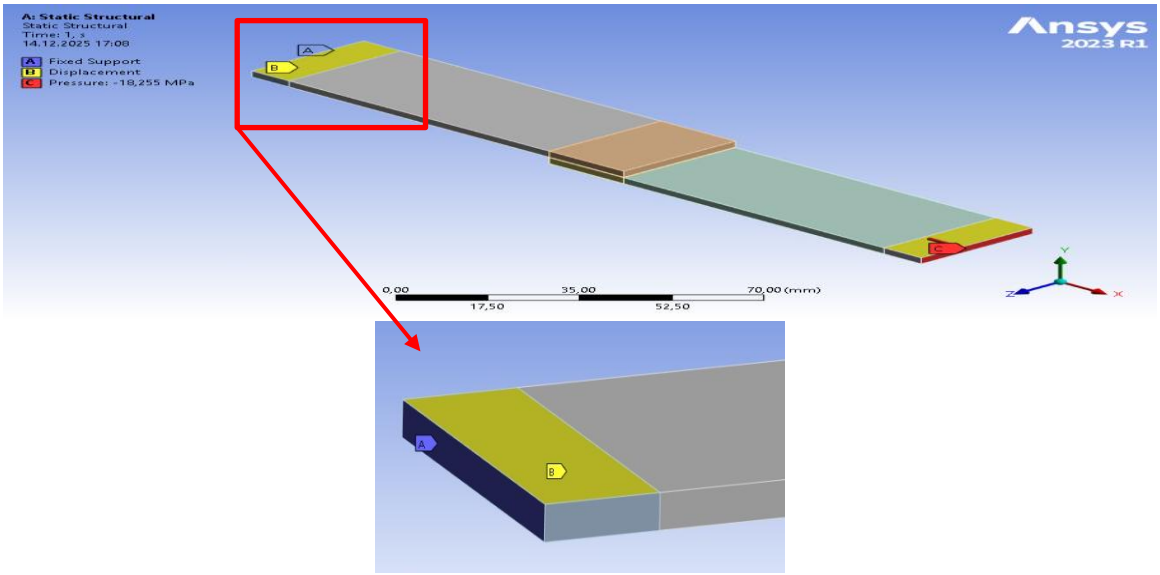


Görsel 4. Çift Bindirmeli Bağlantı Analizinin Mesh Yapısı

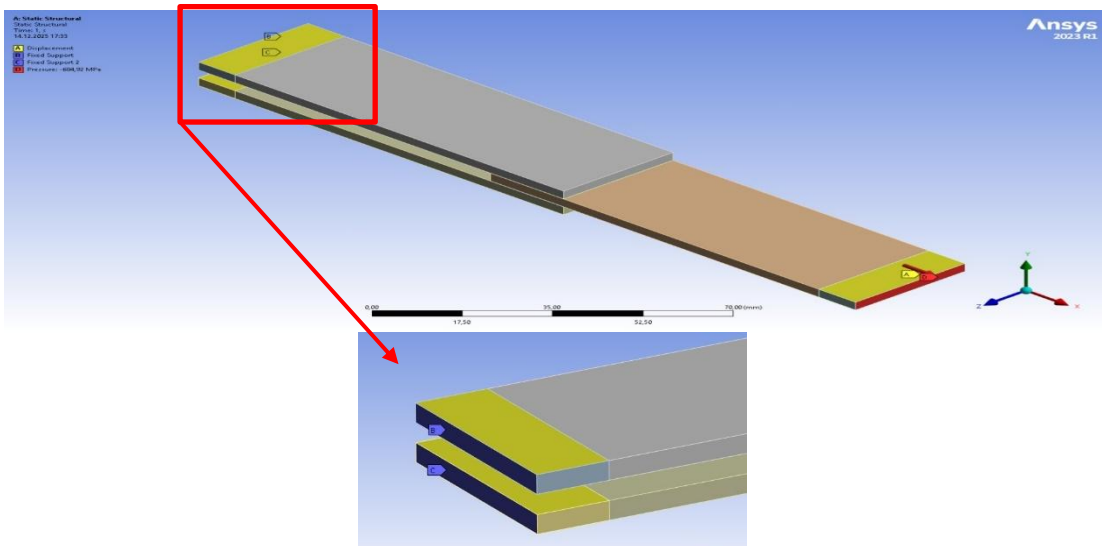
2.4. Sınır Şartları ve Yükleme Koşulları

Bu çalışmanın başlangıç aşamasında, tek bindirmeli (SL) ve çift bindirmeli (DL) yapıştırıcı bağlantıların mekanik davranışları karşılaştırmalı olarak incelenmiştir. Bu amaçla her iki bağlantı tipi için sınır şartları ve yükleme koşulları aynı olacak şekilde tanımlanmıştır. Böylece SL ve DL bağlantıların yük aktarım mekanizmalarının karşılaştırılabilir bir çerçevede değerlendirilmesi amaçlanmıştır. Tüm analizler statik koşullar altında yapılmıştır.

Her iki bağlantı tipi için sınır şartları ve yükleme koşulları, eksenel çekme durumunu temsil edecek şekilde tanımlanmıştır. Görsel 5' te SL modelinde, bağlantı A yüzeyinden ankastre mesnetlenmiştir ve B yüzeylerinden rijit gövde hareketlerini önlemek amacıyla y yönündeki yer değiştirmesi kısıtlanmıştır (Uy=0). C yüzeyinden ise eksenel çekme yükü uygulanmıştır. Görsel 6' da DL modelinde, bağlantı B ve C yüzeylerinden ankastre mesnetlenmiştir ve A yüzeylerinden rijit gövde hareketlerini önlemek amacıyla y yönündeki yer değiştirmesi kısıtlanmıştır (Uy=0). D yüzeyinden ise eksenel çekme yükü uygulanmıştır.



Görsel 5. Tek Bindirmeli Bağlantı Analizinin Sınır Şartları



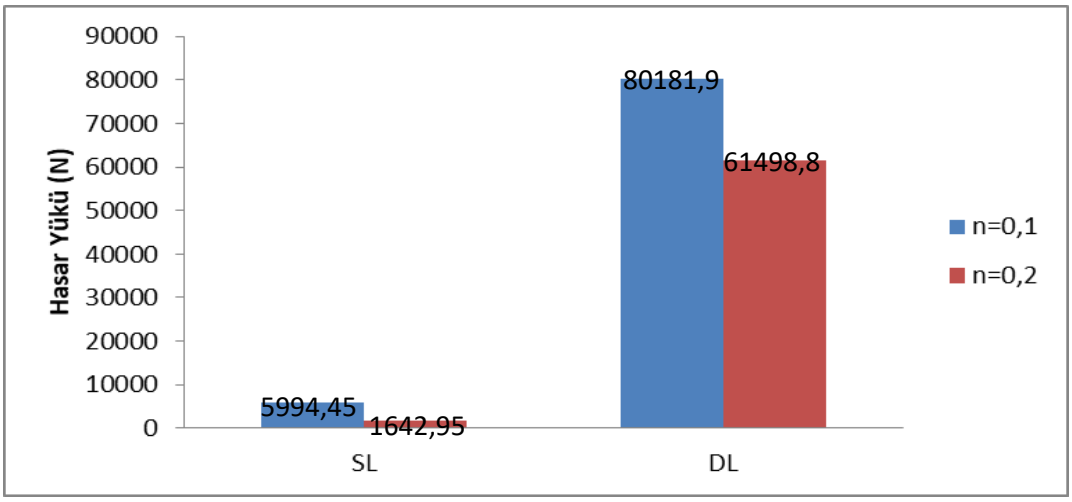
Görsel 6. Çift Bindirmeli Bağlantı Analizinin Sınır Şartları

2.5. Hasar Yükünün Hesaplanması

Hasar yükünün belirlenmesinde, yapıştırıcı tabakasında elde edilen gerilme sonuçları esas alınmıştır. Sonlu elemanlar analizlerinden hesaplanan eşdeğer gerilme değerleri, Von Mises yaklaşımı kullanılarak değerlendirilmiş ve bu değerin yapıştırıcının çekme dayanımına ulaşması hasar başlangıcı olarak kabul edilmiştir.

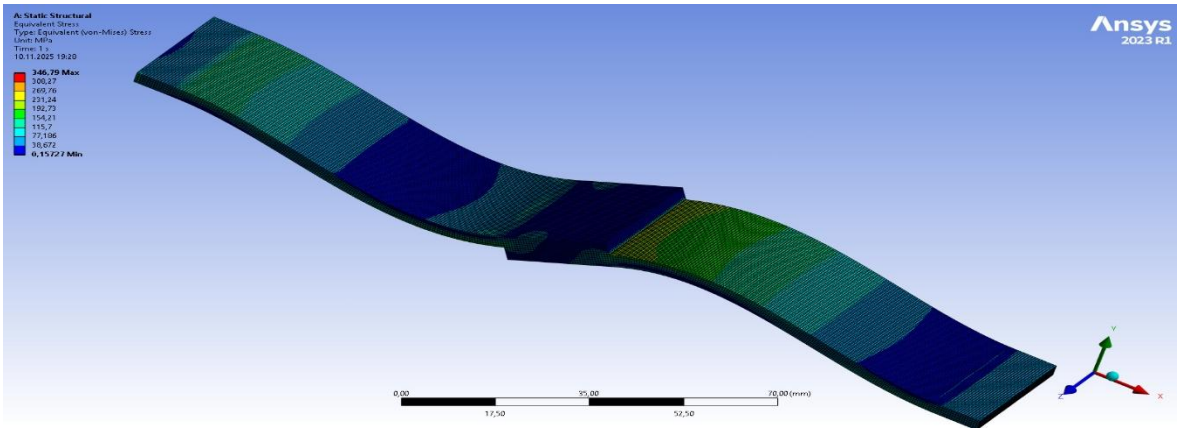
3. SONUÇLAR VE DEĞERLENDİRME

Tek bindirmeli (SL) ve çift bindirmeli (DL) yapıştırıcı bağlantıların mekanik davranışları, sonlu elemanlar analizlerinden elde edilen hasar yükü değerleri üzerinden karşılaştırılmıştır. Görsel 7' de tek bindirmeli ve çift bindirmeli bağlantılar için hesaplanan hasar yükleri karşılaştırmalı olarak sunulmaktadır.

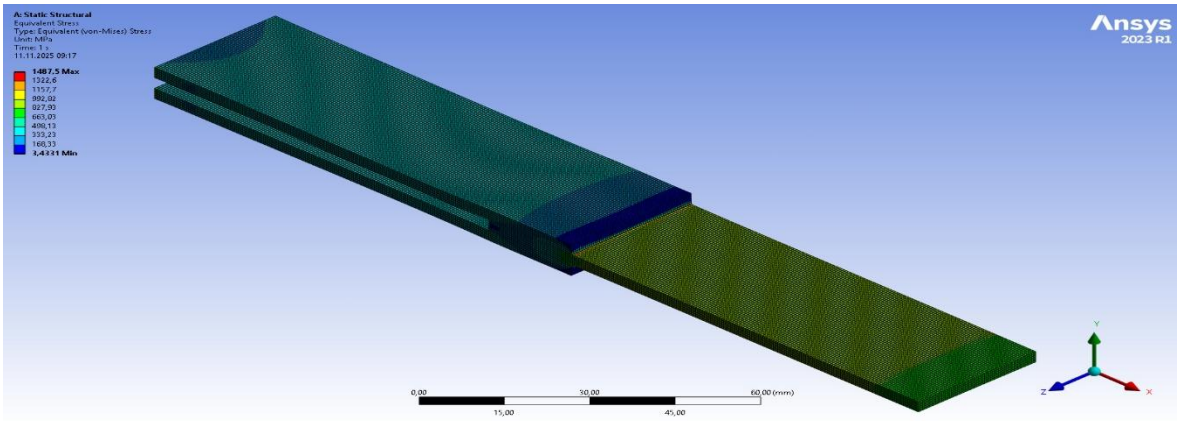


Görsel 7. Tek Bindirmeli (SL) – Çift Bindirmeli (DL) Bağlantılarda Hasar Yükü Karşılaştırması

Görsel 8' de tek bindirmeli yapıştırıcı bağlantıların ve Görsel 9'da çift bindirmeli yapıştırıcı bağlantıların sonlu elemanlar analizi sonucunda elde edilen eşdeğer (Von Mises) gerilme dağılımı gösterilmektedir.

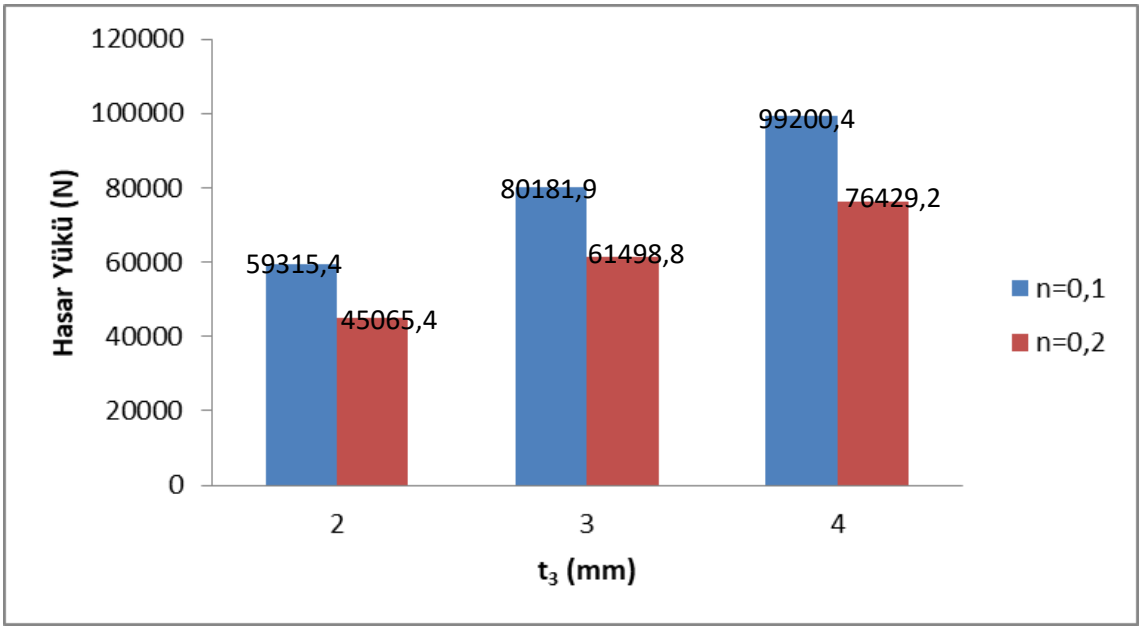


Görsel 8. Tek Bindirmeli Bağlantılarda Von Mises Gerilme Dağılımı



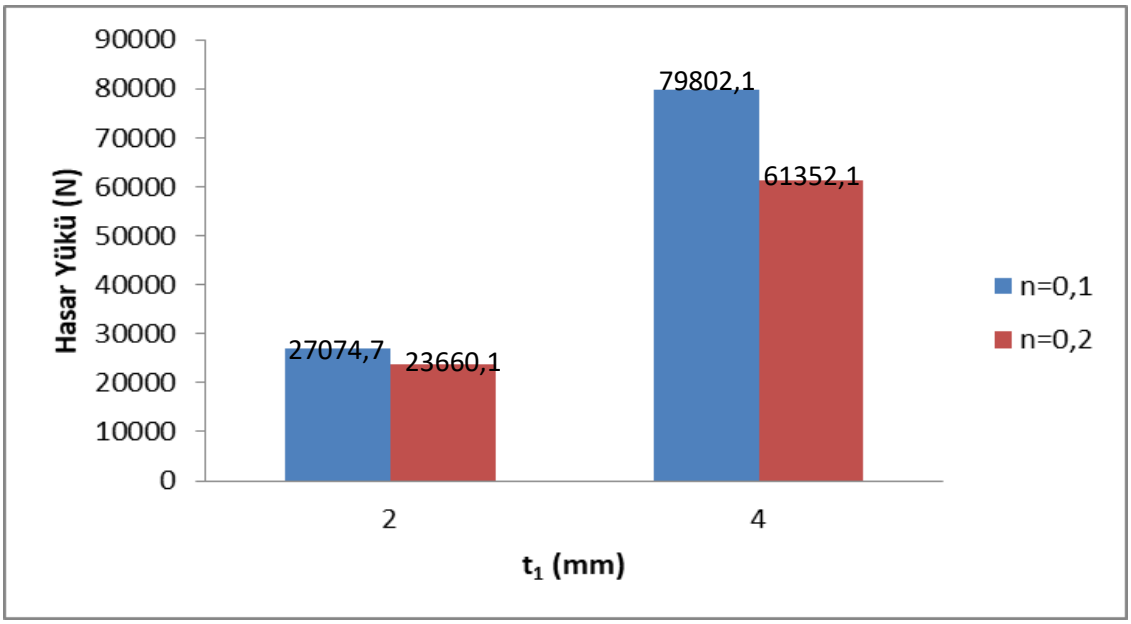
Görsel 9. Çift Bindirmeli Bağlantılarda Von Mises Gerilme Dağılımı

Görsel 10' da üst ve alt yapışan levha kalınlıklarının eşit olduğu (t_1=t_2) ve orta yapışan levha kalınlığının (t_3) değiştirildiği çift bindirmeli bağlantılar için hesaplanan hasar yükleri karşılaştırmalı olarak sunulmaktadır. Her iki yapıştırıcı kalınlığı değeri için de t_3 kalınlığının artmasıyla bağlantının taşıyabileceği maksimum hasar yükünün arttığı görülmüştür.



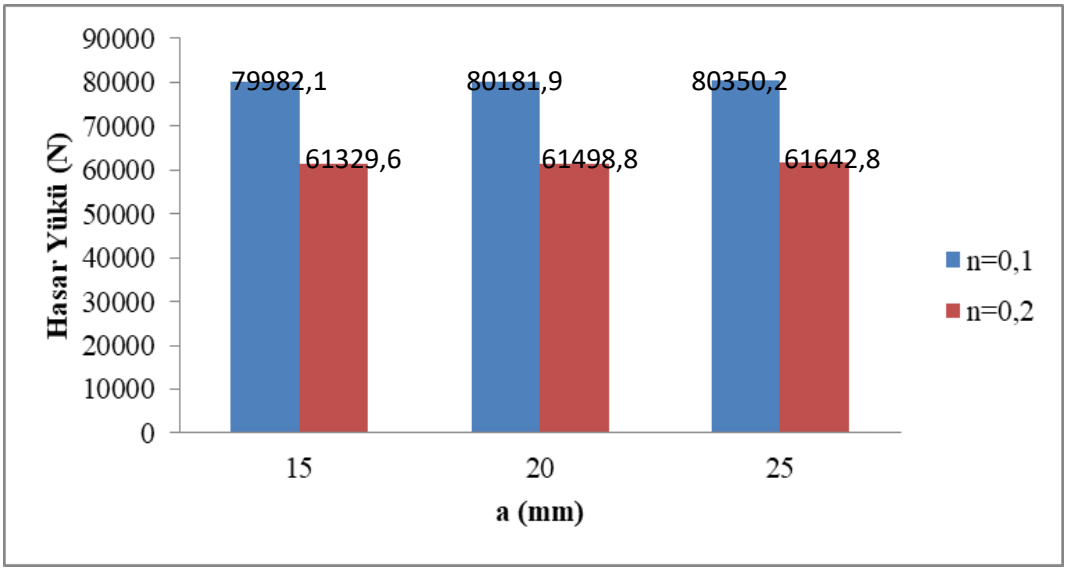
Görsel 10. Çift Bindirmeli Bağlantılarda t_3 Parametresinin Hasar Yüküne Etkisi

Görsel 11' de t_2=4 mm, t_3=3 mm iken üst yapışan levha kalınlığının t_1 hasar yükü üzerindeki etkisi incelenmiştir. t_1 kalınlığının 2 mm' den 4 mm' ye artırılmasıyla bağlantının taşıyabileceği maksimum hasar yükünde belirgin bir artış meydana gelmiştir. Her iki yapıştırıcı kalınlığı değeri için de bağlantının taşıyabileceği maksimum hasar yükünde belirgin bir artış meydana gelmiştir. n=0,1 mm durumunda elde edilen hasar yüklerinin n=0,2 mm durumunda elde edilen hasar yüklerine kıyasla daha yüksek olması, bu durumda bağlantının hasar oluşmadan önce daha fazla yük taşıyabildiğini göstermektedir.



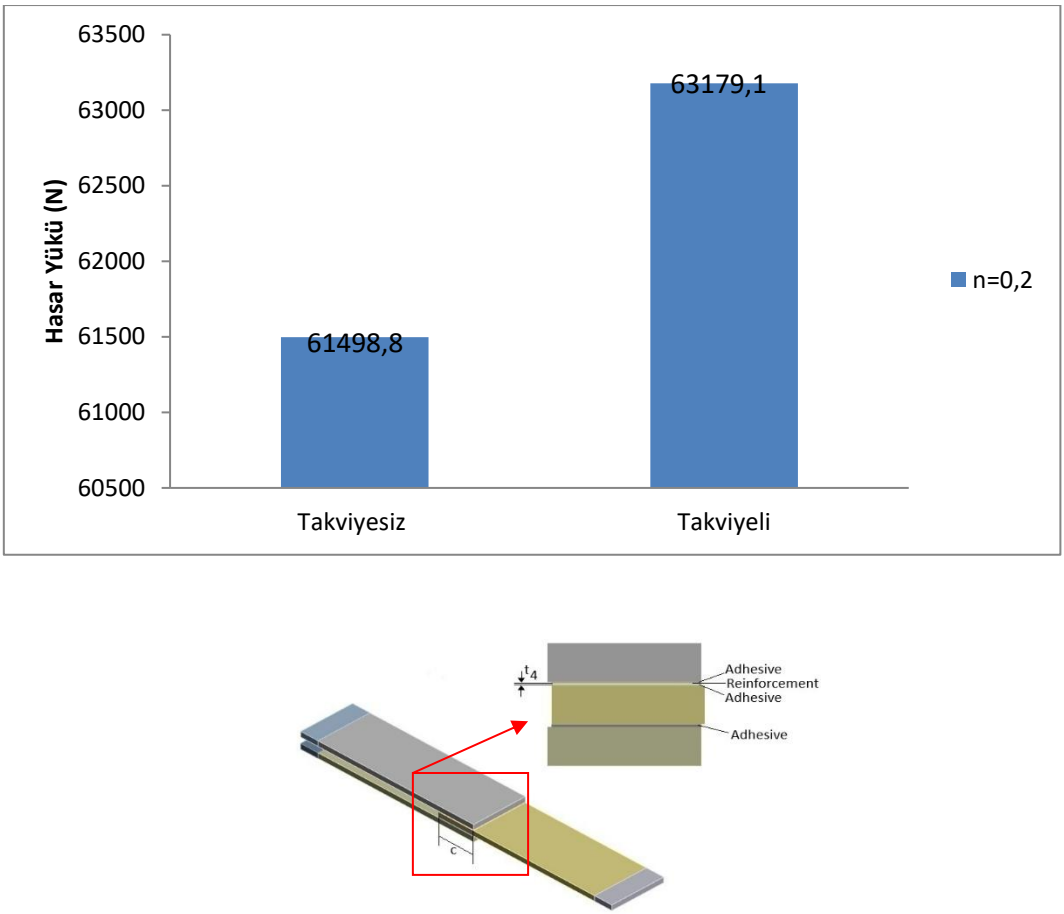
Görsel 11. Çift Bindirmeli Bağlantılarda t_1 Parametresinin Hasar Yüküne Etkisi

Görsel 12' de bindirme mesafesinin hasar yükü üzerindeki etkisi gösterilmektedir. Bindirme mesafesi arttıkça her iki yapıştırıcı kalınlığı için hasar yükünde artış meydana gelmektedir. Ancak bu artış sınırlıdır ve bindirme mesafesi arttıkça artış hızı azalmaktadır.



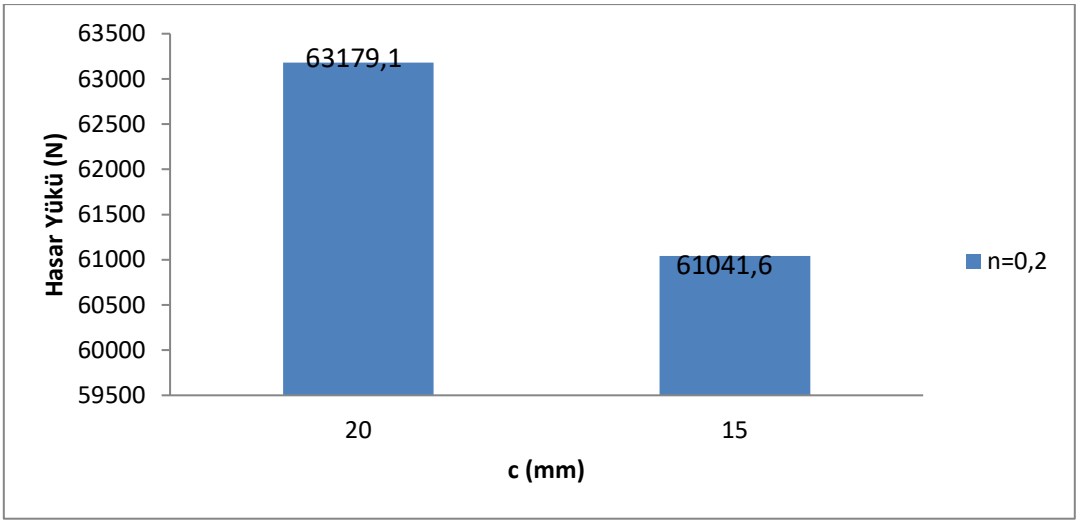
Görsel 12. Çift Bindirmeli Bağlantılarda a Parametresinin Hasar Yüküne Etkisi

Görsel 13' te takviye elemanı kullanımının hasar yükü üzerindeki etkisi gösterilmektedir. Takviye kalınlığı (t_4) 0,05 mm, takviye uzunluğu (c) 20 mm olarak alınmıştır. Takviyenin uygulanmasıyla bağlantının taşıyabileceği maksimum hasar yükünün %2,7 oranında arttığı görülmektedir. Bu artış, takviye elemanının bindirme bölgesinde yük aktarımını iyileştirerek yapıştırıcı tabaka üzerindeki gerilme yoğunlaşmalarını azaltmasıyla açıklanabilir.



Görsel 13. Çift Bindirmeli Bağlantılarda Takviye Elemanının Hasar Yüküne Etkisi

Görsel 14' te bindirme mesafesi a=20 mm sabit tutulduğunda, takviye uzunluğunun (c) hasar yükü üzerindeki etkisi incelenmiştir. a=c=20 mm durumunda bağlantının taşıyabileceği maksimum hasar yükü 63179,1 N olarak bulunurken, c=15 mm' ye düşürüldüğünde hasar yükü 61041,6 N seviyesine düşmektedir. Bu durum takviye uzunluğunun artmasının yük aktarımını geniş bir alana yaydığını ve bağlantının taşıma kapasitesini artırdığını gösterir.



Görsel 14. Çift Bindirmeli Bağlantılarda Takviye Uzunluğunun Hasar Yüküne Etkisi

4. GENEL DEĞERLENDİRME VE SONUÇLAR

Bu çalışmada, yapıştırıcı ile birleştirilmiş çift bindirmeli bağlantıların mekanik davranışı sonlu elemanlar yöntemiyle sayısal olarak incelenmiştir. Hasar yükleri, yapıştırıcı tabakasında oluşan eşdeğer Von Mises gerilmelerinin yapıştırıcının çekme dayanımına ulaşması kriteri esas alınarak belirlenmiştir.

Çift bindirmeli yapıştırıcı bağlantılar, simetrik geometrisi sayesinde eksen kaçıklığını ortadan kaldırarak ve yükün yapıştırıcı tabakalar üzerinden daha homojen bir şekilde aktarılmasını sağladığından tek bindirmeli bağlantılara göre daha yüksek hasar yükleri taşımaktadır.

Orta yapışan levha kalınlığının (t3) artırılması, bağlantının taşıyabileceği maksimum hasar yükünü artırmaktadır.

Yapışan levha kalınlıklarının artırılması, bağlantı rijitliğini yükselterek bağlantı performansını olumlu yönde etkilemektedir.

Yapıştırıcı kalınlığının bağlantının rijitliği ve hasar yükü üzerinde etkili olduğu ve yapıştırıcı kalınlığı düşürüldükçe bağlantının daha yüksek hasar yükleri taşıyabildiği görülmektedir.

Bindirme mesafesinin artırılması çift bindirmeli bağlantıların hasar yükünü artırmaktadır ancak belirli bir bindirme mesafesinden sonra bu artış sınırlı kalmaktadır.

Takviye elemanı kullanımı, bindirme bölgesinde yük aktarımını iyileştirerek yapıştırıcı tabaka üzerindeki gerilme yoğunlaşmalarını azaltmıştır ve bağlantının hasar yükünü artırarak taşıma kapasitesini iyileştirmektedir.

Takviye uzunluğunun azaltılması, bağlantının taşıyabileceği maksimum hasar yükünde azalmaya neden olmaktadır.

Sonuç olarak, çift bindirmeli yapıştırıcı bağlantıların uygun geometrik parametreler ve takviye elemanı kullanımı ile mekanik performanslarının iyileştirilebileceği ve bu bağlantı tipinin yapısal uygulamalarda güvenle tercih edilebileceği görülmüştür.

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COMPARATIVE STUDY OF LASER SURFACE TEXTURING AND THERMAL OXIDATION ON TI6AL4V TRIBOLOGY

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ABSTRACT

Ti6Al4V alloys offer an attractive combination of high specific strength and corrosion resistance, yet their use in many sliding applications is limited by poor tribological performance. In this study, four different surface conditions were comparatively investigated to reveal the effects of applying laser surface texturing (LST) and thermal oxidation (TO) either individually or sequentially on Ti6Al4V: (i) LST, (ii) LST followed by TO, (iii) TO and (iv) TO followed by LST. Friction and wear behaviors under dry sliding conditions were examined together with surface morphology and oxide phase formation. Previous studies have shown that LST can improve the bonding of the oxide film to the substrate. Similarly, it has been reported that under appropriate TO conditions, well-adhered (TiO2) films can provide high load-bearing capacity, leading to a pronounced reduction in wear rate. Within the scope of this work, dry tribological tests were performed to determine the role of the processing sequence (whether LST is applied before TO or vice versa) on oxide-film integrity and tribological properties. After testing, comparative evaluations were conducted in terms of wear rates, average coefficients of friction, and surface morphologies.

Keywords: Ti6Al4V, laser surface texturing, thermal oxidation, tribology.

1. INTRODUCTION

Extensive research has explored laser surface texturing and thermal oxidation as prominent surface modification techniques to enhance the tribological performance of Ti6Al4V (Joshi & Dahotre, 2017). Laser surface hardening, a variant of laser surface texturing, has been shown to induce a self-quenching mechanism, forming a hard-martensitic layer and beneficial residual compressive stresses that collectively impede crack initiation and propagation during wear (Wang et al., 2019). Further investigation into laser-treated samples revealed a smooth, glossy surface devoid of cracks, characterized by an approximately 10 μm thick remelted, martensitic top layer significantly hardened by oxygen solid solution (Kümmel et al., 2020). This hardening effect is attributed to the absorption of oxygen during laser processing, which forms titanium oxides and solid solutions that impede dislocation movement and increase surface hardness (Wang et al., 2020). Moreover, laser texturing has been observed to reduce micro-cracks and produce smoother wear surfaces compared to untreated Ti6Al4V, suggesting a milder wear mechanism.The tribological benefits of laser surface texturing is often linked to its ability to create reservoirs for wear debris, thereby preventing abrasive wear and reducing the coefficient of friction. Furthermore, micro-texturing processes have been identified as effective in improving surface lubrication and overall tribological performance for biomedical applications, although optimized geometric parameters for such textures remain an active area of research (Woźniak et al., 2024). Conversely, thermal oxidation provides a distinct method of surface modification, promoting rapid oxidation and the formation of a thick, non-adherent oxide layer on a diffusion-hardened subsurface (Philip et al., 2019). This oxidation process creates a hard, brittle titanium dioxide layer on the surface, which, despite its initial non-adherence, contributes to wear resistance by providing a sacrificial layer that can reduce direct metal-to-metal contact (Sun et al., 2023). However, the material at the rim of laser-induced textures can melt, increasing the risk of abrasive particle release during contact, which can subsequently escalate wear (Ranuša et al., 2024). Surface melting during laser treatment, as observed in some studies, can be detrimental to the mechanical and tribological properties of the material, leading to a deterioration of performance (Wang et al., 2020).

2. MATERIALS AND METHODS

Ti–6Al–4V alloy specimens were used as the substrate material. The specimens were prepared in the form of plate with dimensions of 10 mm × 10 mm × 10 mm. Prior to surface treatments, all samples were mechanically ground using SiC papers and subsequently polished. The specimens were then ultrasonically cleaned in ethanol, dried under air, and stored in a clean container until processing.

Four different surface conditions were comparatively investigated to evaluate the effect of processing sequence:

(i) **LST (L2)**: laser surface texturing,
(ii) **LST + TO (L2O)**: laser surface texturing followed by thermal oxidation,
(iii) **TO (O)**: thermal oxidation,
(iv) **TO + LST (OL2)**: thermal oxidation followed by laser surface texturing.

For clarity, the groups were denoted as [LST], [LST+TO], [TO], and [TO+LST], respectively. All samples were subjected to identical cleaning procedures before and after each processing step.

Laser surface texturing was performed using a laser. The texture geometry consisted of dimples arranged in a square pattern. The principal texture parameters were: feature width 100 µm, pitch 100 µm. Processing parameters were set to a laser power of 20 W with pulse, repetition rate 20 kHz, scanning speed 1000 mm/s. After texturing, samples were cleaned ultrasonically in ethanol to remove loose debris and re-dried prior to subsequent oxidation.

Thermal oxidation was carried out in a furnace under air atmosphere at 700 °C for 25 h. Cooling was conducted by furnace cooling to room temperature. After oxidation, the samples were lightly rinsed in ethanol and dried prior to characterization and tribological testing. To isolate sequence effects, the same oxidation parameters were applied to both TO and LST + TO conditions.

Surface topography was examined using stylus profilometer. Arithmetic mean roughness (Ra) was measured at 4 different locations per specimen. Texture depth and feature geometry were verified from 2D profiles using profilometer. Processed surfaces and worn surfaces were characterized by optical microscopy.

Dry sliding tests were conducted using a ball-on-disk at room temperature. The counterbody was AISI 52100 steel, with a diameter of 3. Prior to testing, both sample and counterbody were cleaned with ethanol and dried. The tests were performed under a normal load of 2 N, sliding speed of 3 cm/s, and total sliding distance of 50 m. The coefficient of friction (COF) was recorded continuously at a sampling rate of 10 Hz. For each surface condition, tests were repeated n = 3 times to ensure reproducibility.

After tribological testing, wear tracks were examined by optical microscopy and their wear volumes were quantified using profilometer. Wear volume (V) was obtained by integrating the cross-sectional area of the wear track (A) along the track length (L), i.e.,

$$V=A\times L$$

3. RESULTS AND DISCUSSIONS

Figure 1a shows that the LST-treated surface contains dimples arranged in a regular square array, yielding a textured morphology consistent with the targeted characteristic feature size/pitch of approximately 100 µm. Optical glare is visible along the dimple rims, and a fine particulate appearance can be distinguished around the features. Such a “rim build-up/re-solidified ring plus fine debris” morphology is a typical outcome in laser texturing, depending on the applied heat input. From a tribological perspective, these regularly distributed dimples can act as reservoirs that trap wear debris during dry sliding, thereby mitigating third-body abrasion and reducing the effective contact area. Consequently, they can contribute to controlling friction and wear, as frequently reported in the literature. In Figure 1b, for the specimen subjected to TO in air at 700 °C for 25 h after LST, traces of the dimple pattern remain visible; however, the overall surface exhibits darker coloration and a heterogeneous tonal distribution (bluish-brown regions). This appearance suggests that oxidation after texturing more extensively covers the surface and that oxide growth around the dimples may vary locally. Under thermal oxidation conditions comparable to those used in this study, the formation of a TiO_2-dominant oxide layer together with a diffusion-hardened subsurface region on Ti–6Al–4V has been reported, which can enhance wear resistance. In this group, partial “masking” or infilling of the texture by oxides may limit the debris-trapping and contact-area reduction functions of the dimples, providing a plausible mechanism for why friction and wear performance may not always improve as expected. Figure 1c shows that the surface treated only by TO presents a more homogeneous appearance on a non-textured topography; although dark patches and fine linear marks are locally observed, no pronounced macro-texture is present. Thermal oxidation in air at relatively high temperatures such as 700 °C has been reported to form a hard oxide layer (predominantly TiO_2 in many studies) and an oxygen diffusion zone in titanium alloys, increasing load-bearing capacity and reducing wear under dry sliding. However, in the absence of texturing, the frictional response is governed more strongly by oxide-film continuity and adhesion, as well as by the nature of any third-body layer formed during testing. Therefore, even if TO alone provides improved wear resistance, its effect on COF can remain system-dependent. In Figure 1d, where TO was applied prior to LST, the dimples become clearly re-defined and the square array appears highly regular. This observation indicates that LST can locally remove and/or reshape material on an oxidized surface.

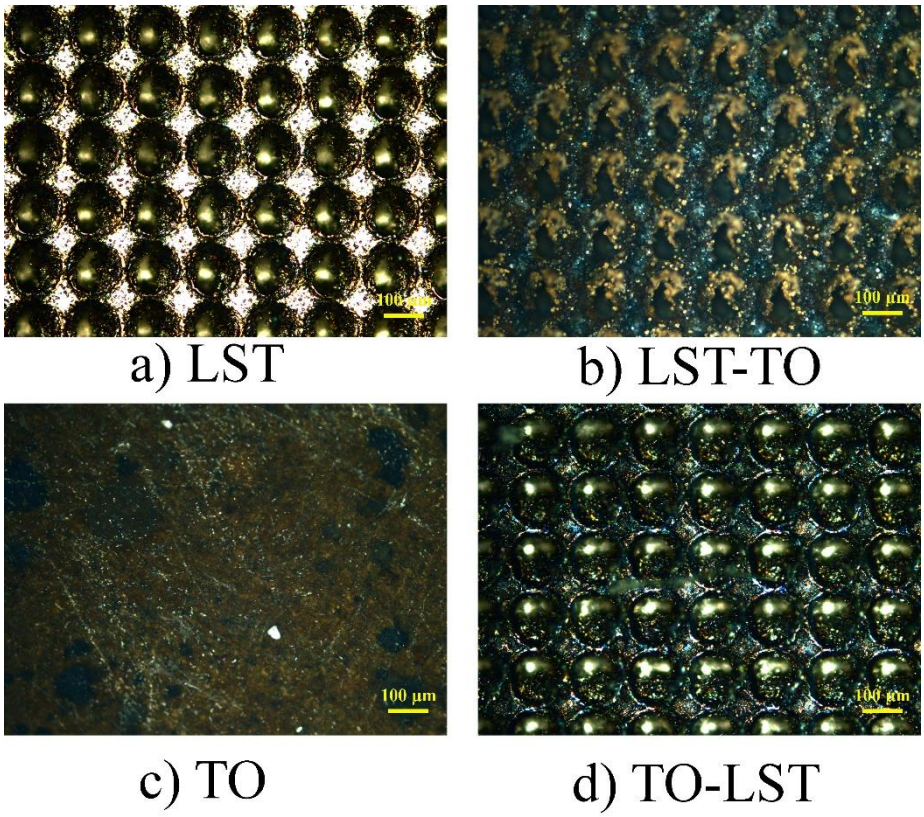


Figure 1. Surface-treated specimens.

Figure 2 shows that the processing sequence markedly changes the worn-surface morphology. For the LST specimen (a), the wear track crosses the textured region and a considerable portion of the dimples remains distinguishable. The accumulation of debris along the track suggests that the dimples can act as reservoirs under dry sliding and help manage third-body particles. In the LST–TO condition (b), the texture becomes largely masked, while bright, fragmented island-like regions indicate pronounced local accumulation and film removal. This appearance is consistent with a scenario where the oxide layer locally loses integrity, detaches, and contributes to a third-body layer. For the TO specimen (c), a distinct and continuous wear ring with a bright, heavily affected band suggests progressive removal and transport of the hard oxide, accompanied by debris build-up along the track, which is compatible with tribo-layer formation during sliding on thermally oxidized surfaces. In the TO–LST specimen (d), the dimples appear more clearly preserved within the worn region and the surrounding area looks comparatively more uniform, implying that the texture may have retained its debris-control and effective contact-area reduction functions and that oxide or tribo-layer damage might have remained more limited under the applied test conditions.

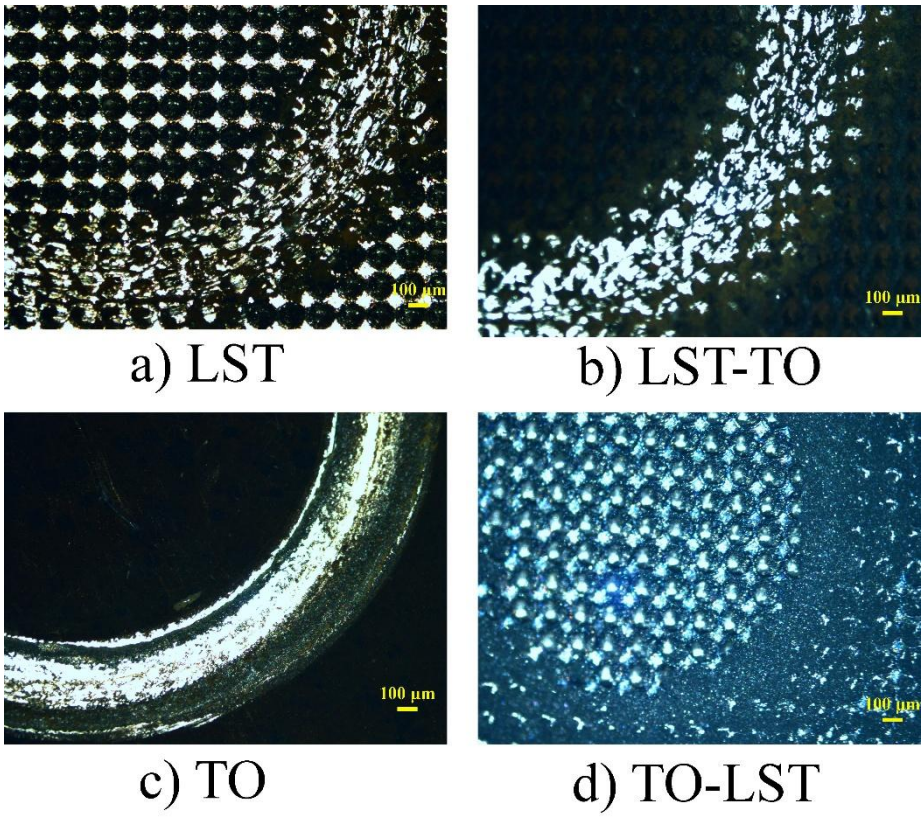


Figure 2. Worn surface images of the surface-treated specimens.

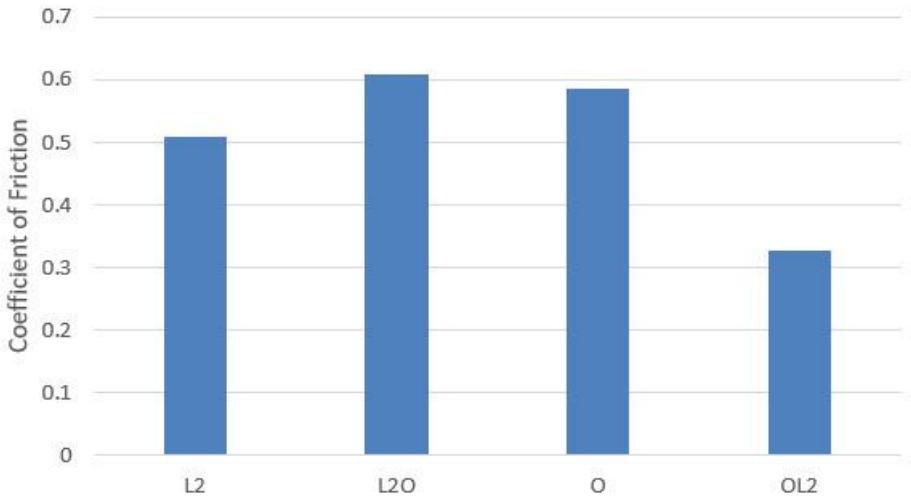


Figure 3. Average surface roughness values of the specimens.

The wear volume data in Figure 4 reveals a clear influence of surface treatment sequence on wear resistance. The LST+TO specimen shows the highest wear volume, followed by LST, while TO and TO + LST exhibit significantly lower values. This trend indicates that thermal oxidation, whether applied before or after laser texturing, markedly improves wear resistance by forming a hard TiO_2-based oxide layer and an oxygen-enriched diffusion zone that enhance surface hardness and load-bearing capacity. The slightly superior performance of the TO + LST

condition suggests that applying laser texturing after oxidation helps maintain debris-trapping features while minimizing oxide delamination, thus achieving the lowest wear volume among all conditions. These results align with prior studies reporting that the synergy of surface hardening from oxidation and micro-reservoir formation from texturing can substantially reduce material loss under dry sliding conditions.

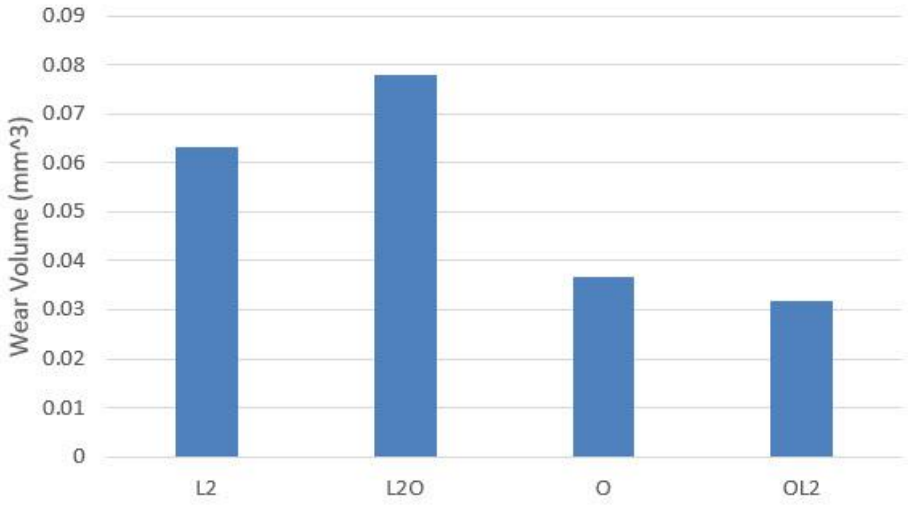


Figure 4. Wear volume values of the specimens.

The average values read from the COF graph (Figure 4) are L2: 0.509**,** L2O: 0.609**,** O: 0.585**,** and OL2: 0.328. Accordingly, the lowest friction was obtained for the OL2 condition; for instance, the COF decreased by 46.5% when transitioning from L2O to OL2. This trend is consistent with literature findings indicating that the micro-dimples/textures produced by LST can trap wear debris at the sliding interface, thereby reducing third-body abrasion and stabilizing friction. In addition, thermal oxidation is reported to improve tribological behavior by forming predominantly a rutile TiO_2 layer and an oxygen diffusion zone on titanium surfaces; however, its effect on COF can vary depending on the counterbody and test conditions. The relatively high COF observed for the O and L2O conditions in this study is therefore consistent with this condition-dependent behavior.

4. CONCLUSIONS

In this study, the tribological response of Ti–6Al–4V under dry sliding was comparatively evaluated for four surface conditions produced by laser surface texturing (LST) and thermal oxidation (TO), applied individually or sequentially (LST, LST+TO, TO, and TO+LST), using a ball-on-disk configuration against AISI 52100 steel (2 N, 3 cm/s, 50 m). The results demonstrate that the processing sequence is critical. The lowest friction was achieved for TO+LST (OL2) with an average COF of 0.328, corresponding to a 46.5% reduction compared with LST+TO (L2O) (0.609 to 0.328). Similarly, the wear volume was minimized in the TO+LST condition, representing a 59.4% decrease relative to LST+TO. Optical microscopy further indicated that the textured features in TO+LST remained more clearly preserved within the wear track, whereas LST+TO tended to show partial masking of the texture and a more

heterogeneous worn-surface appearance, consistent with less stable surface integrity during sliding. Overall, under the selected parameters, applying LST after TO provided the most favorable combination of low friction and low material loss, while LST followed by TO resulted in the poorest tribological performance..

ACKNOWLEDGEMENT

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NUMERICAL ANALYSIS OF THE CHANGE IN STABILITY BEHAVIOR OBSERVED IN WASHING MACHINES DEPENDING ON THE CONFIGURATION OF DAMPING ELEMENTS

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ABSTRACT

In front-loading washing machines, the main drive mechanism operates through an electric motor that transmits torque to the drum via a belt-driven pulley system. The generated motor torque is transferred through the pulley to a spider arm rigidly connected to the shaft, enabling drum rotation under various operating conditions. During the spin cycle, the drum reaches high rotational speeds to enhance moisture extraction; however, the resulting increase in dynamic excitation leads to elevated vibration and acoustic responses. In the medium-speed range, commonly identified as the resonance band, displacement amplitudes increase significantly, creating critical risks such as tub–cabinet contact and increased dynamic force transmission to the machine structure.

To address these issues, a three-stage improvement methodology based on rigid body motion modeling in the NX Motion environment was implemented to enhance the dynamic behavior of the drum–suspension system. In the first stage a parametric design space consisting of six variables—four independent and two dependent—was defined, and 135 distinct design configurations were evaluated using multibody dynamics simulations. Key parameters

included spring stiffness, number and location of springs, damper connection angle, damping coefficient, and number of dampers.

In the second stage, displacement and reaction force outputs obtained from NX Motion simulations were statistically analyzed using Minitab to identify dominant parameters and interaction effects influencing vibration performance. The third stage focused on system-level variations, including alternative damper connection geometries and different operating scenarios, to improve robustness across a wide speed range. Although certain configurations exhibited superior vibration attenuation, increased component count and assembly complexity limited their suitability for mass production. Consequently, an optimized three-damper/two-spring suspension architecture is proposed, achieving the required dynamic performance while reducing high-cost components and providing a measurable manufacturing cost advantage.

Keywords: Washing Machine, Vibration, Acoustics, NX Motion, Rigid Body Motion, Parametric Optimization

ÇAMAŞIR MAKİNELERİNDE ORTAYA ÇIKAN STABİLİTE DAVRANIŞININ SÖNÜMLEME ELEMANLARININ KONFİGÜRASYONUNA BAĞLI DEĞİŞİMİNİN SAYISAL ANALİZİ

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ÖZET

Önden yüklemeli çamaşır makinelerinde ana tahrik mekanizması, kayış tahrikli kasnak sistemi aracılığıyla tambura döndürme momenti aktaran bir elektrik motoru ile çalışmaktadır. Motor torku, kasnak üzerinden mile bağlı flanş koluna iletilerek tamburun farklı çalışma koşullarında dönmesi sağlanır. Sıkma döngüsü sırasında tamburun yüksek devirlere ulaşması, sistemdeki dinamik uyarımı artırmakta ve buna bağlı olarak titreşim ve akustik seviyeler yükselmektedir. Özellikle rezonans bandı olarak tanımlanan orta hız bölgelerinde yer değiştirme genliklerinin büyümesi, kazan–gövde teması riski ile makine gövdesine iletilen kuvvetlerin artmasına neden olmaktadır.

Bu çalışmada, tambur–süspansiyon sisteminin dinamik davranışını iyileştirmek amacıyla NX Motion ortamında katı cisim hareketi (rigid body motion) yaklaşımına dayalı üç aşamalı bir metodoloji uygulanmıştır. İlk aşamada dört bağımsız ve iki bağımlı olmak üzere toplam altı tasarım değişkenini kapsayan parametrik bir tasarım uzayı oluşturulmuş ve 135 farklı tasarım konfigürasyonu için çoklu cisim dinamiği simülasyonları gerçekleştirilmiştir. Yay katsayısı, yay sayısı ve konumu ile sönümleyici bağlantı açısı, sönüm katsayısı ve sönümleyici sayısının sistem cevabı üzerindeki etkileri incelenmiştir.

İkinci aşamada, simülasyonlardan elde edilen yer değiştirme ve kuvvet çıktıları Minitab kullanılarak istatistiksel olarak analiz edilmiş, kritik parametreler ve etkileşimleri belirlenmiştir. Üçüncü aşamada ise alternatif sönümleyici bağlantı geometrileri ve çalışma senaryoları değerlendirilmiştir. Dört sönümleyici/iki yay mimarisi yerine önerilen üç sönümleyici/iki yay konfigürasyonu, hedeflenen dinamik performansı korurken bileşen sayısını azaltarak maliyet açısından daha uygulanabilir bir çözüm sunmuştur.

Anahtar Kelimeler: Çamaşır Makinesi, Titreşim, Akustik, NX Motion, Rigid Body Motion, Parametrik Optimizasyon

AFET YÖNETİMİNDE SÜRDÜRÜLEBİLİR BİR ÇÖZÜM: ŞEBEKEDEN BAĞIMSIZ GÜNEŞ VE RÜZGÂR ENERJİ DESTEKLİ MOBİL GIDA PİŞİRME VE DAĞITIM ÜNİTESİ TASARIMI

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ÖZET

Afet ve kriz dönemlerinde elektrik altyapısının zarar görmesi, sıcak yemeğe erişimi ciddi ölçüde kısıtlamakta ve insani yardım operasyonlarının etkinliğini azaltmaktadır. Bu çalışma, elektrik şebekesinden tamamen bağımsız çalışabilen, %100 yenilenebilir enerji kaynaklarıyla beslenen güneş enerjili mobil bir gıda pişirme ve dağıtım ünitesinin tasarımını sunmaktadır. Amaç, afet bölgelerinde günlük 500–1000 kişiye sıcak yemek sağlayabilecek, çevresel, sosyal ve ekonomik sürdürülebilirlik ilkelerini bütüncül biçimde karşılayan yenilikçi bir çözüm geliştirmektir.

Tasarım sürecinde fotovoltaik paneller, dikey eksenli rüzgâr türbinleri, yüksek verimli endüstriyel mutfak ekipmanları ve gelişmiş batarya depolama sistemleri birlikte değerlendirilmiştir. 25 kW kurulu güce sahip PV paneller ve 6 kW rüzgâr türbinlerinden oluşan hibrit enerji altyapısı, günlük 140–185 kWh enerji üretimi sağlamaktadır. Sistem bileşenlerinin enerji tüketimi analiz edildiğinde, mobil mutfağın günlük yaklaşık 100 kWh enerjiye ihtiyaç duyduğu belirlenmiş ve pozitif enerji dengesi elde edilmiştir. Bu sonuç, fosil yakıtlı jeneratörlere olan bağımlılığı tamamen ortadan kaldırmakta ve karbon emisyonlarında yaklaşık %85 oranında azalma sağlamaktadır.

Çalışma, hızlı konuşlandırılabilirlik, taşınabilirlik, düşük işletme maliyeti, yüksek enerji verimliliği ve uzun ömürlü bileşenler gibi kriterleri karşılayan sürdürülebilir bir insani yardım modeli ortaya koymaktadır. Ayrıca tasarım, Birleşmiş Milletler Sürdürülebilir Kalkınma Amaçları (SDG 1, 2, 7, 11 ve 13) ile doğrudan uyumlu olup afet sonrası gıda güvenliği, enerji erişimi ve toplumsal dayanıklılık açısından önemli katkılar sunmaktadır. Sonuç olarak, geliştirilen mobil mutfak ünitesi, afet yönetiminde yenilenebilir enerji temelli çözümlerin uygulanabilirliğini güçlendiren, saha kullanımına uygun ve ölçeklenebilir bir model olarak değerlendirilmektedir.

Anahtar Kelimeler: Afet Yönetimi, Gıda Güvenliği, Güneş Enerjisi, İnsani Yardım, Mobil Mutfak, Sürdürülebilirlik

A Sustainable Solution in Disaster Management: Design of an Off-Grid Solar and Wind Energy Supported Mobile Food Cooking and Distribution Unit

SUMMARY

Damage to electrical infrastructure during disasters and crises severely limits access to hot meals and reduces the effectiveness of humanitarian aid operations. This study presents the design of a solar-powered mobile food cooking and distribution unit that can operate completely independently of the electrical grid and is powered by 100% renewable energy sources. The aim is to develop an innovative solution that can provide hot meals for 500–1000 people daily in disaster areas, comprehensively meeting environmental, social, and economic sustainability principles.

During the design process, photovoltaic panels, vertical-axis wind turbines, high-efficiency industrial kitchen equipment, and advanced battery storage systems were evaluated together. The hybrid energy infrastructure, consisting of PV panels with an installed capacity of 25 kW and 6 kW wind turbines, provides a daily energy production of 140–185 kWh. Analysis of the energy consumption of the system components determined that the mobile kitchen requires approximately 100 kWh of energy per day, resulting in a positive energy balance. This result completely eliminates dependence on fossil fuel generators and achieves an approximately 85% reduction in carbon emissions.

The study presents a sustainable humanitarian aid model that meets criteria such as rapid deployability, portability, low operating costs, high energy efficiency, and long-lasting components. Furthermore, the design is directly aligned with the United Nations Sustainable Development Goals (SDG 1, 2, 7, 11, and 13), offering significant contributions to post-disaster food security, energy access, and social resilience. Consequently, the developed mobile kitchen unit is considered a field-ready and scalable model that enhances the applicability of renewable energy-based solutions in disaster management.

Keywords: Disaster Management, Food Security, Solar Energy, Humanitarian Aid, Mobile Kitchen, Sustainability

Giriş ve Amaç

Medeniyetler gelişmeye devam ettiği müddetçe enerji talebi artmaya devam etmektedir, dolayısıyla doğal kaynaklar tükenmekte ve insanlık enerji ihtiyacını karşılayacak yeni yollar aramaya koyulmaktadır. Kısıtlı kaynaklar sebebiyle ise şu dönemlerde enerji kaynaklarında tasarruf ve kaynakların verimli kullanılması yoluyla hızla büyüyen enerji krizi yavaşlatılmaya ve kontrol altında tutulmasıyla yoluyla zaman kazanmak isteniyor [1,2].

2015 Yılında Birleşmiş Milletler tarafından kabul edilmiş bir husus olarak Sürdürülebilir Kalkınma Amaçları mefhumu, günümüzden 2030 yılına kadar zaman içinde barış ve refahın tesis edilmesi için gereken faaliyetlerin çağrısının adıdır [3]. Kabul edilen ve tesis edilmeleri insanlığın refahı itibariyle elzem olan yoksulluk, açlık, sağlıklı ve kaliteli hayat, erişilebilir ve temiz enerji, sürdürülebilir şehirler ve topluluklar gibi 17 ana başlık yayınlamışlardır [4]. İnsani Yardım Standartları ve Asgari Gereksinimler olarak ifade edilen Sphere Projesi su temini, hijyenin sağlanması, gıda güvenliği ve beslenme, barınma ve yerleşim ihtiyaçlarını içermektedir [7].

Malzemelerin atık hâlinde kalmayıp yeni kaynaklara dönüştürülmesi, döngüsel ekonomi olarak ifade edilmektedir. Doğal malzemelerin tekrar tabiata kazandırılması ve sentetik malzemelerin tekrar işlevsel hâlde getirilebilmesidir [5].

Afetler esnasında refah düzeyinin bir nebze de olsa sağlanabilmesi için rüzgâr, güneş enerjisi ve diğer enerji kaynaklarından elde edilen enerji ile temel yiyecek ihtiyaçları karşılanabilmektedir [6]. Güneş enerjisi doğrudan veya dolaylı olarak sera ısıtması, elektrik üretimi, belirli bir alanı soğutma veya ısıtmakta kullanılmaktadır. Junjie Li ve diğerleri, afetler sonrası hayatta kalma ve toparlanma için elektrik şebekelerinin kullanılamadığı yerlerde olmak üzere aydınlatma, telefon ve iletişim cihazlarının kullanılabilmesi, yemek pişirme, sıcak duş, tıbbi alanlarda elektrik sağlayan bir güneş enerjisi sistemi kurmuşlardır. [6] Günümüzde mobil mutfaklar; festivaller, baraj ve yol projelerinde, deprem, sel ve yangın sonrası gıda ihtiyacının sağlanması amacıyla kullanılmaktadırlar.

Tüm bunlardan yola çıkarak afet sonrası elektriğe ulaşımın zor ya da hiç olamaması ve lojistik zorlukları sebepleriyle milyonlarca insana sıcak gıda temini sağlanamamaktadır. Bu çalışmada yenilenebilir enerji kaynakları kullanılarak elektriğe ulaşımın kısıtlı veya hiç olmaması durumlarında, elektrik altyapısından bağımsız, mobil bir gıda pişirme ve dağıtım ünitesi tasarımı hedeflenmiştir. Bu tasarım, çevreci, sosyal ve ekonomik sürdürülebilirlik ilkelerini entegre ederek insani yardım ve insani ihtiyaçların temini noktalarına yenilikçi bir çözüm sunmaktadır.

Kullanılan Materyaller ve Yöntem

Prototip tasarımında şu hususlar göz önünde bulundurulmuştur:

- Güneş panelleri ile enerji üretimi ve batarya depolama sistemi
- Elektrik altyapısından tamamen bağımsız çalışma kapasitesi
- Endüstriyel mutfak ekipmanlarını barındıran tır ve platformu
- Günlük 500-1000 kişiye sıcak yemek hazırlama ve dağıtım kapasitesi
- Enerji verimliliği ve karbon ayak izi minimizasyonu
- Hızlı konuşlandırma ve taşınabilirlik özellikleri
- Çevre koşullarına dayanıklılık ve uzun ömür

Bu çalışmada sıfır emisyon mobil endüstriyel bir mutfak uygulaması için 13.6m uzunluk ve 2.5m yüksekliğe sahip yarı römork şeklinde bir tır ve kasası tasarlanmıştır. Kasa iç genişlik ölçüsü 2.45m ve yüksekliği 2.3 m olarak seçildi. Kasanın sağ ve sol dış kısımlarında servis kapakları ve teknik bölme kapıları düşünüldü. Enerji ihtiyacı için tavan üstüne 400 W güneş panelleri entegre edilecek, park halinde enerji üretimini artırması amacıyla açılabilir mekanizma şeklinde yan kapaklar üzerine güneş panelleri entegre edilecektir.

Yangın riski en düşük, -20°C ile +60°C çalışabilme kabiliyeti dolayısıyla Enerjinin depolanması, anlık yüksek güç gereksinimlerini karşılamak üzere 80 kWh kapasiteli Lityum Demir Fosfat ($LiFePO_4$) batarya ve uzun süreli enerji sürekliliğini desteklemek amacıyla 50 kWh kapasiteli akış bataryasından oluşan hibrit bir depolama sistemi ile sağlanacaktır. Bataryanın korunması, dengelenmesi ve güvenliği çalışmasını sağlayacak şekilde BMS sistemli olarak düşünüldü. Mutfak sisteminden yüksek verim elde edilmesi için indüksiyonlar ocakları kullanılacaktır. Soğuk içecek temini ve soğuk su ihtiyacı için soğuk hava deposu ısı izolasyonlu olacaktır.

Tipik 400W enerji üreten panel alan itibariyle yaklaşık 2m² yer kaplamaktadır. Toplam enerji ihtiyacını karşılamak için 120 ila 130 m² alan ihtiyacı ortaya çıkmaktadır. Dolayısıyla enerji ihtiyacının karşılanması ancak açılır kanatlar üzerine güneş panelleri entegre edilecektir.

Verim olarak %85-90 verimli, hızlı ısınma kabiliyetleri, yüzeyleri ısınmaması sebepleriyle indüksiyonlu ocaklar seçildi. İndüksiyonlu bir pişirme ünitesi saatte 15kW enerji harcamaktadır[8]. Enerji tasarrufları ve normal bir tencereye nazaran %70 daha hızlı pişirme kabiliyetleri dolayısıyla yemek pişirmek için elektrikli basınçlı tencereler seçildi. Saatte 1-2kW enerji harcamaktadırlar[9]. Aydınlatmanın temini LED aydınlatma olarak tasarlandı. Floresan, akkor gibi aydınlatma ürünlerine göre daha az enerji harcaması, ısınmamaları, uzun ömürleri sebepleriyle tercih edildi.
Genel aydınlatma 13.6m boy 2.55m genişliğe sahip alana yapılacaktır.
Alan: 13.6 × 2.55 = 34.68 m²
Hedef Aydınlık Seviyesi →
Genel Ortam: 300-500 lux
Pişirme/Tezgâh Üstü : 500-750 lux
Gerekli Toplam Işık Akısı (Lümen): Toplam lümen = Alan x Lux / (Kullanım faktörü x Bakım faktörü)
Kullanım Faktörü (UF): 0.6
Bakım faktörü (MF): 0.8
UF x MF = 0.48
400 lux hedef aydınlatma için: 34.68 x 400 / 0.48 ≈ 28,900 lm
6,500 lm'lik armatür: 30,000-36,000 / 6,500 = 6 adet
6 armatür x 40W ≈ 240 W

Geceleri ve bulutlu günlerden enerji üretimi desteği için 2 adet 3kW dikey eksenli rüzgâr türbini kullanılacak.
Akış bataryası 50kWh olarak seçildi. Çok uzun döngü ömürlerine sahip 10.000+, enerji ve güç ayrı ayrı ölçeklendirilebilir, elektrolit tankları büyütülerek kapasiteleri artırılabilir, sıcaklık ve kendi kendilerine deşarj hassasiyetleri düşüktür, yaz ve kış depolamaya uygundur.

Tablo 1. Sistem Bileşenleri ve Enerji Tüketimleri

Sistem / Ekipman	**Adet**	**Güç (kW)**	**Açıklama / Verim**
LED Aydınlatma	6 armatür	0.15-0.25	%90 daha az enerji, 300-500 lux
İndüksiyon Ocak	1 (6 göz)	5-15 kW	%85-90 verim, hızlı ve güvenli
Elektrikli Basınçlı Tencere	2	1-2 kW	%70 daha hızlı pişirme
Isı Pompalı Su Isıtıcı	1	2 kW	COP 3.5-4.0 → 8 kW ısı
A+++ Buzdolabı / Dondurucu	1	0.3-0.5	Yüksek verimli, sürekli çalışma
Diğer Küçük Yükler	-	0.3-0.5	Fan, kontrol, sensör, BMS
Toplam Anlık Yük (ortalama)	-	7-10 kW	Pik anlarda 12-15 kW

Tablo 2. Enerji Üretim & Depolama

Sistem	**Kapasite**	
Dikey Eksenli Rüzgâr Türbini	2 x 3 kW	Gece & bulutlu gün desteği
Güneş Enerjisi (PV)	63 x 400 W	Ana elektrik üretim kaynağı (gündüz üretimi)
Lityum Demir Fosfat ($LiFePO_4$) Batarya	80 kWh	-20 °C ile +60 °C çalışma aralığı, 4.000+
Akış Bataryası	50 kWh	Uzun süreli enerji sürekliliği ve acil durumlar için destekleyici depolama

İndüksiyon Ocaklar
Verim: %85-90, Hızlı ısınma, Güvenli (yüzey ısınmaz), Tüketim: 5-15 kW/ocak



Şekil 1. İndüksiyon Ocağı [8]

→Elektrikli Basınçlı Tencereler
%70 daha hızlı pişirme, Enerji tasarrufu, Tüketim: 1-2 kW



Şekil 2. Elektrikli Basınçlı Tencere [9]

→Isı Pompalı Su Isıtıcı
COP 3.5-4.0 (her 1 kW → 3.5 kW ısı), %300+ verimlilik, Tüketim: 2 kW (8 kW ısı çıkışı)



Şekil 3. Isı Pompalı Su Isıtıcı [12]

→LED Aydınlatma
%90 daha az enerji, Tüketim: 150-250W toplam

→Yüksek Verimli Buzdolabı/Dondurucu, A+++ sınıfı
Tüketim: 300-500W



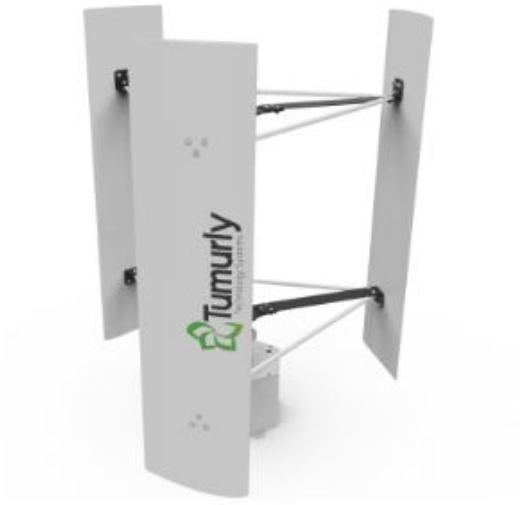
Şekil 4. Yüksek Verimli Buzdolabı, A+++ Sınıfı [13]

Tablo 3. Enerji Dengesi

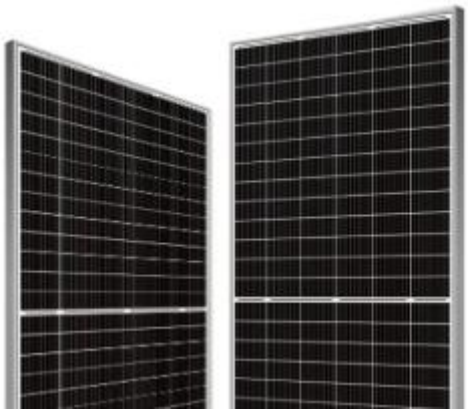
Kaynak	**Kurulu Güç**	**Günlük Üretim**	**Yıllık Üretim**
Güneş Enerjisi (PV)	25 kW	100-125 kWh/gün	36.500 kWh/yıl
Rüzgâr Enerjisi	6 kW	40-60 kWh/gün	18.250 kWh/yıl
Toplam	31 kW	140-185 kWh/gün	55.000 kWh/yıl



Şekil 5. 25 kW Enerjisi Sistemi İçin İnvertör [14]



Şekil 6. Dikey Eksenli Rüzgâr Türbini [10]



Şekil 7. Güneş Enerjisi (PV) Panel [15]

Önerilen sistemde, 25 kW kurulu güce sahip fotovoltaik paneller ile 6 kW kapasiteli dikey eksenli rüzgâr türbinleri birlikte kullanılarak hibrit bir yenilenebilir enerji altyapısı oluşturulmuştur. Fotovoltaik sistemin günlük enerji üretimi 100-125 kWh aralığında olup, yıllık toplam üretimi yaklaşık 36.500 kWh'dir. Rüzgâr türbinleri ise özellikle gece saatlerinde ve düşük güneşlenme koşullarında sisteme katkı sağlayarak günlük 40-60 kWh, yıllık yaklaşık 18.250 kWh enerji üretimi gerçekleştirmektedir.

Bu iki kaynağın birlikte çalışması sonucunda sistemin toplam kurulu gücü 31 kW'a ulaşmakta ve günlük toplam enerji üretimi 140-185 kWh, yıllık toplam üretim ise yaklaşık 55.000 kWh seviyesine çıkmaktadır. Bu üretim miktarı, mobil endüstriyel mutfak tırının tüm operasyonel enerji ihtiyacını karşılamakla kalmayıp, batarya depolama sistemi aracılığıyla enerji sürekliliğini de güvence altına almaktadır.

Pişirme Hattı

- 2 adet elektrikli basınçlı kazan/tencere
- 1 adet 6 göz indüksiyon ocak (veya 2x3 göz modül)
- 1 adet sıcak su (ısı pompalı) ısıtıcı (2 kW sınıfı)

Sıcak Bekletme ve Servis

- 2 adet sıcak bekletme kabini
- 1 uzun servis tezgahı + porsiyonlama hattı

Soğutma

- 1 adet dik tip buzdolabı (A+++/profesyonel)
- 1 adet dik tip dondurucu (donmuş ürünler için)

Hazırlık

- Boydan boya tezgah (iki tarafta toplam 22 m)
- Evye + el yıkama lavabosu

Günlük 1000 kişiye yemek vermek için:

- İndüksiyon ocaklar: 15 kW (3 ocak x 5 kW)x4 saat → 60 kWh
- Elektrikli basınçlı tencereler: 2 adet x 2 kWx4 saat → 16 kWh
- Isı pompalı su ısıtıcı: 2 kW x 4 saat → 8 kWh
- Buzdolabı / dondurucu: 0.5 kW x 24 saat → 12 kWh
- LED aydınlatma: 0.25 kW x 8 saat → 2 kWh
  Toplam 98 kWh / gün

.

Bulgular ve Beklenen Etkiler

Üretim ile karşılaştırdığımızda;

- PV (25 kW): 100 - 125 kWh / gün
- Rüzgâr (6 kW): 40 - 60 kWh / gün
- Toplam: 140 - 185 kWh / gün
- Tüketim: 100 kWh / gün
- Üretim: 140 - 185 kWh / gün
- Fark: +42 ile +87 kWh / gün (fazla)
  Enerji dengesi pozitiftir

Bu çalışmada tasarlanan sistem;

- %100 yenilenebilir enerji ile çalışarak fosil yakıt bağımlılığını ortadan kaldırmaktadır.
- Geleneksel jeneratörlü sistemlere göre %85 karbon emisyonu azaltımı sağlamaktadır
- İlk yatırım maliyeti 3-5 yıl içinde enerji tasarrufuyla karşılanabilmektedir
- Afet ve kriz bölgelerinde hızlı müdahale kapasitesi sunmaktadır
- BM SDG 1, 2, 7, 11 ve 13 hedeflerine doğrudan katkı sağlamaktadır.

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STUDY ON SEALING PERFORMANCE OF GREASE LUBRICATED ROTARY LIP SEALS WITH DETERMINISTIC MICRO-GROOVE TEXTURED ON SHAFT SURFACE

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ABSTRACT

Rotary lip seal reliability is crucial in the long-life cycle of lubrication systems. The bias of oil film pressure between the shaft and seal pair ensures that contaminants are kept out and lubricants are in. In this study, firstly, the meaning of sealing is explained and then, information about sealing elements is provided. After giving detailed descriptions of rotary lip seals, the grease lubricated sealing mechanism is portrayed. In long periods of use of elastomeric lip seal, frictional material loss occurs in the sealing zone, which causes breakdown of film pressure. This paper investigates changes in sealing performance when the film pressure is manipulated via deterministic micro-cavities on the shaft surface. Theoretically, a mathematical model is built and a numerical simulation method is used to understand how deterministic micro-cavities changes film pressure distribution. Experimentally, 9 different types of geometrical patterns were applied to the shaft surface via laser marking. Then, friction torque changes as regards of these surface patterns were measured. Later, the rotary lip seal life test machine is used to record leakage amount during testing for each pattern type. After tests, material volume loss measured to check the correlation between seal lip geometry and leaking. The optimal design parameters were identified using the Taguchi method. The sealing performance of the developed surface texture was validated in life tests, which demonstrated a 7 dB improvement.

Keywords: lip seal, leakage, sealing, surface texturing, Taguchi method

1. INTRODUCTION

As long as a gap exists between two adjacent media, the flow of matter, even at a molecular level, cannot be stopped. The seal's purpose is to regulate the flow of the substance. In practice, this regulatory component prevents the leakage of lubricant or pressurized fluid through the system.

The subject of the study is rotary lip seals which are used in a system consisting of a shaft and a housing and one of them is moving. In the typical setup for a rotating shaft and mounted seal, the internal diameter of the elastomeric seal is usually less than the outer diameter of the shaft. Thus, when the seal is installed, its lip exerts a static force on the shaft. This static force is not the primary reason behind the sealing mechanism, as direct contact between an elastomeric seal and the shaft leads to abrasive wear on the seal’s lip geometry after a short

period of use. In reality, the critical rotary velocity of the shaft results in the lubricant assuming the configuration of an oil film between the surfaces of the seal itself and the shaft. The oil film keeps the lip separated from the shaft counter surface thus avoiding the wearing of elastomer which is a softer material in the system. Besides, thanks to the lip geometry, the formed oil film creates asymmetrical pressure distribution, and a flow has a specified direction which is needed to keep contaminants out. The magnitude of the pressure and flow direction can be manipulated via asperities that exist on both lip and shaft surfaces. These asperities act as micro-level pumps because of the variation of tangential shear of asperities across the contact area. As a result of the manufacturing process, the shaft surfaces exhibit asperities, which are predominantly anisotropic. This means that the asperities demonstrate varied topographies in different directions. In experimental and numerical studies of this study, asperities are manipulated by giving deterministic shapes on the shaft surface and how sealing performance changes is investigated.

The aim of the study is that, searching ways of manipulating liquid flow direction where in grease lubricated sealing contact utilizing changing the shaft surface topography with deterministic micro-cavities.

2. SEALING ELEMENTS

Seals are mainly classified as static and dynamic. While static seals are used to control material passing between two non-moving surfaces, dynamic seals are suitable for regulating the fluid flow between surfaces in relative motion. Sealing element classification is illustrated in Figure 2.1.

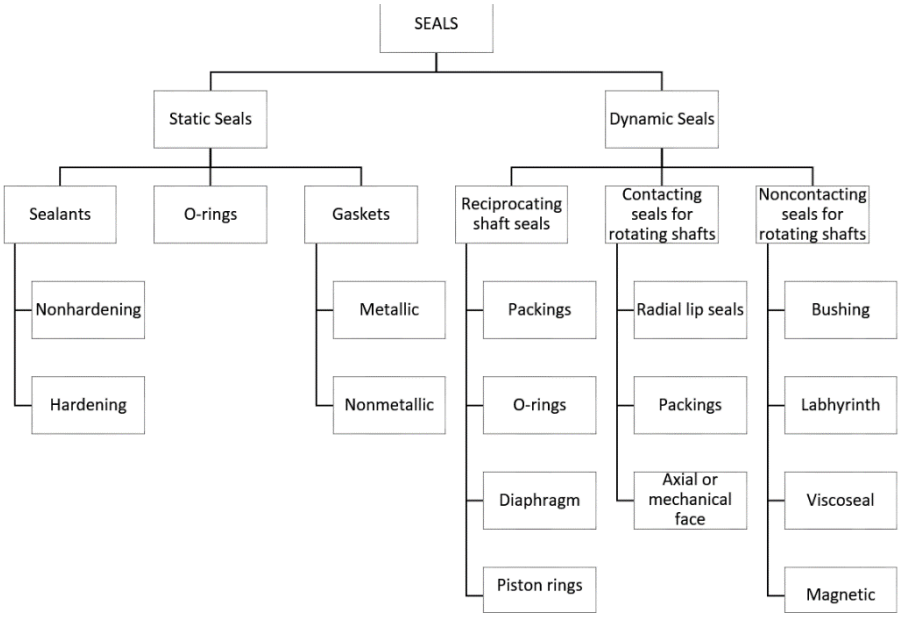


Figure 2.1: Seal Types

Dynamic seals are divided into two class as contact and non-contact seals according to presence of contact to other surfaces in the system:

1. Seals physically in contact with both synchronously working system elements are called contact seals. Wear occurs due to the relative movement at the sealing contact area.

2. In non-contact systems, the resistance created by very narrow channels against oil flow is utilized. Since there is no friction or wear in non-contact seals, they can theoretically have an infinite life.

Carefully designed seal, regardless of its type, adequate to fulfil what it set out to achieve at the beginning. This can lead to choice low-cost solutions in applications. Inexpensive materials with insufficient thermal, mechanical, material properties cause expensive repairing cost and unexpected machine shutdowns. Tribology studies in seals may contribute to reducing global carbon emissions, increasing resource use or reducing equipment wear and lifespan. Statistical studies of tribological improvements show that, in addition to the economic benefits, there are significant improvements to the environment and the quality of human life. [1], [2], [3]

2.1. Radial Lip Seals

Static and dynamic sealing conditions determine the performance of the seal. Design of the sealing lip apex, chosen elastomeric material, geometry of seal outer surface which in contact with housing play critical role for statical sealing. Besides stationary conditions of the system, specification of contact points with consideration of dynamic conditions is crucial. Continuous film thickness between the shaft and seal controls friction and wear, while identifying the load support and reverse pumping mechanisms.

The general elements of a rotary lip seal are elastomeric material and rigid metal case. Most lip seals also contain a third component which is called garter spring. A designation for rotary lip seal can be seen in Figure 2.2.

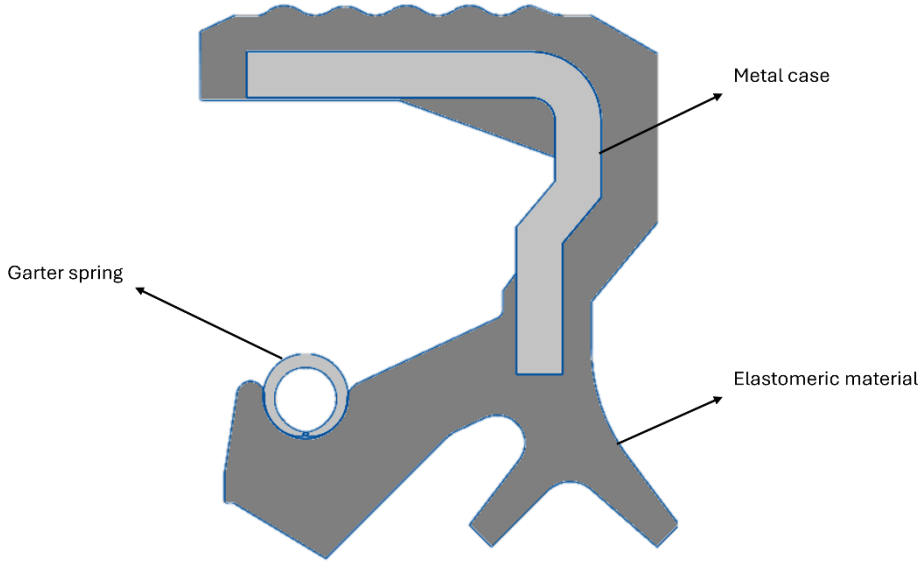


Figure 2.2: Designation for Radial Lip Seal

There is an interference fit between the seal inner diameter and shaft outer diameter. This dimensional difference applies an initial pressure to the shaft surface when the seal is fitted. The magnitude of interference is essential for proper sealing function.

3. SEALING MECHANISM

In dynamic conditions, lubricant acts as a thin film layer, pumps contaminants out of the system and limits friction and wear between the lip seal and the rotating shaft. It has been demonstrated that the hydrodynamic relationship between the lubricant - sealing geometry - shaft surface condition prevents the release of lubricant.

3.1 Sealing Mechanism for Grease Lubricated Seals

The operation of grease-lubricated systems is under partially starved lubrication regimes, where the replenishment of the lubricant film is limited and fluid is non-Newtonian and flow is not continuous. High shear rates generate normal stresses perpendicular to the shear direction. Due to these normal stresses, non-Newtonian fluids tend to flow toward areas with the highest shear as shown in Figure 3.1. This phenomenon is illustrated by a rotating rod in a still vessel filled with a non-Newtonian fluid, causing the fluid to climb up the rod.

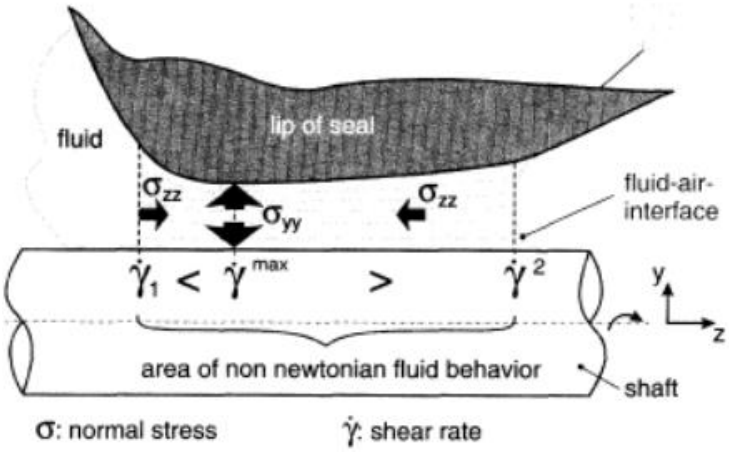


Figure 3.1: Highest Shear Rate Point and Grease Flow Direction on Contact Area of Seal [4]

In the context of high shear rates, which are typical of seal operation, grease exhibits shear-thinning behaviour and generates normal stresses perpendicular to the flow direction. It is shown that these normal stresses can contribute up to 50-60% of the load-bearing capacity in low-pressure sealing contacts.

4. WEARING MECHANISM OF ELASTOMER

The wear on solid surfaces that slide over each other can be influenced by various factors such as lubrication conditions, hardness and surface conditions of sliding surfaces, physical/chemical composition of the environment, applied normal load and sliding speed.

Elastomer wearing establishes a basis on three different mechanism which are abrasion, fatigue and roll formation. In real life application, all of three wearing mechanism occurs together and it makes difficult to distinguish effects of each mechanism on overall wear. The sliding of elastomeric material across a hard counter surface characterized by rough and sharp texture leads abrasive wear and tearing of elastomer surface. Another relevant wear mechanism is fatigue wear occurs when an elastomer slides against rounded asperities on the hard counter-face. A further mechanism that can be observed is roll formation. This occurs when frictional

force tears a particular point on the rubber surface and then rolls along the direction of sliding. Schematic diagram of the friction and wear of elastomers is shown in Figure 4.1.

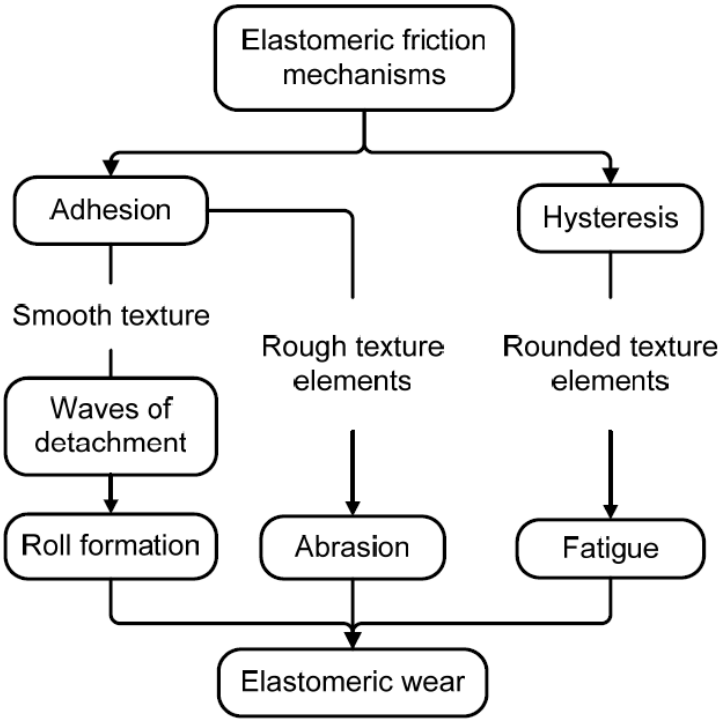


Figure 4.1: Schematic Diagram of the Friction and Wear of Elastomers [5]

In addition to the three fundamental elastomeric wear mechanisms, the working conditions of a radial lip seal expose the component to chemical attack and thermo-oxidative aging. These conditions alter the seal's chemical structure and cross-link density, resulting in changes to its hardness and modulus.

5. EXPERIMENTAL SETUP

The study investigates the effects of deterministic micro-cavities on the surface of the shaft on the performance of grease-lubricated radial lip seals used in front-load washing machines. The procedure to determine effects of micro-cavities on pumping rate can be seen in Figure 5.1. The pumping mechanism of the seal lip effectively prevents leakage of washing water at the beginning of the operational life. During rotation of shaft, seal pumping rate (PR) becomes insufficient because of increasing of wearing and aging. It will be observed experimentally that, whether additional pumping rate coming from textured shaft surface decreases leakage amount measured at the end of test programme. Figure 6.1 is shown differences of position of pressure boundary for both textured and non-textured shaft surfaces after same service time.

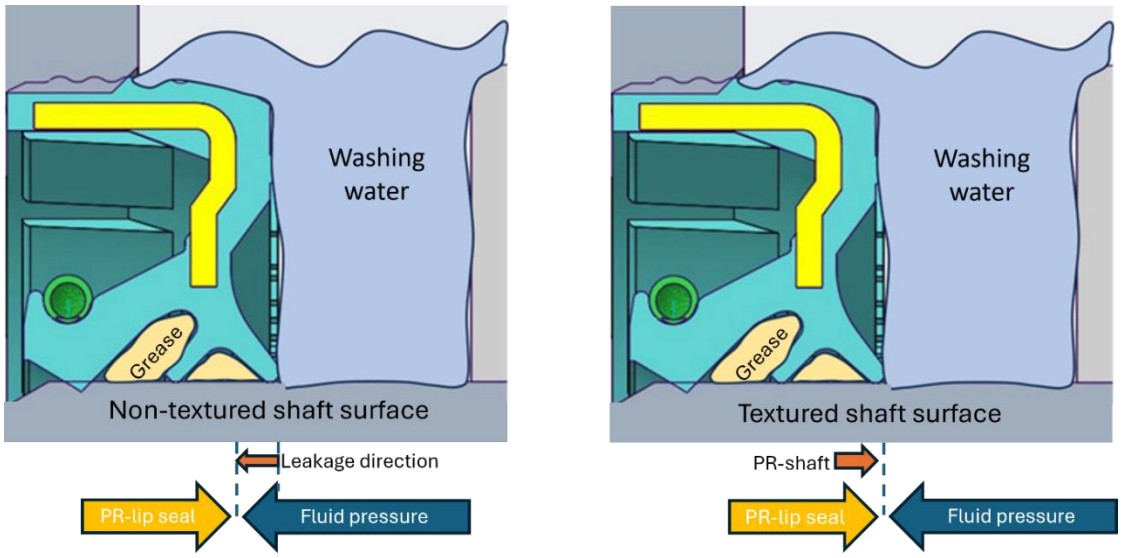


Figure 5.1: Pressure Boundaries for Textured and Non-textured Surfaces (PR = Pumping Rate)

A front-load washing machines consists of a tub which cover the drum. A shaft is used to transmit the motion from pulley to drum and it is horizontally housed in rear of tub thanks to bearings. These bearings must be avoided from water and even moisture. Grease lubricated radial lip seals are used to separate two media as washing water and air from each other. An illustration of the system can be seen in Figure 5.2.

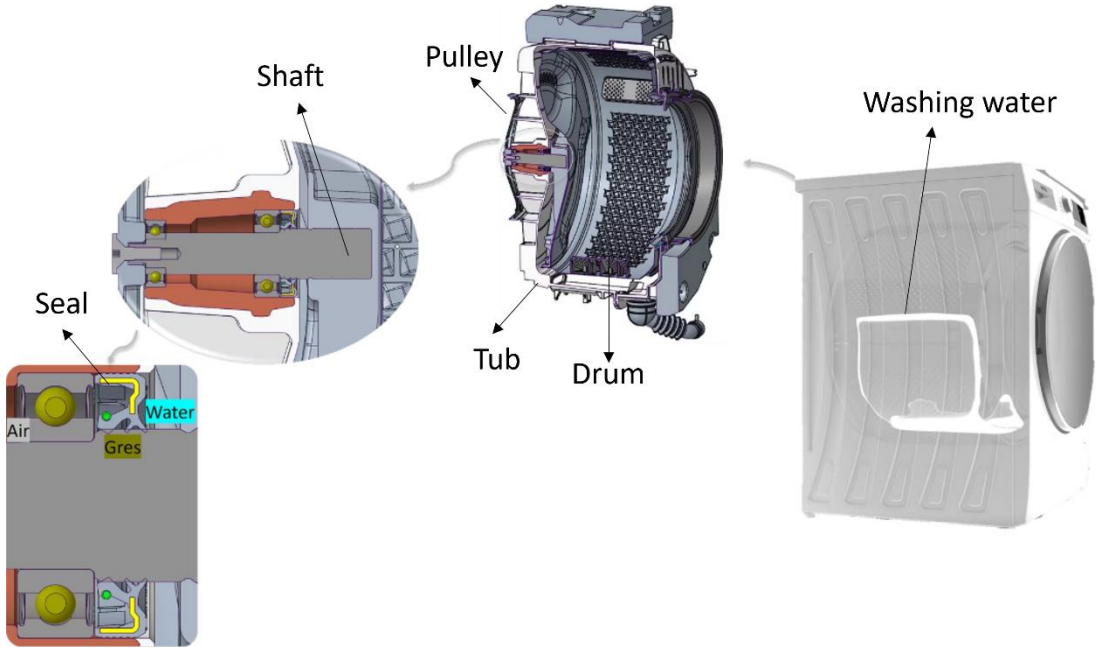


Figure 5.2: Washing Machine Sealing System

Shaft rotates according to software specifications that applied on electric motor. A washing cycle follows briefly 3 stages which are named as main wash, rinse and last rinse during working time. These stages also have several water levels, cycle times, rotational speeds and direction (CWs and CCWs). For instance, during main wash stage, seal submerged in washing water and shaft rotates relatively low speeds and CW-CCW directions. It must be

considered that water pressure has a correlative relationship with the possibility of leakage. In last rinse cycle, conditions change as water level is lowest but, shaft rotates at highest possible speeds which causes an oil film established between shaft and seal that makes grease type and its application more critical. Consequently, it is evident that each stage plays a crucial role in the overall performance of the washing machine seal. An illustration is shown in Figure 5.3.

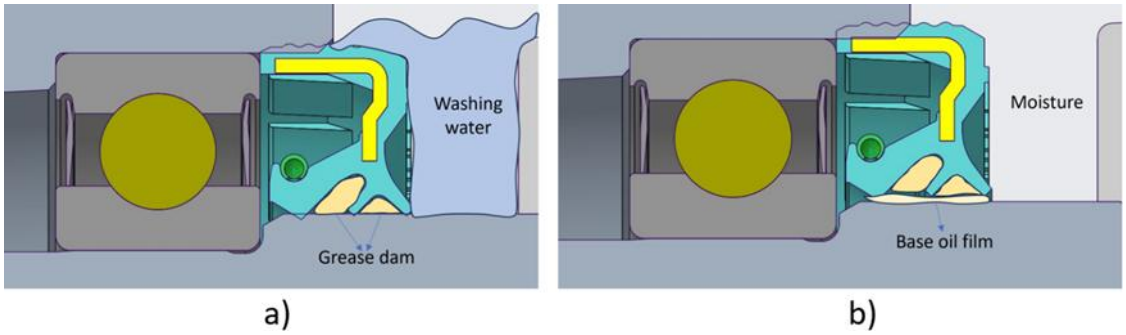


Figure 5.3: Sealing Conditions of Washing Machines According to a) Main Wash (low rpm) and b) Rinse (high rpm)

The non-observability of the sealing system and constantly changing operating conditions make any investigation on sealing system of washing machine more complex. A special test bench is required to understand the effects of micro-grooved counter surface on grease-lubricated washing machine seals in terms of leakage rate.

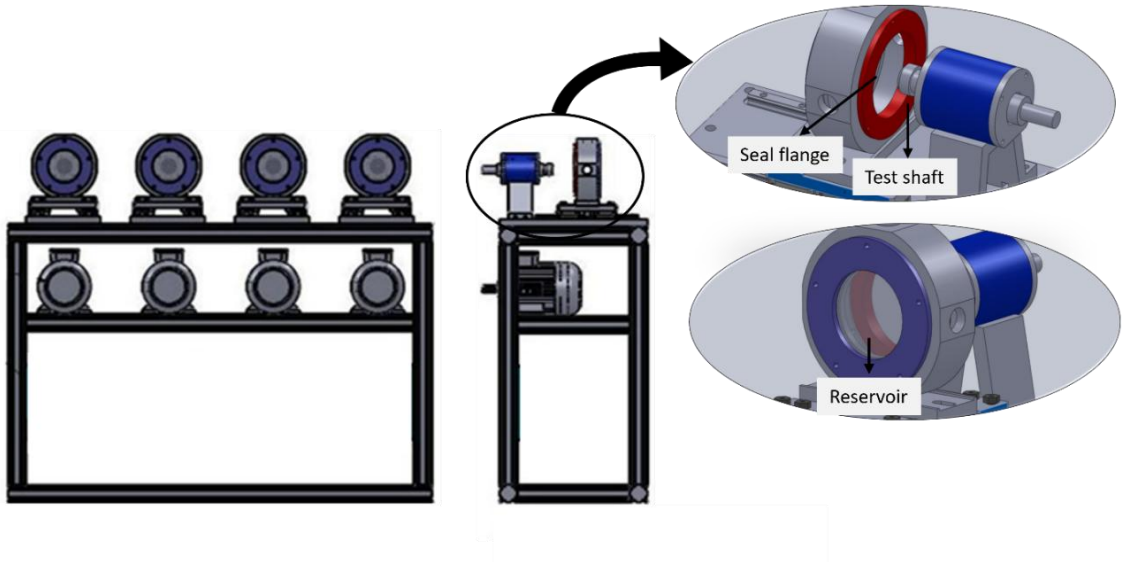
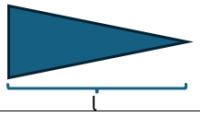
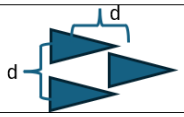


Figure 5.4: Life Test Bench

Texturing process was applied on each washing machine drum shafts having 30h9 mm seal seat diameter. The engineering target is smaller-the-better leakage. The four controllable factors are treated as categorical at 3-levels each and represented in Table 5.1.

Table 5.1: Factors and Levels

Factor	Level 1	Level 2	Level 3	Control Group	Description
Groove depth (µm)	2	4	6	-	
Groove length (µm)	80	140	200	-	
Groove width (µm)	100	160	220	-	
Pattern density / Spacing (d)	250	300	350	-	

The minimum suitable array is Taguchi L9(3^4) providing nine distinct pattern groups. Triangular cavities were drawn in 0,3x0,3 mm^2 imaginary areas to represent cavity to sealing contact area ratio. In Figure 5.5, all patterns drawn with respect to L9 map can be seen.

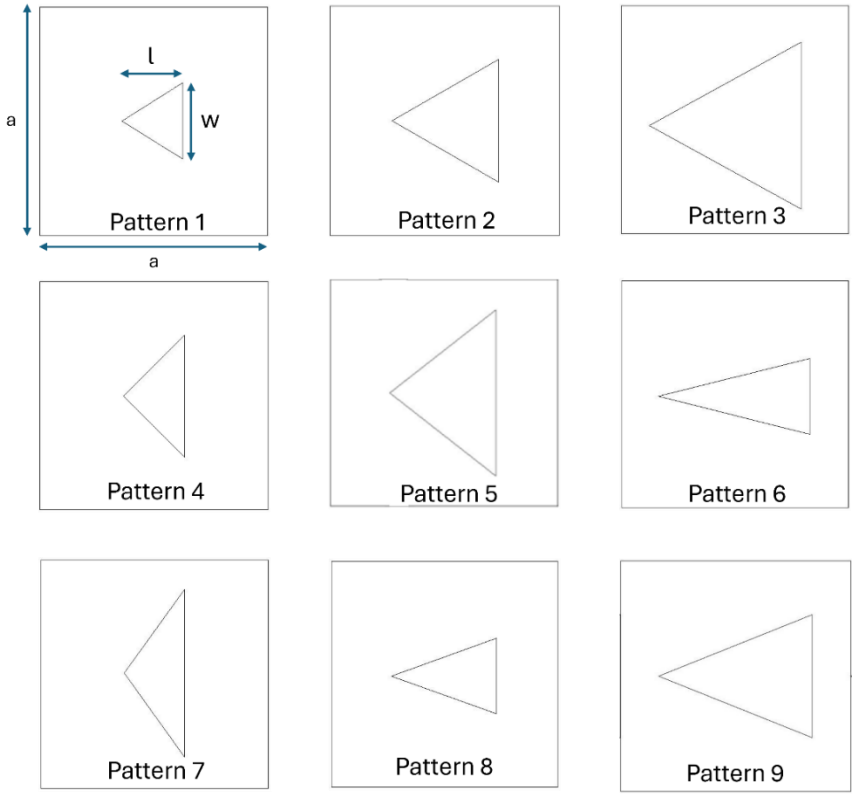


Figure 5.5: 9 Patterns Drawn with respect to L9 Mapping (a= Optimum Seal Contact Width)

Due to its accessibility, widespread use and sufficient controllability, laser marking was chosen for surface texturing method in this study.

6. NUMERICAL SIMULATION AND ANALYSIS

The numerical analysis based on the Reynolds equation was conducted with a clear objective. Instead of replicating the entire complex behaviour of the grease-lubricated seal, the aim was to isolate and quantify the pure hydrodynamic pumping capability of the triangular shaft textures used in the experiments. In other words, the model is intended as a micro-scale of hydrodynamic texture behaviour. It allows a systematic comparison of the Taguchi patterns L1–L9 in terms of their predicted pumping rate and pressure field, independently of mixed lubrication, starvation and wear, which dominate in the real test rig.

For this purpose, a simplified two-dimensional Reynolds formulation was adopted on a 0,3 mm × 0,3 mm computational cell, representing a single texture period on the rotating shaft contact zone. The film thickness distribution h(x,y) was constructed by superimposing a nominal uniform film (7 µm) and the triangular cavity geometry corresponding to each pattern (with depth, length and width as in L1–L9).

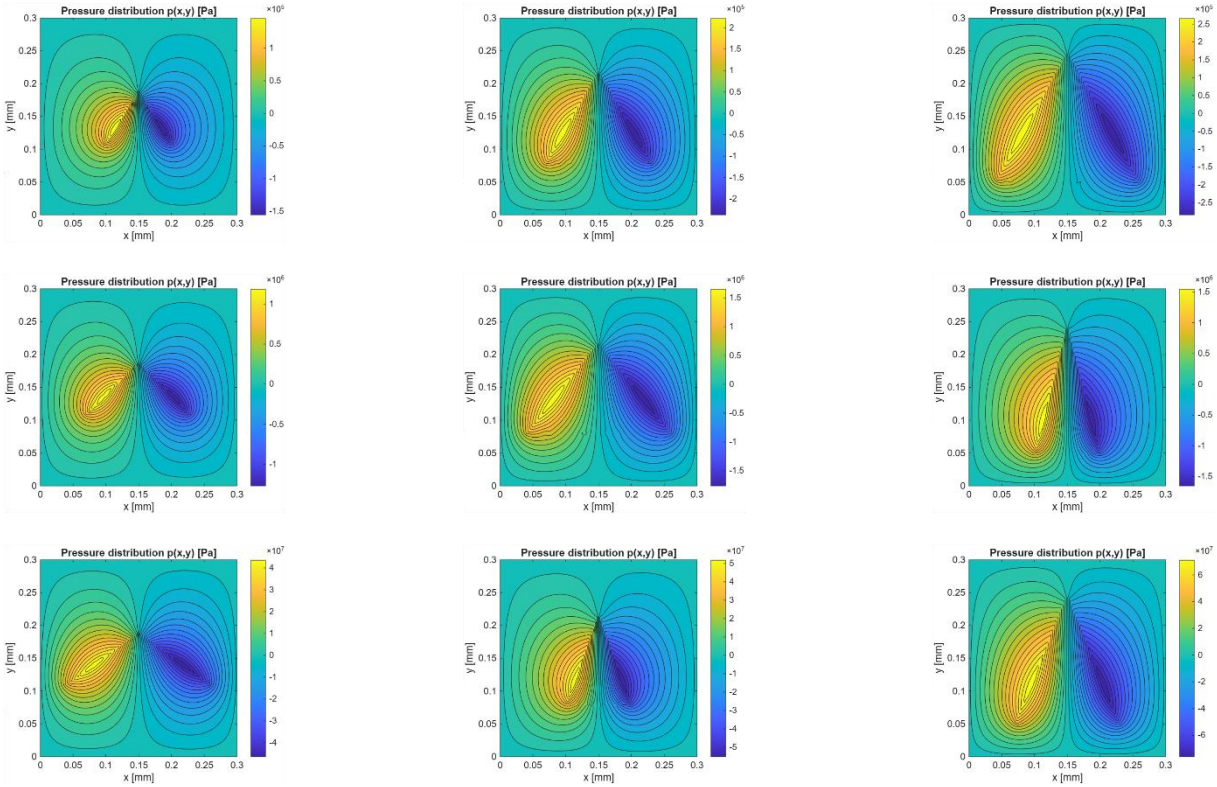


Figure 6.1: Pressure Distribution of L1-L9 Patterns

The effective grease viscosity was taken as a constant, equal to the base-oil viscosity at the operating temperature (µeff=0,03 Pa.s), which is sufficient at this stage to capture relative trends between patterns. The Reynolds equation was solved on this cell with periodic boundary conditions in the circumferential direction and zero pressure at the axial boundaries, using a finite-difference discretization and Gauss–Seidel iteration. From the resulting pressure field p(x,y), the circumferential pumping rate Q, the maximum pressure Pmax and the axial position of the pressure peak were extracted. Pressure distribution graphs for each pattern can be seen in Figure 6.1.

Table 6.1: Ranking of texture patterns (L1–L9) numerically

	Pumping rate (Q) (m^3/s)	Pmax (Pa)	Pmax shifting from y=0,15 mid-line (mm)
max	L7	L9	L6
	L8	L8	L9
	L9	L7	L8
	L6	L5	L2
	L4	L6	L3
	L5	L4	L5
	L3	L3	L1
	L2	L2	L4
min	L1	L1	L7

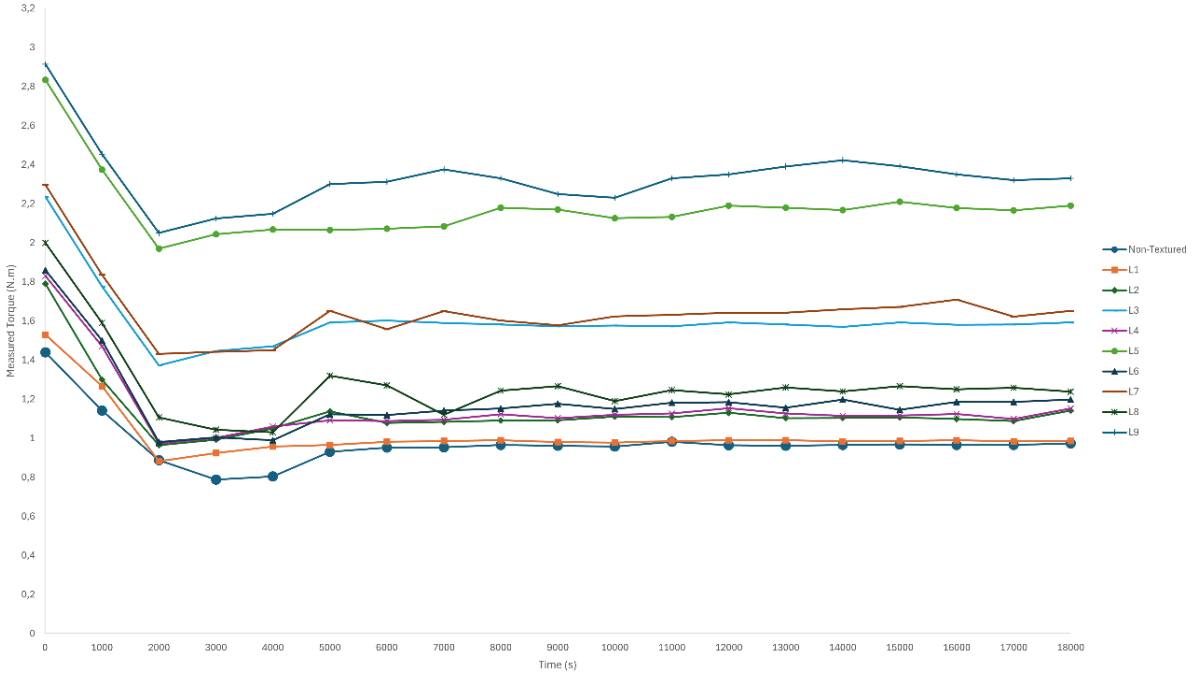
Based on the three numerical indicators compiled in the Table 6.1, L8 occupies consistently high positions in all three rankings: it combines a large pumping rate with a high, yet not extreme, maximum pressure and a pronounced shift of the pressure peak towards the grease side. When the three criteria are considered together, this balanced behaviour suggests that L8 is, in theory, the most effective and robust texture among L1–L9 for enhancing hydrodynamic sealing performance.

7. RESULTS AND DISCUSSION

First response variables taken from experiments were generated friction torque and seal underlip temperatures for 9 different counter surface patterns and non-textured surface during 5 hours measurement. In these observations, it seemed that, for first 1 hour of testing, friction torque values decreased continuously. This is attributed to the low viscous effect resulting from the lack of a full film layer during the mixed lubrication phase. This condition continues until the "run-in" phase is achieved on the test seal, reaching a minimum dry contact point. Upon completion of the "run-in" phase, a full film layer forms between the seal and the shaft, and the oil in the grease begins to increase viscous friction. It was observed that the friction torque curve remained constant at its horizontal value approximately 2 hours after the start of the test.

As shown in Table 8.1, none of 9 group was able to get lower friction than non-textured surface. The reason behind that, grease filled into cavities on shaft surfaces caused creation of micro pads which feed contact area and decrease the dry contact possibility. The presence of grease increases viscous friction, resulting in increased friction torque. According to measurements, the lowest friction torque measured from seal-textured surface contacts belonged to the L1 pattern. The results of this pattern are quite similar to values measured from non-textured surface. The torque value was 1,53 Nm at the beginning of the tests. Then, dropped to 0,882 Nm and reached to its stable value as 0,99 Nm.

Table 7.1: Effects of Patterns on Friction Torque



The stable friction torques measured from tests for total 9 patterns and non-textured surface is shown in Table 7.2. It can be thought that, there is a correlation between area ratio and friction torque but, it must be taken into account figure depth has another main factor on friction torque.

Table 7.2: Friction Torque Measured after 2 Hours in Tests

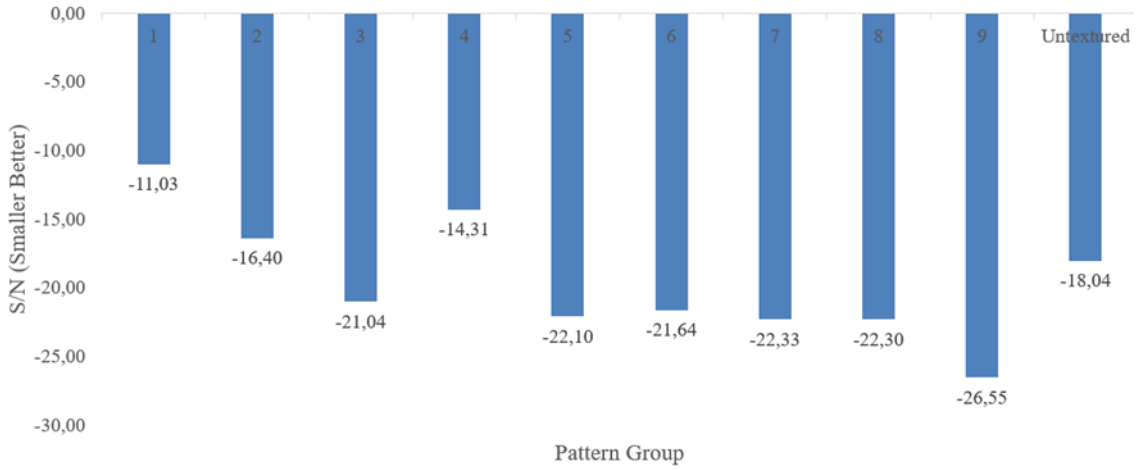
Pattern Type	Friction Torque (Nm) (Stable)
L1	0,99
L2	1,08
L3	1,59
L4	1,09
L5	2,08
L6	1,14
L7	1,65
L8	1,12
L9	2,38
Untextured	0,96

The stable friction torques measured from tests for total 9 patterns and non-textured surface is shown in Table 8.2. It can be thought that, there is a correlation between area ratio and friction torque but, it must be taken into account figure depth has another main factor on friction torque.

As second response variable, leakage amounts were collected during seal life tests. In this section, Taguchi Method was used to rank the effect of design variables on the sealing performance. In Taguchi Method, Signal-to-Noise ratio is used as evaluation metric. Smaller-

the-Better criterion was utilized for leakage minimization. Table 7.3 below shows computed S/N for each pattern from the replicate data.

Table 7.3: S/N (Smaller Better) for Each Pattern Group



S/N (Smaller Better) approach also supports the individual results shared in Table 7.3 and confirms that the textured patterns L1, L4 and L2 outperform the untextured shaft in terms of leakage robustness, with the ranking L1 > L4 > L2 > Untextured. Pattern L1 exhibits the highest (least negative) S/N ratio at approximately −11.0 dB, corresponding to an improvement of about 7 dB over the untextured reference (~ −18.0 dB), which indicates substantially lower leakage and/or reduced variability under the same test conditions. Pattern L4 achieves an intermediate S/N level of about −14.3 dB, still yielding roughly 3.7 dB improvement relative to the untextured surface, while L2, with an S/N of approximately −16.4 dB, provides a more modest but measurable enhancement of around 1.6 dB. These results confirm that suitably designed triangular textures can significantly enhance sealing performance in life tests compared with a smooth shaft, and that the specific geometric combination corresponding to L1 offers the most robust behaviour among the investigated configurations.

Design factors can be ranked according to their average S/N values by factor level. Table 7.4 shows effects of depth, length, width and density of marked figures on leakage amount by Delta (max-min difference) value. When the factors are changed according to the levels determined at the beginning of the study, the change in the average S/N value shows how effective the parameter is.

Table 7.4: Ranking Factors by Average S/N Differences

Factor	Level 1	Level 2	Level 3	Delta (Max-Min)	Rank (1=largest)
Depth	-16,16	-19,35	-23,73	7,57	1
Length	-15,89	-20,27	-23,08	7,19	2
Width	-18,32	-19,09	-21,82	3,50	3
Density	-19,89	-20,12	-19,22	0,91	4

The Taguchi S/N analysis indicates that minimizing leakage requires primarily controlling the groove depth and length, followed by the width, whereas density plays a relatively minor role over the tested range. The combination of shallow, short and narrow triangular grooves (Depth Level 1, Length Level 1, Width Level 1), together with the highest tested density level, corresponds to the most favourable S/N response and can be considered the recommended setting for reducing water leakage in this sealing configuration.

In order to quantify the relative importance of the control factors on the robustness of the sealing performance, an analysis of variance (ANOVA) was carried out on the signal-to-noise (S/N) ratios obtained from the L9(3^4) orthogonal array. In this approach, the S/N value corresponding to each OA row (i.e. each combination of depth, length, width and density) is treated as a single response, and the total variation in S/N is decomposed into contributions associated with the individual factors.

The total sum of squares of the S/N ratios was first computed using the correction factor based on the overall mean. Then, for each factor (depth, length, width and density), the sum of S/N values at each level was used to calculate the factor sum of squares via the standard Taguchi formulation. Since the L9(3^4) array with four three-level factors exhausts all available degrees of freedom, the factor with the smallest sum of squares was pooled into the error term in order to obtain a meaningful estimate of the experimental error. In this study, the areal density of triangular grooves showed the smallest contribution and was therefore combined with the residual. ANOVA table was shared in Table 7.5.

Table 7.5: ANOVA Table

Factor	DOF	SS	MS	F-ratio	%Contribution
Depth (A)	2	86,66	43,33	65,02	46,34
Length (B)	2	78,7	39,35	59,05	42,08
Width (C)	2	20,32	10,16	15,25	10,87
Error*	2	1,33	0,67	–	0,71
Total	8	187,01	–	–	100

The resulting ANOVA table indicates that groove depth has the largest sum of squares and explains approximately 46,3% of the total variation in S/N. Groove length is identified as the second most influential factor, accounting for about 42,1% of the total variation. Groove width contributes a smaller but still appreciable fraction, on the order of 10,9%, while the pooled error term (dominated by the density factor) represents only 0,7% of the total sum of squares. The corresponding mean squares yield F-ratios that are much larger than the error mean square for depth, length and width, confirming that these three factors are statistically significant in their effect on the S/N ratio.

Contrary, in the framework of a purely hydrodynamic Reynolds model, such high pressures and strongly shifted peaks would be interpreted as a very strong reverse-pumping tendency, suggesting that deep textures such as L7–L9 should significantly enhance sealing. However, when numerical approach compared with the experimental results, an inconsistency appears: the patterns with the highest predicted pumping rate and maximum pressure (in particular L7–L9, and to some extent L4–L6) are also those that exhibit the worst leakage and wear behaviour in the life tests. This discrepancy can be rationalised by the relative scale of the texture depth and the lubricant film thickness. The Reynolds model implicitly assumes a shallow micro-texture, where the depth acts as a small perturbation to an otherwise continuous hydrodynamic film. In the present geometry the texture depth is comparable to, or even larger than, the nominal film thickness, so that the cavities behave as macroscopic material removal

rather than true micro-features. Under these conditions the assumptions of the thin-film model are violated: the film is locally disrupted or starved, the contact enters a mixed/boundary regime, and the real contact area and leakage paths are determined by the macro-scale loss of material rather than by subtle pressure rectification. Therefore, the numerical pumping analysis in Chapter 6 should be interpreted as a qualitative micro-scale indicator of how each pattern would behave in an ideal hydrodynamic film, rather than as a quantitative prediction of the experimental sealing performance.

As third response variable, material losses due to abrasion and adhesion were measured for each test seals. Measurement method of material volume loss of the test seal's lip before and after life tests can be seen in Figure 7.1.

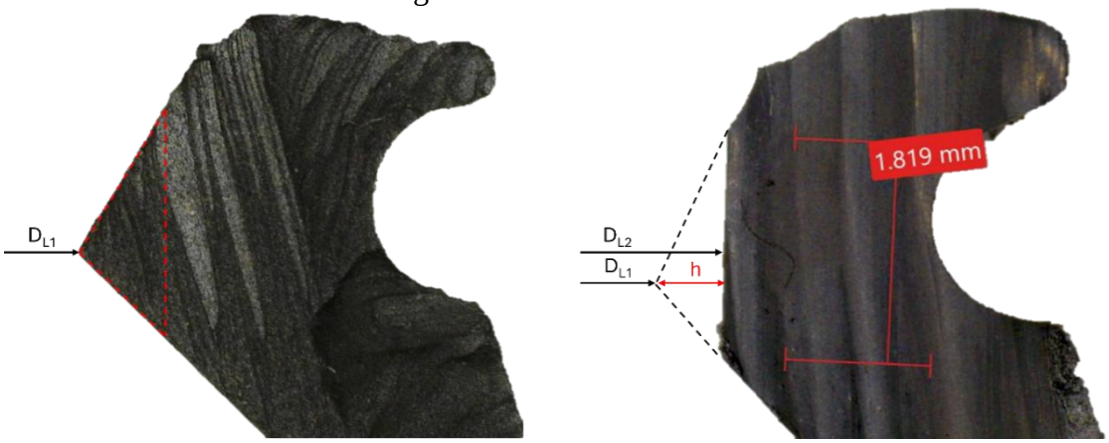


Figure 7.1: Volume Loss of Measurement Results

Archard's wear equation was adopted to interpret the wear behaviour. V (wear volume) calculated by multiplying wear band thickness, changes in internal lip radius ($R_{initial}$-R_{final}) and circumference together. W (normal load) is seal design property and was taken from Table 6.3 for each individual test seal. L (sliding distance) is equal to circumferential speed times duration of testing. H (hardness of seal) is material property and equal to 2140 MPa. For each surface pattern, the measured volumetric loss together with the known test load, sliding distance and material hardness were used to back-calculate an effective, pattern-dependent wear coefficient k. In this way, a distinct k value was obtained for every texture design, which enables a quantitative comparison of the wear performance of the different patterns and provides a consistent basis for correlating endurance test results with surface texturing parameters.

Table 7.6: Abrasion Rates and Wear Coefficient regarding to Pattern

Pattern	Volmetric Material Loss (mm3)	Area Loss (mm2)	Wear Band Thickness (mm)	Δradius (mm)	Amount of Leakage (g)	Hardness of Seal (MPa)	Normal Load (N)	Sliding Distance (mm)	Wear Coefficient k
L1	1,58	0,02	0,3	0,112	3	2140	40,14	5,652x10^8	1,4935E-07
L1	1,58	0,02	0,3	0,112	5	2140	41,25	5,652x10^8	1,4533E-07
L1	2,83	0,03	0,4	0,15	2	2140	40,28	5,652x10^8	2,6578E-07
L2	11,31	0,12	0,8	0,3	5	2140	40,55	5,652x10^8	1,0560E-06
L2	14,34	0,15	0,9	0,338	9	2140	40,93	5,652x10^8	1,3261E-06
L2	6,36	0,07	0,6	0,225	5	2140	41,67	5,652x10^8	5,7805E-07
L3	29,90	0,32	1,3	0,488	8	2140	40,35	5,652x10^8	2,8053E-06
L3	39,80	0,42	1,5	0,563	14	2140	41,96	5,652x10^8	3,5910E-06
L3	25,45	0,27	1,2	0,45	11	2140	40,55	5,652x10^8	2,3761E-06
L4	4,43	0,05	0,5	0,188	7	2140	41,65	5,652x10^8	4,0269E-07
L4	2,83	0,03	0,4	0,15	4	2140	41,62	5,652x10^8	2,5722E-07
L4	1,58	0,02	0,3	0,112	4	2140	41,21	5,652x10^8	1,4548E-07
L5	39,80	0,42	1,5	0,563	14	2140	40,88	5,652x10^8	3,6859E-06
L5	45,24	0,48	1,6	0,6	13	2140	40,25	5,652x10^8	4,2556E-06
L5	21,41	0,23	1,1	0,413	11	2140	40,69	5,652x10^8	1,9921E-06
L6	39,80	0,42	1,5	0,563	13	2140	40,77	5,652x10^8	3,6958E-06
L6	29,90	0,32	1,3	0,488	10	2140	40,31	5,652x10^8	2,8080E-06
L6	34,64	0,37	1,4	0,525	13	2140	40,65	5,652x10^8	3,2261E-06
L7	34,64	0,37	1,4	0,525	12	2140	41,02	5,652x10^8	3,1970E-06
L7	25,45	0,27	1,2	0,45	12	2140	40,84	5,652x10^8	2,3592E-06
L7	39,80	0,42	1,5	0,563	15	2140	40,79	5,652x10^8	3,6940E-06
L8	34,64	0,37	1,4	0,525	10	2140	40,63	5,652x10^8	3,2277E-06
L8	34,64	0,37	1,4	0,525	11	2140	41,56	5,652x10^8	3,1555E-06
L8	51,11	0,54	1,7	0,638	17	2140	41,55	5,652x10^8	4,6575E-06
L9	85,53	0,91	2,2	0,825	25	2140	41,89	5,652x10^8	7,7307E-06
L9	70,69	0,75	2	0,75	17	2140	40,98	5,652x10^8	6,5309E-06
L9	78,18	0,83	2,1	0,79	21	2140	40,85	5,652x10^8	7,2461E-06
Untextured	0,71	0,01	0,2	0,075	5	2140	40,74	5,652x10^8	6,5694E-08
Untextured	1,58	0,02	0,3	0,112	10	2140	41,77	5,652x10^8	1,4352E-07
Untextured	0,71	0,01	0,2	0,075	7	2140	40,25	5,652x10^8	6,6493E-08
Untextured	2,83	0,03	0,4	0,15	9	2140	40,68	5,652x10^8	2,6316E-07

Abrasion rates and corresponding wear coefficient values are shared in Table 7.6. Under identical load, sliding distance and material hardness, the Archard wear coefficient k of the untextured shafts is on the order of 10-7, with an average wear volume of about 1–2 mm³. Pattern L1 exhibits a very similar wear level (mean k ~ 1,9 x 10-7), while reducing the leakage rate by approximately 55% compared with the untextured reference. Pattern L4 also remains in the same order of magnitude as the baseline (mean k ~ 2,7 x 10-7) with slightly improved sealing performance.

In contrast, patterns L2, L3 and L5-L8 lead to an order-of-magnitude increase in the wear coefficient (k ~ 10-6) and L9 reaches values above 7x10-6, accompanied by pronounced wear band growth and a strong increase in leakage. These results indicate that only the mild textures (L1, partly L4) provide a favourable trade-off between sealing performance and lip wear, whereas more aggressive textures cause severe abrasion of the elastomer lip and are not acceptable from a durability standpoint.

The findings of this work open up several directions for further research. First, the present results indicate that for some texture combinations both leakage and lip wear increase in an uncontrolled manner. In particular, textures with large depth and length tend to generate high stress concentrations at the feature edges, so that the micro-pattern behaves more like a defect that rapidly erodes the lip than as a beneficial hydrodynamic element. Future studies should therefore focus the texture design space around small and shallow geometries, and explore depth and length with finer parameter steps, supported by advanced design-of-experiments and multi-objective optimisation strategies that directly target the combined response of leakage, torque and wear.

Second, the laser marking process used in this thesis is likely to be a relatively coarse manufacturing step for the micro-scale features considered. Recast layers, microscopic burrs and irregular edge geometries generated during laser marking can increase local contact

pressures and accelerate wear, while at the same time limiting the intended hydrodynamic function of the texture. It is therefore recommended that the manufacturing route itself be treated as an independent variable in future work. Techniques that are well established for oil-lubricated textured contacts, such as UV photolithography, precision laser micromachining or micro-milling, could be adapted and applied to grease-lubricated systems. Producing nominally identical textures by different manufacturing methods and comparing their leakage–torque–wear performance would help to decouple purely geometric effects from process-induced surface defects.

Third, the modified Reynolds equation developed in this thesis combining a Herschel-Bulkley description of the grease with a Darcy-type term for possible lubricant bleed through the lip material provides a useful basis for more refined numerical investigations. Future modelling work could incorporate more realistic three-dimensional lip profiles and surface topography, in order to resolve the pressure distribution and film load-carrying capacity over different texture geometries and manufacturing-induced microstructures. Finally, detailed surface and material characterisation of worn lips (e.g. optical/SEM imaging and hardness or modulus mapping) correlated with the macroscopic wear coefficients reported here would further improve the design guidelines for textured shafts in grease-lubricated rotary lip seal applications.

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FUTBOLCULARDA ALT EKSTREMİTE BACAK YARALANMALARI

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ÖZET

Futbol, günümüzde genç ve yoğun katılım olarak en popüler spor branşları arasında yer almaktadır. Bu popülerliğe bağlı olarak performansı etkileyen çok sayıda antropometrik, fiziksel ve çevresel parametre bu branşın bilimsel açıdan derinlemesine incelenmesi ihtiyacı doğurmuştur. Antropometrik ölçümlere dayalı çalışmalar futbol performansının geliştirilmesinde kritik rol oynamaktadır ve futbolun oyun anlayışı gereği yüksek temas olması maç ve antrenmanlarda sporcuları önemli yaralanma riskleriyle karşı karşıya bırakmaktadır. Literatürdeki çalışmalar özellikle alt ekstremite yaralanmalarının futbol, basketbol ve atletizm gibi branşlarda oldukça yüksek oranlarda görüldüğünü; profesyonel futbolcularda kas-iskelet sistemi yaralanmalarının önemli bir bölümünün hamstring, adduktör ve kuadriseps kaslarını etkilediğini vurgulamaktadır. Ayak bileği burkulmaları, bağ zorlanmaları ve kas gerginlikleri en sık karşılaşılan yaralanma tipleri arasındadır. Bu yaralanmalarda yanlış teknik, aşırı yüklenme, yetersiz antrenman ve çevresel koşullar temel sebepler arasındadır. Bu yaralanmalara bağlı olarak, sporcuların kariyerlerini erken sonlandırmasına hatta uzun vadede eklem dejenerasyonuna yol açabilmektedir. Bu nedenle futbol akademilerinde genç oyunculara yönelik düzenli fonksiyonel testler uygulanarak risk faktörlerinin erken dönemde tanımlanması hedeflenmektedir. Alt ekstremitenin karmaşık yapısı, özellikle ayak bileği bağlarının

yaralanmalara yatkın oluşu, bu bölgenin klinik olarak hassasiyetini artırmaktadır. Kas ve tendon yaralanmalarının tanısında MRG ve ultrason gibi teknolojik görüntüleme yöntemleri kullanılmakta olup, doğru sınıflandırma ve rehabilitasyon sürecinin etkin yönetimi kişinin performansını sürdürmesinde ve oyuncu kariyerinin devamlılığında büyük önem taşımaktadır.

Anahtar Kelimeler: Futbol, Alt Ekstremite, Sakatlık

. **Abstract**

Football is among the most popular sports today, attracting young people and attracting high levels of participation. This popularity has led to the need for in-depth scientific investigation into the numerous anthropometric, physical, and environmental parameters that influence performance. Studies based on anthropometric measurements play a critical role in improving football performance, and the high-contact nature of football's gameplay exposes athletes to significant injury risks during matches and training. Studies in the literature highlight the high prevalence of lower extremity injuries, particularly in sports such as football, basketball, and athletics. A significant portion of musculoskeletal injuries in professional footballers affect the hamstrings, adductor muscles, and quadriceps muscles. Ankle sprains, ligament strains, and muscle strains are among the most common injuries. Improper technique, overload, inadequate training, and environmental conditions are among the primary causes of these injuries. These injuries can lead to premature career termination and even long-term joint degeneration. Therefore, football academies aim to identify risk factors early by conducting regular functional tests for young players. The complex structure of the lower extremity, particularly the ankle ligaments, increases the clinical sensitivity of this area. Technological imaging methods such as MRI and ultrasound are used to diagnose muscle and tendon injuries, and accurate classification and effective management of the rehabilitation process are crucial for maintaining performance and the continuity of a player's career.

Key Words: Football, Lower Extremity, Injury

1. GİRİŞ

Günümüzde futbol dünyanın en popüler spor branşıdır. Genç yaş gruplarının rekabetçi bir düzeyde katılımıyla futbola olan ilgi artmaya devam etmektedir, bununla birlikte futbolda performansa etki eden ve başarıyı etkileyen, spor branşının doğasına özgü birçok farklı parametre olduğu bilinmektedir (Bianchi ve ark. 2018). Futbol branşı üzerine yapılan çalışmalardaki ilerlemeler antropometrik ölçümlerin bir sonucudur. Bu sebeple sporda bu ölçümlerin yapılması ve antropometrik karakterlerin belirlenmesi önemlidir (Ayan ve Mülazımoğlu 2009). Futbol gibi yüksek yoğunluklu bir temas sporun da eğitim ve rekabete katılımları da fiziksel olarak zorlayıcıdır ve yaralanma riski taşır (Deehan ve ark. 2007). Futbol hem tecrübelilerin hem de gençlerin gelişim yolunda ve müsabakalarında, yüksek düzeyde yaralanmayla ilişkisi bulunmaktadır (Chalmers ve ark. 2013). Spor nedeniyle çok fazla sayıda sportif yaralanma meydana gelmektedir, bu da sportif faaliyetlerin azalmasına ve antrenmanların yapılamamasına sebebiyet vermektedir. Spor yaralanmaları sonucu sporcular erken yaşlarda kariyerlerini sonlandırmak zorunda kalmaktadırlar (Murphy ve ark. 1993). 2000-2001 yıllarında Ulusal Kolej Spor Birliği (UKBS) yaralanma gözetim sistemine göre, futbol, basketbol, lakros atletleri arasında en fazla yaralanmaya maruz kalan bölgeler ayak bileği, bacak ve dizdir (Dick ve ark. 2007). Kas gerginliği, kontüzyonlar ve bağ dokusu burkulması en fazla görülen yaralanma tipleridir. Araştırmacılar ve klinik tedavi uzmanları sportif yaralanmaları önleme ve müdahalede bulunması her geçen gün artmaktadır.

Araştırmacıların müdahalede bulunmadan önce yaralanma için, risk faktörlerini açıkça belirlemelidirler. Dışsal faktörler ve içsel faktörler başta olmak üzere yaralanmaya sebep olan birçok faktör öne sürülmüştür. Dışsal risk faktörleri dış etki, hava durumu, spor malzemeleri, oyun alanı malzemesini içermektedir. İçsel risk faktörleri ise fazladan antrenman yüklemeleri, antrenman yüklemeleri, antrenman eksikliği, psikolojik durum ve yanlış hareket tekniğini içermektedir (İnal, 2006). Alt ekstremite yaralanmaları, spor müsabakaları ve antrenman sırasında en sık gördüğümüz yaralanmadır. Atletizm, basketbol, futbol gibi spor branşlarında, alt ekstremite yaralanmaları çok fazla görülmektedir (Çolak ve ark. 2004). Avrupalı profesyonel futbol oyuncularında bildirilen kas-iskelet sistemi yaralanmaları sıklığı yüksektir (Price ve ark. 2003). Alt ekstremite yaralanmaları istatistiksel olarak birçok ülkede büyük bir oranı kapsamaktadır. Türkiye'de yaralanmaların %19'u üst ekstremite de %90 ise alt ekstemite bölgesinde meydana gelmiştir. Alt ekstremite spor yaralanmaları Almanya da %73,83'tür (Hammes ve ark. 2014). Ayrıca Fontana'ya göre spor yaralanmaları sıklığı anatomik bölgelere göre analiz edildiğinde, en fazla yaralanan bölgeler omuz, diz ve ayak bileğidir (Fontana, 2005).

Sağlık açısından sportif etkinlikler faydalı olmasına rağmen, spor yaralanmaları sportif etkinliklere katılımın önündeki en büyük engellerden birisidir. Futbolda fiziksel değişim ve spor mücadelesinin bu arka planına karşı, kas iskelet yaralanmalarını tespit etmek ve önlemek için bazı testler yapılır ve genellikle genç oyuncular üzerinde, futbol kulüplerindeki akademi tıp ve spor bilimi personeli tarafından yaşa göre veya bir sezon boyunca fonksiyonel değişikliği izlemek ve fonksiyonel özellikleri veya risk faktörlerini tespit etmek için yapılır (Cejudo ve ark. 2009). Alt ekstremite (kalçadan ayak dahil olan bacak bölümü) yaralanmaları yüzde 55-90 oranında görülen en sık spor yaralanması olup önemli bir kısmı ayak bileğinde oluşmaktadır. Bu yaralanmalar çoğunlukla pek önemsenmediğinden uygulanan geleneksel tedaviler yetersiz tedaviye ve sonucunda eklem kireçlenmesine yol açabilmektedir. Ayak bileği eklemi ‘talus, tibia ve kalkaneus’ isimli kemiklerin oluşturduğu hareketli bir eklemdir. Ayak bileği yaralanmaları daha çok ayağın burkulması ile gerçekleşir. Ayak bileği eklemini bu kemik yapılar dışında dış yan, iç yan ve kemikler arası bağlar sabitler. Dış yanda anterior talofibular bağ, posterior talofibular bağ ve kalkaneofibular bağ başlıca bağlar olup iç kısımda ise derin ve yüzeyel deltoid ligament eklemi destekler. Kemikler arası bağlar ise 5 bağ yapısından oluşur.

Ayak bileğinin en gevşek olduğu pozisyon, ayağın aşağı doğru yönlendiği plantar fleksiyonudur. Bu nedenle çoğu yaralanma bu pozisyonda oluşur. Ayak bileğinde bağların yaralanması hafif, orta ve ağır olmak üzere derecelendirilebilir. Hafif derecede bağlarda gerilme oluşur ancak yırtılma olmaz, orta derecede bağlarda kısmi yırtık vardır. Ağır dereceli yaralanmalarda ise bağlarda tam yırtık oluşmaktadır. Yaralanmaların ciddiyetine göre eklemde şişlik, ağrı ve kanama görülmektedir.

2. Hareket Sistemi Anatomisi

2.1. Kemikler

Kemikler kemik iliği, kemik doku ve bunların çevrelendiği bağ dokudan meydana gelen organlardır. Kemikler vücudun hareketini sağlayan, destekleyen ve koruyan bir özelliğe sahiptir. Ayrıca kan yapımında etkili olup, vücudu dış etkenlere 10 karşı korurlar. Kemik dokusunda kalsiyum, fosfat, magnezyum ve sitrat gibi çok sayıda bileşen bulunmaktadır (Muscolino, 2014). Yapı olarak oldukça karmaşık bileşenlerden meydana gelmektedir. Kemik dokuda süngerimsi kemik, sıkı kemik, kan damarları, mineralize fibriller bulunmaktadır. Sert ve mineralize yapısına rağmen kemik dokuda kan damarları bulunmaktadır ve canlı bir yapıya sahiptir (Muscolino, 2014). Kemiğin yapımında ve yeniden inşa edilmesinde osteositler, osteoprojenitor, osteoklastlar gibi hücreler görev yapmaktadır (Bingöl, 2022).

Kemiğin dokusu sekonder ve primer olarak iki şekilde incelenebilir. Primer kemik dokusu kemik onarımı aşamasında gelişmekte olup geçici özelliğe sahiptir. Özellikle fötal gelişim dönemlerinde görülür. Yetişkinlerde ise kafatası kemiklerinin bireşme yerlerinde ve tendonların kemiklere giriş yaptığı bölgelerde görülmektedir. Sekonder kemik dokusu ise uzun ve kısa olarak düzensiz şekillerde, lamelli yapıdadır ve yetişkinlerde görülür. Lameller içindeki kollojen iplikler birbirine paralel iken, komşu lamellerdeki iplikler ise çapraz ve sarmal şekillerdedir. Bu özelliği sayesinde kemiklere dayanıklılık ve esneklik kazandırırlar (Serbest ve Eldoğan 2014). Kemikler vücudun farklı bölgelerinde farklı özelliklerde görülmektedir. Şekilleri, fonksiyonları ve boyları gibi çeşitli özellikler bu kemiklerin sınıflandırılmasına etkili olmaktadır (MEB, 2007). Bu kapsamda kemikler uzun kemikler, yassı kemikler, kısa mekikler ve şekilsiz kemikler şeklinde ifade edilebilir (Viceconti, 2012).

2. 1.1.Uzun Kemikler

Uzunluğu genişlik ve kalınlığından fazla olan kemiklerdir. İskelet sisteminde alt, yan ve üst kısımlarda bulunmaktadır. Kol, bacak, parmak, pazı kemiği, kaval ve uyluk kemikleri buna örnek verilebilir (Viceconti, 2012).

2.1.2. Yassı Kemikler

Yapısı itibariyle ince, yassı ve kavisli özelliğe sahip olan bu kemiklere şakak kemiği ve art kafa kemiği örnek olarak verilebilir (Viceconti, 2012).

2.1.3. Kısa Kemikler

Uzunluk ve genişlik bakımından birbirine benzer olan kemikler kısa kemiklerdir. Ayak bileği ve el bileğinde bulunan kemikler kısa kemiklere örnek verilebilir. Kısa kemiklerin dışında kemik zarı bulunmaktadır. Altında sert kemik ortada ise süngerimsi kemik bulunur. Kısa kemiklerde kemik kanalı bulunmamaktadır.

2.1.4. Şekilsiz Kemikler

Şekilsiz kemikler aynı zamanda düzensiz kemikler olarak da bilinmektedir. Uzun, kısa ya da yassı olarak nitelendirilemeyen kemikler bu grupta yer alır. Şekilsiz kemikler baskı ya da darbelere karşı son derece dayanıklıdırlar. Vücudun baş bölgesinden ayaklara kadar olan bütün kısımlarında yer almaktadırlar. Elmacık kemikleri, omurlar ve çene kemikleri buna örnek olarak gösterilebilir (Dernell, 2011).

2.2. Uzuvlar

2.2.1. Üst Uzuv Kemikleri

Üst uzuv kemikleri omuz, kol, ön kol ve el kemiklerinden meydana gelmektedir. Üst ekstremite kemikleri iki taraflıdır ve toplamda 64 kemik bulunmaktadır (Muscolino, 2014).

2.2.2. Omuz Bölgesi

Üst ekstremitenin omuz bölgesinde köprücük ve kürek kemikleri bulunmaktadır. Kürek kemiği yassı ve üçgen şeklindedir. Omuzun her iki tarafında da bulunmakta olan bu kemik, köprücük kemiği, kürek kemiği ve göğüs kemikleri arasında eklemler yaparak köprü görevi üstlenir (Aktümsek, 2006).

Kol Kemiği: Üst ekstremitenin en uzun kemikleri arasında yer almaktadır. Bu kemik aynı zamanda omuz ve dirsek arasındaki tek kemiktir. Kemik pazu kemiği olarak da bilinir (Aktümsek, 2006).

Ön Kol Kemikleri: Dirsek ile el bileği arasında bulunan bu kemikler birbirine paralel iki kemikten meydana gelir. Biri dirsek kemiği (ulna), diğeri ise döner kemik (radius) olarak bilinir (Aktümsek, 2006).

El İskeleti Kemikleri: El kemikleri, parmaklar, el tarağı ve bilek kemiklerinden meydana gelmektedir. Bilek kısmında sırayla dizilmiş 8 tane kısa kemik bulunmakta olup, parmaklara doğru ise 5 adet el tarağı kemikleri uzanmaktadır. Başparmakta 2 diğer parmaklarda ise 3’er tane kemik bulunmakta ve bir elin parmaklarında toplam 14 kemik bulunmaktadır (Aktümsek, 2006).

2.2.3. Alt Uzuv Kemikleri

Alt ekstremite kemikleri vücudun iki tarafında bulunmakta olup ayak, kalça, uyluk ve bacak kemiklerinden meydana gelmektedir. İki tarafta toplam 62 kemik bulunmaktadır (Yıldırım, 2012).

Kalça(Leğen): Kalça kemiği üç kemiğin birleşmesiyle oluşmaktadır ve iki kemik arasında sağrı kemiği bulunmaktadır. İki kalça kemiği arasında boşluk vardır ve bu boşluk pelvis olarak adlandırılır (Yıldırım, 2012).

Uyluk: Uyluk kemiği vücudun en uzun kemiği olup tek gövdeden ve iki uçtan meydana gelir. Kemiğin üst ucunda kalça kemiği ile eklem yapan, alt kısmında ise diz kapağı ile eklem yapan lokmalar mevcuttur (Yıldırım, 2012).

Ayak İskeleti Kemikleri: Ayak kemikleri, ayak bileği ile ayak parmakları arasında bulunan kemiklerden oluşur, ayak bileğinde 7 tane kemik bulunmakta olup, bunlardan ikisi (topuk ve aşık kemikleri) iri kemikli yapıya sahiptir. Diğer kemikler ise daha ön kısımda bulunurlar. Ayakta, ele benzer şekilde her bir ayak için 5'er tane tarak kemiği bulunur. Yine ele benzer şekilde parmaklarda, başparmakta 2 ve diğer parmaklarda 3'er tane olmak üzere toplam 14 kemik bulunmaktadır. İki ayak için toplam kemik sayısı 28'dir (Yıldırım, 2012).

Diz Kapağı: Diz kapağı kemiği (patella), uyluk ile bacak kemikleri arasında bulunmaktadır. Yapı bakımından yassı ve kısa bir özelliğe sahiptir. Ön yüzü derinin hemen altındadır, arka kısmı ise uyluk kemiğinin ucuna eklem yapmaktadır (Yıldırım, 2012).

Bacak Kemikleri: Bacak kemikleri ayak bileği ile diz arasında bulunan, ön koldaki yapıya benzer şekilde ön ve arka şeklinde iki kısımdan oluşur. Ön ve içte olan kemik kaval kemiği, arka ve dışta olan ise kamış kemiğidir. Vücudun en kalın kemiği kaval kemiğidir ve kaval kemiği de bacak kaslarının içerisine gömülü durumdadır. Kaval kemiği deriye çok yakın olduğu için dışarıdan kolaylıkla fark edilebilir bir özelliğe sahiptir (Yıldırım, 2012).

2.3. Sportif Yaralanmalar ve Çeşitleri

2.3.1.Yumuşak Doku Yaralanmaları

Yumuşak doku yaralanmaları genellikle spor aktiviteleri esnasında ortaya çıkmakta olup kas-iskelet sistemi yaralanmalarına nazaran daha fazla meydana gelmektedir. Bu kapsamda doku hasarının eşlik ettiği yaralanmalar, sportif yaralanmalar ve ciddi yaralanmalar ortaya çıkabilmektedir (Bayraktar, 2005). Yumuşak dokuya ilişkinin yaralanmaların ortaya çıkmasında genellikle ligamanlar, kas ve tendon gibi dokuların tolere edemeyeceği ölçüde bir

zorlama ya da yükle karşı karşıya kalmaları etkili olmaktadır. Sporcu ya da kemiklerde doğrudan bir zarar meydana getirmeyecek kuvvet ile karşı karşıya kaldığında, kuvvete karşı postürünü korumaya çalışmakta ve bu hareketi sırasında dokuların dayanma sınırını aşarak incinme meydana gelmesine neden olmaktadır. Benzer şekilde kuvvete karşılık vücudun hareket sistemi içerisinde uygulanan kuvvetlerin dokuların dayanma kapasitesine açması ile birlikte travmalar ortaya çıkabilir (Bayraktar, 2005). Yumuşak doku yaralanmaları genellikle ligament, kas ve tendon yaralanmaları şeklinde üç kategoride değerlendirilebilir.

2.3.2. Kas Yaralanmaları

Kas yaralanmaları, tüm zaman kaybı yaralanmalarının % 31'ini oluşturur ve erkek profesyonel futbolcularda toplam yaralanma yokluğunun % 27'sine neden olur (Ekstrand ve ark. 2011). Erkek profesyonel futbolcular üzerinde yakın zamanda yapılan bir araştırma, kas yaralanmalarının tüm yaralanmaların % 30'undan fazlasını oluşturduğunu ve toplam yaralanmanın yaklaşık dörtte birine neden olduğunu görülmektedir. Kas yaralanmalarının % 90'ından fazlası alt ekstremitenin dört ana kas grubunu etkiler: hamstringler, adduktörler, kuadriseps ve gastrokinemius. Hamstring kas grubundaki yaralanmanın, tüm yaralanmaların % 12'sini temsil eden en yaygın yaralanma alt tipi olduğu bildirilmektedir (Ekstrand ve ark. 2011). Hamstring yaralanması profesyonel futbolda en sık görülen yaralanmadır. MRG, tanıyı doğrulamak ve işten çıkarma süresinin prognozunu sağlamak için yaygın olarak kullanılır. Gergin hamstringler aktiviteler esnasında kalçanın mobilitesini kısıtlar ve alt ekstremite de sakatlanmalara sebep olabilmektedir. Kas yaralanmaları farklı yaralanma tipleri, yerleri, şiddetleri ve boyutlarından oluşan heterojen bir gruptur, bu iyileşme süresi ve rehabilitasyonla ilgili prognozları zorlaştırır (Müller ve ark. 2010). Kas yaralanmaları çok yaygın olmasına rağmen, sınıflandırma ve tedavi zor olabilir. Akut kas yaralanmalarının teşhisi ve ilişkili prognoz normalde öncelikle tıbbi geçmişe ve klinik bulgulara dayanır ve tanıyı doğrulamak için ek bilgi sağlamak için MRI veya ultrason gibi radyolojik yöntemler kullanılır (Askling ve ark. 2008).

2.3.3. Tendon ve Ligament Yaralanmaları

Tendon ve bağlar birbirine benzemelerine ve basit, homojen ve biyolojik olarak durağan görünmelerine rağmen, gerçekte oldukça farklı, karmaşık, heterojen ve dinamiktirler (Benjamin ve Ralphs 2000). Makro anatomik düzeyden bakılacak olursa basitçe tendonlar kasları kemiklere bağlarken, bağlar kemikleri kemiklere bağlar. Bütün tendonlar kaslara bir ucundan bağlanmıştır ve bu birleşim noktaları myotendinöz bileşke olarak adlandırılır. Bu sayede

tendonlar kaslardan kaynaklanan yükleri taşırlar ve aynı zamanda hem eklemleri destekler, hem de hareket sırasında ekleme yardım ederler. Sonuç olarak da tendonlar hareket sırasında gücü kemiklerden ekleme iletmiş olurlar. Diğer yandan bağlar ise kas yapışmaları olmadığından daha "pasif" yapılardır ve çeşitli durumlarda eklem hareketlerinin kontrolünde ve stabilitenin sağlanmasında görev alırlar (Benjamin ve Ralphs 2000). Tendinopatiler ve bağ yırtılma yaralanmalarının sebebi sporcularda müsabakalarda aşırı kullanılmasından kaynaklanmaktadır. Tendon ve çevresinde fazla kullanılmaya bağlı oluşan klinik ve patolojik değişikliklere "tendinopati" denir. Tendinosis ise histopatolojik olarak kanıtlanmış, tendon ve çevresinde enflamasyonun eşlik etmediği dejeneratif değişiklikler olarak adlandırılır, enflamasyonun eşlik ettiği değişikliler ise "tendinit" olarak isimlendirilir (Maffulli ve ark. 1998). Aşırı kullanım yaralanmaları sporcularda en sık aşiltendonu, patellartendon ve rotator manşet tendonlarında görülür (Rees ve ark. 2006). Aşırı kullanım tipi sakatlıklardan biri olan diz bölgesi ligament yaralanmaları, futbolda en sık görülen sportif yaralanmalardır, özellikle maçın son dakikalarında meydana gelmektedir (Fields ve ark. 2010). Diz üzerinde gövdenin yüksek bir kuvvetle dönmesinde (dışa rotasyonunda) bir kopma sesi işitilir (Ford ve ark. 2003). Ön çapraz bağ (ÖÇB) rüptürü, profesyonel sporcularda en sık rastlanan bağ sakatlıklarından birisidir, tam kopmaları durumunda genellikle cerrahi tedavi olması gerekir (Cook ve Purdam 2009).

2.3.4. Kontüzyon ve Hematomlar

Kontüzyon, çoğu hastada yumuşak doku hasarının yaygın bir nedeni temaslı yapılan sporlardan kaynaklanır (Bass, 1967). Doğrudan, künt sarsıntı baldırda tekmelenme gibi kas kontüzyonları üretir. Kontüzyon, esas olarak, etkilenen kasın göbeğinde veya karında çarpma bölgesinde ödem ve peteşiyal kanama ile karakterize ve daha sonra santrifüj olarak yayılan kas içi bir "çürük" dür. Sonuç, kas liflerini özetleyen suya duyarlı görüntülerde yüksek sinyal yoğunluğunun bir modelidir ve en çok iç yağdan gelen sinyal bastırıldığında göze çarpar (Elsayes ve ark. 2006). Seçkin sporcularda, bazı spor hekimleri büyük bir hematom aspirasyonunun iyileşmeyi hızlandırabileceğine inanmaktadır (Dave ve ark. 2014). Kas hematomunun tedavisi çoğunlukla konservatiftir (Ellis ve Frank 1966). Bazı durumlarda şiddetli ağrı, hassasiyet ve şişme, ameliyat düşünülebilir. Bununla birlikte, klinik değerlendirme türü hakkında herhangi bir bilgi vermez. Kanamanın boyutu veya yerinin değerlendirilmesi için objektif bir teknik önemlidir, ultrason aracılığıyla bakılır (Braunstein ve ark. 1981).

2.3.5. Eklem Yaralanmaları

Eklemler günlük yaşam faaliyetleri, sportif aktiviteler ve yaşamsal aktiviteler sırasında birtakım engeller meydana gelebilmektedir. Bu engeller eklemlerin sınırlarını açtığı durumlarda yaralanmalar meydana gelir. Bu durumda omuz, ayak bileği ve diz gibi eklemlerde rahatsızlıklar görülebilir. Diz eklemi yaralanmaları ve travmaları sıklıkla sporcularda görülmektedir. Menisküs yırtılması, bağ lezyonları, osteokondral kırıklar, patellanın çıkığı görülen diz lezyonlarının başlıcalarıdır. Belirtilen bu lezyonlar derinlemesine incelemeler sonucu ortaya konmuş ve iyi bilinen klinik ve radyolojik bulgularla kolayca tanınabilmektedir (Morscher, 1970). Eklemler hareket sırasında özellikle düşme ve sıçrama gibi durumlarda kontrol edici bir özelliğe sahiptir. Dizde bulunan en büyük kaslardan kuadriceps kasının eklemler vasıtasıyla yüklenmeyi patella üzerine taşımaktadır. Tekrarlı ve yoğun bir şekilde gerçekleşen hareketler patellar tendonda ciddi düzeyde yaralanmalara neden olabilir. Travmaya bağlı olarak meydana gelen lezyonların zaman içerisinde tendon ve tendinit üzerinde hasarlar oluşmasına neden olabilir (Peers ve Lysens 2005). Ligament (bağ) yapı güçlü bir ağ ile sarılı olup, sportif aktiviteler esnasında özellikle de yan tarafa ya da öne eğilme gibi durumlarda pelvis arkasında ağrı meydana getirerek kendini hissettirir. Sadece ligament yapılarla desteklenen bu eklemin yaralanması eklemi saran ligament yapının zorlanması sonucu dejenere olmasıdır (Brolinson ve ark. 2003). Üst ekstremitede bulunan akut ve omuz gibi yaralanmalar, dirsekte meydana gelen burkulmalar, klavikulada meydana gelen kırılmalar ve çıkıklar olarak ortaya çıkabilmektedir (Kocher ve Nichols 2008). Bazı araştırmacılar omuzlara yapılan aşırı yüklenmelerin ligament ve kaslarda hasar riskini artırdırdığı ve zamanla artan ağrıya neden olduğunu belirtmişlerdir (Sakallı, 2008).

2.4. Kemik Yaralanmaları

Kemik yaralanmaları kemikte meydana gelen kontüzyon, kemik ezilmesi, yaralanma ve kemik iliği ödemi gibi şekillerde adlandırılmaktadır. Bu kemiklerde meydana gelen kırıklar ödem, kanama ve enfarkt şeklinde tanımlanabilir (Rangger ve ark. 1998). Bu kırıklar literatürde süngerimsi kemik doku ile ilişkili tamamlanmasına rağmen diz eklemi içinde tarif edildiği görülmektedir. 1988 yılında yaralanmalarda tanımlanan kemik ezilmeleri günümüzde manyetik renozans cihazlarının artması ile birlikte daha sık ve daha kolay tespit edilmektedir (Yao ve Lee 1988). Kemiklerde meydana gelen ezilmeler doğrudan grafiklerle tespit edilemez. Çünkü kortikal kemik bütünlüğü korunmaktadır. Bununla birlikte bu ezilmeye bağlı olarak ortaya çıkan avülsiyon kırığı gibi durumların saptanması daha kolaydır. Kemiğin ezilmesi doğrudan darbe gelmesi, makaslama, kemiklerin birbirine çarpışması, traksiyon kuvveti ya da notasyon gibi durumlara bağlı olarak oluşabilmektedir. Bunlar çoğu zaman diğer yumuşak doku

yaralanmaları ile ilişkili görülebilir (Vanho-enacker ve Snoeckx 2007). Bu yaralanmalar genellikle gizli olmakla birlikte MR cihazları sayesinde görülebilir (Ege, 2001). Ortaya çıkış sebeplerine ve hastalıklara bağlı olarak kemik iliği ödeminin farklı sınıflandırmaları yapılmaktadır. Yapılan bir sınıflandırmaya göre kemik iliği ödemi üç kategoride değerlendirilebilir; (i) İskemik KİÖ (osteonekroz, kemik iliği ödemi sendromu, osteokondritis dissekans, kompleks rejyonel ağrı sendromu), (ii) mekanik KİÖ (kemik kontüzyonu, mikro kırık, stres kaynaklı, stres kırığı, (iii) reaktif KİÖ (gonartroz, osteoartrit, ameliyat sonrası KİÖ, tümör kaynaklı KİÖ) (Starr ve ark. 2008).

2.5. Futbolcularda Sportif Yaralanmalar

Birçok sporda olduğu gibi futbolun da kendine özgü bir takım hareket farklılıkları vardır. Futbol içerisinde submaksimal koşular, sprintler, topla driplingler, yürüyüşler, ani hızlanmalar, ani dönüşler, sıçramalar, ikili mücadeleler, yön değiştirmeli koşular, kayarak müdahaleler ve topla yapılan çok sayıda hareket içeren anaerobik bir spor olmasına rağmen aerobik tabanlıdır (Açıkada ve ark. 1999). Futbol sporunu ve oluşturduğu sektörün devamlılığı ile başarısını etkileyen önemli faktörlerden biriside futbolcuların yaşadığı sportif yaralanmalardır. Futbolcularda meydana gelen yaralanmalar, tüm branşlarda olduğu gibi sportif verimin düşmesine, sporcuların antrenman ve müsabakalardan geri kalmasına ve ayrıca kişiler kulüpler ve ülkeler açısından tıbbi maliyetlere neden olmaktadır. Futbolcularda sportif yaralanmaların nedenlerinin bilimsel verilerle ortaya konulması, yaralanmaların önlenmesinde alınacak tedbirlerin belirlenmesi açısından önemlidir. Antrenmanlarda ve müsabakalarda futbolcular aşırı zorlanma, düşme veya darbe şeklinde hasara uğrayarak sakatlanmaktadırlar. Bu tip hasarlar dışında bilineceği gibi beceri, kondisyon, esneklik, çabukluk, konsantrasyon gibi fizyolojik etkenlerin eksikliği ve aynı zamanda antrenmaların uzunluğu ve zorluğu, tesis, malzeme, olumsuz hava durumu gibi koşullar da yaralanma riskini artırmaktadır. Futbolcuların müsabakalarda yaralanma oranları oldukça yüksektir. Erkek profesyonel futbolcuların bir yıl boyunca en az birkaç kez sahalardan uzak kaldığı ve yaralanmaya maruz kaldığı düşünülmektedir (Grzegorz ve Lukasz 2002). Futbolda fiziksel özellikler ya da bedensel yapı fizyolojik kapasitenin ortaya konulmasını etkilemektedir (Köklü ve ark. 2009). Sahip olunan antropometrik özellikler futbolda bir takım sportif yaralanmalara neden olmaktadır.

2.6. Sporcu yaralanmalarını etkileyen etmenler

2.6.1. Boy

Erkeklerde, kızlarda ve toplam sporcularda boy arttıkça sakatlanma oranları anlamlı bir şekilde artış gösterir. Uzun sporcularda, eklem kaldıraçlarının daha uzun olması sebebiyle diz eklemi bağ yaralanmaları açısından risk oluşturur (Hrysomallis ve ark. 2007). Kısa sporcularda ise kaslarda gerginlik tipi yaralanmaların oluşmasında risk ortaya çıkmaktadır (Orchard, 2001).

2.6.2. Kilo

Spor yaralanmalarının kilo, yaş ve spor branşlarına göre değiştiğini gösteren birçok çalışma mevcuttur (Inklaar ve ark. 1996). Çeşitli popülasyonlarda çeşitli değerlendirme araçlarını kullanan çalışmalar, vücut kütlesi arttıkça dengenin kötüleştiğini göstermiştir (McGraw ve ark. 2000). Futbol gibi spor branşlarında vücut ağırlığının rahat hareket ettirilmesi çok önemlidir, vücut ağır olduğunda erken yorgunluk başlar. 21 Futbolcularda kilo problemi birtakım yaralanmalara zemin hazırlayabilir. Sporcuların vücut ağırlığı yüksek olduğunda alt ekstremitelerine çok yük binmesinden ötürü yaralanma olasılığı daha fazladır (Özdemir, 2004).

3. YÖNTEM

Bu çalışmanın amacı, futbolda sık görülen alt ekstremite yaralanmalarının oluşum mekanizmalarını, risk faktörlerini ve yaralanmaya yatkınlığı artıran değişiklikleri ortaya koymak amacıyla hazırlanmıştır. Bu amaç doğrultusunda “Alt Ekstremite, Futbolda sakatlık, Sakatlık” anahtar kelimeleri kullanılarak “Google Akademik ve uUlusal Tez Merkezi taraması sonucunda elde edilen bilgiler ışığında derlenmiştir.

4. TARTIŞMA

Sharareh ve ark. (2013) yaptıkları bir çalışmada alt ekstremitede bazı çevre ve uzunluk değerleriyle yaralanmalar arasında ilişki bulunduğunu belirtmişlerdir. Hyrsomallis (2009) tarafından yapılan bir diğer çalışmada kalça esnekliği ile sportif yaralanmalar arasındaki ilişki vurgulanmış ancak daha yüksek düzeyde kanıtlara ihtiyaç olduğu belirtilmiştir. Witvrouw ve ark. (2003) Belçika futbol liginde oynayan 146 erkek futbolcu ile yaptıkları araştırmada quadriseps ve hamstring kas sakatlanması olan futbolcuların quadriseps ve hamstring kas gruplarının sakatlanmadan önceki esnekliğini, sakatlanma olmayan sporcuların kaslarının esnekliğinin daha az olduğu bulunmuştur ve futbol sporcularında quadriseps kaslarındaki esneklik kaybının kas sakatlanmasında artışa sebep olduğu sonucuna varmışlardır. Ekstrand ve Gillquist (1982) tarafından yapılan araştırmada spor sakatlıklarının oluşmasında sporcunun fiziksel yapısından kaynaklanan veya sporcu dışındaki sebeplerden kaynaklanan pek çok faktörün etkili olduğu belirtilmiştir. Esneklik te bu faktörler arasında sayılabilmektedir. Spor yaralanmaları açısından esneklik çok önemli bir yere sahiptir, aynı zamanda sporcunun

performansı açısından da önemli bir yere sahiptir. Bu yüzden esneklik ile spor sakatlıkları arasındaki ilişki birçok araştırmada konu edinmiş ve birbiri ile farklı ve çelişkili sonuçlar elde edilmiştir. Malliaras ve ark. (2008) tarafından futbolcularda yapılan bir araştırma sonuçlarına göre kalça esnekliği ile kasık ağrısı arasında ilişki olduğu rapor edilmiştir. Moreno ve ark. (2022) yarı profesyonel futbolcularda tam bir futbol sezonu boyunca futbol antrenmanı ve maç oynamanın hamstring kas gücü ve kalça ve ayak bileği eklem hareket açıklığını incelemişlerdir. Bu araştırmada, hamstring kaslarındaki zayıflığın, kalça ve ayak bileği eklemlerindeki azalmış eklem hareket açıklığının katkısıyla birlikte, hamstring kas gerilme yaralanmasının gelişimi ile ilişkili önemli bir risk faktörü olduğunu öne sürmüşlerdir. Messier ve ark. (2008) diz yaralanma mekanizmalarını belirlemeyi amaçladıkları çalışmalarında, 20 sporcunun, esneklik, Q açısı, yürüyüş analizi ve izokinetik test değerlendirmelerini yapmışlardır. Çalışmanın sonucunda, zayıf hamstring esnekliğinin diz eklemi üzerine yük gereğinden fazla binerek, ciddi yaralanma riski oluşturduğunu göstermişlerdir. Bradley ve ark. (2017) 36 futbolcu ile yaptıkları çalışmada sezon öncesi ölçülen eklem hareket açıklığının sezon sonuna kadar geçirilebilecek hamstring yaralanmalarını ne yönde etkilediğini incelemişlerdir. Sezon başında yapılan incelemeler ve sezon sonuna kadar geçirilen yaralanmaların kaydedilmesi ile, kalça ve diz eklem hareketi esnekliğinin daha az olduğu sporcularda daha fazla yaralanma meydana geldiğini göstermişlerdir. Araştırmacılar ayrıca, esneklik değerlendirmesinin sezon başında yapılmasını ve azalmış eklem hareketi olan oyunculara yoğun bir esneklik programı uygulanması gerektiği görüşünde bulunmuşlardır. Çelik ve Bek (2016) ayak ve ayak bileği yaralanması olan profesyonel futbolcularda ayağın antropometrik özellikleri ile ayak yaralanması arasındaki ilişkiyi inceledikleri araştırmalarında anlamlı bir ilişki bulduklarını belirtmişlerdir. Ayak bileği burkulmaları fiziksel hareketleri yüksek sporcularda en sık görülen kas iskelet sistemi yaralanmalarıdır (Valderrabano ve Easley 2017). Uzun boy ve yüksek vücut ağırlığının ayak bileği yaralanmaları riskini arttırdığı yönünde çalışmalar mevcuttur. Araştırmalar da boy ve vücut ağırlığının artmasının; ekleme, bağ dokusuna ve kas yapılarına binen yükte orantılı bir artışa neden olduğu ve yaralanma kaçınılmaz olduğu sonucuna varılmıştır (Milgrom ve ark. 1991). İlhan (2021) yaptığı araştırmada ayak bileği yaralanması olan sporcularda dinamik ve gonyometrik olarak ölçülen dorsifleksiyon hareket açıklığı ile plantor fleksiyon eklem hareket açıklığının yaralanmayı takip eden 4.hafta ile 8. hafta arasında artış gösterdiği fakat son yapılan ölçümde kontrol grubuna göre kısıtlı olarak kaldığı bulunmuştur. Ayak bileği eklem hareketleri limitasyonun ayak bileği yaralanmaları açısından hazırlayıcı risk faktörleri olduğu düşünülmektedir. Shambaugh ve ark. (1991) tarafından basketbolcularda yapılan çalışmada

bacak uzunluğu ile alt ekstremite yaralanmaları arasında güçlü bir ilişki olduğu belirtilmiştir. Lopez Valenciano ve ark. (2019) bir sezon boyunca ayak bileği dorsifleksiyon eklem hareket açıklığının azalması, yaralanma riskinin arttığının bir göstergesi olabilir ve profesyonel futbolcularda germe egzersizleri ve eksantrik kuvvet antrenmanı gibi önleme çalışmalarının yapılmasını önermişlerdir. Friel ve ark. (2006) tarafından yapılan bir araştırmada yaralanmış ekstremite de plantar fleksiyon eklem hareket açıklığının yaralanmamış tarafa göre belirgin azalmış olduğu sonucuna ulaşılmıştır. Kobayashi ve ark. (2016) yaptıkları sistematik derlemede azalmış dorsifleksiyon hareket açıklığı ile ayak bileği yaralanması arasında önemli bir korelasyon olduğu bulgusunu doğrulamıştır. Kafkas ve ark. (2009) badminton milli sporcuların çeşitli fiziksel, fizyolojik ve antropometrik özellikleri ile yaralanma ilişkilerini inceledikleri araştırmada sporcuların ayak çevresi, diz bölgesi ve uzunlukları, kalça ve uyluk genişlikleri ile yaralanma arasında ilişkinin bulunduğunu belirtmişlerdir. Benzer literatürün bu araştırmanın sonuçlarıyla paralellik gösterdiği ve desteklediği görülmüştür.

5. SONUÇ VE ÖNERİLER

Yapılan araştırma sonucunda; özellikle hamstring, adduktör ve ayak bileği çevresi yaralanmalarının genç sporcularda performans kaybına ve uzun vadeli fonksiyonel sınırlılıklara yol açabileceğini göstermiştir. Literatürle uyumlu olarak, düzenli fonksiyonel taramaların, doğru yüklenme planlamasının ve kas dengesini geliştirmeye yönelik antrenman protokollerinin erken yaşta uygulanmasının yaralanma riskini anlamlı düzeyde azalttığı belirlenmiştir. Futbolun yüksek tempo ve temas içeren yapısı yaralanmaları kaçınılmaz kılsada, bilim temelli bir izleme değerlendirme sistemi ile risk yönetimi en aza indirilebilir.

- Futbolcuların boy, kilo, bacak uzunlukları, kas kitlesi dağılımı ve simetri durumu dönemsel olarak takip edilerek yaralanmaya yatkınlık oluşturan yapısal farklılıklar erkenden tespit edilmelidir.
- Denge, propriosepsiyon, hareket kalitesi ve alt ekstremite kuvvet parametreleri belirli aralıklarla değerlendirilerek riskli oyunculara özel iyileştirme programları hazırlanmalıdır.
- Futbolda sık görülen alt ekstremite yaralanmalarının hangi hareketler sırasında ortaya çıktığı oyunculara anlaşılır şekilde anlatılarak doğru vücut mekaniği ve güvenli hareket stratejileri geliştirilmelidir.
- Oyuncularda tespit edilen kuvvet dengesizlikleri, hareket kısıtlılıkları veya koordinasyon sorunlarına yönelik bireyin ihtiyaçlarına göre uyarlanmış antrenman protokolleri uygulanmalıdır.
- Gelişim dönemindeki sporcuların fizyolojik özelliklerine uygun, yüklenme ve dinlenme stratejileri kullanılmalıdır.
- Antropometrik ve fonksiyonel ölçümlerden elde edilen veriler düzenli olarak analiz edilerek önlemler alınmalıdır.

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PERFORMANSIN GÖRÜNMEYEN YÜZÜ: SPORCULARDA BESLENME VE YEME BOZUKLUKLARI

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ÖZET

Sporcu beslenmesi, maksimum atletik performansın sağlanması ve sürdürülmesi için temel bir unsurdur. Sporcuların beslenme programları; günlük gereksinimlerin yanı sıra antrenman ve müsabaka öncesi, sırası ve sonrasını kapsayacak şekilde planlanmalıdır. Yeterli ve dengeli beslenme, doğru antrenman, uygun genetik yapı, yeterli hidrasyon ve dinlenme ile birlikte performansın önemli belirleyicilerindendir. Enerji gereksiniminin doğru hesaplanması ve yeterli enerji alımının sağlanması; toparlanmayı desteklemek, sakatlık ve hastalık riskini azaltmak ve uygun vücut kompozisyonunu korumak açısından kritik öneme sahiptir. Genel fitness programı uygulayan sporcularda karbonhidrat, protein ve yağ alımının önerilen oranlarda dağıtılması performans ve sağlık açısından gereklidir. Bu doğrultuda geliştirilen "Athlete's Plate" modeli, antrenman şiddetine göre porsiyon ve besin grubu düzenlemeleri için pratik bir rehber sunmaktadır.

Yeme bozuklukları; yeme davranışlarında bozulma ile seyreden, fiziksel, psikolojik ve sosyal işlevselliği olumsuz etkileyen önemli psikiyatrik hastalıklardır. DSM-5'e göre başlıca yeme bozuklukları anoreksiya nervoza, bulimiya nervoza ve tıkınırcasına yeme bozukluğudur. Tanı ölçütlerini tam karşılamayan ancak klinik açıdan anlamlı belirtiler gösteren durumlar ise tanımlanmış veya tanımlanmamış yeme bozuklukları altında sınıflandırılmaktadır. Yeme bozuklukları dünya genelinde yaygın olup, özellikle kadınlarda daha sık görülmektedir.

Anoreksiya nervoza, aşırı kısıtlayıcı beslenme, kilo alma korkusu ve beden algısında bozulma ile karakterizedir ve psikiyatrik hastalıklar arasında en yüksek mortalite oranlarından birine sahiptir. Bulimiya nervoza, tekrarlayan tıkınırcasına yeme atakları ve kilo alımını önlemeye yönelik telafi edici davranışlarla tanımlanırken; tıkınırcasına yeme bozukluğu, benzer kontrolsüz yeme ataklarına rağmen arındırıcı davranışların bulunmamasıyla ayırt edilmektedir. Sporcularda yeme bozuklukları, performans baskısı, beden imajı ve kilo kontrolü odaklı yaklaşımlarla yakından ilişkilidir. Özellikle estetik, kilo kategorili ve dayanıklılık sporlarında risk daha yüksektir. Düşük enerji alımı; hormonal bozukluklar, kemik sağlığında bozulma, sakatlık riskinde artış ve performans düşüşü ile ilişkilidir. Bu nedenle sporcularda yeme bozukluklarının erken taranması, sporcuya özgü beslenme eğitimi verilmesi ve multidisipliner yaklaşımla tedavi edilmesi hem sağlık hem de sürdürülebilir performans açısından büyük önem taşımaktadır.

Anahtar Kelimeler: Sporcu Beslenmesi, Yeme Bozuklukları, Sporcularda Yeme Bozuklukları,

THE INVISIBLE SIDE OF PERFORMANCE: NUTRITION AND EATING DISORDERS IN ATHLETES

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Abstract

Sports nutrition is a fundamental component in achieving and maintaining maximal athletic performance. Athletes' nutrition programs should be planned to cover not only daily requirements but also the periods before, during, and after training and competition. Adequate and balanced nutrition, together with appropriate training, favorable genetic factors, sufficient hydration, and proper rest, is one of the key determinants of performance. Accurate calculation of energy requirements and ensuring sufficient energy intake are critical for supporting recovery, reducing the risk of injury and illness, and maintaining optimal body composition. For athletes following general fitness programs, distributing carbohydrate, protein, and fat intake according to recommended proportions is essential for both performance and health. In this context, the "Athlete's Plate" model provides a practical guide for adjusting portion sizes and food group distributions based on training intensity. Eating disorders are significant psychiatric conditions characterized by disturbances in eating behaviors that negatively affect physical, psychological, and social functioning. According to the DSM-5, the main eating disorders include anorexia nervosa, bulimia nervosa, and binge eating disorder. Conditions that do not fully meet diagnostic criteria but present clinically significant symptoms are classified as other specified or unspecified feeding and eating disorders. Eating disorders are prevalent worldwide and are observed more frequently in women. Anorexia nervosa is characterized by severe dietary restriction, an intense fear of weight gain, and disturbances in body image

perception, and it has one of the highest mortality rates among psychiatric disorders. Bulimia nervosa is defined by recurrent binge eating episodes accompanied by compensatory behaviors aimed at preventing weight gain, whereas binge eating disorder is distinguished by similar episodes of uncontrolled eating without the presence of purging behaviors. In athletes, eating disorders are closely associated with performance pressure, body image concerns, and weight control–oriented approaches. The risk is particularly high in aesthetic, weight-class, and endurance sports. Low energy intake is associated with hormonal disturbances, impaired bone health, increased risk of injury, and decreased performance. Therefore, early screening for eating disorders in athletes, provision of sport-specific nutrition education, and treatment through a multidisciplinary approach are of great importance for both health and sustainable athletic performance.

Keywords: Sports Nutrition, Eating Disorders, Eating Disorders in Athletes

1. GİRİŞ

Sporcularda performansın belirlenmesinde fiziksel kapasite, antrenman yükü ve genetik yatkınlık kadar beslenme de temel bir rol oynamaktadır. Sporcu beslenmesi; yalnızca günlük enerji ve besin ögesi gereksinimlerinin karşılanmasını değil, aynı zamanda antrenman ve müsabaka dönemlerine özgü stratejik planlamayı da içeren çok boyutlu bir yaklaşımdır (Spriet, 2019). Yeterli ve dengeli beslenme, enerji sürekliliğinin sağlanması, toparlanmanın desteklenmesi, sakatlık ve hastalık riskinin azaltılması ve uygun vücut bileşiminin korunması açısından kritik öneme sahiptir (Mahan & Raymond, 2017; Aydenk Köseoğlu & Çelebi Tayfur, 2017). Bu nedenle sporcu beslenmesi, performansı artırmaya yönelik bilimsel temelli uygulamaların merkezinde yer almaktadır. Ancak son yıllarda sporcularda beslenmenin yalnızca performans artırıcı bir araç olarak görülmesi, bazı durumlarda ciddi sağlık sorunlarını da beraberinde getirmektedir. Özellikle düşük kilo, incelik ya da belirli bir vücut kompozisyonunun performansla özdeşleştirildiği spor branşlarında, sporcular üzerindeki kilo ve beden odaklı baskı artmaktadır (Joy et al., 2016; Wells et al., 2020; Ghazzawi et al., 2024). Bu baskı, sporcuları enerji alımını kısıtlamaya, düzensiz yeme davranışlarına ve zamanla klinik düzeyde yeme bozukluklarına sürükleyebilmektedir. Yeme bozuklukları; bireyin fiziksel, psikolojik ve sosyal işlevselliğini olumsuz etkileyen, yaşam kalitesini belirgin biçimde düşüren karmaşık psikiyatrik bozukluklardır (Solmi et al., 2020; Qian et al., 2021). Genel popülasyonda kadınlarda daha sık görüldüğü bildirilen yeme bozuklukları, sporcu gruplarında hem kadın hem de erkeklerde önemli bir sağlık sorunu olarak karşımıza çıkmaktadır (Galmiche et al., 2019; Stice et al., 2020; Karrer et al., 2020). Özellikle elit sporcularda yeme bozukluğu riski, sedanter bireylere kıyasla daha yüksek bulunmuştur (Joy et al., 2016; Wells et al., 2020; Fatt et al., 2024). Estetik sporlar, kilo kategorili sporlar ve dayanıklılık branşları, düşük enerji alımı ve düzensiz yeme davranışları açısından en riskli alanlar olarak tanımlanmaktadır (Mancine et al., 2020; Chapa et al., 2022; Ghazzawi et al., 2024). Bu durum, sporcularda görülen yeme bozukluklarının yalnızca bireysel psikopatoloji ile değil; sporun yapısal özellikleri, antrenman kültürü ve çevresel faktörlerle de yakından ilişkili olduğunu göstermektedir. Sporcularda yeme bozuklukları yalnızca mental sağlığı değil, aynı zamanda performansı ve uzun dönemli fiziksel sağlığı da tehdit etmektedir. Düşük enerji alımı; adet düzensizlikleri, kemik mineral yoğunluğunda azalma, stres kırıkları, büyüme ve gelişme geriliği ile ilişkilidir (Joy et al., 2016; Kontele & Vassilakou, 2021). Ayrıca sakatlanma riskinin artması ve toparlanma sürecinin uzaması, sporcunun performansını ve spor kariyerini doğrudan olumsuz etkileyebilmektedir. İleri düzey anoreksiya nervoza ve bulimiya nervoza olgularında, spora katılımın geçici ya da

kalıcı olarak sınırlandırılması gerekebilmektedir (Joy et al., 2016). Bu bağlamda sporcularda yeme bozukluklarının erken tanınması, önlenmesi ve uygun şekilde yönetilmesi büyük önem taşımaktadır. Güncel literatür, sporcuya özgü tarama araçlarının kullanılması, multidisipliner yaklaşımın benimsenmesi ve antrenörler ile ailelerin bilinçlendirilmesinin koruyucu ve iyileştirici etkilerini vurgulamaktadır (Wells et al., 2020; Kussman & Choo, 2023; Kovács et al., 2025). Sporcu sağlığının korunması ve sürdürülebilir performansın sağlanabilmesi için, beslenme uygulamalarının yeme bozukluğu riski açısından da ele alınması gerekmektedir.

2. KURUMSAL ÇERÇEVE

2.1. Sporcu Beslenmesi

Sporcular sağlam bir beslenme programını maksimum atletik performansa erişmek amacıyla kullanırlar. Bu beslenme programlarının günlük besin ihtiyaçlarının yanısıra antrenman yada müsabaka gününden önce, musabaka günü ve musabaka gününden sonra ihtiyaçlarına uygun planlamnması gerekmektedir (Spriet, 2019). Sporcuların uyguladıkları performans bir çok bileşenin birleşimi ile gerçekleşemektedir. İyi bir performans için beslenme başlıca öneme sahiptir. Beslenmenin yanı sıra; doğru antrenman, genetik uygunluk, yeterli ve doğru beslenme planı, sporcunun isteği, hidrasyon ve iyi dinlenme gerekir. Başarılı antrenman ve performansın en önemli yapı taşı enerji harcamasını desteklemektir. Bunun için enerji kaybının doğru hesaplanması ve yeterli enerji alımının sağlanması gerekmektedir. Enerji ve besin ögesi ihtiyaçları sporcunun fizyolojik, endokrin ve çevresel etkenlerine göre değişkenlik gösterir. Antrenman ve müsabakalar için yeterli enerji gereksinimleri sağlamak, hastalık ve yaralanma riskini azaltmak, antrenmanlar arası toparlanmayı desteklemek ve uygun vücut bileşimini sürdürmek için gereklidir. Genel fitness programı uygulayan bir sporcunun günlük makrobesin gereksinimlerini karşılayabilmesi için toplam enerji alımının belirli oranlarda dağıtılması gerekmektedir. Buna göre, günlük enerjinin yaklaşık %45–55'inin (3–5 g/kg/gün) karbonhidratlardan sağlanması, antrenman sırasında ve sonrasında enerji sürekliliğinin korunması açısından önem taşımaktadır. Protein gereksiniminin ise toplam enerjinin %10–15'ini karşılayacak şekilde, günlük 0,8–1 g/kg düzeyinde olması, kas dokusunun onarımı ve korunması için yeterli kabul edilmektedir. Yağ alımı da hormonal denge ve enerji ihtiyacının desteklenmesi amacıyla toplam enerjinin %25–35'ini oluşturmalı ve günlük 0,5–1,5 g/kg aralığında planlanmalıdır (Mahan & Raymond, 2017; Aydenk Köseoğlu & Çelebi Tayfur, 2017). Amerika Birleşik Devletleri Olimpiyat Komitesi (USOC) bünyesinde görev yapan sporcu diyetisyenleri, sporcuların antrenman şiddetine uygun beslenmelerini desteklemek

amacıyla "Athlete's Plate" (Sporcu Tabağı) yaklaşımını geliştirmiştir. Bu model; hafif, orta ve yüksek şiddetli antrenman dönemlerinde sporcuların besin gruplarını ve porsiyon miktarlarını nasıl düzenlemeleri gerektiğine yönelik pratik bir rehber sunmaktadır. Özellikle haftada 5 saatten fazla antrenman yapan elit sporcular için tasarlanan bu rehber, sporcuların antrenman yoğunluğuna bağlı olarak tüm besin gruplarında miktar ve porsiyon ayarlamaları yapabilmelerine yardımcı olmayı amaçlamaktadır (Reguant-Closa, Harris, Lohman & Meyer, 2018).

2.2. Yeme Bozuklukları

Yeme bozuklukları karmaşık bir psikatrik bozukluk grubu olup, yaşam kalitesini önemli derecede etkileyen, yeme davranış değişiklikleridir (Solmi, vd., 2020, Qian, vd., 2021). Ybu durum zihinsel, Fiziksel ve sosyal açıdan farklı engellere neden olmaktadır (Demmler, vd., 2020; Santomauro, vd., 2021). Yeme bozuklukları, Mesleki başarı düzeyinde düşüşe, eğitim seviyesinde geriliğe, yaşam kalitesinde bozulamlara sebep olur (Steiger & Booij, 2020). Mental Bozuklukların Tanısal ve Sayımsal El Kitabı (DSM-5)'nda belirtilen Anoreksiya Nervoza, Bulimiya Nervoza, Tıkanırcasına Yeme Bozukluğu ana yeme bozukluğu türleridir. Bunların yanı sıra, tanı ölçütlerini tam olarak karşılamamakla birlikte klinik açıdan anlamlı belirtiler gösteren Tanımlanmış Diğer Beslenme veya Yeme Bozukluğu ile belirtilerin yeterince ayrıntılandırılamadığı ya da sınıflandırılamadığı durumları kapsayan Tanımlanmamış Beslenme veya Yeme Bozukluğu kategorileri de yeme bozuklukları sınıflandırması içerisinde yer almaktadır. (Wilkop, vd., 2023). Anoreksiya Nervoza, Bulimiya Nervoza, Tıkanırcasına Yeme Bozukluğu tanısı alamayan yeme bozukluğuna sahip bireyler Tanımlanmış Diğer Beslenme veya Yeme Bozukluğu**,** Tanımlanmamış Beslenme veya Yeme Bozukluğu gruplarından tanı alabilmektedir. Tanımlanmış Diğer Beslenme veya Yeme Bozukluğu grubunda da farklı tanılar bulunmaktadır. Bunlar; atipik Anoreksiya Nervoza, düşük frekanslı veya sınırlı süreli Bulimiya Nervoza, düşük frekanslı veya sınırlı süreli Tıkanırcasına Yeme Bozkuluğu, tasfiye bozukluğu (çıkarma bozukluğu) ve gece yeme sendromu bulunmaktadır (Wilkop, vd., 2023). Yeme bozukluklarını incelen çalışamlarda yeme bozukluklarının dünya genelinde sık görüldüğü ve özellikle de kadın cinsiyette yaygın olduğu vurgulanmaktadır (Galmiche, vd., 2019). Yeme bozukluları kadınlarda görülme oranı %13'tür (Stice, vd., 2020). Türk toplumunda yeme bozukluklarının yaygınlığına dair geniş kapsamlı çalışmalar yetersiz olmakla birlikte üniversite öğrencileri ile yapılan güncel bir çalışmada kadılarda %47,6, erkeklerde %33,3 ve cinsiyet ayrımı olmaksızın üniversite öğrenimi gören öğrencilerde yeme bozukluğu riski %41,4 olarak karşımıza çıkmaktadır.

2.2.1.Anoreksiya Nervoza

Anoreksiya nervoza (AN) hastalığının isim kazanması ve klinik olarak tanımlanması 19. yüzyılda gerçekleşmiştir. İngiltere'de Sir William Gull ve Fransa'da Charles Lasègue, aşırı kilo kaybı ile birlikte psikolojik bozukluk belirtileri gösteren kadın olgularına ait vaka serileri yayımlamışlardır. Gull bu hastalığı günümüzde de yaygın olarak kullanılan adıyla "anoreksiya nervoza" olarak tanımlarken, Lasègue ise ismine "anorexie hystérique" olarak nitelendirmiştir. Batı Avrupa'da anoreksiya nervozaya benzerlik gösteren tabloların ilk tanımlamalarının 12. ve 13. yüzyıllara kadar uzandığı bilinmektedir. Ancak 16. yüzyılda, özellikle dini inançların etkin olduğu dönemlerde, bu hastalığa sahip kişilerin "cadı" olarak nitelendirildiği ve yakılarak öldürüldüğü beliritlmiştir (Vogler, 1989; Gordon, 2000). Anoreksiya nervozaya ilişkin modern anlamda farkındalığın artmasında Hilde Bruch'un 1973 yılında yayımladığı "Yeme Bozuklukları: Obezite, Anoreksiya Nervoza ve İçlerindeki İnsan" adlı erser önemli bir dönüm noktası olmuştur. Bu çalışma, hastalığın yalnızca fiziksel değil, aynı zamanda psikolojik boyutlarına da dikkat çekerek toplumda ve bilim dünyasında AN'ye yönelik bilinç oluşmasına katkı sağlamıştır (Gordon, 2000). Anoreksiya nervozanın en yaygın görüldüğü dönem ergenlik dönemidir. Yapılan incelemelr hastalığın süresine ilişkin farklı sonuçlar ortaya koysalarda, ortalama süresinin 6 yıl olduğu bildirilmektedir (Berend vd., 2018). Psikiyatrik hastalıklar arasında en yüksek mortalite oranına sahip hastalıklardan biri olan anoreksiya nervozada, insanların %20 si intihar ettiği bildirilmiştir (Arcelus vd., 2011). Kelime anlamı "sinirsel iştah kaybı" şeklinde tanımlanan AN., aşırı kısıtlayıcı beslenme davranışı ile karakterizedir. Bu hastalarda kilo almaya korku görülmekte, beden algısında belirgin bozulmalar görülmektedir.

Anoreksiya nervozanın DSM-5 tanı kriterleri (APA, 2013):

1. Kişinin yaşına, cinsiyetine, gelişimsel özelliklerine ve beden sağlığına göre gereksinim duyduğu enerji alımını kısıtlaması sonucunda belirgin derecede düşük vücut ağırlığına sahip olması.

2. Şişmanlamaya yönelik yoğun korku yaşanması ya da belirgin derecede düşük vücut ağırlığına rağmen kilo alımını engellemeye yönelik sürekli girişimlerde bulunulma.

3. Bireyin vücut ağırlığını ve beden biçimini algılamasında bozulma bulunması; kişinin kendilik değerlendirmesinde vücut ağırlığı ve biçimine aşırı önem atfetmesi ya da mevcut düşük vücut ağırlığının ciddiyetini kavrayamamış olması.

2.2.2.Bulimiya nervoza (BN)

Bulimiya nervoza (BN), tıkınırcasına yeme davranışları, kilo alma korkusu ve bu durumu engellemeye yönelik telafi edici davranışlaşmış bir yeme bozukluğudur. Bulimik bireylerde ağırlık artışını önlemeye yönelik davranışlar ve kontrolsüz yeme süreçleri birlikte görülme ihtimali yüksektir (Bernacch, 2017). Bu durumdaki kişiler, yemeyi durduramadıklarını ya da neyi ne kadar yediklerini kontrol altında tutumadıklarını ifade etmektedirler. Tıkınırcasına yeme sonrasında kilo alımını engellemek amacıyla kendini kusturma, laksatif, diüretik veya lavman kullanımı, uzun süreli aç kalma ya da aşırı fiziksel aktivite gibi uygunsuz dengeleyici davrnışlar sergilemektedirler (Castillo & Weiselberg, 2017). DSM-5'e göre bulimiya nervoza tanısı; tekrarlayan tıkınırcasına yeme davranışları, bu davranışlar sırasında kontrol kaybı hissedilmesi ve kilo alımını önlemeye yönelik uygunsuz davranışların bulunmasına dayanmaktadır. Bu yeme ve telafi davranışlarının en az üç ay boyunca, haftada ortalama en az bir kez görülmesi gerekmektedir. Ayrıca bireyin benlik değerlendirmesinin beden ağırlığı ve şekli tarafından orantısız biçimde etkilenmesi ve bu durumun yalnızca anoreksiya nervoza davranışları sırasında ortaya çıkmaması tanı kriterleri arasında yer almaktadır. Telafi edici davranışların sıklığına göre hastalık şiddeti 4 derecede sınıfladnırlamktadır bunlar; hafif, orta, ağır ve aşırı derecedir (Köroğlu, 2018).

2.2.3. Tıkınırcasına Yeme Bozukluğu

Tıkanırcasına yeme bozukluğu, bulimiya nervozaya benzer şekilde kontrolsüz yeme atakları ile seyretmekle birlikte, kusma ya da diğer arındırıcı davranışların bulunmamasıyla ayırt edilmektedir. Bu bozuklukta özellikle yüksek karbonhidrat içeriğine sahip besinlerin aşırı fazla tüketilmesi dikkat çekmektedir. Tıkanırcasına yeme bozukluları, yeme bozuklukları arasında en fazla görülen tanı olarak karşımıza çıkamktadır (Göküstün, 2018). DSM-5'e göre tıkınırcasına yeme bozukluğu tanısı; kısa zamanda normalden daha fazla miktarda yiyecek tüketilmesi ve kontrol kaybı hissedilmesi ile tanımlanan tekrarlayan yeme durumlarını içermektedir. Bu durum sırasında hızlı yemek yeme, rahatsız edici derecede doyum veya tokluk hissi kadar yeme, açlık olmaksızın aşırı yemek tüketimi, yalnız yeme ve sonrasında suçluluk ya da pişmanlık duyma gibi belirtilerden en az üçünün bulunması gerekmektedir. Ayrıca bu yeme davranışlarının bireyde belirgin bir sıkıntıya yol açması, en az üç ay boyunca haftada ortalama bir kez görülmesi ve bulimiya nervozada olduğu gibi telafi edici davranışların bulunmaması tanı kriterleridir. Tıkınırcasına yeme bozukluğu da sıklığına göre hafif, orta, ağır ve aşırı derecede olarak 4 sınıf altında sınıflandırılır (Köroğlu, 2018).

2.3. Sporcularda Yeme Bozuklukları

Sporcularda yeme bozuklukları, performansı artırmaya yönelik yada baskı ile beden görünümü, kilo ve beslenme üzerinde yoğunlaşmış bir alandır. Araştırmalar, her iki cinsiyet sporcuların risk altında olduğunu; ancak spor branşı, cinsiyet, yaş ve kültürel değişimlere göre önemli farklılıklar olduğunu göstermektedir.

2.3.1. Görülme Sıklığı ve Risk Grubu

Dünya genelinde sporcuların yaklaşık **%19'u** yeme bozukluğu riski taşımaktadır (Ghazzawi et al., 2024). Profesyonel sporcularda yeme bozukluğu ve yeme bozukluğu riski, genel topluma göre daha yüksektir (Wells et al., 2020; Joy et al., 2016; Fatt et al., 2024). Cinsiyet olarak kadınlar, özellikle genç kadınlar, erkeklere göre daha riskli gruplardır (Kussman & Choo, 2023; Li et al., 2024; Ghazzawi et al., 2024; Baceviciene et al., 2023; Cavedon et al., 2025; Kovács et al., 2025). Erkek profesyonel sporcularda erişkin dönemde görülme sıklığı %30'lara kadar çıkabiliyor (Karrer et al., 2020; Chapman & Woodman, 2016).

2.3.2. Spor Türüne Göre Risk

Spor branşı	**Risk düzeyi**	**Notlar**	**Kaynaklar**
Estetik / "lean" (jimnastik, artistik branşlar)	Çok yüksek	Daha fazla kısıtlama, beden hoşnutsuzluğu	(Chapa et al., 2022; Wells et al., 2020; Li et al., 2024; Ghazzawi et al., 2024; Baceviciene et al., 2023; Mancine et al., 2020; Kristjánsdóttir et al., 2019; Kovács et al., 2025)
Kilo kategorili (judo, güreş, halter)	Yüksek	Sık kilo kesme, dalgalanmalar	(Chapa et al., 2022; Wells et al., 2020; Ghazzawi et al., 2024; Mancine et al., 2020; Cavedon et al., 2025; Chapman & Woodman, 2016)
Dayanıklılık (uzun mesafe koşu vb.)	Orta–yüksek	İncelik ideali, enerji yetmezliği	(Ghazzawi et al., 2024; Mancine et al., 2020; Kovács et al., 2025; Kontele & Vassilakou, 2021)
Takım, estetik olmayan sporlar	Daha düşük / kısmen koruyucu	Yine de azımsanmayacak risk	(Chapa et al., 2022; Wells et al., 2020; Baceviciene et al., 2023; Kristjánsdóttir et al., 2019; Neglia, 2021)

Tablo 1: Spor türüne göre yeme bozukluğu riskinin özet görünümü

3. Sonuç

Sporcularda yeme bozuklukları yaygın, sıklıkla gizli ve performans ile sağlığı ciddi biçimde tehdit eden bir sorundur. Özellikle estetik, kilo sınıflı ve incelik vurgulu sporlarda, genç kadın ve bazı erkek elit sporcular daha yüksek risk taşır. Erken tarama, sporcuya özgü beslenme eğitimi ve multidisipliner tedavi, hem sağlığı hem de sürdürülebilir performansı korumak için kritik önem taşır.

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OTİZM SPEKTRUM BOZUKLUĞUNDA FİZİKSEL AKTİVİTENİN MOTOR GELİŞİM ÜZERİNE ETKİLERİ

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Özet

Bu çalışmanın amacı, Otizm Spektrum Bozukluğu (OSB) olan bireylerde fiziksel aktivitenin motor gelişim üzerindeki etkilerini inceleyen bilimsel araştırmaların derlenmesi ve mevcut bulguların bütüncül bir bakış açısıyla değerlendirilmesidir. Bu doğrultuda, Google Scholar , PubMed, Web of Science , Scopus ve DergiPark gibi veri tabanlarında yayımlanmış, Otizmli bireylerde fiziksel aktivite ve egzersiz temelli müdahalelerin motor gelişimle ilişkisini ele alan çalışmalar literatür taraması yöntemiyle incelenmiştir. Literatür incelemesi kapsamında değerlendirilen araştırmalar, fiziksel aktivitenin denge, koordinasyon, kaba motor ve ince motor beceriler gibi motor gelişimin temel bileşenleri üzerinde olumlu etkiler sağladığını ortaya koymaktadır. Düzenli ve yapılandırılmış fiziksel aktivite programlarının, Otizmli bireylerin motor yeterlilik düzeylerini artırarak günlük yaşam aktivitelerine katılımını desteklediği bildirilmektedir. Bununla birlikte, incelenen çalışmaların örneklem özellikleri, uygulama süreleri, müdahale türleri ve kullanılan değerlendirme araçları açısından yöntemsel farklılıklar göstermesi, elde edilen bulguların genellenebilirliğini sınırlayan önemli bir unsur olarak öne çıkmaktadır. Ayrıca, kısa süreli ya da düşük yoğunluklu fiziksel aktivite uygulamalarının motor gelişim üzerindeki etkilerinin sınırlı kaldığı; bireysel gereksinimler, yaş özellikleri ve motor beceri düzeyleri dikkate alınarak planlanan, uzun süreli ve düzenli fiziksel aktivite programlarının ise daha etkili sonuçlar ortaya koyduğu belirlenmiştir. Bu bulgular, fiziksel aktivite müdahalelerinin bireye özgü ve sistematik biçimde yapılandırılmasının önemini vurgulamaktadır .Sonuç olarak, fiziksel aktivitenin Otizm Spektrum Bozukluğu olan bireylerin motor gelişimini desteklemede etkili bir yaklaşım olduğu görülmektedir. Ancak bu alandaki bilimsel kanıtların daha net ve karşılaştırılabilir hale gelebilmesi için yöntemsel açıdan güçlü, uzun süreli ve standartlaştırılmış araştırmalara ihtiyaç duyulmaktadır. Bu bağlamda, yapılacak derleme ve deneysel çalışmaların hem akademik literatüre hem de beden eğitimi ve spor uygulamalarına önemli katkılar sunacağı düşünülmektedir.
Anahtar Kelimeler: Otizm Spektrum Bozukluğu(OSB), fiziksel aktivite, motor gelişim,egzersiz, beden eğitimi

THE EFFECTS OF PHYSICAL ACTIVITY ON MOTOR DEVELOPMENT İN AUTISM SPECTRUM DİSORDER

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Abstract

The aim of this study is to compile scientific research examining the effects of physical activity on motor development in individuals with Autism Spectrum Disorder (ASD) and to evaluate the existing findings from a holistic perspective. In this regard, studies published in databases such as Google Scholar, PubMed, Web of Science, Scopus, and DergiPark that address the relationship between physical activity and exercise-based interventions and motor development in individuals with autism were examined using a literature review method. Studies evaluated within the scope of the literature review reveal that physical activity has positive effects on fundamental components of motor development, such as balance , coordination, gross motor skills, and fine motor skills. It is reported that regular and structured physical activity programmes support the participation of individuals with autism in daily living activities by increasing their motor competence levels. However, the methodological differences in the sample characteristics, intervention durations, intervention types, and assessment tools used in the studies reviewed emerge as a significant factor limiting the generalisability of the

findings. Furthermore, it has been determined that the effects of short-term or low-intensity physical activity programmes on motor development are limited; whereas long-term and regular physical activity programmes, planned taking into account individual needs, age characteristics and motor skill levels, yield more effective results. These findings emphasise the importance of tailoring physical activity interventions to the individual and structuring them systematically. Consequently, physical activity appears to be an effective approach in supporting the motor development of individuals with Autism Spectrum Disorder. However, there is a need for methodologically robust, long-term, and standardised research to make the scientific evidence in this field clearer and more comparable. In this context, it is believed that the compilation and experimental studies to be carried out will make significant contributions to both academic literature and physical education and sports practices.

Keywords: Autism Spectrum Disorder (ASD), physical activity, motor development, exercise, physical education

UYARLANMIŞ FİZİKSEL AKTİVİTE EĞİTİMİ ALAN ZİHİNSEL ENGELLİ BİREYLER İLE YÜZME EĞİTİMİ ALAN ZİHİNSEL ENGELLİ BİREYLERİN FİZİKSEL UYGUNLUK PARAMETRELERİNİN KARŞILAŞTIRILMASI

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Özet

Bu çalışmanın amacı, uyarlanmış fiziksel aktivite eğitimi alan zihinsel engelli bireyler ile yüzme eğitimi alan zihinsel engelli bireylerin fiziksel uygunluk ve denge parametrelerini karşılaştırarak, farklı egzersiz türlerinin fiziksel uygunluk düzeylerine etkisini incelemektir. Araştırmaya, 8–15 yaş aralığında yer alan ve Malatya ilinde bulunana Gençlik ve Spor Bakanlığı bünyesinde düzenli olarak 5 ay boyunca haftada 2 gün, günde 1 saat süreyle eğitim alan toplam 18 zihinsel engelli birey (9 yüzme, 9 karasal ortamda fiziksel aktivite eğitimi) katılmıştır. Katılımcıların yaş ortalaması 12,83 ± 3,11 yıl, boy ortalaması 156,33 ± 14,00 cm ve vücut ağırlığı ortalaması 58,28 ± 13,76 kg'dır. Fiziksel uygunluk ve denge parametrelerinin değerlendirilmesinde Flamingo Denge Testi, Fonksiyonel Uzanma Testi (ön, sağ, sol), El Kavrama Kuvveti (sağ, sol), Sırt-Bacak Dinamometresi, Otur-Eriş Testi, Durarak Uzun Atlama Testi ve deri kıvrım kalınlığı ölçümleri (triceps, baldır, abdominal) kullanılmıştır. Verilerin analizinde normal dağılım gösteren değişkenler için bağımsız örneklem t testi, normal dağılım göstermeyen değişkenler için ise Mann-Whitney U testi uygulanmıştır ($p<0,05$). Gruplar arası karşılaştırmalarda, Fonksiyonel Uzanma Testi'nin sağ ve sol yönlerinde ($p=0,023$ ve $p=0,025$) ve Otur-Eriş Testi'nde ($p=0,016$) istatistiksel olarak anlamlı fark gözlenmiştir. Ayrıca, Durarak Uzun Atlama Testi sonuçları da gruplar arasında anlamlı farklılık göstermiştir ($p=0,041$). Diğer tüm parametrelerde ise anlamlı fark saptanmamıştır ($p>0,05$). Sonuç olarak, hem yüzme hem de karasal ortamda uygulanan uyarlanmış fiziksel aktivite programlarının zihinsel engelli bireylerin fiziksel uygunluk düzeyleri üzerinde olumlu etkileri olduğu görülmekle birlikte, özellikle esneklik ve alt ekstremiteye yönelik kuvvet parametrelerinde egzersiz türüne bağlı farklılıklar ortaya çıkmıştır. Bu bulgular, zihinsel engelli bireyler için egzersiz programlarının bireysel ihtiyaçlara ve hedeflenen fiziksel uygunluk bileşenlerine göre planlanmasının önemini ortaya koymaktadır.

Anahtar kelimeler: Zihinsel engellilik, uyarlanmış fiziksel aktivite, yüzme, fiziksel uygunluk, denge

A COMPARİSON OF PHYSİCAL FİTNESS PARAMETERS BETWEEN INDİVİDUALS WİTH INTELLECTUAL DİSABİLİTİES RECEİVİNG ADAPTED PHYSİCAL ACTİVİTY EDUCATİON AND THOSE RECEİVİNG SWİMMİNG TRAİNİNG

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Abstract

The aim of this study is to compare the physical fitness and balance parameters of individuals with intellectual disabilities who participate in adapted physical activity training with those who receive swimming training, and to examine the effects of different types of exercise on physical fitness levels. A total of 18 individuals with intellectual disabilities aged between 8 and 15 years (9 swimming group, 9 adapted physical activity group on land), who regularly participated in training sessions twice a week for 1 hour per day over a 5-month period within the Ministry of Youth and Sports, were included in the study. The participants had a mean age of 12.83 ± 3.11 years, a mean height of 156.33 ± 14.00 cm, and a mean body weight of 58.28 ± 13.76 kg. The physical fitness and balance parameters were evaluated using the Flamingo Balance Test, Functional Reach Test (forward, right, and left), Hand Grip Strength Test (right and left), Back and Leg Dynamometer Test, Sit and Reach Test, Standing Long Jump Test, and skinfold thickness measurements (triceps, calf, abdominal). For data analysis, the Independent Samples t-test was used for normally distributed variables, and the Mann-Whitney U test was applied for variables that did not show normal distribution ($p<0.05$). Statistically significant differences were observed between the groups in the right and left directions of the Functional Reach Test ($p=0.023$ and $p=0.025$), the Sit and

Reach Test (p=0.016), and the Standing Long Jump Test (p=0.041). No significant differences were found in other parameters (p>0.05). In conclusion, both swimming and land-based adapted physical activity programs had positive effects on the physical fitness levels of individuals with intellectual disabilities. However, differences related to the type of exercise were observed, particularly in flexibility and lower extremity strength parameters. These findings highlight the importance of tailoring exercise programs to individual needs and the targeted components of physical fitness in individuals with intellectual disabilities.

Keywords: Intellectual disability, adapted physical activity, swimming, physical fitness, balance.

SERBEST STİL YÜZME PERFORMANSLARININ CİNSİYETE GÖRE KARŞILAŞTIRILMASI*

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ÖZET

Bu çalışmanın amacı yüzme sporcularında boy, vücut ağırlığı, dikey sıçrama, çıkışa ait performans parametreleri ve 50 m serbest stil derecelerinin cinsiyete göre farklılaşıp farklılaşmadığını incelemektir. Araştırma grubunu 39 erkek ve 17 kadın olmak üzere toplamda 56 sporcu oluşturmaktadır. Çalışmada sporcuların boy uzunluğu, vücut ağırlığı, dikey sıçrama yüksekliği, çıkışa ait uçuş süresi, uçuş mesafesi, giriş hızı ve 50 m serbest stil yüzme dereceleri değerlendirilmiştir. Elde edilen verilerin normallik dağılımları test edilmiş ve analizlerde parametrik istatistiksel yöntemler kullanılmıştır. Cinsiyete göre karşılaştırmalarda bağımsız örneklem t-testi uygulanmış, anlamlı farklılıklar için etki büyüklükleri hesaplanmıştır. Sporcuların depar tahtasından atlayışları, Insta360 X3 aksiyon kamerası ile video kaydına alınmıştır. Görüntüler Kinovea yazılımı kullanılarak analiz edilmiştir. Bulgular, erkek ve kadın sporcular arasında boy, vücut ağırlığı, dikey sıçrama, uçuş süresi, uçuş mesafesi ve 50 m yüzme performansı açısından istatistiksel olarak anlamlı farklılıklar olduğunu göstermiştir. Buna karşın giriş hızı değişkeninde cinsiyete göre anlamlı bir fark saptanmamıştır. Sonuç olarak, serbest stil yüzücülerde antropometrik özellikler ve çıkış performansına ait bazı parametrelerin cinsiyete göre farklılaştığı belirlenmiştir.

Anahtar Kelimeler: Video analizi, serbest stil, yüzme performansı.

COMPARISON OF FREESTYLE SWIMMING PERFORMANCES BY GENDER

ABSTRACT

The aim of this study was to examine whether body height, body weight, vertical jump performance, start-related performance parameters, and 50 m freestyle swimming performance differ according to gender in swimmers. The study group consisted of a total of 56 athletes, including 39 males and 17 females. The variables assessed in the study were height, body weight, vertical jump height, flight time, flight distance during the start, entry velocity, and 50 m freestyle swimming performance. The normality of the data distributions was tested, and parametric statistical methods were used in the analyses. Independent samples t-tests were applied for gender based comparisons, and effect sizes were calculated for statistically

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significant differences. The athletes' starts from the starting block were recorded using an Insta360 X3 action camera, and the recordings were analyzed using Kinovea software. The results indicated statistically significant differences between male and female swimmers in terms of height, body weight, vertical jump performance, flight time, flight distance, and 50 m swimming performance. However, no statistically significant difference was found between genders with respect to entry velocity. In conclusion, it was determined that certain anthropometric characteristics and start related performance parameters differ according to gender in freestyle swimmers.

Keywords: Video analysis, freestyle, swimming performance.

1. GİRİŞ

Teknolojinin gelişimi, yüzme sporunda performans analizi, antrenman yöntemleri ve teknik gelişimlerde önemli bir rol oynamaktadır. Serbest stil yüzme yarışlarında, çıkış aşaması (başlangıç) performansı, özellikle kısa mesafeli yarışlarda (50 metre gibi) yüzücüler için kritik bir başarı faktörüdür. Üst düzey müsabakalarda yüzücüler arasındaki farklar genellikle milisaniyelerle belirlenmektedir. Dünya şampiyonası sonuçlarına göre 2024 yılında erkekler 50 m serbest 1.si ve 2.si arasında sadece +00.05 s. fark olduğu görülmektedir (World Aquatics, 2025). Bu nedenle, çıkış aşamasındaki kinematik sistemin (tepki süresi, blok süresi, uçuş süresi, giriş süresi vb.) hız performansının öğrenilmesi, antrenman süreçlerini optimize etmek sporcunun gelişimi için önemlidir. Doğru şekilde gerçekleştirilmiş olan bir çıkış, yüzücünün, yarışa avantajlı bir konumda başlamasını mümkün kılmaktadır (Troup, 1999). Günümüzde teknolojik gelişmelerin de etkisiyle yüzücüler, daha dinamik bir ivmelenme sağlayan ve özel olarak tasarlanmış çıkış platformlarında uygulanan kick çıkış tekniğini tercih etmektedirler (Maglischo, 2018). Serbest yüzme en hızlı olan ve en çok tercih edilen yüzme tekniğidir.Serbest yüzme tekniği, kolların ve bacakların hareketlerinin başın ve nefes alma hareketlerinin uyumuyla en hızlı şekilde yüzülmesini sağlar.Bu durumda, vücut suya paralel bir şekilde dengede kalırken, ardışık kol ve ayak hareketleriyle yatay düzlemde ileri doğru mesafe almaya çalışılır (Bozdoğan ve Özüak, 2003). Bu çalışmanın amacı yüzme sporcularında boy, vücut ağırlığı, dikey sıçrama, çıkışa ait performans parametreleri ve 50 m serbest stil derecelerinin cinsiyete göre farklılaşıp farklılaşmadığını incelemektir.

2. YÖNTEM

Nicel veri toplama yöntemleri kapsamında bu çalışmada, sporcuların çıkış parametreleri ile dikey sıçrama testi sonuçları ölçülmüştür ve 50 metre serbest stil yüzme dereceleri alınarak bu değişkenler arasındaki istatistiksel ilişkiler incelenmiştir.

Araştırmaya, en az üç yıl lisanslı yüzücü olarak spor yapan, 11 yaş ve üzeri bireyler dahil edilmiştir. Araştırma Samsun Atakum Olimpik Yüzme Havuzunda yürütülmüştür ve Gençlik ve Spor Bakanlığından gerekli izin alınmıştır**.** Çalışmadaki örneklem büyüklüğü N = 56'dır. Tüm katılımcılardan ve velilerinden bilgilendirilmiş gönüllü onam formu alınmıştır. Çalışmaya katılım tamamen gönüllük esasına bağlıdır.

Havuz kenarında ayrılan bir alanda sporcuların boy, kilo ve dikey sıçrama değerleri protokole uygun bir şekilde ölçülmüştür. Sporcuların dikey sıçrama değerleri (dikey sıçrama ölçüm aleti

marka: TAKEİ. Model: TKK-5406) alınmıştır. Havuzdaki ölçümlerde sporcular 50 m serbest stil için Kick çıkış tekniğini uygulamıştır. Sporcuların depar tahtasından atlayışları, Insta360 X3 aksiyon kamerası ile 3.6K:3584x2016 çözünürlükte ve 60 FPS ile video kaydına alınmıştır (Insta360, 2025). Kinovea yazılımı kullanılarak analiz edilmiştir (Kinovea, 2025). Sporcular sadece ilk kulvardan çıkış yapmıştır. Kamera havuzun kenar çizgisine 1 m. başlangıç noktasına ise 1.5 m. uzakta olacak şekilde tripod üzerine yerleştirilmiştir ve bütün kayıtlar aynı noktadan alınmıştır. Video analizi depar tahtasından çıkış ile ellerin suya teması arasındaki süreyi kapsayacaktır. Çıkış aşamasında incelenen değişkenler; Uçuş Süresi: Ayak parmaklarının bloktan ayrılması ile ellerin suya girmesi arasındaki süre. Uçuş Mesafesi: Başlangıç duvarı (çıkış bloğunun altındaki duvar) ile ellerin suya girdiği nokta arasındaki mesafe. Giriş Hızı: Sporcuların suya girmeden önceki yatay hızı. ölçülerek değerlendirilmiştir. Yüzücülerin resmi müsabakada gösterdikleri 50 m serbest stil dereceleri kullanılmıştır. Verilerin tamamı veri kayıt formuna işlenmiştir.

Verilerin analizinde SPSS 21.0 yazılımı kullanılmıştır. Tüm değişkenler için ortalama, standart sapma, minimum ve maksimum değerleri raporlanmıştır. One-Sample Kolmogorov-Smirnov testi ile verilerin normal dağılım gösterdiği belirlenmiştir. Cinsiyete göre karşılaştırmalar Independent Sample T testi ile yapılmıştır. İlişkilerin etki değerleri de incelenmiştir. Cohen's d değerleri 0,20 ve altındaysa küçük (düşük), 0,20-0,80 arasındaysa orta, 0,80 ve bu değerin daha üstündeyse büyük (geniş) düzeyde bir etki olarak yorumlanmaktadır (Cohen, 1988).

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3. BULGULAR

Bu bölümde, araştırma grubuna ait boy ve vücut ağırlığı ile çıkış ve yüzme performansına ilişkin değişkenlerin cinsiyete göre karşılaştırılmasına yönelik elde edilen bulgular sunulmaktadır.

Çizelge 1. Boy uzunluklarının cinsiyete göre karşılaştırılması

		Boy (cm)				
	n	**Ortalama**	**Standart sapma**	**t**	**p**	**Cohen's d**
Erkek	37	172,62	9,57	5,50	,000	1,55
Kadın	19	161,95	4,96			

Çizelge 1'de verilen boy uzunluğu ortalamaları incelendiğinde, erkek katılımcıların (Ort. = 172,62, SS = 9,57) kadın katılımcılara (Ort. = 161,95, SS = 4,96) göre daha yüksek değerlere sahip olduğu görülmektedir. Gruplar arasındaki bu fark istatistiksel olarak anlamlıdır, $t(53,98) = 5,50$, $p < ,05$ ve etki düzeyi büyüktür ($d = 1,55$).

Çizelge 2. Vücut ağırlıklarının cinsiyete göre karşılaştırılması

		Vücut ağırlığı (kg)				
	n	**Ortalama**	**Standart sapma**	**t**	**p**	**Cohen's d**
Erkek	37	64,51	10,43	5,16	,000	1,46
Kadın	19	54,05	4,71			

Çizelge 2'de sunulan vücut ağırlığı ortalamalarına göre erkek katılımcıların (Ort. = 64,51, SS = 10,43) kadın katılımcılardan (Ort. = 54,05, SS = 4,71) daha yüksek vücut ağırlığına sahip olduğu belirlenmiştir. Bu fark istatistiksel olarak anlamlıdır, $t(53,42) = 5,16$, $p < ,05$ ve etki düzeyi büyüktür ($d = 1,46$).

Çizelge 3. Dikey sıçrama değerlerinin cinsiyete göre karşılaştırılması

		Dikey sıçrama (cm)				
	n	**Ortalama**	**Standart sapma**	**t**	**p**	**Cohen's d**
Erkek	37	42,73	6,69	5,59	,000	1,58
Kadın	19	35,16	3,44			

Çizelge 3'te yer alan dikey sıçrama değerleri incelendiğinde, erkek katılımcıların (Ort. = 42,73, SS = 6,69) kadın katılımcılara (Ort. = 35,16, SS = 3,44) kıyasla daha yüksek performans sergilediği görülmektedir. Gruplar arasındaki fark istatistiksel olarak anlamlıdır, $t(53,99) = 5,59$, $p < ,05$ ve etki düzeyi büyüktür ($d = 1,58$).

Çizelge 4. Kick çıkış tekniğinde uçuş süresi değerlerinin cinsiyete göre karşılaştırılması

		Uçuş süresi (sn)				
	n	**Ortalama**	**Standart sapma**	**t**	**p**	**Cohen's d**
Erkek	37	0,31	0,06	3,03	,004	0,86
Kadın	19	0,26	0,05			

Çizelge 4'te verilen uçuş süresi ortalamalarına göre erkek katılımcıların (Ort. = 0,31 sn, SS = 0,06) kadın katılımcılara (Ort. = 0,26 sn, SS = 0,05) göre daha uzun uçuş süresine sahip olduğu görülmektedir. Bu fark istatistiksel olarak anlamlıdır, $t(45,26) = 3,03$, $p < ,05$ ve etki düzeyi büyüktür ($d = 0,86$).

Çizelge 5. Kick çıkış tekniğinde uçuş mesafesi değerlerinin cinsiyete göre karşılaştırılması

		Uçuş mesafesi (cm)				
	n	**Ortalama**	**Standart sapma**	**t**	**p**	**Cohen's d**
Erkek	37	276,78	32,91	4,86	,000	1,37
Kadın	19	247,47	11,68			

Çizelge 5 incelendiğinde, erkek katılımcıların uçuş mesafesi ortalamasının (Ort. = 276,78 cm, SS = 32,91) kadın katılımcılardan (Ort. = 247,47 cm, SS = 11,68) daha yüksek olduğu görülmektedir. Cinsiyetler arasındaki fark istatistiksel olarak anlamlıdır, $t(49,83) = 4,86$, $p < ,05$ ve etki düzeyi büyüktür ($d = 1,37$).

Çizelge 6. Kick çıkış tekniğinde suya giriş hızı değerlerinin cinsiyete göre karşılaştırılması

		Giriş hızı (m/sn)				
	n	**Ortalama**	**Standart sapma**	**t**	**p**	**Cohen's d**
Erkek	37	9,29	2,31	−0,71	,481	—
Kadın	19	9,75	2,27			

Çizelge 6'da verilen giriş hızı ortalamaları incelendiğinde, erkek (Ort. = 9,29, SS = 2,31) ve kadın (Ort. = 9,75, SS = 2,27) katılımcılar arasında istatistiksel olarak anlamlı bir fark bulunmamıştır, $t(36{,}98) = -0{,}71$, $p > ,05$.

Çizelge 7. Serbest stil 50 m yüzme derecelerinin cinsiyete göre karşılaştırılması

	Serbest stil 50 m yüzme derecesi (sn)					
	n	**Ortalama**	**Standart sapma**	**t**	**p**	**Cohen's d**
Erkek	37	28,53	2,00	−4,68	,000	1,32
Kadın	19	30,66	1,37			

Çizelge 7'de yer alan 50 m yüzme dereceleri incelendiğinde, erkek katılımcıların (Ort. = 28,53 sn, SS = 2,00) kadın katılımcılara (Ort. = 30,66 sn, SS = 1,37) göre daha iyi performans sergilediği görülmektedir. Gruplar arasındaki fark istatistiksel olarak anlamlıdır, $t(49{,}32) = -4{,}68$, $p < ,05$ ve etki düzeyi büyüktür ($d = 1{,}32$).

4. TARTIŞMA VE SONUÇ

Bu çalışmada serbest stil yüzücülerinde boy ve vücut ağırlığı ile çıkışa ait performans parametrelerinin cinsiyete göre farklılaşıp farklılaşmadığı incelenmiştir. Elde edilen sonuçlar, erkek ve kadın katılımcılar arasında boy uzunluğu, vücut ağırlığı, dikey sıçrama, uçuş süresi, uçuş mesafesi ve 50 m yüzme derecesi değişkenleri açısından istatistiksel olarak anlamlı farklılıklar bulunduğunu göstermektedir. Bu değişkenlerde erkek katılımcıların daha yüksek ortalama değerlere sahip olduğu belirlenmiştir. Elde edilen bu bulgular, yüzücülerde cinsiyete bağlı antropometrik farklılıkların bulunduğunu ortaya koyan önceki çalışmalarla paralellik göstermektedir. Nitekim Çağlayan ve Yanar (2017), erkek ve kadın yüzücüler ile gerçekleştirdikleri çalışmada erkek yüzücülerin boy ve vücut ağırlığı değerlerinin kadın yüzücülere göre daha yüksek olduğunu bildirmiştir. Bununla birlikte literatürde, özellikle daha küçük yaş gruplarında cinsiyete bağlı performans farklarının belirgin olmadığına işaret eden çalışmalar da bulunmaktadır. Nitekim Bingöl, Saygın ve Salman (2023), yıldızlar kategorisinde yer alan yüzücüler üzerinde gerçekleştirdikleri çalışmada, 50 m serbest stil yüzme performansı açısından kız ve erkek sporcular arasında istatistiksel olarak anlamlı bir fark saptamamıştır. Söz konusu çalışmanın örneklemini, yaş ortalaması 13.00±1.13 yıl olan sporcuların oluşturması, cinsiyetler arası performans farklılıklarının gelişim düzeyine bağlı olarak henüz belirginleşmemiş olabileceğini düşündürmektedir. Bostancı, Ateş, Yılmaz ve Kabadayı (2017), 12–13 yaş grubunda yer alan yüzücüler üzerinde gerçekleştirdikleri çalışmada, erkek ve kız yüzücüler arasında boy ve vücut ağırlığı değişkenleri açısından istatistiksel olarak anlamlı bir fark bulunmadığını bildirmiştir. Yüzgeç, Karsavuranoğlu ve Müniroğlu (2023) yüzücülerde 50 m serbest stil yüzme derecelerini inceledikleri çalışmalarında, 13–14 yaş grubunda kız ve erkek yüzücüler arasında anlamlı bir fark bulunmadığını; buna karşın 15–16 yaş grubunda cinsiyetler arasında anlamlı performans farklarının ortaya çıktığını bildirmiştir. Bu bulgu, cinsiyet temelli performans farklılıklarının yaşla birlikte, özellikle ergenlik döneminin ilerleyen evrelerinde daha belirgin hâle geldiğini göstermektedir. Mevcut çalışmada gözlenen cinsiyetler arası anlamlı performans farklılıklarının, örneklemin yaş ve fiziksel gelişim düzeyiyle ilişkili olabileceği değerlendirilmektedir.

Araştırma kapsamında incelenen değişkenler arasında yalnızca giriş hızı açısından cinsiyetler arasında istatistiksel olarak anlamlı bir fark bulunmamıştır. Diğer tüm performans ve antropometrik değişkenlerde saptanan farklılıkların büyük etki düzeyiyle desteklenmesi, cinsiyet temelli farklılıkların belirgin olduğunu ortaya koymaktadır. Sonuç olarak, serbest stil yüzücülerinde cinsiyetin boy, vücut ağırlığı, çıkış performansı ve 50 m yüzme derecesi üzerinde ayırt edici bir faktör olduğu belirlenmiştir. Elde edilen bulgular, kısa mesafe yüzme performansının değerlendirilmesinde cinsiyete özgü fiziksel ve performans parametrelerinin dikkate alınmasının önemini ortaya koymaktadır.

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YÜZME PERFORMANSININ DEĞERLENDİRİLMESİNDE KİNOVEA TABANLI VİDEO ANALİZ YAKLAŞIMLARI*

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ÖZET

Bu çalışma, yüzme performansının değerlendirilmesinde video tabanlı biyomekanik analiz yaklaşımlarının kullanımını ve Kinovea yazılımının bu alandaki uygulama alanlarını kapsamlı biçimde incelemeyi amaçlamaktadır. Yüzmede performans; kulaç mekaniği, çıkış ve dönüş evreleri, sualtı fazı, postür, denge ve biyomotor özellikler gibi çok sayıda değişkenin etkileşimiyle şekillenmektedir. Bu karmaşık yapının anlaşılabilmesi için güvenilir ve erişilebilir ölçüm araçlarına ihtiyaç duyulmaktadır. Literatürde yer alan çalışmalar, Kinovea yazılımının açı, zaman, mesafe, hız ve frekans gibi kinematik parametrelerin iki boyutlu analizinde yaygın olarak kullanıldığını göstermektedir. İncelenen araştırmalarda Kinovea; yüzme performansı ve kulaç mekaniğinin değerlendirilmesi, kısa mesafe yarışlarda çıkış performansı ve alt ekstremite patlayıcı gücü ilişkisi, çıkış ve dönüş sonrası sualtı dolfin ayak vuruşunun performansa etkisi, postür ve dinamik denge ile çıkış başarısı arasındaki ilişkiler ile paralimpik ve artistik yüzme disiplinlerinde teknik analiz amacıyla kullanılmıştır. Bulgular genel olarak, Kinovea'nın farklı yaş grupları ve yüzme branşlarında performansa ilişkin kinematik değişkenlerin objektif biçimde değerlendirilmesine olanak sağladığını ortaya koymaktadır. Sonuç olarak, Kinovea yazılımı yüzme biyomekaniği alanında hem araştırmacılar hem de antrenörler için pratik, ekonomik ve etkili bir analiz aracı olarak öne çıkmaktadır.

Anahtar Kelimeler: Yüzme, Kinovea, biyomekanik analiz, performans analizi.

KINOVEA-BASED VIDEO ANALYSIS APPROACHES IN THE EVALUATION OF SWIMMING PERFORMANCE

ABSTRACT

This study aims to comprehensively examine the use of video-based biomechanical analysis approaches in the evaluation of swimming performance and the application areas of the Kinovea software in this field. Swimming performance is shaped by the interaction of numerous variables, including stroke mechanics, start and turn phases, the underwater phase, posture, balance, and biomotor characteristics. Understanding this complex structure requires reliable, accessible, and repeatable measurement tools. The reviewed literature indicates that Kinovea is

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widely used for two-dimensional analysis of kinematic parameters such as angle, time, distance, velocity, and frequency. Across the analyzed studies, Kinovea has been employed to assess swimming performance and stroke mechanics, to examine the relationship between start performance and lower-limb explosive strength in short-distance events, to analyze the effects of underwater dolphin kick following starts and turns on performance, and to investigate the associations between posture, dynamic balance, and start success. In addition, the software has been applied for technical analysis in Paralympic and artistic swimming disciplines. Overall, the findings demonstrate that Kinovea enables objective evaluation of performance-related kinematic variables across different age groups and swimming disciplines. In conclusion, Kinovea stands out as a practical, cost-effective, and efficient analysis tool for both researchers and coaches in the field of swimming biomechanics.

Keywords: Swimming, Kinovea, biomechanical analysis, performance analysis.

1. GİRİŞ

Yüzme performansının bilimsel temelde değerlendirilmesi, hareketin karmaşık yapısı nedeniyle geçerli, erişilebilir ve tekrar edilebilir ölçüm yöntemlerinin kullanılmasını gerekli kılmaktadır. Özellikle son yıllarda video tabanlı biyomekanik analiz yaklaşımları, yüzme tekniği, performans bileşenleri, çıkış ve sualtı evreleri gibi kritik aşamaların ayrıntılı biçimde incelenmesine olanak sağlamıştır. Bu bağlamda Kinovea yazılımı; maliyet etkinliği, kullanım kolaylığı ve kinematik parametreleri iki boyutlu olarak analiz edebilme kapasitesi sayesinde yüzme araştırmalarında ve antrenman uygulamalarında yaygın biçimde tercih edilmektedir (Kinovea, 2025). Bu bildiride, Kinovea temelli çalışmalar; yüzme performansı ve kulaç mekaniği, çıkış performansı ve alt ekstremite gücü, sualtı dolfin ayak vuruşu, postür ve denge, paralimpik yüzme ve artistik yüzme bağlamlarında tematik olarak ele alınarak mevcut literatür bütüncül bir bakış açısıyla değerlendirilmektedir.

2. YÜZMEDE VİDEO TABANLI BİYOMEKANİK ANALİZ VE KİNOVEA YAZILIMI

Yüzme performansının analizi, biyomekanik ve kinematik değişkenlerin güvenilir biçimde ölçülmesini gerektirmektedir. Bu bağlamda, video tabanlı analiz yazılımları antrenman ve araştırma süreçlerinde yaygın olarak kullanılmaktadır. Kinovea, açık kaynaklı ve ücretsiz bir yazılım olması nedeniyle hem spor bilimleri araştırmalarında hem de uygulamalı antrenman ortamlarında sıklıkla tercih edilmektedir. Yazılım; açı, zaman, mesafe, hız ve frekans gibi kinematik parametrelerin iki boyutlu analizine olanak sağlamaktadır.

Çocuk yüzücülerde serbest stil tekniğinin incelendiği çalışmada Franken ve ark. (2022), 50 m maksimal yüzme testi sırasında kulaç oranı, kulaç uzunluğu ve yüzme hızı gibi değişkenleri Kinovea yazılımı ile analiz etmiş ve kısa mesafeli yarışlarda dahi tekniğin değişkenlik gösterdiğini ortaya koymuştur. Benzer şekilde, López-Contreras ve ark. (2022) farklı teknik egzersizlerin (nefes tutma, nefes alma sağ, kol uzatarak nefes alma sağ, nefes alma sol, kol kapatarak nefes alma sağ, nefes alma sol) omuz ve kalça rotasyonları üzerindeki etkisini Kinovea aracılığıyla inceleyerek simetriye etkisini bildirmiştir.

3. YÜZME PERFORMANSI VE KULAÇ MEKANİĞİNİN KİNEMATİK ANALİZİ

Kinovea'nın yüzme performansı ile ilişkili değişkenlerin analizinde yaygın biçimde kullanıldığı görülmektedir. Martins ve ark. (2024), kelebek stilinde skapular mobilizasyon ve miyofasyal gevşetmenin akut etkilerini incelemiş; kulaç frekansı, kulaç uzunluğu ve ortalama yüzme hızını Kinovea kullanarak değerlendirmiştir.

Altan ve ark. (2024) ise kritik hız sonrası yüzme performansı ile kan laktat düzeyleri arasındaki ilişkiyi incelemiş ve 50 m yüzme testlerinin bitiş sürelerini Kinovea aracılığıyla belirlemiştir. Çalışma, Kinovea'nın performans zamanı belirlemede geçerli bir araç olarak kullanılabileceğini desteklemektedir. Benzer biçimde, Mersin ve Agopyan (2025), kısa mesafe yüzme performansı ve ayak bileği eklem hareket açıklığını Kinovea ile ölçmüş, farklı ısınma protokollerinin akut performans üzerine etkilerini değerlendirmiştir. Kara ve su ısınmasının yanı sıra, farklı miyofasyal gevşeme aletlerinin ayak bileği esnekliğini ve alt ekstremite yüzme performans bileşenlerini artırmada üstünlükleri olmadığını belirlemişlerdir. Uyguladıkları egzersizlerin performans açısından artış sağlamamasına rağmen, antrenmanlarda kısa mesafe ayak vuruş çalışmaları öncesinde alternatif bir ısınma modeli olabileceğini ifade etmişlerdir.

Kıstak ve Odabaş (2023), kız ve erkek genç yüzücülerde ısınma yapılarak ve ısınma yapılmadan gerçekleştirilen 4×50 m karışık yüzme performansında kulaç mekaniği parametreleri karşılaştırılmıştır. Kinovea yazılımı ile yapılan analizler sonucunda, kelebek, kurbağalama ve serbest stillerde kulaç sayısı, kulaç mesafesi, kulaç sıklığı, kulaç indeksi ve bitiş süresi gibi değişkenlerin ısınmalı ve ısınmasız koşullar arasında anlamlı farklılıklar gösterdiği belirlenmiştir. Bulgular, ayak, drill ve yüzme çalışmalarını içeren ısınma protokolü sonrasında kısa mesafe karışık yüzme performansına ait kulaç mekaniği göstergelerinin daha iyi değerler sergilediğini ortaya koymaktadır.

4. YÜZMEDE ÇIKIŞ PERFORMANSI, ALT EKSTREMİTE GÜCÜ VE TEKNİK BİLEŞENLER

Yüzme çıkışı, özellikle kısa mesafeli yarışlarda toplam performansı belirleyen kritik bir bileşen olarak değerlendirilmektedir. Pereira ve ark. (2023), pliometrik egzersizlerin çıkış tekniği üzerindeki etkisini incelemiş ve suya giriş öncesi kat edilen mesafeyi Kinovea kullanarak analiz etmiştir. Bulgular, pliometrik egzersiz sisteminin, çıkış tekniğinin uygulanmasında yüzücünün kas gücünü geliştirdiği, vücudun suya girmeden önce ulaştığı mesafeyi artırdığını ve alt ekstremite patlayıcı gücündeki artışın çıkış performansına doğrudan katkı sağladığını ortaya koymuştur.

Öğrenme ve öğretim bağlamında Kinovea'nın kullanımı da literatürde yer bulmaktadır. Sima ve Potop (2018), üniversite öğrencilerinde yüzme çıkışının öğretiminde (ısınma egzersizleri) ve kas gücünü geliştirmeye yönelik egzersizler) video analizine dayalı yaklaşımın teknik farkındalığı artırdığını ve motor öğrenmeye katkı sağladığını bildirmiştir. Hazırlık aşaması-başlangıç bloğundan dalış hareketine başlamadan önce; temel aşama-uçuş aşaması ve son aşama–suya girme için son duruş ile ilgili açısal özellikler gibi teknik parametreler Kinovea ile değerlendirildi.

Mengütay (2019), elit genç erkek yüzücülerde squat sıçrama yüksekliği ile grab start çıkış performansı arasındaki ilişki incelenmiştir. Kinovea video analiz programı kullanılarak elde edilen kinematik veriler, dikey sıçrama performansı yüksek olan sporcuların grab start çıkış

süresinin anlamlı düzeyde daha kısa olduğunu, ancak suya giriş öncesi kat edilen mesafenin sıçrama yüksekliğinden bağımsız kaldığını göstermiştir. Bulgular, patlayıcı alt ekstremite gücünün grab start çıkışında zaman avantajı sağladığını, ancak çıkış mesafesini belirleyen tek faktör olmadığını ortaya koyarak, kısa mesafe yüzme performansının geliştirilmesinde sıçrama temelli güç antrenmanlarının önemini vurgulamaktadır.

5. ÇIKIŞ VE DÖNÜŞ SONRASI SUALTI EVRESİ VE DOLFİN AYAK VURUŞU

Bozdoğan Kurt (2024), genç yüzücülerde 50 m serbest ve sırtüstü yüzmede duvar itişiyle çıkış ve dönüş sonrası gerçekleştirilen sualtı dolfin ayak vuruşunun kinematik özellikleri ve performansla ilişkisi incelenmiştir. Kinovea yazılımı kullanılarak yapılan analizler, dolfin ayak vuruş frekansı arttıkça ilk 25 m, ikinci 25 m ve toplam 50 m yüzme sürelerinin azaldığını ve yüzme hızının arttığını ortaya koymuştur. Bulgular, sualtı dolfin ayak vuruşunun özellikle çıkış ve dönüş evrelerinde kısa mesafe yüzme performansının belirleyici bileşenlerinden biri olduğunu ve antrenman süreçlerinde bu evreye özgü teknik çalışmaların önemini vurgulamaktadır.

6. ÇIKIŞ PERFORMANSINDA POSTÜR, DENGE VE BİYOMOTOR ÖZELLİKLER

Coşkun (2024) tarafından gerçekleştirilen çalışmada, genç yüzücülerin serbest stil (track) ve sırtüstü çıkış performansları kinematik, performans ve postüral parametreler açısından incelenmiştir. Kinovea 0.9.5 ile yapılan video analizleri sonucunda, track çıkışta kalça açısı, çıkış hızı ve dikey sıçrama performansı arasında anlamlı pozitif ilişkiler belirlenmiş; ön kalça eğrisi değeri yüksek olan sporcularda uçuş süresi ve suya giriş mesafesinin arttığı saptanmıştır. Sırtüstü çıkışta ise dinamik dengenin, çıkış sırasında kalçanın su üzerinde etkin biçimde korunması açısından belirleyici bir biyomotor özellik olduğu ortaya konmuştur. Bulgular, serbest ve sırtüstü çıkışların farklı biyomotor gereksinimlere sahip olduğunu ve antrenman planlamasında bu farklılıkların dikkate alınması gerektiğini göstermektedir.

7. PARALİMPİK YÜZÜCÜLERDE TEKNOLOJİ DESTEKLİ KİNEMATİK ANALİZLER

Kinovea, paralimpik sporcuların analizinde de etkin biçimde kullanılmaktadır. Pablo (2024), kol, gövde ve bacak hareketleri düşük ila orta düzeyde sınırlı olan paralimpik yüzücülerde ayak vuruşunun etkisini Kinovea destekli kinematik analizle incelemiş ve ayak vuruşunun itici olmaktan çok direnç artırıcı bir rol oynayabileceğini göstermiştir. Slopecki ve ark. (2024) ise havuzda yüzme tur süresini, kulaç sayısını, kulaç süresini, anlık kulaç hızını ve kulaç başına mesafeyi doğru bir şekilde tahmin etmek için ataletsel ölçüm birimi tabanlı sistem ile elde edilen verileri Kinovea ve Dartfish üzerinden yapılan video analizleriyle doğrulamış, Kinovea'nın referans ölçüm aracı olarak kullanılabileceğini ortaya koymuştur.

8. ARTİSTİK YÜZMEDE PERFORMANSIN VİDEO TABANLI ANALİZİ

Kinovea'nın kullanımı yalnızca klasik yüzme branşlarıyla sınırlı değildir. Yue ve ark. (2023), artistik yüzmede takım serbest rutinlerinde hibrit figürlerin performans puanlarını öngörmedeki rolünü incelemiş ve bacak açısı, bacak yüksekliği gibi değişkenleri Kinovea ile ölçmüştür. Çalışma, video tabanlı ölçümlerin estetik ve teknik spor dallarında da objektif değerlendirme imkanı sunduğunu göstermektedir.

9. GENEL DEĞERLENDİRME

Literatür incelendiğinde, Kinovea yazılımının yüzmede teknik analiz, performans değerlendirmesi, öğrenme süreçleri ve paralimpik sporlar dahil olmak üzere geniş bir kullanım alanına sahip olduğu görülmektedir. Çalışmaların büyük çoğunluğu, Kinovea'nın geçerli ve pratik bir analiz aracı olduğunu ortaya koymakla birlikte, iki boyutlu analizle sınırlı olması ve örneklem büyüklüklerinin görece küçük olması temel sınırlılıklar olarak öne çıkmaktadır. Buna rağmen, maliyet etkinliği ve erişilebilirliği nedeniyle Kinovea, yüzme biyomekaniği alanında hem tez çalışmalarında hem de bildirilerde güçlü bir metodolojik araç olarak değerlendirilebilir.

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BEL AĞRISI OLAN HASTALARIN KAYROPRAKTİK TEDAVİ SONRASINDA SUBJEKTİF SAĞLIK ŞİKAYETLERİNİN YAŞAM KALİTESİ ÜZERİNE ETKİSİNİN İNCELENMESİ

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ÖZET

Bu çalışma, kronik bel ağrısı olan hastaların kayropraktik tedavi sonrasında yaşam kalitesi ve subjektif sağlık şikayetlerindeki değişiklikleri incelemeyi amaçlamıştır. Üsküdar Üniversitesi Etik Kurulu onayı ile gerçekleştirilen araştırmaya, yaş ortalamaları benzer ($p=0.779$) olan toplam 64 katılımcı dahil edilmiştir. Katılımcılar, kayropraktik tedavi uygulanan (n=32) ve uygulanmayan (n=32) olmak üzere iki gruba ayrılmıştır. Gruplar arasında cinsiyet, medeni durum, eğitim durumu ve düzenli egzersiz yapma gibi demografik faktörler açısından anlamlı bir fark bulunmamıştır ($p>0.05$). Sonuçlar, kayropraktik tedavi uygulanmayan hastaların VAS skorlarının, tedavi alanlara kıyasla anlamlı derecede daha yüksek olduğunu göstermiştir ($p<0.001$). Tedavi sonrası, kas iskelet sistemi, psödonörolojik, gastrointestinal, alerji ve grip şikayetlerinde belirgin azalma saptanmıştır ($p<0.001$). Ayrıca, kayropraktik tedavi gören hastaların fiziksel fonksiyon, emosyonel rol güçlüğü, enerji/canlılık, sosyal işlevsellik ve genel sağlık kalitesi skorlarının daha yüksek olduğu bulunmuştur ($p<0.05$). Bu bulgular, kayropraktik

tedavinin kronik bel ağrısında yaşam kalitesini artırmada ve sağlık şikayetlerini azaltmada etkili olduğunu göstermektedir.

Anahtar Kelimeler : Kronik Bel Ağrısı, Kayropraktik Tedavi, Subjektif Sağlık, Yaşam Kalitesi

1.Giriş

Ağrı, doku hasarının varlığına bakılmaksızın beynin zararlı olarak yorumladığı uyaranlara karşı geliştirdiği koruyucu bir savunma mekanizmasıdır ve bireyin en sık karşılaştığı hoş olmayan duyumlardan biridir (Moseley, 2003). Küresel ölçekte yaygınlığı oldukça yüksek olan ağrı, akut ve kronik olmak üzere iki temel kategoride ele alınmaktadır (Henschke ve ark., 2015). Akut ağrı; zaman, yer ve yoğunluk açısından lezyonla yakın ilişkili olup doku iyileşmesiyle birlikte azalan bir süreç olarak tanımlanırken, kronik ağrı üç ay veya daha uzun süren, kendiliğinden iyileşmeyen ve bireyin fiziksel, duygusal ve bilişsel işlevlerini olumsuz etkileyen bir durumdur (Özyalçın, 2005; Uyar ve Köken, 2017).

Kronik bel ağrısı, kronik ağrı türleri arasında en yaygın olanlardan biridir ve engellilik ile iş gücü kaybının başlıca nedenleri arasında yer almaktadır (Hoy ve ark., 2014). Ayrıca, üst solunum yolu enfeksiyonlarından sonra hastaneye yatışın önde gelen nedenlerinden biri olarak bildirilmektedir (Hartvigsen ve ark., 2018). Bu durum, kronik bel ağrısının yalnızca bireysel değil, aynı zamanda toplumsal ve ekonomik açıdan da önemli bir sağlık sorunu olduğunu göstermektedir.

Bel ağrısının tedavisinde ilaç tedavisi, fizik tedavi ve rehabilitasyon uygulamaları, akupunktur, cerrahi girişimler ve spinal manipülasyon gibi çeşitli yaklaşımlar kullanılmaktadır. Spinal manipülasyonun hem akut hem de kronik bel ağrısının tedavisinde etkinliğini destekleyen çok sayıda çalışma bulunmaktadır (Chou ve ark., 2007). Bununla birlikte, kayropraktik spinal manipülasyon tedavisinin diğer tedavi yöntemleriyle karşılaştırıldığında maliyet-etkin bir bakım alternatifi sunduğu da rapor edilmiştir (Nelson, 2005; Oliphant, 2004; Weeks ve ark., 2016; Hurwitz ve ark., 2016).

Kayropraktik tedavi, bel ağrısı yönetiminde sık kullanılan alternatif yaklaşımlardan biri olup omurga manipülasyonları ve manuel teknikler aracılığıyla ağrının azaltılmasını ve fonksiyonel kapasitenin artırılmasını hedeflemektedir (Rubinstein ve ark., 2011). Özellikle kronik bel ağrısı olan bireylerde subjektif sağlık şikayetleri ve genel sağlık algısı üzerinde olumlu etkiler

oluşturduğu bildirilmiştir (Goertz ve ark., 2013). Ancak, bu etkilerin yaşam kalitesi üzerindeki yansımalarının sistematik olarak değerlendirilmesine yönelik çalışmalar sınırlıdır.

Bu çalışmanın amacı, kronik bel ağrısı olan hastalarda kayropraktik tedavinin subjektif sağlık şikayetleri, ağrı düzeyi ve yaşam kalitesi üzerindeki etkilerini incelemektir. Bu doğrultuda, kayropraktik tedavi uygulanan ve uygulanmayan bireylerin tedavi öncesi ve sonrası durumları karşılaştırılarak, kayropraktik tedavinin etkinliği değerlendirilmiştir. Ayrıca, subjektif sağlık şikayetlerindeki değişimlerin yaşam kalitesi ile ilişkisi analiz edilmiştir.

Bu çalışmanın hipotezleri; kayropraktik tedavi uygulanan kronik bel ağrılı hastalarda VAS skorlarının tedavi uygulanmayan gruba kıyasla daha düşük olacağı, subjektif sağlık şikayetlerinin azalacağı ve yaşam kalitesi alt boyutlarında anlamlı artış görüleceği yönündedir. Ayrıca, tedavi uygulanmayan grupta VAS skorlarında zamana bağlı sınırlı bir iyileşme beklenmekle birlikte bu iyileşmenin kayropraktik tedavi uygulanan gruba göre daha düşük düzeyde olacağı ve her iki grupta da yaş, cinsiyet, eğitim durumu, medeni durum ve düzenli egzersiz yapma gibi demografik değişkenlerin VAS skorları üzerinde anlamlı bir etki oluşturmayacağı öngörülmektedir.

2.Yöntem

2.1.Araştırma Tasarımı

Bu çalışma, kronik bel ağrısı olan hastalarda kayropraktik tedavi sonrasında subjektif sağlık şikayetleri ve yaşam kalitesindeki değişimleri incelemek amacıyla planlanmış yarı deneysel bir araştırmadır. Çalışma, ön test–son test kontrol gruplu bir tasarıma sahiptir. Katılımcılar deney ve kontrol gruplarına rastgele atanmıştır.

Çalışmaya dahil edilen kronik bel ağrılı katılımcılar, başlangıçta rastgele olarak deney (n=32) ve kontrol (n=32) gruplarına ayrılmış olup, grupların demografik özellikler açısından benzer olduğu belirlenmiştir. Tüm katılımcılardan yaş, cinsiyet, medeni durum, eğitim durumu ve sportif aktivite düzeyine ilişkin demografik bilgiler toplanmıştır. Çalışma kapsamında değerlendirmeler tedavi öncesinde ve tedavi sürecinin tamamlanmasının ardından yapılmıştır. Ağrı düzeyi, yaşam kalitesi ve subjektif sağlık şikayetleri sırasıyla Visual Analog Skala (VAS), SF-36 Yaşam Kalitesi Ölçeği ve Subjektif Sağlık Şikayetleri Ölçeği kullanılarak değerlendirilmiştir.

Tedavi grubundaki katılımcılara haftada bir seans olmak üzere toplam 8 seans süren bir kayropraktik tedavi programı uygulanmıştır. Bu program; omurga manipülasyonu, mobilizasyon, myofasiyal serbest bırakma teknikleri, egzersiz ve rehabilitasyon uygulamaları ile postüral eğitimi kapsamakta olup, müdahaleler katılımcıların bireysel ihtiyaçlarına göre planlanmıştır. Kontrol grubundaki katılımcılara ise çalışma süresince herhangi bir kayropraktik müdahale uygulanmamıştır. Kayropraktik uygulamaların tamamı Qualista Danışmanlık bünyesinde gerçekleştirilmiştir. Çalışma, Helsinki Bildirgesi ilkelerine uygun olarak planlanmış olup, tüm katılımcılardan yazılı bilgilendirilmiş gönüllü onam alınmıştır.

Dahil edilme kriterleri:

- En az 3 aydır devam eden kronik bel ağrısı tanısına sahip olmak
- 18–65 yaş aralığında olmak
- Kayropraktik tedaviye tıbbi açıdan uygun olmak ve tedaviye katılmayı kabul etmek

Dışlanma kriterleri:

- Akut veya subakut bel ağrısına sahip olmak (≤3 ay)
- Son 6 ay içinde bel bölgesine yönelik cerrahi müdahale geçirmiş olmak
- Nörolojik hastalık veya bel ağrısı ile ilişkili sinir sistemi bozukluğu bulunması
- Gebelik durumu
- Ciddi psikiyatrik rahatsızlık öyküsünün bulunması

2.2.Kayropraktik Manüpülasyon

Lumbal omurgaya uygulanan **HVLA manipülasyonu**, kısa ve hızlı bir itme (thrust) ile eklem yüzeylerinin normal aralığı içinde hızlı bir hareketle mobilizasyonunu hedefleyen kayropraktik bir tekniktir (Herzog, 2005). Roll pozisyonu, lumbal eklemlere yönelik HVLA uygulamasında sık kullanılan bir yerleştirme yöntemidir. Bu teknikte hasta yan yatış pozisyonuna getirilir; üst ekstremite hafif fleksiyona alınırken, alt ekstremite dizleri fleksiyonlu ve kalça hafif fleksiyon-addüksiyon pozisyonuna yerleştirilir. Terapist, lumbal segment üzerinde tercih edilen rotasyon segmentini stabilize eder ve lezyonlu segmenti lokalize eder (Cleland ve ark., 2008). Manipülasyonun etkinliği için terapist, her iki pelvis yarısını kontrollü şekilde rotasyona yönlendirerek lezyon segmentini hedefler. Daha sonra, kısa ve kontrollü bir itme (thrust) ile lumbal vertebrayı fiziolojik hareket sınırları içinde hızlıca hareket ettirir. Bu itme, genellikle

çıtlama (cavitation) ile sonuçlanır ve sinovyal gaz boşalması ile ilişkilidir (Ernst, 2010). Uygulama, kas-iskelet sistemi üzerindeki refleks modülasyonu ve segmental mobilite artışı ile ağrı azaltımını destekler.

2.3.Veri Toplama Araçları

2.3.1.Visual Analog Skala (VAS)

Katılımcıların ağrı düzeyleri, tedavi öncesi ve sonrasında Görsel Analog Skala (VAS) kullanılarak değerlendirilmiştir. VAS, 0 (ağrı yok) ile 10 (en şiddetli ağrı) arasında derecelendirilen, ağrı şiddetinin öznel değerlendirilmesinde yaygın olarak kullanılan geçerli ve güvenilir bir ölçüm aracıdır. Klinik ve araştırma ortamlarında özellikle kas-iskelet sistemi ağrılarının değerlendirilmesinde sıklıkla tercih edilen VAS, duyarlılığı yüksek olması ve değişime yanıt verebilmesi nedeniyle tedavi etkinliğinin izlenmesinde etkili bir yöntem olarak kabul edilmektedir. Güncel çalışmalar, VAS'ın kronik bel ağrısı gibi durumlarda ağrı şiddetindeki değişimleri saptamada güvenilir bir araç olduğunu göstermektedir (Hawker et al., 2011).

2.3.2.SF-36 Yaşam Kalitesi Ölçeği

Yaşam kalitesi, SF-36 Yaşam Kalitesi Ölçeği kullanılarak değerlendirilmiştir. SF-36, bireylerin fiziksel ve zihinsel sağlık durumlarını çok boyutlu olarak ölçmek amacıyla geliştirilmiş, yaygın kullanıma sahip bir öz-bildirim aracıdır (Ware ve ark., 1992). Ölçeğin Türkiye'de geçerlilik ve güvenilirliği Koçyiğit ve arkadaşları tarafından gösterilmiştir (Koçyiğit ve ark., 1999). SF-36; genel sağlık algısı, fiziksel işlev, fiziksel rol güçlüğü, duygusal rol güçlüğü, sosyal işlevsellik, ağrı, enerji/canlılık ve zihinsel sağlık olmak üzere sekiz alt boyuttan oluşmaktadır. Alt boyutlar 2–10 maddeden oluşmakta olup, her bir madde tek bir ölçekte değerlendirilmekte ve puanlar 0–100 aralığında hesaplanmaktadır. Düşük puanlar daha kötü sağlık durumunu, yüksek puanlar ise daha iyi yaşam kalitesini göstermektedir.

2.3.3.Subjektif Sağlık Şikayetleri Ölçeği

Katılımcıların subjektif sağlık durumları, Subjektif Sağlık Şikayetleri Ölçeği kullanılarak değerlendirilmiştir. Bu ölçek, bireylerin ağrı şiddeti, hareket kabiliyeti ve genel sağlık algılarını

çok boyutlu olarak değerlendirmek amacıyla geliştirilmiştir (Kalaycıoğlu ve ark., 2022). Ölçek; kas-iskelet sistemi, psödonörolojik, gastrointestinal, alerji ve grip şikayetleri olmak üzere beş alt boyuttan oluşmaktadır.

2.4.Örneklem Büyüklüğü Hesaplaması

Araştırmanın örneklem büyüklüğü, G*Power yazılımı kullanılarak yapılan güç analizi ile belirlenmiştir. Orta düzey etki büyüklüğü (d = 0.5), alfa seviyesi 0.05 ve istatistiksel güç 0.80 olarak kabul edilmiştir. Yapılan analiz sonucunda her bir grup için en az 30 katılımcının yeterli olduğu belirlenmiştir. Çalışmaya toplam 64 birey dahil edilmiş olup, deney grubunda 32 ve kontrol grubunda 32 katılımcı yer almıştır. Bu örneklem büyüklüğü, istatistiksel analizler için yeterli kabul edilmiştir.

2.5.Etik Onay

Bu çalışma, Üsküdar Üniversitesi Girişimsel Olmayan Araştırmalar Etik Kurulu tarafından 29.06.2024 tarihinde onaylanmıştır. Tüm katılımcılardan çalışma öncesinde bilgilendirilmiş onam alınmıştır.

2.6.İstatistiksel Analiz

Veriler SPSS 21.0 yazılımı kullanılarak analiz edilmiştir. Tanımlayıcı istatistikler ortalama, standart sapma ve yüzde olarak sunulmuştur. Kategorik değişkenler için ki-kare testi uygulanmış; iki grup karşılaştırmalarında bağımsız örneklem t testi, üç ve daha fazla grup karşılaştırmalarında tek yönlü ANOVA kullanılmıştır. Sürekli değişkenler arasındaki ilişkiler Pearson korelasyon analizi ile değerlendirilmiş, ön test–son test karşılaştırmaları ise eşleştirilmiş örneklem t testi ile yapılmıştır. Tüm analizlerde anlamlılık düzeyi $p<0.05$ olarak kabul edilmiştir.

3.Bulgular

Çalışmada yer alan deney ve kontrol gruplarındaki katılımcıların temel demografik özelliklerini özetlemektedir. Analiz sonuçları, iki grubun yaş, cinsiyet, medeni durum, eğitim düzeyi ve düzenli egzersiz yapma durumu açısından benzer dağılım gösterdiğini ortaya koymaktadır. Deney ve kontrol gruplarının yaş ortalamaları birbirine yakın olup gruplar arasında belirgin bir fark bulunmamaktadır. Cinsiyet dağılımı her iki grupta dengeli olup genel katılımcı profili eşit

kadın ve erkek oranından oluşmaktadır. Medeni durum, eğitim düzeyi ve düzenli egzersiz yapma durumu açısından da gruplar arasında homojen bir dağılım gözlenmiştir. Bu bulgular, deney ve kontrol gruplarının demografik açıdan karşılaştırılabilir olduğunu ve demografik değişkenlerin çalışma sonuçları üzerinde karıştırıcı bir etki oluşturmadığını göstermektedir (Tablo 1).

Tablo 1. Katılımcıların Demografik Durumları

Değişken	**Kategori**	**Deney (n=32)**	**Kontrol (n=32)**	**Toplam (n=64)**
Yaş	Ort. ± Ss	29.96 ± 9.27	29.35 ± 8.06	29.65 ± 8.67
Cinsiyet	Kadın	13 (40.6%)	19 (59.4%)	32 (50.0%)
	Erkek	19 (59.4%)	13 (40.6%)	32 (50.0%)
Medeni Durum	Evli	9 (28.1%)	7 (21.9%)	16 (25.0%)
	Bekar	23 (71.9%)	25 (78.1%)	48 (75.0%)
Eğitim Durumu	Lise	7 (21.9%)	7 (21.9%)	14 (21.9%)
	Önlisans	4 (12.5%)	4 (12.5%)	8 (12.5%)
	Lisans/Lisansüstü	21 (65.6%)	21 (65.6%)	42 (65.6%)
Düzenli Egzersiz/Spor	Evet	19 (72.6%)	21 (65.6%)	42 (65.6%)
	Hayır	13 (34.4%)	11 (34.4%)	22 (34.4%)

Tablo 2. Kayropraktik Uygulaması Yapılan Kronik Bel Ağrılı Hastalarda Müdahale Öncesi ve Sonrası Ağrı Seviyelerinin Karşılaştırılması

		Ort.	Ss (±)	t	p
Pair 1	VAS Öntest	3,03	1,71	7.048	**0.000**
	VAS Sontest	2,18	1,25		

Kayropraktik tedavi uygulanan kronik bel ağrılı hastaların yaşı ile VAS öntest ve sontest skorları arasında ilişki saptanmamıştır (p>0.05). (Tablo 2)

Tablo 3: Kayropraktik Uygulaması Olmayan Deneklerde Müdahale Öncesi ve Sonrası Ağrı Seviyelerinin Karşılaştırılması

		Ort.	Ss (±)	t	p
Pair 1	VAS Öntest	4,89	2,61	3.402	0.**002**
	VAS Sontest	4,64	2,41		

Kayropraktik tedavi uygulanmayan kronik bel ağrılı hastaların yaşı ile VAS öntest ve sontest skorları arasında pozitif yönde ve düşük şiddette ilişki saptanmıştır ($p<0.05$). Başka bir deyişle yaş arttıkça bel ağrısı şiddeti de anlamlı şekilde artmaktadır. (Tablo 3)

Tablo 4. Deney Ve Kontrol Grubu VAS Skorlarının Karşılaştırılması

Parametreler		N	Ort.	Ss (±)	t	p
VAS Öntest	Deney Grubu	32	3,03	1,71	-3.439	0.**001**
	Kontrol Grubu	32	4,89	2,61		
VAS Sontest	Deney Grubu	32	2,18	1,25	-5.182	0.**000**
	Kontrol Grubu	32	4,64	2,41		

Kayropraktik tedavi almayan kronik bel ağrısı hastalarında yapılan VAS öntest ve sontest skorları karşılaştırıldığında, sontest skorlarının öntest skorlarına göre anlamlı derecede daha düşük olduğu tespit edilmiştir ($p<0.05$). Bu sonuç, kayropraktik tedavi uygulanmasa bile hastaların zamanla bir miktar iyileşme gösterdiğini ya da ağrılarında bir azalma yaşadığını işaret etmektedir. Ancak, kaydedilen bu iyileşme kayropraktik tedaviye ihtiyaç duymadan gerçekleşmiş olup, farklı müdahale veya tedavi yöntemlerinin etkili olabileceğini düşündürmektedir. Tedavi planları oluşturulurken, bu doğal iyileşme süreci göz önünde bulundurulabilir. (Tablo 4)

Tablo 5. Kayropraktik Tedavisi Yapılan ve Yapılmayan Kronik Bel Ağrılı Hastalarda Müdahale Öncesi ve Sonrası Subjektif Sağlık Şikayetlerinin Karşılaştırılması

Parametreler		N	Ort.	Ss (±)	t	p
Kas iskelet şikayetleri Öntest	Deney Grubu	32	20,56	2,24	-1.367	0.176
	Kontrol Grubu	32	21,18	1,54		
Kas iskelet şikayetleri Sontest	Deney Grubu	32	16,75	2,00	-9.554	0.000
	Kontrol Grubu	32	20,67	1,39		
Psödonörolojik şikayetler Öntest	Deney Grubu	32	18,87	1,45	-0.142	0.888
	Kontrol Grubu	32	18,91	1,11		
Psödonörolojik şikayetler Sontest	Deney Grubu	32	16,40	1,54	-6.117	0.000
	Kontrol Grubu	32	18,48	1,28		
Gastrointestinal şikayetler Öntest	Deney Grubu	32	19,21	1,45	0.397	0.693
	Kontrol Grubu	32	19,08	1,42		
Gastrointestinal şikayetler Sontest	Deney Grubu	32	16,50	1,41	-6.542	0.000
	Kontrol Grubu	32	18,75	1,44		

Alerji Öntest	Deney Grubu	32	3,03	,73	0.023	0.982
	Kontrol Grubu	32	3,02	,76		
Alerji Sontest	Deney Grubu	32	1,93	,66	-0.5655	0.000
	Kontrol Grubu	32	2,91	,75		
Grip Şikayetleri Öntest	Deney Grubu	32	2,15	,80	-0.600	0.551
	Kontrol Grubu	32	2,27	,76		
Grip Şikayetleri Sontest	Deney Grubu	32	1,65	,70	-2.650	0.010
	Kontrol Grubu	32	2,13	,78		

Kayropraktik tedavi uygulanan ve uygulanmayan kronik bel ağrılı hastalarda subjektif sağlık şikayetlerindeki değişimleri karşılaştırmaktadır. Tedavi öncesi değerlendirmelerde kas-iskelet, psödonörolojik, gastrointestinal, alerji ve grip şikayetleri açısından gruplar arasında anlamlı bir fark bulunmamıştır (tüm $p>0.05$). Tedavi sonrasında ise kayropraktik tedavi uygulanan grupta tüm alt boyutlarda anlamlı düzeyde azalma gözlenmiştir. Buna göre, kas-iskelet şikayetleri ($p<0.001$), psödonörolojik şikayetler ($p<0.001$), gastrointestinal şikayetler ($p<0.001$), alerji şikayetleri ($p<0.001$) ve grip şikayetleri ($p=0.010$) tedavi sonrası dönemde anlamlı şekilde azalmıştır. Bu bulgular, kayropraktik tedavinin yalnızca kas-iskelet sistemiyle sınırlı kalmayıp, kronik bel ağrısı olan bireylerde çeşitli subjektif sağlık şikayetlerinin azaltılmasında etkili olduğunu göstermektedir. (Tablo 5)

Tablo 6. Kayropraktik Tedavisi Yapılan Kronik Bel Ağrılı Hastalarda Müdahale Öncesi ve Sonrası Subjektif Sağlık Şikayetlerinin Karşılaştırılması

		Ort.	N	Ss (±)	t	p
Pair 1	Kas iskelet şikayetleri Öntest	20,56	32	2,24	10.746	0.000
	Kas iskelet şikayetleri Sontest	16,75	32	2,00		
Pair 2	Psödonörolojik şikayetler Öntest	18,87	32	1,45	14.204	0.000
	Psödonörolojik şikayetler Sontest	16,40	32	1,54		
Pair 3	Gastrointestinal şikayetler Öntest	19,21	32	1,45	19.925	0.000
	Gastrointestinal şikayetler Sontest	16,50	32	1,41		
Pair 4	Alerji Öntest	3,03	32	,73	9.659	0.000
	Alerji Sontest	1,93	32	,66		
Pair 5	Grip Şikayetleri Öntest	2,15	32	,80	5.568	0.000
	Grip Şikayetleri Sontest	1,65	32	,70		

Kayropraktik tedavi uygulanan kronik bel ağrılı hastalarda subjektif sağlık şikayetlerinin tedavi öncesi ve sonrası değişimini göstermektedir. Bulgular, kayropraktik tedavi sonrasında tüm alt boyutlarda anlamlı düzeyde iyileşme olduğunu ortaya koymaktadır. Kas-iskelet şikayetleri tedavi öncesine kıyasla anlamlı şekilde azalmış (20.56'dan 16.75'e; $p<0.001$), psödonörolojik şikayetler de benzer biçimde düşüş göstermiştir (18.87'den 16.40'a; $p<0.001$). Gastrointestinal şikayetlerde tedavi sonrası belirgin bir azalma gözlenmiş (19.21'den 16.50'ye; $p<0.001$), alerji şikayetleri (3.03'ten 1.93'e; $p<0.001$) ve grip şikayetleri (2.15'ten 1.65'e; $p<0.001$) de anlamlı

düzeyde azalmıştır. Bu sonuçlar, kayropraktik tedavinin kronik bel ağrılı bireylerde yalnızca kas-iskelet sistemi değil, farklı subjektif sağlık şikayetleri üzerinde de olumlu etkiler sağladığını göstermektedir. (Tablo 6)

Tablo 7. Kayropraktik Tedavisi Yapılan ve Yapılmayan Kronik Bel Ağrılı Hastalarda Müdahale Öncesi ve Sonrası Yaşam Kalitesi Seviyelerinin Karşılaştırılması

Parametreler		N	Ort.	Ss (±)	t	p
Fiziksel Fonksiyon Öntest	Deney Grubu	32	79,68	24,22	1.982	0.052
	Kontrol Grubu	32	67,70	25,72		
Fiziksel Fonksiyon Sontest	Deney Grubu	32	89,84	19,11	3.608	0.001
	Kontrol Grubu	32	70,13	25,26		
Fiziksel Rol Güçlüğü Öntest	Deney Grubu	32	82,81	34,45	3.204	0.002
	Kontrol Grubu	32	52,70	42,40		
Fiziksel Rol Güçlüğü Sontest	Deney Grubu	32	86,71	26,16	3.508	.001
	Kontrol Grubu	32	61,48	32,59		
Emosyonel Rol Güçlüğü Öntest	Deney Grubu	32	76,04	35,14	3.579	0.001
	Kontrol Grubu	32	42,34	42,05		
Emosyonel Rol Güçlüğü Sontest	Deney Grubu	32	86,71	19,53	5.254	0.000
	Kontrol Grubu	32	45,81	40,09		
Enerji/Canlılık Öntest	Deney Grubu	32	40,00	14,75	-4.046	0.000
	Kontrol Grubu	32	53,64	13,26		
Enerji/Canlılık Sontest	Deney Grubu	32	69,37	12,55	3.981	0.000
	Kontrol Grubu	32	57,02	13,09		
Ruhsal Sağlık Öntest	Deney Grubu	32	35,21	12,38	-3.786	0.000
	Kontrol Grubu	32	45,93	11,12		
Ruhsal Sağlık Sontest	Deney Grubu	32	57,18	10,23	3.635	0.000
	Kontrol Grubu	32	48,00	10,66		
Sosyal İşlevsellik Öntest	Deney Grubu	32	37,29	22,97	-2.407	0.019
	Kontrol Grubu	32	51,25	24,90		
Sosyal İşlevsellik Sontest	Deney Grubu	32	63,59	18,93	2.186	0.032
	Kontrol Grubu	32	51,97	24,36		
Ağrı Öntest	Deney Grubu	32	30,39	12,65	-4.792	0.000
	Kontrol Grubu	32	48,17	17,37		
Ağrı Sontest	Deney Grubu	32	15,59	8,40	-9.393	0.000
	Kontrol Grubu	32	47,67	17,65		
Genel Sağlık Öntest	Deney Grubu	32	39,95	8,78	-1.119	0.267
	Kontrol Grubu	32	42,18	7,75		
Genel Sağlık Sontest	Deney Grubu	32	49,34	9,32	3.286	0.002
	Kontrol Grubu	32	41,62	10,07		

Kayropraktik tedavi uygulanan ve uygulanmayan kronik bel ağrılı hastalar arasında yaşam kalitesi açısından anlamlı farklılıklar olduğunu göstermektedir. Bağımsız örneklem t-testi sonuçlarına göre, kayropraktik tedavi uygulanan grupta son testte fiziksel fonksiyon, fiziksel rol güçlüğü, emosyonel rol güçlüğü, enerji/canlılık, sosyal işlevsellik ve genel sağlık kalitesi skorları, tedavi uygulanmayan gruba kıyasla anlamlı derecede daha yüksek bulunurken; ağrı düzeyi anlamlı şekilde daha düşük saptanmıştır (tüm $p<0.05$). Özellikle fiziksel fonksiyon

puanı kayropraktik tedavi grubunda 89.84, kontrol grubunda ise 70.13 olarak belirlenmiş ve bu fark istatistiksel olarak anlamlı bulunmuştur (p=0.001). Benzer şekilde emosyonel rol güçlüğü, enerji/canlılık ve sosyal işlevsellik alt boyutlarında da kayropraktik tedavi uygulanan grup lehine anlamlı farklılıklar gözlenmiştir. Ağrı alt boyutunda ise kayropraktik tedavi grubunda son test puanı 15.59 iken, tedavi uygulanmayan grupta bu değer 47.67 olarak ölçülmüş ve gruplar arasındaki fark yüksek düzeyde anlamlı bulunmuştur (p<0.001). Genel sağlık algısı da kayropraktik tedavi uygulanan grupta anlamlı derecede daha yüksek saptanmıştır (p=0.002). Bu bulgular, kayropraktik tedavinin kronik bel ağrılı hastalarda ağrıyı azaltarak yaşam kalitesinin çok boyutlu olarak iyileştirilmesinde etkili olduğunu göstermektedir. (Tablo 7).

Tablo 8. Kayropraktik Tedavisi Yapılan Kronik Bel Ağrılı Hastalarda Müdahale Öncesi ve Sonrası Yaşam Kalitesi Seviyelerinin Karşılaştırılması

		Ort.	Ss (±)	t	p
Pair 1	Fiziksel Fonksiyon Öntest	79,68	24,22	-8.062	.000
	Fiziksel Fonksiyon Sontest	89,84	19,11		
Pair 2	Fiziksel Rol Güçlüğü Öntest	82,81	34,45	-2.296	.023
	Fiziksel Rol Güçlüğü Sontest	86,71	26,16		
Pair 3	Emosyonel Rol Güçlüğü Öntest	76,04	35,14	-3.451	.002
	Emosyonel Rol Güçlüğü Sontest	86,71	19,53		
Pair 4	Enerji Canlılık Öntest	40,00	14,75	-20.497	.000
	Enerji Canlılık Sontest	69,37	12,55		
Pair 5	Ruhsal Sağlık Öntest	35,21	12,38	-26.417	.000
	Ruhsal Sağlık Sontest	57,18	10,23		
Pair 6	Sosyal İşlevsellik Öntest	37,29	22,97	-23.955	.000
	Sosyal İşlevsellik Sontest	63,59	18,93		
Pair 7	Ağrı Öntest	30,39	12,65	11.779	.000
	Ağrı Sontest	15,59	8,40		
Pair 8	Genel Sağlık Öntest	39,95	8,78	-13.323	.000
	Genel Sağlık Sontest	49,34	9,32		

Kayropraktik tedavi uygulanan kronik bel ağrılı hastalarda yaşam kalitesinin çok boyutlu olarak anlamlı düzeyde iyileştiğini göstermektedir. Tedavi sonrası dönemde fiziksel fonksiyon skorları anlamlı şekilde artmış (79.68'den 89.84'e; p<0.001) ve fiziksel rol güçlüğü puanlarında da belirgin bir iyileşme gözlenmiştir (82.81'den 86.71'e; p=0.023). Psikososyal boyutlar incelendiğinde, emosyonel rol güçlüğü skorunun tedavi sonrası anlamlı düzeyde yükseldiği (76.04'ten 86.71'e; p=0.002) ve enerji/canlılık düzeyinin belirgin biçimde arttığı saptanmıştır (40.00'dan 69.37'ye; p<0.001). Ruhsal sağlık (35.21'den 57.18'e; p<0.001) ve sosyal işlevsellik (37.29'dan 63.59'a; p<0.001) alanlarında da tedavi sonrası anlamlı iyileşmeler kaydedilmiştir. Buna ek olarak, ağrı düzeyi tedavi sonrasında belirgin şekilde azalmış (30.39'dan 15.59'a; p<0.001) ve genel sağlık algısı anlamlı düzeyde artmıştır (39.95'ten

49.34'e; $p<0.001$). Bu bulgular, kayropraktik tedavinin kronik bel ağrılı hastalarda hem fiziksel hem de psikososyal boyutları kapsayan yaşam kalitesi üzerinde güçlü ve olumlu etkiler sağladığını göstermektedir. (Tablo 8).

4. Tartişma

Kronik bel ağrısı (KBA), dünya genelinde yüksek prevalansa sahip, bireylerin yaşam kalitesini belirgin biçimde düşüren ve önemli sosyoekonomik sonuçlara yol açan yaygın bir sağlık sorunudur. Engelliliğin önde gelen nedenleri arasında yer alan KBA, yalnızca fiziksel işlevleri değil, aynı zamanda psikolojik iyi oluşu ve sosyal katılımı da olumsuz yönde etkilemektedir (Patrick ve ark., 2014; Agnus Tom ve ark., 2022). Bu çok boyutlu etki alanı nedeniyle KBA'nın yönetimi karmaşık olup, geleneksel tedavi yaklaşımlarının özellikle kronik olgularda sınırlı etki gösterdiği bildirilmektedir (Guzmán ve ark., 2001; Bogduk, 2004). Bu durum, hastaların alternatif ve tamamlayıcı tedavi yöntemlerine yönelmesine neden olmuş; kayropraktik tedavi bu bağlamda öne çıkan yaklaşımlardan biri haline gelmiştir (Haas ve ark., 2004).

Bu çalışmada, kayropraktik tedavinin kronik bel ağrılı hastalarda ağrı düzeyi, subjektif sağlık şikayetleri ve yaşam kalitesi üzerindeki etkileri değerlendirilmiştir. Bulgular, kayropraktik tedavi uygulanan hastalarda hem tedavi öncesi–sonrası karşılaştırmalarda hem de tedavi almayan kontrol grubuna kıyasla ağrı düzeyinde anlamlı bir azalma olduğunu göstermektedir. VAS skorlarındaki bu düşüş, kayropraktik tedavinin kronik bel ağrısının yönetiminde etkili bir ağrı azaltma yöntemi olabileceğini ortaya koymaktadır. Benzer şekilde, literatürde Hinto ve arkadaşları (2010) ile Peterson ve arkadaşları (2012) çalışmaları da kayropraktik tedavi sonrası ağrı şiddetinde anlamlı azalma bildirmiştir. Bu sonuçlar, çalışmamızın bulgularını desteklemekte ve kayropraktik tedavinin analjezik etkisini güçlendirmektedir.

Çalışmanın önemli bulgularından biri, kayropraktik tedavi uygulanan hastalarda subjektif sağlık şikayetlerinin tedavi almayan gruba kıyasla anlamlı derecede azalmasıdır. Özellikle kas-iskelet sistemi, psödonörolojik, gastrointestinal, alerji ve grip şikayetlerinde tedavi sonrası belirgin iyileşmeler saptanmıştır. Bu durum, kayropraktik tedavinin yalnızca lokal ağrı üzerinde değil, farklı sistemleri etkileyen subjektif sağlık şikayetleri üzerinde de olumlu etkiler yaratabileceğini düşündürmektedir. Subjektif şikayetlerde gözlenen bu çok boyutlu iyileşme, kayropraktik tedavinin bütüncül bir etki mekanizmasına sahip olabileceğini desteklemektedir.

Yaşam kalitesi sonuçları da çalışmanın dikkat çekici bulguları arasındadır. Kayropraktik tedavi uygulanan grupta fiziksel fonksiyon, fiziksel rol güçlüğü, emosyonel rol güçlüğü, enerji/canlılık, sosyal işlevsellik ve genel sağlık algısı gibi yaşam kalitesinin hem fiziksel hem de psikososyal boyutlarında anlamlı artışlar gözlenmiştir. Buna karşılık ağrı alt boyutunda anlamlı bir düşüş saptanmıştır. Bu sonuçlar, kayropraktik tedavinin kronik bel ağrılı hastalarda yaşam kalitesini çok yönlü olarak iyileştirdiğini göstermektedir. Parkinson ve arkadaşlarının (2003) sistematik derlemesi ile Hays ve arkadaşlarının (2019, 2022) çalışmaları da kayropraktik tedavinin yaşam kalitesi üzerinde olumlu etkiler sağladığını bildirmiş olup, mevcut bulgular bu çalışmalarla uyumludur.

Çalışmanın sonuçları, kronik bel ağrısı yönetiminde tedavi hedefinin yalnızca ağrının azaltılmasıyla sınırlı kalmaması gerektiğini, aynı zamanda hastaların fonksiyonel kapasitesi, psikososyal durumu ve genel sağlık algısının da iyileştirilmesinin önemli olduğunu göstermektedir. Bu bağlamda kayropraktik tedavi, kronik bel ağrısının bütüncül yönetiminde etkili ve tamamlayıcı bir yaklaşım olarak değerlendirilebilir. Bununla birlikte, elde edilen bulguların genellenebilirliğini artırmak ve kayropraktik tedavinin uzun vadeli etkilerini daha iyi ortaya koymak amacıyla, daha geniş örneklemli ve uzun süreli takip içeren çalışmalara ihtiyaç vardır. Ayrıca, hangi spesifik kayropraktik tekniklerin veya müdahale bileşenlerinin bu olumlu sonuçlara daha fazla katkı sağladığının belirlenmesi, gelecekte geliştirilecek daha hedefe yönelik ve kişiselleştirilmiş tedavi protokolleri açısından önem taşımaktadır.

5. Sonuç

Bu çalışmanın bulguları, kayropraktik tedavinin kronik bel ağrısı olan hastalarda ağrı düzeyini azaltmada ve yaşam kalitesini çok boyutlu olarak iyileştirmede etkili bir tedavi seçeneği olduğunu göstermektedir. Kayropraktik tedavi alan hastalarda ağrı şiddetinde belirgin azalma ile birlikte fiziksel ve emosyonel işlevsellik, enerji/canlılık ve genel sağlık algısında anlamlı iyileşmeler gözlenmiştir. Ayrıca kas-iskelet sistemi, psödonörolojik ve gastrointestinal şikayetler başta olmak üzere çeşitli subjektif sağlık şikayetlerinde de anlamlı azalmalar saptanmıştır. Bu bulgular, kayropraktik tedavinin yalnızca ağrı yönetimiyle sınırlı kalmayıp, kronik bel ağrılı hastaların genel sağlık durumu ve yaşam kalitesi üzerinde bütüncül bir etki sağladığını ortaya koymaktadır. Bununla birlikte, kayropraktik tedavinin uzun vadeli etkilerini değerlendiren, daha geniş örneklemli ve karşılaştırmalı çalışmalara ihtiyaç duyulmaktadır.

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PERİFERİK ARTER HASTALIĞINDA EGZERSİZE UYUM VE FİZYOTERAPİ TEMELLİ YAKLAŞIMLAR

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ÖZET

Periferik arter hastalığı (PAH), alt ekstremite arterlerinde aterosklerotik daralma ile karakterize, fonksiyonel kapasiteyi ve yaşam kalitesini olumsuz etkileyen bir kardiyovasküler hastalıktır. Periferik arter hastalığı tedavisinde en güçlü kanıt düzeyine sahip konservatif yaklaşımlardan biri egzersiz tedavisi olmasına karşın, bu hasta grubunda egzersize uyum oranlarının düşük olduğu bildirilmektedir. Egzersize uyumun yetersiz olması ise; ağrı korkusu, intermittan klaudikasyon semptomları, motivasyon eksikliği ve çeşitli psikososyal faktörlerle ilişkilendirilmiştir. Literatürdeki çalışmaların büyük bir kısmı egzersizin fizyolojik etkilerine odaklanırken, egzersize uyumu etkileyen faktörleri ve fizyoterapi yaklaşımlarını bütüncül olarak ele alan derlemeler sınırlıdır. Bu nedenle bu derlemenin amacı, periferik arter hastalarında egzersize uyumu etkileyen güncel kanıtları incelemek ve fizyoterapi temelli güncel yaklaşımları sentezlemektir. Bu kapsamda "PubMed, Scopus ve Google Scholar" veri tabanlarında "peripheral arterial disease (periferik arter hastalığı), exercise adherence (egzersize uyum), supervised exercise therapy (gözetimli egzersiz tedavisi), physiotherapy (fizyoterapi), claudication (klaudikasyon / intermittan klodikasyon" anahtar kelimeleri kullanılarak son 10 yıl içinde yayımlanmış çalışmalar taranmıştır. Bulgular, gözetimli egzersiz programlarının gözetimsiz programlara kıyasla egzersize bağlılığı ve yürüme performansını anlamlı düzeyde artırdığını ortaya koymaktadır. Ayrıca, bireyselleştirilmiş egzersiz reçeteleri, ağrı yönetimi stratejileri, hasta eğitimi ve davranışsal destek yaklaşımlarının egzersize uyumu olumlu yönde etkilediği bildirilmiştir. Sonuç olarak, periferik arter hastalarında egzersize uyum, yalnızca fizyolojik değil, davranışsal ve çevresel faktörlerle de yakından ilişkilidir.

Anahtar Kelimeler: periferik arter hastalığı, egzersiz uyumu, intermittan klodikasyon.

1. PERİFERİK ARTER HASTALIĞI

Periferik arter hastalığı (PAH), aterosklerotik süreçler sonucunda alt ekstremite arterlerinde gelişen daralma ve tıkanıklıkla karakterize, kronik ve ilerleyici bir kardiyovasküler hastalıktır (Eid, Mehta ve Goodney, 2021). Hastalık genellikle orta ve ileri yaş grubunda görülmekte olup, prevalansı yaşla birlikte artış göstermektedir (ESO vd., 2011). PAH olgularının önemli bir bölümü uzun süre asemptomatik seyredebilmekte, bu durum hastalığın gerçek prevalansının ve tanısal dağılımının doğru biçimde ortaya konmasını güçleştirmektedir. Nitekim literatürde, asemptomatik PAH olgularının semptomatik olgulara kıyasla yaklaşık üç kat daha fazla olduğu bildirilmektedir (Velescu vd., 2016). Güncel epidemiyolojik veriler ise, PAH'ın dünya genelinde 200 milyondan fazla bireyi etkilediğini ortaya koymaktadır (Fowkes vd., 2013). Türkiye'de yapılan çalışmalarda ise PAH prevalansı yaklaşık %20 olarak rapor edilmiştir (Karabay vd., 2012).

PAH gelişiminde ileri yaş, cinsiyet, genetik yatkınlık ve etnik faktörlerin yanı sıra sigara kullanımı, diyabet, hipertansiyon ve dislipidemi gibi kardiyovasküler risk faktörleri önemli rol oynamaktadır (Brevetti vd., 2010). Ayrıca fiziksel inaktivite ve sedanter yaşam tarzı, hastalığın ortaya çıkışı ve ilerlemesi açısından bağımsız risk faktörleri arasında yer almaktadır (Haugen vd., 2007; Farah vd., 2016). PAH'ın en erken ve en sık görülen klinik bulgusu, egzersizle ortaya çıkan ve istirahatle gerileyen intermittan klodikasyondur. Bu semptom, alt ekstremite kaslarına giden kan akımının egzersiz sırasında artan metabolik gereksinimleri karşılayamaması sonucunda gelişen doku hipoksisine bağlıdır. Hastalar genellikle yürüyüş sırasında baldır, uyluk veya gluteal bölgede ağrı, kramp ya da uyuşma hissinden yakınmakta ve bu şikâyetler istirahatle azalmaktadır. Hastalığın ilerleyen evrelerinde ise ağrı istirahat halinde dahi ortaya çıkabilmektedir.

İntermittan klodikasyon, PAH'lı bireylerin yaklaşık %10–35'inde görülmekte olup, yürüyüş kapasitesini ve fiziksel aktivite düzeyini belirgin biçimde sınırlamaktadır (Hamburg ve Balady, 2011). Bu fonksiyonel kısıtlılığın ortaya çıkmasında yalnızca arteriyel daralma değil; mikrovasküler dolaşım bozukluğu, kas oksijenasyonunun azalması, kas atrofisi ve buna bağlı kas kuvvet kaybı gibi yapısal ve metabolik değişiklikler de etkili olmaktadır (Crowther vd., 2008). Klinik uygulamada hastalık şiddetinin değerlendirilmesinde en yaygın kullanılan sınıflama sistemlerinden biri Fontaine sınıflamasıdır. Fontaine sınıflaması, hastaları asemptomatik dönemden ülserasyon ve gangren ile karakterize ileri evrelere kadar dört klinik evrede değerlendirmektedir (Fontaine, 1954; Hardman vd., 2014). Bu sınıflama sistemi tanısal testlere dayanmaksızın, yalnızca klinik semptomların derecesine göre hastalığın evresini tanımlamaktadır (Novo, 2002).

PAH ilerledikçe immobilizasyon artmakta ve buna paralel olarak alt ekstremite kas kuvvetinde belirgin azalma meydana gelmektedir (Schieber vd., 2017). Fonksiyonel mobilitenin azalması, hastalık progresyonunu hızlandıran önemli bir faktör olarak değerlendirilmektedir (Kim vd., 2021). PAH'lı bireylerde, sağlıklı bireylerle karşılaştırıldığında alt ekstremite kas liflerinde sayısal azalma ve belirgin atrofi olduğu gösterilmiştir (McDermott vd., 2004). Ayrıca baldır kas kuvveti, diz ekstansör kas kuvveti ve kavrama kuvvetindeki azalmanın artmış mortalite ile ilişkili olduğu bildirilmiştir (McDermott vd., 2012). Hastalığın ileri evrelerinde ise vasküler

lezyonlar kronik iskemiye, doku kaybına, ülserasyonlara, gangrene ve amputasyonlara yol açabilmektedir.

PAH tedavisinde yaşam tarzı değişiklikleri, egzersiz tedavisi, farmakolojik yaklaşımlar ve gerektiğinde cerrahi girişimler uygulanmaktadır. Asemptomatik ya da hafif semptomlu bireylerde en etkili tedavi seçeneklerinden biri egzersiz tedavisidir. Düzenli egzersizin, PAH'lı bireylerde yürüme mesafesini, egzersiz toleransını ve fonksiyonel kapasiteyi anlamlı düzeyde artırdığı gösterilmiştir (Parmenter, Raymond ve Fiatarone Singh, 2013). Bunun yanı sıra fiziksel aktivite düzeyinin artırılmasının, intermittan klodikasyonu olan bireylerde mortalite riskini azalttığı da bildirilmektedir (Gardner, Montgomery ve Parker, 2008).

2. PERİFERİK ARTER HASTALIĞINDA EGZERSİZE UYUMUN BELİRLEYİCİLERİ

Periferik arter hastalığının en sık görülen semptomu olan intermittan klaudikasyon, egzersiz sırasında ortaya çıkan ağrı ve rahatsızlık hissi nedeniyle fiziksel aktivite düzeyini belirgin biçimde azaltmaktadır (McDermott, 2015). Bu durum, PAH hastalarında egzersize uyumun önündeki temel fizyolojik engellerden biri olarak kabul edilmektedir.

Egzersize uyum yalnızca fizyolojik sınırlılıklar ile değil, aynı zamanda psikolojik ve davranışsal faktörlerle de yakından ilişkilidir. Ağrı hissetmekten korkma, hareketten kaçınma davranışı ve egzersizin zararlı olabileceğine dair yanlış inanışlar, PAH hastalarında egzersize başlama ve sürdürme oranlarını olumsuz etkilemektedir (Cunningham et al., 2020). Buna ek olarak, depresyon ve sosyal destek eksikliği gibi psikososyal faktörlerin de egzersiz davranışı üzerinde belirleyici olduğu gösterilmiştir (Treat-Jacobson et al., 2019).

Son yıllarda yapılan çalışmalar, egzersize uyumun çevresel faktörlerden de etkilendiğini ortaya koymaktadır. Ulaşım zorlukları, egzersiz programlarına erişim kısıtlılığı ve sağlık sisteminde yapılandırılmış rehabilitasyon programlarının yetersizliği, PAH hastalarının uzun dönemli egzersiz katılımını sınırlandırmaktadır (Fakhry et al., 2018). Bu bulgular, egzersize uyumun çok boyutlu bir yapı sergilediğini ve yalnızca hastaya değil, sağlık hizmetinin sağlanma biçimine de bağlı olduğunu göstermektedir.

3. PERİFERİK ARTER HASTALIĞINDA EGZERSİZ TEDAVİSİ VE UYUM ÜZERİNDEKİ ETKİLERİ

Egzersiz tedavisi, PAH tedavisinde en yüksek kanıt düzeyine sahip konservatif yaklaşımlardan biri olarak kabul edilmektedir. Özellikle gözetimli egzersiz tedavisi, yürüme mesafesi, ağrısız yürüme süresi ve yaşam kalitesi üzerinde anlamlı iyileşmeler sağlamaktadır (Aboyans et al., 2018). Gözetimli programların, gözetimsiz egzersizlere kıyasla egzersize uyumu artırmasının temel nedenleri arasında düzenli takip, profesyonel geri bildirim ve güvenli egzersiz ortamı yer almaktadır (Hiatt et al., 2015).

Egzersiz sırasında tekrarlayan iskemik uyarılar, periferik dolaşımda adaptif değişiklikleri tetiklemekte ve kas oksijen kullanım kapasitesini artırmaktadır. Bu fizyolojik adaptasyonlar,

zamanla klodikasyon semptomlarının azalmasına ve egzersiz toleransının artmasına katkı sağlamaktadır (Hamburg & Creager, 2017). Ancak bu olumlu etkilerin ortaya çıkabilmesi için egzersiz programlarının yeterli süre ve yoğunlukta uygulanması gerekmektedir; bu da doğrudan egzersize uyum ile ilişkilidir.

Ev temelli ve teknoloji destekli egzersiz programları, son dönemde egzersize erişim sorunlarını azaltmaya yönelik alternatif yaklaşımlar olarak öne çıkmaktadır. Tele-rehabilitasyon, giyilebilir teknolojiler ve uzaktan izlem sistemlerinin, özellikle egzersize katılımı düşük olan hasta gruplarında uyumu artırabileceği bildirilmiştir (Gardner et al., 2020). Bununla birlikte, bu yaklaşımların etkinliği büyük ölçüde hasta eğitimi ve davranışsal destek ile uygulanmasına bağlıdır.

4. FİZYOTERAPİ TEMELLİ YAKLAŞIMLAR

Fizyoterapi, PAH hastalarında egzersize uyumun artırılmasında önemli bir role sahiptir. Fizyoterapistler tarafından planlanan bireyselleştirilmiş egzersiz reçeteleri, hastanın semptom düzeyi, fonksiyonel kapasitesi ve komorbiditeleri dikkate alınarak düzenlenmekte ve bu durum egzersizin sürdürülebilirliğini artırmaktadır (Treat-Jacobson et al., 2019). Özellikle ağrı yönetimi stratejilerinin egzersiz programlarına entegre edilmesi, hastaların egzersiz sırasında yaşadıkları kaygıyı azaltmaktadır. Hasta eğitimi, fizyoterapi temelli yaklaşımların vazgeçilmez bir bileşenidir. PAH'ın patofizyolojisinin, egzersizin güvenliğinin ve uzun vadeli faydalarının hastaya açık bir şekilde anlatılması, egzersize yönelik olumsuz algıların kırılmasına katkı sağlamaktadır (Cunningham et al., 2020).

PAH'lı bireylerde yürüyüş egzersizi, klodikasyon ağrısının yönetilmesi ve fonksiyonel yürüme kapasitesinin artırılmasını amaçlayan temel egzersiz yaklaşımıdır. Egzersiz sırasında ağrı veya nefes darlığı geliştiğinde kısa dinlenme aralarının verilmesi önerilmekte; bu yaklaşım, genellikle 'yürü–dinlen–yürü' prensibine dayalı aralıklı yürüyüş modeli şeklinde uygulanmaktadır (Norgren vd., 2007). Bu model, hastaların ağrı korkusu yaşamadan egzersizi sürdürebilmesine olanak tanıyarak egzersize uyumu desteklemektedir. Yürüyüş sırasında efor düzeyinin Modifiye Borg Skalası'nda orta şiddeti temsil eden 4–5 aralığında tutulması, periferik dolaşımın uyarılması açısından uygun kabul edilmektedir (McDermott, 2017). Egzersiz programına kısa süreli yürüyüşlerle başlanması ve sürenin kademeli olarak artırılması, hem fizyolojik adaptasyonların gelişmesini hem de uzun dönemli egzersiz katılımının korunmasını kolaylaştırmaktadır.

Davranış değişikliği teknikleri, hedef belirleme ve motivasyonel görüşme gibi yöntemlerin kullanılması, egzersize uyumun uzun dönemde korunmasında etkili bulunmuştur (Fakhry et al., 2018). Multidisipliner rehabilitasyon yaklaşımları, fizyoterapinin etkinliğini daha da artırmaktadır. Kardiyolog, fizyoterapist ve psikolog gibi farklı sağlık profesyonellerinin iş birliği ile yürütülen programlar hem fizyolojik hem de psikososyal bariyerlerin eş zamanlı olarak ele alınmasına olanak tanımaktadır (Aboyans et al., 2018). Bu bütüncül yaklaşım, PAH hastalarında egzersize uyumun artırılması ve yaşam kalitesinin iyileştirilmesi açısından güncel klinik uygulamaların temelini oluşturmaktadır.

5. SONUÇ

Periferik arter hastalarında egzersize uyum, yalnızca alt ekstremite dolaşım bozukluğuna bağlı fizyolojik sınırlılıkların değil; ağrı algısı, psikososyal etmenler ve sağlık hizmetlerine erişim gibi çok sayıda faktörün etkileşimiyle şekillenmektedir. Egzersiz tedavisi, özellikle gözetimli programlar aracılığıyla yürüme kapasitesi, fonksiyonel bağımsızlık ve yaşam kalitesini artırmada temel bir tedavi yaklaşımı olmakla birlikte, bu faydaların sürdürülebilmesi egzersize uzun dönemli uyumun sağlanmasına bağlıdır. Bu bağlamda fizyoterapi temelli bireyselleştirilmiş yaklaşımlar, hasta eğitimi, davranışsal destek stratejileri ve multidisipliner rehabilitasyon modelleri egzersize uyumun artırılmasında kritik öneme sahiptir. Güncel kanıtlar doğrultusunda, PAH yönetiminde egzersiz tedavisinin yalnızca bir fiziksel müdahale olarak değil, biyopsikososyal bir süreç olarak ele alınması, klinik sonuçların iyileştirilmesi ve hasta merkezli bakımın güçlendirilmesi açısından gereklidir.

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ALT EKSTREMİTE KAS OKSİJENASYONU VE NON-İNVAZİV DEĞERLENDİRİLMESİ

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ÖZET

Alt ekstremite kas oksijenasyonu, doku perfüzyonu ile metabolik gereksinimler arasındaki dengeyi yansıtan bir fizyolojik parametre olup, vasküler hastalıkların değerlendirilmesinde ve egzersiz fizyolojisinin izlenmesinde temel bir gösterge olarak kabul edilmektedir. Kas dokusundaki oksijenasyon, egzersiz ve günlük yaşam aktivitelerinin sürdürülebilmesi için gerekli kas kontraksiyonları ve kas dokusunun canlılığı açısından önemli bir rol oynamaktadır. Kasın oksijen tüketim kapasitesindeki değişimler; yaşlanma, kardiyovasküler hastalıklar ve spor yaralanmaları gibi klinik durumlarla yakından ilişkilidir ve kas oksijenlenmesinin regülasyonunda meydana gelen patofizyolojik bozulmalar kas kuvveti ve enduransında azalmaya yol açmaktadır. Bu derlemenin amacı, alt ekstremite kas oksijenasyonunun değerlendirilmesinde kullanılan güncel non-invaziv yöntemlere ilişkin bilimsel kanıtları incelemek ve klinik kullanım alanlarını sentezlemektir. Bu kapsamda "Google Scholar, PubMed ve Scopus" veri tabanlarında "muscle oxygenation, near-infrared spectroscopy, lower extremity, non-invasive assessment" anahtar kelimeleri kullanılarak son 10 yıl içinde yayımlanan çalışmalar taranmıştır. İncelemeler sonucunda, özellikle Yakın Kızılötesi Spektroskopi (NIRS) yönteminin doku oksijen satürasyonunu sürekli ve gerçek zamanlı olarak izleme olanağı sunduğu belirlenmiştir. NIRS; invaziv girişim gerektirmemesi, taşınabilirliği ve mikrovasküler fonksiyonu yansıtma kapasitesi ile öne çıkmaktadır. Sonuç olarak, alt ekstremite kas oksijenasyonunun non-invaziv yöntemlerle izlenmesi, doku hipoksisinin erken saptanması ve tedaviye yanıtın objektif olarak değerlendirilmesi açısından önemli katkılar sunmaktadır.

Anahtar Kelimeler: alt ekstremite, kas oksijenasyonu, NIRS, non-invaziv değerlendirme.

1. GİRİŞ

Alt ekstremite kas oksijenasyonu, kas dokusundaki oksijen ile kasın metabolik gereksinimleri arasındaki dinamik dengeyi yansıtan temel bir fizyolojik parametredir (De Blasi et al., 2002). Bu denge, arteriyoller, kapillerler ve venüllerden oluşan mikrovasküler dolaşım ağı aracılığıyla sağlanmakta olup, oksijen ve besin maddelerinin kas dokusuna etkin biçimde taşınmasından sorumludur. Oksijen, eritrositlerde bulunan hemoglobin aracılığıyla taşınmakta, kapiller düzeyde serbestleştirilerek kas liflerindeki mitokondrilere doğru difüze olmaktadır (Hendrickse & Degens, 2019). Bu süreç, kas kasılmasının sürdürülebilmesi ve kas dokusunun metabolik bütünlüğünün korunması açısından kritik öneme sahiptir.

Kasın fonksiyonu, oksijenin pulmoner sistemden başlayarak kas hücresinin mitokondrisine kadar uzanan çok basamaklı bir taşıma zincirinin bütünlüğüne bağlıdır. Bu zincirin herhangi bir basamağında meydana gelen bozulma, kas oksijenlenmesinde azalmaya ve buna bağlı olarak fonksiyonel kapasitede düşüşe yol açabilmektedir (Richardson et al., 2006; Boushel et al., 2003). Bu nedenle kas oksijenasyonu hem dolaşımsal hem de periferik düzeydeki fizyolojik süreçlerin bütüncül bir göstergesi olarak değerlendirilmektedir.

Egzersiz sırasında artan metabolik gereksinimlere yanıt olarak kas dokusuna olan kan akımı belirgin biçimde artmaktadır. Oksijen sunumu; kardiyak debi, bölgesel kan akımı dağılımı ve kapiller-perfüzyon ilişkisi tarafından belirlenirken, oksijen tüketimi esas olarak mitokondriyal oksidatif fosforilasyon kapasitesi ile ilişkilidir (Richardson et al., 2006; Wagner, 2012). Wagner (2012), egzersiz sırasında kas hücresi içi oksijen parsiyel basıncındaki azalmanın yalnızca oksijen yetersizliğini yansıtmadığını, aksine oksijen difüzyon gradyanını artırarak oksijen transportunu optimize eden fizyolojik bir adaptasyon mekanizması olduğunu vurgulamaktadır. Bu bağlamda kas oksijenasyonu, kas dokusuna sağlanan oksijen sunumu ile metabolik oksijen gereksinimi arasındaki dengenin duyarlı bir göstergesi olarak değerlendirilmektedir.

Alt ekstremite kaslarında oksijenlenme yanıtı, istirahatten egzersize geçişte hızlı bir desatürasyon ile karakterizedir. Bu desatürasyonun derecesi; egzersiz şiddeti, kas lif tipi dağılımı ve bireyin aerobik kapasitesi gibi faktörlerden etkilenmektedir (De Blasi et al., 2002; Richardson et al., 2006). Egzersiz yoğunluğunun artmasıyla birlikte kas dokusunda oksijen ekstraksiyonunun anlamlı düzeyde arttığı ve bu artışın, deoksijenli hemoglobin konsantrasyonundaki yükselme ile yansıtıldığı bildirilmektedir (De Blasi et al., 2002). Bu fizyolojik yanıt, kasın oksijen kullanımını artırarak aerobik enerji üretiminin sürdürülebilmesini sağlamaktadır (Wagner, 2012).

Kas oksijenasyonu yalnızca akut egzersiz yanıtlarını değil, aynı zamanda uzun dönemli adaptasyon süreçlerini de yansıtmaktadır. Düzenli ve kronik egzersizle birlikte kapiller yoğunlukta artış, mitokondriyal enzim aktivitesinde yükselme ve oksijen kullanım verimliliğinde gelişme meydana gelmektedir (Boushel et al., 2003). Bu nedenle kas oksijenlenmesi, yalnızca performansın bir göstergesi değil, aynı zamanda iskelet kası adaptasyonlarının temel belirleyicilerinden biri olarak değerlendirilmektedir.

2. EGZERSİZ SIRASINDA KAS OKSİJENASYONU REGÜLASYONU

Egzersiz sırasında kas oksijenasyonunun zamansal değişimi, oksijen sunumu ile oksijen tüketimi arasındaki dengenin doğrudan bir yansımasıdır (Richardson et al., 2006). Egzersizin başlamasıyla birlikte kas metabolik hızı hızla artmakta ve buna paralel olarak oksijen gereksinimi yükselmektedir. Artan iş yükü ile kas oksijen tüketimi belirgin şekilde artarken, oksijen sunumunun bu gereksinimi karşılayamaması durumunda kas oksijen saturasyonunda progresif bir azalma meydana gelmektedir (De Blasi et al., 2002). Bu desatürasyon yanıtı özellikle yüksek şiddetli egzersizlerde daha belirgin hale gelmektedir (Boushel et al., 2003).

İskelet kasının metabolik gereksinimlerinin karşılanması, kardiyovasküler sistem ile kas-iskelet sistemi arasındaki koordineli düzenlemeye bağlıdır. Kas kasılması sırasında oksidatif metabolizmanın sürdürülebilmesi için kas dokusuna yeterli oksijen sunulması gerekmekte olup, bu süreç esas olarak kas kan akımının düzenlenmesi yoluyla sağlanmaktadır. Egzersize bağlı kas kan akımındaki artış, “egzersiz hiperemisi” olarak tanımlanmakta ve mekanik pompa etkisi, metabolik vazodilatörlerin salınımı, oksihemoglobin desatürasyonuna bağlı vazodilatasyon ve endotel kaynaklı nitrik oksit üretimi gibi çok sayıda mekanizmanın eş zamanlı etkisiyle kontrol edilmektedir. Özellikle nitrik oksit, egzersiz sırasında vazodilatasyonun sağlanmasında temel düzenleyici yolaklardan biri olarak kabul edilmektedir. De Blasi ve arkadaşları (2002), artan egzersiz şiddeti ile kas oksijenlenme düzeylerinin belirgin şekilde azaldığını ve bu azalmanın kas yorgunluğunun gelişimi ile yakından ilişkili olduğunu göstermiştir. Benzer biçimde Richardson ve ark. (2006), egzersiz sırasında kas oksijenlenmesindeki değişimlerin yalnızca santral dolaşımsal yanıtları değil, aynı zamanda kas kan akımı ve oksijen difüzyon kapasitesi gibi periferik faktörleri de yansıttığını ortaya koymuştur. Bu bulgular, kas oksijenlenmesinin egzersiz toleransını belirleyen önemli bir fizyolojik gösterge olduğunu desteklemektedir.

Egzersiz sırasında artan oksijen sunumu büyük ölçüde kas kan akımındaki artışla sağlanmakla birlikte, maksimal kan akımına ulaşıldığında ilave iş yükleri kas oksijenlenmesinde ek bir artış sağlamayabilmektedir. Bu durum, kas oksijenasyonunun yalnızca kan akımına değil, aynı zamanda oksijen ekstraksiyon kapasitesine de bağlı olduğunu göstermektedir (Richardson et al., 2006). Egzersiz sonrası iyileşme döneminde ise kas oksijenlenmesi hızla artmakta ve çoğu zaman istirahat düzeylerinin üzerine çıkmaktadır. Bu reoksijenasyon yanıtı, egzersiz sırasında oluşan oksijen borcunun telafi edilmesine yönelik fizyolojik bir mekanizma olarak kabul edilmektedir (Boushel et al., 2003). Reoksijenasyon hızının ve büyüklüğünün aerobik kapasite ve vasküler fonksiyon durumu hakkında önemli bilgiler sunduğu bildirilmektedir (Richardson et al., 2006).

3. NON-İNVAZİV DEĞERLENDİRME

Kas oksijenlenmesinin değerlendirilmesinde kullanılan noninvaziv yöntemler arasında yer alan Yakın Kızılötesi Spektroskopi (Near-Infrared Spectroscopy, NIRS), son yıllarda hem deneysel fizyoloji araştırmalarında hem de klinik uygulamalarda yaygın olarak kullanılan bir ölçüm tekniği haline gelmiştir (Boushel et al., 2003). NIRS, biyolojik dokuların yakın kızılötesi ışık spektrumundaki optik özelliklerinden yararlanarak oksijenlenmiş ve deoksijenlenmiş

hemoglobin konsantrasyonlarındaki değişimleri belirlemeye dayanmaktadır (De Blasi et al., 2002). Bu yöntem sayesinde kas dokusundaki oksijen sunumu, oksijen ekstraksiyonu ve mikrovasküler hemodinamik yanıtlar noninvaziv ve gerçek zamanlı olarak izlenebilmektedir (Richardson et al., 2006).

NIRS sistemleri genellikle 700–900 nm dalga boyu aralığında ışık yaymakta ve bu ışığın doku içerisinden geçerken uğradığı absorpsiyon ve saçılma özelliklerini analiz etmektedir (Boushel et al., 2003). Oksijenli ve deoksijenli hemoglobinin bu dalga boylarında farklı absorbsiyon katsayılarına sahip olması, kas oksijen satürasyonu (SmO_2), total hemoglobin konsantrasyonu ve göreceli kan hacmi gibi parametrelerin hesaplanmasına olanak sağlamaktadır (De Blasi et al., 2002). Bu özellikleriyle NIRS, egzersiz sırasında kas oksijenlenmesindeki dinamik değişimleri kesintisiz olarak izleyebilen önemli bir değerlendirme aracı olarak öne çıkmaktadır (Richardson et al., 2006).

Alt ekstremitede kas oksijenasyonunun non-invaziv değerlendirilmesi, genellikle yüksek metabolik aktiviteye sahip ve periferik vasküler değişimlere hızlı yanıt veren ana kas grupları üzerinden gerçekleştirilir. Ölçümlerde en sık tercih edilen bölgeler, yürüme ve egzersiz fizyolojisinin temelini oluşturan m. vastus lateralis (uyluk dış yan kısım) ve m. gastrocnemius (baldır) kaslarıdır. Uygulama sürecinde, Yakın Kızılötesi Spektroskopi (NIRS) probları, kasın anatomik olarak en belirgin olduğu (genellikle kas gövdesinin orta noktası) bölgeye, kas liflerine paralel olacak şekilde yerleştirilir. Işık sinyalinin dokuya daha iyi nüfuz etmesi ve saçılmanın önlenmesi için ölçüm yapılacak deri bölgesi temizlenmeli, gerekirse kıllardan arındırılmalı ve deri altı yağ dokusu kalınlığı (skinfold) mutlaka kaydedilmelidir; çünkü aşırı yağ dokusu ışığın kas tabakasına ulaşmasını zorlaştırabilir. Ölçüm sırasında denek ya sabit bir pozisyonda (istirahatte bazal değerler için) ya da dinamik bir protokol (koşu bandı, bisiklet ergometresi veya geçici iskemi yaratan manşet testi) eşliğinde takip edilir. Bu süreçte cihaz, oksi-hemoglobin ve deoksi-hemoglobin konsantrasyonlarındaki anlık değişimleri takip ederek, dokunun oksijen sunumu ile tüketimi arasındaki dengeyi yansıtan doku oksijen satürasyonu verisini sürekli olarak sağlar (Ferrari, 2011).

Richardson ve arkadaşları (2006), NIRS ölçümlerinin egzersiz esnasında kas oksijen ekstraksiyonunu ve mikrovasküler oksijenlenmeyi güvenilir biçimde yansıttığını bildirmiştir. Özellikle alt ekstremite kaslarından elde edilen NIRS verilerinin, bölgesel kas kan akımı ve oksijen kullanım kapasitesi ile anlamlı ilişkiler gösterdiği ortaya konmuştur (Richardson et al., 2006). Bu bulgular, NIRS'in periferik kas fizyolojisinin değerlendirilmesinde geçerli ve fizyolojik açıdan anlamlı bilgiler sunduğunu desteklemektedir (Boushel et al., 2003).

Bununla birlikte, NIRS ölçümlerinin yorumlanmasında bazı metodolojik sınırlılıklar da bulunmaktadır. Subkutan yağ dokusu kalınlığı, ölçüm derinliğini ve sinyal kalitesini etkileyerek bireyler arası değişkenliğe neden olabilmektedir (Boushel et al., 2003). Ayrıca NIRS sinyalleri hemoglobin ve miyoglobinin optik özelliklerini birlikte yansıttığından, bu iki bileşenin ayrı ayrı değerlendirilmesi mümkün olmamaktadır (De Blasi et al., 2002). Bu nedenle elde edilen verilerin yorumlanmasında ölçüm yapılan kasın anatomik özellikleri, bireysel

farklılıklar ve uygulanan egzersizin fizyolojik bağlamı mutlaka dikkate alınmalıdır (Richardson et al., 2006).

Teknolojik gelişmelerle birlikte NIRS tabanlı taşınabilir ve giyilebilir ölçüm sistemleri de yaygınlaşmıştır. Bu kapsamda Moxy Monitor ve Train.Red gibi cihazlar, sporcu performansının izlenmesi ve egzersiz sırasında kas oksijenlenmesinin değerlendirilmesi amacıyla sıklıkla kullanılmaktadır. Bu cihazlar, özellikle saha koşullarında ve dinamik egzersizler sırasında kas oksijen satürasyonundaki değişimleri anlık olarak izleme olanağı sunmaktadır. Yapılan çalışmalar, bu tür giyilebilir NIRS sistemlerinin egzersiz şiddeti, yorgunluk gelişimi ve aerobik kapasite göstergeleriyle ilişkili anlamlı veriler sağladığını ortaya koymuştur (Boushel et al., 2003; Richardson et al., 2006). NIRS yönteminin klinik uygulama alanları da giderek genişlemektedir. Egzersiz fizyolojisi alanında, kas oksijenlenme kinetiğinin ve özellikle deoksijenli hemoglobin yanıtlarının değerlendirilmesi, bireyin aerobik kapasitesi ve egzersiz toleransı hakkında önemli bilgiler sunmaktadır (Wagner, 2012). Patofizyolojik durumlarda ise periferik arter hastalığı, kalp yetmezliği ve diyabet gibi vasküler ve kardiyometabolik hastalıklarda kas oksijenlenmesindeki bozulmaların belirlenmesi ve rehabilitasyon sürecinin izlenmesinde NIRS yaygın olarak kullanılmaktadır (Boushel et al., 2003). Ayrıca yoğun bakım ve cerrahi süreçlerde doku perfüzyonunun izlenmesi amacıyla da klinik açıdan değerli bir araç olarak değerlendirilmektedir (De Blasi et al., 2002).

4. SONUÇ

Kas oksijenasyonu, kas kan akımı, oksijen sunumu ve oksijen ekstraksiyonu arasındaki hassas dengeyle düzenlenen çok boyutlu bir fizyolojik süreçtir. Bu sürecin noninvaziv yöntemlerle değerlendirilmesi, özellikle NIRS teknolojisi sayesinde hem araştırma hem de klinik uygulamalarda önemli avantajlar sağlamaktadır (Wagner, 2012). Kas oksijenlenmesinin doğru ve güvenilir biçimde izlenmesi, egzersiz toleransının belirlenmesi, rehabilitasyon programlarının planlanması ve tedavi etkinliğinin değerlendirilmesi açısından kritik öneme sahiptir (Richardson et al., 2006).
İskelet kası oksijenasyonunun değerlendirilmesinde NIRS teknolojisinin gelişimi, kompleks fizyolojik mekanizmaların noninvaziv, sürekli ve uygulanabilir biçimde izlenmesine olanak tanımıştır. Özellikle giyilebilir NIRS sistemlerinin yaygınlaşmasıyla birlikte, kas oksijenlenmesi ölçümlerinin gelecekte fizyoloji araştırmaları, klinik tanı ve rehabilitasyon takibinde standart bir değerlendirme aracı haline gelme potansiyeli taşıdığı düşünülmektedir (Boushel et al., 2003; Wagner, 2012).

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SÜLFATLI SULARA MARUZ BETONLARIN BASINÇ DAYANIMI AÇISINDAN ARAŞTIRILMASI

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ÖZET

Beton iyi mekanik ve dayanım özellikleri, işlenebilirliği ve düşük maliyeti nedeniyle dünyada en yaygın kullanılan yapı malzemesidir.

Bu çalışma kapsamında, yerel kullanılan hazır beton agregaları ile üretilen beton numunelerin su kürleme işleminde MgSO4 Magnezyum Sülfat ve Sodyum Sülfat çözeltisi kullanılmış, beton numunelere sülfat saldırısı üzerinde yapılan basınç dayanım testlerinin sonuçları sunulmaktadır. Mevcut çalışma yerelde kullanılan hazır beton agregalarının sülfatlı su maruziyetinde 28günlük, 90 günlük basınç dayanım testlerinin sonuçları tartışılmıştır.

Referans numunenin 28 gün sonunda çimentonun dayanımı sağladığı, 90 gün sonunda dayanımın arttığı gözlendi. Sodyum Sülfat suyunda kürlenen numunelerin 28 gün sonunda 51 Mpa basınç dayanımında olduğu, 90 gün sonunda 55Mpa basınç dayanımına çıkmıştır. Magnezyum sülfatlı suda kürlenen numunelerde 28 gün sonunda 44Mpa basınç dayanımında olduğu, 90 gün sonunda 49Mpa seviyesinde çıktığı görüldü.

Numunelerin bu kısa süre içinde etkilenmemesi olarak su-çimento oranının yerinde olması, numunenin vibrasyona tabii tutulması, geçirimsiz beton olarak üretilmiş olduğu söylenebilir.

Magnezyum sülfat çözeltisine maruz kalan beton numunelerde beyazımsı bir tuz tabaksı oluştuğunu ve bu beyazımsı tabakanın elde kayganlaştırıcı özelliğe sahip olduğu görüldü.

Geçirimsiz beton ve betonarme elemanların üretilmesinde gereken hassasiyetin gösterilmesi beton ürünlerin yerinde korunması adına önem arz etmektedir.

Anahtar Kelimeler:

Magnezyum Sülfat, Sodyum Sülfat, Beton, Basınç Dayanımı,

INVESTİGATİON OF THE COMPRESSİVE STRENGTH OF CONCRETE EXPOSED TO SULFATE-CONTAİNİNG WATERS

ABSTRACT

Concrete is the most widely used construction material in the world due to its good mechanical and strength properties, workability, and low cost.

Within the scope of this study, MgSO4 Magnesium Sulfate and Sodium Sulfate solutions were used in the water curing process of concrete samples produced with locally used ready-mix concrete aggregates, and the results of the compressive strength tests performed on the sulfate attack on the concrete samples are presented. The current study discusses the results of 28-day and 90-day compressive strength tests on locally used ready-mix concrete aggregates exposed to sulfate water.

It was observed that the reference sample achieved the strength of the cement at the end of 28 days, and the strength increased at the end of 90 days. The samples cured in sodium sulfate water had a compressive strength of 51 MPa at the end of 28 days and reached a compressive strength of 55 MPa at the end of 90 days. The specimens cured in magnesium sulfate water had a compressive strength of 44 MPa at 28 days and increased to 49 MPa at 90 days.

The specimens were not affected in this short period of time, which can be attributed to the appropriate water-cement ratio, the specimen being subjected to vibration, and it being produced as impermeable concrete.

It was observed that a whitish salt layer formed on concrete samples exposed to magnesium sulfate solution and that this whitish layer had a lubricating effect.

Demonstrating the necessary precision in the production of impermeable concrete and reinforced concrete elements is important for the proper preservation of concrete products.

Keywords:

Magnesium Sulfate, Sodium Sulfate, Concrete, Compressive Strength

1.GİRİŞ:

Beton iyi mekanik ve dayanım özellikleri, işlenebilirliği ve düşük maliyeti nedeniyle dünyada en yaygın kullanılan yapı malzemesidir.

Günümüzde dünyanın her bir yanında araştırmacılar beton kalitesi üzerine odaklanıp, her türlü maruziyete dayanabilen beton üretimini araştırmaktadırlar.

Standart portland çimentosu dünya genelinde önem arz eden inşaat malzemesidir. Çimentonun üretilen beton kalitesinin oluşmasında katkısı bulunmaktadır.

Biczoc (1972): Sülfat atak mekanizmasının ayrıntılı incelemelerini yürütmüştür. Sülfat atağının, sülfat konsantrasyonundaki artışla birlikte korozyona neden olduğunu belirtmektedir.

Mehta ve Haynes (1978), Los Angeles'ta altı farklı çimento ve her biri üç farklı beton karışımıyla yapılmış, deniz suyuna kısmen batırılmış 67 yıllık düz bir beton bloğun davranışını bildirmiştir. Yoğun betonlar mükemmel durumdaydı, ancak zayıf betonda malzeme kaybı görüldü ve yumuşak ve zayıftı. Bir dizi pratik örnek ve uzun vadeli araştırmanın sonuçları, yüksek fırın çimentolarının açık deniz inşaatlarında başarılı bir şekilde kullanıldığını göstermektedir. Hollanda'daki fırtına dalga bariyeri, yüksek fırın çimentosu kullanılarak inşa edilmiştir. 200 yıllık beklenen hizmet ömrü, yüksek fırın çimentosu ile dayanıklı betona duyulan güvenin etkileyici bir göstergesidir.

Yıldırım K, Sümer M yaptıkları bu çalışmada, NaCl ve MgSO4 çözeltilerinin uçucu küllü ve uçucu külsüz harçların mekanik ve fiziksel özellikleri üzerindeki etkisi üzerine yürütülmüştür. Deneyler, standart harçlar ve %20-50 ikame oranında uçucu kül içeren harçlar üzerinde gerçekleştirilmiştir. Sınıf F Çayırhan, uçucu kül ve CEM I 42,5 N çimento kullanılmıştır. Harçların NaCl ve MgSO4'e maruz bırakılması, 28 günlük standart su küründen sonra başlatılmıştır. Eğilme dayanımı, basınç dayanımı, birim ağırlık, hacimsel su emilimi, kılcal su emilimi, rezonans frekansı ve ultrason hızı için 28, 56 ve 90. günlerde testler yapılmıştır. Her seriden 40 160 mm boyutlarında dokuz numune, aynı 40.000 mg/l konsantrasyonlarda NaCl ve MgSO4 içinde tutulmuştur. Tahribatlı ve tahribatsız testler sonucunda, NaCl çözeltisinde saklanan numunelerin, MgSO4 çözeltisinde saklanan numunelere göre daha düşük basınç ve eğilme dayanımına sahip olduğu görülmüştür. NaCl çözeltisi, numunelere MgSO4 çözeltisinden daha fazla zarar vermiştir.

Al-Amoudi: Sade çimento ve silika dumanından yapılmış harç numunelerinin Na2SO4'e daldırılmasıyla 460 günden fazla dayanımın %9 arttığı görülmüştür.

Koral S, Yüzer N. Vd. (1995) Sodyum sülfat konsantrasyonunun harçların sülfat direncine olan etkisi araştırılmıştır. RILEM portland çimentosu standart harçları ve portland çimentosu-silika dumanı harçları üzerinde deneyler yapılmıştır. Harçların sülfata maruz bırakılması, 28 günlük kireçle doymuş su kürlenmesinden sonra başlatılmıştır. Bazı fiziksel ve mekanik özellikler 300 güne kadar periyodik olarak belirlenmiştir. 18000 mg/L'yi aşmayan düşük sodyum sülfat konsantrasyonları, harçların basınç ve eğilme dayanımı üzerinde önemli bir etkiye sahip olmamıştır. Ancak 18000 mg/L konsantrasyonunda bazı özellikler, yani hacim yoğunluğu, hacimsel su emilimi, kritik zaman denebilecek bir maruz kalma süresinde harç yapısının hızlı bir şekilde bozulmaya başladığını göstermiştir. 72000 mg/L konsantrasyonu, hem basınç hem de eğilme dayanımları için 90 ila 180 gün arasında keskin bir dayanım azalmasına neden olmuştur. Silika dumanı ikamesi, en yüksek sülfat konsantrasyonunda bile harcın sülfat direncinde önemli bir artışa neden olmuştur.

Yıldırım K, Sümer M.(2013) yaptıkları bu çalışmada, NaCl ve MgSO4 çözeltilerinin uçucu küllü ve uçucu külsüz harçların mekanik ve fiziksel özellikleri üzerindeki etkisi üzerine yürütülmüştür. Deneyler, standart harçlar ve %20-50 ikame oranında uçucu kül içeren harçlar üzerinde gerçekleştirilmiştir. Sınıf F Çayırhan, uçucu kül ve CEM I 42,5 N çimento kullanılmıştır. Harçların NaCl ve MgSO4'e maruz bırakılması, 28 günlük standart su küründen sonra başlatılmıştır. Eğilme dayanımı, basınç dayanımı, birim ağırlık, hacimsel su emilimi, kılcal su emilimi, rezonans frekansı ve ultrason hızı için 28, 56 ve 90. günlerde testler yapılmıştır. Her seriden 40 160 mm boyutlarında dokuz numune, aynı 40.000 mg/l konsantrasyonlarda NaCl ve MgSO4 içinde tutulmuştur. Tahribatlı ve tahribatsız testler sonucunda, NaCl çözeltisinde saklanan numunelerin, MgSO4 çözeltisinde saklanan numunelere göre daha düşük basınç ve eğilme dayanımına sahip olduğu görülmüştür. NaCl çözeltisi, numunelere MgSO4 çözeltisinden daha fazla zarar vermiştir.

Akyüncü ve Sümer, çalışmalarında magnezyum sülfat etkisine maruz kalan elementlerde en fazla bozulmanın saf karışım kontrol numunelerinde görüldüğünü gözlemlemişlerdir. Magnezyum sülfat çözeltisine maruz kalan elementlerde beyazımsı bir tabaka oluştuğunu ve bu beyazımsı tabakanın yumuşayarak çamurlu bir yapıya dönüştüğünü tespit etmişlerdir. Katkı maddesi olarak kullandıkları F sınıfı ve C sınıfı uçucu kül numunelerinde, F sınıfı uçucu kül betonunda bozulmanın azaldığını bulmuşlardır.

Dandan S, vd. (2019) Yaptıkları bu çalışmada, beton malzemelerin dış sülfat etkisi altındaki zamana bağlı elastik deformasyon davranışını tahmin etmek için entegre bir hesaplamalı model geliştirmiştir. İyonların reaktif taşınım süreci, gözenek boyutuna bağlı difüzyon katsayısı ve beton gözenekleri içinde etrenjit oluşumunun neden olduğu iç gerilim gelişimi modelde dikkate alınmıştır. Model tahminlerini doğrulamak için farklı sülfat iyonu konsantrasyonları altında numunelerin boylamasına genleşmesi deneyleri gerçekleştirilmiştir. Sonuçlar, modelin tek bir model parametresi seti kullanarak betonun deneysel olarak gözlemlenen elastik deformasyon davranışını yeniden üretebildiğini ve etrenjit tarafından oluşturulan basınç ile etrenjit konsantrasyonu arasındaki ilişkinin Hill Fonksiyonu ile tanımlanabileceğini göstermektedir. Bu, etrenjit oluşumuyla oluşan iç gerilimin başlangıçta nispeten yavaş bir oranda arttığını, konsantrasyonunun izin verilen maksimum cEtt_max konsantrasyonunun %20'sine ulaştığını ve bu noktada iç genleşme geriliminde önemli bir artışın tetiklendiğini ve son olarak etrenjit konsantrasyonu cEtt_max'ın %50'sinin üzerine çıktığında iç gerilimdeki değişimin kademeli olarak kararlı bir durumda kaldığını göstermektedir. Ayrıca, reaksiyon ürününün birikmesinin etkisi altında, sülfat iyonu difüzyon katsayısının zamanla azaldığını ve nispeten yüksek bir sülfat konsantrasyonunun betonun elastik sınırlarına ulaşması için gereken süreyi azalttığını göstermektedir.

Sülfat iyonları klorür iyonlarına kıyasla çok az olduğundan, sülfat zamanla beton malzemelerle reaksiyona girecek ve sülfürik asit adı verilen zayıf bir aside dönüşecektir. Sülfat, içindeki çimentoyu bozamaz, ancak numunenin yüzeyindeki aşınma direnci, deniz suyuna çok uzun süre maruz kalması durumunda etkilenebilir. Khatib ve Wild (1998),

Bu çalışma kapsamında, yerel kullanılan hazır beton agregaları ile üretilen beton numunelerin su kürleme işleminde MgSO4 Magnezyum Sülfat ve Sodyum Sülfat çözeltisi kullanılmış,

beton numunelere sülfat saldırısı üzerinde yapılan basınç dayanım testleri yapılmıştır. Mevcut çalışma yerelde kullanılan hazır beton agregalarının sülfatlı su maruziyetinde 28günlük, 90 günlük basınç dayanım testlerinin sonuçları tartışılmaktadır.

2. DENEYSEL ÇALIŞMA

Deneysel çalışma betonlarda basınç dayanımı ile kürleme de sülfat direncinin beton numuneler üzerindeki etkisini incelemektedir. Betonun ana bileşenleri, hazır beton tesisinden alınan Agrega (0-6mm Kırma Kum ve 6-13mm 1 numara Mıcır), Çimento ve Sudur. Başka herhangi bir ilave malzeme katılmamıştır.

2.1. MALZEMELER

2.1.1. Agrega: Bölgede Faaliyet gösteren hazır beton tesisinden alınan agrega Agrega (0-6mm Kırma Kum ve 6-13mm 1 numara Mıcır), olup özgül ağırlığı 2,71gr/cm3 bulunmuştur.

2.1.2. Magnezyum Sülfat ve Sodyum Sülfat:

Magnezyum Sülfat ve Sodyum Sülfat Alkim Konya tesislerinden elde edilmiştir.

Magnezyum Sülfat kimyasal formülü $MgSO_4$ olup özellikleri tablo 1'de verilmiştir. Magnezyum sülfat kimyasal formülü $MgSO_4$ olan, magnezyum, kükürt ve oksijen ihtiva eden bir inorganik tuz. Genellikle heptahidrat formunda sülfat minerali olan Epsomit ya da diğer adıyla Epsom tuzu halinde bulunur.

Sodyum Sülfat kimyasal formülü Na_2SO_4 olup özellikleri tablo 1'de verilmiştir. Sodyum sülfat, sülfürik asitin sodyum tuzudur. Susuz halde tenardit minerali olarak bilinen ve formülü Na_2SO_4 olan katı, beyaz ve kristal halinde bulunur. Dekahidrat halinde mirabilit minerali olarak bilinen doğal formunda bulunur.

Çizelge 1. Magnezyum Sülfat ve Sodyum Sülfata ait Kimyasal Analiz Değerleri

$MgSO_4$ Analiz Sonuçları		Na_2SO_4 Analiz Sonuçları	
	Analiz Sonucu		Analiz Sonucu
% Kızdırma Kaybı	34,95	Renk Görünüm	BEYAZ Akışkan
%Cl	0,53	Yığın Yoğunluğu	1,445
Ph (%5'lik çözelti)	8,66	Ph (%1'lik Solüsyon)	8,53
% Suda Çözünmeyen	0,072	Na_2SO_4	99,36
MgO %	18,95	Nem	0,095
		Suda Çözünmeyen Madde %	0,022
		NaCl	0,259

		Ca^{+2}	0,235
		Mg^{+2}	0,026
		Fe toplam	Eser <10ppm

2.1.3. Çimento:

ASR deneylerinde kullanılan CEM I 42,5 R tipi çimentonun kimyasal analiz sonuçları Tablo 2'de sunulmaktadır.

Çizelge 2. Çimentoya ait Kimyasal analiz değerleri

		CEM I 42,5 R (12/03/2025)
H_2O	%	0,22
Serbest Kireç	%	2,21
Kızdırma Kaybı	%	3,60
CaO	%	62,22
SiO_2	%	19,09
Al_2O_3	%	4,74
Fe_2O_3	%	3,20
MgO	%	2,93
SO_3	%	3,03
Na_2O	%	0,38
K_2O	%	0,67
Na_2O Eşdeğer	Hsp.	0,82
Cl-	%	0,0219
32 Mikron	%	10,00
45 Mikron	%	------
90 Mikron	%	0,60
Özgül Ağırlık		3,12
Blaine (cm^2/gr)		3667

2.1.4. Numune gruplarının hazırlığı

Karıştırma işleminin ardından taze betonda slamp deneyi yapıldı. Numuneler 10*10*10cm numunelerde vibrate edilerek üretildi. Çıkan numuneler 3 grupta kürlemeye tabii tutuldu.

1 grup beton numuneler sadece suda, 2. Grup beton numuneler 20 litre suya 1,5 kg Sodyum sülfat karışımlı suda, 3. Grup beton numuneler 20 litre suya 1,5 kg magnezyum sülfat karışımlı suda kürlenmek üzere konuldu.

Numune fotoğrafında 2. Grup beton numuneleri 3 numaralı beton numuneleri olarak, 3. Grup beton numuneleri 5 numaralı beton numuneleri olarak kür havuzunda konulmuştur.

Çizelge 3. Beton Karışım Hesabı Döküman Tablosu

Beton karışım hesabı m3/kg	
S/C: 0,50	0,50
Su	225,00 Litre
Cement	450 kg.
Çimento Özgül Ağırlık	3,12 gr/cm3
Kırma Kum	%45 745,000 kg.
1 No Mıcır	%55 910,000kg.
TOPLAM	2.330,00 kg.



Görsel 1. Deneysel Çalışma Fotoğrafları

3. BULGULAR VE TARTIŞMA

Birinci Grup referans numune, 2. Grup Sodyum Sülfatlı suda bekletilmiş numuneler, 3. Grup Magnezyum Sülfatlı suda kürlenmiş beton numuneler üzerinde her gruptan üçer numune alınarak 28 gün ve 90 gün basınç dayanımları test edilerek bulundu.



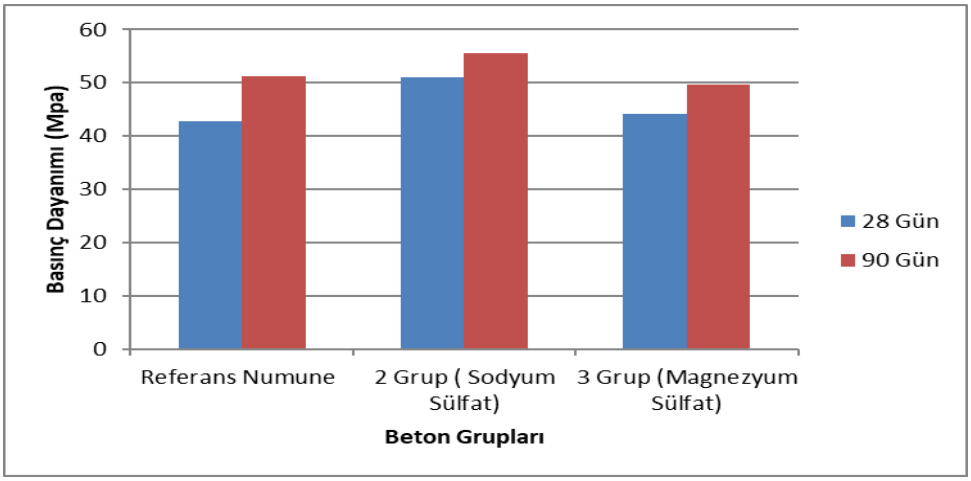
Görsel 2. Beton Numuneleri 22 gün Basınç Dayanım Görüntüleri



Görsel 3. Beton Numuneleri 90 gün Basınç Dayanım Görüntüleri

Çizelge 4. Beton Numuneleri 28 ve 90 gün Basınç Dayanım Sonuçları Değerleri

	28 Gün Mpa	90 Gün Mpa
Referans Numune	42,87	51,3
2 Grup (Sodyum Sülfat)	51,11	55,6
3 Grup (Magnezyum Sülfat)	44,1	49,67



Görsel 4. Beton Numuneleri 28 ve 90 gün Basınç Dayanım Sonuçları Değerleri Grafiği

Referans numunede 28 günlük dayanım çimento dayanımını yakaladığı, 90 gün sonunda ise 51,3Mpa dayanım ile sertleşmenin arttığını görüldü.

Sodyum ve Magnezyum sülfatlı su içinde kürlenen beton numunelerin basınç dayanımının 28 gün ve 90 gün sonunda artmaya devam ettiği bunun nedeni olarak beton numuneler üzerinde oluşan tuz kaplamasının sülfatlı suyun betona zararının başlamadığı yönünde gözlemlenmiştir.

28 gün sonunda dayanım için alınan numuneler üzerinde tuz oluşum başlangıcı görülmüştür.

90 gün sonunda dayanım için alınan numuneler üzerinde mineral tuz oluşumu görüldü. Tuz oluşumu belki de sülfatlı suyun betona zarar vermesini geciktirdiği şeklinde yorumlanabilir.

4. SONUÇLAR

Beton ürünlerin bulunduğu ortam yatağında kimyasal ataklara maruziyeti kaçınılmazdır. Betonun bu maruziyetlerden korunması adına araştırmaların devam ettiği, bu çalışma numunelerin basınç dayanımının 28 gün ve 90 günlük basınç dayanımları tespit edildi.

Referans numunenin 28 gün sonunda çimentonun dayanımı sağladığı, 90 gün sonunda dayanımın arttığı gözlendi. Sodyum Sülfat suyunda kürlenen numunelerin 28 gün sonunda 51 Mpa basınç dayanımında olduğu, 90 gün sonunda 55Mpa basınç dayanımına çıkmıştır.

Magnezyum sülfatlı suda kürlenen numunelerde 28 gün sonunda 44Mpa basınç dayanımında olduğu, 90 gün sonunda 49Mpa seviyesinde çıktığı görüldü.

Numunelerin bu kısa süre içinde etkilenmemesi olarak su-çimento oranının yerinde olması, numunenin vibrasyona tabii tutulması, geçirimsiz beton olarak üretilmiş olduğu söylenebilir.

Magnezyum sülfat çözeltisine maruz kalan beton numunelerde beyazımsı bir tuz tabaksı oluştuğunu ve bu beyazımsı tabakanın elde kayganlaştırıcı özelliğe sahip olduğu görüldü.

Su-çimento oranı düşük üretilen numunelerde etkileşimin nasıl olacağı araştırmalarımızın devamını oluşturacaktır.

Geçirimsiz beton ve betonarme elemanların üretilmesinde gereken hassasiyetin gösterilmesi beton ürünlerin yerinde korunması adına önem arz etmektedir.

Teşekkür

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INFLUENCE OF RED MUD INCORPORATION ON THE SELF-CLEANING PERFORMANCE OF GYPSUM–LIME–SILICA FUME TERNARY BLENDED CEMENTLESS MORTARS

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ABSTRACT

This study investigates the development of a sustainable, cement-free self-cleaning mortar by utilizing industrial byproducts such as red mud. The aim is to reduce the environmental impact associated with traditional cement production and to enhance urban air quality through the incorporation of advanced photocatalytic materials. The concrete formulation is designed to provide superior mechanical properties and effective pollution degradation capabilities. Environmental sustainability in the construction industry is a pressing concern due to the high carbon emissions from Portland cement production. This study explores alternative materials to create a cementless mortar that not only addresses environmental issues but also offers enhanced functionality, such as self-cleaning and pollution reduction. In this research, we developed a cementless mortar mix incorporating red mud and other materials like gypsum, lime, silica fume, sand, water, and PVA fibers. The mortar was subjected to various tests, including compressive strength, splitting tensile strength, water absorption, unit volume weight,

flowability, and photocatalytic activity. The results demonstrated that the mortar with higher red mud content exhibited improved mechanical strengths, reduced water absorption, and enhanced self-cleaning properties due to the photocatalytic degradation of pollutants.

Keywords: Ternary blended mortar, red mud utilization, waste recycling, photocatalysis, sustainable construction.

1. INTRODUCTION

The construction industry plays a pivotal role in the development of infrastructure worldwide, but it also significantly contributes to environmental degradation. One of the primary materials used in construction, Portland cement, is responsible for approximately 5-10% of global CO_2 emissions [1–3]. These emissions arise from both the chemical processes involved in cement production and the energy consumed during manufacturing. The urgent need for sustainable construction materials has led researchers and engineers to explore alternatives that reduce the industry's carbon footprint while maintaining or enhancing the functional properties of traditional materials.

Cementless construction material production emerges as a promising solution to the environmental issues posed by traditional construction material. This type of materials does not rely on Portland cement as a binder; instead, it utilizes alternative materials such as geopolymers, fly ash, and slag) [4–6]. These materials are not only abundant and often considered waste by-products but also exhibit properties that can match or exceed those of conventional concrete in terms of strength and durability. Moreover, the production of cementless concrete significantly reduces CO_2 emissions, presenting a dual benefit of waste reduction and environmental protection.

Another method frequently encountered in the literature to reduce cement usage is the ternary and quaternary binder systems. The number of these studies based on the procedure of simultaneous replacement of two or three different types of pozzolans with cement has been increasing in the literature in recent years. Hassan and Ibrahim [7] examined the effects of replacing up to 70% of Portland cement with supplementary cementitious materials (SCMs) in high-strength flowable concrete (HSFC). Their investigation, which involved testing 16 mixes under both normal and elevated temperature conditions, revealed that HSFC incorporating high SCM contents performed comparably to—or even better than—concrete cured under standard conditions, including those exposed to hot climates. Dave et al. [8] developed quaternary binder and mortar systems in which 30–50% of Portland cement was partially substituted with various SCMs (FA, SF, GGBS, MK, LP). Experimental results on binder and mortar mixes indicated that quaternary systems, particularly those containing GGBS and MK, achieved higher compressive strength and superior permeability performance compared to lime-based mixtures, demonstrating their suitability for industrial applications. In a related study, Dave et al. [9] evaluated quaternary binders containing 30–50% SCMs (FA, GGBS, MK, SF) while keeping the water-to-binder ratio and binder content constant. Mechanical and durability tests showed that certain quaternary mixtures outperformed both control and binary concretes, offering enhanced strength, improved durability, and greater sustainability relative to 100% OPC mixes.

Zhang et al. [10] designed a quaternary binder comprising GGBS, red mud, steel slag, and flue gas desulfurization gypsum, aiming to recycle various solid wastes. Experimental findings and artificial neural network (ANN) predictions demonstrated synergistic interactions among the components. Some additives enhanced hydration and compressive strength, and a genetic algorithm successfully identified the optimal binder composition. Golewski [11] investigated plain concretes incorporating a quaternary binder composed of FA, SF, and nanosilica, with a focus on nanotechnology applications. The results showed that the quaternary concrete exhibited high mechanical performance, a well-developed microstructure, and significantly lower CO_2 emissions, making it a sustainable and effective alternative to conventional OPC concrete. Vignesh and Rahim [12] developed a high-strength quaternary binder incorporating 30–40% GGBS, 5–15% MK, and 5% lime powder to mitigate cement-related CO_2 emissions. Compressive strength and microstructural analyses showed that the mix with the highest GGBS content achieved 54.13 MPa at 28 days. Han et al. [13] explored the optimal design of quaternary cement pastes composed of cement, limestone, clay, and slag. Their findings revealed that increasing the proportions of limestone, clay, and slag reduced compressive strength, enhanced electrical resistivity, and lowered material cost. The proposed optimization method proved effective in balancing these factors for the development of sustainable structural materials. Shetty et al. [14] evaluated a high-strength quaternary binder system containing CSSP, FFA, GGBS, and OPC. Among six mixtures, the optimum M2 composition (10% CSSP, 20% GGBS) reached 48.5 MPa at 90 days, exhibited minimal strength and mass losses under aggressive environments, and reduced CO_2 emissions and cost by 68.58% and 22.78%, respectively—indicating its potential as a sustainable and economical alternative to OPC.

A review of the literature on building materials with ternary and quaternary binder systems reveals the use of cement in the production of these materials. This limits the environmental concerns of these products. On the contrary, in this study, cement was completely omitted from the ternary binder system mortars produced.

Red mud, a byproduct of the aluminum refining process, has been identified as a potential mineral admixture to enhance the physical and mechanical properties of cementitious materials [15]. Rich in iron oxide and other minerals, red mud has shown promise in photocatalytic applications, where it helps degrade organic pollutants on materials surfaces when exposed to sunlight. The incorporation of red mud not only helps in recycling a hazardous waste material but also improves the ecological footprint of the resulting building materials products. Moreira et al. [16] investigated the use of Nb_2O_5 and red mud as photocatalytic additives in Portland cement mortars, characterizing the modified materials through UV–vis DRS, FTIR-ATR, thermogravimetry, SEM, and photocatalytic tests. Their findings showed that both additives were well-dispersed within the mortar matrix, altered its bandgap, and enabled photocatalytic degradation of methylene blue under UV irradiation. Among the studied mixtures, the RM-containing mortar exhibited the highest photocatalytic efficiency, while Nb_2O_5 showed reduced activity when incorporated into the mortar, demonstrating the potential of RM-modified cementitious materials for self-cleaning applications. Cui et al. investigated the use of red mud—an environmentally challenging byproduct of bauxite processing—combined with steel slag, fly ash, and phosphogypsum to develop a low-carbon quaternary cementitious material. Through XRD, TGA, FTIR, MIP, and SEM–EDS analyses, along with ANN and genetic

algorithm–based optimization, they identified synergistic hydration mechanisms that enhanced gel formation and microstructural density. The quaternary binder outperformed traditional binary and ternary systems in compressive strength, achieving up to 21.4 MPa, and demonstrated improved environmental performance by effectively immobilizing Na^+ and reducing non-renewable resource and energy consumption by over 80%. The study highlights the potential of quaternary binders as a sustainable solution for red mud utilization and green construction materials. Kaya-Özkiper et al. [17] investigated red mud- and metakaolin-based geopolymers for methylene blue adsorption and photocatalytic degradation, demonstrating their potential as self-cleaning construction materials. The geopolymers showed compressive strengths of 37.7–43.2 MPa and functioned as both adsorbents and photocatalysts, even without anatase. Increasing anatase content further enhanced photocatalytic performance, with 3.7 wt% anatase yielding a degradation rate over three times higher than pure anatase. These results highlight the feasibility of valorizing red mud in sustainable, mechanically robust building materials.

Based on the results of an extensive literature review, it was determined that the number of studies on cementless binder systems for ternary and quaternary binder construction materials is insufficient. Furthermore, it has been observed that red mud is an effective additive in construction materials due to its self-cleaning properties. Therefore, in this study, a ternary binder system was designed for the production of mortars using gypsum, lime, and silica fume without using cement. Red mud was used in certain proportions to impart self-cleaning properties to these mortars. The physical, mechanical, and self-cleaning properties of these mortars were experimentally investigated in this study, and the results are discussed.

2. MATERIALS AND METHODS

2.1. Materials

In this study, blast furnace slag and mill scale were evaluated as waste-based components in the design of a ternary binder system. In other words, two different triple binder combinations were produced by incorporating gypsum, lime, and silica fume with blast furnace slag in one mixture, and with mill scale in another, each prepared in specific proportions.

Gypsum (Figure 1) is a commonly utilized mineral in the construction sector, consisting of calcium sulfate hemihydrate ($CaSO_4 \cdot 1/2H_2O$). It is distinguished by characteristics such as rapid setting, good workability, and high fire resistance. Gypsum is widely applied in interior wall and ceiling coatings, as an additive in cementitious materials, and in architectural or decorative components. Moreover, it contributes to sustainability through its low energy demand during production and its recyclability. Nonetheless, its susceptibility to moisture and limitations in mechanical strength require careful consideration. In this study, gypsum was incorporated to ensure that the mortar hardened within an appropriate timeframe and achieved a stable, solid structure.

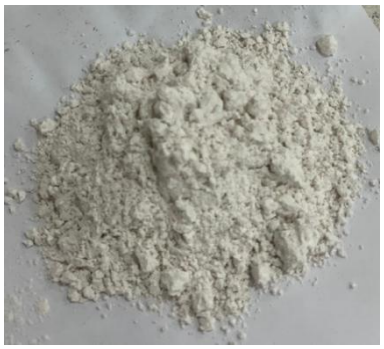


Figure 1. Gypsum

CL90 lime (Figure 2) is a widely used lime type in construction and various industrial fields. Also referred to as high-calcium lime or Type S lime, it is distinguished by its high calcium oxide content—typically above 90%—and its low level of impurities. Owing to its excellent plasticity and workability, it is suitable for applications such as mortar production, soil stabilization, and chemical processes. In the construction sector, CL90 lime is commonly incorporated into masonry mortars, plaster layers, and as a binder in traditional lime-based coatings and renders. Its use enhances the workability and durability of mortars and contributes positively to the performance of lime-based materials, particularly in heritage restoration and conservation works. Overall, CL90 lime is a versatile and valuable material that provides advantages such as improved plasticity, workability, durability, and hydraulic behavior, making it integral to both traditional and modern construction practices. In this study, lime was included to react with the pozzolanic components in the ternary binder system and to promote the initiation of the pozzolanic reaction.

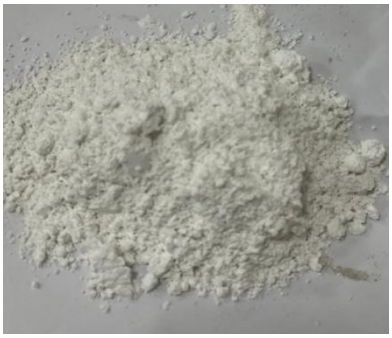


Figure 2. CL-90 Lime

In this study, the final component of the ternary binder system is silica fume (Figure 3). Silica fume is widely utilized as a supplementary cementitious material (SCM) in high-performance concrete, especially in applications that require enhanced strength, improved durability, and resistance to aggressive environmental conditions. Typical areas of use include bridge decks, marine structures, high-rise buildings, and industrial flooring. Its incorporation supports the production of high-performance and sustainable concrete mixtures, meeting the increasing performance requirements of contemporary construction practices.



Figure 3. Silica Fume

Red mud, a byproduct of the aluminum refining process, has been identified as a potential mineral admixture to enhance the physical and mechanical properties of cementitious materials [15]. Rich in iron oxide and other minerals, red mud has shown promise in photocatalytic applications, where it helps degrade organic pollutants on materials surfaces when exposed to sunlight. In this study, red mud was used to react with lime to produce a pozzolanic effect and to add self-cleaning properties to the mortar.



Figure 4. Red Mud

In this study, PVA fiber was employed as the reinforcing material. Polyvinyl alcohol (PVA) fiber (Figure 5) is a synthetic fiber known for its high tensile strength, elevated modulus, and strong resistance to chemical attack, which allows it to be used across a wide range of industrial applications. Its remarkable tensile properties make it particularly suitable for reinforcing cementitious materials such as concrete, while its chemical durability enables reliable performance in environments with varying chemical exposure. Additionally, its water-soluble nature offers advantages in applications requiring temporary support structures, such as water-soluble films or binders in specialized concrete formulations.



Figure 5. PVA Fibers

Crushed quartz sand (0/2 mm) was used in the mortars as the aggregate. Specific gravity of the crushed sand is 2.61. The image of the sand is given in the Figure 6.



Figure 6. Sand

The oxide composition of the materials used in the study determined by XRF analysis is given in Table 1.

Table 1. Chemical composition of gypsum, lime, silica fume, mill scale and blast furnace slag.

	Gypsum (%)	Lime (%)	SF (%)	RM (%)	Sand (%)
SiO_2	2.81	2.58	95.12	14.41	98.32
Al_2O_3	0.67	0.35	0.24	26.39	0.33
Fe_2O_3	0.41	0.24	0.35	30.22	0.24
MgO	2.57	1.76	0.37	0.40	0.01
CaO	31.2	71.08	0.27	3.10	0.02
Na_2O	0.01	0.01	0.26	5.94	0.47
K_2O	0.11	0.02	0.54	0.20	0.20
SO_3	40.3	0.05	0.29	-	-
TiO_2	-	-	-	5.98	-
LOI	21.94	23.87	2.53	11.21	0.40

2.2. Methods

In this study, the mixture design shown below in Table 2 has been used.

Table 2. Mixture design

	Gypsum (g)	Lime (g)	SF (g)	Sand (g)	PVA Fiber (g)	RM (g)	Water (g)
R	250	125	62.5	750	2.5	0	450
RM1	250	125	56.25	750	2.5	6.25	450

RM2	250	125	50.00	750	2.5	12.50	450
RM3	250	125	43.75	750	2.5	18.75	450
RM4	250	125	37.50	750	2.5	25.00	450
RM5	250	125	31.25	750	2.5	31.25	450

In this study, a total of six mortar mixtures were produced, consisting of a reference mix (R) and one additional series in which silica fume (SF) was partially substituted with red mud (RM). The reference mixture was composed of 250 g of gypsum, 125 g of lime, 62.5 g of SF, 750 g of sand, 2.5 g of PVA fiber, and 450 g of water, without any RM content. In the RM series, SF was incrementally replaced by RM at five levels, which are 6.25 g, 12.50 g, 18.75 g, 25.00 g, and 31.25 g, while the remaining SF content was adjusted accordingly. The quantities of gypsum, lime, sand, PVA fiber, and water were kept constant, and no RM was added. This mix design allowed for the evaluation of the influence of substituting SF with RM on both the fresh, hardened and self-cleaning characteristics of ternary binder mortars.

The mortars prepared with these proportions were cast into cylindrical molds measuring 50 mm in diameter and 50 mm in height. After 24 hours, the specimens were demolded and subsequently cured in water at 20 ± 1 °C until the testing age. The production stages of mortars are shown in Figure 7.



Figure 7. Production of the Mortars

Fresh and hardened unit weights of the mortars were determined in accordance with TS EN 1015-6 [18] and TS EN 1015-10 [19], respectively. The flowability of fresh mortars was measured using a flow table apparatus following TS EN 1015-3 [20]. Water absorption testing was performed in line with ASTM C642-13 [21]. Compressive strength measurements were conducted according to ASTM C39 [22], and splitting tensile strengths were assessed based on ASTM C496 [23].

The evaluation of the self-cleaning performance of the ternary blended mortar specimens containing red mud was carried out by tracking the discoloration and degradation of a model organic dye, methylene blue (MB), using a spectrophotometer (Shimadzu UV-1240 UV–vis spectrophotometer). For this purpose, composite samples with dimensions of 5 × 5 × 5 mm were first immersed in beakers filled with 30 ml of 10^{-5} M aqueous MB solution. During the photocatalytic experiments, UV-A (Philips PL-L 36 W UVA) and UV-B (Philips PL-L 36 W UVB) lamps positioned 20 cm above the specimens served as irradiation sources. A separate

MB solution without any composite specimen was also prepared to monitor dye degradation in the absence of a catalyst.

In addition, adsorption tests were conducted to identify the initial adsorption behavior of the specimens, which contributes to the overall self-cleaning effect prior to photocatalysis. For this purpose, all aqueous samples were kept in the dark for 24 hours in the test chamber, after which they were exposed to UV irradiation for 120 minutes. The variations in the characteristic absorbance peak of MB at 664 nm, measured at selected time intervals using the spectrophotometer, were used to analyze both adsorption capacity and photocatalytic activity. All experiments were carried out under ambient laboratory conditions. Images of photocatalytic tests are shown in Figure 8.



Figure 8. Images of Photocatalytic Tests of Mortars

3. EXPERIMENTAL TEST RESULTS

3.1. Flowability

The flow diameters of the mortars determined by the flow table test are shown in Figure 7.

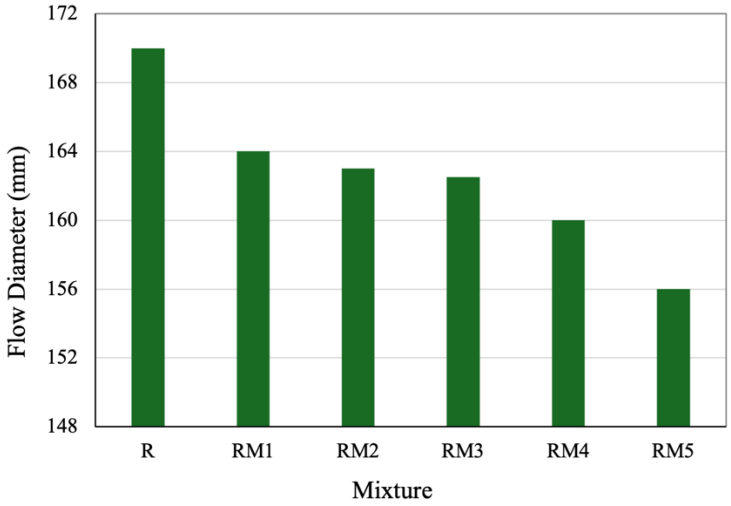


Figure 9. Flowability of Ternary Blended Mortars

Figure 9 presents the influence of substituting silica fume with different proportions of RM on the flowability of mortar mixtures. The reference mixture (R), composed solely of gypsum, lime and silica fume, achieved the highest flow diameter, measuring approximately 170 mm. As silica fume was progressively replaced by RM, a gradual decline in flowability was

recorded. From mixtures RM1 through RM5, the flow diameter consistently decreased. This reduction can be attributed to the distinct physical characteristics of the materials: silica fume possesses a spherical morphology that enhances mortar fluidity by improving particle packing and lowering interparticle friction. Conversely, red mud particles are angular despite being nearly spherical and irregular shapes [24,25], which, when incorporated in place of silica fume, increase internal friction and thus diminish the mixture's flow performance [26]. The observed irregular morphology may be linked to hygroscopic phases within the material, which are indicative of its high water-absorption capacity [25,27].

3.2. Unit Weight

Fresh and hardened unit weights of the reference mortar and all test mortars are given in Figure 10. Examination of the figure reveals that replacing silica fume with RM leads to an increase in both fresh and hardened densities. The reference mixture showed the lowest values, with a fresh unit weight of 1710 kg/m^3 and a hardened unit weight of 1309 kg/m^3. As the proportion of RM increased, a steady rise in unit weights was observed in both states. This behavior indicates that RM possess higher specific gravities than silica fume, thereby producing denser mortar mixtures.

RM is not recognized as an effective pozzolanic material [28], and its effect is expected to contribute to a denser microstructure as filler material while simultaneously increasing the unit weight due to its higher specific gravity relative to silica fume. Also, as indicated in Table 1, MS is not classified as pozzolanic owing to its chemical and mineralogical composition. Pozzolanic materials are typically rich in amorphous silica (SiO_2) and alumina (Al_2O_3), which react with calcium hydroxide [$Ca(OH)_2$] in the presence of moisture to form additional calcium silicate hydrate (C–S–H). Consequently, RM exhibits no meaningful pozzolanic activity and primarily acts as an inert filler. Its contribution to microstructural densification and mechanical performance therefore arises mainly from physical effects rather than chemical reactions.

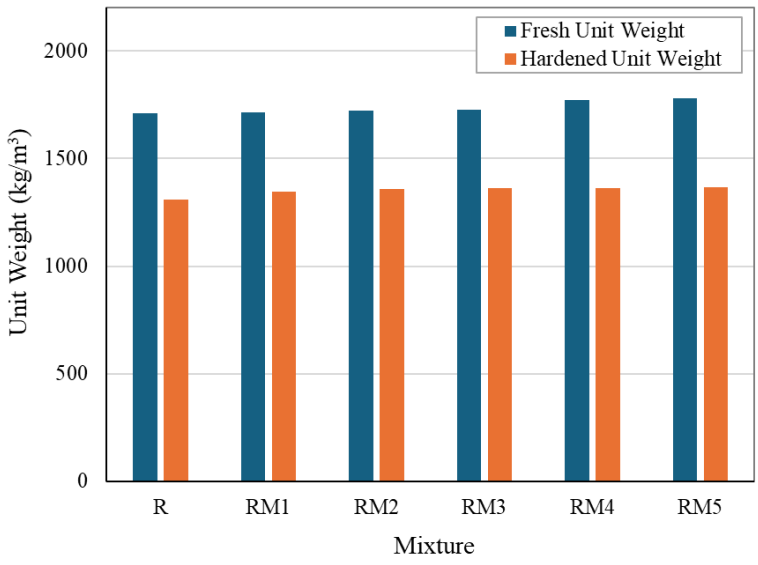


Figure 10. Fresh and Hardened Unit Weights of Ternary Blended Mortars

3.3. Compressive Strength

Compressive strength values of the reference mortar and all test mortars are given in Figure 11.

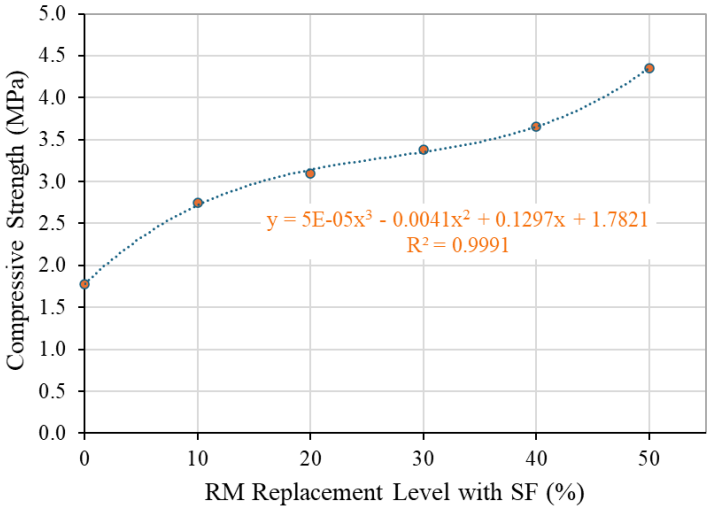


Figure 11. Fresh and Hardened Unit Weights of Ternary Blended Mortars

The graph illustrates the compressive strength development of mortars in which silica fume was partially replaced by RM. The reference mixture, composed of gypsum, lime and silica fume, recorded the lowest compressive strength at approximately 1.76 MPa. When silica fume was substituted with RM, an increase in compressive strength was observed. In particular, the test series demonstrated a steady rise in strength, reaching nearly 4.4 MPa at the RM5 level. This improvement is attributed to the lower pozzolanic and higher filling effect properties of RM, which promote additional C–S–H formation and contribute to a denser, more cohesive microstructure.

The increases observed in both fresh and hardened unit weights for the RM modified mortars are directly reflected in their compressive strength behavior. As the proportion of RM increased, the overall density of the mixtures increases, resulting in lower porosity and a more compact internal structure. This densification facilitated improved stress distribution within the hardened matrix, thereby supporting higher compressive strength values. The influence of increased density was particularly evident in test mixtures, where higher unit weights provided noticeable mechanical benefits. The strong correlation between higher unit weight and improved compressive strength underscores that incorporating RM not only elevated the physical density of the mortars but also strengthened their mechanical performance by reducing voids and increasing structural compactness.

In addition, according to TS EN 998-1, the minimum required compressive strength for mortars is 0.4 MPa. The results of this study show that the compressive strengths of both the reference and modified mortars exceed this limit by factors ranging from four to ten. Furthermore, the TS EN 13279-1 standard specifies a minimum compressive strength of 2 MPa for gypsum–lime-based mortars. Based on this criterion, all test mixtures (RM1 through RM5) meet the required strength threshold.

The combined use of SF and RM creates a synergistic effect that enhances the compressive strength of mortars beyond what each material can achieve individually. This synergy arises from the simultaneous contribution of two complementary mechanisms within the microstructure. Silica fume, owing to its high amorphous SiO_2 content and ultrafine particle size, reacts with calcium hydroxide during hydration and forms additional C–S–H phases, thereby significantly densifying the matrix. Red mud, on the other hand, contributes mainly through its filler effect; its fine particles and mineral content reduce the void ratio and promote a more compact structure.

When SF and RM are incorporated together, the chemical reactivity of silica fume and the physical densification provided by red mud complement one another, strengthening the matrix both chemically and structurally. The extra C–S–H phases produced by silica fume create a stronger bonding network around the voids partially filled by red mud particles, enhancing stress transfer within the hardened mortar. Additionally, the relatively high specific gravity of red mud increases the overall density of the mixture, further supporting improvements in mechanical performance. The resulting refined and compacted microstructure, characterized by reduced porosity and a more stable binding framework, leads to higher compressive strength values.

3.4. Self-Cleaning Performance

The self-cleaning performance of the produced ternary blended mortar heterostructures in removing methylene blue, used as a model organic pollutant, was evaluated under UV irradiation through heterogeneous photocatalysis. Photocatalytic reactions occur on the surface of the photocatalyst where the reactant molecules are adsorbed; therefore, preliminary adsorption of the target pollutant is a prerequisite for its subsequent degradation [29]. For this reason, adsorption experiments were first conducted by keeping the composite specimens in the dark for 24 h to ensure saturation of their adsorption capacities. The discoloration of the methylene blue during this period, in the absence of UV light, confirms that the dye molecules were successfully adsorbed onto the specimen surfaces [16]. After 24 h, the reference specimen without RM (RM0) was able to adsorb 60% (efficiency) of the MB dye, as illustrated in Figure 12. The incorporation of RM into the mortar structure was found to reduce the adsorption capacity of the ternary blended matrix to a certain extent. This behavior is likely associated with gypsum, lime and silica fume and other ingredients, aside from RM, exhibiting a higher affinity toward MB molecules. Furthermore, the adsorption capacity showed a gradual decline to the RM5 specimen containing 50% RM replacement level with SF.

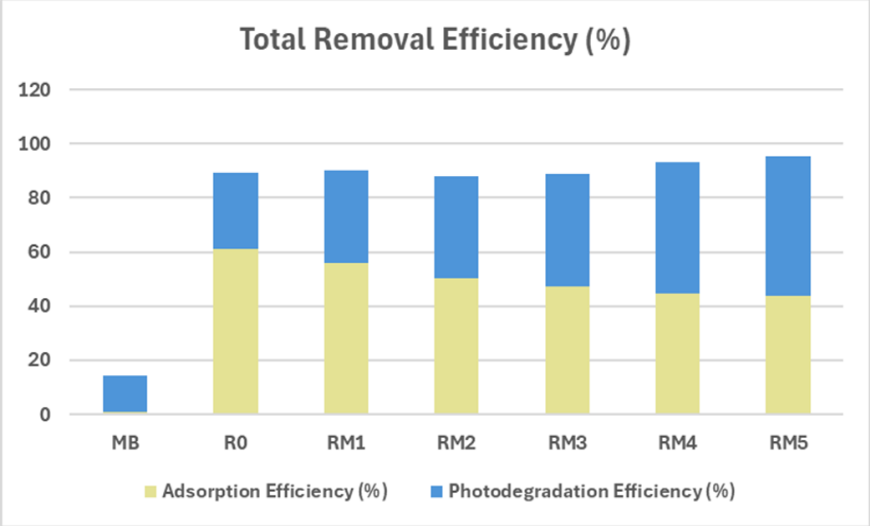


Figure 12. Total Removal Efficiency Values

The detailed photocatalytic performance of the ternary blended mortars with addition of RM is presented in Figure 12, which illustrate the degradation bars corresponding degradation efficiencies. As shown in the figure, the R0 specimen, prepared without RM, exhibited a very limited ability to decompose MB dye under 120 min of UV irradiation following the 24 h adsorption stage, displaying behavior nearly same to the MB reference solution. In contrast, the addition of RM progressively enhanced the degradation rate, with specimens replacement levels of 10% (RM1) to 50% (RM5) RM demonstrating similar overall trends.

The degradation efficiencies, calculated based on the difference between initial and final dye concentrations, revealed that RM5 achieved the highest performance, reaching an efficiency of almost 55%, which corresponds to an improvement of approximately 2 times compared to the control specimen. The RM1 to RM4 composites also exhibited substantial removal efficiencies of 30%, 40%, 45%, and 50%, respectively. Notably, even the RM1 specimen, containing only 10% RM replacement (this means that there are 6.25 grams of red mud in the total mixture amount of 1640 grams, or 0.38% of the total weight), achieved a degradation efficiency of 30%, demonstrating that small additions of RM can considerably enhance photocatalytic activity.

4. CONCLUSIONS

This study investigates the potential use of red mud within a fully cement-free ternary binder system aimed at developing sustainable construction materials. As an industrial byproduct, red mud presents an opportunity to both reduce environmental impacts and impart functional properties to building materials. When incorporated alongside silica fume and lime, red mud exerts a combined influence on the mechanical performance, microstructural characteristics, and photocatalytic activity of the mortars. In this context, the research provides a comprehensive evaluation of the physical, mechanical, and self-cleaning properties of red mud–modified cementless mortars, demonstrating that industrial waste materials can be transformed into high-value products for use in the construction sector. According to the test results of this study;

1. The partial replacement of silica fume (SF) with red mud (RM) resulted in increased fresh and hardened unit weights, indicating that RM behaves as a high-specific-gravity filler material within the cementless mortar system.
2. The flowability of the mixtures decreased progressively with increasing RM content. This reduction is attributed to the spherical particle morphology of silica fume, which enhances workability, whereas the irregular and angular shape of RM particles increases internal friction within the mixture.
3. Compressive strength values exhibited a consistent improvement as the RM replacement ratio increased, with the highest strength obtained in the RM5 mixture. The enhancement in mechanical performance is closely associated with the higher unit weight and reduced porosity of the mixtures.
4. Although RM exhibits low pozzolanic reactivity, its pronounced filler effect contributed to microstructural densification and thus supported strength development.
5. All produced mixtures met the minimum compressive strength requirement of 0.4 MPa specified in TS EN 998-1, and RM-containing mortars also satisfied the 2 MPa minimum limit defined in TS EN 13279-1, demonstrating compliance with relevant construction standards.
6. The combined use of SF and RM generated a synergistic improvement in performance through the coexistence of chemical (C–S–H formation driven by SF) and physical (filler effect associated with RM) mechanisms, resulting in enhanced microstructural integrity.
7. Photocatalytic activity increased with higher RM content, primarily due to the presence of metal oxides in RM, which contributed to improved degradation of methylene blue under UV irradiation. Consequently, the RM-modified mortars demonstrated effective self-cleaning behavior.
8. Adsorption tests revealed that RM-containing mixtures could adsorb a portion of the dye even prior to UV exposure, indicating that the intrinsic affinity of RM for organic molecules contributes positively to overall photocatalytic efficiency.

The study confirms that RM is a sustainable supplementary material capable of enhancing both mechanical and functional properties within cement-free ternary binder systems. Overall findings emphasize that red mud is a valuable industrial by-product that can be effectively utilized in the development of sustainable construction materials, offering both environmental benefits and performance advantages.

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EFFECT OF TOBACCO UNDERSIZE WASTE ON TECHNICAL PROPERTIES OF CEMENTITIOUS LIGHTWEIGHT COMPOSITE MORTARS

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ABSTRACT

Tobacco waste poses a significant challenge in environmental waste management while also standing out as an innovative resource for sustainable material development processes. This study examines the effects of incorporating tobacco waste into cement-based construction materials at varying proportions on their physical, mechanical, and thermal properties in detail. The mixtures prepared within the scope of the study consist of cement, expanded perlite, fly ash, fiber, water, and specific proportions of tobacco waste. Undersize waste tobacco was used in mortars by replacing it with expanded perlite at percentages of 5%, 10%, 15%, 20%, 25%, and 30% by weight. Experimental analyses were conducted on critical parameters such as unit weight, compressive and flexural strength, thermal conductivity coefficient, water absorption capacity, and workability properties of the materials. The results reveal that while tobacco waste improves the thermal insulation properties of the material by reducing thermal conductivity, it also leads to noticeable changes, such as a decrease in unit weight and mechanical performance and increase in water absorption ratio. The findings of this study demonstrate that tobacco waste can make a significant contribution to the development of sustainable and environmentally friendly construction materials. The use of tobacco waste is expected to provide environmental benefits in terms of waste management while enabling the development of innovative construction materials. In this context, the results obtained present significant potential for

reducing environmental impacts in the construction sector and enhancing the efficient use of economic resources.

Keywords: Tobacco waste, sustainable materials, cement-based composites, thermal conductivity, eco-friendly construction, waste management.

1. INTRODUCTION

The increasing environmental issues and the need for sustainability in today's world necessitate the effective utilization of waste and its integration into innovative material development processes. Efforts aimed at reducing environmental impacts and conserving natural resources play a significant role in the construction sector. Waste accumulation is recognized as one of the most critical forms of pollution and has been considered a major environmental threat over recent decades. In the field of building materials, current research and development efforts primarily focus on creating environmentally friendly, green products. These green cementitious materials are designed to preserve natural resources, lower CO_2 emissions by reducing cement content, enhance thermal insulation performance, and incorporate waste materials into cement-based systems [1,2]. In addition, the accumulation of agricultural residues constitutes another significant environmental concern. Recyclable agricultural wastes, particularly those in particulate or fibrous forms such as wood, hemp, sisal, jute, rice, coconut, flax, palm nut shells, olives, and dates, have attracted growing attention from researchers in recent years [3–8]. In particular, the evaluation of by-products from industrial and agricultural activities offers substantial economic and environmental benefits. Tobacco waste, a by-product of the globally extensive tobacco industry, is typically disposed of directly or used for energy production. However, due to its organic structure, physical properties, and chemical composition, tobacco waste presents a significant potential for innovative material development processes.

Cement-based building materials are among the most widely used materials in the construction sector, and their production is closely linked to substantial consumption of natural resources and environmental impacts. Cement production, in particular, is an energy-intensive process that generates a large amount of carbon emissions. Also, climate change represents one of the most pressing challenges confronting modern society, with greenhouse gas emissions identified as a primary driving factor. Reducing energy consumption is therefore considered a key strategy for mitigating greenhouse gas emissions [9]. In recent years, energy-efficient buildings have gained significant global importance due to their economic and environmental benefits. As buildings account for more than one-third of total energy consumption, many countries are increasingly prioritizing the development and implementation of energy-efficient building practices [10]. Integrating tobacco waste into cement-based materials can provide environmental benefits through effective waste management and enhance the thermal properties of these materials. In this context, incorporating tobacco waste into cement-based mixtures has the potential to improve critical parameters such as thermal insulation, unit weight, water absorption capacity, and workability of the materials. However, integrating tobacco waste

into these materials may also create some adverse effects. Therefore, it is crucial to conduct an in-depth investigation into the impacts of tobacco waste on building materials.

Prusty et al. [11] examined the potential use of agro-waste materials as partial replacements for fine aggregate in concrete in the context of rapid urbanization and agricultural waste disposal challenges. This review evaluates the fresh and hardened properties, durability, and thermal performance of agro-waste–modified concrete and mortar, highlighting that certain agro-waste types can improve workability, mechanical performance, chloride resistance, and thermal insulation. The study emphasizes the need for further research to ensure the reliable and widespread application of agro-waste materials in concrete.

Shafigh et al. [12] highlighted that concrete is the most extensively used construction material, leading to substantial consumption of natural resources due to rapid industrialization and urbanization. To mitigate the environmental impacts of concrete production and enhance sustainability, the use of industrial and agricultural wastes as alternative concrete constituents is proposed. Their review focused on the potential application of agricultural wastes (oil palm shell, coconut shell, corn cob, rise husk and tobacco waste) as aggregates in concrete, discussing their engineering properties and suitability. The study aims to encourage the utilization of these wastes and to support the identification of other viable waste materials for sustainable concrete production through interdisciplinary collaboration. They concluded that certain agricultural solid wastes, such as oil palm shell, coconut shell, rice husk, and tobacco waste, can be effectively used as aggregates in concrete with acceptable performance. Given that aggregates constitute approximately 60–80% of concrete by volume, the partial or full replacement of conventional aggregates with such solid wastes can provide notable benefits in terms of cost reduction, energy savings, and decreased environmental impact within the construction industry.

Çelikten and Canbaz [13] reported that approximately 10,000 tons of waste are generated annually during tobacco production in Turkey, indicating a considerable potential for utilization in concrete technology. In their study, the feasibility of using tobacco waste ash as a mineral admixture was investigated, considering its possible pozzolanic activity due to its fineness, amorphous structure, and high silica content. Two types of tobacco waste ash were partially substituted for cement by weight at replacement levels of 0%, 10%, 20%, and 30%. Mechanical and physical properties, including compressive and flexural strength, unit weight, ultrasonic pulse velocity, and dynamic modulus of elasticity, were determined at 28 days. The experimental results showed that these properties decreased with increasing tobacco waste ash content. Although no improvement was observed compared to the control mortar, the study suggests that the use of tobacco waste ash as a mineral admixture may provide ecological and economic benefits through the utilization of this non-renewable waste material.

Öztürk and Bayraklı [14] examined the feasibility of using tobacco waste in the production of lightweight concrete. Concrete samples were prepared using mixtures of tobacco waste, pumice, sand, and cement. The results indicated that the produced specimens met the criteria for lightweight concrete based on consistency, unit weight, porosity, compactness, compressive strength, and thermal conductivity. The unit weight values ranged between 0.50 and 0.56 kg/dm^3, compressive strength values varied from 0.20 to 0.60 MPa, and thermal conductivity

coefficients were found to be between 0.194 and 0.210 W/mK. Based on experimental observations and evaluations, the study concluded that lightweight concrete incorporating tobacco waste could be used as a coating and partitioning material in construction applications.

Moreno et al. [15] addressed the environmental impact of cement production, noting that global cement output reached 4.6 billion tons in 2015 and that conventional cement manufacturing is responsible for significant CO_2 emissions. The study investigated tobacco waste ash (TWA) as a sustainable supplementary cementitious material in hydraulic concrete, particularly in the context of agro-waste disposal challenges in Colombia. TWA was ground to below 75 μm and characterized using X-ray fluorescence, and its effects were evaluated through a central composite experimental design considering cement replacement level and water-to-binder ratio. The results demonstrated that replacing 10% of cement with TWA at a w/b ratio of 0.5 led to a 51% increase in 28-day compressive strength compared to the control mixture, along with an 86% improvement in 7-day compressive strength, highlighting the strong potential of TWA as a high-performance and low-carbon cement replacement.

Thammaiah et al. [16] investigated the characteristics of tobacco waste ash (TWA) and its applicability as a partial cement replacement in self-compacting concrete. The study evaluated both fresh and hardened properties of self-compacting concrete produced with TWA, aiming to reduce cement consumption and enhance sustainability. The elemental composition of TWA, along with cement and fly ash, was determined using Energy Dispersive X-ray Analysis, and mix proportions were designed according to Nan Su's method. Cement was partially replaced with TWA at rates of 10–30% to identify the optimum replacement level based on compressive strength. Fresh properties were assessed using slump flow, L-box, V-funnel, and U-box tests, while hardened properties were evaluated through mechanical strength tests. The results demonstrated improved cohesiveness and segregation resistance in the fresh state, as well as enhanced compressive, flexural, and split tensile strengths at the optimum TWA replacement level.

A review of the existing literature shows that agro-waste materials have significant potential in cementitious products. However, studies on tobacco waste, which accounts for a significant volume of waste production, are quite limited and have been overlooked in recent years. Also, even from a limited number of studies, it has been observed that the use of tobacco waste in cement products may have positive effects on some physical and/or mechanical properties, and especially on environmental concerns.

The purpose of this study is to comprehensively analyze the effects of incorporating tobacco waste at varying proportions into cement-based building materials on their physical, mechanical, and thermal properties. The environmental benefits achieved through the incorporation of tobacco waste into cement-based building materials depend on the proper management of these wastes. Recycling waste and combining it with innovative materials will not only contribute to the conservation of natural resources but also help reduce the carbon footprint of the construction sector.

2. MATERIALS AND METHODS

2.1. Materials

In this study, CEM I 42.5R cement conforming to the TS EN 197-1 standard was used as the binder material.
In this study, expanded perlite sized at 0/2 mm was used as the main aggregate.
To improve the mechanical properties of the mortars to be produced, 6mm long PVA fibers were used as reinforcement.
Fly ash has been used to improve the mechanical properties of mortars through its filling effect and pozzolanic properties.
In this study, sieved tobacco undersize waste with a size of 0/2 mm was used as replacement of expanded perlite aggregate in certain proportions. This organic waste consists of inorganic materials, scrap, midrib, and very finely powdered tobacco. Because these components are undesirable materials in cigarette production, tobacco from the fields is screened to separate them from such mixtures. The material above the screen is sent to cigarette production, while the material below the screen is treated as waste. In this study, screened undersize material was used.
The materials used in this study are shown in Figure 1. The chemical properties of the materials are given in Table 1.

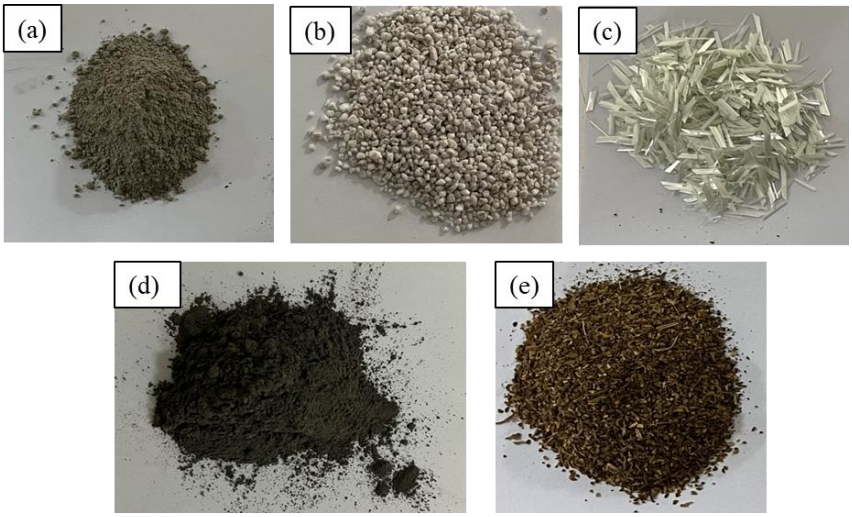


Figure 1. Materials Used in This Study: (a) Cement, (b) Expanded Perlite, (c) PVA Fiber, (d) Fly Ash, (e) Tobacco Undersize Waste

Table 1. Chemical Properties of the Materials

Oxides (%)	Cement	Expanded Perlite	Fly Ash	Tobacco Undersize Waste
SiO_2	20.05	74.36	54.69	15.76
Al_2O_3	5.18	14.32	24.97	13.25
Fe_2O_3	3.38	0.69	7.11	9.10
MgO	1.55	0.37	1.97	7.79

CaO	64.01	1.84	5.90	36.14
Na_2O	0.53	3.38	0.38	9.65
K_2O	0.84	4.63	0.28	3.79
SO_3	2.9	0.01	0.15	0.50
TiO_2	0.24	0.08	1.17	0.80
LOI	1.31	0.33	3.38	57.21

2.2. Methods

In this study, the mixture design shown below in Table 2 has been used.

Table 2. Mixture Design

	Cement (g)	Expanded Perlite (g)	Tobacco Undersize Waste (g)	PVA Fiber (g)	Fly Ash (g)	Water (g)
TW0	1235	1235	0	12.35	123.5	2087.5
TW5	1235	1173.25	61.75	12.35	123.5	2087.5
TW10	1235	1111.5	123.5	12.35	123.5	2087.5
TW15	1235	1049.75	185.25	12.35	123.5	2087.5
TW20	1235	988	247	12.35	123.5	2087.5
TW25	1235	926.25	308.75	12.35	123.5	2087.5
TW30	1235	864.5	370.5	12.35	123.5	2087.5

In this study, a total of seven mortar mixtures were produced, consisting of a reference mix (TW0) and one additional series in which silica expanded perlite (EP) was partially substituted with tobacco undersize waste (TUW). The reference mixture was composed of 1235 g of gypsum, 1235 g of EP, 12.35 g of PVA fiber, 123.5 g of fly ash (FA), and 2087.5 g of water, without any TUW content. In the TW series, EP was incrementally replaced by TUW at six levels, which are 61.75 g, 123.50 g, 185.25 g, 247.00 g, 308.75 g and 370.5 g, while the remaining EP content was adjusted accordingly. The quantities of cement, PVA fiber, FA and water were kept constant in all mixtures. This mix design allowed for the evaluation of the influence of substituting EP with TUW on both the fresh, hardened and thermal characteristics of composite cement mortars.

The mortars prepared with these proportions were cast into $4 \times 4 \times 4$ cm^3 prismatic molds to test flexural and compressive strengths of the specimens. Also, $20 \times 40 \times 4$ cm^3 plate specimens were produced to analyze the thermal conductivity of the mortars. After 24 hours, the specimens were demolded and subsequently cured in water at 20 ± 1 °C until the testing age. The production stages of mortars are shown in Figure 2.



Figure 2. Production of the Mortars

Fresh and hardened unit weights of the mortars were determined in accordance with TS EN 1015-6 [17] and TS EN 1015-10 [18], respectively. The flowability of fresh mortars was measured using a flow table apparatus following TS EN 1015-3 [19]. Water absorption testing was performed in line with ASTM C642-13 [20]. Compressive and flexural strength measurements were conducted according to TS EN 1015-11 [21].

Thermal conductivity tests were conducted using the Hot Box method (Figure 3). The test setup consists of three main components: a heating unit containing an electric heater (hot chamber), a central section where the specimen is positioned, and a cold chamber. During testing, surface temperatures on both sides of the specimen were recorded from a minimum of nine evenly distributed points forming a grid pattern. Temperature sensors in the hot and cold chambers were placed in full contact with the specimen surfaces, allowing surface temperature measurements with a sensitivity of 0.1 °C. The heat input was regulated by a continuously adjustable power supply ranging from 20 to 400 W. Prior to data acquisition, specimens were allowed to reach thermal equilibrium, and measurements were taken only after steady-state conditions were achieved. The required temperature gradient across the specimen was generated by the electrical power (Q_T, W) supplied to the heater, and the temperature difference (ΔT, °C) between the two surfaces was calculated as the average of the measured values. The thermal conductivity (λ, W/mK) of the specimen was then determined using Eq. (1):

$$\lambda = \frac{Q_T \times d}{A \times \Delta T} \quad (1)$$

where λ represents the thermal conductivity of the specimen (W/mK), QT is the electrical power applied to the heater (W), d is the specimen thickness (m), A is the heated surface area (m^2), and ΔT is the temperature difference between the specimen surfaces (°C).



Figure 3. Hot Box Test

3. EXPERIMENTAL TEST RESULTS

3.1. Flowability

The flow diameters of the mortars determined by the flow table test are shown in Figure 4.

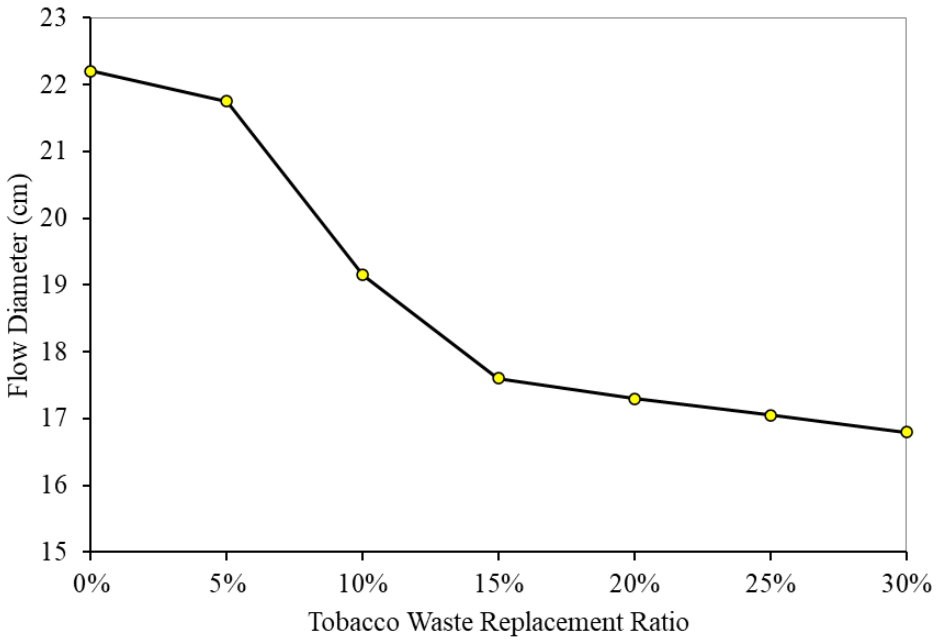


Figure 4. Flowability of Composite Cement Mortars

The workability of the cement mortars incorporating tobacco waste was evaluated using the flow table test, and the results are presented in Figure 4. As observed, the flow diameter decreased consistently with increasing replacement ratio of EP aggregate with TUW. The reference mixture exhibited the highest flow diameter, indicating superior workability, while a

slight reduction was recorded at a 5% replacement level. A more pronounced decline in flow diameter occurred at 10% replacement, revealing a significant change in the fresh-state behavior of the mortars. For replacement ratios exceeding 10%, the reduction in workability continued at a slower rate, with flow diameters between 15% and 30%. This behavior can be attributed to the highly porous structure and elevated water absorption capacity of TUW, which reduces the amount of free water available for lubrication and flow. Additionally, the irregular particle morphology and increased specific surface area of the TUW-containing mixtures further contributed to the loss of workability. Furthermore, TUW's more fibrous structure compared to EP increased the internal friction of the fresh mortar, reducing its workability. Overall, the results indicate that the incorporation of tobacco waste adversely affects mortar workability, and replacement levels above approximately 10–15% may necessitate mix design modifications, such as water content adjustment or the use of chemical admixtures, to achieve adequate consistency.

3.2. Unit Weight

The variation of fresh and hardened unit weights of the mortars incorporating tobacco waste is illustrated in Figure 5.

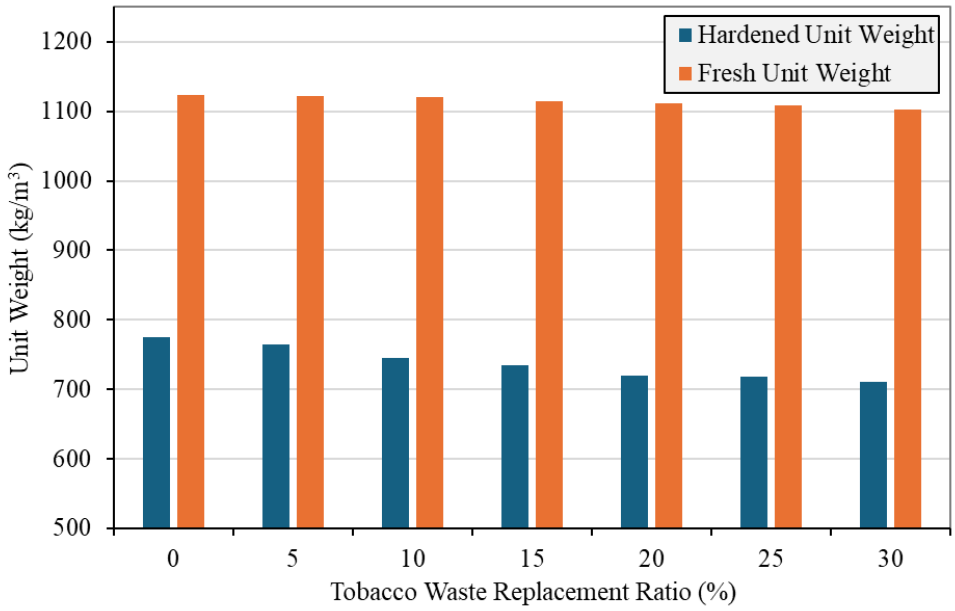


Figure 5. Unit Weight Values of Composite Cement Mortars

As seen from the results, the fresh unit weight exhibited only a slight decrease with increasing replacement ratio, remaining within a narrow range throughout all mixtures. This behavior indicates that the incorporation of TUW aggregate had a limited influence on the bulk density of the mortars in the fresh state, despite the observed reduction in workability. In contrast, the hardened unit weight showed a clear and progressive decrease as the replacement ratio increased. Compared to the reference mixture, a noticeable reduction was observed even at low replacement levels, with the most significant decrease occurring at higher substitution ratios. This reduction can be attributed to the low density and highly porous structure of TUW, which

increases the overall void content of the hardened matrix and leads to lighter mortar specimens. The growing difference between fresh and hardened unit weights with increasing replacement ratio further suggests enhanced internal porosity and water loss during curing. Furthermore, the fact that the fresh unit weight of the mortars remained almost constant while their hardened unit weights decreased noticeably with the increase in TUW usage indicates that TUW has a high water retention capacity. Furthermore, the apparent decrease in hardened unit weights also suggests that TUW has introduced some air into the mortars. TUW's organic structure consists of fatty acids, cellulose, hemicellulose, and lignin [22–24]. It has been determined in studies conducted by researchers that fatty acids, lignin and cellulose have some air-entraining properties in cement-binding products [25,26]. The hardened unit weights of TW5-TW30 mixtures were determined to be in the range of 765 to 711 kg/m^3. Öztürk and Bayrakl [14] in their study, they found that the densities of concrete samples produced using pumice and tobacco waste ranged from 500-560 kg/m^3. Consequently, the results demonstrate that the use of tobacco waste aggregate is effective in producing lighter cement mortars, particularly at replacement ratios above 10–15%, which may be advantageous for applications where reduced dead load and improved thermal performance are desired.

3.3. Water Absorption

Figure 6 illustrates the variation in water absorption of cement mortars produced by replacing EP aggregate with TUW.

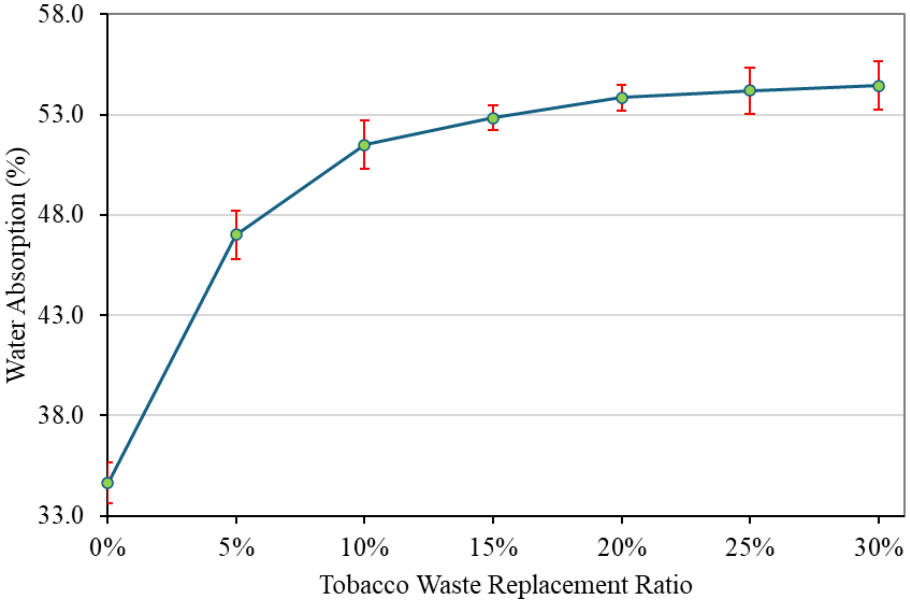


Figure 6. Water Absorption Values of Composite Cement Mortars

As seen from the graph, the water absorption values show a distinct and continuous increasing trend with increasing TUW replacement ratio. The reference mixture exhibits the lowest water absorption (34.6%), while a sharp increase is observed even at a 5% TUW replacement level (47% water absorption by weight). This behavior indicates that the high porosity and hydrophilic constituents of TUW significantly enhance the water retention capacity of the

mortars. Up to a replacement ratio of 10%, the increase in water absorption is relatively rapid. Beyond this level, the rate of increase becomes more gradual and tends to approach a fix value. The nearly constant water absorption values observed between 15% and 30% replacement ratios suggest that the water absorption capacity of TUW approaches saturation at higher contents. This trend is directly associated with the increased internal void content, open pore structure, and high water retention capacity of TUW containing mortars.

When evaluated together with the flowability and unit weight results, the water absorption findings confirm that TUW incorporation leads to a more porous and less compact microstructure. In particular, the noticeable reduction in hardened unit weight, while the fresh unit weight remains relatively constant, indicates that TUW retains both water and a certain amount of entrapped air within the mortar matrix. Moreover, the presence of cellulose, hemicellulose, lignin, and fatty acids in the organic structure of TUW has been reported in the literature to contribute to water retention and air-entraining effects in cement-based systems [22–24]. Although TUW replacement increases water absorption, thereby enhancing the lightweight character and potential thermal insulation performance of the mortars, the water absorption behavior, especially at replacement ratios above 10–15%, should be carefully considered from a durability perspective. Therefore, the use of water-repellent admixtures or microstructural refinement strategies may be required for mortars containing high TUW contents.

3.4. Compressive Strength

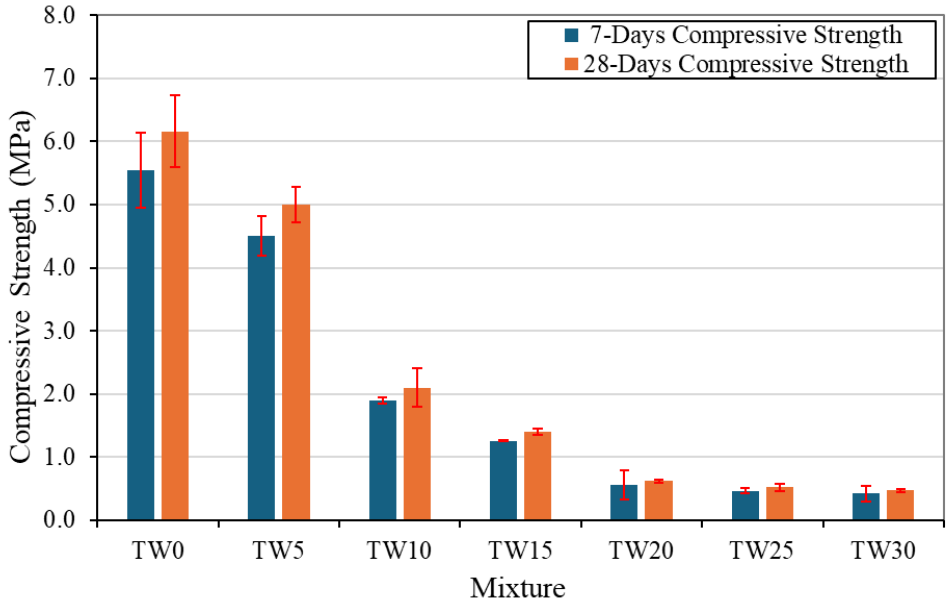


Figure 7. Compressive Strength Values of Composite Cement Mortars

Figure 7 presents the 7-day and 28-day compressive strength results of cement mortars incorporating TUW at different replacement ratios. As observed, both early-age and 28-days age compressive strengths decrease markedly with increasing TUW content. The reference mixture (TW0) exhibits the highest compressive strength (5.55 MPa for 7-days cured, 6.16 MPa for 28-days cured specimens), while a gradual reduction is observed at 5% replacement. A

pronounced drop in strength occurs at 10% TUW, indicating that the incorporation of tobacco waste significantly alters the load-bearing capacity of the mortars. Beyond a replacement ratio of 10%, the reduction in compressive strength becomes severe, with strength values at 15% and higher TUW contents falling below 2 MPa. At replacement ratios of 20–30%, both 7-day and 28-day strengths remain very low, suggesting that the cementitious matrix is no longer sufficiently continuous or dense to effectively transfer stresses. This behavior can be attributed to the low mechanical strength, high porosity, and organic nature of TUW, which weakens the interfacial transition zone and increases the overall void content of the mortar. For all mixtures, the 28-day compressive strength values are higher than the corresponding 7-day values, indicating that cement hydration continues over time even in the presence of TUW. However, the magnitude of strength gain with curing age diminishes as the TUW content increases, implying that the adverse effects of TUW on microstructural development outweigh the benefits of continued hydration at higher replacement levels. In addition, according to TS EN 998-1, the minimum required compressive strength for mortars is 0.4 MPa. The results of this study show that the compressive strengths of both the reference and modified mortars exceed this limit (minimum compressive strength is 0.47 MPa with TW30 series).

When evaluated together with the workability, unit weight, and water absorption results, the compressive strength findings confirm that TUW incorporation leads to a lighter but significantly weaker mortar structure. Nevertheless, mixtures with high TUW content may still be considered for non-structural, lightweight, and insulating applications, where low density and enhanced thermal performance are prioritized over mechanical strength.

3.5. Flexural Strength

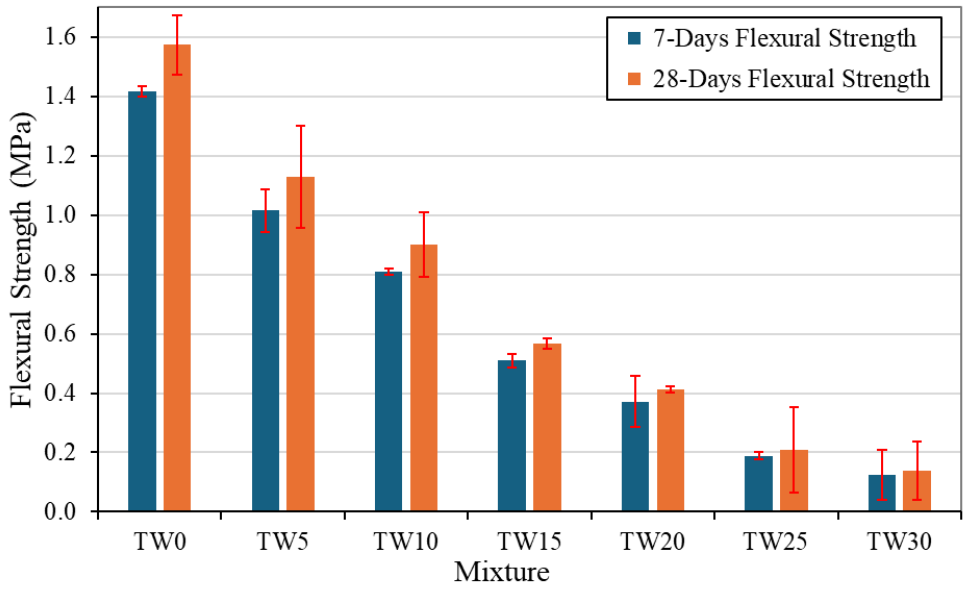


Figure 8. Flexural Strength Values of Composite Cement Mortars

Figure 8 illustrates the variation in flexural tensile strength of mortars in which EP was partially replaced by TUW. The reference mixture (TW0), containing 0% TUW, exhibited the highest tensile strength as 1.58 MPa. With the incorporation of TUW, the flexural tensile strength of the mortars decreased noticeably. Similar to the trend observed in compressive strength, TUW-containing mortars achieved lower flexural tensile strength values than those of reference specimens. The minimum flexural tensile strength (0.14 MPa) was obtained in the TW30 mixture. It was determined that as the use of TUW in mortars increased, the hardened unit weight decreased and water absorption values increased sharply (Figure 5 and Figure 6). One of the reasons for this decrease in unit weight and increase in water absorption is that the TUW have some air-entraining effect. The chemical composition of TUW includes fatty acids, lignin and cellulose. It has been determined in studies conducted by researchers that fatty acids, lignin and cellulose have some air-entraining properties in cement-binding products [25,26]. Another reason for the sharp decrease in strength values may be due to the double bonds in the structure of fatty acids, which are easily oxidized by the dissolved oxygen of tap water during the curing period and cause microscopic cracks in the concrete [27].

3.6. Thermal Conductivity

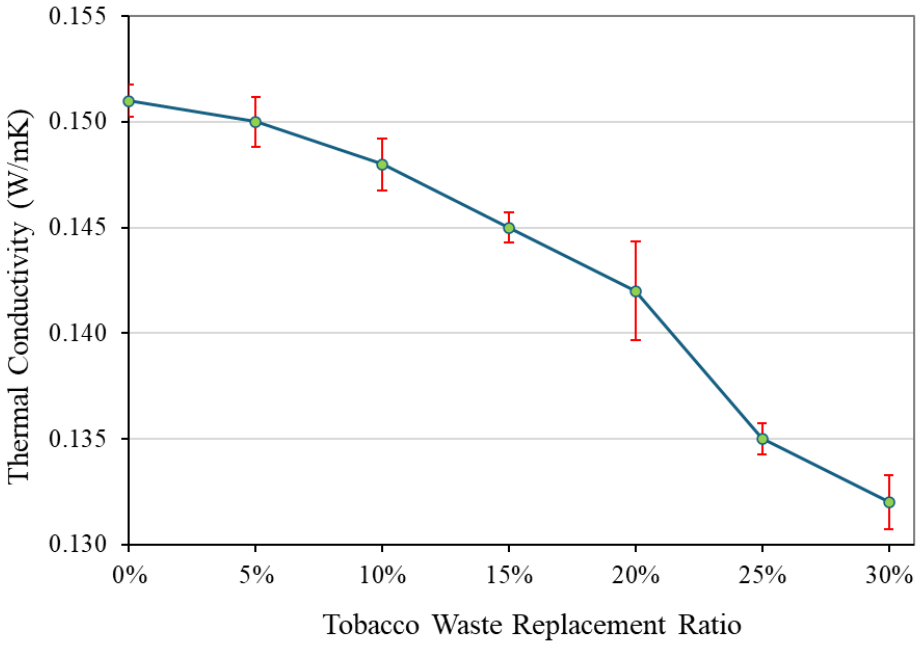


Figure 9. Thermal Conductivity Values of Composite Cement Mortars

Thermal conductivity values of all hardened composite cement mortar specimens were experimentally determined for oven dry condition after 28 days of curing period, and the test results are given in Figure 9. According to the test results, thermal conductivity value of reference mortar was 0.151 W/mK, and thermal conductivity of hardened specimens with using TUW were changed between 0.150 and 0.132 W/mK. The thermal conductivity values of the cement mortars decreased compared to reference mortar by 0.66 %, 1.99 %, 3.97 %, 5.96 %, 10.60 % and 12.58 at 5 %, 10 %, 15 %, 20 %, 25 % and 30 % EP and TUW replacement levels, respectively. As hardened density decreases, the thermal conductivity coefficient of the

hardened cement mortar specimens decreases. Furthermore, an increase in the water absorption values of mortars is an indication that the porosity of the mortars has also increased. In other words, the hardened composite mortars tend to exhibit a more pronounced insulating behavior. Materials characterized by relatively low thermal conductivity coefficients can be regarded as more effective thermal insulators. In line with expectations, the increasing incorporation of TUW imparted enhanced thermal insulation properties to the cement mortars. As the TUW content increased, the intrinsic low thermal conductivity of the TUW particles, together with the additional air voids generated within the mortar matrix, contributed significantly to improving the overall thermal insulating performance of the composites. Comparable findings have also been reported in the literature, where a reduction in thermal conductivity with increasing TUW content was consistently observed. For instance, Öztürk and Bayrakl [14] reported low thermal conductivity values with using tobacco waste with pumice aggregate in concrete. They found thermal conductivity values ranges from 0.194 to 0.220 W/mK with density of 500 - 560 kg/m³.

4. CONCLUSIONS

This study comprehensively investigated the effects of replacing expanded perlite aggregate with tobacco undersize waste at varying proportions on the physical, mechanical, and thermal properties of cement-based composite mortars. Based on the experimental results, the following conclusions can be drawn:

1. The incorporation of TUW significantly influenced the fresh properties of the mortars. Flow table results indicated a continuous reduction in workability with increasing TUW content, primarily due to the porous, fibrous, and irregular structure of TUW, its high water absorption capacity, and increased internal friction.
2. Fresh unit weight values remained relatively stable for all mixtures, whereas hardened unit weights decreased progressively with increasing TUW content. This behavior demonstrates that TUW contributes to the formation of a lighter mortar structure, mainly due to its low density, high porosity, and water retention capability. The observed divergence between fresh and hardened unit weights also suggests that TUW introduces additional air voids into the mortar matrix.
3. Water absorption values increased markedly with TUW incorporation, particularly up to a replacement ratio of 10%, after which the increase tended to stabilize. The elevated water absorption is attributed to the hydrophilic and porous nature of TUW and confirms the development of a more open and less compact microstructure.
4. Both compressive and flexural strengths decreased significantly with increasing TUW replacement ratio. Although all mixtures satisfied the minimum compressive strength requirement specified in TS EN 998-1, the strength losses became pronounced beyond 10% TUW content. These reductions are associated with the low mechanical strength of TUW, increased porosity, weakened interfacial transition zones, and the organic constituents of TUW, which may induce air-entraining effects and microcracking during curing.
5. Thermal conductivity values decreased consistently with increasing TUW content, demonstrating an improvement in the thermal insulation performance of the mortars. The reduction in thermal conductivity is closely related to the decrease in hardened

density, increase in porosity, and the intrinsic low thermal conductivity of TUW. At the highest replacement level, the mortars exhibited up to a 12.58% reduction in thermal conductivity compared to the reference mixture.

The results indicate that tobacco undersize waste can be effectively utilized as a partial replacement for expanded perlite aggregate to produce lightweight cement mortars with enhanced thermal insulation properties. However, due to the associated reductions in mechanical performance and increases in water absorption, TUW-containing mortars are more suitable for non-structural applications such as insulation layers, partition elements, and lightweight filling materials. From an environmental perspective, the reuse of tobacco waste in cement-based materials offers a promising approach for sustainable waste management, conservation of natural resources, and reduction of the environmental footprint of the construction sector.

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2007 VE 2018 TÜRK DEPREM YÖNETMELİKLERİNİN ORTA KATLI BETONARME YAPILARIN SİSMİK TALEPLERİNE ETKİSİNİN İNCELENMESİ

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ÖZET

Türkiye, yüksek sismik tehlike altında bulunan ülkelerden biri olup, son yıllarda meydana gelen büyük depremler mevcut yapı stokunun deprem performansının sorgulanmasını zorunlu kılmıştır. Bu bağlamda, deprem yönetmeliklerinde yapılan güncellemelerin yapı tasarımına etkilerinin incelenmesi büyük önem taşımaktadır. Bu çalışma, Deprem Bölgelerinde Yapılacak Binalar Hakkında Yönetmelik (DBYBHY-2007) ile yürürlükte olan Türkiye Bina Deprem Yönetmeliği'nin (TBDY-2018) deprem yükleri açısından karşılaştırılmasını ve bu farklılıkların orta katlı betonarme binalar üzerindeki etkilerini incelemeyi amaçlamaktadır. Çalışma kapsamında, zemin + 4 katlı tipik bir betonarme konut binası ele alınmış ve yapı, Kocaeli ilinin 12 farklı ilçesinde yer aldığı varsayılarak her iki yönetmeliğe göre doğrusal analiz yöntemleriyle tasarlanmıştır. Yapısal analizler sonucunda, yapılar için elde edilen taban kesme kuvvetleri, düşey taşıyıcı eleman kesit alanları, göreli kat ötelemeleri ile beton ve donatı metrajları karşılaştırılmıştır. Elde edilen sonuçlar, TBDY-2018'e göre hesaplanan deprem taleplerinin, özellikle yüksek spektral ivmelere sahip ilçelerde, DBYBHY-2007'ye kıyasla daha büyük taban kesme kuvvetleri ve daha yüksek taşıyıcı eleman kesit gereksinimleri doğurduğunu göstermektedir. Bulgular, güncel yönetmeliğin daha güvenli ancak daha muhafazakâr tasarım sonuçları ürettiğini ortaya koymakta ve mevcut yapıların performans değerlendirilmesinde önemli çıkarımlar sunmaktadır.

Anahtar Kelimeler: DBYBHY-2007, TBDY-2018, orta katlı betonarme bina, taban kesme kuvveti, göreli kat ötelemesi

INVESTIGATION OF THE EFFECTS OF THE 2007 AND 2018 TURKISH EARTHQUAKE CODES ON THE SEISMIC DEMANDS OF MID-RISE REINFORCED CONCRETE STRUCTURES

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ABSTRACT

Türkiye is one of the countries located in a region of high seismic hazard, and the major earthquakes that have occurred in recent years have made it necessary to question the seismic performance of the existing building stock. In this context, examining the effects of updates in earthquake codes on structural design is of great importance. This study aims to compare the Code on Buildings to Be Constructed in Earthquake Zones (DBYBHY-2007) and the currently enforced Turkish Building Earthquake Code (TBDY-2018) in terms of seismic loads, and to investigate the effects of these differences on mid-rise reinforced concrete buildings. Within the scope of the study, a typical reinforced concrete residential building with a ground floor and four storeys was considered, and the structure was assumed to be located in 12 different districts of Kocaeli province. The building was designed according to both codes using linear analysis methods. As a result of the structural analyses, the base shear forces, cross-sectional areas of vertical load-bearing elements, interstorey drift ratios, as well as concrete and reinforcement quantities were compared. The results indicate that the seismic demands calculated according to TBDY-2018 lead to larger base shear forces and higher cross-sectional requirements for load-bearing elements compared to DBYBHY-2007, particularly in districts with high spectral acceleration values. The findings reveal that the current earthquake code produces safer but more conservative design outcomes and provide significant implications for the seismic performance assessment of existing reinforced concrete buildings.

Keywords: DBYBHY-2007, TBDY-2018, mid-rise reinforced concrete building, base shear force, interstorey drift

1. GİRİŞ

Türkiye, Alp–Himalaya deprem kuşağı üzerinde yer almakta olup tarihsel ve aletsel dönem boyunca çok sayıda yıkıcı depreme maruz kalmıştır. 1999 Gölcük ve Düzce depremleri ile son olarak 6 Şubat 2023 Kahramanmaraş depremleri, yapı stokunun deprem güvenliğinin ne derece kritik bir sorun olduğunu bir kez daha ortaya koymuştur (Erdik, 2013; Celep ve Kumbasar, 2017). Bu depremler sonucunda meydana gelen can ve mal kayıpları, yapıların deprem etkileri altında güvenli davranış göstermesinin zorunluluğunu açıkça göstermektedir. Depreme dayanıklı yapı tasarımı, ülkelerin deprem yönetmelikleri ile tanımlanmakta ve bu yönetmelikler, yaşanan depremlerden elde edilen deneyimler ve bilimsel gelişmeler doğrultusunda sürekli güncellenmektedir. Türkiye'de 1998 Afet Bölgelerinde Yapılacak Yapılar Hakkında Yönetmelik, 1999 depremleri sonrasında revize edilerek 2007 yılında DBYBHY-2007 olarak yürürlüğe girmiştir. Daha sonra, deprem tehlikesinin daha gerçekçi biçimde tanımlanması ve performansa dayalı tasarım yaklaşımının geliştirilmesi amacıyla Türkiye Bina Deprem Yönetmeliği (TBDY-2018) hazırlanarak 2019 yılında yürürlüğe girmiştir. DBYBHY-2007 ile TBDY-2018 arasındaki en temel farklardan biri, deprem etkilerinin tanımlanma biçimidir (AFAD,2018). 2007 yönetmeliğinde deprem bölgesi kavramına dayalı sabit etkin yer ivmesi katsayıları kullanılırken, 2018 yönetmeliğinde yapı konumuna ve yerel zemin koşullarına bağlı, noktasal deprem tehlike parametreleri esas alınmaktadır. Bu durum, aynı yapının farklı lokasyonlarda önemli ölçüde farklı deprem taleplerine maruz kalmasına neden olmaktadır (DBYBHY-2007, TBDY-2018).

Bu çalışmanın amacı, DBYBHY-2007 ve TBDY-2018 yönetmeliklerini deprem yükleri açısından karşılaştırmak ve bu farklılıkların orta katlı betonarme bir konut yapısı üzerindeki etkilerini sayısal olarak ortaya koymaktır. Bu kapsamda, Kocaeli ilinin 12 farklı ilçesinde yer aldığı varsayılan tipik bir betonarme bina her iki yönetmeliğe göre analiz edilmiş ve elde edilen sonuçlar karşılaştırmalı olarak değerlendirilmiştir.

2. UYGULAMA VE YÖNTEM

2.1. DBYBHY-2007'ye Göre Deprem Yüklerinin Belirlenmesi

DBYBHY-2007'de deprem etkileri, deprem bölgelerine bağlı olarak tanımlanan etkin yer ivmesi katsayısı (A_0) kullanılarak belirlenmektedir. Deprem yüklerinin hesabında spektral ivme katsayısı A(T), bina önem katsayısı (I) ve spektrum katsayısı S(T) dikkate alınmaktadır. Elde edilen elastik deprem yükleri, taşıyıcı sistem davranış katsayısı (R) aracılığıyla azaltılarak

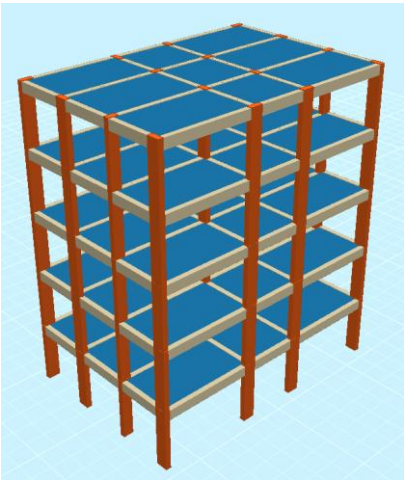
tasarım deprem yükleri elde edilmektedir. Bu çalışmada DBYBHY-2007 kapsamında eşdeğer deprem yükü yöntemi kullanılmıştır. Bu yöntem, belirli yükseklik ve düzensizlik koşullarını sağlayan binalar için pratik ve yaygın olarak kullanılan doğrusal bir analiz yöntemidir (DBYBHY-2007).

2.2. TBDY-2018'e Göre Deprem Yüklerinin Belirlenmesi

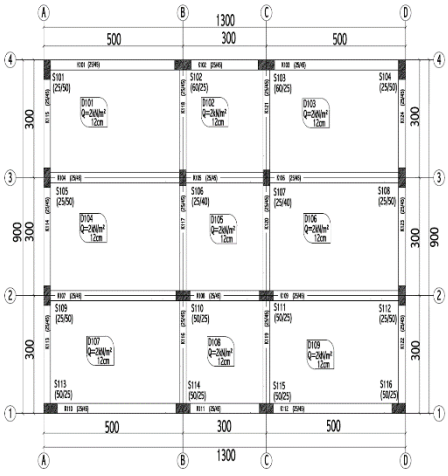
TBDY-2018 ile birlikte Türkiye Deprem Tehlike Haritası (TDTH-2018) yürürlüğe girmiş ve deprem bölgesi kavramı kaldırılmıştır. Yeni yaklaşımda, yapı konumuna bağlı olarak kısa periyot (S_s) ve 1.0 saniye periyot (S_1) harita spektral ivme katsayıları kullanılmaktadır. Bu katsayılar, yerel zemin etki katsayıları (F_s ve F_1) ile çarpılarak tasarım spektral ivme katsayıları (S_{DS} ve S_{D1}) elde edilmektedir. TBDY-2018'de deprem tasarım sınıfları, bina kullanım sınıfları ve bina yükseklik sınıfları gibi yeni kavramlar tanımlanmıştır. Ayrıca göreli kat ötelemeleri, DD-3 deprem yer hareketi düzeyi esas alınarak sınırlandırılmakta ve betonarme taşıyıcı sistemler için farklı rijitlik kabulleri yapılmaktadır (TBDY-2018).

2.3. İncelenen Yapı ve Analiz Yaklaşımı

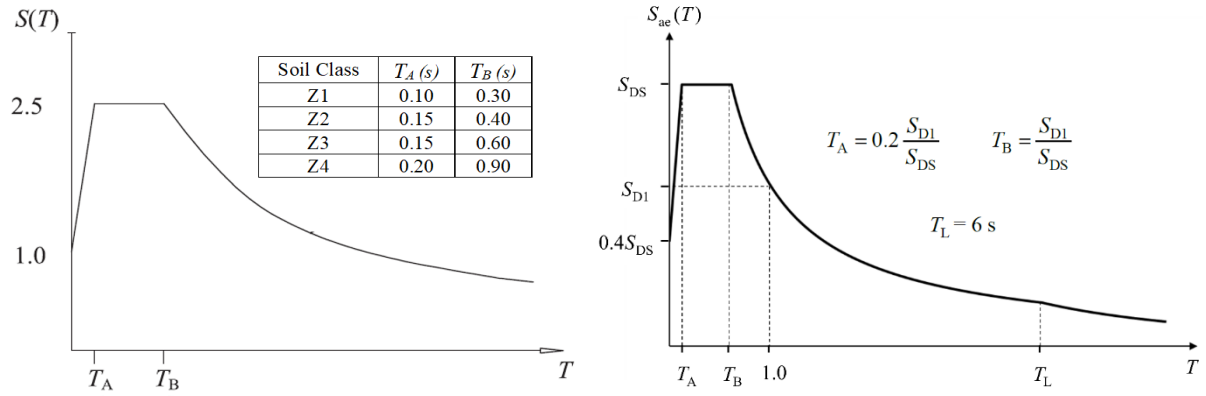
Çalışma kapsamında incelenen yapı, zemin + 4 katlı, simetrik planlı tipik bir betonarme konut binasıdır. Yapı geometrisi, kat yükseklikleri ve malzeme özellikleri her iki yönetmelik için sabit tutulmuştur. Beton sınıfı C30, donatı sınıfı S420 olarak seçilmiş ve taşıyıcı sistem çerçeve sistem olarak modellenmiştir. Yapının iki doğrultuda üç açıklığının bulunduğu ve kat yüksekliğinin 2.9 metre olduğu kabul edilmiştir. Yapının analitik modeli Görsel 1'de kat planı Görsel 2'de verilmiştir. İki yönetmeliğe göre elastik tasarım spektrumları Görsel 3'de, yapıların bulunduğu konumlara ilişkin koordinatlar ise Çizelge 1'de verilmiştir.



Görsel 1. Yapı analitik modeli



Görsel 2. Yapı kat planı



$$S(T) = 1 + 1.5\,\frac{T}{T_A} \qquad (0 \le T \le T_A)$$
$$S(T) = 2.5 \qquad (T_A < T \le T_B)$$
$$S(T) = 2.5\left(\frac{T_B}{T}\right)^{0.8} \qquad (T_B < T)$$

$$S_{ae}(T) = A_0\, I\, S(T) g$$

(a)

$$S_{ae}(T) = \left(0.4 + 0.6\,\frac{T}{T_A}\right) S_{DS} \qquad (0 \le T \le T_A)$$
$$S_{ae}(T) = S_{DS} \qquad (T_A \le T \le T_B)$$
$$S_{ae}(T) = \frac{S_{D1}}{T} \qquad (T_B \le T \le T_L)$$
$$S_{ae}(T) = \frac{S_{D1}\,T_L}{T^2} \qquad (T_L \le T)$$

(b)

Görsel 3. Yönetmeliklere göre tasarım spektrumlar (a) DBYBHY-2007; (b) TBDY 2018

Yapının Kocaeli ilinin Başiskele, Çayırova, Darıca, Derince, Dilovası, Gebze, Gölcük, İzmit, Kandıra, Karamürsel, Kartepe ve Körfez ilçelerinde yer aldığı varsayılmıştır. Analizler Sta4-CAD sonlu elemanlar programı kullanılarak doğrusal yaklaşımla gerçekleştirilmiştir. Yapının periyodu x yönü için 0.68 sn, y yönü için 0.61 sn olarak elde edilmiştir.

Çizelge 1. Yapıların her bir ilçede bulunduğu koordinatlar

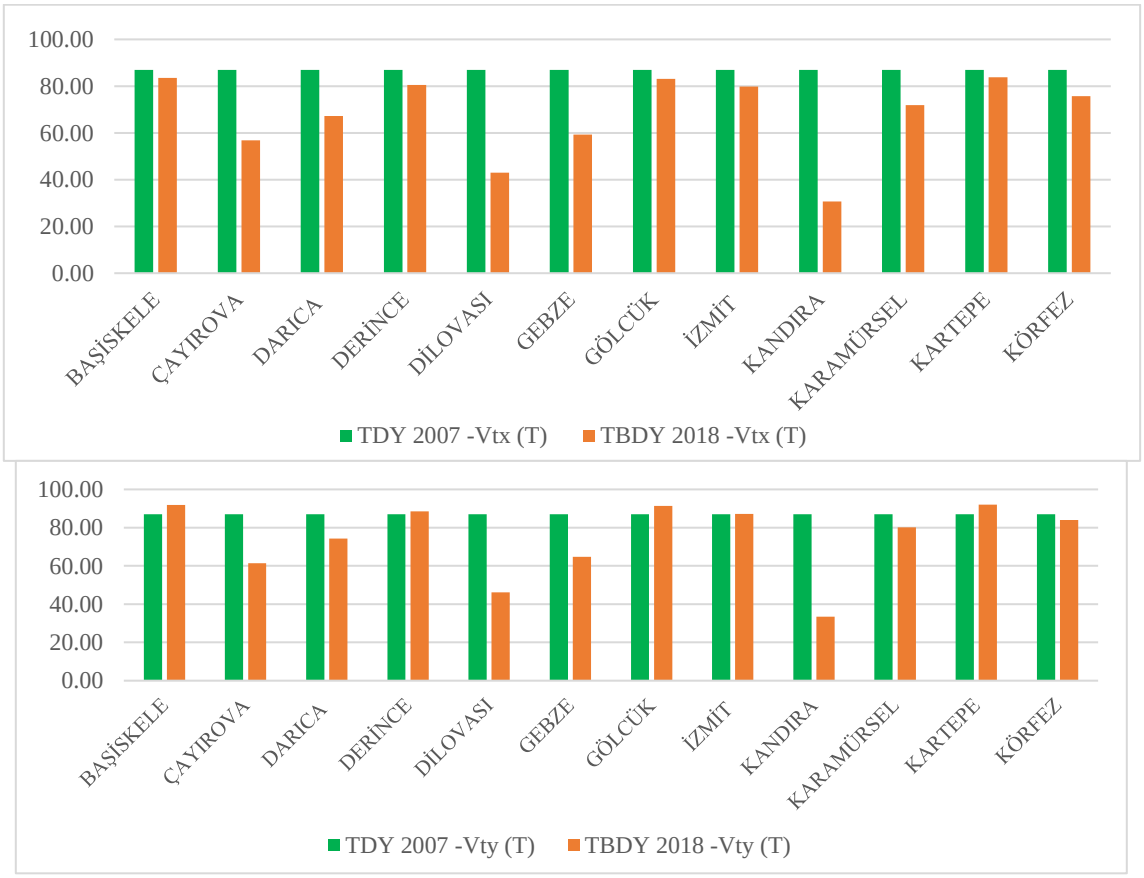
İlçe	Enlem	Boylam	İlçe	Enlem	Boylam
Başiskele	40.74414	29.956734	Gölcük	40.713853	29.818925
Çayırova	40.823552	29.370226	İzmit	40.764306	29.931608
Darıca	40.762124	29.383894	Kandıra	41.070271	30.152946
Derince	40.75765	29.830764	Karamürsel	40.690308	40.690308
Dilovası	40.786185	29.541612	Kartepe	40.752785	30.022734
Gebze	40.806751	29.438992	Körfez	40.776432	29.738166

3. BULGULAR VE DEĞERLENDİRME

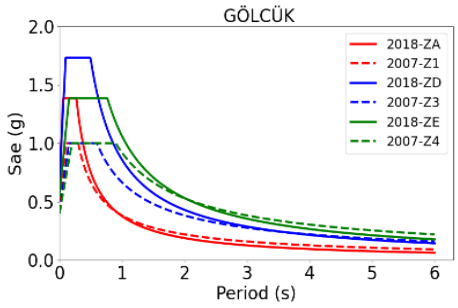
Bu bölümde. DBYBHY-2007 ve TBDY-2018 yönetmeliklerine göre yapılan doğrusal analizler sonucunda elde edilen taban kesme kuvvetleri. düşey taşıyıcı eleman kesit alanları ve göreli kat ötelemeleri karşılaştırmalı olarak sunulmuş ve değerlendirilmiştir. Tüm analizlerde yapı geometrisi ve malzeme özellikleri sabit tutulmuş, yalnızca deprem yükü tanımları ve yönetmelik esasları değiştirilmiştir.

3.1. Taban Kesme Kuvvetlerinin Karşılaştırılması

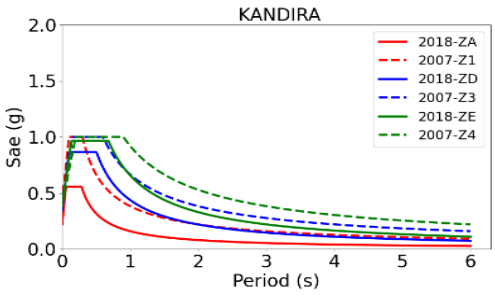
Yapı için hesaplanan toplam taban kesme kuvvetleri X ve Y yönü için Görsel 4'de verilmiştir. X yönünde elde edilen taban kesme kuvvetlerinin DBYBHY-2007'ye göre elde edilen taban kesme kuvvetlerinin TBDY-2018'e göre elde edilenlere göre daha yüksek olduğu görülmektedir. Ancak y yönünde Başiskele, Gölcük ve Kartepe ilçelerinden elde edilen taban kesme kuvvetleri TBDY-2018'de az da olsa daha yüksek çıkmıştır. TBDY-2018'e göre en düşük taban kesme kuvveti Kandıra ilçesinde elde edilmiştir. İki yönetmeliğe göre elde edilen tasarım spektrumlarında oluşan farklılıklar sebebiyledir. Örnek olarak verilen Gölcük ve Kandıra ilçeleri için oluşan tasarım spektrumlarında bu fark görülmektedir.



Görsel 4. Bina için x ve y yönlü taban kesme kuvvetleri



(a)

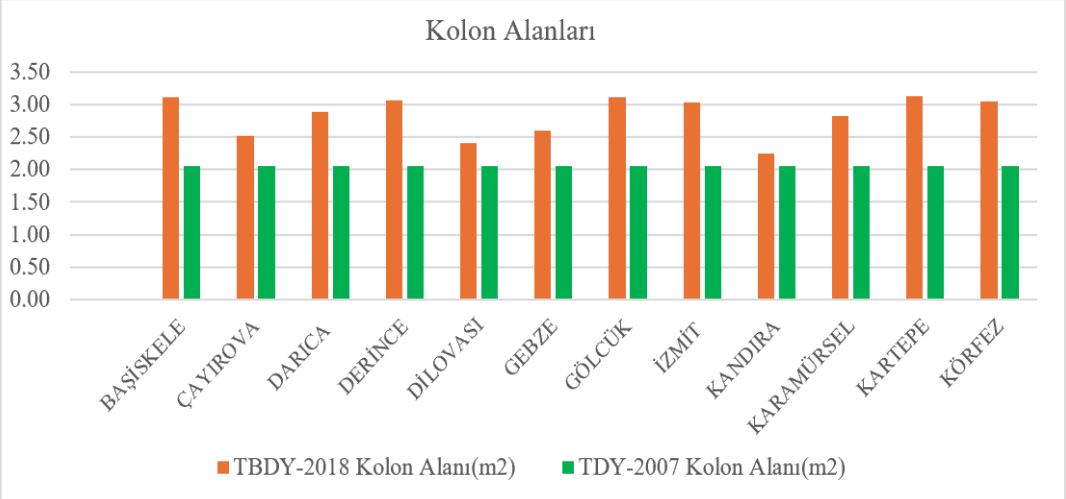


(b)

Görsel 5. Gölcük ve Kandıra ilçeleri için iki yönetmeliğe göre tasarım spektrumları

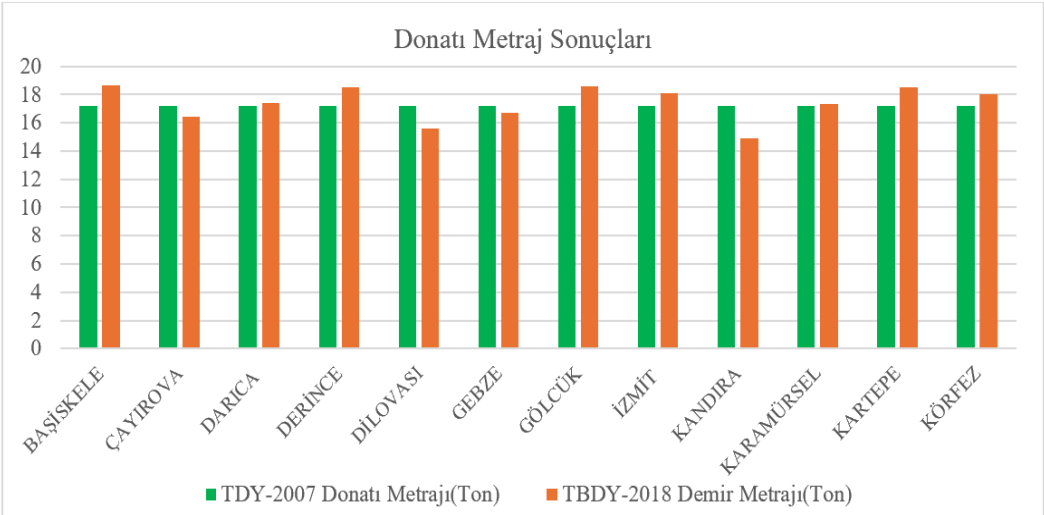
3.2. Düşey Taşıyıcı Eleman Kesit Alanı, Donatı ve Beton Metrajlarının Karşılaştırılması

Her iki yönetmeliğe göre yapılan tasarımlar sonucunda TBDY-2018'e göre tasarlanan yapılarda kolon kesit boyutlarının ve toplam kolon kesit alanlarının arttığı belirlenmiştir (Görsel 6). DBYBHY-2007 kapsamında yapı için toplam kolon kesit alanı daha düşük seviyelerde kalırken, TBDY-2018 kapsamında bu alanların %20–50 aralığında arttığı gözlemlenmiştir. Bu artışın sebebi kolonların minimum boyutlarının TBDY-2018'de daha büyük olmasıdır.

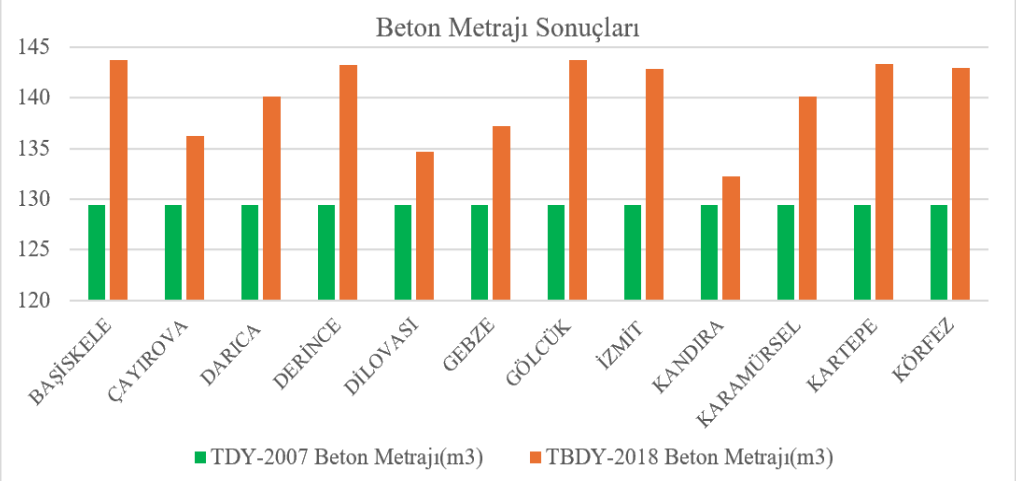


Görsel 6. Düşey taşıyıcı eleman alanlarının karşılaştırılması

İki yönetmeliğe göre binalarda kullanılan donatı alanının miktarının kıyaslanması Görsel 7'de verilmiştir. Bu görsele göre donatı miktarı açısından iki yönetmelik açısından belirgin bir fark olmadığı görülmektedir. Ancak Görsel 8'de verilen beton metrajı açısından bakıldığında TBDY-2018 yönetmeliğine göre tasarlanan yapıda kullanılacak beton miktarının DBYBHY-2007'ye göre tasarlanandan çok daha fazla olduğu görülmektedir.



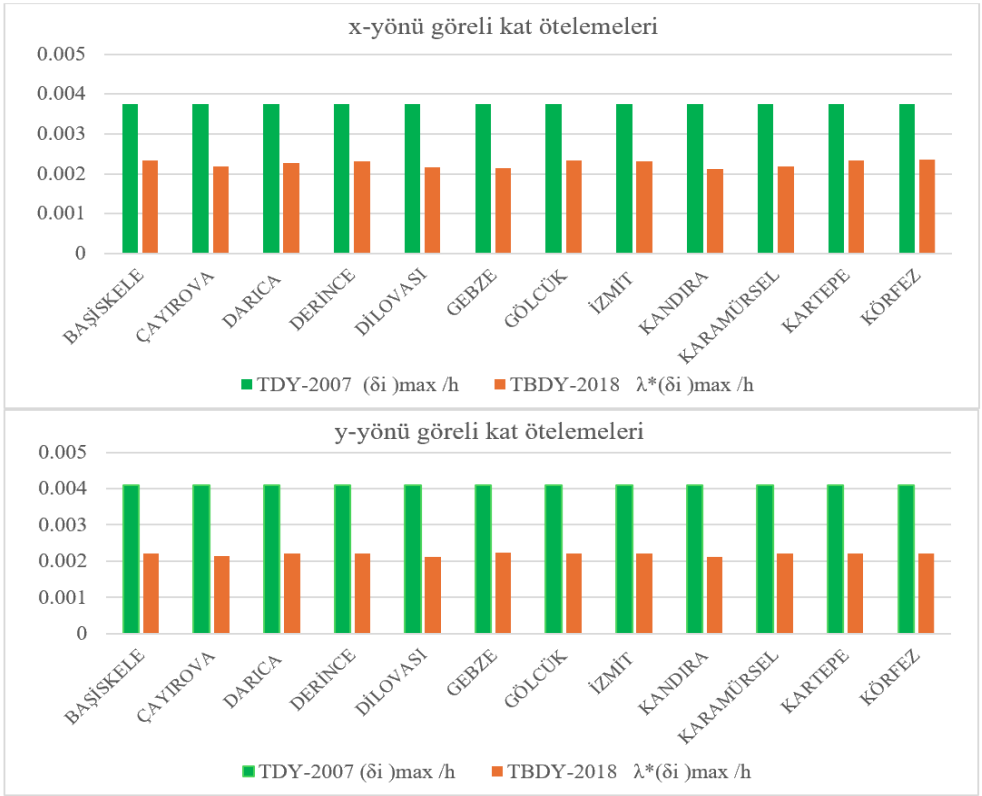
Görsel 7. İki yönetmeliğe göre tasarlanan yapılarda kullanılan donatı miktarının kıyaslanması



Görsel 8. İki yönetmeliğe göre tasarlanan yapılarda kullanılan beton miktarının kıyaslanması

3.3. Göreli Kat Ötelemelerinin Değerlendirilmesi

Göreli kat ötelemeleri açısından yapılan değerlendirmelerde her iki yönetmelik için hesaplanan değerlerin izin verilen sınırlar içerisinde kaldığı belirlenmiştir. Bununla birlikte Görsel 9'dan görüldüğü gibi TBDY-2018'e göre elde edilen göreli kat ötelemelerinin DBYBHY-2007'ye kıyasla daha düşük olduğu görülmüştür. Bunun sebebi TBDY-2018'e bina kat taşıyıcı eleman alanlarının daha büyük dolayısı ile rijitliğinin fazla olmasıdır.



Görsel 8. İki yönetmeliğe göre tasarlanan yapıların göreli kat ötelemelerin kıyaslanması

4. SONUÇLAR

Mevcut halde yürürlükte olan TBDY-2018 ile birlikte deprem bölgesi kavramından vazgeçilerek deprem tehlike haritasından binanın yapılacağı alana özgü ivme değerlerinin seçilerek tasarımda kullanılmasına başlanmıştır. Bu değişiklikle birlikte önceden aynı deprem bölgesinde yer alan tüm yapılar aynı etkin yer ivmesine maruz kalırken yeni yönetmelikle birlikte farklı deprem yüklerine maruz kalır hale gelmiştir. Bu değişimin Kocaeli iline yansımasının incelenmesi hedeflenen bu çalışmada orta katlı bir betonarme yapının Kocaeli ilinin 12 farklı ilçesinde bulunduğu kabul edilerek bu yapı her iki yönetmeliğe göre tasarlanmış ve çalışma sonunda aşağıdaki sonuçlara ulaşılmıştır.

- Yapı için tüm ilçelerde DBYBHY-2007'ye göre x yönü için elde edilen taban kesme kuvvetleri TBDY-2018'e göre elde edilenlerden daha yüksek olduğu görülmektedir. y yönünde Başiskele, Gölcük ve Kartepe ilçelerinden elde edilen taban kesme kuvvetleri TBDY-2018'de az da olsa daha yüksek çıkmıştır. Bu farklılıklar iki yönetmeliğe göre elde edilen tasarım spektrumlarında oluşan farklılıklar sebebiyle oluşmuştur.

- Her iki yönetmeliğe göre yapılan tasarımlar sonucunda TBDY-2018'e göre tasarlanan yapılarda kolon kesit boyutlarının ve toplam kolon kesit alanlarının DBYBHY-2007'ye göre arttığı belirlenmiştir

- İki yönetmeliğe göre tasarlanan yapılarda kullanılacak donatı miktarı açısından belirgin bir fark olmadığı görülmüştür. Beton metrajı açısından bakıldığında TBDY-2018 yönetmeliğine göre tasarlanan yapıda kullanılacak beton miktarının DBYBHY-2007'ye göre tasarlanandan çok daha fazla olacağı tespit edilmiştir.

- TBDY-2018'e göre kolon minimum boyutları dolayısı ile rijitlikleri DBYBHY-2007'ye göre artmış olduğundan TBDY-2018'e göre elde edilen göreli kat ötelemeleri DBYBHY-2007'ye kıyasla daha düşük oluşmuştur.

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YAKIN KAYNAK DEPREMLERİ YÖNELİM ETKİSİNİN TEK SERBESTLİK DERECELİ SİSTEMLERİN TABAN KESME KUVVETLERİNE ETKİSİ

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ÖZET

Bu çalışma yönelim etkisi içeren yakın kaynak yer hareketlerinin tek serbestlik dereceli (TSD) sistemlerde oluşturduğu taban kesme kuvveti taleplerini, yönelim etkisi içermeyen deprem kayıtları ile karşılaştırmalı olarak incelemeyi amaçlamaktadır. Bu kapsamda, kayıt yeri ile deprem odak noktası arasındaki mesafe 20 km'den az olan yakın saha koşullarında kaydedilmiş, benzer büyüklük, fay uzaklığı ve zemin koşullarına sahip 10 adet yönelim etkisi özellikli deprem kaydı içeren, 10 adet yönelim etkisi içermeyen deprem kayıtlarından oluşan iki ayrı deprem kayıt seti oluşturulmuştur. Her bir deprem kaydı kullanılarak TSD bir sistemin zaman tanım alanında doğrusal dinamik analizleri gerçekleştirilmiştir. Analizler sonucunda elde edilen maksimum taban kesme kuvvetleri, periyoda bağlı olarak karşılaştırılmış; yönelim etkisi içeren ve içermeyen kayıt setlerinin oluşturduğu talepler istatistiksel göstergeler yardımıyla incelenmiştir. Elde edilen bulgular, yönelim etkisi içeren yakın kaynak yer hareketlerinin özellikle belirli periyot aralıklarında TSD sistemlerde daha yüksek taban kesme kuvveti taleplerine yol açtığını ve bu etkinin yönelim etkisi içermeyen kayıtlara kıyasla belirgin farklılıklar oluşturduğunu göstermektedir. Çalışma, yakın kaynak ve yönelim etkilerinin doğrusal sistem talepleri üzerindeki rolünü ortaya koyarak, deprem mühendisliği uygulamalarında kayıt seçimi ve sismik talep değerlendirmelerine katkı sağlamayı hedeflemektedir.

Anahtar Kelimeler: Yönelim etkisi, yakın kaynak deprem kayıtları, doğrusal analiz, tek serbestlik dereceli sistem, taban kesme kuvveti.

INFLUENCE OF NEAR-FAULT DIRECTIVITY EFFECTS ON BASE SHEAR DEMANDS OF SINGLE-DEGREE-OF-FREEDOM SYSTEMS

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ABSTRACT

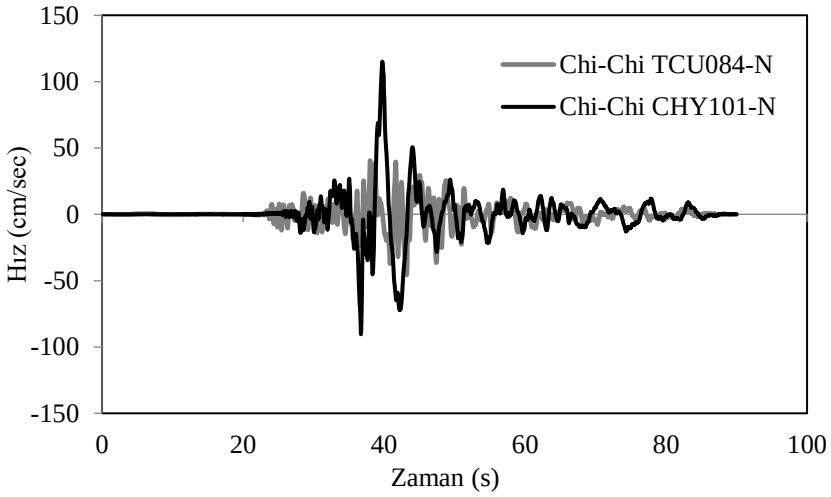
This study investigates the influence of near-fault ground motions exhibiting forward directivity (FD) effects on base shear force demands of single-degree-of-freedom (SDOF) systems, in comparison with near-fault earthquake records without FD effects. For this purpose, two distinct ground motion sets were compiled: one consisting of 10 near-fault records with pronounced FD characteristics and another comprising 10 near-fault records without FD effects. All records were selected under comparable conditions in terms of earthquake magnitude, fault distance, soil properties, and a source-to-site distance of less than 20 km. Linear time-history analyses were conducted on SDOF systems each ground motion record. The resulting maximum base shear demands were evaluated as a function of the structural period, and the responses obtained from the FD and non-FD record sets were comparatively assessed using statistical indicators. The results demonstrate that near-fault ground motions with FD effects generate significantly higher base shear demands in SDOF systems, particularly within specific period ranges, compared to records without FD effects. These findings highlight the critical role of near-fault directivity in seismic demand estimation and contribute to improved ground motion selection and seismic performance assessment in earthquake engineering applications.

Keywords: Forward directivity effects, near-fault ground motion, single-degree-of-freedom systems, base shear demand, linear time-history analysis

1. GİRİŞ

Yapı tasarımda dikkate alınması gereken en önemli parametrelerden biri tasarımda kullanılan deprem kayıtları olup her depremin kendine has karakteristik özellikleri bulunmaktadır. Bu karakteristik özelliklerden hangilerinin yapı davranışında ne şekilde rol alacağı hakkında net bir görüş birliği bulunmamaktadır. Bu sebeple deprem karakteristik özellikleri hakkında geçmişte ve günümüzde çok sayıda çalışma yapılmaktadır ve yapılmaya devam etmektedir. Meydana gelen her bir deprem farklı kaynak mekanizması, ortam yayılım ve yerel zemin etkilerine göre farklı özellikler ihtiva etmektedir. Bu sebeple elde edilen kaydın hız, ivme ve deplasman geçmişleri farklı karakteristik özellikler göstermektedirler. Sayılan bu farklılıklar sebebiyle depremler de birbirine göre yapılarda farklı tepkilere sebep olabilmektedir. Bu farklılıklardan başka, incelenecek yapının deprem merkezine olan mesafesi de yakın veya uzak ortam diye tanımlanabilecek bir diğer faktörün göz önüne alınmasını gerektirmektedir. Dolayısıyla farklı ivme kayıtları ile yapılan analizlerden elde edilen sonuçlar da yapılar açısından farklılıklar göstermektedir (Engin, 2014).

Kaydın yakın sahadan kaydedilmiş olmasının yanı sıra kaydın içeriği de yapının davranışını önemli ölçüde etkilemektedir. Kaydedilmiş deprem kaydının yapı davranışını etkileyen en karakteristik özelliklerinden biri kaydın içeriğinde yer alan yönelim etkisi (YE) özelliğidir.



Görsel 1. YE içeren ve içermeyen deprem kayıtları

Metin tarafından yapılan çalışmada [2] fay yüzey kırığından yerleşim alanına doğru, yüksek hızdaki deprem hareketi yayılımının fay normali doğrultusunda yüksek genlikli itkiye sebep olduğu ve bu etkinin de yönelim olarak adlandırıldığını belirtmiştir. Bunun yanında, Mavroeidis [3] yaptığı çalışma ile yönelim etkisini, kaydın başlangıcındaki yoğun periyot ile uyumlu olarak faydaki elastik enerjinin hemen hemen tümünün sismik yayılımı olarak tanımlamıştır. Deprem

hareketi yayılımının çalışılan alana doğru olması durumunda YE'nin görüldüğü, bunun tersine deprem hareketi yayılımının alandan uzaklaşması durumunda YE gözlenmediği söylenebilmektedir. YE içeren ve içermeyen iki deprem ivme zaman geçmişi aşağıda yer alan Görsel 1'de verilmiştir. Bu şekilde sunulan deprem kayıtları 1991 Chi-Chi depremine ait TCU084-N ve CHY101-N istasyonlarındaki deprem kaydının ivme-zaman grafiğidir. Görselde de görüldüğü üzere CHY101-N istasyonuna ait kayıtın kırılma yönünde ileri etkiye sahip olduğu yani YE içeren bir deprem kaydı olduğu görülmektedir. TCU084-N istasyonuna ait deprem kaydının ise tersi bir şekilde YE içermeyen bir deprem kaydı olduğu görülmektedir.

Bu çalışmada YE içeren ve içermeyen farklı zemin sınıfından kayıtlardan oluşan dört farklı kayıt seti oluşturulup bu setlerde yer alan depremler kullanılarak, tek serbestlik dereceli (TSD) sistemin dinamik analizleri gerçekleştirilmiştir. Analizler sonucunda yapının taban kesme kuvvetleri elde edilmiş, elde edilen taban kesme kuvvetleri kıyaslanarak zemin sınıfının ve deprem kaydı YE içeriğinin yapıda oluşacak deprem kuvvetine etkisi tartışılmıştır.

2. YÖNTEM

Çalışmanın bu bölümünde seçilen deprem kayıtları, TSD sistem yapının özellikleri, yapılan analizler ve analizlerden elde edilen veriler sunulmuştur.

2.1. Seçilen Deprem Kayıtları

Türkiye'de mevcut halde yürürlükte olan deprem yönetmeliğine göre (TBDY-2018) göre zemin dalgası kayma hızı (Vs30) 0 ile 180 m/sn arasında yer alan zemin sınıfı ZE, 180 ile 360 m/sn arasında olan zemin sınıfı ZD, 360 ile 760 m/sn arasında olan zemin sınıfı ZC, 760 ile 1.500 m/sn arasında olan kayıtlar ZB, 1.500 m/sn'den büyük olan kayıtlar ise ZA zemin sınıfında yer almaktadır. Bu çalışmada benzer deprem moment büyüklüğü, kayıt yeri ile deprem odak noktası arasındaki mesafesi (<20 km) benzer olan kayıtlar ile dinamik analizlerde kullanılmak ZC zemin sınıfından YE içeren ve içermeyen; ZD zemin sınıfından YE içeren ve içermeyen olmak üzere dört farklı kayıt seti oluşturulmuştur. Analizde kullanılacak deprem ivme kayıtları, PEER [1] veri tabanından elde edilmiştir.

Çizelge 1'de YE içeren ZC zemin sınıfından alınan deprem kayıtları verilmiştir. Tablodaki ilk sütun kaydın PEER veri tabanındaki kayıt numarasını, ikinci sütun depremi, üçüncü sütun kaydın alındığı istasyonu, dördüncü sütun deprem olduğu yılı, beşinci sütun zemin sınıfını, sondan ikinci sütun depremim moment büyüklüğünü, son sütun ise deprem odak noktası ile kayıt yeri arasındaki mesafeyi göstermektedir. Bu sette deprem büyüklükleri Mw = 6.00 ile

Mw = 7.62 arasında, kırılan fay yüzeyi ile kayıt seti arasındaki mesafe Rjb = 0.00 ile Rjb = 9.85 km arasında, zemin ortalama kayma dalgası hızı (Vs)30 = 380.89 ile (Vs)30 = 717.00 m/s arasında değişmektedir.

Çizelge 1. YE içeren ZC zemin sınıfı deprem kayıtları

RSN	Deprem	İstasyon	Yıl	Zemin Sınıfı	Mw	Rjb (km)
292	Irpinia, Italy-01	Sturno (STN)	1980	ZC	6.90	6.78
459	Morgan Hill	Gilroy Array #6	1984	ZC	6.19	9.85
802	Loma Prieta	Sara.-Aloha Ave	1989	ZC	6.93	7.58
1493	Chi-Chi, Taiwan	TCU053	1999	ZC	7.62	5.95
1510	Chi-Chi, Taiwan	TCU075	1999	ZC	7.62	0.89
4103	Parkfield-02, CA	Parkfield-Cho. 4W	2004	ZC	6.00	3.3
8164	Düzce, Turkey	IRIGM 487	1999	ZC	7.14	2.65
1489	Chi-Chi, Taiwan	TCU049	1999	ZC	7.62	3.76
3473	Chi-Chi, Taiwan-06	TCU078	1999	ZC	6.30	5.72
4482	L'Aquila, Italy	L'Aquila - V. Aterno	2009	ZC	6.30	0.0
4483	L'Aquila, Italy	L'Aquila - Parking	2009	ZC	6.30	0.0

Çizelge 2'de YE içeren ZC zemin sınıfından alınan deprem kayıtları verilmiştir. Bu setteki Mw = 6.00 ile 7.35, Rjb = 0.00 ile 23.46 km, (Vs)30 = 381.27 ile 729.65 m/s arasındadır. Çizelge 3'de YE içeren ZD zemin sınıfı deprem kayıtları verilmiş olup burada Mw = 6.00 ile 7.62, Rjb = 0.00 ile 12.02 km, (Vs)30 = 202.89 ile 344.02 m/s arasında değişmektedir.

Çizelge 2. YE içermeyen ZC zemin sınıfı deprem kayıtları

RSN	Deprem	İstasyon	Yıl	Zemin Sınıfı	Mw	Rjb (km)
139	Tabas, Iran	Dayhook	1978	ZC	7.35	0.0
587	New Zealand-02	Matahina Dam	1987	ZC	6.60	16.09
763	Loma Prieta	Gilroy - Gavilan Coll.	1989	ZC	6.93	9.19
3750	Cape Mendocino	Loleta Fire Station	1992	ZC	7.01	23.46
4864	Chuetsu-oki, Jap.	Yoitamachiy Yoita	2007	ZC	6.80	4.69
5678	Iwate, Japan	MYGH02	2008	ZC	6.90	5.09
125	Friuli, Italy-01	Tolmezzo	1976	ZC	6.50	14.97
230	Mammoth Lakes-01	Convict Creek	1980	ZC	6.06	1.1
4481	L'Aquila, Italy	L'Aquila - V. Aterno	2009	ZC	6.30	0.0
4130	Parkfield-02, CA	Parkfield - Vineyard	2004	ZC	6.00	1.59
139	Tabas, Iran	Dayhook	1978	ZC	7.35	0.0

Çizelge 3. YE içeren ZD zemin sınıfı deprem kayıtları

RSN	Deprem	İstasyon	Yıl	Zemin Sınıfı	Mw	Rjb (km)
171	Imperial Valley-06	El Centro-Mel.Geo.A	1979	ZD	6.53	0.07
179	Imperial Valley-06	El Centro Array #4	1979	ZD	6.53	4.9
185	Imperial Valley-06	Holtville Post Office	1979	ZD	6.53	5.35
1244	Chi-Chi. Taiwan	CHY101	1999	ZD	7.62	9.94
4098	Parkfield-02. CA	Parkfield - Cholame	2004	ZD	6.00	1.66
4102	Parkfield-02. CA	Parkfield - Cholame	2004	ZD	6.00	2.55
4115	Parkfield-02. CA	Parkfield - Fault Zone	2004	ZD	6.00	0.88
6897	Darfield. New Z.	DSLC	2010	ZD	7.00	5.28
6906	Darfield. New Z.	GDLC	2010	ZD	7.00	1.22
1602	Düzce. Turkey	Bolu	1999	ZD	7.14	12.02
6962	Darfield. New Z.	ROLC	2010	ZD	7.00	0.00

Çizelge 4'de YE içermeyen ZD zemin sınıfından alınan deprem kayıtları verilmiştir. ZD zemin sınıfına ait YE içermeyen kayıt setinde deprem büyüklükleri Mw = 6.20 ile 7.20, kırılan fay

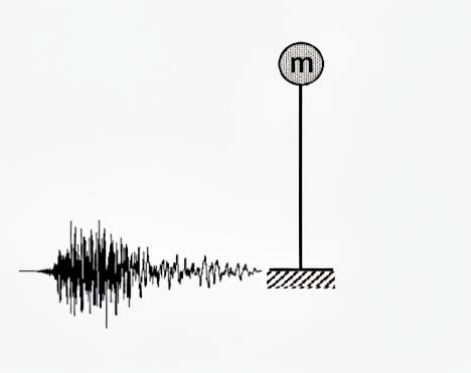
yüzeyi ile kayıt seti arasındaki mesafe Rjb = 3.3 ile 24.55 km, (Vs)30 = 187.00 ile 355.18 arasında değişmektedir.

Çizelge 4. YE içermeyen ZD zemin sınıfı deprem kayıtları

RSN	Deprem	İstasyon	Yıl	Zemin Sınıfı	Mw	Rjb (km)
3749	Cape Mendocino	Fortuna Fire Station	1992	ZD	7,01	16,54
5825	El Mayor-Cucapah	Cerro Prieto Geo.	2010	ZD	7,20	8,88
6975	El Mayor-Cucapah	Calexico Fire Station	2010	ZD	7,20	19,12
6953	Darfield, New Z.	Pages Road Pum. Sta.	2010	ZD	7,00	24,55
6	Imperial Valley-02	El Centro Array #9	1940	ZD	6,95	6,09
6890	Darfield, New Z.	Christ.Cas.High Sch.	2010	ZD	7,00	17,64
8124	Christchurch,New Z.	Riccarton High Sch.	2011	ZD	6,20	9,43
1082	Northridge-01	Sun Valley-Roscoe B.	1994	ZD	6,69	5,59
949	Northridge-01	Arleta-Nordhoff Fire	1994	ZD	6,69	3,3
4860	Chuetsu-oki, Japan	Sanjo Shinbori	2007	ZD	6,80	15,89
8063	Christchurch,New Z.	Christchurch Bot.Gar.	2011	ZD	6,20	5,52

2.2. Yapılan Analizler

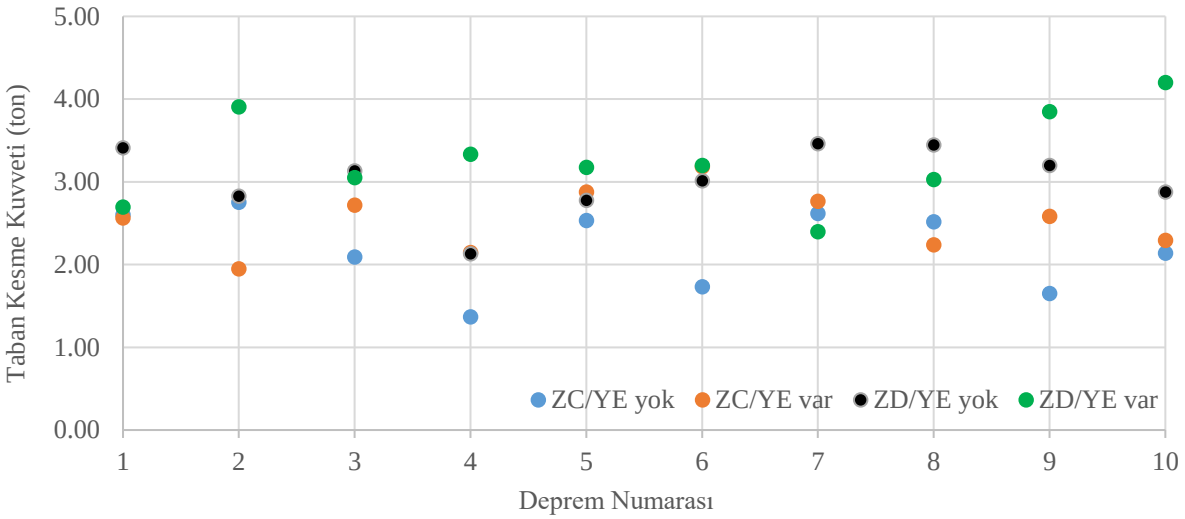
Seçilen deprem kayıtları kullanılarak aşağıda şematik gösterimi verilen TSD bir sistemin dinamik analizleri gerçekleştirilmiştir. Yapının periyodu T=0.6 saniye olarak seçilmiş ve kütlenin 5 ton olduğu kabul edilmiştir. Yapılan analizler sonucunda deprem kaydının iki bileşeni için sistemin taban kesme kuvveti elde edilerek ortalaması bileşenlerin karesinin toplamının karekökü alınarak belirlenmiştir.



Görsel 2. Çalışmada kullanılan TSD sistemin şematik gösterimi

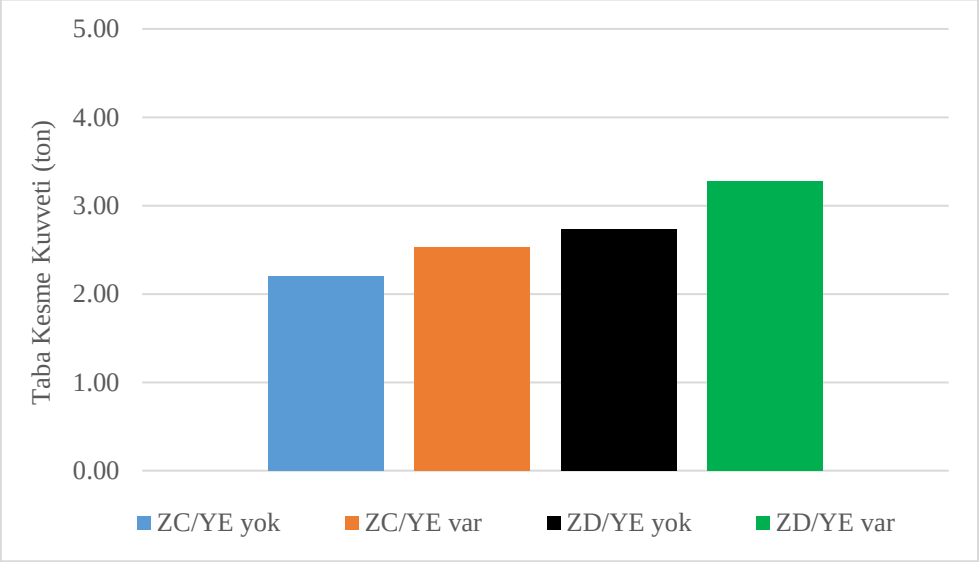
3. BULGULAR VE TARTIŞMA

Her bir kayıt setinde bulunan deprem kayıtları için hesaplanan taban kesme kuvvetleri Görsel 3'de verilmiştir. Görselde mavi noktalar ZC zemin sınıfında YE içermeyen depremlerin, turuncu noktalar aynı zeminde YE içeren kayıtların, siyah noktalar ZD zemindeki YE içermeyen, yeşil noktalar ise aynı zeminde YE içeren deprem kayıtlarının sonuçlarını göstermektedir.



Görsel 3. Her bir setteki deprem kaydı için taban kesme kuvvetleri

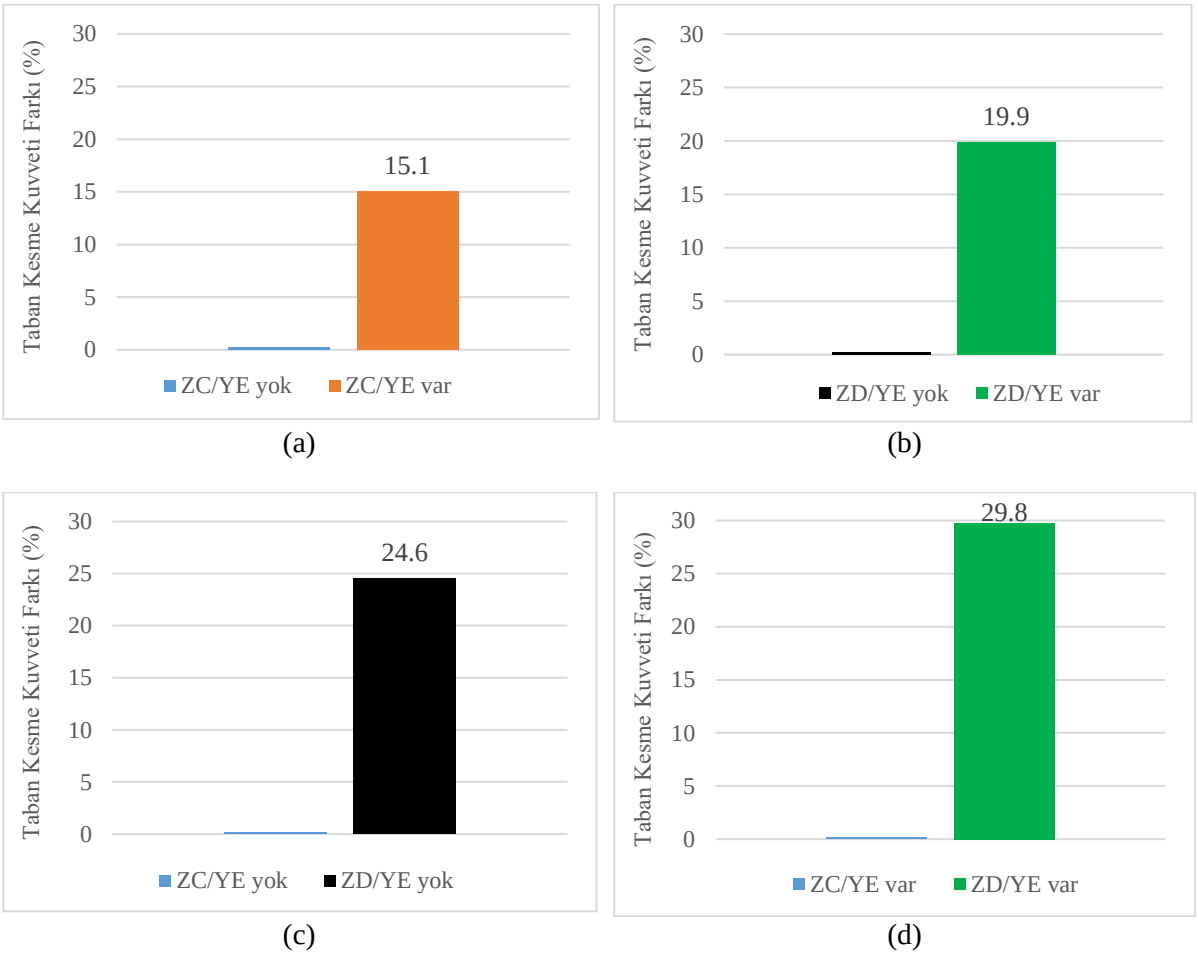
Görsel 4'de her bir sette yer alan depremler için elde edilen taban kesme kuvvetlerinin ortalaması verilmiştir. Grafikten en düşük taban kesme kuvvetinin ZC zemin sınıfında YE olmayan sette, sonrasında aynı zeminde YE içeren kayıtlarda, devamında sırasıyla ZD zemin grubunda YE olmayan ve olan deprem setlerinde artışın devam ettiği görülmektedir.



Görsel 4. Her bir deprem setin ortama ortalama taban kesme kuvvetleri

Kayıt setlerinin karşılaştırmalı analizi Görsel 5'de verilmiştir. Görsel 5(a)'da yer alan grafikten görüldüğü üzere ZC zemin sınıfının YE içermesi durumunda yapıdaki taban kesme kuvveti YE içermeyen sete göre %15.1 daha yüksek olmuştur. Görsel 5(b)'den ZD zemin grubunda YE'nin taban kesme kuvvetini %19.9 oranında arttırdığı görülmektedir. YE içermeyen ZC ve ZD zemin gruplarının kıyaslanmasından ZD zemin sınıfından elde edilen taban kesme kuvvetinin ZC

zemine göre %24.6 oranında fazla olduğu gözlemlenmektedir. Görsel 5(d)'ye göre YE içeren kayıtlarda ZD zemin grubundaki kesme kuvveti ZC zemine göre %29.8 daha fazla gerçekleşmiştir.



Görsel 5. Kayıt setlerinden elde edilen kuvvetlerin kıyaslanması

4. SONUÇLAR

Deprem kaydı yönelim etkisi ve zemin sınıfının TSD sistemin taban kesme kuvvetine etkisinin incelenmesi hedeflenen bu çalışmada ZC ve ZD zemin sınıfından YE içeren ve içermeyen deprem kayıtları içeren dört farklı deprem kaydı seti oluşturulmuştur. Seçilen deprem kayıtları kullanılarak TSD sistemin dinamik analizleri gerçekleştirilerek taban kesme kuvvetleri elde edilmiştir. Çalışma sonunda aşağıdaki sonuçlara ulaşılmıştır.

- Kayıt setlerinde elde edilen en küçük taban kesme kuvveti ZC zemin sınıfında YE içermeyen sette oluşmuş, taban kesme kuvvetleri sırasıyla ZC zeminde YE içeren, ZD zeminde YE içermeyen ve ZD zeminde YE içeren kayıt setine doğru artmaya devam etmiştir.

- ZC zemin sınıfında YE içeren kayıtlardan elde edilen taban kesme kuvveti YE içermeyen sete göre %15.1 daha yüksek olmuştur.

- ZD zemin grubunda YE'nin taban kesme kuvvetini %19.9 oranında arttırdığı görülmüştür.

- YE içermeyen ZC ve ZD zemin gruplarının kıyaslanması sonucunda, ZD zemin sınıfından elde edilen taban kesme kuvvetinin ZC zemine göre %24.6 oranında fazla olduğu gözlemlenmiştir.

- YE içeren kayıtlarda ZD zemin grubundaki kesme kuvveti ZC zemine göre %29.8 daha fazla gerçekleşmiştir.

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ATIKSU ARITMA TESİSLERİNİN PERFORMANS DEĞERLENDİRMESİ VE HİDROLİK MODELLEMESİNDE İSTATİSTİKSEL VE YAPAY ZEKÂ TABANLI YAKLAŞIMLAR

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ÖZET
Su kaynaklarının korunması ve atıksu arıtma tesislerinin sürdürülebilir işletimi, hidrolik ve biyolojik süreçlerin karmaşıklığı nedeniyle ileri modelleme tekniklerine ihtiyaç duymaktadır. Bu çalışma, atıksu yönetiminde kullanılan deneysel analizler ile veri odaklı yapay zekâ yaklaşımlarını sentezleyerek, tesis performansının ve çevresel etkilerin değerlendirilmesindeki güncel metodolojileri ortaya koymaktadır. Arıtılmış atıksuların tarımsal sulamada yeniden kullanımı, toprak gözenekliliğini ve doymuş hidrolik iletkenliği değiştirerek drenaj ve yüzey akış dinamiklerini etkileyebilmektedir. Tesis içi süreçlerin izlenmesinde ise Temel Bileşen Analizi gibi çok değişkenli istatistiksel yöntemler, büyük ve karmaşık veri setlerini basitleştirerek mevsimsel yük değişimlerini ve arıtma verimliliğini karakterize etmede kritik rol oynamaktadır. Çalışma ayrıca, giriş debisi ve çıkış suyu kalitesinin tahmin edilmesinde yapay zekâ algoritmalarının etkinliğini vurgulamaktadır. Destek vektör makineleri ve genetik algoritma destekli hibrit modellerin, klasik mekanistik modellere kıyasla debi dalgalanmalarını ve şok yüklemeleri daha yüksek doğrulukla tahmin ettiği görülmüştür. Bununla birlikte, faktör analizi ile entegre edilen makine öğrenmesi modelleri, veri gürültüsünü minimize ederek toplam azot gibi hassas parametrelerin gerçek zamanlı tahminini iyileştirmektedir. Sonuç olarak, hidroloji ve hidrolik prensiplerin büyük veri analitiği ve yapay zekâ teknolojileri ile entegrasyonu; arıtma tesislerinin operasyonel güvenilirliğini artırmak, enerji maliyetlerini optimize etmek ve alıcı ortam kalitesini korumak için önemli bir yaklaşım olarak öne çıkmaktadır.
Anahtar Kelimeler: Atıksu Arıtma Tesisleri, Hidrolik Modelleme, Makine Öğrenmesi, Tesis Performans Değerlendirmesi

STATISTICAL AND ARTIFICIAL INTELLIGENCE-BASED APPROACHES IN PERFORMANCE EVALUATION AND HYDRAULIC MODELING OF WASTEWATER TREATMENT PLANTS

ABSTRACT
The conservation of water resources and the sustainable operation of wastewater treatment plants require advanced modeling techniques due to the complexity of hydraulic and biological

processes. This study synthesizes experimental analyzes used in wastewater management with data-driven artificial intelligence approaches, presenting current methodologies for evaluating facility performance and environmental impacts. The reuse of treated wastewater in agricultural irrigation can affect drainage and surface runoff dynamics by altering soil porosity and saturated hydraulic conductivity. In monitoring on-site processes, multivariate statistical methods such as Principal Component Analysis play a critical role in characterizing seasonal load changes and treatment efficiency by simplifying large and complex datasets. The study also highlights the effectiveness of artificial intelligence algorithms in predicting influent flow and effluent water quality. It has been observed that Support Vector Machines and hybrid models powered by genetic algorithms predict flow fluctuations and shock loads with higher accuracy compared to classical mechanistic models. However, machine learning models integrated with factor analysis improve the real-time prediction of sensitive parameters like total nitrogen by minimizing data noise. In conclusion, the integration of hydrological and hydraulic principles with big data analytics and artificial intelligence technologies stands out as a significant approach to enhance the operational reliability of treatment plants, optimize energy costs, and protect receiving water quality.

Keywords: Wastewater Treatment Plants, Hydraulic Modeling, Machine Learning, Plant Performance Evaluation

1. GİRİŞ

Su kaynaklarının sürdürülebilir yönetimi ve çevre sağlığının korunması açısından atıksu yönetimi, inşaat ve çevre mühendisliğinin en kritik alanlarından birini oluşturmaktadır. Atıksu arıtma tesislerinin tasarımı ve işletilmesi, hidroloji ve hidrolik prensiplerine dayalı karmaşık süreçleri içermekte olup, bu süreçlerin başarısı büyük ölçüde giriş debisi ve kirlilik yüklerinin doğru tahmin edilmesine bağlıdır. Geleneksel olarak, atıksu sistemlerinin analizi mekanistik modellere dayanmakla birlikte, son yıllarda veri odaklı yaklaşımlar ve çok değişkenli istatistiksel yöntemler, sistemlerin dinamik yapısını anlamada önemli bir alternatif haline gelmiştir. Özellikle arıtılmış atıksuların sulama amaçlı yeniden kullanımı gibi uygulamalarda, toprağın hidrolik iletkenliği üzerindeki etkilerin anlaşılması, suyun yeraltına sızma ve drenaj kapasitesinin korunması açısından hayati önem taşımaktadır. Örneğin, arıtılmış atıksu ile yapılan sulamaların, toprak gözenek yapısında değişikliklere yol açarak doymuş hidrolik iletkenliği (Ksat) önemli ölçüde azalttığı ve bunun da yüzey akış ve taşkın risklerini artırabileceği gözlemlenmiştir (Gonçalves vd., 2007). Benzer şekilde, foseptik sistemlerin çevresindeki zeminlerin hidrolik davranışı incelendiğinde, zemin tekstürü ve organik madde birikiminin infiltrasyon kapasitesini doğrudan etkilediği belirlenmiştir (Ganiyu vd., 2018).

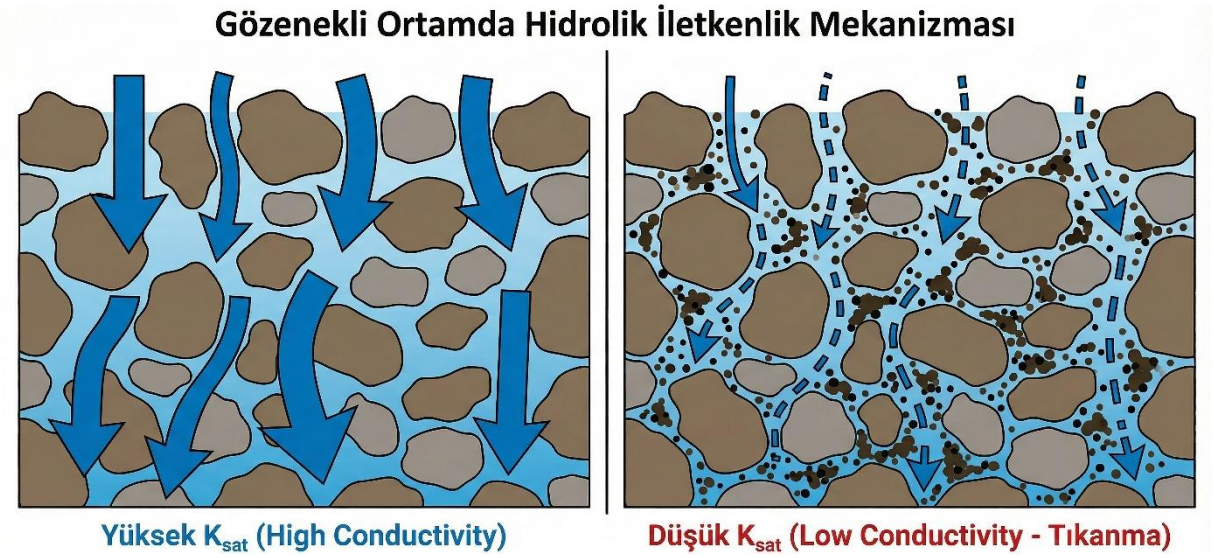
Öte yandan, atıksu arıtma tesislerinin performansının izlenmesi, büyük miktarda verinin analizini gerektiren zorlu bir süreçtir. Tesislerin verimliliğini etkileyen debi dalgalanmaları, yağış olayları ve kirletici konsantrasyonlarındaki değişimler, işletmeciler için sürekli bir belirsizlik kaynağı oluşturmaktadır. Bu bağlamda, büyük veri analitiği ve istatistiksel araçlar, ham veriyi anlamlı bilgilere dönüştürerek operasyonel kararları desteklemektedir (Wongburi & Park, 2021). Ayrıca, merkezi arıtma tesisleri ile yerinde (on-site) arıtma sistemlerinin karşılaştırılması, farklı ölçeklerdeki hidrolik ve biyolojik performansın değerlendirilmesi açısından önem arz etmektedir. Aerobik arıtma üniteleri gibi gelişmiş yerinde sistemlerin,

konvansiyonel aktif çamur sistemlerine benzer kalitede çıkış suyu üretebildiği, ancak septik sistemlerin performansının daha düşük kaldığı belirtilmektedir (Garcia vd., 2013).

Bu çalışma kapsamında, atıksu arıtma süreçlerinin hidrolik ve kalite parametrelerinin modellenmesinde kullanılan güncel yaklaşımlar sentezlenmiştir. Özellikle, giriş debisinin tahmini ve tesis performansının değerlendirilmesinde kullanılan yapay sinir ağları, destek vektör makineleri ve bulanık mantık gibi yapay zekâ tekniklerinin yanı sıra, Temel Bileşen Analizi (PCA) gibi çok değişkenli istatistiksel yöntemlerin etkinliği incelenmiştir. Amaç, hidroloji ve su kaynakları mühendisliği perspektifinden, atıksu sistemlerinin daha verimli ve öngörülebilir bir şekilde yönetilmesine katkı sağlayacak metodolojik yaklaşımları ortaya koymaktır.

2. LİTERATÜR ARAŞTIRMASI VE METEDOLOJİSİ

Atıksu arıtma sistemlerinin karmaşık yapısını ve hidrolik davranışlarını çözümlemek amacıyla literatürde deneysel ve hesaplamalı olmak üzere iki temel metodolojik yaklaşım öne çıkmaktadır. Deneysel çalışmalarda, Ganiyu ve ark. (2018) tarafından detaylandırıldığı üzere, özellikle foseptik sistemleri çevresindeki zeminlerin hidrolik özelliklerinin belirlenmesi için, farklı lokasyonlardan alınan zemin numuneleri üzerinde fizikokimyasal analizler gerçekleştirilmekte ve bu veriler çoklu doğrusal regresyon analizleri ile doymuş hidrolik iletkenliğin (Ksat) tahmin edilmesinde kullanılmaktadır (Ganiyu vd., 2018) (Görsel 1). Benzer şekilde, yapay sulak alanların performansının değerlendirildiği çalışmalarda, yatay ve düşey akışlı sistemlerin kirletici giderim verimleri, bitki biyokütle üretimi ve hidrolik bekletme süreleri gibi parametreler üzerinden karşılaştırmalı olarak analiz edilmektedir (Verma & Suthar, 2018). Bu tür deneysel veriler, sistemin fiziksel davranışını anlamak için temel teşkil ederken, elde edilen büyük veri setlerinin işlenmesi için ileri istatistiksel yöntemlere ihtiyaç duyulmaktadır.



Görsel 1 Gözenekli ortamda hidrolik iletkenliği etkileyen parametrelerin şematik gösterimi

Hesaplamalı yöntemler tarafında ise, atıksu arıtma tesislerinden elde edilen zaman serisi verilerinin analizi için çeşitli yapay zekâ ve makine öğrenmesi algoritmaları kullanılmaktadır. Örneğin, giriş debisinin tahmini için Grup Veri İşleme Yöntemi (GMDH) gibi polinom ağları, Genetik Algoritmalar (GA) ile optimize edilerek hibrit modeller oluşturulmakta ve Fourier serisi analizi ile birleştirilerek zaman serilerindeki periyodik bileşenler modellenmektedir (Piri

vd., 2021). Ayrıca, tesislerin performansını izlemek ve anormal durumları tespit etmek için Temel Bileşen Analizi (PCA) yaygın olarak kullanılmaktadır. Avella ve ark. (2010) ile Bayo ve Lopez-Castellanos (2016) çalışmalarında gösterildiği gibi, PCA, çok boyutlu veri setlerini daha az sayıda ve ilişkisiz bileşenlere indirgeyerek, verilerdeki temel varyasyon kaynaklarını ve gizli yapıları ortaya çıkarmaktadır (Bayo & Lopez-Castellanos, 2016).

Bununla birlikte, modelleme çalışmalarında veri kalitesini artırmak ve model performansını iyileştirmek adına faktör analizi (FA) gibi özellik mühendisliği teknikleri, yapay sinir ağları (BPNN, LSTM) ile entegre edilmektedir. Bu entegre yaklaşım, giriş verilerindeki gürültüyü azaltarak ve temel faktörleri belirleyerek, çıkış suyu kalitesinin (örneğin toplam azot) daha hassas bir şekilde tahmin edilmesine olanak tanımaktadır (Lv vd., 2023). Ayrıca, atıksu kalitesini tek bir sayısal değerle ifade etmek için Atıksu Kalite İndeksi (WWQI) gibi indeksleme yöntemleri geliştirilmekte ve bu indekslerin tahmini için çoklu doğrusal regresyon (MLR) ve PCA tabanlı modeller kullanılmaktadır (Rahmat vd., 2022). Bu yöntemler, tesis operatörlerine karmaşık veri setleri yerine, sistemin genel durumu hakkında hızlı ve güvenilir bilgi sağlayan araçlar sunmaktadır. Son çalışmalar, klasik yapay sinir ağlarının ötesine geçerek, uzun-kısa süreli bellek (LSTM) mimarilerinin atıksu arıtma süreçlerindeki kalite parametrelerinin tahmininde etkin performans gösterdiğini ortaya koymaktadır (örneğin NH_4^+ ve NO_3^- konsantrasyonlarının tahmini için LSTM modelleri kullanılmıştır) (Farhi vd., 2021).

Bu bağlamda, Tablo 1'de literatürde rapor edilen farklı model türlerinin AAT performans tahminine yönelik genel eğilimleri özetlenmiştir. Çizelge 1, sayısal bir karşılaştırmadan ziyade, farklı yöntemlerin göreli güçlü ve zayıf yönlerini nitel olarak ortaya koymayı amaçlamaktadır.

Çizelge 3 Farklı model türlerinin AAT performans tahminine yönelik genel eğilimleri

Yöntem	Genel Bulgular	Kaynak
SVR	Doğrusal olmayan ilişkilerde daha düşük tahmin hataları rapor edilmiştir	Granata vd., 2017
ANN (FFBP)	Karmaşık biyolojik süreçlerde yaygın kullanım	Avella vd., 2010
ANFIS	Belirsizlik içeren sistemlerde esnek yapı	Najafzadeh & Zeinolabedini, 2019
FA + ANN	Değişken seçimi sonrası daha kararlı tahminler	Lv vd., 2023

3. SONUÇLAR VE DEĞERLENDİRME

Yapılan analizler, atıksu yönetiminde hidrolik ve kalite parametrelerinin tahmin edilmesinde veri odaklı modellerin, klasik mekanistik modellere kıyasla yüksek başarı gösterdiğini ortaya koymaktadır. Özellikle giriş debisinin tahmini konusunda, Destek Vektör Makineleri (SVM) ve İleri Beslemeli Geri Yayılımlı Sinir Ağları (FFBP-NN) gibi yapay zekâ tabanlı modellerin, Adaptif Nöro-Bulanık Çıkarım Sistemlerine (ANFIS) göre daha düşük hata oranlarına (RMSE ve MAE) sahip olduğu ve debi tahmininde daha üstün performans sergilediği görülmüştür (Najafzadeh & Zeinolabedini, 2019).

Benzer şekilde, kentsel drenaj alanlarının özelliklerine dayalı olarak atıksu kalite göstergelerinin (BOD, COD, AKM) tahmin edilmesinde, SVM modellerinin Regresyon Ağaçlarına (RT) kıyasla daha iyi genelleme yeteneğine sahip olduğu ve özellikle askıda katı madde ve kimyasal oksijen ihtiyacı parametrelerinde daha yüksek doğruluk sağladığı belirlenmiştir (Granata vd., 2017). Derin öğrenme tabanlı yaklaşımlar, özellikle karmaşık ve

zaman gecikmeli sistemlerde süreçlerin daha iyi modellenmesini sağlamaktadır. Literatürde bu yöntemlerin klasik modellere göre daha iyi genelleme yeteneği sunduğu bildirilmiştir (Alvi vd., 2023). Bu bulgular, hidrolik tasarım ve işletme stratejilerinin belirlenmesinde makine öğrenmesi algoritmalarının güvenilir araçlar olduğunu göstermektedir.

Tesis içi süreçlerin izlenmesi ve arıza tespiti açısından, çok değişkenli istatistiksel yöntemlerin sağladığı avantajlar dikkat çekicidir. Uyarlamalı PCA modelleri, proses verilerindeki mevsimsel ve günlük değişimlere adapte olarak yanlış alarm oranlarını düşürmekte ve sistemdeki anormallikleri (toksisite, hidrolik şok yüklemeleri vb.) etkin bir şekilde tespit edebilmektedir (Aguado & Rosen, 2008). Ayrıca, PCA analizi sonucunda elde edilen temel bileşenler, tesisin organik yükü, besin maddesi giderimi ve hidrolik verimliliği gibi farklı operasyonel durumlarını karakterize eden faktörlerin belirlenmesini sağlamıştır. Örneğin, bir çalışmada elde edilen faktörler, mevsimsel değişimlerin ve hafta sonu etkilerinin atıksu karakteristiği üzerindeki etkisini net bir şekilde ortaya koymuştur (Bayo & Lopez-Castellanos, 2016).

Biyolojik arıtma süreçlerinin optimizasyonu ve çevresel etkilerin değerlendirilmesi bağlamında, farklı arıtma konfigürasyonlarının performansı da değişkenlik göstermektedir. Düşey akışlı yapay sulak alanların, yatay akışlı sistemlere kıyasla organik madde (BOD, COD) ve amonyak gideriminde daha yüksek performans gösterdiği, buna karşın nitrat gideriminde yatay akışlı sistemlerin daha etkili olduğu saptanmıştır (Verma & Suthar, 2018). Ayrıca, atıksu ile sulanan toprakların hidrolik özellikleri incelendiğinde, sodyum birikiminin toprak strüktürünü bozarak makro gözenekliliği azalttığı ve bunun sonucunda hidrolik iletkenlikte düşüşe neden olduğu gözlemlenmiştir. Bu durum, drenaj problemlerine ve tuz birikimine yol açarak, uzun vadede toprak kalitesini tehdit etmektedir (Gonçalves vd., 2007). Zaman serisi analizleri, bu tür dinamik değişimlerin izlenmesi ve gelecekteki giriş koşullarının simüle edilmesi için güçlü bir çerçeve sunmaktadır (Van Dongen & Geuens, 1998).

Atıksu arıtma tesisleri, su kaynaklarının korunması ve çevresel sürdürülebilirliğin sağlanması açısından kritik altyapı sistemleridir. Atıksu arıtma tesislerinin performansının doğru bir şekilde değerlendirilmesi; hidrolik yükleme, giriş suyu karakteristikleri ve işletme koşullarının birlikte ele alınmasını gerektirmektedir. Geleneksel performans analizleri çoğunlukla fiziksel ve kimyasal parametrelere dayansa da bu yaklaşımlar karmaşık ve doğrusal olmayan süreçleri açıklamakta sınırlı kalabilmektedir. Bu çalışmada incelenen literatür bulguları, veri tabanlı ve makine öğrenmesi temelli yaklaşımların, özellikle biyolojik arıtma süreçlerinin doğrusal olmayan yapısını temsil etmede daha başarılı olduğunu göstermektedir (Najafzadeh & Zeinolabedini, 2019). Arıtılmış atıksuyun yeniden kullanımı ve deşarj süreçleri, yalnızca çıkış suyu kalitesi açısından değil, alıcı ortam ve toprak özellikleri üzerindeki etkileri bakımından da değerlendirilmelidir. Gonçalves ve arkadaşları (2007), arıtılmış atıksu ile sulamanın uzun vadede toprak hidrolik iletkenliğinde azalmaya yol açabildiğini ortaya koymuştur. Bu bulgu, arıtılmış atıksu ile sulamanın yalnızca toprak ölçeğinde değil, yüzey akışı ve infiltrasyon süreçleri üzerinden havza ve alıcı ortam ölçeğinde de uzun vadeli etkiler yaratabileceğini göstermektedir.

Makine öğrenmesi tabanlı modeller, Atıksu arıtma tesisleri çıkış parametrelerinin tahmininde giderek daha yaygın kullanılmaktadır. Granata ve arkadaşları (2017), drenaj alanı özellikleri ve hidrolik değişkenler kullanılarak biyokimyasal oksijen ihtiyacı (BOİ), kimyasal oksijen ihtiyacı

(KOİ) ve askıda katı madde (AKM) gibi parametrelerin destek vektör regresyonu (SVR) yöntemi ile başarılı şekilde tahmin edilebildiğini göstermiştir. Çalışmada SVR modelinin, geleneksel regresyon yaklaşımlarına kıyasla daha düşük hata değerleri sunduğu rapor edilmiştir. Bununla birlikte, tek başına ML modellerinin performansı, giriş değişkenlerinin seçimine yüksek derecede bağlıdır. Bu bağlamda, öznitelik seçimi (feature selection) yöntemleri ile ML modellerinin birlikte kullanımı dikkat çekmektedir. Lv ve arkadaşları (2023), faktör analizi (FA) ile birlikte kullanılan yapay sinir ağlarının, özellikle azot bazlı çıkış parametrelerinin tahmininde daha kararlı ve güvenilir sonuçlar sunduğunu belirtmiştir. Bu yaklaşım, yüksek boyutlu ve çok değişkenli atıksu arıtma tesisleri verilerinin hidrolik yorumlanabilirliğini artırma potansiyeline sahiptir. Literatürde ayrıca, bulanık mantık ve evrimsel algoritmalar ile desteklenen hibrit modellerin de AAT performans tahmininde umut verici sonuçlar sunduğu görülmektedir (Najafzadeh & Zeinolabedini, 2019). Bu çalışmalar, tek bir yöntemin her koşulda üstün olmadığını, model performansının veri yapısı ve tesis karakteristiklerine bağlı olarak değiştiğini ortaya koymaktadır.

4. GENEL DEĞERLENDİRME VE SONUÇLAR

Atıksu arıtma tesislerinin planlanması, tasarımı ve işletilmesinde hidroloji ve hidrolik prensiplerin, ileri istatistiksel yöntemler ve yapay zekâ teknolojileri ile entegrasyonu, su kaynakları mühendisliğinde yeni bir paradigma oluşturmaktadır. Bu çalışma, giriş debisi ve kirletici yüklerinin tahmin edilmesinde, mekanistik modellerin yetersiz kaldığı durumlarda makine öğrenmesi ve hibrit modellerin (örneğin Genetik Algoritma destekli GMDH veya Faktör Analizi destekli Sinir Ağları) yüksek doğruluk ve genelleme yeteneği sunduğunu göstermiştir. Ayrıca makine öğrenmesi ve hibrit yaklaşımlar, özellikle doğrusal olmayan süreçlerin temsilinde geleneksel yöntemlere kıyasla önemli avantajlar sunmaktadır. Bu modeller, tesislerin hidrolik şok yüklemelerine karşı direncini artırmak ve enerji verimliliğini optimize etmek için kritik öneme sahiptir.

Ayrıca, toprağın hidrolik iletkenliği ve arıtma çamurunun özellikleri gibi fiziksel parametrelerin, çok değişkenli analiz yöntemleri (PCA, korelasyon analizi) ile incelenmesi, sistemdeki gizli ilişkilerin anlaşılmasını kolaylaştırmaktadır. Bu analizler, hem arıtılmış atıksuların yeniden kullanımında toprak yapısının korunması hem de arıtma süreçlerindeki biyolojik aktivitenin izlenmesi için gerekli olan operasyonel içgörüleri sağlamaktadır. Özellikle mevsimsel ve günlük salınımların istatistiksel olarak modellenmesi, işletme stratejilerinin dinamik olarak uyarlanmasına olanak tanımaktadır.

Gelecekteki çalışmalarda, sensör teknolojilerindeki gelişmelerle birlikte elde edilen büyük verinin, gerçek zamanlı kontrol sistemlerine entegre edilmesi, atıksu arıtma tesislerinin otonom yönetimine giden yolu açacaktır. Bu bağlamda, hidrolik ve hidrolojik modellerin veri odaklı algoritmalarla birleştirildiği hibrit yaklaşımların geliştirilmesi, su kaynaklarının sürdürülebilirliği ve çevresel koruma hedeflerine ulaşılmasında belirleyici rol oynayacaktır.

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Uranyum (U) Potansiyel Alanların Belirlenmesinde Jeolojik, Jeokimyasal ve Uzaktan Algılama Verilerinin Entegre Analizi

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Bu çalışma, bölgesel maden arama çalışmalarında hedef alanları daraltmak amacıyla potansiyel uranyum (U) zenginleşme alanlarını belirlemek için Litoloji, Uzaktan Algılama (RS) ve Jeokimya veri setlerini entegre eden Çok Kriterli Analiz metodolojisini kullanmıştır.

Analizde, tüm veri katmanları mineralizasyon potansiyellerine göre 1 ile 5 arasında ağırlıklandırılmıştır. Litolojik değerlendirmede, U potansiyeli yüksek olan kumtaşı ve kumtaşı-çamurtaşı birimlerine en yüksek ağırlıklar (5) verilmiştir. RS verileri kullanılarak, Band 2 / Band 1 oranı ile Ferrik Demir (Fe^{3+}) ve Band 4 / Band 6 oranı ile Alüminyum Hidroksit (AlOH) anomalileri haritalanmış ve anomalinin yüksek olduğu alanlar 5 puanla derecelendirilmiştir. Jeokimya verileri, çarpık dağılımı gidermek için log dönüşümü sonrasında kriging yöntemiyle mekânsal olarak işlenmiştir. İlişkili bir gösterge olarak Bakır (Cu) anomalileri de değerlendirilmiş; 70 ppm eşik ve 150 ppm anomali değeri kullanılarak ağırlıklandırma yapılmıştır.

Tüm ağırlıklandırılmış ve yeniden sınıflandırılmış veri katmanları, Coğrafi Bilgi Sistemleri (CBS) ortamında ArcGIS Pro yazılımının raster calculator (SUM) fonksiyonu ile entegre edilerek nihai Uranyum Potansiyel Haritası oluşturulmuştur.

Elde edilen sonuç haritası, bölgedeki uranyum (U) potansiyelinin Çok Düşük'ten Çok Yüksek'e kadar değişen göreceli sınıflar halinde dağılımını ortaya koymaktadır. En yüksek potansiyel sınıflarının özellikle Kırıkkale civarında Kazmaca, İncik ve Bayındır formasyonları ile ilişkili alanlarda yoğunlaştığı görülmektedir. Bununla birlikte, bu çalışma arazi doğrulaması ve jeofizik verilerle desteklenmeden, yalnızca jeolojik, jeokimyasal ve uzaktan algılama verilerinin CBS tabanlı entegrasyonuna dayalı bir ön değerlendirme niteliği taşımaktadır. Bu nedenle, belirlenen potansiyel alanların kesin uranyum cevherleşmesi olarak yorumlanabilmesi

için detaylı arazi çalışmaları, mineralojik-petrografik incelemeler ve uygun jeofizik yöntemlerle desteklenmesi gerekmektedir. Çalışma sonuçları, bölgesel ölçekte hedef alan daraltmaya yönelik bir karar destek aracı olarak değerlendirilmelidir.

Anahtar Kelimeler: Uranyum (U) Potansiyeli, Uzaktan Algılama (RS), Jeokimya, Kriging, ArcGIS Pro.

Integrated Analysis of Geological, Geochemical, and Remote Sensing Data for Determining Uranium (U) Potential Areas

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This study employs a Multi-Criteria Analysis methodology to delineate potential uranium (U) enrichment areas by integrating Lithology, Remote Sensing (RS), and Geochemistry datasets, aiming to narrow down target zones in regional mineral exploration campaigns.

In the analysis, all data layers were weighted on a scale of 1 to 5 based on their mineralization potential. For the lithological assessment, units like sandstone and sandstone-mudstone, which have high U potential, were assigned the maximum weight of 5. RS data were utilized to map anomalies of Ferric Iron (Fe3+) using the Band 2 / Band 1 ratio and Aluminum Hydroxide (AlOH) using the Band 4 / Band 6 ratio. Areas with high anomalies in these indicators were also scored with 5 points. Geochemical data, which exhibited skewed distribution, were spatially processed using kriging after log transformation. As a related indicator, Copper (Cu) anomalies were evaluated, with a threshold value of 70 ppm and an anomaly value of 150 ppm used for weighting.

All weighted and reclassified data layers were integrated using the SUM function of the raster calculator in ArcGIS Pro within a Geographic Information Systems (GIS) environment to generate the final Uranium Potential Map. The resulting map grades the U potential of the region from Very Low to Very High, visually highlighting the areas with the highest potential.

The resulting map reveals the distribution of uranium (U) potential across the study area in relative classes ranging from Very Low to Very High. The highest potential classes are observed to be concentrated particularly in areas associated with the Kazmaca, İncik, and Bayındır formations around the Kırıkkale region. However, this study represents a preliminary assessment based solely on the GIS-based integration of geological, geochemical, and remote sensing data, without field verification or geophysical support. Therefore, the identified potential areas should be supported by detailed field investigations, mineralogical–petrographic analyses, and appropriate geophysical methods before being interpreted as confirmed uranium mineralization. The results should be considered a decision-support tool for narrowing down target areas at the regional scale.

Keywords: Uranium (U) Potential, Remote Sensing (RS), Geochemistry, Kriging, ArcGIS Pro.

1. Giriş

Uranyum, nükleer enerji üretimi başta olmak üzere stratejik öneme sahip bir elementtir ve arama çalışmaları genellikle geniş alanları kapsayan çok disiplinli yaklaşımlar gerektirmektedir. Bölgesel ölçekte yapılan klasik arama çalışmaları, zaman ve maliyet açısından önemli sınırlılıklar içermektedir. Bu nedenle, farklı veri setlerinin birlikte değerlendirilmesine olanak sağlayan CBS tabanlı entegre analizler, potansiyel alanların önceliklendirilmesinde etkili bir araç olarak öne çıkmaktadır.

Bu çalışmada, jeolojik, jeokimyasal ve uzaktan algılama verileri kullanılarak uranyum potansiyel alanlarının belirlenmesi amaçlanmıştır. Özellikle litolojik özellikler, hidrotermal alterasyon göstergeleri ve jeokimyasal anomaliler birlikte değerlendirilerek bölgesel ölçekte hedef alan daraltma yaklaşımı benimsenmiştir.

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2. Çalışma Alanı ve Kullanılan Veri Setleri

Çalışmada kullanılan veri setleri üç ana grupta toplanmaktadır: jeolojik veriler, uzaktan algılama verileri ve jeokimyasal veriler.

Jeolojik veriler kapsamında litoloji bilgileri kullanılmıştır. Litolojik birimler, uranyumun mobilizasyonu ve çökelimi açısından uygunluk durumlarına göre değerlendirilmiştir. Bu veriler MTA tarafından üretilmiş 1/100.000 ölçekli jeoloji haritalarından elde edilmiştir.

Uzaktan algılama verileri olarak ASTER uydu görüntüleri kullanılmıştır. Bu verilerden ferrik demir (Fe^{3+}) ve alüminyum hidroksit (AlOH) alterasyonlarını temsil eden bant oranları türetilmiştir. Bu göstergeler, hidrotermal süreçlerin ve alterasyon zonlarının belirlenmesinde kullanılmıştır.

Jeokimyasal veriler ise MTA tarafından hazırlanan 11450 numaralı derleme raporundan alınmıştır. Veriler sayısallaştırılarak analizlere uygun hale getirilmiş ve bakır (Cu) elementi gösterge element olarak değerlendirilmiştir.

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3. Yöntem

3.1. Litolojik Değerlendirme

Litolojik birimler, uranyum potansiyeline olan uygunlukları dikkate alınarak 1 ile 5 arasında ağırlıklandırılmıştır. Kumtaşı ve kumtaşı–çamurtaşı birimleri, sedimanter ortamlarda redoks kontrollü uranyum mobilizasyonu ve çökelimi açısından elverişli olmaları nedeniyle en yüksek ağırlık değeri ile derecelendirilmiştir. Diğer litolojik birimler ise göreceli potansiyellerine bağlı olarak daha düşük ağırlıklar almıştır.

3.2. Uzaktan Algılama Analizleri

ASTER uydu verileri kullanılarak iki farklı bant oranı analizi gerçekleştirilmiştir. Ferrik demir anomalilerinin belirlenmesi amacıyla Band 2 / Band 1 oranı hesaplanmıştır. Bu oran, oksidasyon süreçleri ve yüzeydeki demir oksit zenginleşmelerinin tespit edilmesinde kullanılmıştır.

Kil mineralleri ve hidrotermal alterasyon göstergesi olarak ise Band 4 / Band 6 oranı kullanılarak AlOH anomalileri belirlenmiştir. Her iki analiz sonucunda elde edilen anomali yoğunluğu haritaları 1–5 arasında yeniden sınıflandırılmış ve potansiyel değerlendirmede kullanılmıştır.

3.3. Jeokimyasal Analizler

Jeokimyasal verilerin istatistiksel değerlendirilmesi sonucunda, verilerin çarpık dağılım gösterdiği belirlenmiştir. Bu nedenle veriler üzerinde logaritmik dönüşüm uygulanmıştır. Bakır (Cu) elementi, uranyum ile birlikte bulunabilen ve hidrotermal süreçleri yansıtan bir gösterge element olarak seçilmiştir.

Bakır için eşik değer 70 ppm, anomali değeri ise 150 ppm olarak belirlenmiştir. Bu değerlere göre Cu anomalileri derecelendirilmiş ve mekânsal dağılımları kriging interpolasyon yöntemi kullanılarak modellenmiştir.

3.4. Çok Kriterli CBS Entegrasyonu

Tüm veri katmanları ortak bir ölçekte değerlendirilmek üzere 1–5 arasında yeniden sınıflandırılmıştır. Veri setlerinin entegrasyonu Raster Calculator aracılığıyla gerçekleştirilmiş ve toplam potansiyel değeri aşağıdaki şekilde hesaplanmıştır:

Toplam Potansiyel = Litoloji + Uzaktan Algılama + Jeokimya

Bu yaklaşım ile her hücre için toplam potansiyel değeri hesaplanarak uranyum potansiyel haritası üretilmiştir.

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4. Bulgular

CBS tabanlı çok kriterli analiz sonucunda elde edilen uranyum potansiyel haritası; çok düşük, düşük, orta, yüksek ve çok yüksek olmak üzere beş sınıfa ayrılmıştır. Sonuçlar, özellikle belirli formasyonlar üzerinde yoğunlaşan yüksek ve çok yüksek potansiyel alanların varlığını ortaya koymuştur.

Kazmaca, İncik ve Bayındır formasyonları çevresinde yer alan alanlar, litolojik uygunluk, alterasyon göstergeleri ve jeokimyasal anomalilerin çakışması nedeniyle öne çıkan hedef

bölgeler olarak belirlenmiştir. Bu alanlar, bölgesel ölçekte öncelikli arama alanları olarak değerlendirilmiştir.

5. Tartışma, Sonuç ve Öneriler

Bu çalışma, yalnızca jeolojik, jeokimyasal ve uzaktan algılama verilerinin CBS ortamında entegrasyonuna dayalı bir ön değerlendirme niteliği taşımaktadır. Arazi doğrulaması, detaylı mineralojik-petrografik incelemeler ve jeofizik veriler bu çalışma kapsamında değerlendirilmemiştir.

Bu nedenle, belirlenen potansiyel alanların doğrudan uranyum cevherleşmesi olarak yorumlanması mümkün değildir. Ancak elde edilen sonuçlar, bölgesel ölçekte hedef alanların daraltılması ve ileri arama çalışmalarının planlanması açısından önemli bir karar destek aracı sunmaktadır.

İlerleyen çalışmalarda, belirlenen yüksek potansiyelli alanların detaylı arazi çalışmaları, örnekleme programları ve uygun jeofizik yöntemlerle desteklenmesi önerilmektedir. Bu tür bütünleşik yaklaşımlar, uranyum arama çalışmalarının etkinliğini artıracaktır.

CBS ORTAMINDA JEOKİMYASAL ANOMALİ VE MADEN POTANSİYELİ HARİTALAMASI

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ÖZET

Jeokimya anomalileri, maden aramalarında en kritik bileşenlerinden biridir. Jeokimyasal anomaliler diğer jeolojik verilerle birleştirilerek potansiyel maden alanlarının belirlenmesinde etkili rol oynamaktadır. Bu çalışmada, jeokimyasal anomalilerin istatistiksel yöntemlerle belirlenmesi ve Coğrafi Bilgi Sistemleri (CBS) ortamında maden potansiyel haritalanmasında kullanımı bütüncül olarak ele alınmıştır.

Çalışmanın bulguları, farklı veri kaynaklarının bütünleştirilmesiyle oluşturulan hibrit CBS modellerinin potansiyel maden alanlarının belirlenmesini sağlayarak maden aramacılığında hedef alanların etkin biçimde daraltılmasına imkân verdiğini göstermektedir. Jeokimyasal anomalilerin mekânsal davranışını ve mineralizasyonu kontrol eden jeolojik süreçlerin birlikte değerlendirilmesi, hedef belirleme sürecinde güçlü ve güvenilir bir karar desteği sunmaktadır.

Anahtar Kelimeler : Jeokimyasal anomaliler, maden potansiyeli haritalama, CBS

MAPPING OF GEOCHEMİCAL ANOMALIES AND MİNERAL POTENTİAL IN THE GIS ENVIROMENT

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ABSTRACT

Geochemical anomalies are one of the most critical components in mineral exploration. Geochemical anomalies play an effective role in identifying potential mineral areas when combined with other geological data. This study comprehensively addresses the identification of geochemical anomalies using statistical methods and their use in mapping mineral potential within a Geographic Information System (GIS) environment.

The findings of the study show that hybrid GIS models created by integrating different data sources enable the identification of potential mineral areas, thereby allowing for the effective

narrowing down of target areas in mineral exploration. The joint evaluation of the spatial behavior of geochemical anomalies and the geological processes controlling mineralization provides strong and reliable decision support in the target identification process.

Keywords: Geochemical anomalies, mineral potential mapping, GIS

IDENTIFICATION OF DIFFERENT AE SIGNATURES IN CFRP-STRENGTHENED CONCRETE

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ABSTRACT

Nondestructive testing methods (NDT) plays a crucial role in investigating the condition and failure prediction of concrete. Acoustic Emission (AE) is an effective NDT technique as it provides real-time monitoring of damage evaluation by capturing elastic waves released from the internal damage processes. Important information such as the type, location, and initiation time of a damage can be obtained from the parameters of the signals recorded by AE sensors.

Particularly in strengthened concrete, AE results can provide valuable insights about the differences between the damage mechanisms of the strengthened material and the concrete matrix damage. Among strengthening materials, CFRP (Carbon Fiber Reinforced Polymer) composite consists of carbon fibers in an epoxy matrix. It is a widely used strengthening material for concrete due to its high strength-to-weight ratio. By this means, it does not only

offer significant improvement on flexural and shear capacities, but also enhances the overall failure behavior of structural concrete members by delaying crack growth and increasing energy consumption capacity.

The purpose of this study is to comparatively identify the different AE signatures of conventional and CFRP-strengthened concrete specimens. For this purpose, AE analyzes were performed on the collected AE signals during loading tests and the distinguishing characteristics of different AE sources are identified.

Keywords: CFRP strengthening, concrete, damage mechanisms, AE signatures.

1. INTRODUCTION

Civil infrastructure systems are subjected to various loadings throughout their service life; therefore, the acoustic emission method, as a passive nondestructive structural health monitoring technique, is widely used to detect damage initiation and location in large structures through sensor arrays, ensuring safety, durability, and functionality (Tayfur et al., 2023; 2025).

Faults during concrete production, thermal stresses, and damage caused by mechanical and structural loads have increased the need for strengthening techniques of the structure. Among the available methods, Carbon Fiber Reinforced Polymer (CFRP) strengthening is widely used due to its high strength-to-weight ratio, corrosion resistance, and ease of application (Alver et al., 2016). Since the concrete exhibits high strength under compression, however it is weak against tensile stresses; CFRP bonds its surface through adhesion, absorbing the tensile forces generated under loading and increasing the overall load-bearing capacity of the structural member.

Previous studies have shown that CFRP strengthening significantly improves the mechanical performance of concrete members while also altering the damage progression. Hanif et al. (2023) demonstrated that debonding damage in CFRP-strengthened reinforced concrete beams can be effectively and continuously monitored using the acoustic emission technique, and that interfacial defects significantly influence the debonding mechanism. Wang et al. (2023) demonstrated that damage progression in CFRP-strengthened concrete member can be effectively monitored using the acoustic emission (AE) technique and reported notable improvements in strength and ductility due to CFRP confinement. Liu et al. (2021) demonstrated that CFRP shear strengthening is an effective method for improving the impact resistance of reinforced concrete columns by mitigating shear damage and transforming brittle

shear failure into a more ductile flexural failure mode. In a study on CFRP strip spacing, denser CFRP application improved crack control and stiffness, while wider spacing resulted in shear-dominated failure (Alver et al., 2014). Araujo et al. (2016) observed that columns strengthened with CFRP significantly increased their load-bearing capacity under axial compression. Similarly, some studies have confirmed that AE parameters are closely related to different damage modes in reinforced concrete members. Prem et al. (2021) reported that AE features provide reliable indicators for identifying crack development and damage mechanisms under various loading conditions. Previous studies have shown that AE technique can detect and characterize active fractures in concrete even at low load levels by evaluating waveform-based signal parameters (Tayfur et al., 2019).

Accordingly, this study aims to comparatively identify the different AE signatures of conventional and CFRP-strengthened concrete specimens. For this purpose, compressive behavior and damage evolution of CFRP-wrapped concrete cylindrical specimens were investigated experimentally. AE parameters recorded during loading are evaluated together with mechanical responses to identify damage stages and fracture mechanisms. The findings of this study are expected to contribute to a better understanding of AE-based damage monitoring in CFRP-confined concrete and to provide valuable information for the assessment and design of strengthened concrete structures.

2. METHODS

2.1. AE Method

AE is a non-destructive monitoring method based on the detection of elastic waves generated by the release of strain energy within a material under stress. These waves occur due to damage mechanisms such as microcrack initiation, crack propagation, fiber rupture, and interfacial debonding. AE sensors are attached to the surface of the specimen and continuously record damage-related signals during loading, allowing real-time evaluation of damage progression. A single detected AE signal contains information about the internal condition of the material, while the use of multiple sensors enables identification of crack locations and types (Alver et al., 2015).

The characterization of damage mechanisms in AE monitoring is achieved through the analysis of several signal parameters. Figure 1 shows parameters of a typical AE signal. The basic parameter of AE data is defined as a hit, which represents a single AE activity exceeding a

defined threshold. Amplitude corresponds to the maximum voltage of the AE signal and is generally associated with the intensity of the damage source. Counts represent the number of pulses the signal crosses the threshold. Duration is defined as the time interval between the first and last counts of a hit, while rise time is the time from the first count to the peak amplitude. AE energy, calculated as the area under the rectified signal envelope, reflects the total energy released during a damage event and is often correlated with crack severity. Other seconder AE parameters are average frequency (count/duration) of the waveform and peak and centroid frequencies of the frequency spectrum of the signal. These parameters are related with type of the damage. On the other hand, RA value (rise time/amplitude) is inversely related with average frequency which is attributed to damage mode as well.

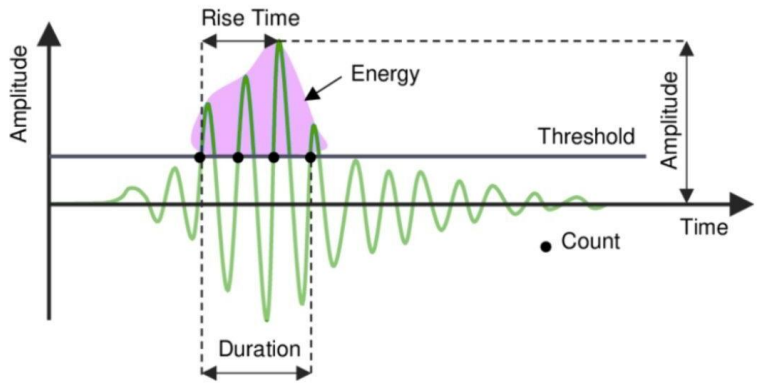


Figure 1. AE Parameters (Tayfur et al., 2024)

2.2. CFRP Strengthening

CFRP strengthening is an externally composite bonding technique used to improve the mechanical performance of concrete and cement-based materials. The method involves surface preparation, application of epoxy resin, and placement of carbon fiber sheets in the direction of principal stresses. After curing, the carbon fiber layer enhances load-carrying capacity, limits crack development, and improves structural stiffness.

3. EXPERIMENTAL WORK

3.1. Specimen Production

In the experimental study, three cylindrical concrete specimens with a diameter of 100 mm and a height of 200 mm were prepared. A ready-mixed concrete was used for all specimens. All specimens were cured under standard conditions for 28 days.

For CFRP strengthening, two different wrapping configurations were applied to the specimens. While one of the specimens (REF) was reference conventional concrete, the other was strengthened with CFRP strips with a width of 25 mm, applied at 25 mm spacing (CF25). For the other specimen, three CFRP strips with a width of 50 mm were applied with 25 mm spacing (CF50). Prior to CFRP application, the concrete surfaces were cleaned to remove dust and loose particles. An epoxy resin was then applied to the surface, followed by the placement of CFRP strips. After positioning the CFRP, an additional layer of epoxy resin was applied to ensure proper bonding. The CFRP-wrapped specimens and concrete specimen are shown in Figure 2.



Figure 2. CFRP-Wrapped Specimens (CF25 and CF50) & Concrete Specimen (REF)

3.2. Test Setups

In the experiments, an automatic concrete compression testing machine was used. The loading rate was set to 2 kN/s. To investigate the fracture characteristics using the AE technique, four AE sensors with a resonance frequency of 150 kHz were attached to the specimens (Figure 3.a). The sensors were connected to an eight-channel AE system by Mistras, threshold and amplification gain levels were set as 40 dB. Load and displacement data were recorded simultaneously during the uniaxial compression tests (Figure 3.b)

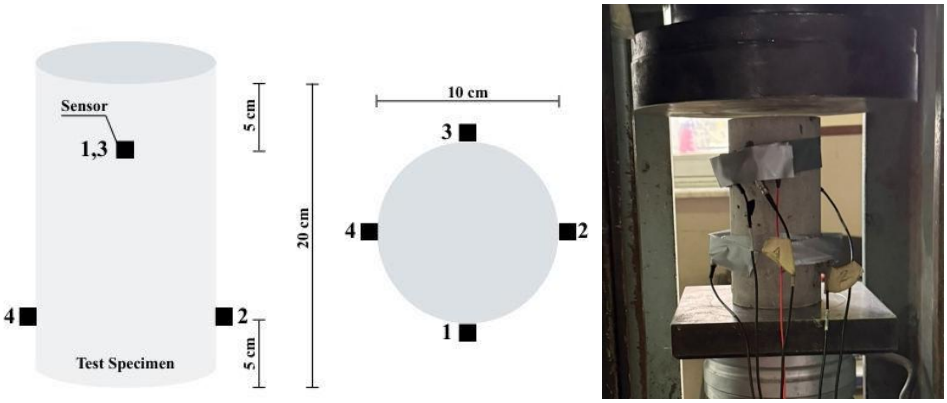


Figure 3. a) AE Sensor Locations b) Uniaxial Compression Test Setup

4. RESULTS

4.1. Mechanical Results

The experimental results clearly demonstrate an increase in load-carrying capacity and an improvement in ductility for the CFRP-strengthened specimens compared to the reference specimen. The REF specimen exhibited a sudden and brittle failure at a load level of 153.3 kN. In contrast, the specimen CF25 reached a maximum load of 197.9 kN, while the specimen strengthened CF50 achieved the highest load capacity of 254.3 kN.

An increase in CFRP strip width resulted not only in higher strength but also in significant changes in the post-peak behavior of the load-time curve. While CF50 exhibited a more stable and controlled load reduction after peak load, CF25 showed load fluctuations and sudden drops due to insufficient confinement in certain regions. Post-failure views illustrating the observed failure modes are shown in Figure 4. For specimen REF, since the load-time curve could not be obtained from the testing device, it was constructed based on the maximum load value recorded during the tests. In the subsequent tests of CF25 and CFR50, the load-time curves were generated using load values extracted from the video recordings as time-dependent.



Figure 4. Post-Failure Views of the Specimens

4.2. AE Results

AE parameter analyzes were conducted on AE data which their variations are presented with time vs. load curves of the specimens. In the graphs, red lines and markers indicate AE parameters, while the black ones indicate the load curve. When the specimens are compared in terms of amount of the AE activities, it is observed that both the number of AE hits (Figure 5) and the AE energy accumulation (Figure 6) are strongly related to the presence and width of the CFRP confinement. In the plain concrete REF specimen, AE energy accumulation was

limited and progressed slowly, resulting in a total cumulative energy of 280,435 aJ. In contrast, the CFRP-strengthened specimens exhibited a significant increase in AE energy, reaching values in the order of millions due to the stretching of CFRP fibers and the adhesion mechanisms at the epoxy-concrete interface.

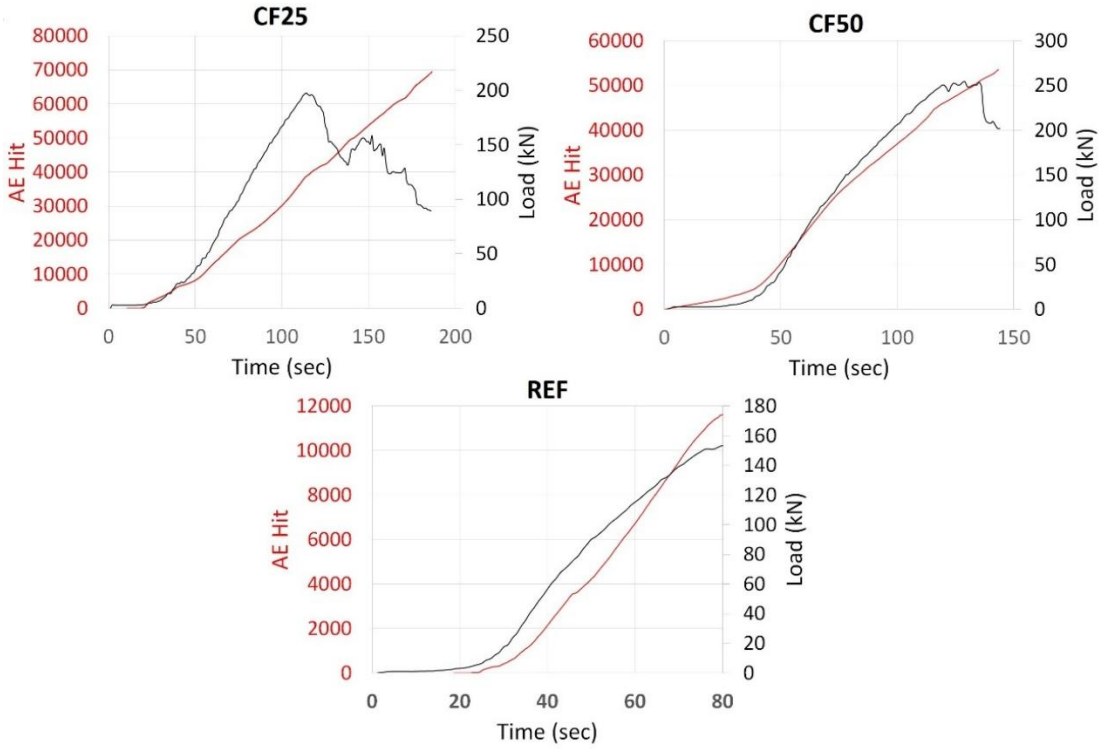


Figure 5. AE Hit Curves

CF25 exhibited the highest cumulative AE energy, reaching a total value of 4,663,007 aJ. This behavior indicates that the narrower CFRP confinement led to increased friction, microcracking, and delamination processes, resulting in a more distributed and progressive energy release throughout the loading process. Conversely, in the specimen CF50, the stiffer confinement provided by the wider CFRP strips restricted damage development, causing AE energy to remain relatively lower and to be released in a more concentrated manner at the moment of failure, reaching 1,375,962 aJ.

An analysis of AE amplitude distributions (Figure 7) reveals that, in the reference specimen, amplitudes are primarily distributed within the 40-70 dB range. In CFRP-strengthened specimens, however, a pronounced concentration of high-amplitude signals extending up to the 80-100 dB band is observed. These high-amplitude AE signals are associated with CFRP fiber rupture and fiber-matrix interaction mechanisms. Furthermore, as the CFRP strip width

increases, the number of high-amplitude AE events increases, and the moving average of the amplitude remains stable at higher levels.

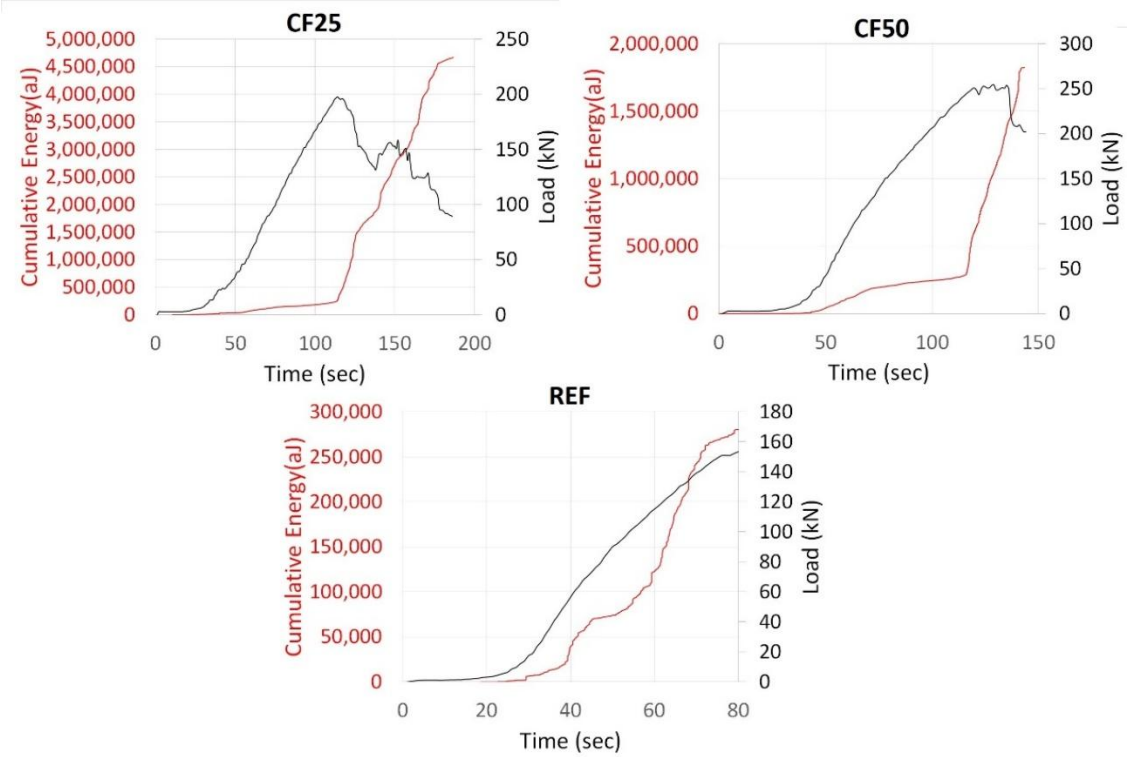


Figure 6. Cumulative AE Energy Curves

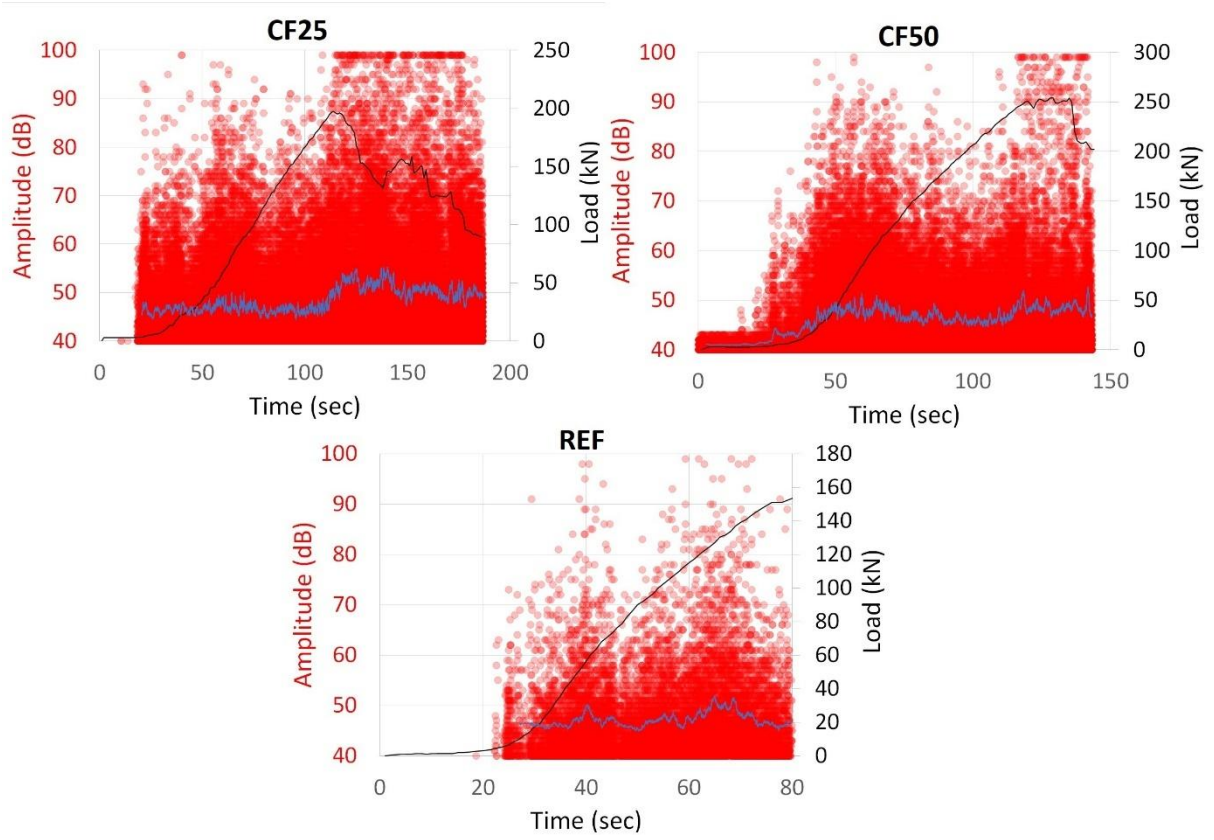


Figure 7. Amplitude Distributions

When the centroid frequency (Figure 8), representing the centroid of the signal frequency spectrum, and the peak frequency (Figure 9), indicating the dominant frequency component, are examined, the REF specimen exhibits narrower frequency bands with relatively stable values, which is characteristic of brittle concrete cracking behavior. This observation reflects the typical fracture mechanisms associated with unconfined concrete. With increasing CFRP content, the frequency bands broaden and fluctuations are observed in the moving average curves (dashed blue lines), indicating the activation of additional damage mechanisms. In the CF25 specimen, the frequency distribution becomes wider, reflecting a mixed damage mode resulting from both concrete cracking and shear, friction, and debonding mechanisms occurring at the CFRP-concrete interface. While amplitude and energy are associated with the damage severity. (Tayfur et al., 2022)

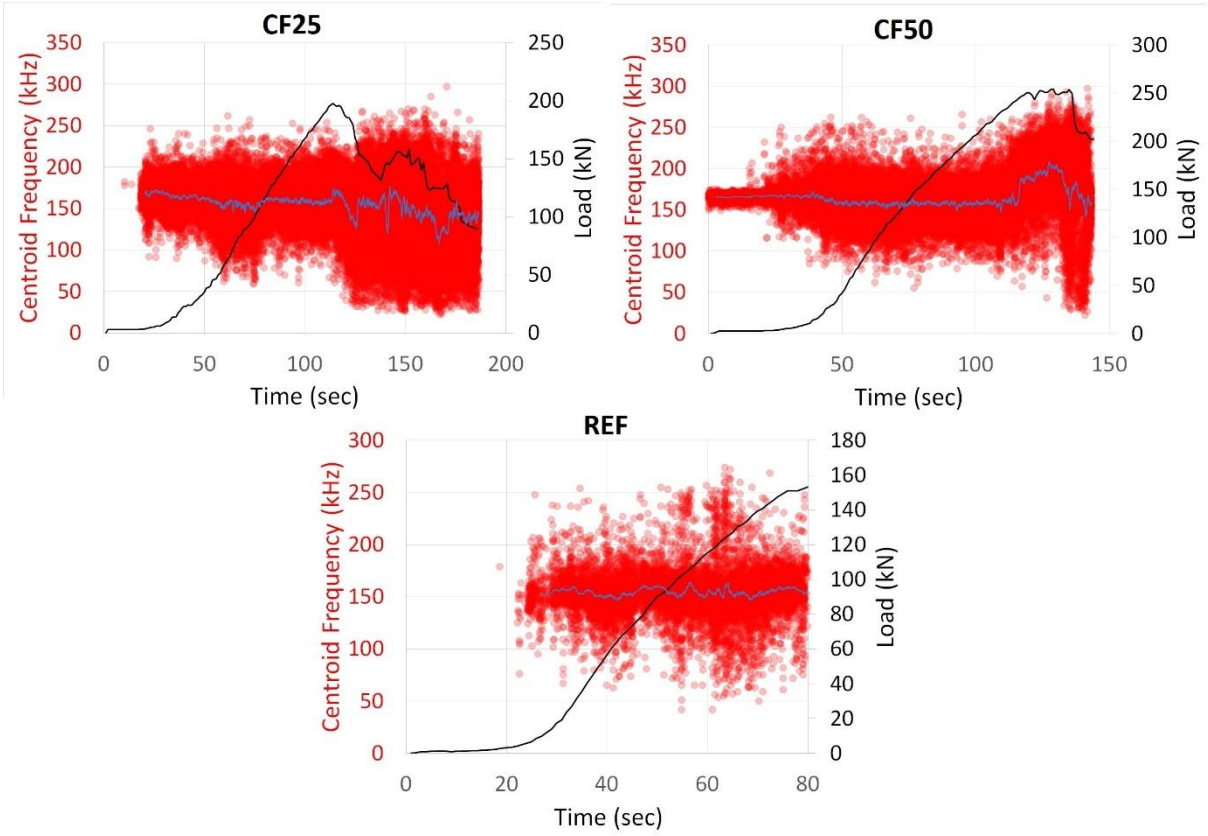


Figure 8. Centroid Frequency Distributions

In contrast, the specimen CF50 exhibits a clear upward shift in frequency values as the peak load is approached, with a notable concentration of AE signals in higher frequency ranges. This increase indicates that the stronger confinement effect effectively suppresses macro-scale concrete cracking and redirects damage evolution toward CFRP-related mechanisms, such as fiber rupture, matrix damage, and interfacial debonding. Consequently, the AE signals are characterized by higher-frequency content associated with more micro-scale damage mechanisms.

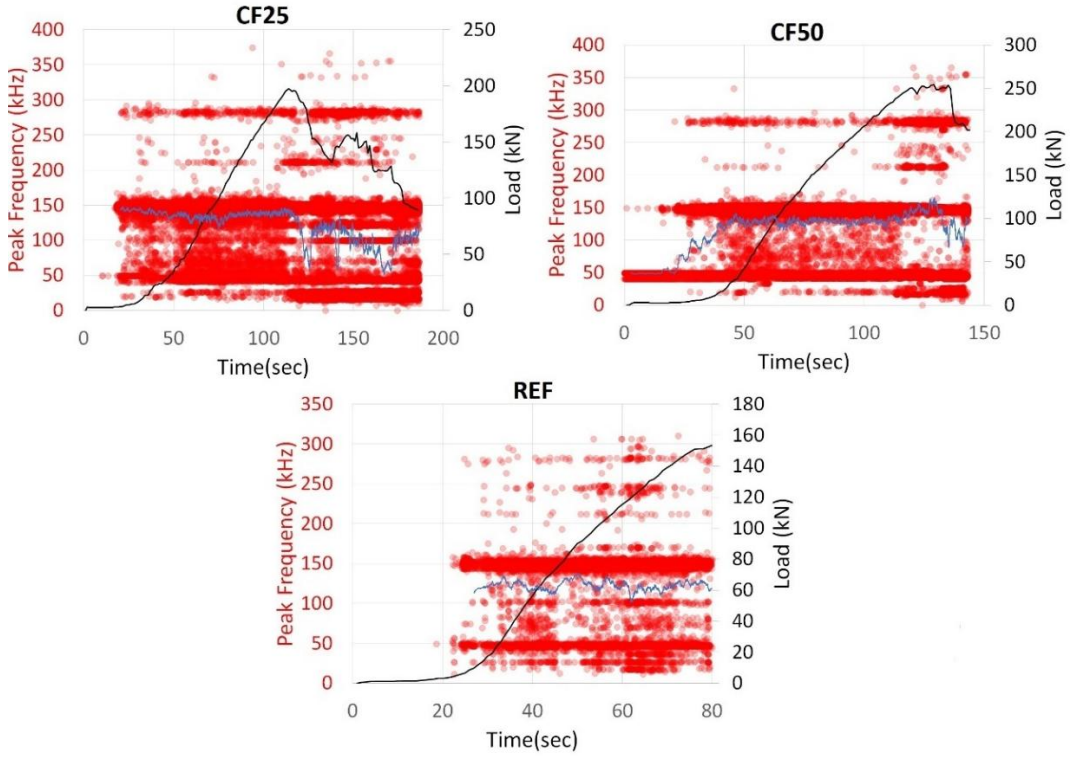


Figure 9. Peak Frequency Distributions

A similar trend is also observed in the RA value, which plays a critical role in distinguishing tensile- and shear-dominated damage mechanisms. RA value (rise time/amplitude) and average frequency (count/duration) are useful for identifying damage type (Tayfur et al., 2018). In the REF specimen, RA values remain relatively low, indicating damage primarily governed by tensile concrete cracking. In contrast, CFRP-strengthened specimens exhibit increased RA values, reflecting the activation of additional damage mechanisms.

The RA value distributions of the specimens are presented in Figure 10. In CF25, the RA distribution broadens significantly, with an increased number of high-RA activities, indicating the dominance of CFRP-related mechanisms such as interfacial shear, friction, and debonding. Conversely, the CF50 specimen shows a more compact RA distribution, suggesting that the wider CFRP confinement effectively limits crack opening and promotes a more stable and controlled damage progression.

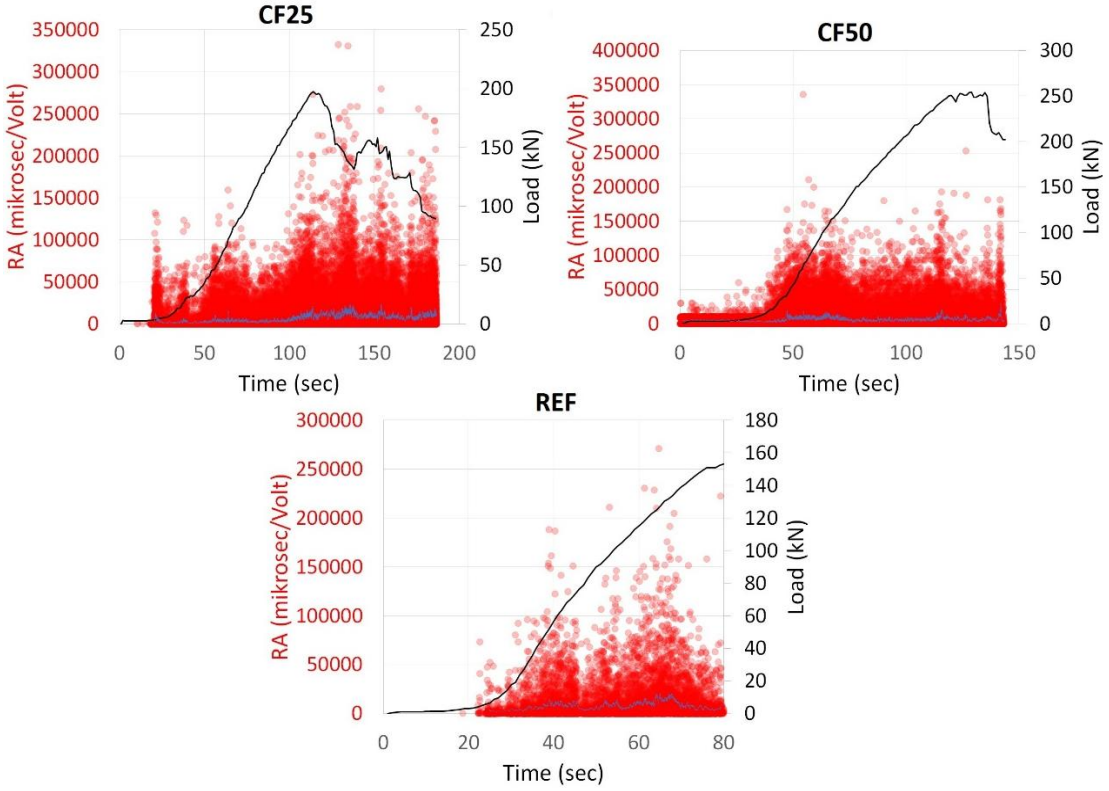


Figure 10. RA Value Distributions

As a summary, Table 1 was presented to show the overall mechanical and AE results of the specimens.

Table 1. Summary of Mechanical Results and AE Parameters

	REF	CF25	CF50
Maximum Load	153.3 kN	197.9 kN	254.3 kN
Fracture Character	Brittle	Semi-Ductile	Ductile
Total AE Hit	11,610	69,473	53,540
Cumulative Energy	280,435 aJ	4,663,007 aJ	1,822,498 aJ
Dominant Amplitude	40 - 70 dB	40 - 100 dB (Dispersed)	80 - 100 dB (Concentrated)
RA Value	Low / Narrow	High / Wide	High / Narrow
Frequency	Stable / Narrow Band	Fluctuating / Wide Band	High Frequency Peaks

4. CONCLUSIONS

In this study, AE signatures of CFRP-strengthened concrete and effect of CFRP strip width were investigated. For this purpose, three concrete cylinders were tested under uniaxial compression tests and monitored with AE. The results showed that CFRP strengthening improves the compressive performance and capacity of the concrete. Moreover, higher strip width enhances the post-peak stability exhibiting a more controlled load reduction. While

limited AE hit and cumulative AE energy were recorded in plain concrete due to brittle fracture, CFRP-strengthened specimens produced higher AE hits and energies due to CFRP fiber-related mechanisms such as friction and debonding. On the other hand, stronger CFRP confinement with higher CFRP strip width restricted widespread damage resulting in more concentrated AE release.

Similarly, CFRP-strengthened specimens showed higher amplitude signals and wider frequency distributions associated with CFRP activities. Both frequency and RA value analyzes indicated the transition toward micro-scale damage mechanisms under stronger confinement. As a conclusion, the mechanical results and AE signatures demonstrate that increasing CFRP confinement not only enhances the strength but also changes damage progression and damage mode.

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USE OF BAYBURT GREEN SPOTTED WHITE TUFF AS A CEMENT ADDITIVE

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ABSTRACT

Volcanic tuffs with green speckles and a color close to white, extracted from the Bayburt region, are used in decorative facade claddings and also in load-bearing walls of masonry structures due to their ease of processing. A large amount of waste is generated from green speckled Bayburt white tuffs (SBWT), which have a density less than 2 g/cm³, in industrial facilities. In this study, SBWT powder (0-0.063 mm) obtained from the waste was used to replace 10-30% of the cement. The aim is to produce structural lightweight concrete (SLCC) using waste aggregates. SBWT wastes were ground to a maximum particle size (D_{max}) of 11.2 mm and classified into 9 different sieve sizes (0-0.063, 0.063-0.125, 0.125-0.25, 0.25-0.5, 0.5-1, 1-2, 2-4, 4-8, 8-11.2 mm), and aggregate tests were performed. A granulometric curve conforming to D_{max} 8 mm (Turkısh Standart, Europe Norm 802) was determined. SLCC mixtures with a binder dosage of 450 kg/m³ and a water/cement ratio of 0.50 were poured into 10×10×10 cm cubic molds in two layers. The SBWT samples produced were subjected to compressive strength tests after being soaked in lime-saturated water for 7 and 28 days. The results showed that substituting 10-20% SBWT powder into the cement did not significantly affect the strength, but a 20% substitution significantly reduced the strength. Furthermore, it was determined that increasing the substitution rate reduced costs by 15-30%.

Keywords: Lightweight concrete, Bayburt speckled white tuff, waste

POZZOLANIC ACTIVITY OF BAYBURT STONE

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ABSTRACT

Today, approximately 8% of air pollution stems from carbon dioxide released into the environment during cement production. Tuffs extracted from the Bayburt region, which are yellow and white in color, are generally used for decorative purposes due to their light weight, microporous nature, and ease of processing. Large amounts of waste are generated from Bayburt tuffs (BT) in industrial operations. In this study, the pozzolanic activities of yellow and whitish stones extracted from the Bayburt region were investigated for their potential use as cement additives. The experiment was conducted according to TS 25 and Turkısh Standart, Europe Norm 196-1. The aggregates were crushed to 0.5-1 mm and dried. They were then ground in a ball mill until no more than 8% of the total mass remained on a 90-micron sieve. Slaked lime with a minimum purity of 95%, standard sand, and pozzolan were mixed in a mixer until homogeneous.

It was poured into three 4×4×16cm molds in two stages and left at room temperature (23°C ± 2) for 24 hours. Then, without being removed from the molds, it was dried in an oven at 55°C (±2) for 6 days. The compressive strengths of Bayburt white stone (BWT) and Bayburt yellow stone (BYS) were found to be 4.2 and 2.8 MPa, respectively. As a result, it was determined that BWT, which exceeded the minimum compressive strength value of 4 MPa required by TS 25, could be evaluated as pozzolan.

Keywords: Bayburt tuff, waste, pozzolan

YENİ HEGZADECA-SÜBSTİTÜE KOBALT (II) FTALOSİYANİN; SENTEZ VE ÇÖZÜNÜRLÜK

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ÖZET

Ftalosiyaninler düzlemsel iki boyutlu aromatik yapıya sahip oldukları için halkalar arasındaki mesafe π-π interaksiyonu nedeni ile azalıp agregasyon meydana gelir. Oluşan agregatların zayıf çözünürlüğü bu yapıların birçok bilimsel ve teknolojik uygulamalarda potansiyel kullanımlarını sınrlar [1]. Ancak, bu makromolekül halkanın çevresi çeşitli hacimli organik sübstituentler ile aromatik yerdeğiştirme reaksiyonu esnasında modifiye edilebilir. Böylece, halkaların arasındaki mesafe artarak çözünürlüğü artar. Ayrıca, eklenen gruplar bu bileşiklere yeni özellikler katabilir. Öte yandan, halka içine farklı metal iyonları yerleştirilip hem çözünürlükleri hemde kimysal ve fiziksel özellikleri iyileştirilebilir. Bu değişiklikler kontrollu ve planlı olarak uygulanırsa elde edilen sübstitüe ftalosiyaninler hedefe yönelik malzemeler olarak tasarlanıp potansiyel aktivitesi incelenir [2,3].

Bu çalışma kapsamında, yeni iki triflorometilfenil grupları içeren hegzadeca- sübstitüe kobalt(II) ftalosiyanin sentezlenip karakterize edildi. Elde edilen ftalosiyaninin farklı çözücülerde UV-vis metotu kullanılarak incelendi.

Anahtar Kelimeler : Ftalosiyanin; Çözünürlük; Solvent etkisi; Florlu gruplar

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EXPLORING DUAL METAL–ORGANIC FRAMEWORK AS NEXT-GENERATION PHOTOCATALYST IN WASTEWATER REMEDIATION PROCESSES

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Metal–organic frameworks (MOFs), which are crystalline structures formed by the coordination of metal ions with organic ligands, have been getting attention as photocatalysts due to their exceptionally large surface area, tunable pore size, and efficient light-absorption capability. Owing to their ability to generate photo-excited electrons and holes under irradiation—thus producing reactive species—manganese (Mn)- and cerium (Ce)-based MOFs have emerged as strong candidates for light-driven oxidation systems. On the other side, recent studies have demonstrated that diversifying the metal nodes—namely, incorporating more than one type of metal ion—can enable the design of tailored redox potentials for specific photocatalytic reactions. Therefore, in this study, Mn/Ce-MOF catalytic materials was synthesized to simultaneously exploit the photocatalytic advantages of both manganese and cerium within a single system. The catalytic system was performed in visible-light driven antibiotic (tetracycline) degradation process. Furthermore, the effect of environmental parameters—including catalyst amount, initial antibiotic concentration, initial solution pH—on the photocatalytic performance was thoroughly investigated to explore the catalytic mechanism in detail. Herein, innovative and high-performance metal–organic framework was developed by integrating the advantages of both metals in metal-based organic framework system.

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Keywords: Tetracycline, Metal organic framework. Photocatalysis

1. INTRODUCTION

In recent years, the mineralization of organic contaminants present in pharmaceutical wastewater via advanced oxidation processes (AOPs), through various reactive oxygen species (ROS), has played a crucial role in the development of innovative wastewater treatment technologies due to its rapid and non-selective nature. The selection of catalytic materials holds significant potential for enhancing the efficiency of these processes. In this context, metal–organic frameworks (MOFs) have increasingly been employed as photocatalysts owing to their tunable band-gap structures, high light-absorption capacity, and effective charge carrier mobility [1].

Metal–organic frameworks (MOFs) are, in general, crystalline materials composed of metal ions coordinated with organic ligands. These materials offer advantageous features such as large specific surface area, adjustable pore size, and efficient light absorption, which make them highly promising for photocatalytic applications [2,3]. Owing to their ability to generate photo-excited electrons and holes under irradiation, and th,us to promote the formation of reactive species, manganese- (Mn) and cerium- (Ce) based MOFs have emerged as strong candidates for light-driven oxidation systems [4,5]. Although only a limited number of studies have investigated the photocatalytic applications of Mn-MOFs and Ce-MOFs, several notable examples exist in the literature. For instance, Luo et al. demonstrated that photocatalytic hydrogen production could be achieved using Mn-MOF materials [6]. Liao and Li [7] reported that Mn-MOF was capable of generating superoxide radicals required for photocatalytic oxidation reactions solely under 420 nm light irradiation. In another study, the incorporation of persulfate significantly enhanced the efficiency of Mn-MOF catalysts in antibiotic removal processes [8]. Karunakaran et al. [9] synthesized a hydrothermally derived, stable Mn-MOF and showed that it functioned as a reusable catalyst for methylene blue (MB) degradation under visible light irradiation. On the other hand, Karmakar et al. reported that Ce-MOF catalysts exhibited effective CO_2 reduction performance under visible light [10]. Sangeetha and Krishnamurthy [11] successfully synthesized a nanoscale Ce-MOF via a simple, low-cost, and environmentally friendly method at room temperature, demonstrating stable redox transitions between different cerium oxidation states, high surface area, and thermal stability up to 320 °C. Similarly, Yuan et al. [12] achieved approximately 96% dye removal within 150 minutes under visible light irradiation in the presence of Ce-MOF. Collectively, these studies indicate that Mn-MOF and Ce-MOF materials possess a strong capability to adsorb large-molecule pollutants from aqueous effluents and subsequently transform them into smaller molecular species. However, recent research has demonstrated that tailoring redox potentials for specific photocatalytic reactions can be achieved by diversifying the metal nodes, i.e., by incorporating multiple metal ions into the framework [13].

Therefore, in the present study, Mn/Ce-MOF catalytic materials will be synthesized for the first time in order to simultaneously exploit the complementary advantages of manganese and cerium in photocatalytic processes. Mn/Ce-MOF catalyst was fabricated by performing a hydrothermal method and it was utilized for visible-light-assisted activation to degrade tetracycline (TC) molecules. The effect of catalyst amount and initial antibiotic concentration on the degradation performance were examined. Additionally, the role of initial antibiotic solution

pH on the reaction was examined. This research offers novel insights into the effective utilization of Mn/Ce-MOF catalyst in the realm of visible-light photocatalysis.

2. EXPERIMENTAL

2.1. Photocatalyst Synthesis

The synthesis of the Mn-MOF catalyst was conducted according to the following procedure. Initially, 0.79 g of manganese chloride ($MnCl_2$) and 0.83 g of tetrafluoroterephthalic acid was dissolved in 40 mL of N,N-dimethylformamide (DMF) under continuous stirring until complete dissolution was achieved. Subsequently, 10 mL of methanol was added to the solution, and the mixture was further stirred until a homogeneous solution is obtained. The resulting synthesis mixture was then be transferred into a stainless-steel autoclave and maintained at 120 °C for 24 h. After the autoclave was naturally cooled to room temperature, the solid catalyst was separated from the synthesis medium by filtration. Finally, the obtained product was washed three times with 10 mL of methanol and dried overnight at 200 °C. For the synthesis of the Ce-MOF catalyst, the same procedure was followed, except that cerium nitrate hexahydrate ($Ce(NO_3)_3 \cdot 6H_2O$) was used as the metal precursor instead of manganese chloride. In addition, the Mn/Ce-MOF catalyst was synthesized using the same method, with manganese chloride (0.18 g) and cerium nitrate hexahydrate (0.79 g) employed as metal sources at a Mn-to-Ce molar ratio of 1:2.

2.2. Photocatalytic Antibiotic Degradation

The photocatalytic performance of Mn-, Ce-, and Mn/Ce-MOF catalysts were investigated in the degradation of antibiotic molecules. The photoreactor consists of a stainless-steel chamber equipped with visible-light lamps (150 W; $\lambda = 400–800$ nm) mounted on the inner walls. The reaction vessel, a glass container, was placed on a magnetic stirrer located at the base of the chamber, allowing uniform irradiation of the reaction solution from all directions. In addition, a cooling fan was installed beneath the stirrer to maintain a constant reaction temperature during the experiments. For the photocatalytic activity tests, 20 mg of catalyst was dispersed in 40 mL of tetracycline solution with an initial concentration of 10 mg L^{-1}. Prior to light irradiation, the suspension was magnetically stirred in the dark for 30 min to establish adsorption–desorption equilibrium. Subsequently, the reaction mixture was irradiated under visible light with continuous stirring for 2 h, and aliquots was withdrawn at 30 min intervals to monitor the reaction progress. The concentrations of tetracycline before and after the photocatalytic experiments was determined using a UV–Vis spectrophotometer at a wavelength of 360 nm. In a subsequent stage, the effects of catalyst amount (10-30 mg), antibiotic concentration (10-30 mg L^{1-}) on the photocatalytic performance were examined. Additionally, to investigate the influence of pH, experiments was conducted under acidic (pH 3), neutral (pH 6.5), and alkaline (pH 10) conditions.

3. RESULTS AND DISCUSSION

3.1. Primarily experiments

The photocatalytic performance of Mn-MOF, Ce-MOF, and Mn/Ce-MOF catalysts toward tetracycline (TC) degradation was comparatively evaluated, as illustrated in Figure 1a. Among the investigated catalysts, Mn-MOF exhibited a relatively low removal efficiency (%27.6), which was attributed to its limited visible-light absorption and the rapid recombination of photogenerated charge carriers. In contrast, Ce-MOF showed a significantly enhanced degradation efficiency (66.2%), likely originating from the reversible Ce^{3+}/Ce^{4+} redox couple and the presence of oxygen vacancies that promoted reactive oxygen species (ROS) generation. Notably, the bimetallic Mn/Ce-MOF achieved the highest TC removal efficiency (75.2%), demonstrating a clear synergistic effect between Mn and Ce metal centers. The coexistence of dual metal ions facilitated more efficient charge separation and interfacial electron transfer, thereby suppressing electron–hole recombination and enhancing photocatalytic activity. This enhanced performance was further supported by the UV–Vis absorbance spectra (Figure 1b), where Mn/Ce-MOF exhibited the most pronounced decrease in the characteristic TC absorption bands, indicating effective molecular degradation rather than mere adsorption. Overall, these results confirmed that bimetallic MOF construction was a promising strategy for optimizing photocatalytic antibiotic degradation in aqueous systems.

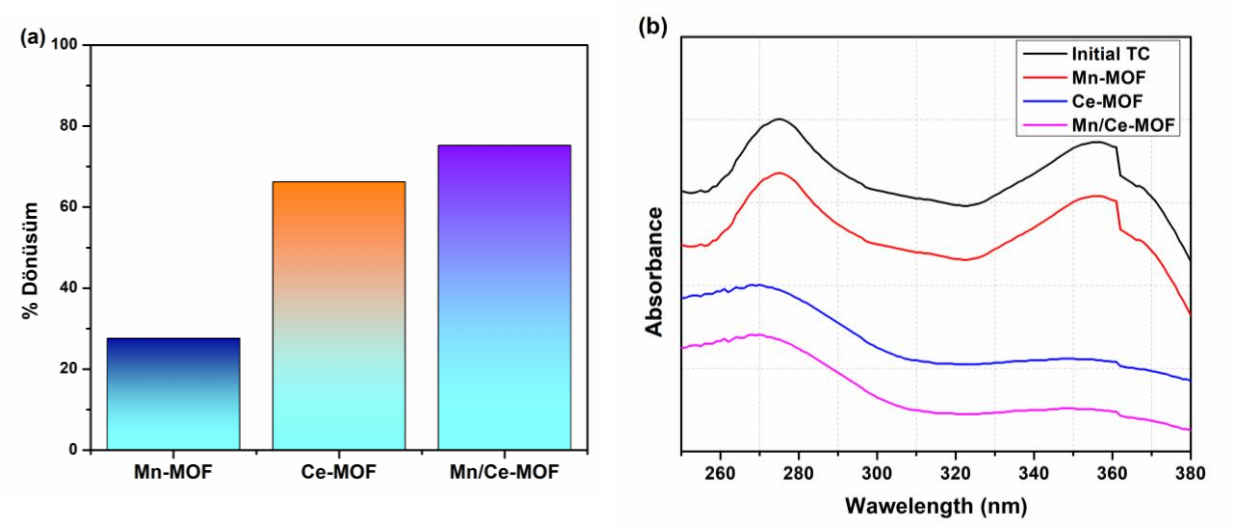


Figure 1. (a) Photocatalytic tetracycline (TC) removal efficiencies of Mn-MOF, Ce-MOF, Mn/Ce-MOF catalysts, and (b) the corresponding UV–Vis absorbance spectra.

3.2. Effect of catalyst amount

The effect of catalyst dosage on the photocatalytic degradation of tetracycline (TC) is illustrated in Figure 2a. As the catalyst amount increased from 10 to 30 mg, a clear enhancement in TC removal efficiency was observed. At a lower catalyst dosage (10 mg), the relatively limited degradation performance (63.7%) could be attributed to the insufficient number of available active sites and restricted light absorption capacity. Increasing the catalyst loading to 20 mg

resulted in a notable improvement in TC removal (75.2%), indicating that a higher density of catalytically active centers and enhanced photon utilization effectively promoted the generation of reactive oxygen species (ROS). The highest degradation efficiency (88.1) was achieved at a catalyst dosage of 30 mg, suggesting that this amount provided an optimal balance between active surface area and light harvesting, thereby maximizing photocatalytic activity. However, it is well established that excessive catalyst loading may lead to light scattering, particle agglomeration, and shielding effects, which can hinder effective light penetration and reduce catalytic efficiency. Therefore, within the investigated range, 30 mg was identified as the optimal catalyst dosage for efficient TC degradation under visible-light irradiation.

3.3. Effect of initial antibiotic solution

Figure 2b illustrated the effect of initial tetracycline (TC) concentration on photocatalytic removal efficiency. As the initial TC concentration increased from 10 to 30 mg L^{-1}, a gradual decline in degradation efficiency was observed (from 75.2% to 54.7%). At a lower TC concentration (10 mg L^{-1}), the highest removal efficiency was achieved, which can be attributed to the sufficient availability of active catalytic sites relative to the number of TC molecules, enabling effective adsorption and subsequent photocatalytic oxidation. When the TC concentration was increased to 20 mg L^{-1}, a moderate decrease in removal efficiency (66.9%) was observed, likely due to partial saturation of active sites and increased competition among TC molecules for reactive oxygen species (ROS). At the highest concentration (30 mg L^{-1}), the photocatalytic performance declined more significantly, which can be explained by excessive surface coverage of the catalyst, limited ROS availability, and reduced light penetration caused by the increased solution turbidity. These results indicate that lower initial TC concentrations favor more efficient photocatalytic degradation, whereas higher pollutant loadings impose kinetic and mass-transfer limitations on the system.

3.3. Effect of solution pH

The initial pH of the solution played a critical role in the removal of organic molecules from wastewater, as it strongly influenced the interaction between the pollutant molecules and the catalyst surface. The pH not only altered the surface charge of the photocatalyst but also governed the ionic speciation of the adsorbate in the aqueous phase. In general, photocatalyst surfaces tended to be positively charged under acidic conditions and negatively charged at alkaline pH values. Tetracycline exhibited multiple pKa values, resulting in different ionic forms depending on the solution pH. Specifically, tetracycline existed as a doubly protonated species (TCH_3^+) at pH < 3.32, as a monoprotonated form (TCH_2^+) within the pH range of 3.32–7.78, as a negatively charged species (TCH^-) at 7.78 < pH < 9.7, and as a doubly negatively charged form (TC^{2-}) at pH > 9.7 [14]. Accordingly, the photocatalytic performance of Mn/Ce-MOF under different pH conditions was evaluated by adjusting the initial pH of the tetracycline solution using 0.1 M HCl and NaOH, and the corresponding results were presented in Figure 2c. The results demonstrated that decreasing the pH from 6 to 3 led to a reduction in photocatalytic efficiency, with removal efficiencies declining to 44.4%. Similarly, a further decrease in TC removal efficiency was observed under strong alkaline conditions (pH = 11), where efficiencies dropped to 30.4%. The suppressed performance under both acidic and

alkaline conditions could be attributed to unfavorable electrostatic interactions. At pH = 3, enhanced electrostatic repulsion between the positively charged tetracycline species and the positively charged photocatalyst surface likely hindered adsorption. Likewise, at pH = 11, electrostatic repulsion between negatively charged tetracycline species and the negatively charged catalyst surface inhibited effective TC removal. Overall, these findings indicated that visible-light-driven TC degradation in the presence of Mn/Ce-MOF was most favorable under near-neutral pH conditions.

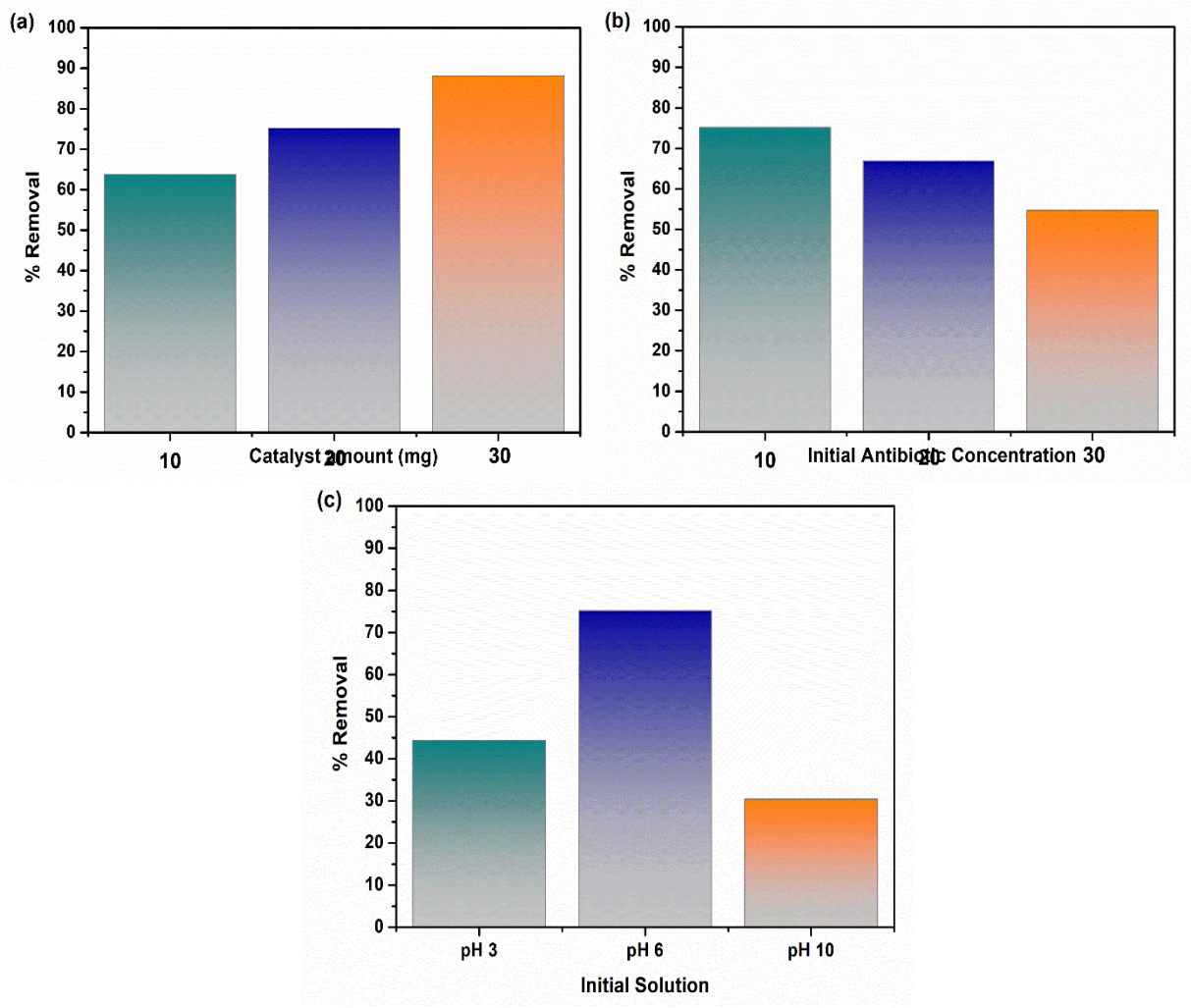


Figure 2. Effects of (a) catalyst amount, (b) initial antibiotic concentration and (c) initial solution pH on photocatalytic tetracycline (TC) removal efficiency of Mn/Ce-MOF catalyst

4. CONCLUSION

In this study, Mn-MOF, Ce-MOF, and bimetallic Mn/Ce-MOF catalysts, along with their NCQDs-modified composites, were systematically synthesized and evaluated for the visible-light-driven degradation of tetracycline (TC) in aqueous media. Comparative photocatalytic tests demonstrated that the Mn/Ce-MOF exhibited superior degradation performance compared to its monometallic counterparts, highlighting the synergistic interaction between Mn and Ce metal centers that effectively promoted charge separation and suppressed electron–hole recombination. The incorporation of NCQDs further enhanced photocatalytic activity by facilitating interfacial electron transfer and acting as efficient electron reservoirs, thereby improving reactive oxygen species generation. Parametric studies revealed that photocatalytic performance was strongly influenced by solution pH, catalyst dosage, and initial TC concentration, with optimal degradation achieved under near-neutral pH conditions, an appropriate catalyst loading, and lower pollutant concentrations. The observed decline in performance under acidic and alkaline conditions, excessive catalyst loading, and high TC concentrations was mainly attributed to unfavorable electrostatic interactions, light-shielding effects, and limited availability of reactive species. Overall, the results underscore the effectiveness of bimetallic MOF-based architectures combined with carbon quantum dot modification as promising photocatalysts for antibiotic removal and provide valuable insights into the rational design of high-performance materials for wastewater treatment applications.

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COMPARISON OF PHOTOCATALYTIC EFFICENY OF $CeNiO_3$/N-CQDs AND $NiTiO_3$/N-CQDs HETEROJUNCTIONS IN ANTIBIOTIC REMOVAL SYSTEM

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Tetracycline (TC), a widely used broad-spectrum antibiotic with low cost and strong antimicrobial activity, has emerged as a critical environmental pollutant due to its persistence and resistance to conventional treatment processes. Among various remediation strategies, photocatalytic oxidation has attracted significant attention, owing to its ability to mineralize TC into harmless end-products through reactive oxygen species generated under light irradiation. In this study, cerium nickel oxide / nitrogen-doped carbon quantum dots ($CeNiO_3$/N-CQDs) and nickel titanate / nitrogen-doped carbon quantum dots ($NiTiO_3$/N-CQDs) were performed for visible light-driven TC decomposition. The effect of operating parameters (initial solution pH and scavengers) were carried out and the related photocatalytic mechanisms were investigated with the help of trapping experiments. This work provides new catalytic material as nickel-included perovskite/ nitrogen enriched carbon quantum dots for light activated system.

Keywords: Tetracycline, Cerium nickel oxide, Nickel titanate, Carbon quantum dots, Photocatalysis

1. INTRODUCTION

The extensive use of antibiotics in human medicine, veterinary applications, and agriculture has led to their continuous release into aquatic environments, raising serious environmental and public health concerns. Among these contaminants, tetracycline (TC) has been frequently detected in surface water, groundwater, and wastewater effluents due to its broad-spectrum antibacterial activity, low cost, and resistance to biodegradation. The persistence of TC in aquatic systems not only contributes to the proliferation of antibiotic-resistant bacteria but also poses potential risks to aquatic organisms and human health. Conventional wastewater treatment processes are often insufficient for the complete removal of TC, necessitating the development of more effective and sustainable remediation technologies [1,2].

Photocatalytic oxidation has emerged as a promising advanced treatment approach for antibiotic removal, owing to its ability to generate highly reactive oxygen species (ROS), such as hydroxyl radicals (•OH) and superoxide radicals ($\bullet O_2^-$), under light irradiation. These reactive species can non-selectively decompose complex antibiotic molecules into smaller, less toxic intermediates and ultimately mineralize them into CO_2 and H_2O. However, the practical application of photocatalysis is often limited by rapid electron–hole recombination, insufficient visible-light absorption, and low quantum efficiency of conventional photocatalysts. Therefore, the rational design of photocatalytic materials with enhanced charge separation and visible-light responsiveness remains a major research focus [3,4].

Perovskite-type metal oxides have attracted increasing attention in photocatalytic applications due to their flexible crystal structures, tunable electronic properties, and excellent chemical stability. In particular, nickel-based perovskites, such as $CeNiO_3$ and $NiTiO_3$, have demonstrated promising photocatalytic activity arising from their suitable band structures and redox-active metal centers. Nevertheless, their photocatalytic performance is still hindered by limited charge carrier mobility and recombination losses. To overcome these drawbacks, the construction of heterojunction architectures and the incorporation of conductive carbon-based materials have been widely explored as effective strategies [5-8].

Nitrogen-doped carbon quantum dots (N-CQDs) have emerged as attractive modifiers for photocatalytic systems due to their excellent electron-accepting capability, strong light absorption, upconversion photoluminescence behavior, and abundant surface functional groups. When coupled with semiconductor photocatalysts, N-CQDs can serve as efficient electron reservoirs and conductive bridges, facilitating interfacial charge transfer and suppressing electron–hole recombination. Moreover, the formation of heterojunctions between perovskite oxides and N-CQDs can significantly enhance visible-light utilization and ROS generation, leading to improved photocatalytic performance [9-11].

In this context, the present study aims to comparatively investigate the visible-light-driven photocatalytic degradation of tetracycline using $CeNiO_3$/N-CQDs and $NiTiO_3$/N-CQDs heterojunctions. The influence of key operational parameters, including initial solution pH and reactive species scavengers, was systematically examined to evaluate photocatalytic efficiency and stability. Furthermore, the underlying photocatalytic mechanisms were elucidated through trapping

experiments, providing insight into charge transfer pathways and dominant reactive species. This work highlights the potential of nickel-containing perovskite/N-CQDs heterostructures as efficient and sustainable photocatalysts for antibiotic removal in aqueous environments.

2. EXPERIMENTAL

2.1. Synthesis of photocatalysts

The $CeNiO_3$ perovskite catalyst was synthesized via a two-step procedure involving coprecipitation followed by high-temperature calcination. In the first step, equal volumes of 0.1 M cerium nitrate hexahydrate ($Ce(NO_3)_3 \cdot 6H_2O$) solution and 0.1 M nickel chloride hexahydrate ($NiCl_2 \cdot 6H_2O$) solution were mixed thoroughly under continuous stirring to form a homogeneous solution. Subsequently, 1 M NaOH solution was slowly added dropwise to adjust the pH of the mixture to 9. The resulting suspension was magnetically stirred for 6 h and then aged under static conditions for an additional 12 h to ensure complete precipitation. After aging, the precipitate was collected by centrifugation and repeatedly washed with deionized water until a neutral pH was reached. The obtained solid was then dried in an oven at 120 °C for 12 h to yield the Ce–Ni precursor. In the second step, the dried precursor was calcined in a muffle furnace by heating to 600 °C at a ramp rate of 5 °C min^{-1} and maintained at this temperature for 5 h. After natural cooling to room temperature, the $CeNiO_3$ perovskite oxide powder was obtained [12].

The $NiTiO_3$ perovskite catalyst was synthesized via a facile co-precipitation method. In a typical procedure, 1.7 mL of titanium(IV) butoxide (TBT) was dissolved in 60 mL of ethylene glycol under vigorous stirring for 2 h to obtain a homogeneous solution. Subsequently, 1.24 g of nickel acetate tetrahydrate was added to the mixture, and the solution was further stirred for an additional 2 h. Afterward, 100 µL of deionized water was slowly introduced into the greenish solution to initiate the hydrolysis and precipitation process. The resulting suspension was continuously stirred for 24 h to ensure complete reaction.The final product was collected by centrifugation and thoroughly washed several times with ethanol to remove residual organic species and unreacted precursors. The obtained solid was then dried at 80 °C overnight. Finally, the dried precursor was calcined in a muffle furnace at different temperatures at 750°C for 2 h to obtain the crystalline $NiTiO_3$ perovskite oxide [13].

Nitrogen-doped carbon quantum dots (N-CQDs) were synthesized via a hydrothermal method. Briefly, 1.26 g of melamine and 2.10 g of citric acid were dissolved in 50 mL of distilled water under magnetic stirring until a clear solution was obtained. The resulting solution was stirred continuously for 1 h and then transferred into a stainless-steel Teflon-lined autoclave. The hydrothermal treatment was carried out at 220 °C for 18 h. After naturally cooling to room temperature, a yellow-colored N-CQDs aqueous solution was obtained and used directly for subsequent composite preparation [14].

NiO_3/N-CQDs and $NiTiO_3$/N-CQDs heterostructured catalysts with N-CQDs loading were prepared via a simple impregnation and assembly approach. In a typical procedure, 25 mg of $CeNiO_3$ or $NiTiO_3$ catalyst powder was dispersed into a total liquid volume of 20 mL containing

predetermined ratios of N-CQDs solution and distilled water. The suspension was magnetically stirred for 2 h to ensure uniform interaction between the perovskite particles and N-CQDs.

2.2. Photocatalytic Antibiotic Degradation

The photocatalytic performances of $CeNiO_3$/N-CQDs and $NiTiO_3$/N-CQDs heterojunctions were systematically evaluated for the degradation of tetracycline (TC) under visible-light irradiation. The photocatalytic experiments were carried out using a custom-designed photoreactor consisting of a stainless-steel chamber equipped with visible-light lamps (150 W; λ = 400–800 nm) mounted on the inner walls. A glass reaction vessel was placed on a magnetic stirrer located at the base of the chamber, allowing uniform illumination of the reaction solution from all directions. To maintain a constant reaction temperature during irradiation, a cooling fan was installed beneath the stirrer. For the photocatalytic activity tests, 20 mg of catalyst was dispersed in 40 mL of aqueous tetracycline solution with an initial concentration of 10 mg L^{-1}. Prior to light exposure, the suspension was magnetically stirred in the dark for 30 min to establish adsorption–desorption equilibrium. Subsequently, the reaction mixture was irradiated under visible light with continuous stirring for 2 h, and aliquots were withdrawn at 30 min intervals to monitor the degradation process. The concentrations of tetracycline before and after the photocatalytic experiments were determined using a UV–Vis spectrophotometer at a characteristic wavelength of 360 nm. Furthermore, the effect of initial TC solution pH was examined by performing the experiments under different pH values. In addition, scavenger studies were conducted to elucidate the primary reactive oxidant radicals for TC decomposition under visible light radiation. For that, different scavengers, including EDTA-2Na, ethanol (EtOH) and benzoquinone (BQ) were utilized to capture h^+, •OH, $•O_2^-$, respectively. The percentage of tetracycline elimination was calculated using Equation (1),

$$\%Removal=(C_0-C)/C_0x100 \quad (1)$$

where C_0 and C represent the initial and final antibiotic concentrations at the beginning and t minutes of irradiation time, respectively.

3. RESULTS AND DISCUSSION

3.1. Primarily experiments

The photocatalytic degradation efficiencies presented in Figure 1 clearly revealed the significant influence of both perovskite composition and N-CQDs incorporation on tetracycline removal under visible-light irradiation. Pristine $CeNiO_3$ exhibited relatively low photocatalytic activity (25.7%), which could be attributed to its limited visible-light utilization and rapid recombination of photogenerated electron–hole pairs. Upon coupling with nitrogen-doped carbon quantum dots, the photocatalytic performance of $CeNiO_3$ was markedly enhanced (44.1%), indicating that N-CQDs effectively facilitated interfacial charge transfer and acted as electron acceptors, thereby suppressing charge recombination and promoting reactive oxygen species (ROS) generation.

In comparison, $NiTiO_3$ demonstrated a considerably higher photocatalytic efficiency than $CeNiO_3$, suggesting that the intrinsic electronic structure and band alignment of $NiTiO_3$ were more favorable for visible-light-driven photocatalysis (64.7%). The superior performance of $NiTiO_3$ could be associated with its suitable band gap and enhanced redox capability, which enabled more efficient separation and migration of photogenerated charge carriers. Notably, the incorporation of N-CQDs into the $NiTiO_3$ matrix resulted in a dramatic increase in TC removal efficiency (958%), achieving the highest performance among all investigated catalysts. This pronounced enhancement highlights the strong synergistic interaction between $NiTiO_3$ and N-CQDs, where N-CQDs served not only as conductive bridges for electron transport but also as photosensitizers that broadened light absorption and prolonged charge carrier lifetimes.

Overall, the observed trend ($CeNiO_3$ < $CeNiO_3$/N-CQDs < $NiTiO_3$ < $NiTiO_3$/N-CQDs) demonstrates that both the selection of an appropriate perovskite host and the rational integration of carbon quantum dots are crucial for maximizing photocatalytic efficiency. The results confirm that constructing $NiTiO_3$/N-CQDs heterojunction could be presented as an effective strategy to overcome the intrinsic limitations of single-component photocatalysts and to achieve highly efficient visible-light-driven antibiotic degradation. Additionally, further studies were performed in the presence of $NiTiO_3$/N-CQDs due to its highest performance.

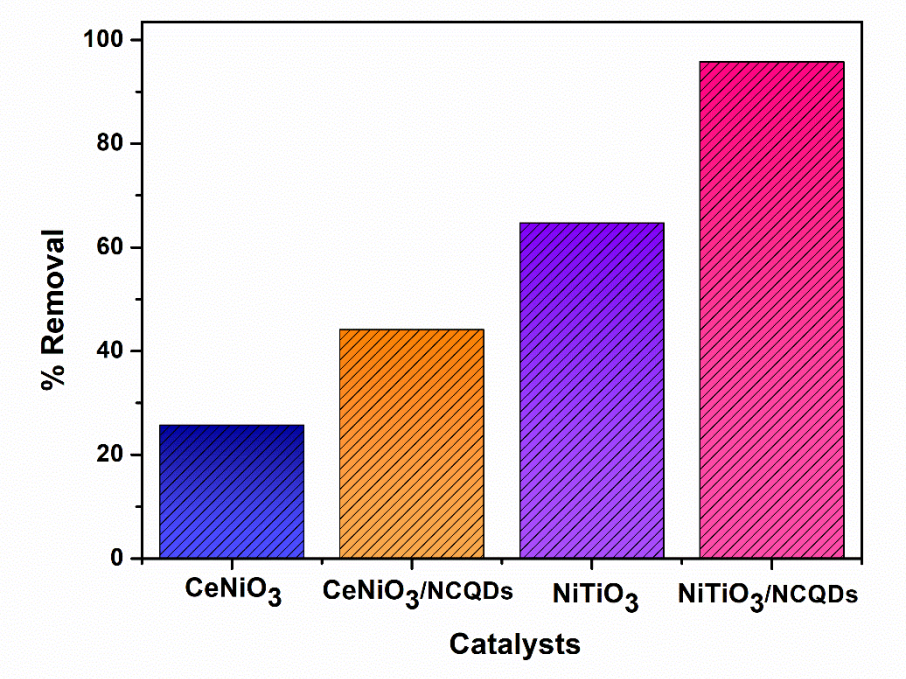


Figure 1. Photocatalytic tetracycline (TC) removal efficiencies of $CeNiO_3$, $CeNiO_3$/N-CQDs, $NiTiO_3$ and $NiTiO_3$/N-CQDs

3.2. Effect of solution pH

Solution pH was identified as a key operational parameter controlling the photocatalytic degradation behavior of tetracycline, as it simultaneously affected both catalyst surface properties and antibiotic speciation in the aqueous phase. Variations in pH modified the surface charge characteristics of the photocatalyst, while also determining the dominant ionic form of tetracycline in solution. Under acidic conditions, photocatalyst surfaces generally carried a net positive charge, whereas alkaline environments promoted negatively charged surfaces. Due to its amphoteric nature, tetracycline underwent pH-dependent structural transformations associated with its multiple pKa values, existing as TCH_3^+ at pH below 3.32, TCH_2^+ between pH 3.32 and 7.78, TCH^- in the range of 7.78–9.7, and TC^{2-} under strongly alkaline conditions (pH > 9.7).

The effect of pH on photocatalytic performance was evaluated by adjusting the initial solution pH using 0.1 M HCl and NaOH, and the corresponding results are presented in Figure 2a. Unlike alkaline conditions, acidic environments significantly enhanced tetracycline degradation, with the highest removal efficiency observed at pH 3 (99.8%). This improvement could be attributed to the increased generation of reactive oxygen species, particularly hydroxyl radicals (•OH), under acidic conditions, as well as more favorable surface reactions facilitated by proton-assisted charge transfer. In contrast, the photocatalytic efficiency declined markedly under alkaline conditions (pH = 11) (61.7%) which could be ascribed to electrostatic repulsion between negatively charged tetracycline species and the negatively charged $NiTiO_3$/N-CQDs surface, hindering effective adsorption and interfacial charge transfer. Overall, these findings demonstrate that visible-light-driven tetracycline degradation over $NiTiO_3$/N-CQDs was favored under acidic and neutral conditions, where enhanced oxidative capability and efficient surface reactions jointly contributed to improved photocatalytic performance.under near-neutral pH conditions, where electrostatic interactions were minimized and surface reactions were favored.

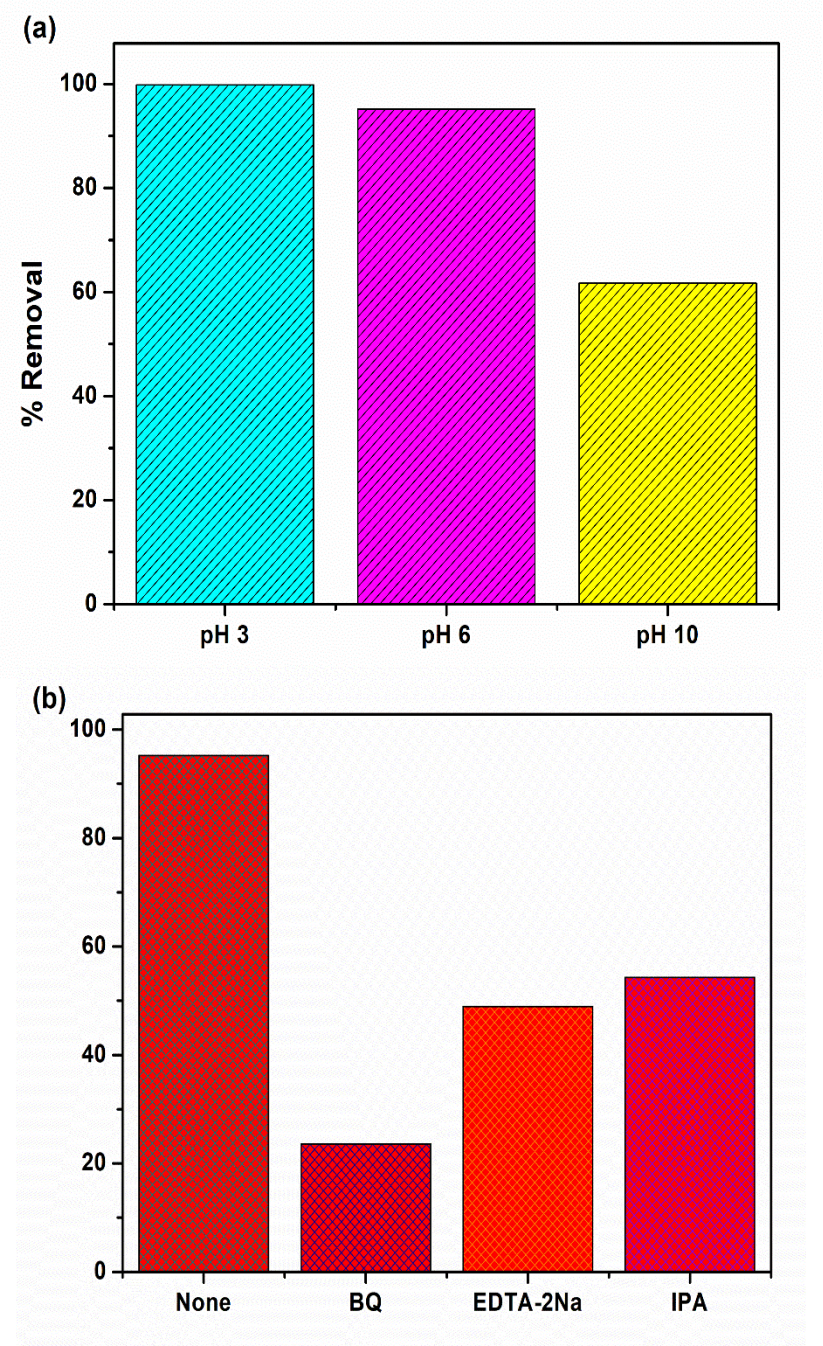


Figure 2. Effects of (a) initial antibiotic concentration and (b) scavengers on photocatalytic tetracycline (TC) removal efficiency of $NiTiO_3$/N-CQDs

3.3. Effect of scavengers and degradation mechanism

Scavenger experiments were performed to identify the dominant reactive species involved in the photocatalytic degradation of tetracycline over the $NiTiO_3$/N-CQDs heterojunction under visible-light irradiation. To selectively quench the active species, isopropanol (IPA), EDTA-2Na, and benzoquinone (BQ) were employed as scavengers for hydroxyl radicals (•OH), photogenerated holes (h^+), and superoxide radicals ($•O_2^-$), respectively. The corresponding results are presented in Fig. X. Upon the addition of BQ into the reaction system, the photocatalytic degradation efficiency of tetracycline dropped dramatically (23.6%), indicating that $•O_2^-$ radicals played a dominant role in the oxidation process. This pronounced inhibition suggested that photogenerated electrons transferred from the conduction band of $NiTiO_3$ to N-CQDs were efficiently captured by dissolved oxygen, leading to the formation of superoxide radicals that actively participated in TC degradation. In the presence of EDTA-2Na, a noticeable decrease in photocatalytic performance was also observed (48.9%), demonstrating that photogenerated holes contributed significantly to the oxidation reactions by directly attacking the antibiotic molecules or by promoting •OH formation. In contrast, the addition of IPA caused a relatively moderate reduction in degradation efficiency (54.3%), indicating that hydroxyl radicals were involved in the reaction pathway but did not constitute the primary oxidative species. These results collectively reveal that the photocatalytic degradation of tetracycline over $NiTiO_3$/N-CQDs followed a multi-radical mechanism, in which $•O_2^-$ radicals acted as the predominant reactive species, while photogenerated holes and •OH radicals played synergistic supporting roles. The efficient separation of charge carriers at the $NiTiO_3$/N-CQDs heterointerface and the electron-accepting behavior of N-CQDs were therefore crucial in governing the overall photocatalytic oxidation pathway.

4. CONCLUSION

In this study, a systematic investigation was carried out to evaluate the visible-light-driven photocatalytic degradation of tetracycline using nickel-based perovskite catalysts modified with nitrogen-doped carbon quantum dots. Preliminary screening experiments demonstrated that pristine perovskite catalysts exhibited limited photocatalytic activity, whereas the incorporation of N-CQDs significantly enhanced tetracycline removal efficiency by improving interfacial charge transfer and suppressing electron–hole recombination. Among the investigated systems, $NiTiO_3$/N-CQDs showed the highest photocatalytic performance, highlighting the crucial role of heterojunction construction and conductive carbon modification in promoting reactive oxygen species generation. Parametric studies revealed that photocatalytic efficiency was strongly dependent on solution pH, with acidic conditions favoring tetracycline degradation due to proton-assisted surface reactions, enhanced charge separation, and intensified oxidative capability. Furthermore, scavenger experiments provided direct mechanistic evidence that superoxide radicals ($•O_2^-$) were the dominant reactive species responsible for tetracycline oxidation, while photogenerated holes and hydroxyl radicals contributed synergistically to the

degradation process. Overall, the combined results demonstrate that the rational design of $NiTiO_3$/N-CQDs heterostructures enables efficient regulation of charge carrier dynamics and reactive species pathways, making these materials promising photocatalysts for visible-light-driven antibiotic removal in wastewater treatment applications.

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BİRİNCİ PRENSİPLER HESAPLAMALARI YOLUYLA $GdIr_2$ LAVES FAZI BİLEŞİĞİNİN KAPSAMLI BİR ARAŞTIRMASI

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ÖZET

Bu çalışmada, Yoğunluk Fonksiyonel Teorisi (DFT) kapsamında, C15 kristal yapısına sahip ikili kübik $GdIr_2$ intermetalik Laves faz bileşiğinin yapısal, elastik ve titreşimsel özellikleri ayrıntılı olarak incelenmiştir. İlk-prensip hesaplamalar sonucunda elde edilen kafes parametreleri ve birim hücre hacminin, literatürde raporlanan teorik ve deneysel verilerle oldukça iyi bir uyum içinde olduğu görülmüştür. Hesaplanan hacim modülü, $GdIr_2$ Laves faz bileşiğinin düşük sıkıştırılabilirliğe sahip olduğunu ortaya koyarken, negatif oluşum entalpisi değeri bileşiğin termodinamik açıdan kararlı olduğunu doğrulamaktadır. Elastik özellikler, kübik kristal sistemler için tanımlı C_{11}, C_{12} ve C_{44} elastik sabitleri temel alınarak değerlendirilmiştir. Bu sabitlerden yararlanılarak hacim modülü, kayma modülü, Young modülü ve Poisson oranı gibi temel elastik parametreler Voigt–Reuss–Hill (VRH) yaklaşımı ile hesaplanmıştır. Elde edilen elastik sonuçlar, $GdIr_2$ Laves faz bileşiğinin elastik açıdan anizotropik bir davranış gösterdiğini ve mekanik olarak kararlı olduğunu ortaya koymaktadır. Ayrıca Pugh oranı analizi, bileşiğin sünek doğasını destekleyen ek bir gösterge sunmaktadır. Öte yandan, dinamik kararlılık yüksek simetrili doğrultular boyunca hesaplanan fonon dispersiyon eğrileri yardımıyla incelenmiştir. Fonon spektrumunda hayali frekansların bulunması, $GdIr_2$ Laves faz bileşiğinin dinamik olarak kararsız bir yapıya sahip olduğunu açıkça göstermektedir.

Anahtar Kelimeler: İntermetalik bileşikler, İlk-prensip hesaplamalar, Laves fazı, Fonon özellikleri.

1. GİRİŞ

Laves fazlı kübik $MgCu_2$ (C15) tipi intermetalik bileşikler, 0,07 K kadar düşükten 10 K'nin üzerine kadar geniş bir süperiletken geçiş sıcaklığı aralığı sergileyerek süperiletkenlik için umut vadeden adaylar olarak kabul edilmektedir [1, 2]. Aynı kristal sınıfına ait bileşikler arasında süperiletken kritik sıcaklıkta önemli bir varyasyon olması nedeniyle, bu malzemelerin ayrıntılı bir şekilde incelenmesi büyük önem taşımaktadır. Farklı süperiletkenlerdeki süperiletkenliğin altında yatan mekanizmaların anlaşılması, öncelikle kristal yapı, manyetizma ve elektronik arasındaki karmaşık etkileşim nedeniyle, modern yoğun madde fiziğinde büyük bir zorluk olmaya devam etmektedir. Bununla birlikte, Laves fazlı bileşiklerin kristal yapısı ve kimyasal bileşimi nispeten basit olduğundan, bu sistemlerin kapsamlı çalışmaları, süperiletkenliğin temel doğasına dair değerli bilgiler sağlayabilir.

Gadolinyum içeren kübik Laves fazlı bileşikler üzerinde yapılan önceki deneysel çalışmalar, hiperfine alanların manyetik davranışlarını belirlemede çok önemli bir rol oynadığını göstermiştir. Özellikle, sıfır alan spin-eko NMR ölçümleri, ferromanyetik olarak düzenlenmiş Gd bazlı Laves fazlı sistemlerde hem Gd hem de geçiş metal bölgelerinde önemli hiperfine etkileşimlerini ortaya çıkarmış ve yerelleştirilmiş 4f momentleri ile çevredeki elektronik ortam arasındaki güçlü bağlantıyı vurgulamıştır [3, 4].

Literatürde Gd bazlı kübik Laves fazlı bileşiklerin manyetik ve rezonans davranışları üzerine yapılan kapsamlı deneysel araştırmalara rağmen, $GdIr_2$'nin tüm fiziksel özelliklerini ele alan kapsamlı deneysel ve teorik çalışmalar oldukça azdır. Literatürdeki bu belirgin boşluk, bu çalışmayı motive etmektedir. Buna göre, $GdIr_2$ intermetalik bileşiğinin fiziksel özelliklerinin sistematik ve kapsamlı bir teorik incelemesini sunuyoruz. Bu çalışmada, yapısal, elastik, mekanik ve titreşimsel özellikler, düzlem dalga psödo-potansiyel yoğunluk fonksiyonel teorisi (DFT) yaklaşımı çerçevesinde incelenmektedir.

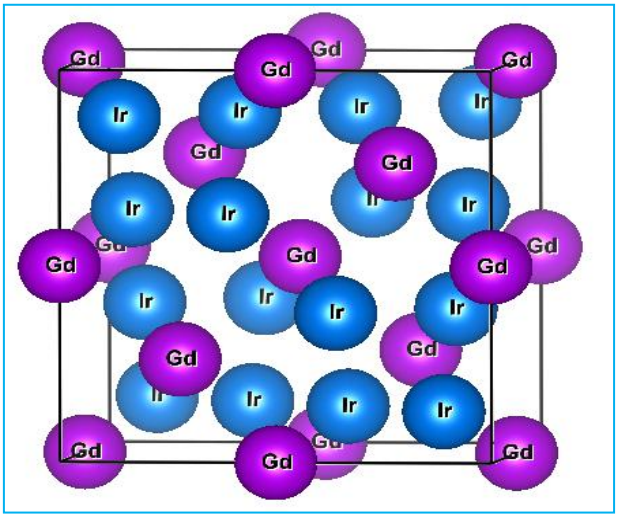
2. ÇALIŞMANIN METODOLOJİSİ

$GdIr_2$ intermetalik bileşiğinin temel fiziksel özelliklerinden yapısal kararlılık, mekanik ve dinamik özelliklerini araştırmak için, Quantum ESPRESSO yazılım paketi [5] kullanılarak yoğunluk fonksiyonel teorisi (DFT) çerçevesinde ilk prensip hesaplamaları yapılmıştır. Hesaplamalar, iyonik çekirdekler ve değerlik elektronları arasındaki etkileşimi tanımlamak için psödo-potansiyellerle birlikte düzlem dalga taban kümesi kullanılarak gerçekleştirilmiştir. Perdew–Burke–Ernzerhof (PBE) değişim-korelasyon fonksiyoneli biçiminde genelleştirilmiş gradyan yaklaşımı (GGA) benimsenmiştir [6]. Elektron-iyon etkileşimlerini doğru bir şekilde hesaba katmak için projektör artırılmış dalga (PAW) yöntemi kullanılmıştır [7]. Sistematik yakınsama testlerinden sonra, tüm hesaplamalar için 50 Ry'lik bir düzlem dalga kinetik enerji kesme değeri seçilmiştir. Brillouin bölgesi entegrasyonları, 12 × 12 × 12 Monkhorst–Pack k-nokta ağı kullanılarak gerçekleştirilmiştir [8]. Elastik sabitler, küçük deformasyonlar altında malzemenin mekanik stabilitesinin ve elastik tepkisinin güvenilir bir şekilde değerlendirilmesini sağlayan gerilim-gerinim yaklaşımı [9] kullanılarak hesaplandı.

3. SONUÇLAR VE DEĞERLENDİRME

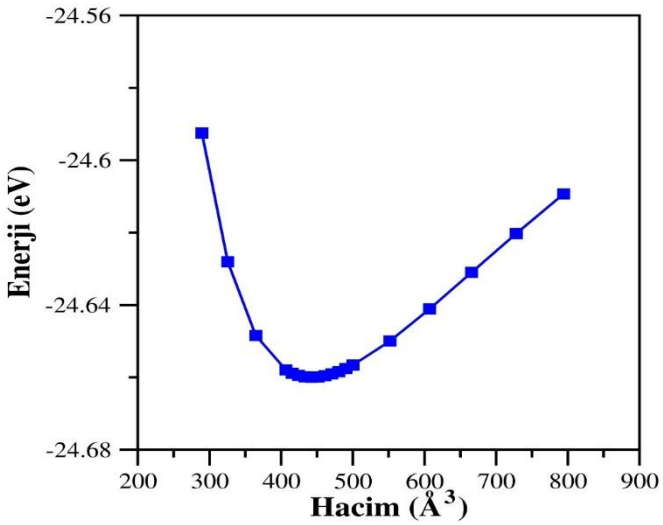
$GdIr_2$, Fd–3m (No. 227) uzay grubuna sahip yüz merkezli kübik (fcc) bir yapıda kristalleşir. Gd ve Ir atomlarının sırasıyla (0, 0, 0) ve (0.625, 0.625, 0.625) Wyckoff pozisyonlarını işgal ettiği, iyi bilinen $MgCu_2$ tipi Laves fazı yapısını benimser. Geleneksel birim hücre, karakteristik C15

tipi kristal düzenini yansıtan sekiz formül biriminden oluşur. Optimize edilmiş C15 tipi kristal yapısının üç boyutlu görselleştirmesi Görsel 1'de sunulmuştur.



Görsel 1. C15 tipi kübik kristal yapıya sahip $GdIr_2$ bileşiğinin üç boyutlu görünümü

Bu çalışmada, toplam enerjiyi en aza indirerek uygulanan normal gerilim altında $GdIr_2$'nin kafes parametresi ve atomik pozisyonları optimize edilmiştir. Hesaplanan enerji-hacim ilişkisi Görsel 2'de gösterilmiştir ve buradan denge yapısal parametreleri türetilmiştir.



Görsel 2. $GdIr_2$ Laves faz bileşiği için enerji–hacim ilişkisi

Kafes sabiti, hacim modülü, hacim modülünün basınca göre türevi, birim hücre hacmi ve oluşum entalpisi dahil olmak üzere hesaplanan tüm yapısal parametreler, karşılaştırma için mevcut teorik ve deneysel verilerle birlikte Çizelge 1'de özetlenmiştir. Optimize edilmiş kafes sabiti 7,603 Å olarak bulunmuştur; bu değer, önceki teorik raporla çok iyi bir uyum içindedir ve yalnızca küçük bir sapma göstermektedir. Bu küçük tutarsızlık, yoğunluk fonksiyonel teorisi hesaplamalarının tipik doğruluğu dahilindedir ve mevcut hesaplama yaklaşımının güvenilirliğini doğrulamaktadır.

Çizelge 1. $GdIr_2$ Laves faz bileşiğinin hesaplanan yapısal parametreleri ve oluşum entalpisi (ΔH_f).

	Ref.	a_0 (Å)	B_0 (GPa)	B_0'	V (Å³/f.u.)	ΔH_f (eV/atom)
$GdIr_2$	Present	7.603	195.30	4.78	439.536	-0.797
	[Teorik]	7.586	-	-	436.512	-0.793
	[2]	-	-	-	-	-0.710

Elde edilen hacim modülü (195,30 GPa), $GdIr_2$'nin nispeten düşük sıkıştırılabilirliğe sahip olduğunu ve bunun da intermetalik bağ karakteriyle tutarlı olduğunu göstermektedir. Negatif oluşum entalpisi, bu Laves faz bileşiğinin termodinamik kararlılığını doğrulamaktadır.

Elastik sabitler, Debye sıcaklığı, kimyasal bağ özellikleri ve malzemelerin mekanik kararlılığı da dahil olmak üzere çeşitli temel katı hal olaylarını anlamak için gerekli malzeme parametreleridir. Elastik sabitlerin ayrıntılı bir analizi, özellikle malzeme sertliği ve kararlılığı açısından, katılardaki atomlar arası kuvvetlerin dinamik davranışı ile mekanik özellikler arasında önemli bir bağlantı kurar [10]. Dahası, elastik sabitler, sertlik, kırılganlık, süneklik, anizotropi ve genel yapısal kararlılık gibi temel mekanik özellikler hakkında değerli bilgiler sağlar. $GdIr_2$ Laves faz bileşiğinin elastik sabitleri ve mekanik özellikleri kapsamlı bir şekilde incelendi. Elastik sabitler, Hooke yasasına göre hesaplanan gerilim-gerinim ilişkilerine doğrusal bir uyum yapılarak belirlendi [10]. Kübik kristal simetrisi nedeniyle, $GdIr_2$ üç bağımsız elastik sabite (Çizelge 2) sahiptir: C_{11}, C_{12} ve C_{44}. Elde edilen değerler kübik kristaller için Born-Huang mekanik kararlılık kriterlerini karşılamaktadır [10]:

Çizelge 2. $GdIr_2$ Laves faz bileşiği için DFT ile elde edilen elastik sabitler (C_{ij}) ve Cauchy basıncı (C_P)

Material	C_{11} (GPa)	C_{12} (GPa)	C_{44} (GPa)	C_P (GPa)
$GdIr_2$	286.82	151.72	98.70	58.86

Hesaplanan C_{ij} değerlerine dayanarak, hacim modülü (B), kayma modülü (G), Young modülü (E) ve Poisson oranı (ν) dahil olmak üzere temel mekanik parametreler, Voigt–Reuss–Hill (VRH) ortalaması [15] kullanılarak değerlendirildi ve Çizelge 3'te özetlendi.

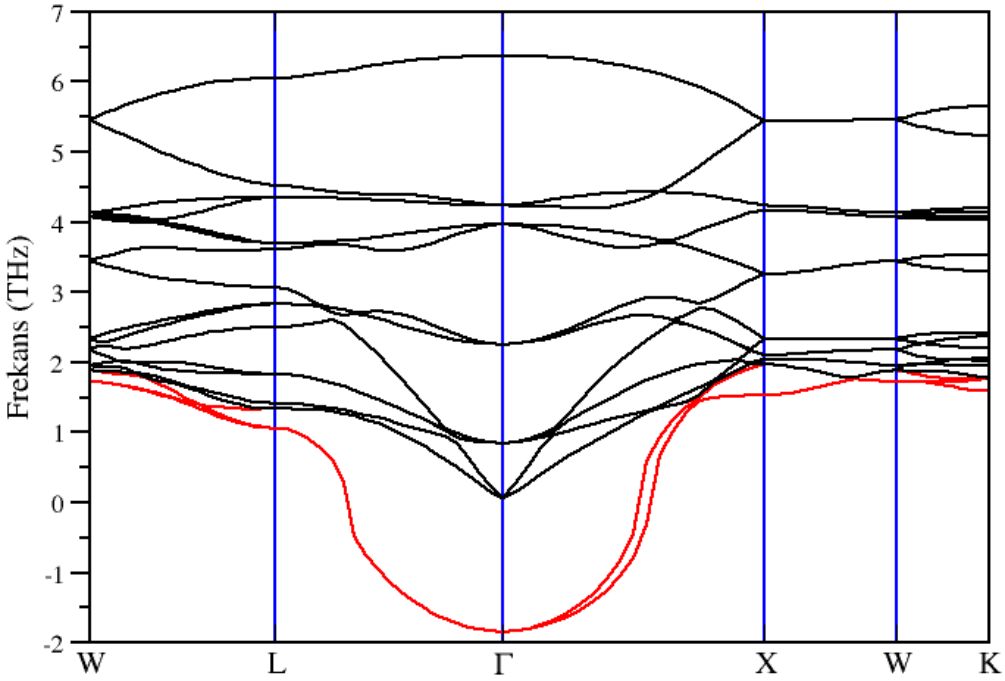
Çizelge 3. $GdIr_2$ Laves faz bileşiği için elastik sabitlerden türetilen mekanik parametreler

	B (GPa)	G_V (GPa)	G_R (GPa)	G_H (GPa)	B/G	E (GPa)	ν
$GdIr_2$	196.75	86.24	83.33	84.79	2.32	222.41	0.31

$GdIr_2$ Laves faz bileşiği için hesaplanan 196,75 GPa'lık hacim modülü, $GdIr_2$'nin hacim sıkıştırmasına karşı yüksek direnç gösterdiğini ve nispeten sert atomlar arası bağlarını yansıttığını göstermektedir. Voigt (86,24 GPa) ve Reuss (83,33 GPa) yaklaşımlarından elde edilen kayma modülü değerleri birbirine yakındır ve bu da Hill ortalama kayma modülüne (G_H = 84,79 GPa) yol açarak mekanik olarak kararlı ve neredeyse izotropik bir kayma deformasyonuna tepkiyi göstermektedir.

Hesaplanan B/G oranı 2,32, kritik değer 1,75'i aşmaktadır ve bu da $GdIr_2$'nin Pugh kriterine göre sünek bir mekanik yapıya sahip olduğunu göstermektedir. Bu sonuç, önemli merkezi kuvvet etkileşimlerine sahip sünek metalik sistemler için karakteristik olan ν = 0,31 Poisson oranıyla da desteklenmektedir. Dahası, 222,41 GPa'lık nispeten yüksek Young modülü, malzemenin önemli sertliğini ve elastik deformasyona dayanma yeteneğini doğrulamaktadır. Genel olarak, bu mekanik parametreler, $GdIr_2$'nin mekanik olarak sağlam, sünek ve elastik

olarak kararlı bir intermetalik bileşik olduğunu ve hem yapısal bütünlüğün hem de mekanik güvenilirliğin gerekli olduğu uygulamalar için uygun olduğunu göstermektedir.



Görsel 3. Brillouin bölgesinde yüksek simetri çizgileri boyunca $GdIr_2$ bileşiğinin hesaplanan fonon dispersiyon eğrileri

Görsel 3, $GdIr_2$'nin birinci Brillouin bölgesindeki yüksek simetri yönleri W–L–Γ–X–W–K boyunca fonon dağılım eğrilerini göstermektedir. $GdIr_2$'nin temel birim hücresi altı atom içerdiğinden, üç akustik (bir boyuna ve iki enine) ve on beş optik moddan oluşan toplam 18 fonon dalı beklenmektedir. L–Γ–X bölgesinde sanal (negatif) frekansların varlığı, bileşiğin dinamik kararsızlığını açıkça doğrulamaktadır.

4. GENEL DEĞERLENDİRME VE SONUÇLAR

Bu çalışmada $GdIr_2$ Laves faz bileşiğinin yapısal, mekanik ve dinamik özellikleri birinci ilke hesaplamalarıyla incelenmiştir. Elde edilen denge kafes parametresi ve negatif oluşum entalpisi, bileşiğin termodinamik açıdan kararlı olduğunu göstermektedir. Hesaplanan elastik sabitler ve mekanik modüller, bu Laves faz bileşiğinin elastik kararlılığa ve sünek karaktere sahip olduğunu doğrulamaktadır. Fonon dağılım eğrilerinde hayali frekansların bulunması, bileşiğin dinamik açıdan kararsız olduğunu göstermektedir.

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$C1_b$ KÜBİK YAPILI SmPtBi YARI-HEUSLER BİLEŞİĞİNİN ELASTİK VE TİTREŞİMSEL ÖZELLİKLERİ ÜZERİNE İLK PRENSİP ÇALIŞMASI

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ÖZET
Bu çalışmada, SmPtBi üçlü yarı-Heusler bileşiği genelleştirilmiş gradyan yaklaşımı (GGA) çerçevesinde yoğunluk fonksiyonel teorisi (DFT) kullanılarak ayrıntılı biçimde incelenmiştir. SmPtBi bileşiklerinin yapısal kararlılığı, mekanik dayanımı ve titreşimsel davranışları, F-43m (No. 216) uzay grubuna ait C1b tipi kübik kristal yapı temel alınarak optimize edilmiş denge geometrileri üzerinden değerlendirilmiştir. Çalışma kapsamında, atomların kafes içerisindeki konumsal düzenlenişleri de dikkate alınarak her bileşik için birbirinden farklı üç yapısal faz (α, β ve γ) ele alınmıştır. Bu fazlar, toplam enerji hesaplamaları ve oluşum entalpileri üzerinden karşılaştırılmıştır. Hesaplanan negatif oluşum entalpileri, SmPtBi bileşikleri için γ fazının termodinamik açıdan en kararlı yapı olduğunu açıkça ortaya koymuştur. Enerji karşılaştırmaları sonucunda, γ fazının, α ve β fazlarına kıyasla daha düşük toplam enerjiye sahip olduğu ve bu nedenle enerjitik olarak daha elverişli olduğu belirlenmiştir. Buna ek olarak, elastik sabitler ve fonon dispersiyon hesaplamaları, γ fazlı SmPtBi bileşiklerinin hem mekanik hem de dinamik kararlılık koşullarını sağladığını göstermektedir. Elastik özelliklerin ayrıntılı analizi, bu malzemelerin düşük elastik modül değerleri ve yüksek süneklik göstergeleri ile karakterize edildiğini ortaya koymaktadır. Elde edilen bu bulgular, SmPtBi yarı-Heusler bileşiklerinin yapısal olarak kararlı, mekanik açıdan yumuşak ve sünek karaktere sahip malzemeler olduğunu ve ileri fonksiyonel uygulamalar için potansiyel adaylar arasında yer aldığını göstermektedir.

Anahtar Kelimeler: SmPtBi, C1b Kübik Yapı, Mekanik Özellikler, Elastik Sabitler, Dinamik Kararlılık.

1. GİRİŞ
Topolojik yalıtkanlar, temel bilimsel önemleri ve geniş kapsamlı teknolojik potansiyelleri nedeniyle yoğun madde fiziği ve malzeme biliminde en öne çıkan ve hızla gelişen malzeme sınıflarından birini

oluşturmaktadır [1, 2]. Bu malzemeler, elektronik bant yapılarında önemsiz olmayan bir topolojik düzen ile karakterize edilir; bu düzen, zaman tersine çevirme simetrisi ile korunan sağlam metalik yüzey veya kenar durumlarıyla birlikte var olan yalıtkan bir kütle durumuna yol açar [3]. Bu benzersiz elektronik özellikler, topolojik yalıtkanları spintronik, kuantum hesaplama ve düşük kayıplı elektronik cihazlar için son derece cazip kılarken, yarı-Heusler bileşiklerinin yapısal esnekliği ve kimyasal olarak ayarlanabilir doğası, bant ters çevrilmesi ve güçlü spin-yörünge eşleşmesinin etkin biçimde düzenlenmesine olanak tanımakta; bu iki özellik ise topolojik davranışın ortaya çıkması için temel gereksinimleri oluşturmaktadır. Özellikle, LuPtBi ve YPtBi gibi çeşitli platin-bismutidler ile ErPdBi, CePdBi ve LuPdBi dahil olmak üzere paladyum-bismutidlerin Fermi seviyesine yakın bant inversiyonu sergilediği ve bu nedenle topolojik süperiletkenlik için umut vadeden adaylar olduğu bildirilmiştir [4–7].

Bu çalışmada, SmPtBi yarı-Heusler bileşiğinin yapısal, mekanik ve titreşimsel özellikleri, GGA düzlem dalga sözde potansiyel yaklaşımı çerçevesinde yoğunluk fonksiyonel teorisi kullanılarak incelenmiştir. Optimize edilmiş yapılar, bileşiğin kararlılığını, mekanik davranışını ve kafes dinamiklerini değerlendirmek ve temel özelliklerine dair genel bir anlayış sağlamak için kullanılmıştır.

2. YÖNTEM

Yarı-Heusler bileşiği SmPtBi'nin yapısal kararlılığını, mekanik ve dinamik özelliklerini araştırmak için, Quantum ESPRESSO yazılım paketi [8] kullanılarak yoğunluk fonksiyonel teorisi (DFT) çerçevesinde ilk prensip hesaplamaları yapılmıştır. Hesaplamalar, iyonik çekirdekler ve değerlik elektronları arasındaki etkileşimi tanımlamak için psödo-potansiyellerle birlikte düzlem dalga taban kümesi kullanılarak gerçekleştirilmiştir. Perdew–Burke–Ernzerhof (PBE) değişim-korelasyon fonksiyoneli biçiminde genelleştirilmiş gradyan yaklaşımı (GGA) benimsenmiştir [9]. Elektron-iyon etkileşimlerini doğru bir şekilde hesaba katmak için projektör artırılmış dalga (PAW) yöntemi kullanılmıştır [10]. Sistematik yakınsama testlerinden sonra, tüm hesaplamalar için 50 Ry'lik bir düzlem dalga kinetik enerji kesme değeri seçilmiştir. Brillouin bölgesi entegrasyonları, 12 × 12 × 12 Monkhorst–Pack k-nokta ağı kullanılarak gerçekleştirilmiştir [11]. Elastik sabitler, küçük deformasyonlar altında malzemenin mekanik stabilitesinin ve elastik tepkisinin güvenilir bir şekilde değerlendirilmesini sağlayan gerilim-gerinim yaklaşımı [12] kullanılarak hesaplandı.

3. SONUÇLAR VE DEĞERLENDİRME

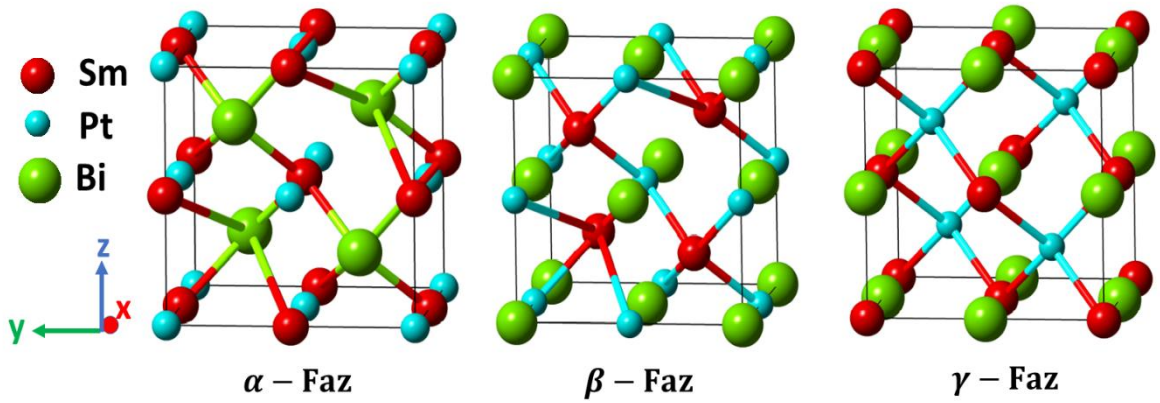
Yarı Heusler bileşiği SmPtBi, F-43m (No. 216) uzay grubuna ait olup, MgAgAs tipi kübik yapısında kristalleşir. Bu yapı, iç içe geçmiş üç yüz merkezli kübik alt kafesle karakterize edilir; dört fcc alt kafesten biri boş kalır ve bu da yarı Heusler bileşiklerinin tanımlayıcı bir özelliğidir. En kararlı atomik konfigürasyonu belirlemek için, yaygın olarak α, β ve γ fazları olarak adlandırılan üç farklı atomik düzenleme dikkate alınarak yapısal optimizasyonlar gerçekleştirildi. Bu konfigürasyonlar, bileşen atomların (Sm, Pt ve Bi) üç mevcut Wyckoff pozisyonu üzerindeki farklı permütasyonlarından kaynaklanır: 4*a* (0, 0, 0), 4b (1/2, 1/2, 1/2) ve 4c (1/4, 1/4, 1/4). α fazında, Sm atomu 4b Wyckoff pozisyonunu (0,5, 0,5, 0,5), Pt 4*a* pozisyonunu (0, 0, 0) ve Bi 4c pozisyonunu (0,25, 0,25, 0,25) işgal eder. Bu atomik düzenleme, MgAgAs tipi yarı Heusler bileşikleri için sıklıkla bildirilen geleneksel işgal şemasına karşılık gelir ve genellikle referans konfigürasyon olarak kabul edilir. İkinci olarak, β fazı için, atomik

pozisyonlar yeniden düzenlenir; Sm 4c pozisyonunu (0,25, 0,25, 0,25), Pt 4b pozisyonunu (0,5, 0,5, 0,5) işgal eder ve Bi 4*a* pozisyonuna (0, 0, 0) kaydırılır. Bu permütasyon, kristal içindeki yerel koordinasyon ortamlarını ve atomlar arası bağ özelliklerini değiştirir. γ fazında ise Sm 4*a* konumunda (0, 0, 0), Pt 4c konumunda (0,25, 0,25, 0,25) ve Bi 4b konumunda (0,5, 0,5, 0,5) yer almaktadır. Bu konfigürasyon, mevcut Wyckoff konumları arasında üçüncü olası atomik sıralamayı temsil eder. α, β ve γ fazlarına karşılık gelen Sm, Pt ve Bi atomlarının kristalografik konumları Çizelge 1'de özetlenmiştir.

Çizelge 1. SmPtBi bileşiğinde Sm, Pt ve Bi atomlarının α, β ve γ fazlarına karşılık gelen kristalografik yerleşimleri

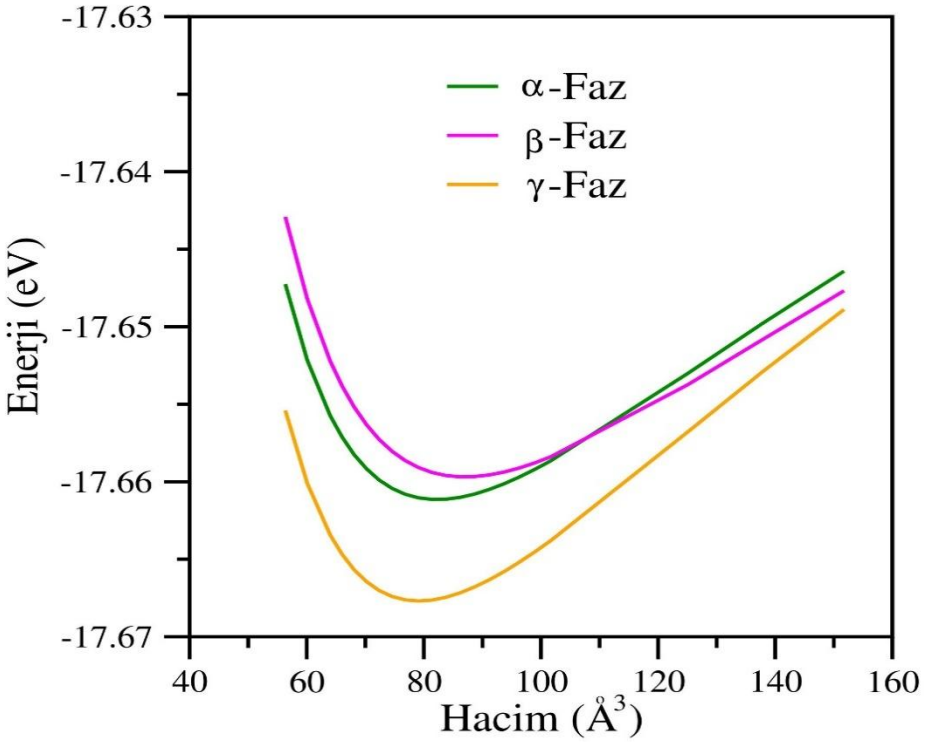
Faz	Sm	Pt	Bi
α	(0.5, 0.5, 0.5)	(0, 0, 0)	(0.25, 0.25, 0.25)
β	(0.25, 0.25, 0.25)	(0.5, 0.5, 0.5)	(0, 0, 0)
γ	(0, 0, 0)	(0.25, 0.25, 0.25)	(0.5, 0.5, 0.5)

Bu fazların üç boyutlu atomik düzenlemeleri ise Görsel 1'de gösterilmiştir. Daha sonra, enerjisel olarak en uygun fazı belirlemek için karşılaştırmalı bir toplam enerji analizi yapılmıştır.



Görsel 1. SmPtBi yarı-Heusler bileşiğinin α, β ve γ fazlarında kristal yapıların şematik gösterimi

SmPtBi yarı-Heusler bileşiğinin temel durum yapısal özellikleri, Birch-Murnaghan [13] durum denklemi kullanılarak hesaplanan toplam enerjinin hacme bağlı bir fonksiyon olarak uyarlanmasıyla belirlendi. Bu amaçla, ele alınan her atomik konfigürasyon (α, β ve γ fazları) için denge kafes hacmi etrafında bir dizi toplam enerji hesaplaması yapıldı. Elde edilen enerji-hacim (E-V) verileri daha sonra denge yapısal parametrelerini çıkarmak için Birch-Murnaghan formalizmine uyarlandı. SmPtBi'nin α, β ve γ fazları için uyarlanmış E-V eğrileri Görsel 2'de sunulmuştur.



Görsel 2. SmPtBi bileşiğinde α, β ve γ fazları için enerji–hacim (E–V) eğrileri

Üç fazın tümü için hesaplanan yapısal parametreler, denge kafes sabiti (a_0), hacim modülü (B_0), basınç türevi (B_0'), minimum toplam enerji (E_{tot}) ve denge hacmi (V) dahil olmak üzere Çizelge 2'de özetlenmiştir.

Çizelge 2. SmPtBi yarı-Heusler bileşiğinin α, β ve γ fazları için DFT ile hesaplanan yapısal parametreler

F-43m	Faz	a_0 (Å)	B_0 (GPa)	B_0'	E_{top} (Ry)	V (Å^3/f.u.)
SmPtBi	α	6.883	73.30	5.13	-312.383	-
	β	7.011	61.90	4.82	-312.342	-
	γ	6.813	85.80	4.76	-312.510	82.597
	[Teorik]	6.896	-	-	-	81.993

Üç konfigürasyon arasında, γ fazı en düşük toplam enerjiye sahiptir ve bu da SmPtBi için en enerjik olarak kararlı yapı olduğunu gösterir. Bu enerjik tercih, α ve β fazlarına kıyasla hacim deformasyonuna karşı artan direnci gösteren nispeten daha yüksek hacim modülü (85,80 GPa) ile daha da desteklenmektedir. γ fazının denge kafes sabiti 6,813 Å olarak hesaplanmıştır ve bu, mevcut teorik referans değeri (6,896 Å) ile mükemmel bir uyum göstermekte ve mevcut hesaplama yaklaşımının güvenilirliğini doğrulamaktadır. Buna karşılık, α ve β fazları daha yüksek denge enerjileri ve daha düşük hacim modülleri sergileyerek, γ fazına göre daha düşük yapısal kararlılık ve mekanik sertlik göstermektedir.

Genel olarak, enerji-hacim analizi, γ fazının SmPtBi yarı-Heusler bileşiğinin temel durum konfigürasyonu olarak açıkça tanımlamaktadır; bu nedenle, sonraki bölümlerde tartışılan elastik ve titreşimsel özelliklerin tüm hesaplamaları için bu faz benimsenmiştir.

Elastik sabitler, uygulanan dış gerilim altında kristal malzemelerin mekanik tepkisini tanımlamada temel bir rol oynar; çünkü gerilim ve gerinim arasındaki ilişkiyi karakterize eder ve kafes bozulmaları ile ilişkili enerji değişimlerine doğrudan bir bakış açısı sağlar. SmPtBi kübik bir yapıda kristalleştiğinden, elastik davranışı üç bağımsız elastik sabit tarafından tamamen tanımlanır: boyuna elastik sabit C_{11}, enine elastik sabit C_{12} ve kayma elastik sabit C_{44}. SmPtBi yarı-Heusler bileşiğinin γ fazı için hesaplanan elastik sabitler Çizelge 3'te sunulmuştur.

Çizelge 3. SmPtBi yarı-Heusler bileşiğinin γ fazında mekanik kararlılığı belirleyen elastik sabitler

	C_{11} (GPa)	C_{12} (GPa)	C_{44} (GPa)
SmPtBi	139.81	56.10	39.24

Elde edilen değerler kübik kristaller için Born-Huang mekanik kararlılık kriterlerini karşılamaktadır [14]:

$C_{11} > 0$, $C_{44} > 0$, $C_{11} - C_{12} > 0$ ve $C_{11} + 2C_{12} > 0$.

Bu, SmPtBi'nin γ fazının küçük deformasyonlar altında mekanik olarak kararlı olduğunu doğrulamaktadır. Bu elastik sabitlere dayanarak, Voigt-Reuss-Hill (VRH) yaklaşımı kullanılarak birkaç önemli makroskopik mekanik modül türetildi ve sonuçlar Çizelge 4'te özetlendi.

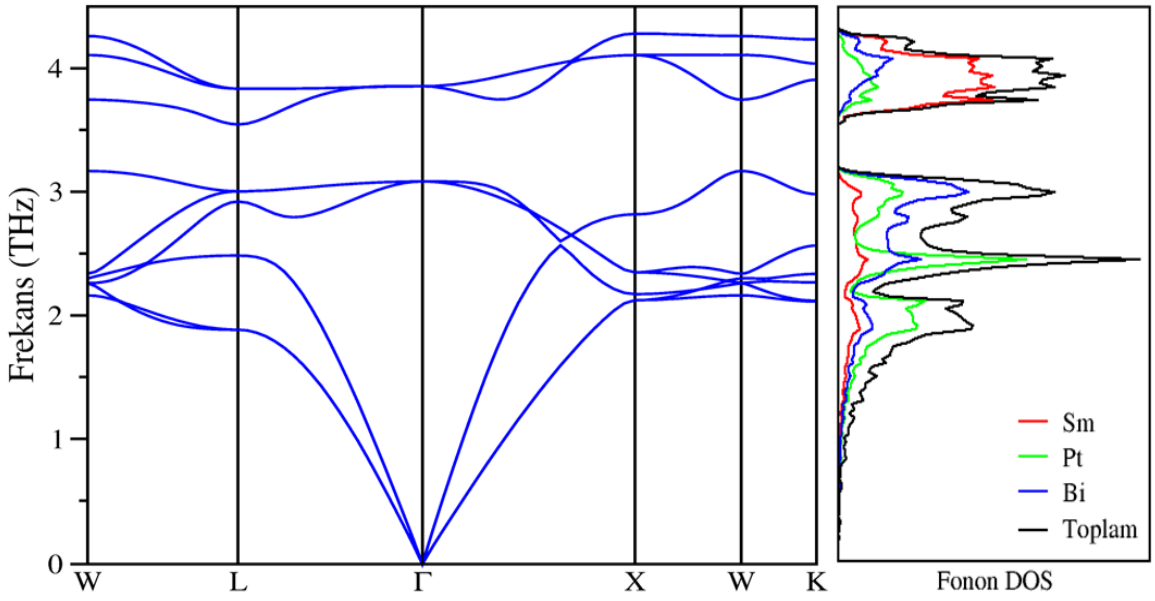
Çizelge 4. SmPtBi yarı-Heusler bileşiği için elastik sabitlerden türetilen mekanik modüller

	B (GPa)	G_V (GPa)	G_R (GPa)	G (GPa)	B/G	E (GPa)	ν
SmPtBi	84.00	40.29	40.25	40.27	2.09	104.16	0.29

Hacim modülü (B), malzemenin düzgün hacimsel sıkıştırmaya karşı direncini temsil eder ve Birch-Murnaghan durum denkleminden elde edilen değerle tutarlı olarak 84,00 GPa olarak hesaplanmıştır. Kayma deformasyonuna karşı direnci ölçen kayma modülü (G), Voigt (G_V = 40,29 GPa) ve Reuss (G_R = 40,25 GPa) limitlerine çok yakın olup, neredeyse izotropik kayma davranışını gösteren 40,27 GPa olarak bulunmuştur. Tek eksenli çekme gerilimi altında malzemenin sertliğini ölçen Young modülü (E), orta derecede elastik sertliği gösteren 104,16 GPa olarak hesaplanmıştır. Poisson oranı (ν) 0,29 olarak bulunmuştur; bu da SmPtBi'deki atomlar arası bağın, baskın metalik katkı ile karışık metalik-iyonik karaktere sahip olduğunu göstermektedir. Bileşiğin sünekliği veya kırılganlığı, Pugh oranı (B/G) kullanılarak değerlendirilebilir. Pugh kriterine göre, bir malzeme B/G> 1,75 ise sünek kabul edilir. SmPtBi için hesaplanan B/G değeri 2,09, bu eşiği açıkça aşmaktadır ve mekanik dayanıklılığın gerekli olduğu pratik uygulamalar için elverişli olan sünek bir mekanik yapıyı göstermektedir.

Genel olarak, elastik sabit analizi, γ-fazlı SmPtBi yarı-Heusler bileşiğinin mekanik olarak kararlı, büyük ölçüde elastik olarak izotropik ve sünek olduğunu göstermektedir; bu da onu termal ve taşıma özelliklerinin daha fazla incelenmesi için umut vadeden bir aday haline getirmektedir.

SmPtBi yarı-Heusler bileşiğinin dinamik kararlılığını araştırmak için, Görsel 3'te gösterildiği gibi, Brillouin bölgesinin yüksek simetri yönleri boyunca, yani W–L–Γ–X–W–K boyunca fonon dağılım ilişkileri hesaplandı.



Görsel 3. SmPtBi bileşiğinin fonon dispersiyonları ve toplam/parçalı fonon durum yoğunlukları

Fonon hesaplamaları, kafes titreşimlerine ilişkin kritik bilgiler sağlar ve bir kristal yapının kararlılığının harmonik düzeyde doğrudan değerlendirilmesine olanak tanır. SmPtBi için, fonon dağılım spektrumu, ilkel birim hücredeki üç atoma karşılık gelen dokuz farklı titreşim dalından oluşur. Bu dallar üç akustik mod ve altı optik moda sınıflandırılabilir. Dağılım eğrilerinde akustik ve optik dalları ayıran açık bir fonon bant aralığı gözlemlenir. SmPtBi için fonon aralığı yaklaşık 0,38 THz olarak hesaplanmıştır. Bu aralık, esas olarak bileşen atomlar (Sm, Pt ve Bi) arasındaki büyük kütle farkından ve bu da düşük frekanslı akustik titreşimler ile yüksek frekanslı optik salınımlar arasında bir ayrışmaya yol açar. Γ noktasındaki optik fonon modları 3,084 THz ve 3,854 THz'de bulunur ve bu da daha ağır Pt ve Bi atomlarını içeren nispeten sert atomlar arası bağları gösterir. Görsel 3'te sağ kısımda gösterilen fonon durum yoğunluğu (PDOS), atomlar arasındaki titreşimsel katkıların net bir şekilde ayrıldığını ortaya koymaktadır. Düşük ve orta frekanslı modlar ağırlıkla Pt-Bi atomları tarafından domine edilirken, yüksek frekanslı optik modlar esas olarak Sm atomu ile ilişkilidir.

Tüm Brillouin bölgesinde negatif fonon frekansları gözlemlenmemektedir. Bu tür yumuşak modların yokluğu, SmPtBi bileşiğinin temel durum γ-faz yapısında dinamik kararlılığını kesin olarak doğrulamaktadır. Bu sonuç, elastik sabit analizinden elde edilen daha önce belirlenmiş mekanik kararlılıkla tamamen tutarlıdır.

4. GENEL DEĞERLENDİRME VE SONUÇLAR

Bu çalışmada, yarı-Heusler yapısına sahip SmPtBi bileşiğinin yapısal, mekanik ve dinamik özellikleri yoğunluk fonksiyonel teorisi kapsamında incelenmiştir. Toplam enerji hesaplamaları, γ fazının en kararlı temel hâl yapı olduğunu açıkça ortaya koymuştur. Hesaplanan elastik sabitler Born–Huang kararlılık kriterlerini sağlamakta olup, türetilen elastik

modüller ve B/G oranı, SmPtBi'nin mekanik olarak kararlı ve sünek bir malzeme olduğunu göstermektedir. Fonon dispersiyonlarında hayali frekansların bulunmaması ise bileşiğin dinamik olarak da kararlı olduğunu doğrulamaktadır. Bu sonuçlar, SmPtBi yarı-Heusler bileşiğinin ileri fonksiyonel malzeme uygulamaları için umut vadeden bir aday olduğunu göstermektedir.

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ŞEKER PANCARI TOHUMLARI İÇİN DÖNGÜSEL TOHUM KAPLAMA

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ÖZET

Beslenme insan yaşamının temel ihtiyacıdır ve bu zincirin başlangıcı olan tohum, ülkeler için stratejik bir güvenlik unsuru haline gelmiştir. Yerli tohumların korunması, çimlenme ve çıkış performanslarının artırılması, zararlılara karşı korunması ve raf ömrünün uzatılması amacıyla tohum kaplama teknolojileri geliştirilmektedir. Bu çalışmada şeker üretim prosesi esnasında açığa çıkan kıymetli yan ürünler ve artıklar kullanılarak, tohum kaplamada kullanılan materyallere alternatif olabilecek doğada kendiliğinden parçalanabilen özgün ve sürdürülebilir bir tohum kaplama preparatı geliştirilmesi amaçlanmıştır. Çalışmada fabrikamız yan ürünlerinden olan şeker pancarı küspesi ve melasından elde edilen 4 farklı formülasyon (KS1, KS2, KS3, KS4) şeker pancarı tohumlarına kaplanarak, kaplanmış tohumların çıkış gücü ve çıkış yüzdesi özellikleri incelenmiştir. Denemeler viyollerde torf ve toprak karışımından oluşan düzeneklere tohum ekimleri yapılarak gerçekleştirilmiştir. Çalışma sonunda elde edilen verilere göre 4 formülasyondan gözlemlenen tohum çıkışları kontrol grubunda %43, KS1'de %23, KS2' de %36, KS3' de %10 ve KS4' de %50 olup; çıkış gücü değerleri ise kontrolde %83 KS1'de %73, KS2' de %90, KS3' de %86, KS4' de %93 olarak belirlenmiştir. Endüstriyel ölçekte yüksek hacimlerde açığa çıkan bu yan ürünlerin içerdiği organik bileşenler ve fonksiyonel özellikler tohum kaplama uygulamalarında işlevsel bir hammadde olarak kullanılabileceğini göstermektedir. Şeker üretim sürecinde ortaya çıkan yan ürün ve atıkların yeniden değerlendirilerek tohum kaplama materyali olarak kullanılması sıfır atık yaklaşımını ile döngüsel bir proses oluşturmakta ve hem çevresel sürdürülebilirliğe hem de tohumun fizyolojik performansına katkı sağlayacağı öngörülmektedir.

Anahtar kelimeler: Şeker pancarı, tohum, tohum kaplama, tohum çıkışı, tohum gücü

CYCLIC SEED COATING FOR SUGAR BEET SEEDS

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ABSTRACT

Nutrition is a fundamental human need, and seeds, as the starting point of this chain, have become a strategic security element for countries. Seed coating technologies are being developed to protect local seeds, enhance germination and emergence performance, protect them against pests, and extend their shelf life. In this study, it was aimed to develop an original and sustainable seed-coating preparation that is biodegradable in nature and may serve as an alternative to materials used in seed coating, by utilizing valuable by-products and residues generated during the sugar production process. In the study, four different formulations (KS1, KS2, KS3, KS4) obtained from sugar beet pulp and molasses, which are by-products of our factory, were used to coat sugar beet seeds, and the emergence force and emergence percentage of the coated seeds were examined. The trials were conducted by sowing seeds into setups consisting of peat and soil mixtures in seedling trays. According to the data obtained at the end of the study, seed emergence rates observed for the four formulations were 43% in the control group, 23% in KS1, 36% in KS2, 10% in KS3, and 50% in KS4; and emergence force values were determined as 83% in the control, 73% in KS1, 90% in KS2, 86% in KS3, and 93% in KS4. The organic components and functional properties contained in these by-products, which are generated in large volumes on an industrial scale, indicate that they can be used as functional raw materials in seed-coating applications. Re-evaluating the by-products and wastes generated during the sugar production process as seed-coating materials establishes a circular process aligned with the zero-waste approach and is anticipated to contribute both to environmental sustainability and to the physiological performance of the seed.

Keywords: Sugar beet, seed, seed coating, seed emergence, emergence power

THE EFFECT OF EXERCISE ON IL-6 AND IL-1BETA: A META-ANALYSIS

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ABSTRACT

Aim: The aim of this meta-analysis is to systematically and evidence-based evaluate the effects of exercise interventions on the levels of interleukin-6 (IL-6) and interleukin-1β (IL-1β), which are among the key biomarkers of the inflammatory response.

Method: This study was conducted in accordance with the PRISMA guidelines. The included research consisted of experimental or quasi-experimental designs comparing serum IL-6 and IL-1β levels between individuals who performed exercise and those who did not. A total of six studies for IL-6 and five studies for IL-1β were included in the analysis. Effect sizes were calculated using the standardized mean difference (SMD), and both fixed- and random-effects models were evaluated based on the degree of heterogeneity.

Results: The studies examining IL-6 levels reported a wide range of effect sizes, with one study presenting an extremely high SMD that constituted a clear outlier. The fixed-effects model indicated that exercise significantly increased IL-6 levels (SMD = 0.647; $p < 0.001$); however, this increase did not reach statistical significance under the random-effects model ($p = 0.080$) due to the very high heterogeneity ($I^2 = 98.35\%$). Thus, although there is a tendency for IL-6 levels to rise following exercise, the consistency of these findings is limited.
For IL-1β, most studies reported elevated levels in individuals who exercised, whereas one study demonstrated a notable decrease. The fixed-effects model showed a significant increase in IL-1β

levels (SMD = 0.739; p < 0.001). Despite the very high heterogeneity (I^2 = 98.65%), the random-effects model also supported this increase (SMD = 3.916; p = 0.022); however, the wide confidence interval indicated substantial uncertainty regarding the magnitude of the true effect.

Funnel plots for both cytokines appeared asymmetric due to studies with extreme values; nevertheless, Egger's and Begg's tests did not reveal statistically significant publication bias.

Conclusion: The findings of this meta-analysis indicate a general trend toward increased IL-6 and IL-1β levels following exercise. However, the considerable heterogeneity, methodological variations, and the influence of outlier studies necessitate cautious interpretation of the results. Further research using standardized protocols and larger sample sizes is required to more clearly elucidate the effects of exercise on inflammatory responses.

Keywords: interlökin-6, interlökin-1β, Egzersiz, Serum

EGZERSİZİN IL-6 VE IL-1BETA ÜZERİNE ETKİSİ: BİR META-ANALİZ

ÖZET

Amaç: Bu meta-analizin amacı, egzersiz uygulamalarının inflamatuar yanıtın temel biyobelirteçleri arasında yer alan interlökin-6 (IL-6) ve interlökin-1β (IL-1β) düzeyleri üzerindeki etkisini sistematik ve kanıta dayalı bir yaklaşımla değerlendirmektir.

Yöntem: Bu çalışma PRISMA kılavuzuna uygun olarak yapıldı. Çalışmaya dahil edilen araştırmalar, egzersiz yapılan ve yapılmayan bireylerde serum IL-6 ve IL-1β düzeylerini karşılaştıran deneysel veya yarı deneysel tasarımlardan seçilmiştir. Toplam altı çalışma IL-6 için, beş çalışma IL-1β için analiz edilmiştir. Etki büyüklükleri standartlaştırılmış ortalama fark (SMD) ile hesaplanmış; heterojenlik düzeyine göre sabit ve rassal etkiler modelleri birlikte değerlendirilmiştir.

Bulgular: IL-6 düzeylerini inceleyen çalışmalarda etki büyüklükleri oldukça geniş bir aralık göstermiştir ve özellikle bir çalışmada bildirilen aşırı yüksek SMD değeri belirgin bir uç değer oluşturmuştur. Sabit etkiler modeli, egzersizin IL-6 düzeylerini anlamlı biçimde artırdığını göstermiş (SMD=0,647; p<0,001); ancak çok yüksek heterojenite (I^2=%98,35) nedeniyle dikkate alınan rassal etkiler modeli altında bu artış istatistiksel anlamlılığa ulaşmamıştır (p=0,080). Buna göre, IL-6 düzeylerinde egzersize bağlı bir artış eğilimi bulunmakla birlikte sonuçların tutarlılığı sınırlıdır.IL-1β için yapılan analizde, çalışmaların büyük bölümünde egzersiz uygulanan bireylerde düzeylerin arttığı, bir çalışmada ise belirgin azalma raporlandığı görülmüştür. Sabit etkiler modeli IL-1β düzeylerinde anlamlı artış göstermiştir (SMD=0,739; p<0,001). Çok yüksek heterojenliğe (I^2=%98,65) rağmen rassal etkiler modeli de bu artışı desteklemiş (SMD=3,916; p=0,022); ancak geniş güven aralığı etkinin büyüklüğü konusunda ciddi belirsizlik olduğunu göstermiştir.
Her iki sitokine ilişkin huni grafikleri özellikle uç değer oluşturan çalışmaların etkisiyle asimetrik görünmüş; buna rağmen Egger ve Begg testleri istatistiksel olarak anlamlı bir yayın yanlılığına işaret etmemiştir.

Sonuç: Meta-analiz bulguları, egzersizin hem IL-6 hem de IL-1β düzeylerinde artış eğilimi gösterdiğini ortaya koymaktadır. Bununla birlikte, çok yüksek heterojenlik, yöntemsel farklılıklar ve tekil çalışmaların uç değer etkisi nedeniyle sonuçların dikkatle yorumlanması gerekmektedir.

Egzersizin inflamatuvar yanıt üzerindeki etkisinin daha net biçimde ortaya konabilmesi için standardize protokollerle, daha geniş örneklemler kullanılarak yapılacak ileri araştırmalara ihtiyaç vardır.

Anahtar Kelimeler: İnterlökin-6, İnterlökin-1β, Egzersiz, Serum

GİRİŞ

Egzersiz, kas dokusunda meydana getirdiği mekanik, metabolik ve nöroendokrin uyarılar aracılığıyla hem akut hem de kronik düzeyde önemli fizyolojik adaptasyonları tetikleyen bir stresör olarak kabul edilmektedir. Bu adaptasyonların temel bileşenlerinden biri inflamatuvar yanıt olup, egzersizin bağışıklık sistemi üzerindeki etkileri özellikle son yıllarda yoğun biçimde araştırılmaktadır. İnflamasyonun erken fazında rol alan proinflamatuvar sitokinler, egzersiz kaynaklı iyileşme süreçlerinin, immün modülasyonun ve doku yeniden yapılanmasının önemli belirleyicileridir (Pedersen ve Febbraio, 2012). Bu bağlamda interlökin-6 (IL-6) ve interlökin-1β (IL-1β), hem sistemik inflamasyonun hem de egzersize bağlı fizyolojik yanıtların değerlendirilmesinde sık kullanılan iki kritik biyobelirteçtir. IL-6, egzersize yanıt olarak kas dokusundan salgılanan ilk miyokinlerden biri olup metabolik düzenleme, enerji mobilizasyonu ve immün yanıtın modülasyonunda önemli rol oynamaktadır (Febbraio ve Pedersen, 2005). Özellikle orta–yüksek şiddetli fiziksel aktivitelerin IL-6 düzeylerinde hızlı ve belirgin bir artışa yol açtığı bilinmektedir. Bununla birlikte IL-6'nın hem proinflamatuvar hem de antiinflamatuvar özellik gösterebilmesi, egzersiz sırasında ve sonrasında ortaya çıkan değişimlerin yorumlanmasını karmaşık hale getirmektedir.IL-1β ise inflamasyonun başlatılmasında ve doku hasarının erken fazında görev alan bir diğer güçlü proinflamatuvar sitokindir. Egzersize bağlı kas mikrotravmaları, inflamatuvar hücre infiltrasyonu ve metabolik stres, IL-1β düzeylerinde değişikliklere yol açabilmektedir (Cannon ve Kluger, 1983). Bununla birlikte IL-1β yanıtının büyüklüğü ve yönü, egzersizin türü, süresi, şiddeti ve bireysel fizyolojik özelliklere bağlı olarak önemli ölçüde değişkenlik göstermektedir. Literatürde IL-1β artışını destekleyen çalışmaların yanı sıra, egzersizin antiinflamatuvar etkileri nedeniyle azalma bildiren çalışmalar da bulunmaktadır. Bu değişkenliğin temel nedenlerinden biri, çalışmalarda kullanılan egzersiz protokollerinin, katılımcı özelliklerinin ve biyokimyasal ölçüm yöntemlerinin homojen olmamasıdır. Bu nedenle IL-6 ve IL-1β üzerine yapılan çalışmaların bulguları çoğu zaman tutarsızdır ve genel bir sonuç çıkarmayı güçleştirmektedir. Meta-analiz çalışmaları, mevcut kanıtları bütüncül bir yaklaşımla değerlendirme ve egzersizin inflamatuvar biyobelirteçler üzerindeki gerçek etkisini ortaya koyma açısından önemli bir metodolojik avantaj sunmaktadır. Bu meta-analiz çalışmasında, egzersizin IL-6 ve IL-1β düzeyleri üzerindeki etkilerini inceleyen araştırmalar sistematik olarak değerlendirilmiş ve elde edilen bulgular, egzersizin inflamatuvar yanıt üzerindeki rolünü daha net biçimde ortaya koymak amacıyla birleştirilmiştir. Çalışma sonuçları, hem klinik uygulamalar hem de spor bilimleri alanındaki performans-iyileşme ilişkisini anlamak için önemli bir katkı sağlamaktadır.

YÖNTEM

Çalışma Tasarımı

Bu meta-analiz, PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) kılavuzuna uygun olarak gerçekleştirilmiştir.

Veri Tabanları ve Tarama Stratejisi

Çalışmalar, PubMed, Scopus ve Web of Science (WoS) veri tabanlarında sistematik bir tarama yöntemiyle belirlenmiştir. Tarama sürecinde, egzersiz müdahaleleriyle ilişkili serum IL-6 ve IL-1β düzeylerini raporlayan araştırmalar hedeflenmiştir. Taramada kullanılan anahtar kelimeler; "İnterlökin-6", "İnterlökin-1β", "serum" ve "egzersiz" sözcüklerinden oluşmuştur. Anahtar kelimelerle yapılan ilk taramada toplam **326** referans tespit edilmiştir.

Dahil Etme ve Hariç Tutma Kriterleri

Tarama sonucunda elde edilen çalışmalar, belirlenen dahil etme ve hariç tutma kriterlerine göre değerlendirilmiştir:

Dahil Edilen Çalışmalar:

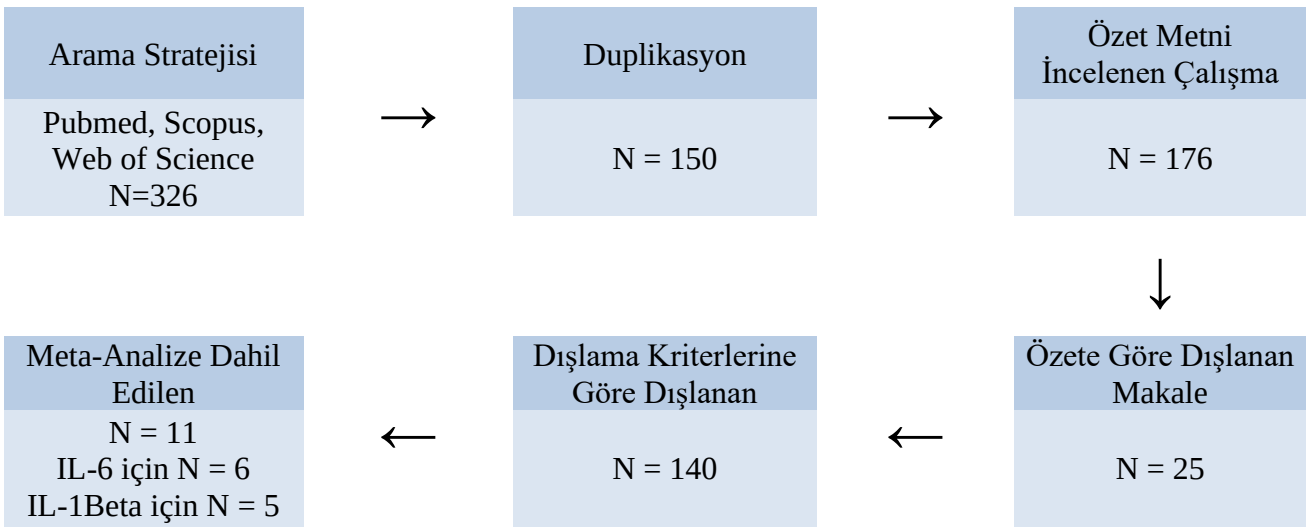
- Egzersiz protokollerine dayalı müdahaleleri raporlayan çalışmalar
- Serum **IL-6 VE IL-1BETA** düzeylerini ölçen ve raporlayan makaleler
- İnsan katılımcılar üzerinde yapılmış ve İngilizce dilinde yayınlanmış tam metin çalışmaları

Hariç Tutulan Çalışmalar:

- Deney hayvanları üzerinde yapılan çalışmalar
- İngilizce olmayan yayınlar
- Tam metnine ulaşılamayan çalışmalar
- Herhangi bir egzersiz protokolü bulunmayan çalışmalar

Tarama sonucunda, **Il-6 Ve Il-1beta** 176 çalışma incelemeye alındı. Yukarıdaki hariç tutma kriterlerine göre yapılan eleme işlemleri sonucunda geriye **İL-6** için 6 çalışma**, İL-1BETA** için 5 çalışma kalmıştır.

Şekil 1 - Akış Şeması



Veri Yönetimi

Çalışmaların yönetimi ve eleme basamaklarının izlenebilirliği için EndNote yazılımı kullanılmıştır. Çalışmaların veri tabanından alınması, duplikasyonların kaldırılması ve kriterlere uygunluk değerlendirmesi bu yazılım aracılığıyla gerçekleştirilmiştir.

Meta-Analiz Süreci

Meta-analiz, MedCalc 23.1.7 yazılımı kullanılarak gerçekleştirilmiştir. Çalışmalardan elde edilen veriler, standardize edilmiş ortalama farklar (Standardized Mean Differences, SMD) kullanılarak değerlendirilmiş ve sonuçlar forest plots ile görselleştirilmiştir. Bu yöntemlerle, serum İL-6 ve İL-1Beta düzeylerinin egzersiz müdahaleleriyle ilişkisini inceleyen sistematik ve güvenilir bir değerlendirme sağlanmıştır.

BULGULAR

Bu meta-analiz, egzersizin serum IL-6 ve IL-1β seviyeleri üzerindeki etkilerini inceleyen toplam 11 çalışmanın sonuçlarını birleştirmiştir. IL-6 için 6 çalışma, IL-1β için 5 çalışma değerlendirmeye alınmış. IL-6 ve IL-1Betaya ait bulgular şu şekilde bildirilmiştir.

IL-6

Etki Büyüklüğü

IL-6 düzeylerini inceleyen 6 çalışma (Moro et al., 2016; Chang et al., 2023; McMurray et al., 2007; Nobari et al., 2021; Roca-Rodríguez et al., 2015; La Gerche et al., 2015) toplam 367 katılımcıyı (184 egzersiz, 183 kontrol) kapsamaktadır. Çalışmalardan elde edilen standartlaştırılmış ortalama farklar (SMD) −1,77 ile 172,87 arasında değişmiş olup, bu geniş aralık IL-6 yanıtının çalışmalara göre önemli farklılıklar gösterdiğini ortaya koymaktadır. Araştırmaların çoğunda egzersiz sonrası IL-6 düzeylerinde artış rapor edilmiş, bazı çalışmalarda ise değişiklik gözlenmemiş ya da azalma bildirilmiştir. Özellikle Chang ve ark. (2023) tarafından rapor edilen son derece yüksek etki büyüklüğü, dağılımdan belirgin biçimde saparak önemli bir uç değer niteliği taşımaktadır.

Heterojenlik Analizi

Sabit etkiler modeli altında egzersiz yapan bireylerde IL-6 düzeyleri anlamlı derecede yüksek bulunmuştur (SMD = 0,647; SH = 0,138; %95 GA 0,376–0,917; $p < 0,001$). Ancak heterojenlik istatistikleri çalışmalar arasında çok yüksek düzeyde tutarsızlık olduğunu göstermektedir ($Q = 302,96$; $sd = 5$; $p < 0,0001$; $I^2 = \%98,35$; %95 GA %97,61–%98,86). Bu nedenle daha güvenilir kabul edilen rassal etkiler modeli uygulanmış; ancak bu model altında birleşik etki büyüklüğü istatistiksel anlamlılığa ulaşmamıştır (SMD = 2,120; SH = 1,206; %95 GA −0,251–4,491; $p = 0,080$). Bu bulgular, IL-6 düzeylerindeki değişimin yönüne ilişkin bir artış eğilimi olduğunu, ancak sonuçların aşırı heterojenlik ve uç değer etkisi nedeniyle yüksek belirsizlik içerdiğini göstermektedir.

Grafiksel Bulgular

Yayın yanlılığına ilişkin yapılan Egger testi (intercept = 11,32; %95 GA −5,71–28,36; $p = 0,139$) ve Begg testi ($\tau = -0,20$; $p = 0,573$) istatistiksel olarak anlamlı bir yayın yanlılığına işaret etmemiştir. Buna karşın huni grafiğinin özellikle Chang ve ark. çalışmasının etkisiyle belirgin asimetri

göstermesi, küçük çalışma etkisinin tamamen dışlanamayacağına işaret etmektedir. Uç değer oluşturan çalışmanın genel dağılımı bozması nedeniyle IL-6 sonuçlarının yorumlanmasında dikkatli olunması gerekmektedir.

Tablo 1 – IL-6'da Meta-Analize Dahil Edilen Çalışmalar ve İstatistiksel Sonuçlar

Study	N1	N2	Total	SMD	SE	95% CI	t	P	Weight (%)	
									Fixed	Random
Moro at al. 2016	17	17	34	-0,383	0,338	-1,072 to 0,306			16,58	19,77
Chang at al. 2023	57	57	114	172,867	11,450	150,181 to 195,554			0,014	1,05
Mc Murray at al. 2007	30	28	58	1,863	0,312	1,239 to 2,488			19,51	19,82
Nobari at al. 2021	14	15	29	-1,772	0,430	-2,654 to -0,891			10,26	19,58
Roca-Rodríguez at al.2015	26	26	52	0,0947	0,273	-0,454 to 0,644			25,36	19,88
La Gerche, A., et al. (2015)	40	40	80	1,696	0,259	1,181 to 2,211			28,27	19,90
Total (fixed effects)	184	183	367	0,647	0,138	0,376 to 0,917	4,697	<0,001	100,00	100,00
Total (random effects)	184	183	367	2,120	1,206	-0,251 to 4,491	1,758	0,080	100,00	100,00

Test for heterogeneity

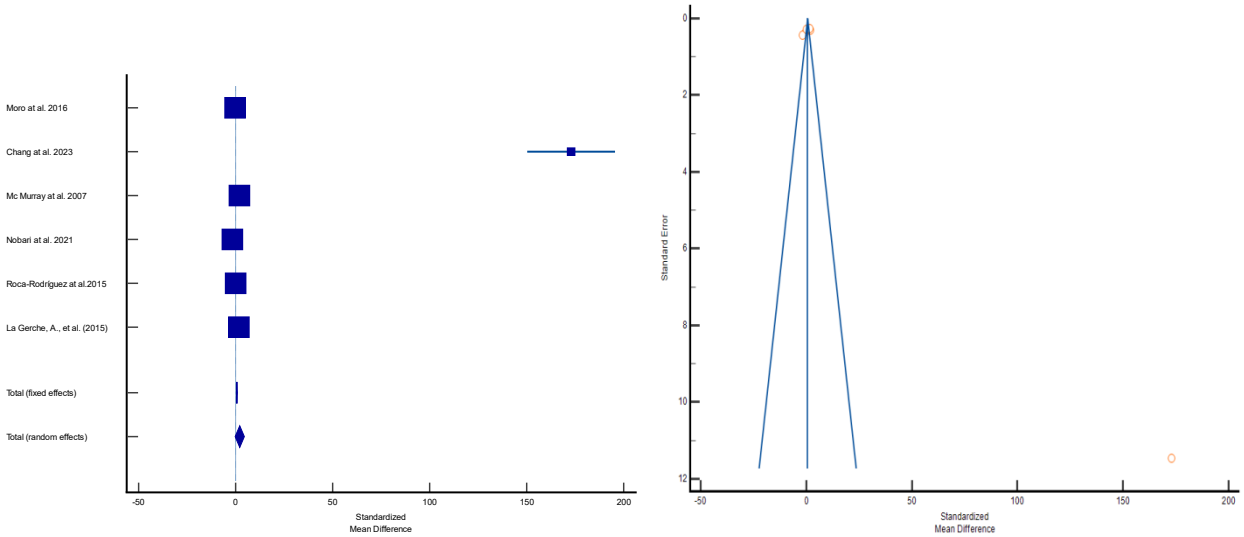
Q	302,9587
DF	5
Significance level	P < 0,0001
I^2 (inconsistency)	98,35%
95% CI for I^2	97,61 to 98,86

Publication bias

Egger's test	
Intercept	11,3212
95% CI	-5,7143 to 28,3566
Significance level	P = 0,1388
Begg's test	
Kendall's Tau	-0,2000
Significance level	P = 0,5730

Çalışmalar arasında gözlenen heterojenite katsayısının son derece yüksek olması (I^2 = %98,35) nedeniyle meta-analizde rassal etkiler modeli tercih edilmiştir. Ancak hem sabit etkiler modeliyle elde edilen birleşik etki büyüklüğü (SMD = 0,647; p < 0,001) hem de rassal etkiler modeliyle hesaplanan etki büyüklüğü (SMD = 2,120; p = 0,080) sonuçların tutarlılığı açısından önemli farklılıklar göstermiştir. Rassal modelde istatistiksel anlamlılığa ulaşılamaması, çalışmalar arasındaki aşırı tutarsızlığın IL-6 düzeylerindeki genel etkinin güvenilir bir şekilde ortaya konmasını güçleştirdiğini göstermektedir. Bu yüksek düzeyde heterojenlik, bulguların yorumlanmasında dikkatli olunması gerektiğine işaret etmektedir.

Tablo 2 – Forest Plot - Funnel Plot Grafikleri



Forest plot grafiği incelendiğinde, IL-6 düzeylerini değerlendiren çalışmaların büyük bölümünün etki büyüklüğü açısından sıfıra oldukça yakın konumlandığı görülmektedir. Bu durum, çalışmaların genel olarak egzersizin IL-6 üzerindeki etkisine ilişkin tutarlı ve güçlü bir bulgu ortaya koymadığını göstermektedir. Ancak Chang et al. (2023) çalışmasının diğer tüm araştırmalardan belirgin biçimde ayrıldığı ve çok yüksek pozitif etki büyüklüğü bildirdiği dikkat çekmektedir. Bu uç değer niteliğindeki çalışma, hem toplam etki büyüklüğünü yukarı yönde etkilemekte hem de meta-analizde gözlenen yüksek heterojenliğin temel kaynaklarından biri olarak öne çıkmaktadır. Sabit ve rassal etkiler modellerinin farklı sonuçlar vermesi de bu çalışmanın birleşik etki üzerindeki ağırlığını doğrulamaktadır.Funnel plot grafiği değerlendirildiğinde, çalışmaların büyük kısmının huni yapısının üst bölümünde simetrik bir şekilde toplandığı, ancak uç değer içeren çalışmanın grafiğin sağ alt bölgesinde tek başına konumlandığı görülmektedir. Bu durum, genel asimetriye sebep olmakta ve dağılımın dengesiz görünmesine yol açmaktadır. Grafiksel açıdan belirgin bir düzensizlik bulunsa da çalışmalara uygulanan Egger ve Begg testlerinin istatistiksel olarak anlamlı yayın yanlılığı göstermemesi, bu asimetrinin büyük ölçüde uç değer etkisinden kaynaklandığını düşündürmektedir.

IL-1BETA

Etki Büyüklüğü

IL-1β düzeylerini bildiren beş çalışma (Moro et al., 2016; Chang et al., 2023; McMurray et al., 2007; Nobari et al., 2021; Roca-Rodríguez et al., 2015) toplam 287 katılımcıyı (144 egzersiz, 143 kontrol) içermektedir. Çalışmalardan elde edilen SMD değerleri −1,77 ile 172,87 arasında geniş bir dağılım göstermiştir. Egzersiz uygulanan bireylerde IL-1β düzeylerinin genellikle daha yüksek olduğu

görülmüş; yalnızca Nobari ve ark. (2021) tarafından yürütülen çalışmada anlamlı bir azalma rapor edilmiştir. Bu sonuçlar IL-1β yanıtının egzersiz türü, süresi ve katılımcı özelliklerine bağlı olarak değişkenlik gösterebileceğini düşündürmektedir.

Heterojenlik Analizi

Sabit etkiler modeli IL-1β düzeylerinde egzersiz lehine anlamlı bir artış göstermiştir (SMD = 0,739; SH = 0,172; %95 GA 0,400–1,078; $p < 0,001$). Ancak heterojenlik istatistikleri çalışmalar arasında çok yüksek düzeyde tutarsızlık bulunduğunu ortaya koymaktadır ($Q = 296,26$; sd = 4; $p < 0,0001$; I^2 = %98,65; %95 GA %98,01–%99,08). Bu nedenle esas alınan rassal etkiler modeli uygulanmış ve IL-1β düzeylerindeki artış istatistiksel anlamlılığını bu modelde de korumuştur (SMD = 3,916; SH = 1,706; %95 GA 0,558–7,274; $p = 0,022$). Bununla birlikte geniş güven aralığı, etki büyüklüğünün yüksek belirsizlik içerdiğini göstermektedir.

Grafiksel Bulgular

Yayın yanlılığını değerlendirmek amacıyla yapılan Egger testi (intercept = 13,04; %95 GA −7,77–33,85; $p = 0,140$) ve Begg testi ($\tau = -0,20$; $p = 0,624$) anlamlı sonuç göstermemiştir. Ancak huni grafiğinde büyük etki bildiren tek bir çalışmanın dağılımı bozduğu görülmüş, bu durum küçük çalışma etkisinin olası olduğunu ancak güçlü şekilde doğrulanmadığını düşündürmüştür. Dolayısıyla IL-1β düzeylerindeki artış eğilimi desteklense de, heterojenlik ve uç değerlerin varlığı nedeniyle sonuçların dikkatli değerlendirilmesi gerekmektedir.

Tablo 3 IL-1β'de Meta-Analize Dahil Edilen Çalışmalar ve İstatistiksel Sonuçlar

Variable for studies	STUDYS
1. Intervention groups	
Variable for number of cases	Exercise_N
Variable for mean	Exercise_MEAN
Variable for SD	Exercise_SD
2. Control groups	
Variable for number of cases	CONTROL_N
Variable for mean	CONTROL_RHB_MEAN
Variable for SD	CONTROL_RHB_SD

Study	N1	N2	Total	SMD	SE	95% CI	t	P	Weight (%)	
									Fixed	Random
Moro at al. 2016	17	17	34	-0,383	0,338	-1,072 to 0,306			25,99	24,52
Chang at al. 2023	57	57	114	172,867	11,450	150,181 to 195,554			0,023	2,04
Mc Murray at al. 2007	30	28	58	1,863	0,312	1,239 to 2,488			30,59	24,55
Nobari at al. 2021	14	15	29	-1,772	0,430	-2,654 to -0,891			16,09	24,37
Roca-Rodríguez at al.2015	26	26	52	1,885	0,330	1,222 to 2,547			27,31	24,53
Total (fixed effects)	144	143	287	0,739	0,172	0,400 to 1,078	4,288	<0,001	100,00	100,00
Total (random effects)	144	143	287	3,916	1,706	0,558 to 7,274	2,295	0,022	100,00	100,00

Test for heterogeneity

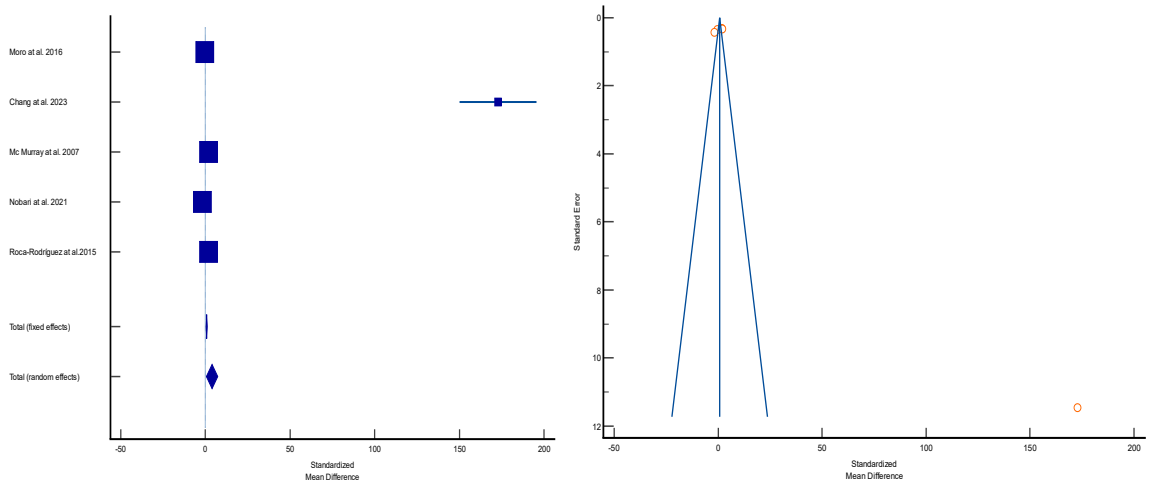
Q	296,2554
DF	4
Significance level	P < 0,0001
I^2 (inconsistency)	98,65%
95% CI for I^2	98,01 to 99,08

Publication bias

Egger's test	
Intercept	13,0356
95% CI	-7,7746 to 33,8459
Significance level	P = 0,1402
Begg's test	
Kendall's Tau	-0,2000
Significance level	P = 0,6242

Heterojenlik testi sonucunda, sabit etkiler modeli altında egzersiz uygulanan bireylerde IL-1β düzeylerinin kontrol grubuna kıyasla anlamlı derecede yüksek olduğu görülmüştür (SMD = 0,739; SH = 0,172; %95 GA 0,400–1,078; p < 0,001). Ancak heterojenlik katsayısının oldukça yüksek çıkması (I^2 = %98,65; Q = 296,26; sd = 4; p < 0,0001), çalışmalar arasında ciddi tutarsızlık bulunduğunu göstermektedir. Bu nedenle daha güvenilir kabul edilen rassal etkiler modeli tercih edilmiş ve IL-1β düzeylerindeki artış bu modelde de istatistiksel olarak anlamlılığını sürdürmüştür (SMD = 3,916; SH = 1,706; %95 GA 0,558–7,274; p = 0,022). Bununla birlikte rassal modeldeki geniş güven aralığı, birleşik etkinin büyüklüğü konusunda yüksek belirsizlik bulunduğuna işaret etmektedir. Dolayısıyla IL-1β düzeylerinin egzersize yanıt olarak artma eğiliminde olduğu görülse de, etkinin büyüklüğüne ilişkin yorumların dikkatle yapılması gerekmektedir.

Tablo 4 – Forest Plot - Funnel Plot Grafikleri



Forest plot grafiği, çalışmalar arasında etki büyüklüğü bakımından ciddi farklılıklar bulunduğunu göstermektedir. Uç değer niteliğindeki bir çalışmanın genel dağılımdan belirgin şekilde sapması, birleşik etki büyüklüğünü yukarı çekmekte ve heterojenliğin çok yükselmesine yol açmaktadır. Çoğu çalışmanın sıfıra yakın etki büyüklüğü bildirmesi, IL-1β düzeylerindeki değişimin tutarlı bir biçimde ortaya konmasını güçleştirmektedir. Funnel plot grafiğinde ise çalışmaların büyük kısmı huni yapısına yakın bir dağılım gösterirken, yüksek etki bildiren tek bir çalışmanın grafiğin sağ alt bölümünde tek başına konumlandığı görülmektedir. Bu durum, görsel asimetriye yol açmakta ve küçük çalışma etkisi olasılığını artırmaktadır. Bununla birlikte Egger testi (intercept = 13,04; %95 GA −7,77–33,85; p = 0,140) ve Begg testi (τ = −0,20; p = 0,624) istatistiksel olarak anlamlı bir yayın yanlılığına işaret etmemektedir. Dolayısıyla grafiksel asimetri esas olarak uç değer oluşturan çalışmadan kaynaklanmakta olup, yaygın bir yanlılığa dair güçlü bir kanıt bulunmamaktadır.

TARTIŞMA

Bu meta-analiz, egzersizin inflamatuvar biyobelirteçlerden IL-6 ve IL-1β üzerindeki etkilerini değerlendirmek amacıyla yapılmış olup, elde edilen bulgular egzersizin her iki sitokinde de artış eğilimine yol açtığını göstermektedir. Ancak sonuçların yorumlanmasında dikkate alınması gereken önemli metodolojik ve istatistiksel unsurlar mevcuttur.IL-6 için sabit etkiler modeli egzersizin IL-6 düzeylerini anlamlı şekilde artırdığını göstermiş olsa da, çalışmalar arasındaki heterojenliğin çok yüksek olması (I^2 = %98,35) birleşik etkinin güvenilirliğini önemli ölçüde azaltmaktadır. Rassal etkiler modelinde istatistiksel anlamlılığın ortadan kalkması, IL-6 yanıtının çalışmalara göre büyük farklar gösterdiğini, özellikle Chang ve ark. (2023) gibi uç değer niteliğindeki bir çalışmanın toplam etkiyi belirgin biçimde etkilediğini ortaya koymaktadır. Egzersizin IL-6 üzerindeki etkisinin tutarlı bir yönde olmadığına ilişkin literatürde de benzer kanıtlar bulunmaktadır; IL-6 kas kökenli bir miyokin olup hem proinflamatuvar hem de antiinflamatuvar özellik gösterebilmesi nedeniyle, düzeylerindeki artış her zaman inflamasyonun şiddetlendiği anlamına gelmemektedir. Bu bağlamda çalışmalardaki farklı egzersiz protokolleri, uygulanan egzersizin süresi–şiddeti ve katılımcı özellikleri IL-6 sonuçlarındaki geniş varyasyonun önemli belirleyicileri olabilir.IL-1β için elde edilen sonuçlar da benzer bir biçimde dikkat çekicidir. Çalışmaların çoğunda egzersiz sonrası IL-1β düzeylerinde artış saptanmış, sabit etkiler modeli bu artışı istatistiksel olarak doğrulamıştır. Heterojenlik katsayısının son derece yüksek olması (I^2 = %98,65), çalışmaların benzer koşulları taşımadığını ve IL-1β yanıtının büyük ölçüde değiştiğini göstermektedir. Buna rağmen rassal etkiler

modeli altında artışın anlamlılığını koruması, IL-1β'nin egzersiz sonrası yükselmesinin daha güçlü bir eğilim olduğunu düşündürmektedir. Bununla birlikte geniş güven aralığı (0,558–7,274), etki büyüklüğünün tam olarak hangi seviyede olduğunu belirlemenin zor olduğunu ortaya koymaktadır.Bu durum IL-1β yanıtının özellikle egzersize bağlı kas hasarı, inflamatuvar hücre infiltrasyonu ve metabolik stresin derecesi gibi değişkenlerden güçlü biçimde etkilendiğini düşündürmektedir. Forest plot grafiklerinde her iki biyobelirteç için de uç değerli çalışmaların genel dağılımı bozduğu görülmüştür. Çalışmaların büyük kısmının etki büyüklüğünün sıfıra yakın kümeleşmesi, egzersizin inflamatuvar yanıt üzerindeki etkisinin tutarlı olmadığını desteklemektedir. Funnel plot grafiklerinde belirgin bir asimetri bulunsa da, Egger ve Begg testlerinin istatistiksel olarak anlamlı olmaması nedeniyle yayın yanlılığına dair güçlü bir kanıt bulunmamaktadır. Bu durum, grafiklerde gözlenen asimetrinin metodolojik farklılıklardan veya uç değer oluşturabilecek tekil çalışmalardan kaynaklanabileceğini düşündürmektedir. Genel olarak ele alındığında, bulgular egzersizin akut inflamatuvar yanıtı belirli ölçüde uyardığını, ancak bu etkinin büyüklüğünün ve yönünün çalışmadan çalışmaya belirgin şekilde değiştiğini göstermektedir. Bu değişkenliğin temel nedenleri arasında egzersiz protokollerinin farklılığı, katılımcıların yaş, cinsiyet ve kondisyon düzeylerinin değişkenliği, örnekleme zamanlarının farklı oluşu ve biyokimyasal ölçüm tekniklerinin heterojenliği yer almaktadır. Bu nedenle, elde edilen sonuçlar egzersizin inflamatuvar sistem üzerindeki etkisine dair genel bir eğilimi ortaya koysa da, kesin mekanizmaların aydınlatılabilmesi için daha standardize edilmiş ve büyük örneklemli çalışmalara ihtiyaç vardır.

SONUÇ

Bu meta-analiz, egzersizin IL-6 ve IL-1β düzeyleri üzerinde genel bir artış eğilimi oluşturduğunu göstermektedir. Bununla birlikte her iki biyobelirteç için de heterojenlik seviyesinin aşırı yüksek olması ve tekil uç değerli çalışmaların birleşik etkiyi güçlü biçimde etkilemesi, sonuçların dikkatle yorumlanmasını gerektirmektedir. Sabit etkiler modeli her iki sitokinde de anlamlı artış gösterse de, rassal etkiler modelindeki belirsizlik özellikle IL-6 için etkinin tutarlı olmadığını ortaya koymaktadır. IL-1β'de artış eğiliminin daha belirgin olduğu görülmekle birlikte, geniş güven aralığı etkinin gerçek büyüklüğünün net biçimde belirlenmesine engel olmaktadır.Bu bulgular, egzersizin inflamatuvar yanıt üzerindeki etkisinin tek yönlü ve homojen bir süreç olmadığını, aksine egzersizin türü, süresi, şiddeti, örnekleme zamanı ve katılımcı özellikleri gibi çok sayıda faktörden etkilendiğini göstermektedir. Gelecekte yapılacak araştırmaların standardize edilmiş protokollerle, daha büyük örneklemlerle ve biyobelirteç ölçümlerinde ortak yöntemlerle yürütülmesi, egzersiz–inflamasyon ilişkisine dair daha net ve genellenebilir sonuçlar sağlayacaktır.

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EFFECT OF VITAMIN D SUPPLEMENTATION ON MUSCLE RECOVERY AFTER EXERCISE: A META-ANALYSIS

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ABSTRACT

Objective: This meta-analysis evaluated the effects of vitamin D supplementation on exercise-induced muscle damage by examining changes in serum creatine kinase (CK) and lactate dehydrogenase (LDH) levels.

Methods: Five eligible studies were analyzed using MedCalc 23.1.7 software. Standardized mean differences (SMD) were calculated under fixed- and random-effects models depending on heterogeneity.

Results: A total of 134 participants were included. For CK, the pooled effect was not significant in either the fixed model (SMD = 0.243, p = 0.154) or the random model (SMD = 0.243, p = 0.179), with low heterogeneity (I^2 = 11.08%). For LDH, fixed (SMD = 0.188, p = 0.276) and random models (SMD = 0.214, p = 0.461) also showed no significant effects, with moderate-to-high heterogeneity (I^2 = 64.76%). Funnel plots and Egger/Begg tests indicated no publication bias.

Conclusion: Vitamin D supplementation did not significantly alter CK or LDH responses following acute exercise, suggesting no meaningful effect on short-term biochemical muscle damage. Larger and more standardized trials considering baseline vitamin D status are needed.

Keywords: Vitamin D, exercise, muscle recovery

EGZERSİZ SONRASI KAS İYİLEŞMESİNE D VİTAMİNİ TAKVİYESİNİN ETKİSİ: BİR META-ANALİZ

ÖZET

Amaç: Bu meta-analiz, vitamin D suplementasyonunun egzersiz sonrası kas hasarı üzerine etkisini değerlendirmek amacıyla serum CK ve LDH düzeylerinde oluşan değişimleri incelemiştir.

Yöntem: PRISMA'ya uygun olarak seçilen beş çalışmadan elde edilen veriler MedCalc 23.1.7 yazılımı ile analiz edilmiştir. Etki büyüklükleri standartlaştırılmış ortalama fark (SMD) olarak hesaplanmış; heterojenlik durumuna göre fixed ve random etkiler modelleri kullanılmıştır.

Bulgular: Toplam 134 katılımcı çalışmaya dâhil edilmiştir. CK için birleşik etki büyüklüğü fixed modelde SMD = 0.243 (p = 0.154), random modelde SMD = 0.243 (p = 0.179) olup sonuçlar anlamsız bulunmuştur (I^2 = %11.08). LDH için fixed modelde SMD = 0.188 (p = 0.276), random modelde SMD = 0.214 (p = 0.461) bulunmuş ve anlamlı bir fark saptanmamıştır (I^2 = %64.76). Funnel plot ve Egger/Begg testleri yayın yanlılığı göstermemiştir.

Sonuç: Vitamin D suplementasyonu, akut egzersiz sonrası CK ve LDH düzeylerinde anlamlı bir değişiklik oluşturmamış; kas hasarını azaltıcı belirgin bir etki göstermemiştir. Daha net sonuçlar için başlangıç vitamin D düzeylerini dikkate alan daha geniş ve standartlaştırılmış çalışmalara ihtiyaç vardır

Anahtar Kelimeler: D vitamini, egzersiz, kas iyileşmesi

GİRİŞ

Vitamin D, kas fonksiyonu, kas gücü ve egzersiz performansı üzerinde önemli düzenleyici rollere sahip olan bir hormondur (Ceglia, 2009). Kas dokusunda vitamin D reseptörlerinin bulunması, bu vitaminin doğrudan kas hücresi üzerinde etkili olabileceğini göstermektedir (Girgis ve ark., 2013). Vitamin D eksikliğinin kas güçsüzlüğü, yorgunluk ve toparlanma kapasitesinde azalmalara yol açtığı çeşitli çalışmalarda bildirilmiştir (Stockton ve ark., 2011).

Egzersize bağlı kas hasarı, özellikle eksantrik kasılmalar veya yüksek şiddetli aktiviteler sonrasında CK ve LDH gibi enzimlerin kana salınmasıyla karakterizedir (Brancaccio ve ark., 2010). CK, kas zar bütünlüğü bozulduğunda dolaşıma geçen en sık kullanılan kas hasarı biyobelirteçlerinden biridir (Nedjar-Arroume ve ark., 2006). LDH ise hücre membranı hasarında artan bir diğer göstergedir ve egzersiz sonrası doku stresinin değerlendirilmesinde kullanılmaktadır (Banfi ve ark., 2012).

Vitamin D'nin kas membran stabilitesi, inflamasyon ve kalsiyum homeostazı üzerindeki etkileri nedeniyle egzersiz sonrası biyokimyasal toparlanmayı iyileştirebileceği öne sürülmüştür (Owens ve ark., 2015). Ancak bu konuda yapılan çalışmalar çelişkili bulgular sunmaktadır. Bazı çalışmalar vitamin D'nin kas hasarını azalttığını bildirirken, diğerleri anlamlı bir farklılık bulmamıştır (Close ve ark., 2013).

YÖNTEM

Çalışma Tasarımı

Bu meta-analiz, PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) kılavuzuna uygun olarak gerçekleştirilmiştir. Çalışmanın amacı, vitamin D suplementasyonunun egzersiz sonrası kas hasarı ve kas toparlanması üzerine etkisini, serum kreatin kinaz (CK) ve laktat dehidrogenaz (LDH) düzeyleri üzerinden sistematik olarak değerlendirmektir.

Veri Tabanları ve Tarama Stratejisi

Çalışmalar, , PubMed, Scopus, Web of Science (WoS) veri tabanlarında sistematik bir tarama yöntemiyle belirlenmiştir. Tarama sürecinde, egzersiz müdahaleleriyle ilişkili serum kreatin kinaz (CK) ve laktat dehidrogenaz (LDH) düzeylerini raporlayan çalışmalar hedeflenmiştir. Taramada kullanılan anahtar kelimeler; ‘’egzersiz’’, ‘‘vitamin D’’, ‘’ kas iyileşmesi’’ sözcüklerinden oluşmuştur. İlk taramada toplam 56 referans tespit edilmiştir.

Dahil Etme ve Hariç Tutma Kriterleri

Tarama sonucunda elde edilen çalışmalar, belirlenen dahil etme ve hariç tutma kriterlerine göre değerlendirilmiştir:

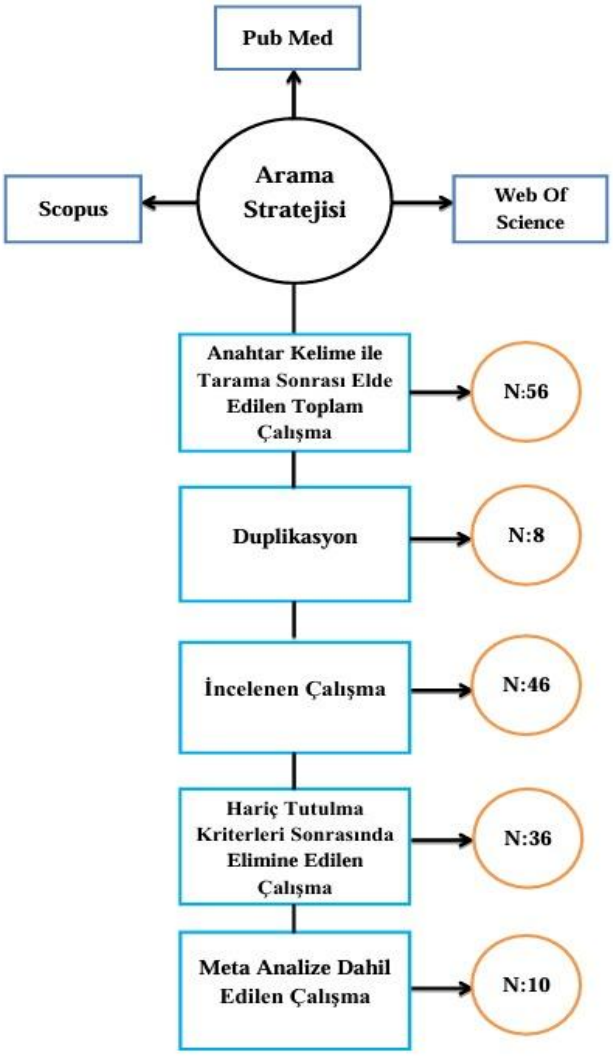
Dahil Edilen Çalışmalar:

- Egzersiz protokollerine dayalı müdahaleleri raporlayan çalışmalar
- Serum kreatin kinaz (CK) ve laktat dehidrogenaz (LDH) düzeylerini ölçen ve raporlayan makaleler
- İnsan katılımcılar üzerinde yapılmış ve İngilizce dilinde yayınlanmış tam metin çalışmaları

Hariç Tutulan Çalışmalar:

- Deney hayvanları üzerinde yapılan çalışmalar
- İngilizce olmayan yayınlar
- Tam metnine ulaşılamayan çalışmalar
- Herhangi bir egzersiz protokolü bulunmayan çalışmalar

Tarama sonucunda, toplamda 56 çalışma incelemeye alındı. Yukarıdaki hariç tutma kriterlerine göre yapılan eleme işlemleri sonucunda geriye 27 çalışma kalmıştır.



Şekil 1- Akış şeması

Veri Yönetimi

Çalışmaların yönetimi ve eleme basamaklarının izlenebilirliği için EndNote yazılımı kullanılmıştır. Çalışmaların veri tabanından alınması, duplikasyonların kaldırılması ve kriterlere uygunluk değerlendirmesi bu yazılım aracılığıyla gerçekleştirilmiştir.

Meta-Analiz Süreci

Meta-analiz, MedCalc 23.1.7 yazılımı kullanılarak gerçekleştirilmiştir. Çalışmalardan elde edilen veriler, standardize edilmiş ortalama farklar (Standardized Mean Differences, SMD) kullanılarak değerlendirilmiş ve sonuçlar forest plots ile görselleştirilmiştir.

Bu yöntemlerle, serum kreatin kinaz (CK) ve laktat dehidrogenaz (LDH) düzeylerinin egzersiz müdahaleleriyle ilişkisini inceleyen sistematik ve güvenilir bir değerlendirme sağlanmıştır.

BULGULAR

Bu meta-analiz, egzersizin serum kreatin kinaz (CK) ve laktat dehidrogenaz (LDH) seviyeleri üzerindeki etkilerini inceleyen 5 çalışmanın sonuçlarını birleştirmiştir. Toplamda 134 katılımcı hem deney hem kontrol gruplarında yer almıştır. Meta-analiz sonuçları şu şekilde özetlenmiştir:

Etki Büyüklüğü

Bu çalışmalar toplam 134 katılımcıyı (68 egzersiz, 66 kontrol) içermekteydi. Tek tek çalışmaların çoğunda CK düzeyleri bakımından gruplar arasında anlamlı fark yokken, yalnızca Nieman ve ark.'nın çalışması egzersiz sonrasında belirgin CK artışı bildirdi (SMD=0,97; %95 GA 0,17–1,77). Tüm çalışmalar birleştirildiğinde sabit etkiler modeli altında küçük–orta büyüklükte ancak istatistiksel olarak anlamsız bir etki saptandı (toplam SMD=0,243; SH=0,170; %95 GA −0,093 – 0,579; p=0,154) ve rassal etkiler modelinde de sonuç değişmedi (SMD=0,243; SH=0,180; %95 GA −0,113 – 0,600; p=0,179).

Aynı çalışmaların rapor ettiği LDH düzeyleri değerlendirildiğinde ise, bireysel etki büyüklükleri −0,20 ile 1,46 arasında değişmekte, yine yalnızca Nieman ve ark.'nın çalışmasında egzersiz grubunda anlamlı LDH artışı görülmekteydi (SMD=1,46; %95 GA 0,60–2,31). Meta-analiz sonucunda sabit etkiler modeli altında egzersiz sonrası LDH düzeyleri için küçük fakat istatistiksel olarak anlamsız bir artış eğilimi bulundu (SMD=0,188; SH=0,172; %95 GA −0,152 – 0,527; p=0,276).

Heterojenlik Analizi

CK düzeylerine ilişkin heterojenlik testi sonuçları, çalışmalar arasında düşük düzeyde tutarsızlık bulunduğunu göstermiştir. Q değerinin 4.4982 ve anlamlılık düzeyinin p=0.3428 olması, çalışmalardaki varyasyonun tamamen rastlantısal olabileceğine işaret etmektedir. Ayrıca I^2 değerinin yalnızca %11.08 olması, çalışmalar arasındaki farklılıkların etki büyüklüğünü anlamlı şekilde etkilemediğini düşündürmektedir. Bu durum, CK sonuçlarının çalışmalar arasında genel olarak uyumlu ve benzer yönde seyrettiğini, metodolojik farklılıkların ya da katılımcı özelliklerinin etki büyüklüğü üzerinde belirgin bir heterojenlik oluşturmadığını göstermektedir.

LDH sonuçları için yapılan heterojenlik analizi, çalışmalar arasında orta–yüksek düzeyde tutarsızlık bulunduğunu göstermiştir. Q değerinin 11.3512 ve anlamlılık düzeyinin p=0.0229 olması, çalışma sonuçları arasındaki varyasyonun rastlantısal olmadığını ve anlamlı heterojenlik içerdiğini belirtmektedir. I^2 değerinin %64.76 olarak hesaplanması, LDH yanıtındaki farklılıkların egzersiz protokolü, suplementasyon süresi, vitamin D dozları ve katılımcı profilleri gibi metodolojik değişkenlerden etkilenmiş olabileceğini göstermektedir. Bu nedenle LDH analizinde rassal etkiler modeli ana model olarak dikkate alınmıştır.

Grafiksel Bulgular

Forest plot analizi, beş çalışmanın CK üzerine etkilerinin çoğunlukla nötr veya hafif pozitif yönde olduğunu göstermektedir. Etki büyüklükleri genel olarak sıfıra yakın bir dağılım sergilemekte olup yalnızca Nieman ve ark.'nın çalışmasında anlamlı düzeyde pozitif bir etki görülmektedir. Diğer çalışmalarda etki boyutları dar güven aralıklarına sahip olup istatistiksel olarak anlamlı değildir. Toplam etki boyutu hem sabit hem rassal etkiler modellerinde pozitif olsa da güven aralıklarının sıfırı kesmesi, vitamin D takviyesinin CK düzeylerini anlamlı biçimde değiştirmediğini desteklemektedir. Funnel plot analizi yayın yanlılığını değerlendirmek amacıyla incelenmiştir. Grafikteki noktalar simetrik bir yerleşim göstermekte olup belirgin bir asimetri görülmemektedir. Bu bulgu, çalışmalarda küçük örneklem etkisi ya da pozitif sonuçların daha fazla yayımlandığına dair bir işaret olmadığını

göstermektedir. Egger (p=0.9656) ve Begg (p=0.1416) testleri de bu gözlemi desteklemekte olup CK sonuçları açısından yayın yanlılığına yönelik bir kanıt bulunmamıştır.

Forest plot incelemesi, LDH düzeylerine ilişkin etki büyüklüklerinin çalışmalara göre geniş bir varyasyon gösterdiğini ortaya koymuştur. Bazı çalışmalarda etkiler nötre yakınken, Nieman ve ark.'nın çalışmasında belirgin şekilde pozitif bir etki gözlenmektedir. Diğer çalışmalarda ise güven aralıkları geniş olup sıfırı kesmektedir; bu durum LDH yanıtında istikrarsız bir örüntü olduğunu göstermektedir. Rassal etkiler modelinde toplam etki pozitif yönde olsa da istatistiksel olarak anlamlı değildir (SMD=0.214). Funnel plot grafiği ise yayın yanlılığı açısından incelendiğinde belirgin bir asimetri göstermemektedir. Verilerin çoğu grafiğin sol tarafında toplanmakla birlikte dağılım dengelidir ve küçük çalışma etkisine işaret eden belirgin bir yapı bulunmamaktadır. Egger (p=0.3929) ve Begg (p=0.3272) testleri de yayın yanlılığına yönelik anlamlı bir bulgu olmadığını doğrulamaktadır.

Tablo 1 – Meta-Analize Dahil Edilen Çalışmalar ve İstatistiksel CK Sonuçları

Variable for studies	STUDYS
1. Intervention groups	
Variable for number of cases	Exercise_N
Variable for mean	Exercise_MEAN
Variable for SD	Exercise_SD
2. Control groups	
Variable for number of cases	CONTROL_N
Variable for mean	CONTROL_RHB_MEAN
Variable for SD	CONTROL_RHB_SD

Study	N1	N2	Total	SMD	SE	95% CI	t	P	Weight (%)	
									Fixed	Random
Nieman et al., 2013	15	13	28	0,971	0,390	0,169 to 1,773			18,91	19,05
Z˙ ebrowska et al., 2020	12	12	24	0,00955	0,394	-0,808 to 0,827			18,52	18,70
Parsaie et al., 2019	11	11	22	-0,0475	0,410	-0,903 to 0,808			17,10	17,40
Ashtary-Larky et al., 2020	14	14	28	0,115	0,367	-0,640 to 0,870			21,33	21,21
Shanely et al., 2014	16	16	32	0,171	0,345	-0,534 to 0,876			24,14	23,63
Total (fixed effects)	68	66	134	0,243	0,170	-0,0925 to 0,579	1,433	0,154	100,00	100,00
Total (random effects)	68	66	134	0,243	0,180	-0,113 to 0,600	1,351	0,179	100,00	100,00

Test for heterogeneity

Q	4,4982
DF	4
Significance level	P = 0,3428
I^2 (inconsistency)	11,08%
95% CI for I^2	0,00 to 82,59

Publication bias

Egger's test	
Intercept	0,4195
95% CI	-28,1211 to 28,9602
Significance level	P = 0,9656
Begg's test	
Kendall's Tau	-0,6000
Significance level	P = 0,1416

Heterojenite katsayısı %50'nin altında olduğu için fixed etki modeli tercih edilmiştir. Bununla

Variable for studies	STUDYS
1. Intervention groups	
Variable for number of cases	Exercise_N
Variable for mean	Exercise_MEAN
Variable for SD	Exercise_SD
2. Control groups	
Variable for number of cases	CONTROL_N
Variable for mean	CONTROL_RHB_MEAN
Variable for SD	CONTROL_RHB_SD

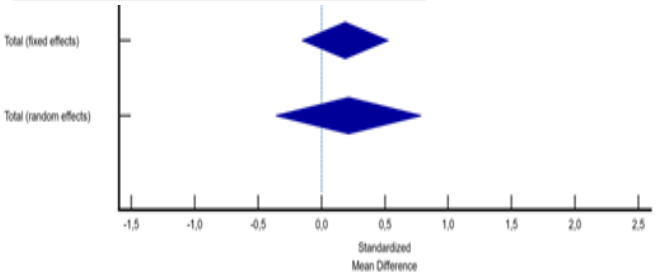
Study	N1	N2	Total	SMD	SE	95% CI	t	P	Weight (%)	
									Fixed	Random
Z˙ ebrowska et al., 2020	12	12	24	-0,196	0,395	-1,016 to 0,623			18,86	19,68
Nieman et al., 2013	15	13	28	1,456	0,416	0,601 to 2,312			17,00	18,92
Shanely et al., 2014	16	16	32	0,000	0,345	-0,704 to 0,704			24,79	21,56
Parsaie et al., 2019	11	11	22	-0,0289	0,410	-0,885 to 0,827			17,50	19,13
Ashtary-Larky et al., 2020	14	14	28	-0,0822	0,367	-0,837 to 0,672			21,85	20,71
Total (fixed effects)	68	66	134	0,188	0,172	-0,152 to 0,527	1,093	0,276	100,00	100,00
Total (random effects)	68	66	134	0,214	0,290	-0,360 to 0,789	0,739	0,461	100,00	100,00

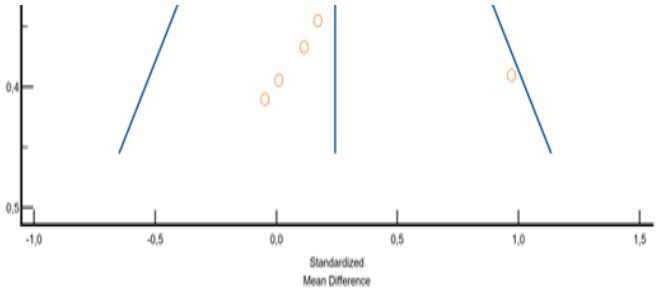
Test for heterogeneity

Q	11,3512
DF	4
Significance level	P = 0,0229
I^2 (inconsistency)	64,76%
95% CI for I^2	7,53 to 86,57

Publication bias

Egger's test	
Intercept	10,4183
95% CI	-22,8878 to 43,7243
Significance level	P = 0,3929
Begg's test	
Kendall's Tau	0,4000
Significance level	P = 0,3272





birlikte hem fixed hem de random etkiler modellerinde elde edilen sonuçlar istatistiksel olarak anlamlı değildi.

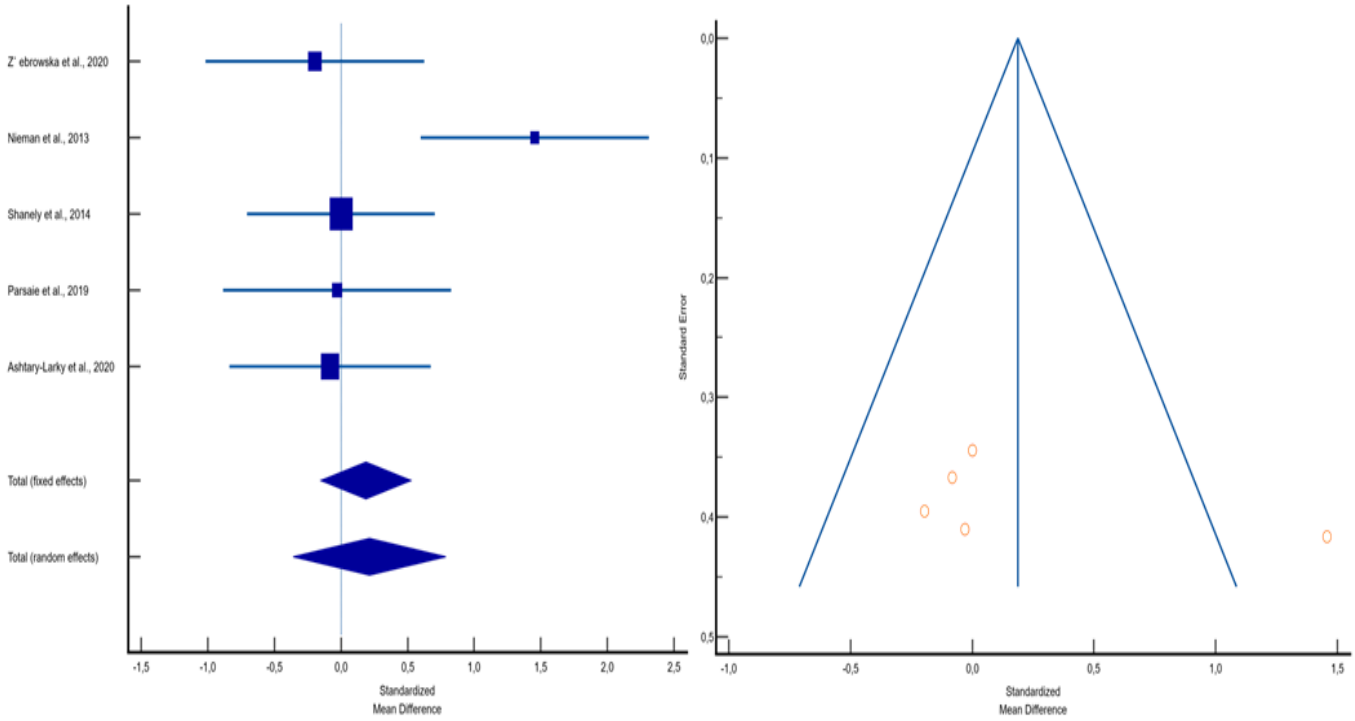
Tablo 2 – Forest Plot - Funnel Plot Grafikleri CK Sonuçları

Heterojenlik düşük düzeydeydi; bu durum çalışmaların genel olarak benzer sonuçlar ortaya koyduğunu göstermektedir. Bu nedenle alt grup analizine ihtiyaç duyulmamaktadır ve mevcut birleşik etki tek başına yeterli bir değerlendirme sunmaktadır.

Tablo 3 – Meta-Analize Dahil Edilen Çalışmalar ve İstatistiksel LDH Sonuçları

Heterojenite katsayısı %50'nin üzerinde olduğu için random etki modeli tercih edilmiştir. Bununla birlikte hem fixed hem de random etkiler modellerinde elde edilen sonuçlar istatistiksel olarak anlamlı değildir.

Tablo 4 - Forest Plot - Funnel Plot Grafikleri LDH Sonuçları



Heterojenlik orta–yüksek düzeydeydi; bu durum çalışmalar arasında belirgin metodolojik ve örneklem farklılıkları bulunduğunu göstermektedir.

TARTIŞMA

Bu meta-analiz, vitamin D suplementasyonunun egzersiz sonrası kas hasarı biyobelirteçleri olan kreatin kinaz (CK) ve laktat dehidrogenaz (LDH) düzeyleri üzerindeki etkilerini değerlendiren beş kontrollü çalışmanın bulgularını bir araya getirerek mevcut literatürdeki tutarsızlığı nicel olarak incelemiştir. Bulgular genel hatlarıyla değerlendirildiğinde vitamin D takviyesinin egzersiz sonrası kas hasarını azaltma yönünde anlamlı bir etkisinin bulunmadığı ve CK ile LDH düzeylerinde çoğunlukla küçük, pozitif fakat istatistiksel olarak anlamsız değişimlere yol açtığı görülmüştür.

CK analizinde elde edilen birleşik etki büyüklüğünün hem fixed hem de random etkiler modellerinde benzer şekilde pozitif bulunmasına rağmen, güven aralıklarının sıfırı kesmesi vitamin D takviyesinin CK yanıtını anlamlı şekilde değiştirmediğini göstermektedir. Ayrıca heterojenlik düzeyinin düşük (I^2 = %11) olması, CK sonuçlarının çalışmalarda oldukça tutarlı olduğunu ve metodolojik farklılıkların bu parametre üzerinde belirgin bir sapma yaratmadığını düşündürmektedir. Bu durum, CK'ın temel olarak kas membran hasarının doğrudan bir göstergesi olmasına rağmen vitamin D'nin akut hasar yanıtı üzerindeki etkisinin sınırlı kalabileceğini işaret etmektedir. Nitekim bireysel çalışmalar incelendiğinde yalnızca Nieman ve ark. (2013) anlamlı CK artışı bildirmiş, kalan çalışmalarda egzersiz sonrası CK değişimleri minimal ve istatistiksel olarak anlamsız bulunmuştur.

LDH analizinde ise heterojenlik düzeyinin orta–yüksek (I^2 = %65) çıkması dikkat çekicidir. LDH, CK'a kıyasla daha genel bir doku hasarı biyobelirteci olduğundan farklı fizyolojik süreçlerden kolayca etkilenebilmekte ve çalışma protokolleri arasındaki metodolojik farklılıklar bu parametrede daha geniş bir varyasyon oluşturmaktadır. Rassal etki modeli altında birleşik etkinin yine istatistiksel olarak anlamlı olmaması (SMD=0.214, $p>0.05$), vitamin D takviyesinin LDH yanıtı üzerindeki etkisinin dağınık ve tutarsız olduğunu göstermektedir. Çalışmalar arasındaki bu heterojenliğin potansiyel nedenleri arasında başlangıç vitamin D düzeylerindeki farklılıklar, suplementasyon süresi, uygulanan egzersiz türü (örneğin aerobik, direnç, yüksek yoğunluklu protokoller), katılımcıların antrenman geçmişi ve kas kütlesi gibi değişkenler sayılabilir. Özellikle LDH'ın farklı dokulardan salınabilmesi, egzersiz protokolündeki küçük değişikliklerin bile biyokimyasal yanıtı önemli ölçüde etkilemesine neden olabilir.

Forest plot analizleri CK için genel olarak nötre yakın bir dağılım ortaya koyarken, LDH sonuçlarında daha geniş güven aralıkları ve çalışmadan çalışmaya belirgin farklılaşan etki yönleri gözlenmiştir. Bu durum LDH'ın CK'a kıyasla daha değişken bir belirteç olduğunu desteklemektedir. Funnel plot incelemeleri ise her iki parametre için de simetrik bir dağılım göstermiş ve Egger ile Begg testlerinin istatistiksel olarak anlamsız çıkması, yayın yanlılığı riskinin düşük olduğunu düşündürmüştür. Bu bulgu, sonuçların sistematik kutuplaşmadan ziyade biyolojik ve metodolojik çeşitlilikten etkilendiğini göstermektedir.

Çalışmaların büyük çoğunluğunda vitamin D suplementasyonunun kas hasarı belirteçlerinde anlamlı bir azalma yaratmaması, vitamin D'nin potansiyel etkilerinin daha çok kas fonksiyonu, inflamasyon modülasyonu, kalsiyum homeostazı ve uzun dönem kas sağlığı üzerinden gerçekleştiğini, ancak akut egzersiz sonrası hasar yanıtı üzerinde belirgin bir biyokimyasal iyileşme sağlamadığını düşündürmektedir. Vitamin D'nin kas membranı stabilitesini artırıcı etkileri teorik olarak CK ve LDH yanıtını azaltabileceği halde mevcut çalışmalar bu hipotezi güçlü bir şekilde desteklememektedir. Bunun olası nedenleri arasında suplementasyon süresinin yetersiz olması, katılımcıların temel vitamin D eksiklik düzeylerinin farklı olması, kas hasarı yanıtının bireysel değişkenlere büyük ölçüde bağımlı olması ve egzersiz protokollerinin standardize edilmemiş olması yer alabilir.

Ayrıca vitamin D'nin etkisinin daha çok kronik adaptasyon süreçlerinde ortaya çıkması, akut egzersiz sonrası birkaç saat veya gün içinde ölçülen CK ve LDH düzeylerinin bu etkileri yakalamakta yetersiz kalmasına neden olabilir. Daha uzun süreli takipler, farklı doz protokolleri ve başlangıç vitamin D seviyelerine göre alt grup analizleri yapılması bu ilişkiyi daha net açıklayabilir.

Genel olarak bu meta-analizin bulguları, vitamin D suplementasyonunun akut egzersiz sonrası kas hasarı biyobelirteçleri üzerinde anlamlı bir iyileştirici etki sağlamadığını, ancak bu ilişkinin karmaşık ve çok faktörlü yapısı nedeniyle gelecekte daha kontrollü, geniş örneklemli ve standardize tasarımlarla yapılacak çalışmalara ihtiyaç olduğunu göstermektedir.

SONUÇ

Bu meta-analiz, vitamin D suplementasyonunun egzersiz sonrası kas hasarı ve kas yenilenmesi süreçleri üzerindeki etkisini CK ve LDH gibi yaygın biyobelirteçler üzerinden değerlendiren güncel kanıtları nicel olarak birleştirmiştir. Analize dahil edilen beş çalışma incelendiğinde, vitamin D takviyesinin akut egzersiz sonrası biyokimyasal kas hasarı yanıtını anlamlı düzeyde azaltmadığı görülmüştür. CK için elde edilen birleşik etki büyüklüğünün küçük pozitif bir yönde olmasına rağmen hem fixed hem de random etki modellerinde istatistiksel olarak anlamsız bulunması, vitamin D'nin kas membran hasarını doğrudan azaltıcı bir etki göstermediğini düşündürmektedir. Benzer şekilde LDH düzeyi için hesaplanan birleşik etki büyüklüğünün de anlamlı olmaması, vitamin D suplementasyonunun doku hasarına bağlı enzim salınımını belirgin şekilde değiştirmediğini ortaya koymuştur.

Heterojenlik düzeylerinin parametreler arasında farklılık göstermesi, vitamin D'nin etkisinin çalışmalarda kullanılan yöntemlerden yoğun biçimde etkilendiğini göstermektedir. CK analizinde düşük heterojenlik, sonuçların daha tutarlı olduğunu gösterirken; LDH'de orta–yüksek heterojenlik, egzersiz türü, suplementasyon süresi, doz farklılıkları ve başlangıç vitamin D düzeyi gibi faktörlerin sonuçlar üzerinde belirgin değişkenlik oluşturabileceğine işaret etmektedir. Bununla birlikte funnel plot analizlerinin simetrik dağılım göstermesi ve Egger ile Begg testlerinin anlamlı çıkmaması, yayın yanlılığının sonuçları etkileme olasılığının düşük olduğunu desteklemektedir.

Bu bulgular, vitamin D suplementasyonunun akut egzersiz sonrası kas hasarı yanıtını iyileştirmekte sınırlı etkiye sahip olduğunu ve CK ile LDH düzeylerinde anlamlı bir düzeltme sağlamadığını göstermektedir. Vitamin D'nin bilinen biyolojik etkileri; inflamasyonun modülasyonu, kas kontraksiyonunda rol oynayan kalsiyum dengesinin düzenlenmesi ve uzun vadede kas fonksiyonunun korunması gibi süreçlerle ilişkili olsa da, mevcut kanıtlar bu etkilerin kısa süreli egzersiz sonrası kas hasarı yanıtında doğrudan yansımadığına işaret etmektedir.

Bu nedenle, vitamin D'nin kas sağlığı üzerindeki etkilerinin daha net anlaşılabilmesi için gelecekte yapılacak çalışmaların daha büyük örneklemlerle, başlangıç vitamin D durumuna göre alt grup analizleri içerecek şekilde, farklı egzersiz şiddeti ve protokollerini standardize ederek yürütülmesi gerekmektedir. Ayrıca suplementasyon süresi ve dozunun etkinliği belirleyici olabileceğinden uzun süreli ve karşılaştırmalı tasarımlar da önem taşımaktadır. Genel olarak bu meta-analiz, vitamin D suplementasyonunun akut kas hasarını azaltıcı etkisine dair güçlü bir kanıt ortaya koymamakta; ancak vitamin D'nin kas fonksiyonu, toparlanma kapasitesi ve genel fizyolojik adaptasyonlar üzerindeki daha geniş kapsamlı etkilerinin gelecekte ayrıntılı biçimde araştırılması gerektiğini vurgulamaktadır.

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PREDİYABETTE ADİPOİMMÜN DENGENİN BOZULMASI: ERKEN DÖNEMDE ORTAYA ÇIKAN YENİ BİR FENOTİPİN DEĞERLENDİRİLMESİ

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ÖZET

Bu çalışma, prediyabet döneminde adiposit kökenli immünometabolik belirteçlerde ortaya çıkan erken değişimleri değerlendirmeyi ve bu değişimlerin özgün bir biyolojik fenotip çerçevesinde tanımlanmasını amaçlamaktadır. Prediyabet, yalnızca glisemik düzenlemedeki bozulmalarla sınırlı olmayan; adipoz dokunun enflamatuvar yanıtı ve metabolik işlevlerinde erken dönemde başlayan yapısal ve fonksiyonel değişikliklerle karakterize edilen heterojen bir metabolik durumdur. Bu dönemde adipoz dokunun yalnızca enerji depolayan bir yapı olmaktan çıkarak, aktif bir endokrin ve immün organ gibi davrandığı bilinmektedir. Adipokin profili ve ilişkili metabolik belirteçlerde meydana gelen değişiklikler, hastalığın ilerleyici doğasına eşlik eden erken biyolojik süreçlerin anlaşılmasında önemli bilgiler sunmaktadır.

Mevcut çalışma verileri, anti-enflamatuvar adipokinlerden adiponektin ve omentin düzeylerinde azalma eğilimi bulunduğunu, buna karşılık pro-enflamatuvar özellikteki resistin ve visfatin düzeylerinin arttığını göstermektedir. Lipid taşınımı ve lipotoksisite ile ilişkili FABP4 ve FABP5 düzeylerinin prediyabet grubunda yükseldiği saptanmıştır. CTRP ailesi üyeleri değerlendirildiğinde, CTRP1 düzeylerinde artış ve CTRP3 düzeylerinde azalma ile karakterize ters yönlü bir değişim gözlenmiştir. Ayrıca PPAR-γ düzeylerinin prediyabet grubunda kontrol grubuna kıyasla daha düşük olduğu belirlenmiştir.

Elde edilen bulgular, prediyabetin erken evresinde adipoz dokuda immünometabolik dengenin değişebileceğine işaret etmektedir. Bu değişimlerin “Adipoimmün Shift” modeli çerçevesinde ele alınması, prediyabet sürecinde ortaya çıkan biyolojik farklılaşmaların sistematik olarak değerlendirilmesine olanak sağlayabilir. Bununla birlikte, bu yaklaşım ön çalışma niteliğinde olup, klinik anlamlılık ve biyolojik geçerliliğin ortaya konabilmesi için daha geniş örneklem gruplarını içeren, uzunlamasına ve mekanistik çalışmalarla desteklenmesi gerekmektedir.

Anahtar Kelimeler: Adipokin, immünometabolik belirteç, prediyabet.

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PREDİYABETTE BAĞIRSAK KAYNAKLI İMMÜNOMETABOLİK DEĞİŞİMLER: MİKROBİYOTA–İMMÜN–ENDOKRİN EKSENİNİN DEĞERLENDİRİLMESİ

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ÖZET

Bu çalışmada, prediyabet sürecinde bağırsak kaynaklı metabolik ve immün sinyallerde ortaya çıkan erken değişimlerin sistemik düzeydeki etkilerinin incelenmesi amaçlanmıştır. Prediyabet, yalnızca glukoz metabolizmasındaki bozulmalarla değil; bağırsak mikrobiyotası, bağışıklık yanıtı ve endokrin sinyalizasyon arasındaki etkileşimlerin erken dönemde farklılaşmasıyla da karakterize edilmektedir. Bu bağlamda bağırsak kökenli moleküler sinyallerin, metabolik homeostazın korunmasında oynadığı rolün prediyabet evresinde yeniden şekillenebileceği öngörülmektedir.

Çalışma kapsamında yapılan değerlendirmelerde, kısa zincirli yağ asitleri (SCFA) düzeylerinde azalma ile birlikte bu metabolitlerin reseptörleri olan GPR41 ve GPR43 ekspresyonunda düşüş saptanmıştır. Doğal bağışıklık yanıtı ile ilişkili inflamazom bileşenleri incelendiğinde, NLRP3 düzeylerinin arttığı, buna karşılık NLRP6 aktivitesinin azaldığı belirlenmiştir. Ayrıca inkretin sistemiyle ilişkili parametreler değerlendirildiğinde, GLP-1, GLP-1R ve PYY düzeylerinin prediyabet grubunda kontrol grubuna göre daha düşük olduğu gözlenmiştir. Bu gözlemler, prediyabetin erken döneminde bağırsak–immün–endokrin etkileşimlerinde eşzamanlı ve çok boyutlu değişimlerin ortaya çıkabileceğini göstermektedir.

Söz konusu değişimlerin "Mikrobiyota–İmmün–Endokrin Değişim" modeli çerçevesinde ele alınması, prediyabet patofizyolojisinde bağırsak kaynaklı immünometabolik süreçlerin bütüncül biçimde değerlendirilmesine katkı sağlayabilir. Bununla birlikte, bu model hipotez oluşturucu nitelikte olup, biyolojik mekanizmaların ve klinik karşılıklarının netleştirilebilmesi için ileri düzey ve geniş örneklemli çalışmalarla desteklenmesi gerekmektedir.

Anahtar Kelimeler: İmmünometabolik değişimler, Mikrobiyota–İmmün–Endokrin Eksen, Prediyabet

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ETHNOBOTANICAL USES OF *SILENE* L. (CARYOPHYLLACEAE) TAXA GROWING IN TURKIYE

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ABSTRACT

This study is the first to aim at revealing the traditional uses of *Silene* L. (Caryophyllaceae) taxa, one of the important genera of the Turkish flora. Turkey, due to its geographical location and climatic diversity, is an important gene center for *Silene* species, harboring more than 160 taxa. This high diversity, combined with the rich ethnobotanical culture that has developed in Anatolia throughout history, has paved the way for the use of the *Silene* genus in various aspects of folk life. Within the scope of this study, ethnobotanical articles, postgraduate theses, and some floristic and ethnobotanical works published between 1990 and 2025 were examined. It was determined that *Silene* taxa growing in Turkey have a multifaceted history of use and possess cultural value in various fields, primarily folk medicine and food. The data obtained are of a nature that will both contribute to the preservation of traditional knowledge and provide a basis for future scientific research. The study classified the traditional uses of *Silene* species in Turkey as follows: medicinal use, food consumption, use as ornamental and landscape plants, use in animal husbandry, and cultural/ritual practices. Of the 27 *Silene* species identified for ethnobotanical purposes, 14 (51.85%) were used in folk medicine for the treatment of various ailments, 5 (18.52%) were used for food purposes, and 3 (11.11%) were used as ornamental plants. In addition, 1 species (3.70%) was used for animal feed and animal health, 1 species (3.70%) for cultural purposes in beliefs or regional practices, 1 species (3.70%) for soap making, 1 species (3.70%) as a cleaning agent, and 1 species (3.70%) for fiber or packaging. This study concludes that the ethnobotanical potential of *Silene* taxa growing in Turkey is quite high.

Keywords: Caryophyllaceae, *Silene*, Ethnobotany, Türkiye.

TÜRKİYE'DE YETİŞEN *SİLENE* L. (CARYOPHYLLACEAE) TAKSONLARININ ETNOBOTANİK KULLANIMLARI

ÖZET

Bu çalışma, Türkiye florasının önemli cinslerinden biri olan *Silene* L. (Caryophyllaceae) taksonlarının geleneksel kullanım biçimlerinin ortaya konulmasını amaçlamayan ilk çalışmadır. Türkiye, coğrafi konumu ve iklim çeşitliliği gibi nedenlerle *Silene* türleri için önemli bir gen merkezi olup 160'tan fazla takson barındırmaktadır. Bu yüksek çeşitlilik, tarih boyunca Anadolu'da oluşan zengin etnobotanik kültürle birleşerek *Silene* cinsinin halk yaşamında farklı alanlarda kullanılmasına zemin hazırlamıştır. Çalışma kapsamında 1990–2025 yılları arasında yayımlanmış etnobotanik içerikli makaleler, lisansüstü tezler ve bazı floristik ve etnobotanik eserler incelenmiştir. Türkiye'de yetişen *Silene* taksonlarının çok yönlü kullanım geçmişine sahip olduğu, halk hekimliği ve gıda başta olmak üzere çeşitli alanlarda kültürel bir değer taşıdığı belirlenmiştir. Elde edilen veriler, hem geleneksel bilginin korunmasına hem de ileride yapılacak bilimsel araştırmalara temel oluşturacak niteliktedir. Çalışma sonucunda *Silene* türlerinin Türkiye'deki geleneksel kullanımları; tıbbi kullanım, gıda olarak tüketim, süs ve peyzaj bitkisi olarak kullanım, hayvancılıkta kullanım ve kültürel/ritüel uygulamalar şeklinde sınıflandırılmıştır. Çalışmada etnobotanik amaçlarla kullanıldığı belirlenen toplam 27 *Silene* türünden 14 türün (%51,85) halk hekimliğinde çeşitli rahatsızlıkların tedavisinde kullanıldığı, 5 türün (%18,52) gıda amaçlı kullanıldığı, 3 türün (%11,11) süs bitkisi olarak kullanıldığı belirlenmiştir. Bunlara ilaveten 1 türün (%3,70) hayvan yemi ve hayvan sağlığı için, 1 türün (%3,70) kültürel amaçla inanç veya yöresel pratiklerde, 1 türün (%3,70) sabun yapımı için, 1 türün (%3,70) temizlik maddesi olarak, 1 türün (%3,70) lif veya ambalaj için kullanıldığı ortaya konulmuştur. Bu çalışma ile Türkiye'de yetişen *Silene* taksonlarının Etnobotanik potansiyellerinin oldukça yüksek olduğu sonucuna varılmıştır.

Anahtar Kelimeler: Caryophyllaceae, *Silene*, Etnobotanik, Türkiye.

1. GİRİŞ

Etnobotanik terimi, ilk kez 1896 yılında, bir biyoloji profesörü olan John W. Harshberger tarafından, lokal halkın doğa tarihinin araştırılmasını belirtmek için kullanılmaya başlanmış olup, basitçe "bitkilerin yerel halk tarafından kullanımı" olarak tanımlanmıştır. Ancak günümüzde sadece bitkilerin kullanımı değil, aynı zamanda niçin kullanıldığını ve yetişmesini anlamak, bitkilerin yetiştiği ortam şartlarının belirlenmesi konularına da odaklanmış olup etnobotanik teriminin tanımı sürekli değişmektedir (Cotton, 1996).

Etnobotanik çalışmalar, halk arasında bitkilerin geleneksel olarak sınıflandırılması, yönetimi ve kullanımı konusunda yapılan çalışmalardır. Bu çalışmalar; yalnızca insanlarla bitkilerin yüzyıllardan beri devam eden karşılıklı etkileşimlerini kaydetmekle kalmaz aynı zamanda bu etkileşimden doğan sonuçların, biyolojik çeşitliliğin korunması ve kırsal kesimde yaşayan

halkın gelişiminde kullanılmasına da olanak verir (Özhatay ve ark., 1997). İnsanlar bitkilerle sürekli etkileşim halindedir. Bitkiler en çok gıda ve ilaç olarak kullanılmakla beraber, yakıt, yapı malzemesi, süs eşyası, boya, büyü (inançsal) vb. amaçlar için de kullanılmaktadır. Dünya üzerinde 750.000-1.000.000 arasında bitki türünün bulunduğu tahmin edilmektedir. Bunlardan 500.000 kadarı tanımlanıp isimlendirilmiştir. Her yıl 2000 kadar yeni tohumlu bitki türü tanımlanıp isimlendirilmektedir. Gıda elde etmek için yetiştirilen türler 3.000 civarındadır. Buna karşılık, gıda olarak kullanılan yabani bitki türü sayısı 10.000'nin üzerindedir. Türkiye'de kullanılan tıbbı bitkilerin miktarı en az 500 civarındadır. Bu sayının diğer ülkeler içinde geçerli olabileceği düşünülürse gerçekte kullanılan tıbbi bitki miktarının da 100.000 civarında olduğu tahmin edilebilir (Baytop, 1999).

Bazı türler yemeklere koku ve tat vermek bazıları da çay olarak oldukça yaygın kullanılmaktadır (Baytop, 1999) Hititler dönemi tıbbi tabletlerinde bulunan reçete formüllerinde kayıtlı bitki adları bunun bir kanıtıdır. Bu dönemlerde yabani bitkilerden yararlanıldığı gibi, bazı önemli tıbbi bitkiler, drog elde etmek için yetiştirilmekteydi. Kırsal bölgelerde, ilaç hazırlamak için genellikle çevrede yetişen veya yetiştirilen bitkiler kullanılmaktadır (Baytop, 1999). Eskiden kumaş veya dokumaların boyanmasında genellikle bitkisel kökenli boyar maddeler kullanılmaktaydı. Yüzyıl kadar önce, boyar maddelerin sentetik olarak yapılma olanaklarının bulunması ve bunların ucuz olarak ticarete çıkartılması, bütün dünyada olduğu gibi memleketimizde de sentetik boyar maddelerin geniş bir oranda kullanılmasına neden olmuştur. Bununla beraber, Anadolu'nun bazı bölgelerinde bitkisel kökenli boyar maddeler halen kullanılmaktadır. Son yıllarda bitkisel boyar maddelere ilgi de artmıştır. Bunun başlıca nedeni birçok bitkisel boyar maddenin renklerini ve parlaklıklarını uzun zaman korumalarıdır (Baytop, 1999). Bitkilerin yapı malzemesi, yakıt ve süs eşyası olarak kullanımı geçmişten günümüze devam etmektedir. Özellikle kırsal kesimde yapı malzemesi olarak kullanımı çok yaygın olup, inançsal kullanımı da (çoğunlukla kadınlar tarafından) nazar başta olmak üzere değişik şekillerde yapılmaktadır.

Bu çalışma Türkiye'de doğal olarak yetişen *Silene* taksonlarının etnobotanik kullanımlarını belirlemek üzere yapılmış ilk çalışmadır.

2. CARYOPHYLLACEAE FAMİLYASI

Bir veya çok yıllık otlar veya yalnız tabanı odunsu olan otsu bitkilerdir. Yapraklar karşılıklı, genellikle dar ve şeritsi, yaprak kenarı düz, basit, tek parçalı, stipüllü veya stipülsüzdür. Çiçek durumları çoğunlukla dikazyum, çiçekler genellikle hermafrodit nadir olarak tek eşemli, tek veya kimöz şeklinde, aktinomorf simetrilidir. Periant, kaliks ve korolla şeklinde farklılaşmıştır. Sepaller 4-5 adet, serbest veya tüp şeklinde birleşmiştir. Petaller (0-)4-5 adet, serbest, genellikle bazal kısmı dar, çoğunlukla tırnak mevcuttur ve bazen iç yüzeyinde ligula ve koronal pullar taşır. Stamenler bir veya iki daire üzerinde (0-)3-10 adet, bazılarında petalsi staminodlar mevcuttur. Ovaryum üst durumlu, 1 bölmeli veya tabana yakın kısımda 2 veya 5 bölmeye ayrılır, plasentalanma serbest-sentral, tohum taslakları çok sayıda veya nadiren birkaç tanedir. Petaller, stamenler ve ovaryum bazen uzamış bir internod (antofor)'dan çıkar veya sepal, petal ve stamenler nadiren perigindir. Stiluslar 2-5 adettir, serbest veya kısmen bileşiktir. Meyve genellikle dişle veya valv ile açılan kapsül tipinde, dişler veya valv stilus sayısı kadar ya da

stilus sayısının iki katı kadar sayıda, nadiren düzensiz olarak açılan bakka veya kapsül tipindedir. Tohumlar çok sayıda veya bir tanedir (Er, 2012).

2.1. Caryophyllaceae Familyasının Tıbbi Özellikleri

Asırlardan beri halkın tedavi amaçlı kullandığı bitkiler ve başvurduğu yollar değişikliklere uğrayarak günümüze kadar gelmiştir. Özellikle eski çağlarda yabani bitkiler ilaç olarak kullanılmış ve genellikle hayvan hareketleri izlenerek onların yediği bitkiler seçilip tedavi amacı güdülmüştür. İnsan hayatına fayda sağlaması için kullanılan şifalı bitkiler hakkında araştırmaların çoğalması, yöresel uygulamaların toplanıp değerlendirilmesi, bitkisel aktif bileşenlerin farmakolojik ve klinik etkilerinin özgün yayınlarla kanıtlanması toplumları bitkilerle tedavi alanına yönlendirmiştir (Karagöz, 2003). Kronik hastalıklarda ve özellikle sağlığın korunmasında tıbbi bitkilerin önemli katkılar sağlayabileceği bilimsel olarak ortaya konmuştur (Kılıç, 2007).

Caryophyllaceae familyasına ait birçok tür solunum yolu enfeksiyonları, öksürük, ateş, sindirim sistemi düzensizlikleri, idrar yolu hastalıkları, deri hastalıkları ve yaraların iyileştirilmesi başta olmak üzere çok çeşitli rahatsızlıkların tedavisinde halk tıbbında kullanılmıştır. Özellikle *Stellaria media, Saponaria officinalis, Silene* ve *Gypsophila* türlerinin hem dahili hem harici uygulamalarda önemli yer tuttuğu bildirilmektedir. Bazı türlerden elde edilen özütlerin hücresel ve moleküler düzeyde kansere karşı etkili olduğu, ayrıca antioksidan aktivitelerinin serbest radikallerin neden olduğu biyolojik hasarı azaltmada güçlü rol oynadığı belirlenmiştir.

Caryophyllaceae familyasının medikal açıdan taşıdığı potansiyel güçlü olmakla birlikte, (Chandra ve Rawat, 2015) tarafından vurgulandığı üzere klinik veriler henüz sınırlıdır ve laboratuvar sonuçlarının klinik onay için daha ileri çalışmalara ihtiyaç duyduğu ifade edilmektedir. Buna rağmen mevcut bilimsel bulgular, familyanın yeni fitoterapötik ilaç adaylarının geliştirilmesi için önemli bir doğal kaynak olduğunu göstermektedir.

Caryophyllaceae ailesi dünyada halk hekimliğinde özellikle Çin geleneksel tıbbında çeşitli hastalıkların tedavisi için kullanılır ve genel olarak antikanser, antibakteriyel, antioksidan ve antiinflamatuar özellikler göstermektedir (Chandra ve Rawat, 2015).

Caryophyllaceae familyası, saponinler, benzenoidler, nitrojen içeren bileşikler, fitoekdisteroidler gibi kimyasal bileşenleri içermektedir. Saponinlerin varlığından dolayı etnobotanik olarak eski zamanlardan beri sabun olarak kullanılmaktadır.

3. *SİLENE* L. CİNSİ

Bir, iki veya çok yıllık otsular. Gövdeler genellikle caespitos, dik, bazen yatık; glandular, eglandular, puberulous bazılarında seyrek basit tüylü, nadiren tüysüz. Yapraklar oblong-oblanseoloat, kordat, spatulat, obovat, oblanseolat, lanseolat, linear; genellikle Petiyolat nadiren sesil; yaprak kenarları düz, küçük dişli, nadiren loblu; 1, 3 veya daha fazla damarlı; genellikle puberulous nadiren tüysüz. Çiçek durumu dikazyum, bileşik dikazyum, monokazyum, boğulmuş veya gevşek panikula. Çiçekler kısa veya uzun saplı, nadiren sapsız. Pedisel ve pedinkul genellikle tüylü. Kaliks tüpsü, 3-45 mm; 10-60 damarlı; genellikle glandular,

eglandular veya basit tüylü, nadiren tüysüz. Kaliks 5 dişli; diş uzunluğu 1-5 mm. Petal 5; petal dudağı (limb) genellikle 2 parçalı; petal klavları (sap) tüysüz, nadiren basit tüylü; bazı taksonların limb ve klav'ın birleşme noktalarında iki yan kulakçık (auricles) ve iki dilcik mevcut; koronal pullar genellikle mevcut, değişken şekilli; petaller çoğunlukla beyaz, kirli beyaz, sarı veya açık pembe; genellikle kaliksten daha uzun. Stilus 3 veya 5; stigma genellikle tüylü. Stamen sayısı 10; 5'i iç tarafta antofora bağlı, 5'i dış tarafta petalin tabanına bağlı; flament genellikle tüysüz, nadiren basit tüylü; anter bağlantısı versatil. Meyve değişken ve gelişmiş alt bölmeli (septa) dentisid kapsül, bazılarında septa olmayabilir; diş sayısı stilus sayısının iki katı kadar. Petaller, stamenler ve ovaryum çiçeğin tabanında sap şeklinde uzun bir yapı oluşturan antofor üzerinden yükselir. Meyvede bu yapı karpofor adını alır. Antofor genellikle tüysüz, nadiren tüylü; 1-30 mm. Çiçek simetrisi aktinomorf; çiçek formülü K(5)C5A5+5G(3). Plesentasyon serbest sentral. Tohumlar reniform, 0,2-3 mm, açık veya koyu kahverengi (Kılıç, 2007).

3.1. *Silene* L. Cinsinin Tıbbi Özellikleri

Silene L. cinsine ait bazı türlerin saponin maddesi bulundurması nedeniyle ekonomik ve tıbbi önemi vardır. *Silene vulgaris*'in köklerinin kaynar suda yavaş yavaş kaynatılmasıyla sabun elde edilmektedir. Kökleri ve toprak üstü kısımları infüsyon haline getirilerek (%5) idrar kesesi ve idrar yolları hastalıklarının tedavisinde kullanılmaktadır (Baytop, 1984). Bitki içerdiği maddeler nedeniyle buhar banyolarında rahatlatıcı olarak kullanılır. Bitkinin suyunun oftalmia tedavisinde kullanıldığı belirtilmiştir. Güney Anadolu'nun çeşitli köylerinde bitkinin genç sürgünleri ve yaprakları pişirilerek yenir. 5 cm'den daha uzun olarak toplanan genç sürgünler pişirildiğinde tadı biraz acımsı olmakla birlikte, ağızda bezelyeyi andıran bir tat bırakır. Yapraklar aynı zamanda ince olarak doğranıp salataya katılabilir. Bitkide çiçekler oluşmaya başlamadan önce yaprakların toplanmasına özen gösterilmelidir (Baytop, 1984). Yapılan literatür araştırmalarında *Silene L*. cinsine ait türler için kaydedilmiş bir toksisite bilinmemekle birlikte bu türlerin saponin içermelerinden dolayı dikkatli kullanılmaları gerekmektedir (Kılıç 2009). *Silene acaulis* var. Acaulis. çocukların kalın bağırsağında ve karın boşluğunda duyulan sancıyı tedavi etmek amacıyla kullanılır. Karaciğerde ilaçların emiliminde görev alan enzimlerin üretimini destekler. Kore'de gebelik önleyici, adet 7 düzenleyici, süt salgısını çoğaltıcı olarak ve bel soğukluğu hastalığı tedavisinde kullanılır. *Silene nigrescens* Edgew. çiçekleri Tibet tıbbında acı ve ekşi tatları gidermek için kullanılır. İşitme kaybı, kulak yolu tıkanıklığı hastalıklarında tedavi amaçlı kullanıldığı belirtilmiştir. *Silene conoidea L*. türü derinin yumuşamasını sağlar. Aynı zamanda dezenfektan özelliği vardır. Bitkinin özütü göz enfeksiyonu hastalığında tedavi amaçlı kullanılır (Baytop, 1999).

3. BULGULAR

Çizelge 1. Belirlenen *Silene* türlerinin taksonomik özellikleri

Sıra No.	Takson	Türkçe Adı	Yöresel Adı	Elementi/ Endemizm	Kullanılan Kısım	Literatür
1.	*Silene acaulis* (L.) Jacq. var. *acaulis*	Bodursinekkapan	–	–	Çiçek	(Körner, 2003)
2.	*Silene latifolia* subsp. *eriocalycinae* (Boiss.) Greuter & Burdet	Gıcıme	Gıcı, Gıcıoğlak	–	Yaprak	(Yüzbaşıoğlu ve ark, 2020)
3.	*Silene brevicaulis* Boiss.	Goşberk	Dımsok	İran-Turan, **Endemik**	Çiçek	(Eksik, 2020)
4.	*Silene caryophylloides* subsp. *echinus* (Boiss. & Heldr.) Coode & Cullen	Kirpi nakılı	Kara geven	D.Akdeniz, **Endemik**	Toprak Üstü	(Kargıoğlu, 2008)
5.	*Silene colorata* Poir. subsp. *colorata*	Kum nakılı	–	Akdeniz	Toprak Üstü	(Fidan ve Akan, 2019)
6.	*Silene conica* L.	Sivri nakıl	Toklubaşı	–	Toprak Üstü	(Yücel ve ark., 2012)
7.	*Silene conoidea* L.	Şıvanan otu	İnekbiciği	–	Bitkinin Tamamı	(Ullah ve ark, 2019)
8.	*Silene confertiflora* Chowdhuri	Gıcı pancar	Gıcı Pancar	D. Akdeniz	Yaprak	(Baytop, 1999)

9.	*Silene chlorifolia* Sm.	Puşkullu	_	İran-Turan	Toprak üstü	(Chandra ve Rawat, 2015)
10.	*Silene compacta* Fisch. ex Hornem.	Kanlıbasıraotu	Gıvışık	_	Yaprak	(Karagöz ve ark., 2024)
11.	*Silene dichotoma* Ehrh. subsp. *dichotoma*	Çatal nakıl	Toklubaşı	_	Toprak üstü	(Arı, 2014)
12.	*Silene laxa* Boiss. & Kotschy	Gevşeksim otu	Sinek otu	İran-Turan	Toprak üstü	(Akkan, 2024)
13.	*Silene longipetala* Vent.	Çiçekli süpürge	_	_	Toprak üstü	(Şenkardeş, 2013)
14.	*Silene monerantha* F.N. Williams	Botan nakılı	_	İran-Turan	Yaprak	(Kaya ve Ertekin, 2009)
15.	*Silene odontopetala* Fenzl	Kunduz otu	_	_	Toprak üstü	(Korkmaz ve Alpaslan, 2014)
16.	*Silene fortunei Vis*	Nakıl otu	_	_	Kök	(Chandra ve Rawat, 2015)
17.	*Silene saxatilis* Sims	Simotu	Mayasıl Otu, Zembil	_	Yaprak	(Sezik vd., 1997)

18.	*Silene subconica* Friv.	Mahruti Nakıl	İnekbiciği	–	Çiçek	(Şenkardeş, 2013)
19.	*Silene stenobotrys* Boiss. & Hausskn.	Maraş nakılı	–	İran-Turan	Toprak üstü	(Akan ve Ayaz, 2016)
20.	*Silene supina* M. Bieb.	Fırat nakılı	–	–	Toprak üstü	(Chandra ve Rawat, 2015)
21.	*Silene swertiifolia* Boiss.	Bozkır nakılı	Yabani kereviz	İran-Turan	Toprak üstü	(Kargıoğlu, 2008)
22.	*Silene italica* (L.) Pers.	Yuğuşyüreği	–	–	Tohum	(Chandra ve Rawat, 2015)
23.	*Silene pendula* L.	Nakıl	–	Akdeniz	Çiçekli dal, Yaprak, Kök	(Baytop, 1999)
24.	*Silene viridiflora* L.	Dilli nakıl	–	–	Toprak üstü	(Chandra ve Rawat, 2015)
25.	*Silene vulgaris* var. *commutata* (Guss.) Coode & Cullen	Cırvınık	–	–	Yaprak	(Doğan, 2014)
26.	*Silene vulgaris* var. *macrocarpa* (Turril) Coode & Culen	Gıcırık	–	–	Yaprak	(Kurt ve ark., 2018)
27.	*Silene vulgaris* (Moench) Garcke	Ecibücü	Has Pancarı	–	Yaprak	(Korkmaz ve Alpaslan, 2014)

Çizelge 2. Belirlenen *Silene* türlerinin etnobotanik kullanım özellikleri

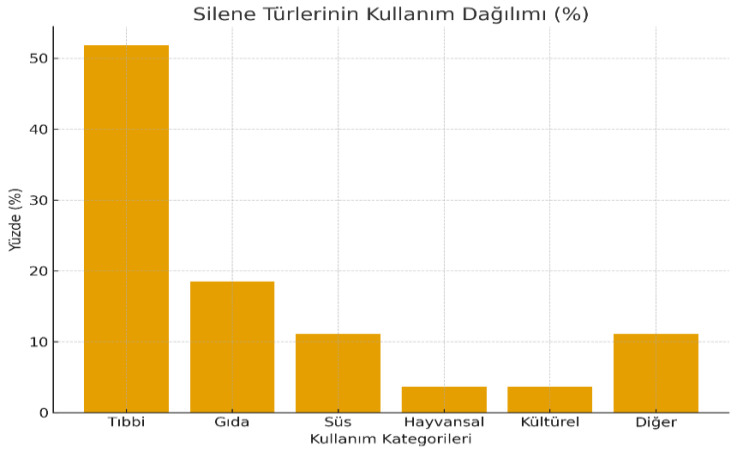
Tür	Kullanılan Kısım	Tıbbı	Gıda	Süs	Hayvan Yemi	Kültürel/ Ritüel	Diğer
Silene acaulis (L.) Jacq. var. *acaulis*	Çiçek			+			
Silene latifolia subsp. *eriocalycinae* (Boiss.) Greuter & Burdet	Yaprak	+					
Silene brevicaulis Boiss.	Çiçek		+				
Silene caryophylloides subsp. *echinus* (Boiss. & Heldr.) Coode & Cullen	Toprak Üstü				+		
Silene colorata Poir. subsp. *colorata*	Toprak Üstü	+	+	+			
Silene compacta Fish. ex Hornem.	Yaprak	+	+	+			
Silene conica L.	Toprak Üstü		+				
Silene confertiflora Chowdhuri	Yaprak		+				
Silene conoidea L.	Bitkinin Tamamı	+	+			+	
Silene dichotoma Ehrh. subsp. *dichotoma* Ehrh.	Toprak Üstü	+					
Silene laxa Boiss. & Kotschy	Toprak Üstü			+		+	

Silene longipetala Vent.	Toprak Üstü					+	
Silene monerantha F.N. Williams	Yaprak						+
Silene odontopetala Fenzl	Toprak Üstü						+
Silene pendula L.	Kök	+					
Silene saxatilis Sims	Yaprak	+	+				
Silene stenobotrys Boiss. & Hausskn.	Toprak Üstü						+
Silene subconica Friv.	Toprak Üstü		+				
Silene swertiifolia Boiss.	Toprak Üstü			+			
Silene fortunei Vis	Kök	+					
Silene supina M. Bieb.	Toprak Üstü	+					
Silene chlorifolia Sm.	Toprak Üstü	+					
Silene italica (L.) Pers.	Tohum	+					
Silene viridiflora L.	Toprak Üstü	+					
Silene vulgaris var. *commutata* (Guss.) Coode et Cullen	Yaprak	+					
Silene vulgaris var. *macrocarpa* (Turril) Coode & Cullen	Yaprak		+				
Silene vulgaris (Moench) Garcke	Yaprak	+	+				

4. GENEL DEĞERLENDİRME VE SONUÇLAR

Bu çalışma, Türkiye'de yayılış gösteren *Silene* (Cayophyllaceae) türlerinin etnobotanik kullanım özelliklerini ortaya koymak amacıyla yapılmıştır. Çalışma sonucu 27 *Silene* türünün farklı amaçlarla kullanıldığı ortaya çıkarmıştır.

Bu *Silene* türlerinden %51,85'inin (14 tür) halk hekimliğinde çeşitli rahatsızlıkların tedavisinde tıbbi amaçla kullanıldığı belirlenmiştir. Bu türlerden %18,52'i (5 tür) gıda amaçlı kullanılmaktadır. Süs bitkisi olarak kullanım oranı %11,11 (3 tür)'dir. Hayvansal kullanım oranı %3,70 (1 tür) olup, bu kategori çoğunlukla hayvan yemi veya hayvan sağlığı ile ilgili geleneksel uygulamalar şeklindedir. Kültürel kullanım oranı %3,70 (1 tür) olup, bu tür özellikle ritüel, inanç veya yöresel pratiklerde kullanılmaktadır. Son olarak, %11,11 oranında (3 tür) diğer kategorisinde olup sabun yapımında veya temizlik maddesi olarak kullanılmaktadır (Görsel 1).



Görsel 1. Silene türlerinin etnobotanik kullanım amaçları

Çalışmada etnobotanik kullanımları belirlenen türlerden 14'ünün tıbbi amaçlarla kullanıldığı belirlenmiştir. Bu yüksek oran, *Silene* türlerinin halk hekimliğinde yaygın olarak tercih edildiğini ve özellikle idrar yolu rahatsızlıkları, iltihap giderme, yara iyileştirme gibi tıbbi amaçlarla başvurulan bitkiler arasında yer almaktadır. Tıbbi amaçla kullanıldığı belirlenen bu türler; *Silene latifolia* subsp. *eriocalycinae*, *Silene colorata* subsp. *colorata*, *Silene compacta*, *Silene conoidea*, *Silene dichotoma* subsp. *dichotoma*, *Silene pendula*, *Silene saxatilis*, *Silene serveti*, *Silene supina*, *Silene chlorifolia*, *Silene italica*, *Silene viridiflora*, *Silene vulgaris* var. *commutata*, *Silene vulgaris*'dir (Çizelge 1, 2). *Silene vulgaris*'in halk hekimliğinde özellikle idrar söktürücü ve iltihap giderici özellikleri nedeniyle yaygın olarak kullanılması, bu cinsin tıbbi açıdan Anadolu florasında önemli bir yere sahip olduğunu desteklemekte ve çalışmada ortaya konan yüksek tıbbi kullanım oranını açıklayıcı nitelik taşımaktadır. Çalışma *Silene* üyelerinin Anadolu'da önemli bir kültürel, tıbbi ve ekonomik değere sahip olduğunu göstermektedir.

Çalışmada 10 türün gıda amaçlı kullanıldığı belirlenmiştir. *Silene saxatilis* Sims ve *Silene vulgaris* var. *vulgaris* taksonlarının yaygın gıda kullanımı, bu türlerin yerel gastronomide köklü bir geçmişe sahip olduğunu düşündürmektedir. Ayrıca: *Silene brevicauli*, *Silene colorata* subsp.

colorata, Silene compacta, Silene conica, Silene confertiflora, Silene conoidea, Silene subconica, Silene vulgaris var. macrocarpa türleri gıda kullanımında ön plana çıkmaktadır (Çizelge 2). Bu durum, *Silene* türlerinin özellikle kırsal bölgelerde geleneksel beslenme kültürünün önemli bir parçası olduğunu ortaya koymaktadır. Genç sürgünlerin haşlanarak sebze yemeği şeklinde tüketilmesi, börek içi olarak kullanılması veya kavrulup saklanması, bu türlerin halk mutfağındaki pratik ve besleyici rolünü göstermektedir. *Silene* türlerinin lif, mineral ve biyoaktif bileşikler bakımından zengin olması, geleneksel tüketim alışkanlıklarının besleyici bir temele dayandığını göstermektedir.

Çalışmada beş türün süs bitkisi olarak kullanıldığı belirlenmiştir. Bu türler; *Silene acaulis* var. acaulis, *Silene swertiifolia, Silene laxa, Silene colorata* subsp. colorata ve *Silene compacta*'dır (Çizelge 2). Renkli çiçek yapıları, kompakt gelişim formları ve bahçe düzenlemelerine uygun morfolojik özellikleri sayesinde *Silene acaulis* var. acaulis, *Silene swertiifolia* ve *Silene laxa* gibi türler peyzaj düzenlemelerinde tercih edilmektedir. Özellikle *Silene colorata* subsp. colorata ve *Silene compacta*'nın hem süs, hem tıbbi hem de gıda amaçlı kullanılabilmesi, bu türlerin çok yönlü etnobotanik ve kültürel değer taşıdığını göstermektedir. *Silene* türleri yalnızca tıbbi ve gıda olarak değil, aynı zamanda estetik açıdan da önem taşımaktadır.

Çalışmada üç türün kültürel ve ritüel amaçlarla kullanıldığı belirlenmiştir. Bunlar *Silene conoidea, Silene laxa* ve *Silene longipetala*'dır (Çizelge 2). Bu türlerin kültürel amaçlarla kullanılması, *Silene* türlerinin yalnızca biyolojik yönüyle değil, aynı zamanda halkın geleneksel ritüelleri ve inanç sistemleri içinde de özel bir yere sahip olduğunu göstermektedir. *Silene conoidea, Silene laxa* ve *Silene longipetala*'nın bazı yörelerde ritüel amaçlı, sembolik anlam yüklenerek veya özel törenlerde kullanılması, bitkinin antropolojik açıdan taşıdığını ortaya koymaktadır.

Çalışmada yalnızca bir türün (*Silene caryophylloides* subsp. echinus) hayvan yemi olarak hayvancılıkta değerlendirildiği belirlenmiştir (Çizelge 2). Her ne kadar sayı düşük görünse de, bu kullanım *Silene* cinsinin otlatma alanlarında hayvan beslenmesine katkı sağlayan bir bitki olduğunu göstermektedir. Bu türle birlikte arazi gözlemlerimize göre çok sayıda *Silene* türünün otçul hayvanlar tarafından tüketilmesi, türün besleyici bileşenlerce zengin olabileceğini düşündürmektedir. Bununla birlikte, türlerin hayvan yemi olarak kullanımı ile ilgili bulguların sınırlı olması, bu konuda daha fazla araştırmaya ihtiyaç duyulduğunu göstermektedir.

Silene monerantha, Silene odontopetala ve Silene stenobotrys olmak üzere üç türün "diğer kullanım" kategorisinde yer aldığı belirlenmiştir. Örneğin *Silene monerantha* süs eşyası yapımında kullanılırken *Silene odontopetala ve Silene stenobotrys* sabun yapımı ve temizlik amacıyla kullanılmaktadır (Çizelge 2).

Yapılan çalışmada iki türün; *Silene brevicaulis* ve *Silene caryophylloides* subsp. *echinus* endemik olduğu belirlenmiştir. Altı tür (*Silene brevicaulis, Silene chlorifolia, Silene laxa, Silene monerantha, Silene stenobotrys, Silene swertiifolia*) İran-Turan elementi, iki tür (*Silene caryophylloides* subsp. *echinus, Silene confertiflora)* D. Akdeniz, iki tür ise (*Silene colorata* Poir. subsp. *colorata, Silene pendula)* Akdeniz Elementi olarak belirlenmiştir (Çizelge 1).

Taranan literatürde Chandra ve Rawat (2015) tarafından gerçekleştirilen derleme çalışmasında, Caryophyllaceae familyasına ait *Silene* cinsi üyelerinin etnobotanik açıdan önemli olduğu vurgulanmış ve toplam beş *Silene* türünün (*Silene chlorifolia, Silene fortunei, Silene supina, Silene italica, Silene viridiflora*) geleneksel kullanım özellikleri literatür verileri ışığında ele alınmıştır.

Sonuç olarak, Türkiye'de yetişen *Silene* taksonlarının çok yönlü kullanım geçmişine sahip olduğu, halk hekimliği ve gıda başta olmak üzere çeşitli alanlarda etnobotanik ve kültürel bir değer taşıdığı belirlenmiştir. Elde edilen veriler, hem bitkilerle ilgili geleneksel bilginin korunmasına hem de ileride yapılacak bilimsel araştırmalara temel oluşturacak niteliktedir. Ayrıca, bazı taksonların endemik oluşu, sürdürülebilir kullanım ve koruma çalışmalarının önemini artırmaktadır.

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DETERMINING THE LEVEL OF TRADITIONAL MEDICINAL PLANTS USE AMONG UNIVERSITY STUDENTS

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ABSTRACT

Plants have been widely used by humankind for therapeutic purposes since ancient times. Written evidence of the medicinal use of plants dates back 5,000 years. It is reported that there are approximately half a million plant species in the world, and about 20,000 of them are used for ethnobotanical purposes. Turkey possesses a richer flora than all its neighboring countries and European nations. A total of 12,476 plant taxa grow in Turkey, 3,963 of which are endemic. It is reported that approximately 2,500 natural plant species grow in Erzincan, and about 450 of these are endemic. Several studies have been conducted to reveal the ethnobotanical characteristics and medicinal uses of plants growing around Erzincan. These studies demonstrate that the local population continues to widely utilize natural plants for medicinal and other traditional purposes. In Turkey, very few studies have been conducted to determine university students' approaches to traditional plant use. This research was carried out at Erzincan Binali Yıldırım University in 2024-2025 to determine university students' approaches to and characteristics of traditional plant use for medicinal purposes. The study was conducted in the form of a survey with the voluntary participation of 140 students studying in different departments of the university. According to the study results, the vast majority of participants are women in the 18-23 age group. The majority of the students' families use traditional medicinal plants. The most commonly used plants by families are Mint, Thyme, Linden, Chamomile, and Sage, respectively. Plants are mostly obtained from nature, gardens, and herbalists. A significant portion of the participants prefer traditional medicinal plants alongside modern medical drugs. The plants most frequently used by the students themselves are Chamomile, Linden, Mint, Thyme, and Ginger, respectively. The most common methods of preparation are infusion (brewing) and decoction (boiling). The vast majority of survey participants did not encounter any side effects after using traditional medicinal plants.

Key Words: EBYU, Traditional Use, University Students, Medicinal Plants.

ÜNİVERSİTE ÖĞRENCİLERİNİN GELENEKSEL TIBBİ BİTKİ KULLANIM DÜZEYLERİNİN BELİRLENMESİ

ÖZET

Bitkiler insanoğlu tarafından çok eski çağlardan beri tedavi amacıyla yaygın olarak kullanılmaktadır. Bitkilerin tıbbi amaçla kullanımlarına dair yazılı kanıtlar 5000 yıl öncesine kadar uzanmaktadır. Dünyada yarım milyon civarı bitki türü bulunduğu ve bunlardan yaklaşık 20.000 bitkinin etnobotanik amaçlarla kullanıldığı bildirilmektedir. Türkiye komşusu olan tüm ülkelerden ve Avrupa ülkelerinden daha zengin bir floraya sahiptir. Türkiye'de 3.963'ü endemik toplam 12.476 bitki taksonu yetişmektedir. Erzincan'da yaklaşık 2500 doğal bitki türünün yetiştiği ve bunlardan 450 kadarının endemik olduğu bildirilmektedir. Erzincan çevresinde yetişen bitkilerin etnobotanik özelliklerinin ve tıbbi kullanımlarının ortaya konulması amacıyla bazı çalışmalar yapılmıştır. Bu çalışmalar yöre halkının doğal bitkilerden tıbbi ve diğer amaçlarla geleneksel olarak yararlanmaya yaygın şekilde devam ettiğini ortaya koymaktadır. Türkiye'de üniversite öğrencilerinin geleneksel bitki kullanımına yaklaşımlarının belirlenmesi amacıyla çok az çalışma yapılmıştır. Bu araştırma, Üniversite öğrencilerinin tıbbi amaçlar için geleneksel bitki kullanımına yaklaşımlarını ve kullanım özelliklerini belirlemek amacıyla Erzincan Binali Yıldırım Üniversitesi'nde 2024-2025 yıllarında gerçekleştirilmiştir. Çalışma kapsamında üniversitenin farklı bölümlerinde okuyan 140 öğrencinin gönüllü katılımı ile anket uygulaması şeklinde gerçekleştirilmiştir. Çalışma sonuçlarına göre katılımcıların büyük çoğunluğu 18-23 yaş aralığında kadınlardan oluşmaktadır. Öğrencilerin ailelerinin büyük çoğunluğu geleneksel tıbbi bitki kullanmaktadır. En çok kullanılan bitkiler sırasıyla Nane, Kekik, Ihlamur, Papatya ve Adaçayı'dır. Bitkiler çoğunlukla doğadan, bahçelerden, aktarlardan temin edilmektedir. Katılımcıların önemli bir kısmı modern tıp ilaçları ile birlikte geleneksel tıbbi bitkileri de tercih etmektedir. Öğrencilerin en çok kullandığı bitkiler ise sırasıyla Papatya, Ihlamur, Nane, Kekik, Zencefil'dir. En çok kullanılan yöntem demleme ve kaynatmadır. Ankete katılanların büyük çoğunluğu geleneksel tıbbi bitki kullanımı sonrasında herhangi bir yan etki ile karşılaşmamıştır.

Anahtar Kelimeler: EBYÜ, Geleneksel kullanım, Üniversite öğrencileri, Tıbbi bitkiler.

1. GİRİŞ

Bitkilerin insanoğlu tarafından çok eski çağlardan bu yana tedavi amacıyla kullanıldığı bilinmektedir. Hatta bazı kaynaklar, bitkilerin ilaç olarak kullanımının neandertal döneme kadar uzandığına işaret etmektedir (Akbulut, 2025). Bitkilerin tıbbi amaçla kullanımlarına dair yazılı kanıtlar 5000 yıl öncesine kadar uzandığı bildirilmektedir. Dünyada yarım milyon civarı bitki türü bulunduğu ve bunların büyük bir çoğunluğunun henüz araştırılmadığı ancak önemli bir kısmının tıbbi potansiyele sahip olabileceği bildirilmektedir (Akbulut, 2025, Ertuğ, 2014). Dünyada yaklaşık 20.000 bitkinin farklı etnobotanik amaçlarla kullanıldığı bildirilmiştir

(Baytop, 1999). Dünya Sağlık Örgütü (DSÖ) 2000 yılındaki Avrupa, Avustralya ve Kuzey Amerika'da yaşayan insanların yaklaşık yarısının alternatif tedavi yöntemlerini kullandıklarını bildirmiş ve bu yöntemlerden en yaygın kullanılanların bitkisel ilaçlar olduğunu rapor etmiştir. Ancak tıbbi amaçla bitkilerin veya bitkisel ürünlerin modern tıbbi ilaçlarla birlikte kullanımı ciddi sağlık sorunları oluşturabilmektedir (Kaner vd., 2017; Gürün, 2004).

Türkiye komşusu olan tüm ülkelerden ve Avrupa'daki her bir ülkeden daha zengin bir Floraya sahiptir. Son kayıtlar Türkiye Florasında 3.963'ü endemik toplam 12.476 bitki taksonun yetiştiğini göstermektedir. Erzincan'da yetişen endemik takson olduğu belirtilmektedir. Yapılan son çalışmalardan Erzincan'daki toplam endemik takson sayısının 437'ye ulaştığı anlaşılmaktadır. Bu bitkilerden 60'a yakını Dünyada sadece Erzincan'da yetişmektedir (Korkmaz ve Onkaş, 2024).

Toplam 11.903 km^2 yüzölçümü bulunan Erzincan'da karasal iklim görülmesine karşın bölge illerine kıyasla daha ılıman bir iklime sahiptir. Yıllık sıcaklık ortalamaları 16,6 C^o'dir. En soğuk ayın Ocak (ortalama sıcaklık -3,7 C^o), en sıcak ayın Ağustos (ortalama sıcaklık (23,9 C^0) olduğu bildirilmektedir. İl, Karadeniz Bölgesi, İç Anadolu Bölgesi ve Doğu Anadolu Bölgesi'nin kesiştiği noktada yer almaktadır. Bu durum, ilin farklı iklim ve bitki türlerine ev sahipliği yapmasına imkân tanımaktadır. Erzincan'ın bitki zenginliği, ilin coğrafi konumu, topografyası ve iklim koşullarından kaynaklanmaktadır. Yapılan bir çalışmada ilde en az 125 odunsu bitki taksonunun yetiştiği bildirilmiştir (Korkmaz ve Aslan, 2024). Erzincan çevresinde yetişen bitkilerin etnobotanik kullanımları ve tıbbi bitki zenginliğinin ortaya konulması amacıyla çok sayıda çalışma yapılmıştır. Bu çalışmalara (Korkmaz, Alpaslan, Turgut, İlhan, 2014; Korkmaz ve Karakuş, 2015; Korkmaz, Karakuş ve Selvi, 2016; Korkmaz, 2024; Gözcü, Korkmaz, Çorlu, Tuysuz, 2024) örnek verilebilir. Yapılan çalışmalar yöre halkının doğal bitkilerden tıbbi ve diğer amaçlarla yararlanmaya yaygın şekilde devam ettiğini ortaya koymaktadır.

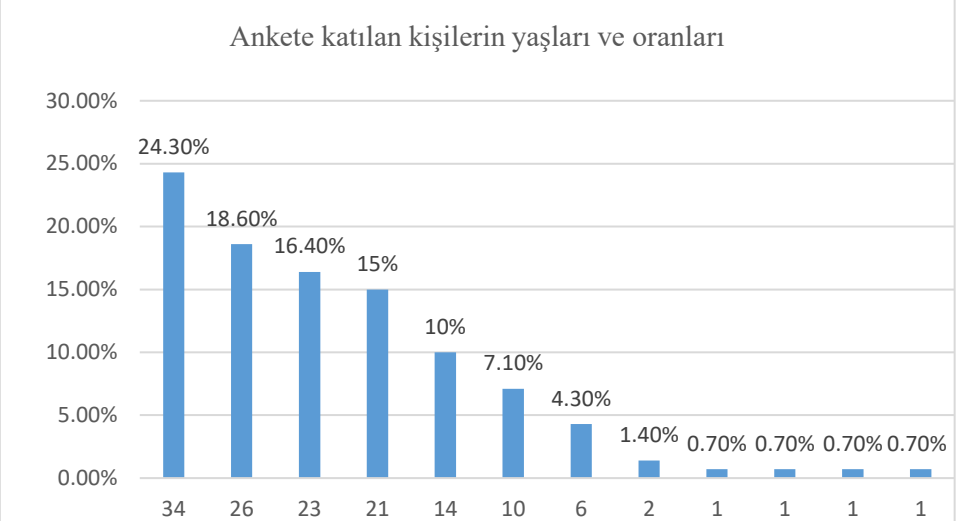
Türkiye'de üniversite öğrencilerinin geleneksel bitki kullanımına yaklaşımlarının belirlenmesi amacıyla çok az çalışmaya (Sucaklı vd., 2014; Demirçivi ve Altaş, 2016; Kaner vd., 2017; Şahin vd., 2019; Aygör ve Çayır, 2020; Değirmenci vd., 2024) rastlanmıştır. Bu çalışmalardan Kaner vd. (2017) tarafından Kayseri ilindeki üniversite öğrencileri ve aileleri üzerinde yapılan araştırma kapsam bakımından çalışmamıza en yakın araştırmadır. Erzincan'da gerçekleştirilen bu araştırma Doğu Anadolu bölgesinde de ilk çalışmadır.

2. MATERYAL VE YÖNTEM

Bu araştırma, Üniversite öğrencilerinin tıbbi amaçlar için geleneksel bitki kullanımına yaklaşımlarını ve kullanım özelliklerini belirlemek amacıyla gerçekleştirilmiştir. Çalışma 2024-2025 yıllarında Erzincan Binali Yıldırım Üniversitesi'nde farklı bölümlerde okuyan ve rastgele seçilen 140 öğrencinin gönüllü katılımı ile gerçekleştirilmiştir. Görüşmeler yüz yüze yapılmış ve daha önceden hazırlanmış anket formlarının doldurulması şeklinde gerçekleştirilmiştir. Görüşmeye başlamadan önce öğrencilere çalışmanın amacı ve içeriği hakkında bilgi verilmiştir. Ankette öğrencilere 25 adet soru yöneltilmiştir. Bu sorular kişisel bilgiler, eğitim ve memnuniyet, öğrencilerin ve ailelerinin gelir durumu, geleneksel tıbbi bitki kullanım özellikleri bölümlerinden oluşmaktadır.

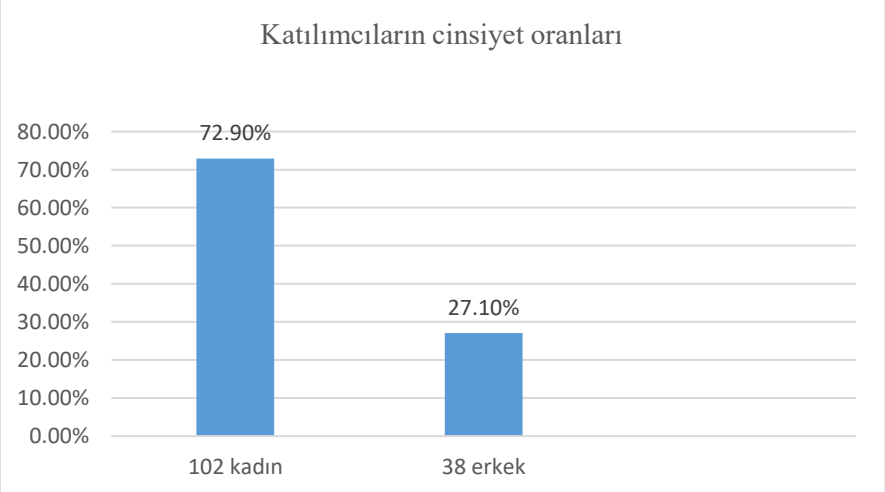
3. BULGULAR VE TARTIŞMA

Erzincan Binali Yıldırım Üniversitesi öğrencilerine uygulanan bu anket sonuçlarına göre katılımcıların 34'ü (% 24,3) 21 yaşında, 26'sı (% 18,6) 22 yaşında, 23'ü (% 16,4) 20 yaşında, 21'i (% 15) 23 yaşında, 14'ü (% 10) 19 yaşında, 10'u (% 7,1) 18 yaşında, 6'sı (% 4,3) 24 yaşında, 2'si (% 1,4) 27 yaşında, 1'er kişi (% 0,7) 17, 25, 26 ve 42 yaşındadır (Görsel 1). Katılımcıların büyük çoğunluğu 128 kişi (% 82,8) 18-23 yaş aralığındadır Ankete en fazla katılımı 21 yaşındaki 34 öğrenci (% 24,3) sağlamıştır.



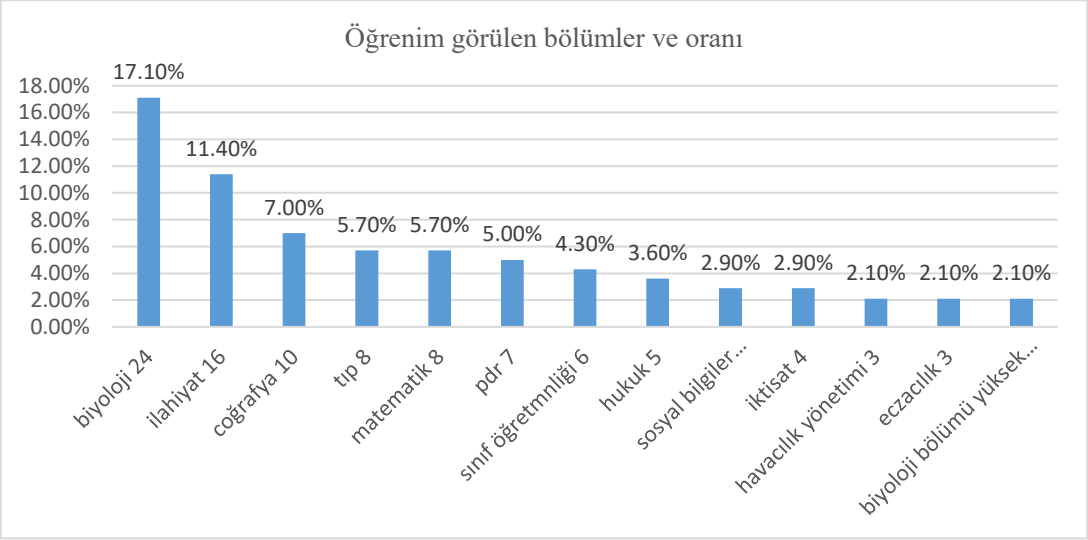
Görsel 1. Ankete katılan kişilerin yaş aralıkları

Anket sonuçlarına göre katılımcılardan 102 kişi (%72,9) kadınlardan oluşurken, 38 kişi (%27,1) erkeklerden oluşmaktadır (Görsel 2). Ankete katılanların büyük çoğunluğu 102 kişi ile (%72,9) kadınlardan oluştuğu görülmüştür. Kadın katılımcıların oranı erkek katılımcıların oranının yaklaşık 2,7 katıdır



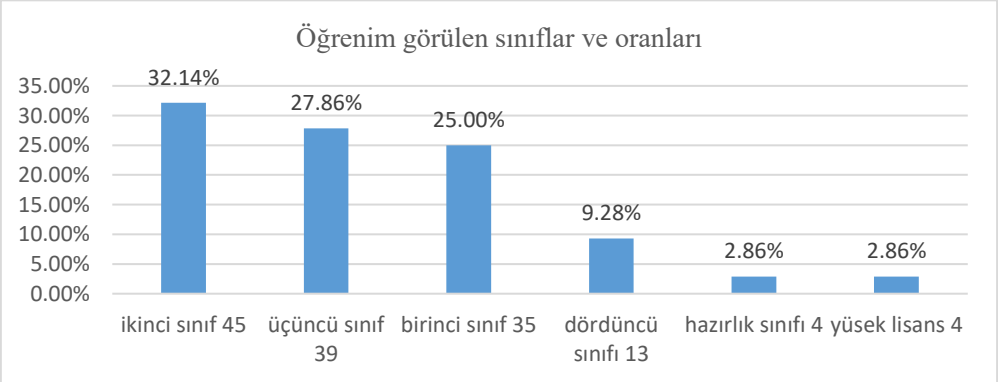
Görsel 2. Ankete katılan kişilerin cinsiyete göre dağılımları

Katılımcılardan 24 kişi (% 17,1) Biyoloji, 16 kişi (% 11,4) İlahiyat, 10 kişi (% 7,1) Coğrafya, 8'er kişi (% 5,7) Tıp ve Matematik, 7 kişi (% 5,0) PDR, 6 kişi (% 4,3) Sınıf Öğretmenliği, 5 kişi (% 3,6) Hukuk, 4'er kişi (% 2,9) Sosyal Bilgiler Öğretmenliği ve İktisat, 3'er kişi (% 2,1) Havacılık Yönetimi ve Eczacılık, Biyoloji bölümü Yüksek Lisans, 2'şer kişi (% 1,4) İlköğretim Matematik Öğretmenliği, Bilgisayar Mühendisliği, Hemşirelik, Resim Bölümü, Sosyal hizmetler, Okul Öncesi Öğretmenliği, Resim İş Öğretmenliği, Uçak Teknolojisi ve Türkçe Öğretmenliği 1'er kişi (% 0,7) Finans ve Bankacılık, Tarih, Siyaset Bilimi, Lojistik, Sosyal Bilgiler Yüksek Lisans, Mimarlık ve Şehir Planlama, Uçak bakım ve onarımı, Evde Hasta Bakımı, Eczane hizmeti, Bilgisayar programcılığı, İngilizce Mütercim ve Tercümanlık, Türk Dili ve Edebiyatı, Diş Hekimliği, İşletme ve müzik öğretmenliği bölümleridir (Görsel 3). En çok katılımcıların sırasıyla Biyoloji 24 kişi (% 17,1), İlahiyat 16 kişi (% 11,4) ve Coğrafya 10 kişi (% 7,1) bölümlerinden olduğu görülmüştür. Bu bölümlerden katılımcıların oranı yaklaşık % 36'dır.



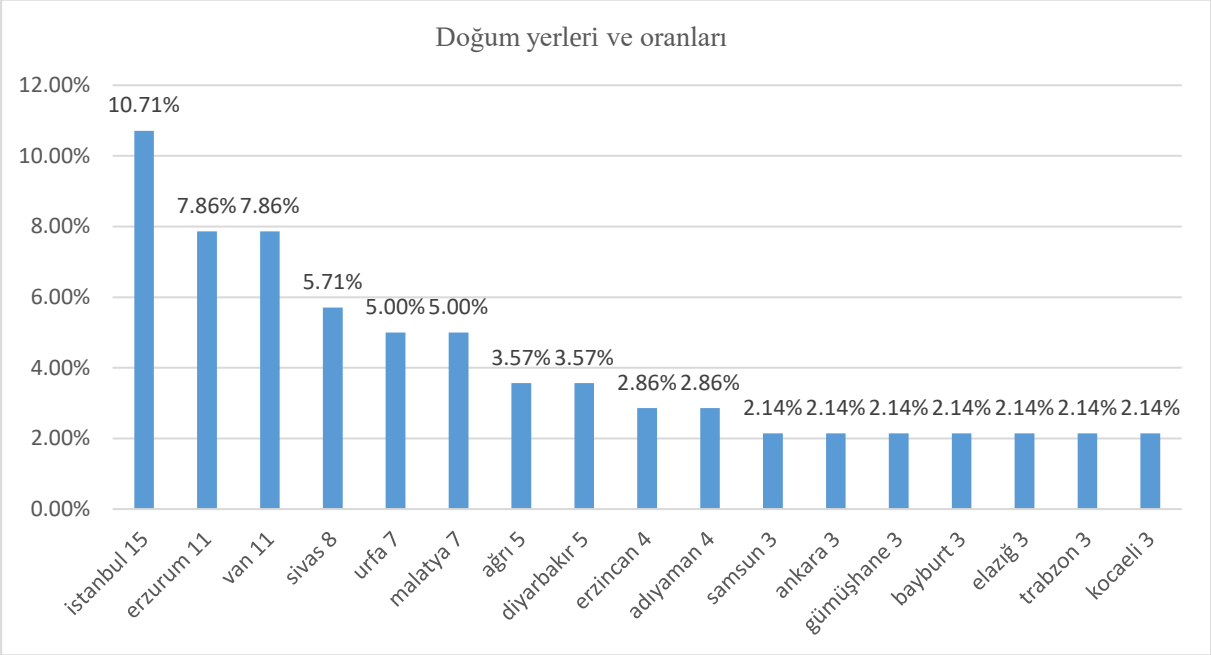
Görsel 3. Ankete katılan kişilerin öğrenim gördüğü bölümler

Katılımcılardan 45 kişi (% 32,14) ikinci sınıf, 39 kişi (% 27,86) üçüncü sınıf, 35 kişi (% 25.00) birinci sınıf, 13 kişi (% 9,28) dördüncü sınıf, 4 kişi (%2,86) hazırlık sınıfı öğrencileridir. Ayrıca katılımcılardan 4 kişi (%2,86) Yüksek lisans öğrencileridir (Görsel 4). Ankete en fazla katılımı 45 kişi (% 32,14) ile ikinci sınıf ve 39 kişi (% 27,86) ile üçüncü sınıf öğrencileri sağlamıştır.



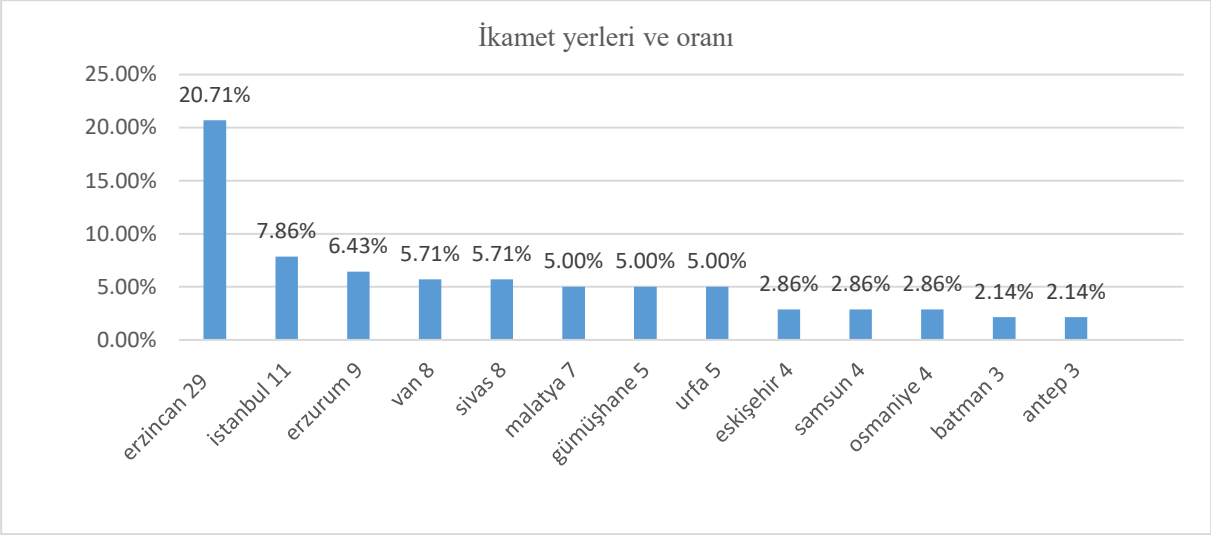
Görsel 4. Ankete katılan kişilerin öğrenim gördüğü sınıflar

Katılımcılardan 15 kişi (%10,71) İstanbul, 11'er kişi (%7,86) Erzurum ve Van, 8 kişi (%5,71) Sivas, 7'şer kişi (%5,00) Urfa ve Malatya, 5'er kişi (%3,57) Ağrı ve Diyarbakır, 4'er kişi (%2,86) Erzincan ve Adıyaman, 3'er kişi (%2,14) Samsun, Ankara, Gümüşhane, Bayburt, Elazığ ve Trabzon ve Kocaeli, 2'şer kişi (%1,43) Adana, Bursa, Mersin, Ardahan, Kayseri, Maraş Tokat ve Kars, 1'er kişi (%0,71) Eskişehir, Hatay, Şırnak, Giresun, Batman, Siirt, Isparta, Kırklareli (Lüleburgaz), İzmir, Bitlis (Hizan), Konya, Bingöl ve Muş doğumludurlar. İlaveten katılımcılardan 1 kişi (%0,71) Almanya doğumludur (Görsel 5). Ankete katılan öğrenciler 38 farklı ilde doğmuştur. 15 öğrencinin (%10,71) doğum yeri olan İstanbul en büyük il olup, onu 11'er kişi (%7,86) ile Erzurum ve Van, 8 kişi (%5,71) Sivas takip etmiştir. Bu dört ilde doğan öğrencilerin oranı % 32 civarındadır.



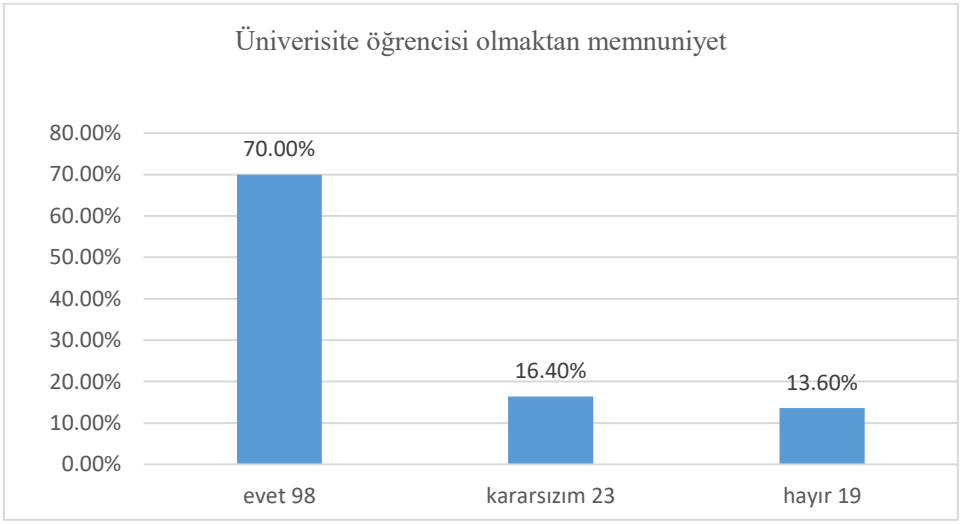
Görsel 5. Ankete katılan kişilerin doğum yerleri

Katılımcılardan 29 kişi (% 20,71) Erzincan, 11 kişi (% 7,86) İstanbul, 9 kişi (% 6,43) Erzurum, 8 kişi (% 5,71) Van ve Sivas, 7 kişi (% 5) Malatya, 5'er kişi (% 3,57) Gümüşhane ve Urfa, 4'er kişi (%2,86) Eskişehir, Samsun ve Osmaniye, 3 kişi (% 2,14) Batman ve Gaziantep, 2'şer kişi (%1,43) Tokat, Siirt, Elazığ, Bursa, Giresun, Mersin, Diyarbakır, Ardahan, Antalya, Bingöl, Ankara, Adana, Gaziantep ve Kocaeli, 1'er kişi (% 0,71), Amasya, Kayseri, Maraş, Bitlis, Iğdır, Muğla, Ağrı (Patnos), Şırnak, Muş illerinde ikamet etmektedir. Katılımcılardan bir kişi ikametini belirtmemiştir (Görsel 6). Katılımcıların İkamet ettiği iller arasında Erzincan 29 kişi (% 20,71) ile birinci, İstanbul 11 kişi (% 7,86) ikinci ve Erzurum 9 kişi (% 6,43) ile üçüncü il olmuştur.



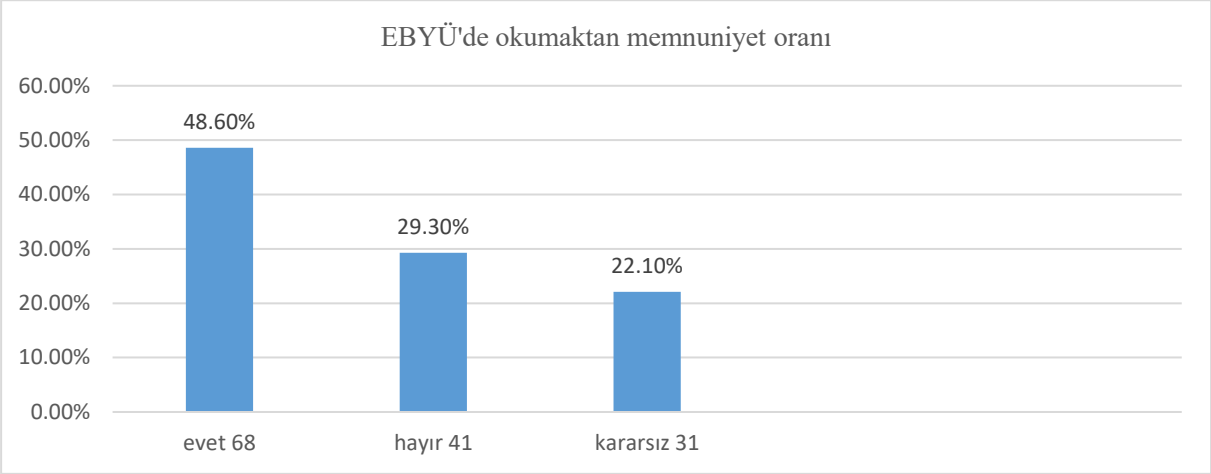
Görsel 6. Katılımcıların ikamet yerleri

Üniversite öğrencisi olmaktan memnuniyet sorusuna, katılımcılardan 98 kişi (% 70) evet, 23 kişi (% 16,4) kararsızım, 19 kişi (% 13,6) hayır cevabını vermiştir (Görsel 7). Katılımcılardan 98 kişi (% 70)'nin üniversite öğrencisi olmaktan memnun olduğu, 19 kişi (% 13,6)'nin ise memnun olmadığı görülmüştür.



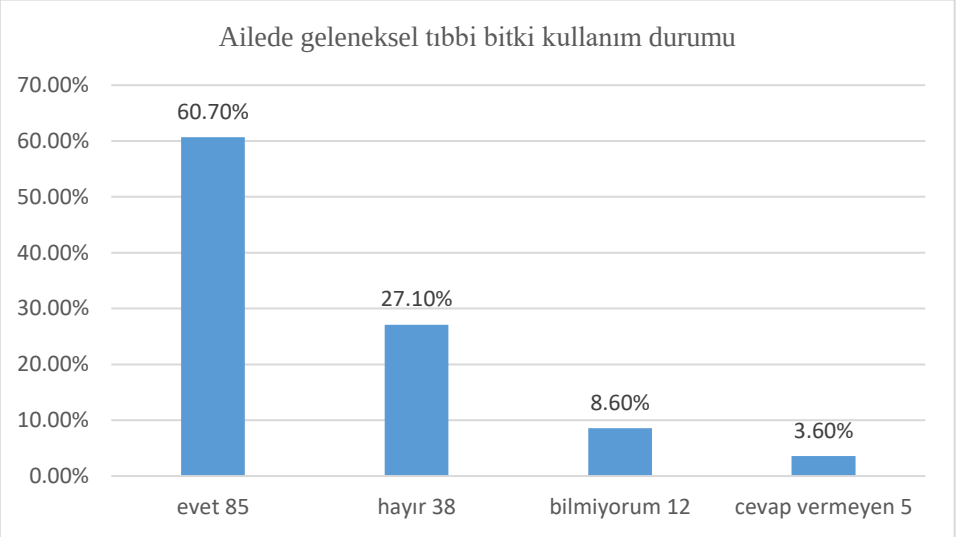
Görsel 7 üniversite öğrencisi olmaktan memnuniyet durumları

Katılımcıların Erzincan Binali Yıldırım Üniversitesinde okumaktan memnun musunuz? sorusuna 68 kişi (%48,6) evet cevabını, 41 kişi(%29,3)'ü hayır cevabını vermiştir. Kararsızlar ise 31 kişi (%22,1)'dir (Görsel 8). Ankete katılanların yaklaşık yarısı (68 kişi, % 48,6)'nın Erzincan Binali Yıldırım Üniversitesi'nde okumaktan memnun olduğu, 41 kişi % 29,3)'nin ise memnun olmadığı görülmüştür.



Görsel 8 Erzincan Binali Yıldırım Üniversitesinde okumaktan memnuniyet durumu

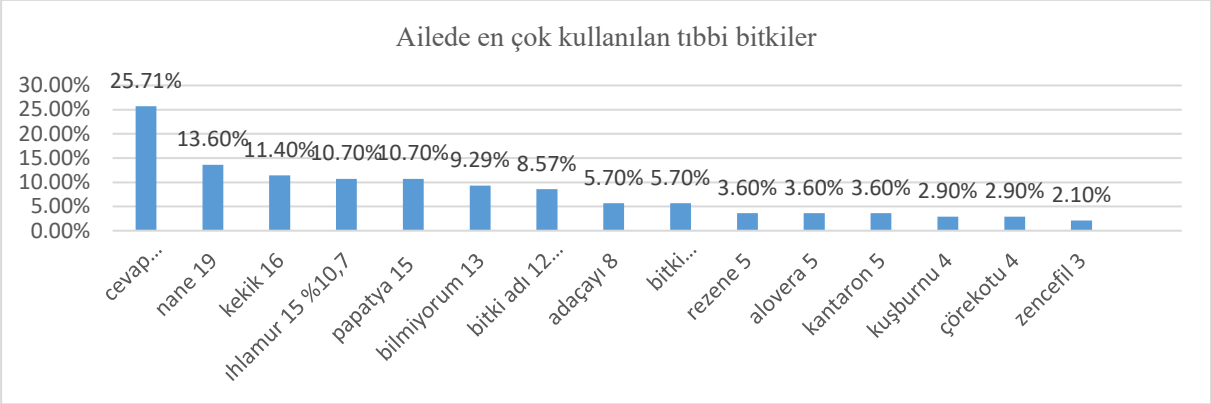
Aileniz geleneksel tıbbi bitki kullanır mı? Sorusuna katılımcılardan 85 kişi (% 60,7) evet derken, 38 kişi (%27,1) hayır cevabını vermiştir. Bilmiyorum diyenler 12 kişi (% 8,6), cevap vermeyenler ise 5 kişi (%3,6)'dir (Görsel 9). Ankete katılanların ailelerinin büyük çoğunluğu (85 kişi, % 60,7) geleneksel tıbbi bitki kullanmaktadır.



Görsel 9. Ailede geleneksel tıbbi bitki kullanımı

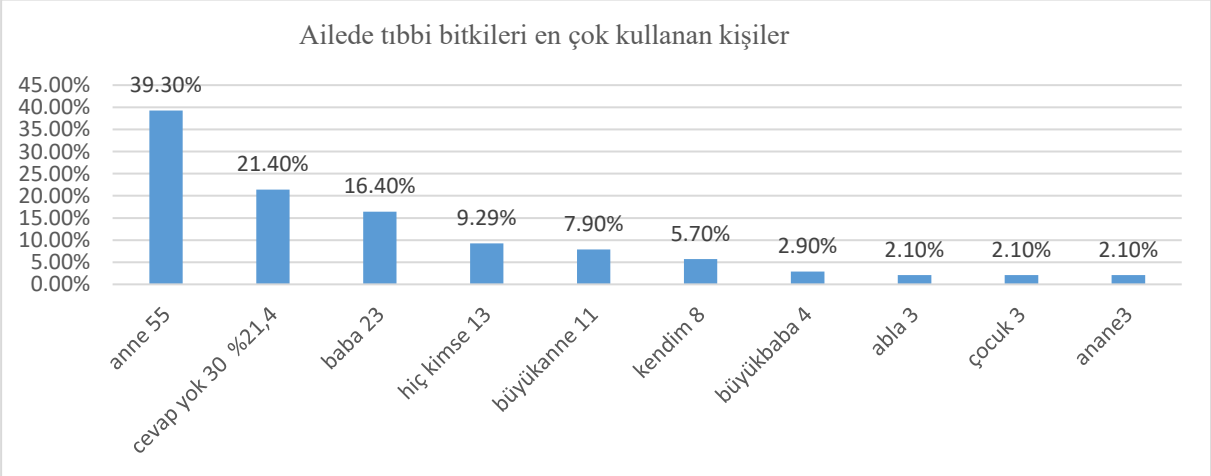
Aileniz hangi bitkileri kullanırlar? Sorusuna, 36 kişi (% 25,71) cevap vermemiş, 19 kişi (% 13,6) Nane, 16 kişi (% 11,4) Kekik, 15 kişi (% 10,7) Ihlamur, 15 kişi (% 10,7) Papatya, 13 kişi (%9,29) bilmiyorum, 12 kişi (%8,57) bitki adı vermemiş ama kullanım amacı belirtmiş, 8 kişi (% 5,7) Adaçayı, 8 kişi (%5,7) Bitki kullanmıyor, 5'er kişi (%3,6) Rezene, Alovera, Kantaron, 4 kişi (%2,9) Kuşburnu, Çörekotu, 3 kişi (%2,1) Zencefil, 2'şer kişi (%1,4) Biberiye, Zeytinyağı, Kış çayı, Kuzukulağı, Sığır Kuyruğu Mantarı, Hibiskus, Isırgan, 1'er kişi (% 0,7) Yeşil Soğan, Karahindiba, Balmumu, Amla yağı, Karanfil suyu, Hint yağı, Ceviz ağacı yaprağı, Kaktüs, Defneyaprağı, Kaysı, Ceviz yağı, Sarımsak, Keçiboynuzu, Çiçek, Andıran otu, Anason, Mesir macunu, Haşhaş tohumu, Kimyon, Soğan, Karaçalı kökü, Çınar yaprağı, Ebegümeci

(Göze Morusu), Ebegümeci, Maydanoz, Lavanta cevabını vermiştir (Görsel 10), 1 kişi (% 0,7) Evet demiştir ancak bitki adı belirtmemiştir. Bu soruya verilen cevaplarda birden fazla bitki adı belirtenler olmuştur. Öğrencilerin ailelerinin en çok kullandığı tıbbi bitkiler sırasıyla Nane (19 kişi, % 13,6), Kekik (16 kişi, % 11,4), Ihlamur ve Papatya (15'er kişi, % 10,7) olmuştur. Bu bitkilerin toplam kullanım oranı % 46,43 (65 kişi)'dür. Bu soruya cevap vermeyenlerin oranı ise % 25,71 (36 kişi)'dir.



Görsel 10. Ailede en çok kullanılan tıbbi bitkiler

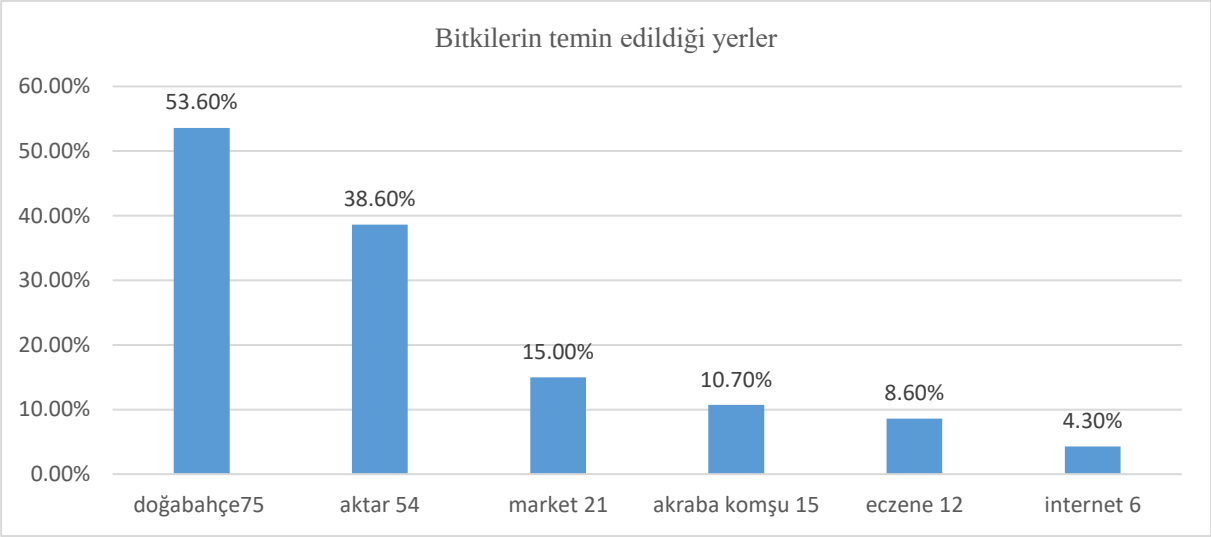
Ailenizde tıbbı bitkiyi en çok kimler kullanır? Sorusuna 55 kişi (% 39,3) annem, 30 kişi (% 21,4) cevap vermeyen, 23 kişi, (% 16,4) babam, 13 kişi (% 9,29) kimse kullanmıyor, 11 kişi (% 7,9) büyükannem, 8 kişi (% 5,7) kendim, 4 kişi büyükbabam, 3'er kişi (% 2,1) ablam, çoçuklar ve anannem, 2 kişi herkez (% 1,42) 1'er kişi (% 0,7) abim, halam, teyzem, yengem cevaplarını vermişlerdir (Görsel 11). Ailelerde en çok tıbbi bitki kullanan kişiler kimdir sorusuna 55 kişi (% 39,3) annem, 23 kişi, (% 16,4) babam demiştir. Ailelerde en çok tıbbi bitki kullanan kişilerin 78 kişi (% 55,7) ile anne ve baba olduğu belirlenmiştir. Bu soruya 30 kişi (% 21,4) cevap vermemiştir.



Görsel 11. Ailede tıbbı bitkileri en çok kullanan kişiler

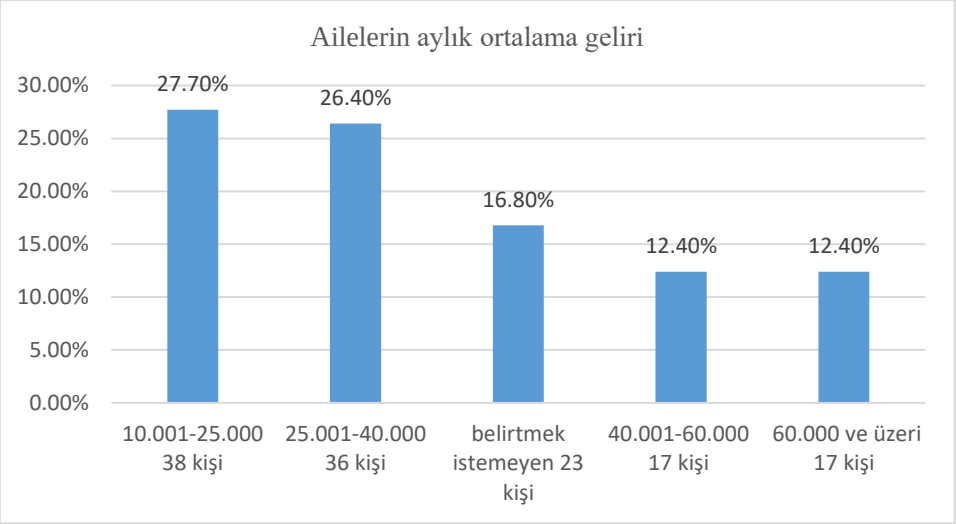
Kullandıkları bitkileri nereden temin ederler? Sorusuna 75 kişi (% 53,6) doğadan/ bahçeden, 54 kişi (%38,6) aktardan, 21 kişi(%15,0) marketten, 15 kişi (%10,7) akraba/ komşudan, 12 kişi

(%8,6) eczaneden, 6 kişi(%4,3) internet'ten temin etmektedir (Görsel 12). Bu soruya verilen cevaplarda birden fazla seçenek işaretleyenler olmuştur. Aileler kullandıkları tıbbi bitkileri çoğunlukla doğadan, bahçeden, ve aktarlardan temin etmektedir.



Görsel 12. Ailelerin tıbbi bitkileri temin ettikleri yerler

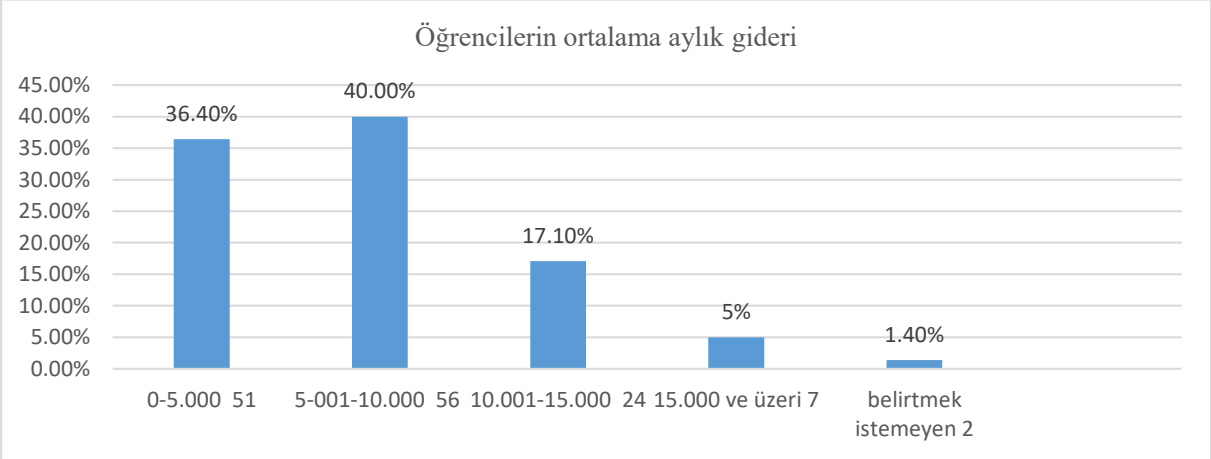
Ailenizin aylık ortalama geliri ne kadar? Sorusuna, 38 kişi (% 27,7) ile 10.001-25.000, 36 kişi (% 26,40) ile 25.001-40.000, 23 kişi (%16,8) ile belirtmek istemiyorum, 17'şer kişi (%12,4) 40.001-60.000 ve 60.000 ve üzeri aylık geliri vardır demiştir (Görsel 13). Öğrencilerden 74 kişi (%54,1) ailelerinin aylık gelirinin 10.000-40.000 TL arasında olduğunu belirtmişlerdir.



Görsel 13. Ailelerin aylık ortalama geliri

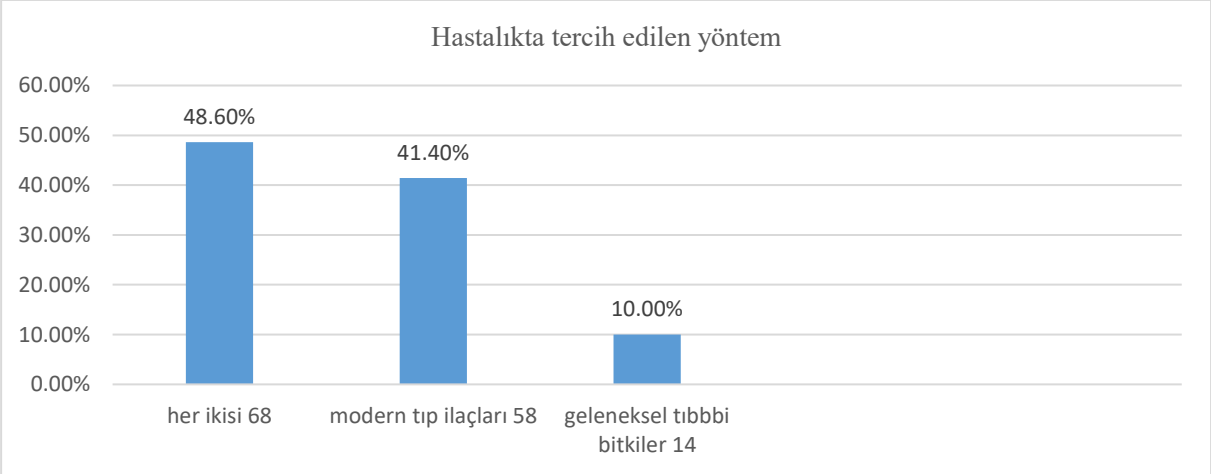
Sizin aylık ortalama gideriniz ne kadar? Sorusuna, 56 kişi (%40) 5-001-10.000 arasında, 51 kişi (%36,4) 0-5.000 arasında, 24 kişi (%17,1) 10.001-15.000 arasında, 7 kişi(%5) 15.000 ve üzeri, 2 kişi(%1,4) belirtmek istemiyorum şeklinde cevap vermişlerdir (Görsel 14).

Öğrencilerden 107 kişi (% 76,4) aylık ortalama giderlerinin 0-10.000 TL arasında olduğunu belirmiştir.



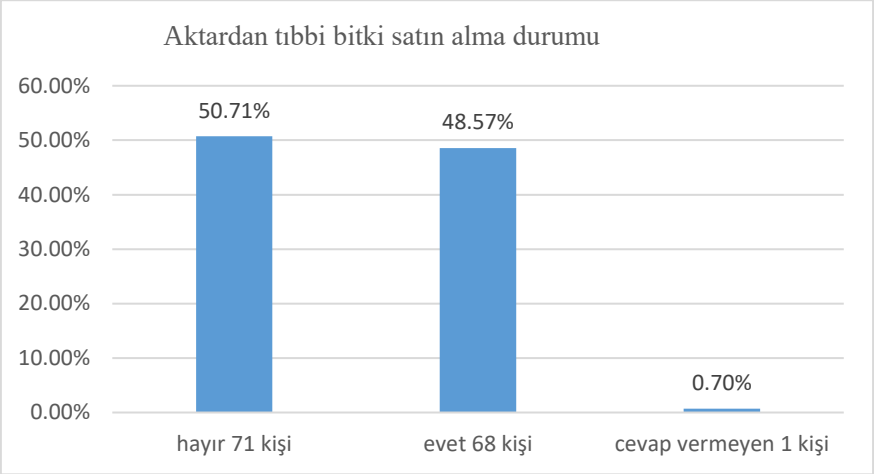
Görsel 14. Öğrencilerin ortalama aylık gideri

Hastalandığınızda öncelikle modern tıp ilaçlarını mı, geleneksel tıbbi bitkileri mi tercih edersiniz? Sorusuna, Katılımcılardan 68 kişi (% 48,6) her iki yöntemi de, 58 kişi (% 41,4) modern tıp ilaçlarını, 14 kişi (% 10) geleneksel tıbbi bitkileri tercih ederim cevabını vermiştir (Görsel 15). Öğrencilerin yaklaşık yarısı modern tıp ilaçları ile birlikte geleneksel tıbbi bitkileri de tercih etmektedir.



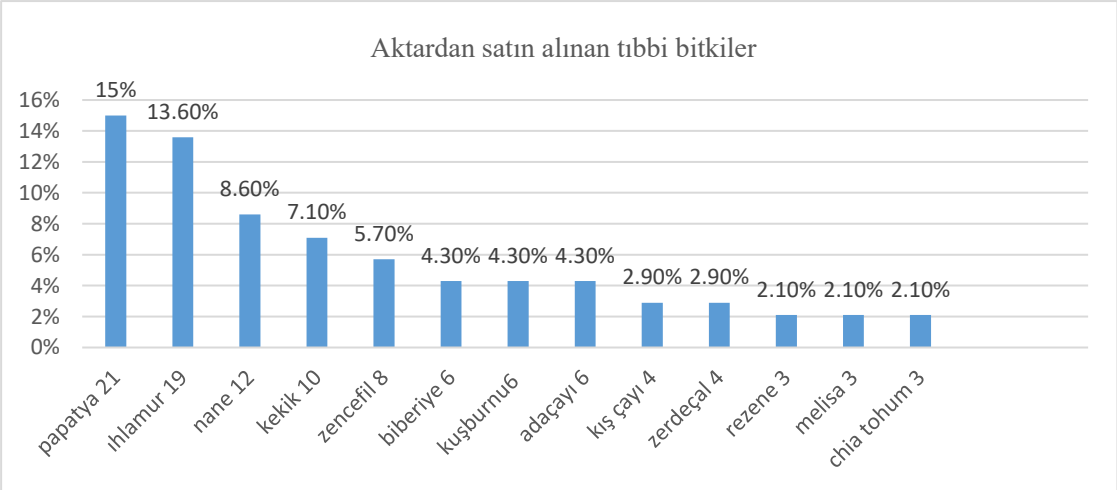
Görsel 15. Hastalıkta öncelikle tercih edilen uygulama

Aktardan tıbbi bitki satın aldınız mı? Sorusuna katılımcılardan 71 kişi (% 50,71) hayır, 68 kişi (% 48,57) evet cevabını vermiş, 1 kişi (% 0,7) ise cevap vermemiştir (Görsel 16). Aktardan tıbbi bitki satın aldınız mı? Sorusuna evet ve hayır diyenlerin oranı birbirine çok yakındır.



Görsel 16. Aktardan tıbbi bitki satın alma durumu

Aktardan hangi bitkileri satın aldınız? Sorusuna 63 kişi (% 45) bitki satın almadığını belirtmiş, 21 kişi (% 15) papatya, 19 kişi (%13,6) ıhlamur, 12 kişi (%8,6) nane, 10 kişi (%7,1) kekik, 8 kişi (%5,7) zencefil, 6 ‘şar kişi (% 4,3) biberiye, kuşburnu, adaçayı, 4’er kişi (%2,9) kış çayı, zerdeçal, 3kişi (%2,1) rezene, melisa, çia tohumu, 2’şer kişi (%1,4) alovera, karanfil, hibiskus, tarçın,1’er kişi (%0,7) ısırgan otu, patlıcan, yeşil çay, çınar yaprağı, sarımsak, defne yaprağı, portakal nergizi, sarı kantaron, hünnap, kaktüs, reyhan, iğde tozu, keten tohumu, kayısı, yılan yağı, anason, at kestanesi, ebegümeci, oğul otu, öz fidancı, polen, karanfil yağı, kuş otu, kayısı yağı cevaplarını vermiştir (Görsel 17). Bu soruda birden fazla bitki adı belirtenler vardır. Aktarlardan en çok satın alınan tıbbi bitkiler sırasıyla papatya, ıhlamur, nane, kekik ve zencefildir.

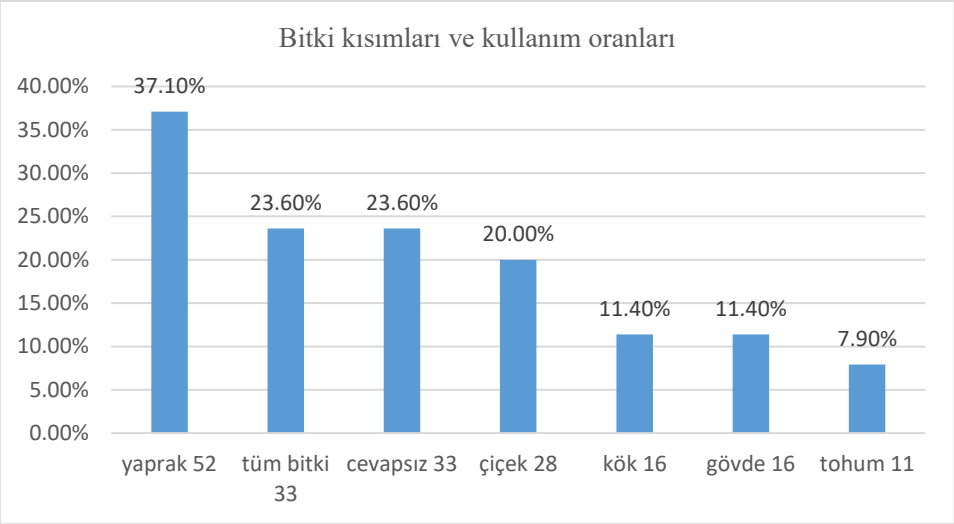


Görsel 17. Aktardan satın alınan tıbbi bitkiler

Öğrenciler aktardan en çok satın aldıkları bitkilerden ilki olan papatya (Görsel 17) soğuk algınlığı, grip, migren, baş ağrısı, sinüzit, mide, stres, rahatsızlıklarına karşı ve vücut rahatlatıcı ve sakinleştirici etkileri olduğunu belirtmişlerdir. İkinci sırada olan Ihlamur bitkisi grip, soğuk algınlığı, öksürük, boğaz ağrısı, halsizlik, durumlarında ve rahatlama sağlaması için kullanılmaktadır. Üçüncü sırada belirtilen nane bitkisi yemeklere lezzet verici, mide rahatlatıcı

olarak ve grip ve soğuk algınlığında kullanılmaktadır. Kekik bitkisi dördüncü sırada belirtilmiştir. Bitki grip, soğuk algınlığı, öksürük, boğaz ağrısı durumlarına ve sakinleştirici ve mide rahatlatıcı olarak kullanılmaktadır. Beşinci sırada kullanılan zencefil bağışıklık arttırıcı, bulantı giderici, boğaz ağrısı, soğuk algınlığı, grip hastalıklarında ve lezzet verici olarak tüketilmektedir.

Aktardan satın aldığınız bitkinin hangi kısmını kullandınız? Sorusuna Katılımcılardan 52 kişi (% 37,1) yaprak, 33'er kişi (% 23,6) tüm bitki ve cevap vermeyenler, 28 kişi (% 20,0) çiçek, 16'şar kişi (% 11,4) kök ve gövde, 11 kişi (% 7,9) tohum, şeklinde cevap vermişlerdir (Görsel 18). Öğrenciler tıbbi amaçla bitkilerin en çok yaprağını (52 kişi, % 37,1), en az ise tohumunu (11 kiş, % 7,9) kullanmaktadır.

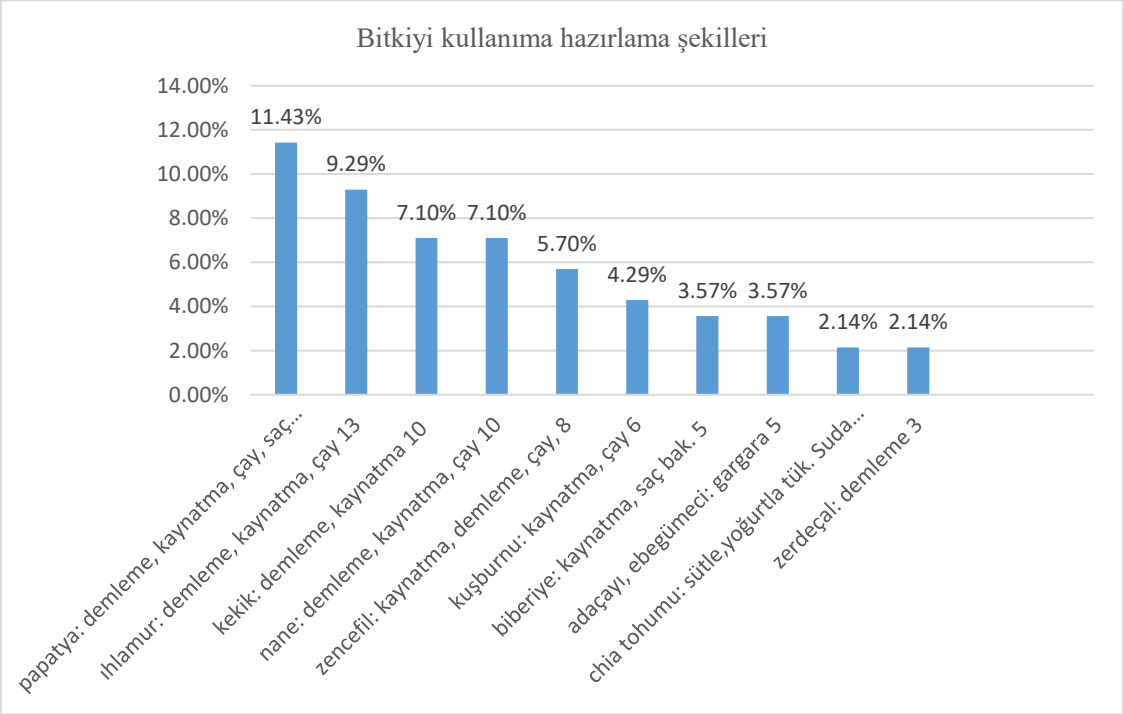


Görsel 18. Satın alınan tıbbi bitkinin kullanılan kısımları

Bitkiyi kullanıma nasıl hazırlarsınız? Sorusuna 16 kişi (% 11,43) papatyayı demliyor, çay olarak içiyor ve saça uyguluyor. 13 kişi (% 9,29) ıhlamuru demliyor veya kaynatıyor, 10 kişi (% 7,1) naneyi demleme veya kaynatma yüntemleri ile hazırlıyor. 10 kişi (% 7,14) kekik demliyor veya kaynatıyor, 3 ay kullanıyor. 8 kişi (% 5,7) zencefili dilimleyip suda kaynatıyor. Kökünü portakal suyuyla karıştırıp içiyor yada rendeleyip sıcak suyla demliyor, bal katıp içiyor. 1 su bardağı su kaynatıp içine 1 tatlı kaşığı rendelenmiş taze zencefil koyup 1-2 dilim limon, bir tutam karabiber koyup süzüp balla içiyor. 6 kişi (% 4,29) kuşburnu kaynar suya atıp demliyor haftada 2-3 kez içiyor. 5 kişi (% 3,57) biberiye suda kaynatıp saçına uyguluyor, 1 ay yada 3-4 ay kullanıyor. 5 kişi (% 3,57) adaçayı, ebegümeci demliyor boğaz ağrısında gargara yapıyor. 3 kişi (% 2,14) chia tohumu süte veya yoğurda katıp kaynatıyor veya suda bekletip tüketiyor. 3 kişi (% 2,14) zerdeçal öğütüyor, demliyor. 2 kişi (%1,4) keten tohumunu demliyor, salataya katıp yiyor, 2 kişi (%1,4) tarçını demliyor, kaynatıyor. 2 kişi (%1,4) melisayı kaynatıp demliyor. 2 kişi (%1,4) rezene kaynatıp demliyor. 2 kişi (%2,14) kış çayı demliyor. 1 kişi (%0,7) alovera bitkisini cilt bakımında 3-4 ay kullanmış. 1 kişi (%0,7) kayısı yağını 3-4 ay kullanıyor. 1 kişi (%0,7) kış çayı demliyor, 1 kişi (%0,7) portakal nergisi kaynar suda ısıtıyor, 1 kişi (%0,7) defne yaprağı yemeklere kullanıyor, 1 kişi (%0,7) hibiskus demliyor, 1 kişi (%0,7) mısır püskülü kaynatıyor, 1 kişi (%0,7) iğde tozu balla karıştırıyor, 1 kişi (%0,7) kiraz sapı

kaynatıyor, 1 kişi (%0,7) avakado yaprağı kaynatıyor, 1 kişi (%0,7) poleni suda kaynatıyor, 1 kişi (%0,7) zeytinyağı ve sarımsağı gece ayakaltınsa sürüyor, 1 kişi (%0,7) maydanoz salata ve yemekte kullanıyor, 1 kişi (%0,7) anasonu demliyor, 1 kişi (%0,7) kengeri pilav yapıyor, 1 kişi (%0,7) karanfil demliyor, 1 kişi (%0,7) yeşil çay demliyor, 1 kişi (%0,7) karanfil yağı pamukla diş etine tutuyor.

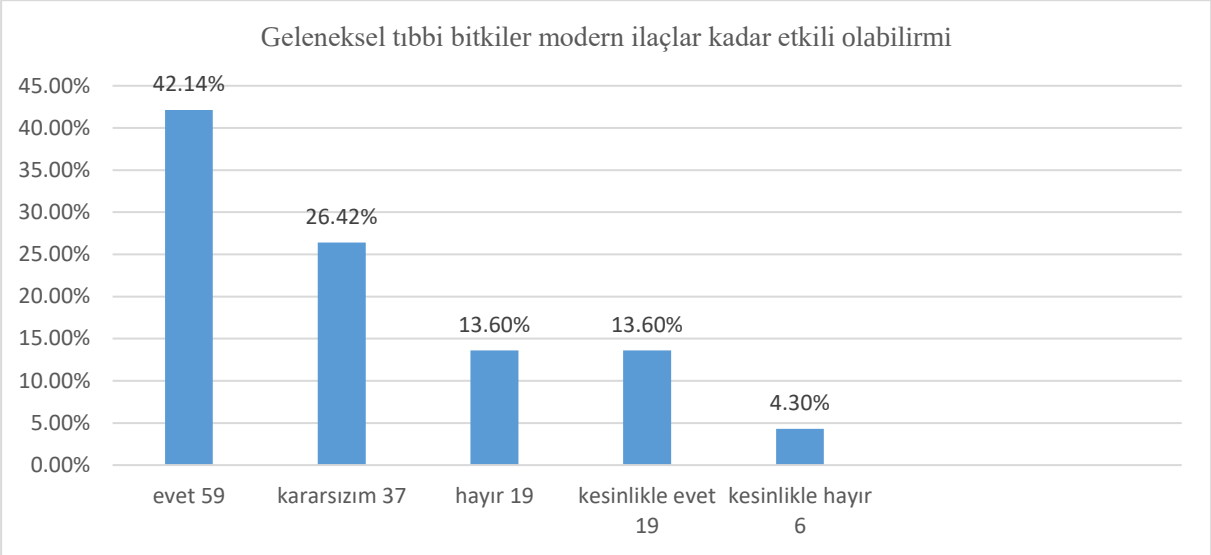
Öğrenciler tıbbi bitkileri en çok kullanıma hazırlama ve kullanma şekilleri olarak papatyayı demleme ve kaynatma yöntemleriyle çay olarak ve saç bakımında kullanmaktadır. Ihlamur, kekik, nane ve zencefil bitkilerini demleme ve kaynatma yöntemleriyle çay olarak; kuşburnu, biberiye ve zerdeçal bitkilerini kaynatma yöntemiyle çay olarak; adaçayı bitkisini boğaz ağrılarında gargara şeklinde ve çia tohumunu süte ve yoğurda katarak ve suda bekleterek zayıflamak için kullanmaktadır.



Görsel 19. Bitkiyi kullanıma hazırlama şekilleri

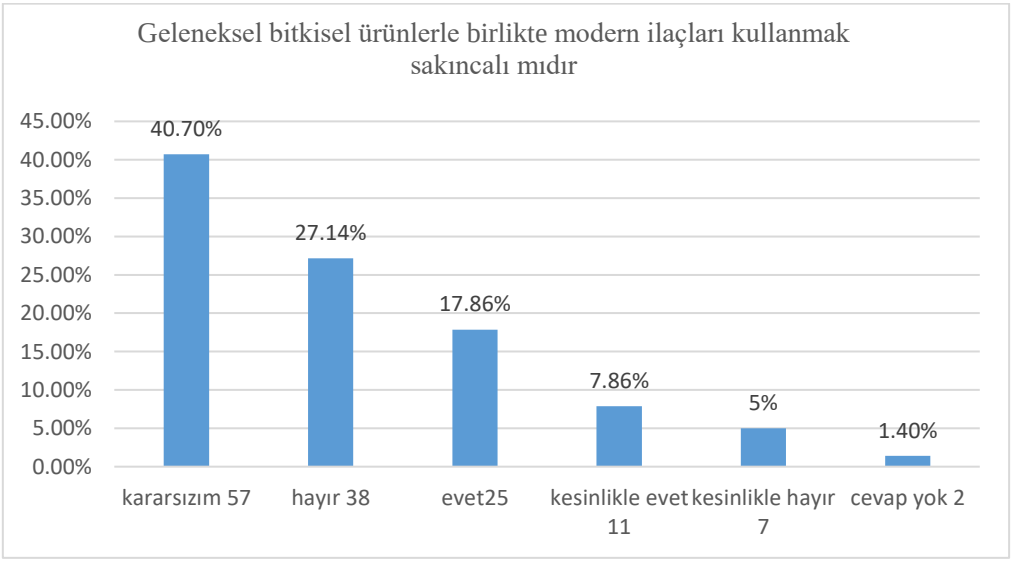
Sizce hastalıkların tedavisinde geleneksel tıbbi bitkiler modern ilaçlar kadar etkili olabilir mi? Sorusuna 59 kişi (% 42,14) evet, 19 kişi (% 13,6) kesinlikle evet, 37 kişi (% 26,42) kararsız, 19 kişi (% 13,6) hayır ve 6 kişi (% 4,3) kesinlikle hayır demiştir (Görsel 20.

Öğrencilerin önemli bir kısmı (78 kişi, % 55,74) hastalıkların tedavisinde geleneksel tıbbi bitkilerin modern tıp ilaçları kadar etkili olabileceğini belirtmiştir.



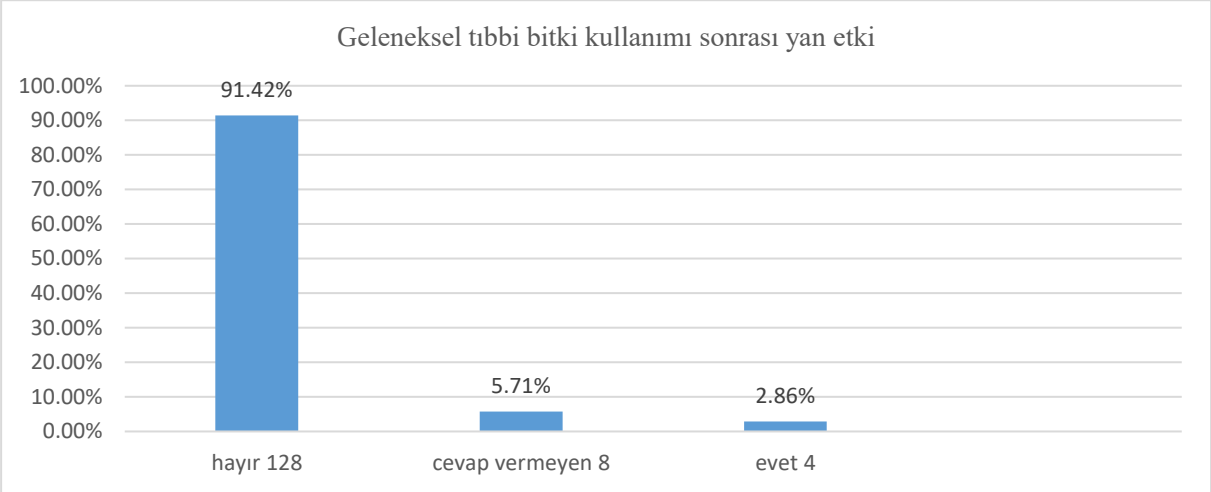
Görsel 20. Hastalıkların tedavisinde geleneksel tıbbi bitkilerin etkisinin modern ilaçlarla kıyaslanması

Sizce geleneksel bitkisel ürünlerle modern ilaçları birlikte kullanmak sakıncalı mıdır? Sorusuna 57 kişi (% 40,71) kararsızım, 38 kişi (% 27,14) hayır, 25 kişi (% 17,86) evet, 11 kişi (% 7,86) kesinlikle evet, 7 kişi (% 5) kesinlikle hayır demiştir, 2 kişi (% 1,43) ise cevap vermemiştir Görsel 21). Geleneksel bitkisel ürünlerle modern ilaçları birlikte kullanmanın sakıncalı olup olmaması konusunda öğrencilerin önemli bir kısmı (57 kişi, % 40,7) kararsız kalmıştır.



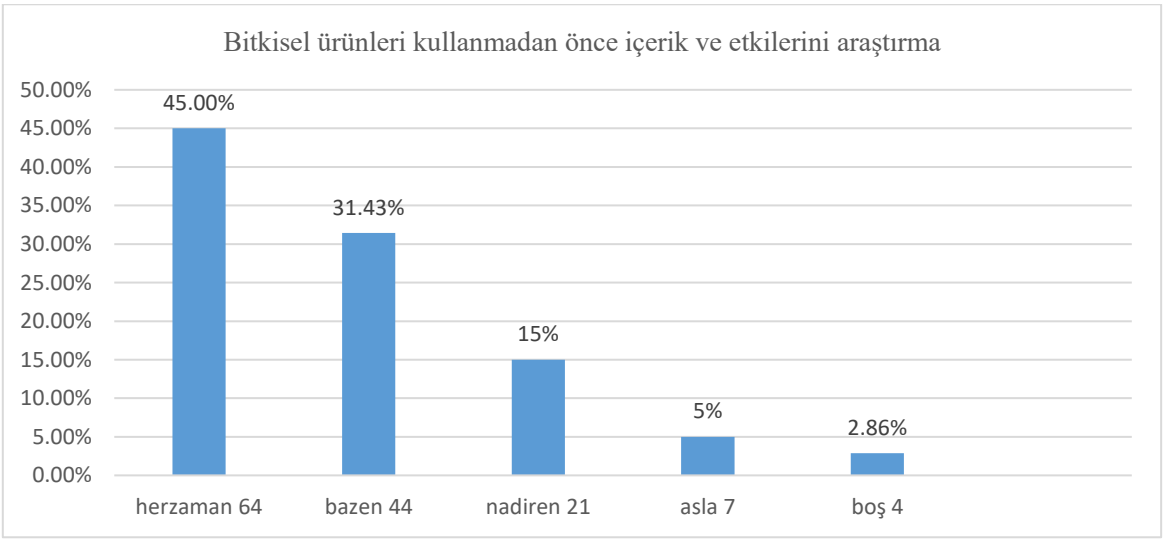
Görsel 21. Sizce geleneksel bitkisel ürünlerle modern ilaçları birlikte kullanmak sakıncalımı

Geleneksel tıbbi bitki kullanım sonrası herhangi bir yan etki yaşadınız mı? Sorusuna 128 kişi (% 91,42) hayır, 8 kişi (% 5,71) boş, 4 kişi (% 2,86) evet cevabını vermiştir. Ankete katılanların büyük çoğunluğu geleneksel tıbbi bitki kullanımı sonrasında herhangi bir yan etki ile karşılaşmamıştır (Görsel 22).



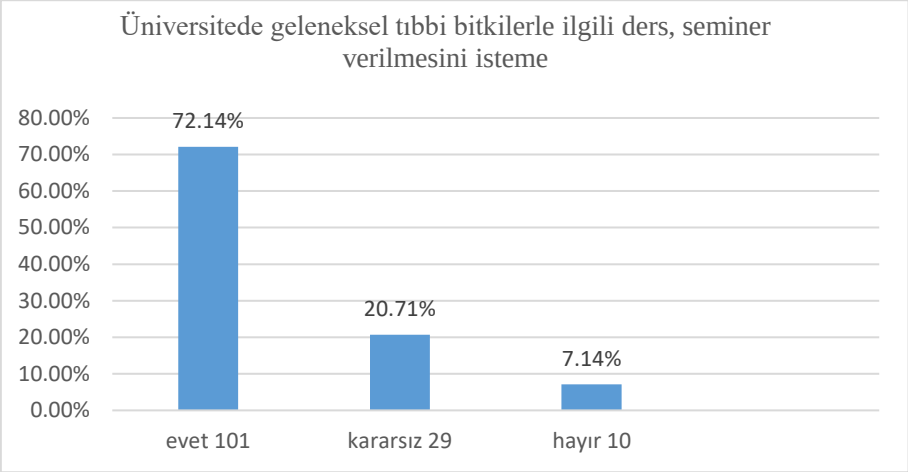
Görsel 22. Geleneksel tıbbi bitki kullanım sonrası yan etki görme

Bitkisel ürünleri kullanmadan önce içerik ve etkilerini araştırır mısınız? Sorusuna 64 kişi (% 45,71) her zaman, 44 kişi (% 31,43) bazen, 21 kişi (% 15) nadiren 7 kişi (% 5) asla cevabını vermiştir. 4 kişi (% 2,86) ise soruya cevap vermemiştir (Görsel 23). Öğrencilerin yaklaşık yarısı bitkisel ürünleri kullanmadan önce içeriklerini ve etkilerini araştırmaktadır.



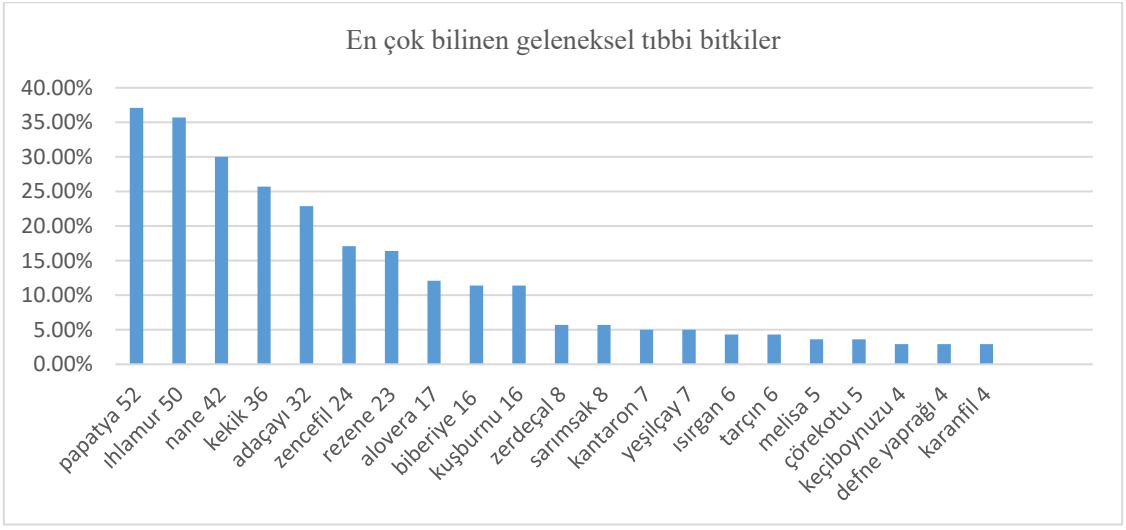
Görsel 23. Bitkisel ürünleri kullanmadan önce içerik ve etkilerini araştırma durumu

Sizce üniversitemizde geleneksel tıbbi bitki ile ilgili ders, seminer verilmesi gerekli midir? Sorusuna 101 kişi (% 72,14) evet, 29 kişi (% 20,71) kararsız, 10 kişi(%7,14) hayır cevabını vermiştir. Ankete katılanların büyük çoğunluğu (% 72,14) geleneksel tıbbi bitkilerle ilgili ders, seminer vb. etkinlik yapılmasını istemektedir (Görsel 24).



Görsel 24. Sizce üniversitede geleneksel tıbbi bitkilerle ilgili ders, seminer verilmesi gereklimi

Bildiğiniz geleneksel tıbbi bitkilere 5 örnek veriniz ve kullanım şekillerini belirtiniz sorusuna 52 kişi (% 37,1) papatya, 50 kişi (% 35,7) ıhlamur, 42 kişi (% 30,0) nane, 36 kişi(%25,7) kekik, 32 kişi(%22,9) adaçayı, 24 kişi(%17,1) zencefil, 23 kişi(%16,4) rezene, 17 kişi (12,1) alovera, 16'şar kişi(%11,4) biberiye, kuşburnu, 8'er kişi (%5,7) zerdeçal, sarımsak, 7'şer kişi (%5,0) kantaron, yeşilçay, 6'şar kişi (%4,3) ısırgan, tarçın, 5'er kişi(%3,6) melisa, çörekotu, 4'er kişi (%2,9) keçiboynuzu, defneyaprağı, karanfil, 2'şer kişi(%1,4) hibiskus, Çia tohumu reyhan, kahve, maydanoz, anason, dereotu, sığırkuyruğu mantarı, mantar, ebegümeci, isot, sarı civanperçemi, kiraz sapı, keten tohumu, 1'er kişi(0,7) Elma, karaçalı kökü, greyfurt, Sumak, haşhaş, patlıcan, hatmi çiçeği, nergis çayı, kimyon, Kenger, kelük, hindistan cevizi, pekmezli su, ballı süt, hindiba kahve, kılıç otu, soya, dut, ceviz ağacı yaprağı, iğde tozu, Kaysı, göze morusu, üzüm pekmezi, bitki çayı, acı çehre, tere, roka, kuzukulağı, yemlik, kenger, ışkın, bazı çiçekler, kişi polen, limon, nar kabuğu, zeytinyağı, fesleğen, avakado yaprağı, mısır püskülü, gül, yılan yağı, at kestanesi cevabını vermiştir. 1 kişi ise kullandığını belirtirken bitki adı vermemiştir. Bu soruya verilen cevaplarda bazı kişiler birden fazla bitki ve kullanım amacı belirtmiştir (Görsel 25). Öğrencilerin en iyi bildiği geleneksel tıbbi bitkiler sırasıyla papatya, (52 kişi, % 37,1), ıhlamur (50 kişi, % 35,7), nane (42 kişi, % 30,0), kekik (36 kişi %25,7) ve adaçayı (32 kişi, %22,9)'dır.



Görsel 25. En çok bilinen geleneksel tıbbi bitkiler

Öğrenciler tarafından en iyi bilinen tıbbi bitkilerden ilk sırada olan papatya (52 kişi, %37,1) soğuk algınlığı, saç bakımı, sakinleşme, sinüzit ve baş ağrında çay olarak kullanılmaktadır. İkinci sırada olan ıhlamur (50 kişi, %35,7) soğuk algınlığında çay olarak kullanılmaktadır. Üçüncü sıradaki nane (42 kişi, %30,0) yemeklere lezzet verici, boğaz ağrısı, grip ve soğuk algınlığında limonla birlikte çay olarak kullanılmaktadır. Dördüncü sıradaki kekik (36 kişi ,%25,7) Korona, öksürük, boğaz ağrısı, ağrı kesici, balgam sökücü, Grip, Mide rahatsızlığı, idrar problemlerinde çay olarak ve yemeklerde lezzet verici olarak kullanılmaktadır. Beşinci sırada olan adaçayı (32 kişi, %22,9) boğaz ağrısı, öksürük, baş ağrısı ve vücut direnci için kullanılmaktadır.

Türkiye'de üniversite öğrencilerinin geleneksel bitki kullanımına yaklaşımlarının belirlenmesi amacıyla yapılan çalışma sayısı oldukça yetersizdir. Yapılan bu çalışmalardan Sucaklı vd., (2014) ve Kaner vd. (2017) çalışmamıza kapsam bakımından en yakın çalışmalardır. Sucaklı vd., (2014) tarafından yapılan çalışma Kahramanmaraş Sütçü İmam Üniversitesinde 540 civarında öğrenci üzerinde yapılmıştır. Kaner vd. (2017) tarafından yapılan çalışma ise Kayseri Nuh Naci Yazgan Üniversitesi'nde gerçekleştirilmiştir. Bu çalışmalarda öğrencilere yöneltilen sorular ve bulgular çalışmamıza benzerlik göstermektedir. Bu çalışmalarda öğrencilerin en sık kullandığı tıbbi bitkilerin karabiber, tarçın, çörek otu, kırmızıbiber ve kekik olduğu görülmüştür. Çalışmamızda ise papatya, ıhlamur, nane, kekik ve zencefil öğrenciler tarafından en sıklıkla kullanılan bitkilerdir. Şahin vd. (2019) ve Aygör ve Çayır (2020) Hemşirelik öğrencilerinin geleneksel bitkisel ürünlerin kullanımı üzerine yapılan çalışmalardır. Değirmenci vd. (2024) Fen Bilgisi Öğretmenliği öğrencilerinin tıbbi bitki bilgisi üzerine yapılan bir araştırmadır. Demirçivi ve Altaş (2016) ise üniversite öğrencilerinin baharatlara ilişkin bilgi düzeylerini oraya koymak amacıyla yapılmıştır.

Erzincan'da gerçekleştirilen bu araştırma aynı zamanda Doğu Anadolu bölgesinde de yapılan ilk çalışma özelliğini taşımaktadır. Bu çalışma İleride yapılacak kapsamlı çalışmalara temel oluşturabilecektir.

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YÜKSEK RAKIM EKOSİSTEMİNDE YETİŞEN AHUDUDU (*Rubus idaeus* L.) BİTKİSİNİN FENOLİK BİLEŞİMİ VE KULLANIM ALANLARI

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ÖZET

Ahududu (*Rubus idaeus* L.), fenolik bileşikler içermesi ve buna bağlı biyolojik etkileri nedeniyle fonksiyonel gıda ve doğal ürün araştırmalarında önemli bir yere sahiptir. Bitkisel sekonder metabolitlerin sentezi yetişme koşullarından güçlü biçimde etkilenmekte; özellikle yüksek rakım ekosistemlerinde düşük sıcaklık ve çevresel stres faktörleri, fenolik metabolizma üzerinde belirleyici rol oynayabilmektedir.

Bu çalışma kapsamında, yüksek rakım koşullarında yetişen ahududu yapraklarından ekstrakt elde edilmiş ve bu ekstraktın fenolik bileşimi analiz edilmiştir. Ayrıca, elde edilen bulgular ahududunun biyolojik faydaları ve olası kullanım alanları bağlamında değerlendirilmiştir. Analitik sonuçlar, ahududu yaprak ekstraktında fenolik içeriğin nicel olarak sınırlı olduğunu, ancak belirli fenolik bileşiklerin seçici biçimde öne çıktığını göstermektedir. Bu kapsamda fumarik asit ve klorojenik asit kantitatif olarak tespit edilmiş, apigenin ise düşük konsantrasyonda belirlenmiştir. Diğer fenolik asitler, flavonoidler ve antosiyanin türevleri ise kantifikasyon sınırının altında bulunmuştur. Klorojenik asidin varlığı, yüksek rakım koşullarında artan çevresel stres faktörlerinin fenolik metabolizma üzerinde bileşik-spesifik bir düzenleyici etkiye sahip olabileceğini düşündürmektedir.

Literatür verileriyle birlikte değerlendirildiğinde, ahududunun antioksidan, antiinflamatuar, antimikrobiyal ve hücresel koruyucu özellikler sergileyebildiği bildirilmektedir. Bununla birlikte, yüksek rakımda yetişen ahududuların toplam fenolik zenginlikten ziyade çevresel adaptasyona bağlı olarak şekillenen özgün ve seçici bir fenolik profil sergilediği görülmektedir. Bu bağlamda, ahududu ekstraktlarının fonksiyonel gıda, farmasötik ve biyolojik uygulamalardaki potansiyelinin, toplam fenolik miktardan çok belirli fenolik bileşikler temelinde değerlendirilmesi gerektiği sonucuna varılmıştır.

Anahtar Kelimeler : Ahududu, *Rubus idaeus* L., fenolik bileşik.

1. GİRİŞ

Birçok bitki türü ve bu bitkilerin farklı kısımları, tarihsel süreç boyunca yalnızca tedavi edici amaçlarla değil, aynı zamanda ilaç üretiminde hammadde olarak da yaygın biçimde

kullanılmıştır. Bu doğrultuda, tıbbi amaçla kullanılan bitkilere yönelik farmakolojik, biyolojik, mikrobiyolojik ve kimya temelli çok sayıda çalışma literatürde rapor edilmiştir (Dağcı, 2005). Bitkisel kaynaklı ilaçların sentetik ilaçlara kıyasla daha fazla tercih edilmesinin temel nedenleri arasında, genellikle daha az yan etkiye sahip olmaları ve insan sağlığı üzerinde çok yönlü biyolojik faydalar sunmaları yer almaktadır (Dikmen, 2009). Bunun yanı sıra bitkiler; gıda, ilaç, kozmetik ve kişisel bakım ürünleri başta olmak üzere baharat, parfüm, alkollü ve alkolsüz içecekler, aroma vericiler, doğal boyalar, çay, sabun ve sirke üretimi gibi pek çok alanda kullanım potansiyeline sahiptir (Türközü, 2010; Harşit, 2015).

Bitki türlerinde bulunan farmakolojik açıdan aktif bileşiklerin %70'inden fazlasının günümüze kadar tanımlandığı bildirilmektedir. Antimikrobiyal aktivite gösteren bitki kaynaklı bileşiklerin kimyasal yapılarında önemli çeşitlilikler gözlenmekte olup, bu farklılıkların mikroorganizmalara karşı korunmayı sağlayan savunma sistemlerinin zaman içerisinde doğal seçilim yoluyla gelişmesi sonucunda ortaya çıktığı düşünülmektedir (Simões ve ark., 2009). Son yıllarda özellikle bitkisel fenolik bileşiklere yönelik araştırmalarda belirgin bir artış gözlenmekte; birçok ilaç firması, çeşitli hastalıkların tedavisinde bitki kaynaklı kombinasyonlardan yararlanmaktadır (Inbaneson ve ark., 2012). Bitkilerin tıbbi açıdan yararlı etkilerinin büyük ölçüde fenolik bileşikler ve diğer sekonder metabolitlerden kaynaklandığı, bu bileşiklerin çeşitliliği ve biyolojik etkinliğinin ise bitkilerin taksonomik farklılıkları ile yakından ilişkili olduğu bilinmektedir (Wink, 1999).

Ahududu (*Rubus idaeus* L.), gıda endüstrisi ve kozmetik alanında yaygın olarak kullanılan önemli bitkilerden biridir. Kendine özgü aroma, tat ve renk özellikleri nedeniyle taze tüketimi önerilmekte olup, içeriğinde bulunan fenolik bileşikler ve flavonoidler gibi biyoaktif maddelerin çeşitliliği ve miktarının, bazı diğer bitkilerle karşılaştırıldığında daha yüksek olduğu rapor edilmiştir (Pehluvan, 2004). Ahududu bitkisinin vücut direncini artırıcı, enerji verici ve genel canlılığı destekleyici etkiler gösterdiği; enfeksiyon etkenlerinin ve toksik maddelerin vücuttan uzaklaştırılmasına katkı sağladığı bildirilmektedir. Ayrıca bazı kanser hücrelerinin proliferasyonunu ve metastazını baskılayıcı potansiyel taşıdığına dair bulgular mevcuttur. Zengin vitamin içeriği sayesinde bağışıklık sistemini destekleyerek hastalıklara karşı koruyucu bir rol üstlendiği de belirtilmektedir (Alhababı, 2024).

Yüksek rakım ekosistemleri, artan UV ışınımı, düşük sıcaklıklar, sıcaklık dalgalanmaları ve zaman zaman su kısıtlılığı gibi çevresel stres faktörleri ile karakterize edilmekte olup, bu koşullar bitkilerin kimyasal bileşimlerinin şekillenmesinde belirleyici bir rol oynamaktadır (Dong ve ark., 2020; Durán ve ark., 2025). Bu çevresel baskılar, bitkilerin antioksidan savunma mekanizmalarını aktive ederek, özellikle fenolik bileşiklerin sentezinde artışa yol açmaktadır (Dong ve ark., 2020; Dong ve ark., 2021). Fenolik bileşikler, bitkilerde UV kaynaklı hasarın azaltılması, oksidatif stresin dengelenmesi ve patojenlere karşı direncin artırılmasında temel rol oynayan bileşenlerdir (Ştefănescu ve ark., 2019; Durán ve ark., 2025). Literatürde, rakım artışı ile birlikte fenolik bileşik profillerinde ve antioksidan kapasitelerde artış gözlendiğini ortaya koyan çok sayıda çalışma bulunmaktadır. *Nardus stricta*, *Rhodiola crenulata* ve *Thalictrum foliolosum* gibi bitki türlerinde gerçekleştirilen araştırmalar, yüksek rakımda yetişen örneklerin daha yüksek toplam fenolik ve flavonoid içeriğine sahip olduğunu ve bu durumun serbest radikal temizleme aktivitelerini artırdığını göstermiştir (Pandey ve ark., 2018; Dong ve ark.,

2020; Dong ve ark., 2021; Durán ve ark., 2025). Benzer şekilde, elma ve bilberry gibi meyve türlerinde de rakıma bağlı olarak fenolik metabolit profillerinde artışlar rapor edilmiş, bu artışların ürün kalitesi ve sağlık destekleyici özellikler üzerinde olumlu etkiler oluşturduğu belirtilmiştir (Kumar ve ark., 2019; Ciulcă ve ark., 2021; Vaneková ve ark., 2020).

Bu çalışma kapsamında, yüksek rakım ekosisteminde yetişen ahududu bitkisinin yapraklarından Soxhlet ekstraksiyon yöntemi kullanılarak bitkisel ekstrakt elde edilmesi ve elde edilen ekstraktın fenolik bileşik içeriğinin analitik yöntemlerle belirlenmesi amaçlanmıştır. Ahududu yapraklarının fenolik profilinin ortaya konulmasının yanı sıra, bu bileşiklerin biyolojik ve fonksiyonel özelliklerinin literatür bulguları ışığında değerlendirilmesi hedeflenmiştir. Ayrıca, ahududu bitkisinin yalnızca fitokimyasal bileşimi açısından değil; gıda, fonksiyonel gıda, farmasötik, kozmetik ve geleneksel kullanım alanları bakımından taşıdığı potansiyelin bütüncül bir yaklaşımla ele alınması amaçlanmıştır.

2. Ahududu (*Rubus idaeus* L.) Türünün Özellikleri

2.1. Botanik Özellikleri

Rubus idaeus L. (kırmızı ahududu), Rosaceae familyasına ait çok yıllık, odunsu ve çalı formunda gelişen bir bitki türüdür. Ilıman bölgelerde doğal olarak yetişmekte olup, geniş coğrafi dağılımı ve adaptasyon yeteneği sayesinde hem doğal ekosistemlerde hem de tarımsal ortamlarda yaygın olarak gözlemlenmektedir. Bitkinin yaprak, çiçek ve meyve morfolojisi, türün tanımlanmasında temel unsurlar arasında yer alır. Yapraklar genellikle üç loblu veya yumruk şeklinde olup, kenarlarında ufak dişler barındırır; çiçekleri ise beyazdan pembeye değişen renklere sahip ve çoğunlukla terminal çiçek salkımları oluşturur (Leoni ve ark., 2024). Bu bitkinin sistematik incelemeleri, morfolojik belirteçlerin yanı sıra genetik marker'lar kullanılarak yapılmış olup, Rubus cinsine özgü yüksek heterozigosite düzeyleri ve morfolojik çeşitlilik gözlemlenmiştir (López ve ark., 2019).

2.2. Morfolojik Özellikler

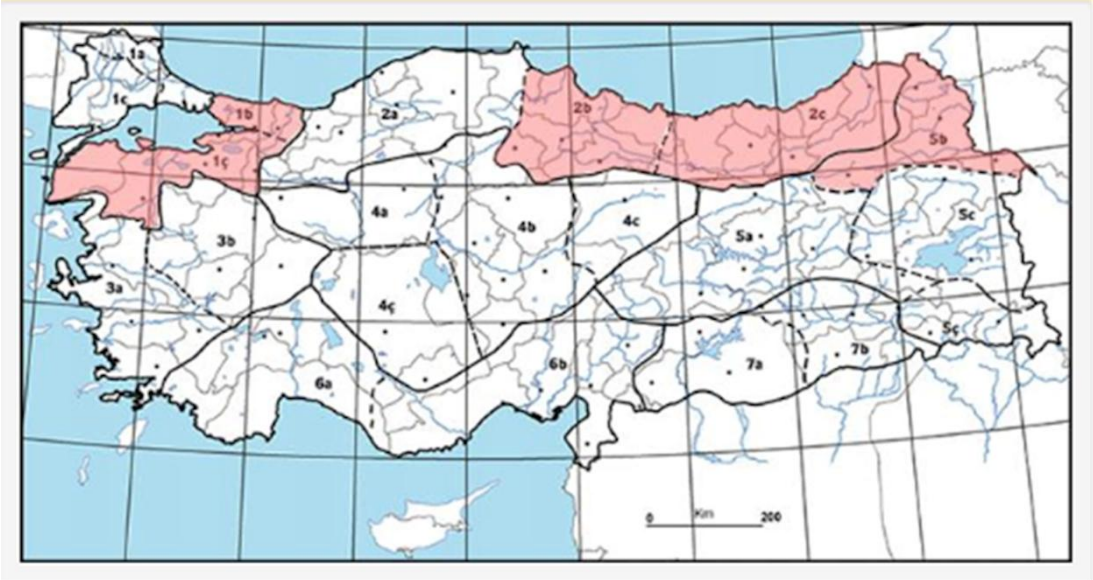
Rubus idaeus L. nin morfolojik yapısı, türün hem ekolojik uyum sağlama kapasitesini hem de tarımsal üretimde tercih edilebilirliğini belirlemektedir. Bitkinin ana sapları ve dalları, genellikle diken barındırmasıyla dikkat çeker; bu dikenlerin yoğunluğu bireysel kültivarlar arasında farklılık gösterebilir. Dikenli yapı, bitkinin savunma mekanizması olarak görülmekte olup, hasat ve yetiştirme işlemlerinde zorluklar oluşturabilmektedir (López ve ark., 2019). Morfolojik açıdan, dalların kısmi yayılımı ve yoğun çalılaşması, türün doğal yapısının rekabet avantajını artırırken; çiçek ve meyve gelişiminde ortaya çıkan simetrik yapılar polinatörlere sağladığı besinsel kaynaklarla ekosistem hizmetlerine katkıda bulunmaktadır (Leoni ve ark., 2024). Bu morfolojik unsurlar, genetik çalışmalarla da desteklenen adaptif varyasyonlar çerçevesinde değerlendirildiğinde, *Rubus idaeus* L. çevresel streslere ve rekabet koşullarına karşı esnek bir yapıya sahip olduğu gösterilmektedir (López ve ark., 2019).

2.3. Doğal Yayılışı

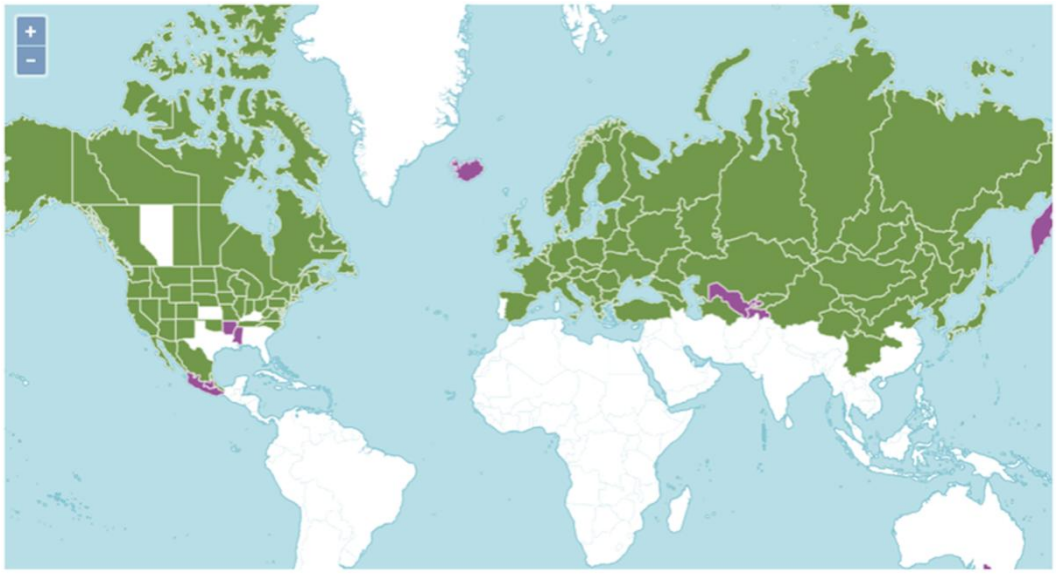
Rubus idaeus L. yayılış açısından hem doğal regenerasyon süreçleri hem de ekolojik nispetlerle dikkat çeken bir tür olarak öne çıkar. Özellikle ormanlarda, büyük çaplı bozulmalardan veya

diğer doğal olaylardan sonra, bu tür hızlıca yayılıp bir çalı tabakası oluşturabilmektedir (Leoni ve ark., 2024). Bu durum, türün erken süksesyon organizmaları arasında yer almasını ve bozulmuş alanlarda hızla koloni kurma kapasitesini destekler. Araştırmalar, türün çeşitli iklim ve toprak tiplerine uyum sağlayabilme yeteneğini, heterotik gen yapısı ve çevresel etkileşimlerle açıklamış; bu sayede *Rubus idaeus* L., ekosistemlerde hem rekabetçi hem de adaptif özellikler sergilemektedir (Leoni ve ark., 2024). Ayrıca, gelişen dikenli yapılar ve yaprak morfolojisi, türün hem doğal yayılımını hem de insan müdahalesiyle şekillenen tarımsal alanlarda var olma stratejilerini destekler niteliktedir (López ve ark., 2019).

Rubus idaeus L. bitkisi dünyada geniş bir yayılım göstermektedir. Bu türün meyvesinin lezzeti ve sağlığa olan faydaları nedeniyle dünya genelinde önemli bir bitkisel ürün olarak kabul edilmektedir (Erdem ve Karakoyun, 2023).



Görsel 1: *Rubus idaeus* L. Türkiye' deki dağılımı (URL 1).



Görsel 2: *Rubus idaeus* L.' nin Dünya Üzerindeki Dağılımı (URL 2).

Rubus idaeus L. türü, botanik açıdan dikkat çekici özellikleri, belirgin morfolojik yapısı (özellikle diken yapısı, yaprak formu ve çiçek simetrisi) ve geniş coğrafi yayılımıyla hem doğal ekosistemlerde hem de tarımsal uygulamalarda önemli bir yer tutmaktadır. Türün yüksek heterozigosite düzeyleri ile desteklenen morfolojik çeşitliliği, hem ekolojik adaptasyon stratejileri hem de üretim süreçleri açısından avantaj sağlamaktadır. Ayrıca, bozulma sonrası doğal çevrelerde hızlı kolonileşebilme kapasitesi, *Rubus idaeus* L. nin türler arası rekabetinde belirleyici bir rol oynamaktadır. Tüm bu unsurlar, türün biyolojik ve ekolojik yapısı ile yayılım paternlerinin anlaşılmasında önemli referans noktaları oluştururken, gelecekteki ıslah çalışmalarında ve sürdürülebilir tarım uygulamalarında temel bir kaynak olarak değerlendirilecektir (López ve ark., 2019).

3. DENEYSEL ÇALIŞMALAR

3.1. *Rubus idaeus* L. Bitki Örneğinin Toplanma Yeri

Bu çalışmada kullanılan *Rubus idaeus* L. bitkisine ait yaprak örnekleri, Kars ili Sarıkamış ilçesi sınırları içerisinde yer alan ormanlık alanda, kayak merkezi çevresinden (40°17'39.4" K, 42°35'38.4" D; 2482 m) 2025 yılı Temmuz ayında toplanmıştır. Arazi çalışması sırasında elde edilen bitki örneklerine ait çiçek, yaprak, kök ve gövde kısımları, taksonomik doğrulamanın yapılabilmesi amacıyla Kafkas Üniversitesi Fen-Edebiyat Fakültesi Biyoloji Bölümü Botanik Anabilim Dalı'na getirilmiş ve burada tür teşhisi gerçekleştirilmiştir. Çalışma kapsamında, ahududu bitkisinin yalnızca yaprak kısımları değerlendirilmiştir. Ahududu bitkisinin meyveleri halk arasında reçel, marmelat ve şurup yapımında yaygın olarak kullanılırken, yapraklarının ise geleneksel olarak çay şeklinde tüketildiği bilinmektedir.



Görsel 3. Toplanan *Rubus idaeus* L. bitki örnekleri

3.2. *Rubus idaeus* L. Yapraklarının Ekstraksiyon İşlemleri

Çalışmada kullanılan ahududu bitkisinin yaprakları Kars-Sarıkamış bölgesinden toplandı. Toplanan yapraklar, laboratuvara getirilerek hava sirkülasyonunun olduğu ve direk güneş ışığı görmeyen alanda kurutuldu. Kurutulan yaprak örnekleri öğütücü (IKA A11 Staufen, Germany) yardımı ile öğütüldü. Öğütülen bitki örneklerinden 50 gr alınarak kartuş içerisinde soxhlet

cihazına alındı. Ekstraksiyon çözücüsü olarak etanol kullanıldı. Kaynama balonuna 650 ml etanol çözücüsü konuldu. Çözücü berrak bir hal alıncaya kadar yaklaşık olarak 10 saat süre ile ekstrakte (10-15 sifon) edildi. 10. saat sonunda elde edilen sıvı ekstraktlar süzgeç kâğıdı (gözenek boyutu <2 µm ve çapı 110 mm olan filtre kâğıdı (Grade 589/3, Whatman, İngiltere) kullanılarak filtrelendi. Süzülerek partüküller uzaklaştırıldı. Süzülen ekstrakt örneği rotary evaporatör (Heidolph WB Laborota 4000, Almanya) ile 35-45 ºC'de çözücüleri uçuruldu. Balon içerisinde kalan ahududu yaprağı ekstraktı 12 saat süre ile desikatörde bekletildi. Çözücüsünden tamamen uzaklaştırılan ahududu ekstraktı 0,1 mg hassasiyetle tartılıp ekstrakt kutusuna konularak +4 ºC'de yapılacak olan çalışma için muhafaza edildi ve UHPLC LC-MS/MS ile analiz edildi (Uluman ve Aksu, 2020).

3.3.Rubus idaeus L. Bitki Yaprak Ekstraktının UHPLC LC MS/MS Yöntemi ile Fenolik Bileşik Analizi

Çalışmada ters faz kromatografi sistemi Agilent 1290 Infinity marka ultra yüksek performanslı sıvı kromatografi (UHPLC) sistemi kullanılmıştır. Ters faz kromatografi sisteminde çalışılan kolon Zorbax SB-C18 (4,6x100mm, 3,5 µm) ve kolon fırını sıcaklığı 30 °C'dir. Gradient yöntem kullanılarak geliştirilen yöntemde mobil faz A'da %0,1 formik asit içeren ultra saf su, mobil faz B'de de %0,1 formik asit içeren asetonitril bulunmaktadır. Kütle spektroskopi (MS) sistemi kullanılarak oluşturulan metot ile çoklu reaksiyon görüntüleme (multiple reaction monitoring, MRM) yöntemi kullanılarak organik asitlerin ve fenolik bileşiklerin miktarsal analizi gerçekleştirilmiştir. Çalışmada kullanılan MS şartları şu şekildedir; kurutucu gaz 350 °C, kurutucu gaz akışı 12 L/dk, püskürtücü gaz basıncı 55 psi, toparlayıcı gaz sıcaklığı 250 °C, toparlayıcı gaz akış hızı 5 L/dk ve kapiler voltajı 3500 V olarak belirlenmiştir. Agilent MassHunter yazılımı kullanılarak çalışma gerçekleştirilmiştir (Can ve ark., 2024).

4. SONUÇLAR VE DEĞERLENDİRME

Çizelge 1: *Rubus idaeus* L. Yaprak ekstraksiyonun fenolik içerik analiz sonuçları.

Bileşik Adı	Retansiyon zamanı (dk)	Cihaz Yanıtı	Konsantrasyon (ng/mL)
Kuinik Asit	2,344	33	0
Fumarik Asit	4,058	49	7,7562
Gallik Asit	5,592	59	0
Pirogallol	6,696	2	0
Siyanidin-3-o-glukozid	10,626	0	0
Kerasiyanin Klorür	10,683	0	0
Kateşin	10,717	3	0

Klorojenik Asit	10,744	907	3,4828
Peonidin-3-o-glukozid	10,799	2	0
4-OH-Benzoik Asit	11,203	404	0
Epikateşin	11,384	3	0
Vanilik asit	11,506	3	0
Epigallokateşin Gallat	11,568	2	0
Kafeik Asit	11,578	19	0
Viteksin	11,685	2	0
Naringin	11,842	5	0
Siringik Asit	11,968	1	0
Hesperidin	11,972	2	0
Ellagik asit	12,05	1	0
p-Kumarik Asit	12,231	963	0
Taksifolin	12,354	2	0
Rosmarinik Asit	12,483	0	0
Ferulik Asit	12,519	11	0
Sinapik Asit	12,533	2	0
Vanillin	12,551	0	0
mirisetin	12,802	0	0
Kuersetin	13,253	2	0
Luteolin	13,429	1282	0
Resveratrol	13,75	2	0
Naringenin	13,951	1	0
Apigenin	14,024	10	0,0501

Isorhamnetin	14,383	1	0
Krisin	15,619	1	0
Galangin	15,676	3	0
Kurkumin	15,7	1	0

Ahududu yaprağına ait etanol ekstraktının fenolik bileşik içeriği, UHPLC–LC-MS/MS analiz yöntemi kullanılarak kantitatif olarak değerlendirilmiştir. Gerçekleştirilen analizlerde toplam 35 farklı fenolik bileşik araştırılmış; ancak bu bileşiklerin yalnızca sınırlı bir kısmı tayin edilebilir düzeylerde tespit edilmiştir. Analiz edilen her bir bileşiğe ait retansiyon zamanı, cihaz yanıtı ve konsantrasyon (ng/mL) değerleri Çizelge 1'de ayrıntılı olarak sunulmuştur.

Elde edilen sonuçlara göre, ekstrakt içerisinde en yüksek konsantrasyona sahip bileşik fumarik asit olarak belirlenmiş ve bu bileşiğin miktarı 7,7562 ng/mL düzeyinde saptanmıştır. Fumarik asidi takiben, klorojenik asit ikinci en yüksek yoğunlukta bulunan fenolik bileşik olup, konsantrasyonu 3,4828 ng/mL olarak tespit edilmiştir.

Bunun yanı sıra, apigenin bileşiği de düşük düzeylerde olmakla birlikte analiz sonuçlarında belirlenmiştir. Örnekte apigeninin konsantrasyonu 0,0501 ng/mL olarak ölçülmüştür.

İncelenen diğer fenolik bileşiklere ait konsantrasyon değerleri, analiz sonuçlarına göre tayin edilebilirlik sınırlarının altında kalmış ve bu nedenle nicel olarak belirlenememiştir. Bu durum, söz konusu bileşiklerin ekstrakt içerisinde çok düşük düzeylerde bulunabileceğini ya da kullanılan ekstraksiyon yöntemi ve analitik koşulların bu bileşiklerin yeterli düzeyde izole edilmesine ve kantitatif olarak belirlenmesine olanak tanımamış olabileceğini düşündürmektedir. Bazı bileşikler için cihaz yanıtı gözlenmiş olmakla birlikte, kalibrasyon eğrileri ve kantifikasyon kriterleri açısından güvenilir konsantrasyon değerleri elde edilememiştir.

Ahududu yaprağı etanol ekstraktının fenolik profili genel olarak değerlendirildiğinde, literatürde yaygın olarak bildirilen bazı fenolik bileşiklerin tespit edilememiş olması, bu bileşiklerin yaprak dokusunda düşük konsantrasyonlarda bulunabileceğini veya kullanılan ekstraksiyon ve analiz yöntemlerinin bu bileşiklerin belirlenmesi açısından sınırlı kalmış olabileceğini ortaya koymaktadır. Bu bulgular, ahududu yaprağı ekstraktının belirli fenolik bileşikler bakımından zengin olmakla birlikte, bazı fenolik bileşenler açısından ise sınırlı bir içeriğe sahip olduğunu göstermektedir. Ayrıca elde edilen bulgular, rakım etkisinin tür, doku ve ekstraksiyon parametrelerine bağlı olarak değişkenlik gösterebileceğini düşündürmektedir.

5. Gıda ve Beslenme Açısından *Rubus idaeus* L. Bitkisinin Önemi

Rubus idaeus L., hem taze tüketimde hem de çeşitli işlenmiş ürünlerde kullanılan, besin değeri ve fonksiyonel bileşenler açısından zengin bir meyve türüdür (Yang ve ark., 2022; Adamczuk ve ark., 2023). Ahududu ürünleri; vitaminler, mineraller, diyet lifi ve antioksidan bileşenler bakımından zengin içerikleri sayesinde sağlıklı beslenmede ve kronik hastalıkların önlenmesinde önemli bir rol oynamaktadır (Murtić ve ark., 2022; Galli ve ark., 2023). Özellikle

yüksek düzeylerde bulunan polifenolik bileşikler, başta antosiyaninler ve ellajitanenler olmak üzere, ahududunun terapötik ve koruyucu özelliklerini destekleyen temel bileşenler arasında yer almaktadır (Wu ve ark., 2019; Yang ve ark., 2022).

Ahududunun taze olarak tüketimi, sahip olduğu doğal tat ve aroma özelliklerinin yanı sıra yüksek besin değeri ile öne çıkmaktadır. Taze ahududu; C vitamini, potasyum ve antioksidan maddeler bakımından zengin olması nedeniyle doğrudan tüketimde besleyici bir gıda olarak değerlendirilmektedir (Murtić ve ark., 2022; Adamczuk ve ark., 2023). Antioksidan içeriği sayesinde oksidatif stresin azaltılmasına katkı sağlamakta ve bağışıklık sistemini desteklemektedir (Wu ve ark., 2019). Ayrıca, meyvenin işlenmeden tüketilmesi, biyoaktif bileşenlerin doğal ve bozulmamış formda alınmasına olanak tanımaktadır (Murtić ve ark., 2022; Adamczuk ve ark., 2023).

Ahududu, reçel ve marmelat üretiminde de yaygın olarak kullanılmakta olup, bu ürünlerde meyvenin doğal şeker içeriği ve pektin düzeyi önemli bir avantaj sağlamaktadır (Zhang ve ark., 2019; Galli ve ark., 2023). Uygulanan işleme teknikleri, polifenolik bileşiklerin ve vitaminlerin mümkün olduğunca korunmasını hedeflemekte; bu sayede hem duyusal özellikler hem de besinsel değer açısından zengin ürünler elde edilmektedir (Rodríguez ve ark., 2019; Yang ve ark., 2022). Geleneksel yöntemlerle modern işleme teknolojilerinin bir arada kullanılması, son ürünlerin sağlık açısından optimum niteliklere sahip olmasını sağlamaktadır (Rodríguez ve ark., 2019; Galli ve ark., 2023).

Bunun yanı sıra *Rubus idaeus* L. şurup ve çeşitli içeceklerin üretiminde de önemli bir hammadde olarak değerlendirilmektedir. Meyvenin karakteristik aroma ve tat profili, fermente içecekler ve meyve bazlı şurupların geliştirilmesinde tercih edilmesini sağlamaktadır (Zhang ve ark., 2019; Galli ve ark., 2023). Fermentasyon süreçleri, doğal şekerlerin mikroorganizmalar aracılığıyla dönüştürülmesine olanak tanıyarak yeni tat profillerinin oluşmasına katkı sağlamaktadır (Galli ve ark., 2023). Ayrıca, ahududu kaynaklı doğal antioksidanların içecek formülasyonlarında kullanılması, ürünlerin raf ömrünü uzatmakta ve besin değerinin korunmasına yardımcı olmaktadır (Wu ve ark., 2019).

Günümüzde gıda endüstrisinde ahududu işlenmesinde modern teknolojilerden yaygın biçimde yararlanılmaktadır. Mikrodalga vakumlu kurutma gibi ileri teknikler, ürünlerin renk, doku ve besin değerlerinin korunmasını sağlayarak yüksek kaliteli nihai ürünlerin elde edilmesine olanak tanımaktadır (Rodríguez ve ark., 2019; Lei ve ark., 2022). Bunun yanı sıra, biyoteknolojik uygulamalar ve gelişmiş fermentasyon teknikleri, ahududu meyvesinden elde edilen bileşenlerin daha verimli ve sürdürülebilir şekilde kullanılmasını desteklemektedir (Yang ve ark., 2021).

Sonuç olarak, *Rubus idaeus* L. gıda ve beslenme alanında çok yönlü kullanım potansiyeline sahip, besinsel ve fonksiyonel değeri yüksek bir meyve türüdür. Taze tüketimde sağladığı yüksek besin değerinin yanı sıra, reçel, marmelat, şurup ve içecek üretiminde de önemli bir hammadde olarak değerlendirilmektedir. Geleneksel yöntemlerle modern teknolojilerin bir arada kullanılması, ahududu bazlı ürünlerin besinsel ve fonksiyonel özelliklerinin korunmasını sağlayarak, hem gıda endüstrisi hem de halk sağlığı açısından sürdürülebilir ve ekonomik bir

yaklaşım sunmaktadır (Rodríguez ve ark., 2019; Zhang ve ark., 2019; Yang ve ark., 2022; Adamczuk ve ark., 2023; Galli ve ark., 2023).

6. Fonksiyonel Gıda ve Nutrasötik Uygulamalarda *Rubus idaeus* L. Bitkisinin Antioksidan Potansiyeli ve Sağlıkla İlişkili Etkileri

Rubus idaeus L., içerdiği geniş polifenolik bileşik profili sayesinde belirgin antioksidan özellikler sergileyen ve bu yönüyle fonksiyonel gıda ve nutrasötik alanında dikkat çeken bir bitki türüdür. Ahudududa bulunan ellagik asit, antosiyaninler ve çeşitli flavonoidler gibi fenolik bileşiklerin, oksidatif strese karşı koruyucu etki gösterdiği ve serbest radikallerin neden olduğu hücresel hasarı baskıladığı çok sayıda çalışma ile ortaya konulmuştur (Renai ve ark., 2021; Lopez-Corona ve ark., 2022; Gomathi ve ark., 2024;). Bu antioksidan bileşenlerin, kalp-damar hastalıkları, kanser ve diyabet gibi kronik hastalıkların gelişiminde rol oynayan oksidatif stres mekanizmalarını modüle ederek koruyucu etki sağladığı bildirilmektedir (Lopez-Corona ve ark., 2022; Gomathi ve ark., 2024). HPLC-ESI-qTOF-MS/MS gibi ileri analitik tekniklerin kullanıldığı çalışmalarda, *Rubus idaeus* L. de bulunan spesifik antioksidan moleküller ayrıntılı biçimde karakterize edilmiş ve bu bileşiklerin biyolojik aktivite potansiyelleri ortaya konulmuştur (Wu ve ark., 2019; Renai ve ark., 2021).

Ahududunun antioksidan bakımından zengin içeriği, bu bitkiyi fonksiyonel gıda ve takviye edici gıda formülasyonları için cazip bir hammadde hâline getirmektedir. Takviye edici gıdalar, bireylerin günlük beslenmesini desteklemek ve sağlıklı yaşamı teşvik etmek amacıyla kullanılan ürünler olup, ahududu kaynaklı polifenollerin bu ürünlerde oksidatif stresin azaltılmasına katkı sağladığı bildirilmektedir (Lopez-Corona ve ark., 2022). Özellikle *in vitro* ve *in vivo* modellerde gerçekleştirilen çalışmalar, ahududu ekstraktlarının antioksidan ve antiinflamatuar etkilere sahip olduğunu doğrulamakta ve bu özelliklerin fonksiyonel gıda olarak kullanımını desteklediğini göstermektedir (Lopez-Corona ve ark., 2022; Gomathi ve ark., 2024).

Nutraseötik ürünler açısından değerlendirildiğinde, *Rubus idaeus* L. nin potansiyeli yalnızca besinsel değerle sınırlı olmayıp, terapötik etkilerle de ilişkilidir. Yüksek düzeyde biyoaktif bileşik içeren ahududu özleri, özellikle cilt sağlığının desteklenmesi ve yaşlanma karşıtı uygulamalar kapsamında nutrasötik ürünlerde yaygın olarak kullanılmaktadır (Papaioanou ve ark., 2018). Bunun yanı sıra, ahududu tohumlarından elde edilen yağların esansiyel yağ asitleri, vitaminler ve antioksidanlar bakımından zengin olması, bu bileşenlerin hem besin takviyesi hem de kozmetik formülasyonlarda değerli birer hammadde olarak değerlendirilmesine olanak tanımaktadır (Ispiryan ve ark., 2021). Ayrıca, gıda işleme süreçlerinde ortaya çıkan posa gibi yan ürünlerin fenolik bileşikler açısından zengin olması, bu materyallerin yeniden değerlendirilerek fonksiyonel ve nutrasötik ürün geliştirme çalışmalarında kullanılmasını desteklemektedir (Wójciak ve ark., 2023).

Fonksiyonel gıda ve nutrasötik ürünlerin geliştirilmesinde, ahududunun antioksidan özelliklerine dayalı stratejiler ön plana çıkmaktadır. Bu kapsamda, standartlaştırılmış ekstraktlar, toz formlar veya sıvı konsantreler gibi farklı ürün formatları, oksidatif strese karşı koruyucu etki sağlamak amacıyla formüle edilmektedir. Ürün geliştirme sürecinde, kullanılan ekstraktların fenolik bileşik konsantrasyonları, uygulanan işleme teknikleri ve üretim koşulları, nihai ürünün biyolojik etkinliği açısından belirleyici faktörler olarak değerlendirilmektedir (Wu

ve ark., 2019; Renai ve ark., 2021). Artan tüketici talebi doğrultusunda, doğal bileşenlere dayalı takviye edici gıdalar ve nutrasötik ürünlerin ticarileştirilmesi giderek önem kazanmakta; ahududu kaynaklı ekstraktların gıda, kozmetik ve farmasötik sektörlerinde kullanımı, sağlık destekleyici ürün yelpazesinin genişlemesine katkı sağlamaktadır (Papaioanou ve ark., 2018; Ispiryan ve ark., 2021).

Sonuç olarak, *Rubus idaeus* L. fonksiyonel gıda ve nutrasötik sektörlerinde yüksek kullanım potansiyeline sahip, biyoaktif bileşikler açısından zengin bir bitki türüdür. Geniş polifenolik ve antioksidan profili sayesinde, hem takviye edici gıdalarda hem de nutrasötik ürünlerde önemli bir rol üstlenmektedir. Gelişen analitik yöntemler, ahudududa bulunan biyoaktif bileşiklerin daha ayrıntılı biçimde tanımlanmasını ve standartlaştırılmasını mümkün kılarak, bu bitkinin sağlık üzerindeki olumlu etkilerinin kronik hastalıkların önlenmesi ve yaşlanma karşıtı uygulamalar bağlamında gelecekte de önemini koruyacağını göstermektedir (Papaioanou ve ark., 2018; Ispiryan ve ark., 2021; Renai ve ark., 2021; Lopez-Corona ve ark., 2022; Wójciak ve ark., 2023; Gomathi ve ark., 2024).

7. Farmasötik Uygulamalarda *Rubus idaeus* L. Bitkisinin Potansiyeli

Rubus idaeus L., sahip olduğu doğal anti-inflamatuar, antioksidan ve koruyucu özellikleri nedeniyle farmasötik uygulamalarda dikkat çeken bitkisel kaynaklardan biridir. Klinik ve *in vitro* çalışmalar, ahududu yaprak ve meyve ekstraktlarının inflamatuar süreçlerin baskılanması ve doku onarımının desteklenmesi üzerinde olumlu etkilere sahip olduğunu ortaya koymaktadır. Özellikle Henrotin ve arkadaşları tarafından gerçekleştirilen çalışmalarda, ahududu yaprak ekstraktının diz osteoartriti hastalarında inflamatuar medyatörlerin ekspresyonunu azalttığı ve buna bağlı olarak eklem ağrılarının hafifletilmesine katkı sağlayabileceği bildirilmiştir. Bu etkilerin, ekstrakt içerisinde yer alan flavonoidler ve fenolik bileşiklerin anti-inflamatuar mekanizmalar üzerindeki düzenleyici rollerinden kaynaklandığı belirtilmiştir (Henrotin ve ark., 2022).

Ahududu ekstraktlarının farmasötik açıdan önemini artıran bir diğer özellik ise güçlü antioksidan kapasiteleridir. Yapılan çalışmalar, bu ekstraktların reaktif oksijen türlerine (ROS) karşı etkili olduğunu ve oksidatif strese bağlı doku hasarının önlenmesinde önemli bir rol oynayabileceğini göstermektedir (Wang ve ark., 2019; Heckmann ve ark., 2024). Wang ve çalışma arkadaşları, *Rubus idaeus* L. ekstraktının UVB ışınımına bağlı cilt hasarını önlemede potansiyel bir koruyucu ajan olarak değerlendirilebileceğini ve bu etkinin antioksidan ve anti-inflamatuar bileşiklerin varlığı ile ilişkili olduğunu bildirmiştir (Wang ve ark., 2019). Bu bulgular, ahududu bazlı preparatların kozmetik ve dermatolojik uygulamalarda kullanım potansiyelini de desteklemektedir (Ziemlewska ve ark., 2022).

Farmasötik preparatlar açısından değerlendirildiğinde, *Rubus idaeus* L. ekstraktlarının hem koruyucu hem de destekleyici ürün formülasyonlarında geniş bir kullanım alanına sahip olduğu görülmektedir. Bu preparatlar, klasik tedavi yaklaşımlarına ek olarak inflamasyonun kontrol altına alınması, ağrı yönetimi ve antioksidan koruma sağlanması amacıyla tercih edilmektedir. Bourmaud ve arkadaşları, ahududu ekstraktı içeren formülasyonların eklem kıkırdağının bozulmasını yavaşlattığını ve inflamasyonla ilişkili gen ekspresyonlarında anlamlı bir azalma sağladığını göstermiştir (Bourmaud ve ark., 2021). Benzer şekilde, Papaioanou ve

meslektaşları, ahududunun besinsel ve fonksiyonel özelliklerinin yaşlanma karşıtı etkiler ve eklem sağlığını destekleyici farmasötik preparatların geliştirilmesinde değerlendirilebileceğini vurgulamıştır (Papaioanou ve ark., 2018).

Ahududu yapraklarının farmasötik hammadde olarak kullanımı, özellikle fenolik asitler, flavonoidler ve antosiyaninler gibi tanımlı biyoaktif bileşikler bakımından zengin olması nedeniyle yaygınlaşmaktadır. Bowman ve arkadaşlarının sistematik derlemesi, *Rubus idaeus* L. yapraklarının özellikle gebelik döneminde güvenli kullanım açısından yaygın biçimde tercih edildiğini ve bu bitkinin maternal sağlık ile doğum süreci üzerindeki potansiyel faydalarına dikkat çekmektedir (Bowman ve ark., 2021). Bununla birlikte, farmasötik alanda güvenli ve etkili kullanımın sağlanabilmesi için uygun standardizasyon süreçlerinin ve optimize edilmiş ekstraksiyon tekniklerinin geliştirilmesinin kritik öneme sahip olduğu belirtilmektedir (Henrotin ve ark., 2022; Bourmaud ve ark., 2021).

Sonuç olarak, *Rubus idaeus* L., farmasötik uygulamalarda inflamasyonun azaltılması, antioksidan korumanın sağlanması, cilt ve eklem sağlığının desteklenmesi ile maternal sağlık preparatlarında kullanım açısından yüksek bir potansiyele sahiptir. Mevcut literatür, ahududu yaprak ve meyve ekstraktlarının preklinik ve klinik çalışmalarda elde edilen olumlu bulgularla desteklendiğini ortaya koymakta olup, bu durum gelecekte daha güvenli, standartlaştırılmış ve yaygın farmasötik kullanım stratejilerinin geliştirilmesine olanak tanımaktadır (Papaioanou ve ark., 2018; Wang ve ark., 2019; Bowman ve ark., 2021; Bourmaud ve ark., 2021; Henrotin ve ark., 2022; Ziemlewska ve ark., 2022).

8. Geleneksel Tıpta *Rubus idaeus* L. Yaprak Çayının Kullanımı ve Sağlıkla İlişkili Etkileri

Rubus idaeus L., Avrupa ve Kuzey Amerika kökenli bir bitki olup, yüzyıllardır geleneksel tıp uygulamalarında özellikle kadın sağlığı ve çeşitli sistemik rahatsızlıkların giderilmesinde kullanılmaktadır (Luo ve ark., 2020; Farnaghi ve Braniff, 2022). Ahududu yapraklarından hazırlanan çay, geleneksel uygulamalarda doğum öncesi ve doğum sonrası dönemlerde rahim kasılmalarının düzenlenmesi, doğum sürecinin desteklenmesi ve doğum ağrılarının hafifletilmesi amacıyla yaygın biçimde tercih edilmiştir. Bu kullanım alanları, son yıllarda yürütülen klinik ve gözlemsel çalışmaların da odağında yer almakta ve geleneksel bilgilerin bilimsel olarak değerlendirilmesine olanak sağlamaktadır (Luo ve ark., 2020; Farnaghi ve Braniff, 2022).

Hamilelik döneminde ahududu yaprak çayının tüketimi, özellikle doğumun kolaylaştırılması, Braxton–Hicks kasılmalarının azaltılması ve doğum sürecinin daha kontrollü ilerlemesi amacıyla önerilmektedir. Farnaghi ve Braniff tarafından bildirilen bulgular, gebelik süresince düzenli olarak tüketilen ahududu yaprak çayının bazı doğumla ilişkili komplikasyonların hafifletilmesine katkı sağlayabileceğini göstermektedir (Farnaghi ve Braniff, 2022). Bu uygulama, sözlü ve yazılı geleneksel tıp kaynaklarında uzun süredir yer almakta olup, kültürler arası aktarım yoluyla günümüze kadar ulaşmıştır (Luo ve ark., 2020).

Ahududu yaprak çayının geleneksel kullanım alanları yalnızca gebelikle sınırlı değildir. Halk tıbbında bu çayın ishal, kolik, kramp ve diğer gastrointestinal rahatsızlıkların giderilmesinde yaygın olarak kullanıldığı bildirilmektedir (Isnawati ve ark., 2019; Kováč ve ark., 2021).

Ayrıca, yara iyileşmesi ve deri iltihaplarının tedavisinde de ahududu yapraklarının değerlendirildiği, bu etkinin bitkinin anti-inflamatuar ve antimikrobiyal özellikleriyle ilişkili olduğu ifade edilmektedir (Yang ve ark., 2020; Héjja ve ark., 2025).

Ahududu yapraklarının bağışıklık sistemini destekleyici etkileri de geleneksel kullanımın önemli bir boyutunu oluşturmaktadır. Yaprakların içerdiği yüksek düzeyde polifenoller, tanenler ve diğer biyoaktif bileşikler, antioksidan özellikler göstererek serbest radikallerin neden olduğu hücresel hasarı azaltmakta ve vücudun doğal savunma mekanizmalarının güçlenmesine katkı sağlamaktadır (Garjonytė ve ark., 2022). Geleneksel tıpta bu bitkinin bağışıklığı artırıcı etkisi, kronik inflamasyon ve enfeksiyonların tedavisinde tamamlayıcı bir yaklaşım olarak değerlendirilmektedir (Yang ve ark., 2020). Bunun yanı sıra, bazı çalışmalarda *Rubus idaeus* L. yapraklarında bulunan bileşiklerin antimikrobiyal aktivite gösterdiği ve bu özelliğin enfeksiyonların önlenmesine destek olabileceği rapor edilmiştir (Héjja ve ark., 2025).

Geleneksel kullanımlara ilişkin bu bilgiler, modern farmakolojik ve biyomedikal araştırmalarla da büyük ölçüde örtüşmektedir. Ahududu yapraklarının antioksidan ve anti-inflamatuar özellikleri, gastrointestinal sistem sağlığının korunmasının yanı sıra, bağışıklık sisteminin desteklenmesi ve kronik hastalıkların önlenmesine yönelik potansiyel etkiler açısından da değerlendirilmektedir (Veljković ve ark., 2018; Yang ve ark., 2020). Bu durum, geleneksel tıp uygulamalarının modern bilimsel yaklaşımlarla entegrasyonuna yönelik önemli bir örnek teşkil etmektedir.

Sonuç olarak, *Rubus idaeus* L. yaprak çayı, geleneksel tıpta uzun yıllardır gebelik sürecinin desteklenmesi, gastrointestinal rahatsızlıkların giderilmesi ve bağışıklık sisteminin güçlendirilmesi amacıyla kullanılan önemli bir bitkisel üründür. Modern bilimsel çalışmalar, bu geleneksel uygulamaların antioksidan, anti-inflamatuar ve antimikrobiyal özelliklerle desteklendiğini ortaya koymaktadır (Yang ve ark., 2020; Farnaghi ve Braniff, 2022; Garjonytė ve ark., 2022; Héjja ve ark., 2025). Bununla birlikte, terapötik etkinliğin ve güvenli kullanımın daha net biçimde ortaya konulabilmesi için ileri düzey klinik çalışmalara ihtiyaç duyulmaktadır.

9. Kozmetik ve Kişisel Bakım Ürünlerinde *Rubus idaeus* L. Bitkisinin Kullanım Potansiyeli

Kozmetik ve kişisel bakım sektöründe doğal ve bitkisel içeriklere olan ilgi son yıllarda belirgin biçimde artmaktadır. Tüketiciler, sentetik katkı maddeleri içeren ürünler yerine, cilt sağlığını destekleyen, antioksidan ve anti-enflamatuar özelliklere sahip doğal bileşenleri içeren formülasyonları tercih etmektedir (Papaioanou ve ark., 2018; Kumar ve ark., 2024). Bu eğilim doğrultusunda bitkisel kaynaklar, güvenilirlikleri ve fonksiyonel özellikleri nedeniyle kozmetik endüstrisinde giderek daha fazla önem kazanmaktadır. Bu bitkiler arasında yer alan *Rubus idaeus* L. zengin biyoaktif bileşen içeriği sayesinde hem besleyici hem de kozmetik açıdan değerli bir doğal hammadde olarak öne çıkmaktadır.

Rubus idaeus L. nin kozmetik uygulamalardaki temel avantajlarından biri, içerdiği flavonoidler ve fenolik asitler aracılığıyla sergilediği güçlü antioksidan etkidir. Bu bileşikler, serbest radikallerin neden olduğu oksidatif hasarı azaltarak cilt yaşlanmasının geciktirilmesine ve cilt yapısının korunmasına katkı sağlamaktadır. Papaioanou ve arkadaşları tarafından yapılan çalışmalarda, ahududunun cosmeceutical özellikleri değerlendirilmiş; yaşlanma karşıtı

etkilerinin yanı sıra cilt yenilenmesini destekleyici ve koruyucu özellikler gösterdiği rapor edilmiştir (Papaioanou ve ark., 2018). Bu özellikler, ahududu kaynaklı bileşenlerin cilt bakım ürünlerinde antioksidan destekleyici aktif maddeler olarak kullanılmasını mümkün kılmaktadır.

Ahududunun kozmetik formülasyonlarda kullanımı, aynı zamanda doğal ve ciltle uyumlu ürünlerin geliştirilmesine olanak tanımaktadır. Bitkisel içeriklerin sentetik bileşenlere kıyasla daha düşük irritasyon potansiyeline sahip olması, özellikle hassas ciltler için geliştirilen ürünlerde önemli bir avantaj sunmaktadır. Günümüzde doğal içerikli kozmetik ürünlere yönelik artan tüketici talebi, *Rubus idaeus* L. gibi bitkisel hammaddelerin formülasyonlarda daha yaygın biçimde yer almasını desteklemektedir (Kumar ve ark., 2024). Bunun yanı sıra, bu tür doğal bileşenlerin cilt bariyerini güçlendirici etkileri, dermokozmetik ürünlerde koruyucu ve onarıcı ajanlar olarak kullanımını da teşvik etmektedir.

Rubus idaeus L. nin anti-enflamatuar özellikleri, ciltte görülen kızarıklık, irritasyon ve inflamatuar reaksiyonların hafifletilmesinde potansiyel bir rol oynamaktadır. Bu özellikler, hassas ve problemli cilt tiplerine yönelik geliştirilen kozmetik ürünlerde doğal aktif bileşen olarak değerlendirilmesini sağlamaktadır. Ayrıca, ahududunun doğal emollient özellikleri cilt nem dengesinin korunmasına katkıda bulunarak, kuru cilt problemlerinin giderilmesinde destekleyici bir etki sunmaktadır (Kumar ve ark., 2024). Bu bağlamda, *Rubus idaeus* L. içeren ekstraktların krem, losyon ve benzeri cilt bakım ürünlerinde etkin bir şekilde kullanılabildiği görülmektedir.

Kozmetik sektöründe estetik etkilerin yanı sıra fonksiyonel faydalar sunan ürünlere olan ilginin artmasıyla birlikte, cosmeceutical ürünler önemli bir gelişim alanı haline gelmiştir. Cilt yenilenmesi, nemlendirme, antioksidan koruma ve yaşlanma karşıtı etkileri bir arada sunmayı amaçlayan bu ürünlerde, ahududunun cosmeceutical özellikleri fonksiyonel bütünlüğü artırmakta ve cilde ilave koruyucu faydalar kazandırmaktadır (Papaioanou ve ark., 2018). Bu durum, *Rubus idaeus* L. temelli kozmetik ürünlerin pazarda hem doğal bir alternatif hem de etkili bir cilt bakım çözümü olarak konumlandırılmasına olanak tanımaktadır.

Sonuç olarak, *Rubus idaeus* L. bitkisi, kozmetik ve kişisel bakım ürünlerinde özellikle cilt bakım uygulamaları açısından önemli bir doğal bileşen olarak değerlendirilmektedir. Antioksidan, anti-enflamatuar ve nemlendirici özellikleri sayesinde cilt sağlığını desteklemekte; yaşlanma karşıtı ve koruyucu etkileri ile doğal içerikli kozmetik formülasyonlarda öne çıkmaktadır (Papaioanou ve ark., 2018; Kumar ve ark., 2024). Doğal ve güvenli ürünlere yönelik artan tüketici talebi, ahududunun kozmetik endüstrisindeki kullanım alanlarının ilerleyen dönemlerde daha da genişleyeceğine işaret etmektedir.

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MİTOMİSİN-C KAYNAKLI GENETİK HASAR VE BİTKİSEL EKSTRAKTLARIN İN VİVO KORUYUCU POTANSİYELİ

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ÖZET

Mitomisin-C (MMC), çeşitli malignitelerin tedavisinde yaygın olarak kullanılan güçlü bir kemoterapötik ajandır. Ancak DNA üzerinde çapraz bağları oluşturması ve oksidatif stres mekanizmalarını tetiklemesi nedeniyle belirgin genotoksik yan etkilere yol açabilmektedir. Bu genetik hasar, mikronükleus oluşumu, kromozomal aberasyonlar gibi biyobelirteçlerle fare ve rat gibi deney hayvanı modellerinde açıkça gözlenmektedir. Son yıllarda, bitkisel kökenli ekstraktların antioksidan ve antimutajenik özellikleri, kemoterapi kaynaklı genetik hasarın azaltılmasına yönelik umut verici bir yaklaşım olarak öne çıkmaktadır. Bu derlemenin amacı, MMC'nin *in vivo* modellerde oluşturduğu genetik hasar mekanizmalarını ve bitkisel ekstraktların bu hasara karşı potansiyel koruyucu etkilerini literatür bulguları ışığında değerlendirmektir.

Çalışmada, mikronükleus testi ve kromozomal aberasyon analizi gibi *in vivo* genotoksisite değerlendirme yöntemlerinin önemi ele alınmış; ayrıca fenolik bileşikler ve flavonoidler açısından zengin bitkisel ekstraktların antioksidan, antimutajenik ve antigenotoksik özellikleri tartışılmıştır. Literatürde yer alan bulgular, bazı bitkisel ekstraktların MMC kaynaklı DNA hasarını doza bağlı olarak azalttığını, oksidatif stres düzeylerini düşürdüğünü ve DNA onarım mekanizmalarını destekleyebildiğini göstermektedir.

Sonuç olarak, uygun doz ve uygulama koşulları altında kullanılan bitkisel ekstraktların, MMC kaynaklı genetik hasara karşı tamamlayıcı ve koruyucu ajanlar olarak umut vadettiği görülmektedir. Bununla birlikte, doz–yanıt ilişkilerinin dikkatle değerlendirilmesi ve ileri preklinik çalışmalarla desteklenmesi gereklidir.

Anahtar Kelimeler: Mitomisin-C, *in vivo*, mikronükleus.

1. Giriş

Genetik hasar, DNA yapısında meydana gelen değişiklikleri ifade ederken; genotoksisite kavramı ise, bu hasarın canlıya veya hücrelere zarar verici etkilerini tanımlamaktadır. Günümüzde, hem laboratuvar hem de klinik çalışmalar, genetik hasarın ve genotoksisitenin, kanser ve diğer kronik hastalıkların patogenezinde önemli roller oynadığını göstermektedir (Lee ve ark., 2018; Barabadi ve ark., 2019). Bu konular, moleküler biyoloji ve biyomedikal araştırmaların temel unsurlarındandır. Ayrıca, genetik materyalde meydana gelen hasarın tespiti için kullanılan çeşitli test yöntemleri DNA hasarının derecesini belirlemede yaygın olarak kullanılmaktadır (Shah ve ark., 2023).

Genetik hasarın temelinde DNA molekülünde yapısal bozukluklar, mutasyonlar ve kromozomal aberasyonlar yer almaktadır (Lee ve ark., 2018; Barabadi ve ark., 2019). Genotoksisite ise bu bozuklukların hücresel fonksiyonlara, özellikle de hücre bölünmesi, apoptoz ve onarım mekanizmalarına olan etkilerini araştırmaktadır (Shah ve ark., 2023). Bilimsel çalışmalar, kemik iliği hücrelerinde ve diğer organizmalarda genetik hasarın, doğrudan veya dolaylı yollardan kanser gibi ciddi hastalıklara yol açabileceğini ortaya koymuştur (Lee ve ark., 2018; Barabadi ve ark., 2019). Bu durum, çeşitli laboratuvar testleri ve *in vitro* modellerle de desteklenmektedir (Lee ve ark., 2018).

Kemoterapötik ajanlar, kanser tedavisinde yaygın biçimde kullanılan temel ilaç grupları arasında yer almaktadır. Bununla birlikte, bu ajanların DNA üzerinde hasar oluşturabilme potansiyeli, tedavi sürecinde istenmeyen toksik etkilerin ve genetik bozuklukların ortaya çıkmasına neden olabilmektedir. Literatürde bildirilen çalışmalar, kemoterapiye bağlı yan etkiler arasında genotoksisitenin önemli bir yer tuttuğunu ortaya koymakta ve tedavi sırasında oluşabilecek genetik hasarın en aza indirilmesinin gerekliliğini vurgulamaktadır. Özellikle genetik hasarın uzun vadeli sonuçları, tedavi sonrası dönemde kanser nüksü gibi ciddi klinik sorunların ortaya çıkma riskini artırabilmektedir. Bu nedenle, genetik hasarın kontrol altına alınması, hem hasta güvenliğinin sağlanması hem de tedavi etkinliğinin artırılması açısından kritik bir öneme sahiptir. Bu durum, klinik uygulamalarda kemoterapiye bağlı genotoksik etkileri azaltmaya yönelik yeni ve tamamlayıcı stratejilerin geliştirilmesi gerekliliğini gündeme getirmektedir (Liu ve ark., 2018).

Son yıllarda bitkisel kökenli doğal ürünlerin sağlık üzerindeki olumlu etkilerine yönelik artan ilgi, hem halk sağlığı hem de klinik uygulamalar açısından önemli bir araştırma alanı haline gelmiştir (Tanaka ve ark., 2023; Kawish ve ark., 2024). Bitkisel bileşikler, özellikle antioksidan ve antiinflamatuar özellikleri sayesinde kemoterapi kaynaklı genetik hasara karşı koruyucu etkiler sergileyebilmektedir. Örneğin, curcumin gibi bitkisel kökenli aktif maddeler, kemoterapötik ajanların neden olduğu yan etkilerin azaltılmasına yardımcı olabilmekte; böylece tedavi sırasında genetik hasarın minimalize edilmesinde destekleyici bir rol oynamaktadır (Liu ve ark., 2018; Ayaz ve ark., 2022). Ayrıca, bitkisel ürünlerin klinik kullanımlara entegre edilmesinin, tedavi protokollerine eklenen koruyucu stratejiler olarak değerlendirilebileceği düşünülmektedir (Tanaka ve ark., 2023). Bu çalışmalar, bitkisel ürünlerin potansiyel olarak kemoterapötik ajanların toksik yan etkilerini hafiflettiğini ve böylece genetik hasarların önlenmesine katkıda bulunduğunu göstermektedir (Liu ve ark., 2018; Ayaz ve ark., 2022).

Bitkisel kaynaklı doğal bileşikler, sadece yan etkilerin azaltılmasında değil, aynı zamanda kanser ve diğer dejeneratif hastalıkların önlenmesinde de umut vaat etmektedir (Tanaka ve ark., 2023; Kawish ve ark., 2024). Preklinik çalışmalardan elde edilen bulgular, özellikle diyet yoluyla alınan biyolojik olarak aktif bileşiklerin, DNA onarım süreçlerini desteklemesi ve oksidatif stres düzeylerini azaltması yoluyla koruyucu etkiler ortaya koyduğunu göstermektedir. Bu bağlamda, bitkisel kökenli ürünlere yönelik araştırmalar, yalnızca temel bilimler açısından değil, aynı zamanda klinik uygulamalara yansıyabilecek yeni ve yenilikçi tedavi yaklaşımlarının geliştirilmesinde de önemli bir potansiyel taşımaktadır (Ayaz ve ark., 2022; Tanaka ve ark., 2023; Hou ve ark., 2024; Kawish ve ark., 2024).

Özetle, genetik hasar ve genotoksisite kavramları, modern tıpta hem tanısal hem de tedavi süreçlerinde merkezî bir yer tutmaktadır. Kemoterapötik ajanlara bağlı genetik hasar, tedavi etkinliğini ve hasta yaşam kalitesini doğrudan etkileyen kritik bir parametre olmakla birlikte, bu hasarın minimalize edilmesine yönelik geliştirilmekte olan stratejiler, özellikle bitkisel kökenli doğal ürünlerin antioksidan, antigenotoksik ve antiinflamatuar özellikleri ile desteklenmektedir. Gelecekte, bu alanda yapılacak bilimsel araştırmalar, hem kemoterapi protokollerinin iyileştirilmesine hem de kanser önleyici stratejilerin geliştirilmesine büyük katkılar sağlayacaktır (Liu ve ark., 2018; Kawish ve ark., 2024).

2. Mitomisin-C'nin Genetik Hasar Oluşturma Mekanizmaları

Mitomisin-C'nın temel antikanser etkisi, hücresel DNA'ya doğrudan zarar vererek tümör hücrelerini yok eden alkile edici özelliklerden kaynaklanmaktadır. Bu ajan, hücre içine girdikten sonra redüktif aktivasyona uğrar ve aktif hale geldiğinde, DNA üzerinde hem interstrand hem de intrastrand çapraz bağlar oluşturan alkile edici grupları ortaya çıkarır. Bu çapraz bağlar, DNA replikasyonunu engelleyerek direkt hücre ölümüne (apoptoz) ve genetik hasara yol açar. Ayrıca, mitomisin-C'nin redüksiyon aşamasında ürettiği ara ürünler, oksijen varlığında redoks döngüsü gerçekleştirerek reaktif oksijen türlerinin (ROS) oluşumuna katkı sağlayabilir; bu da hücresel bileşenler üzerinde oksidatif hasara neden olmaktadır (Abbas Naji ve ark., 2018).

Bu mekanizma, tümör hücrelerinde DNA tamir sistemlerinin yetersiz olmasından dolayı daha belirgin bir etki göstermekte ve özellikle DNA çapraz bağ tamir yollarındaki defektler, mitomisin-C'ye duyarlılığı artırmaktadır. Klinik uygulamalarda Fanconi anemisi gibi DNA tamirinde bozukluklar bulunan hastalarda, mitomisin-C'nin kullanımı, bu hastalıklarda artmış kromozomal kırık duyarlılığı ile ilişkilendirilmiştir. Bu durum, mitomisin-C'nin genetik materyal üzerindeki etkilerinin hem direkt DNA alkilasyonu hem de oksidatif stres aracılığı ile gerçekleştiğini göstermektedir (Bhatt ve ark., 2024).

Modern tedavi rejimlerinde, mitomisin-C'nin doz bağımlı yan etkileri de önemlidir; örneğin, anal kanserde kullanılan kombinasyon tedavilerinde, ilaç dozu arttıkça, hücresel DNA üzerinde meydana gelen genotoksik hasar ve bunun sonucunda gelişen komplikasyonlar, tedavi sürecinde klinik yönetim açısından dikkate alınmaktadır (Sheth ve ark., 2025). Ayrıca, klinik ve moleküler çalışmalar mitomisin-C'nın antikanser etkisinin yanı sıra, hücresel DNA hasarının incelenmesine yönelik metodolojik yaklaşımların geliştirilmesinde referans ajan olarak kullanılmasını da desteklemektedir (Abbas Naji ve ark., 2018).

Mitomisin-C, tanımlandığı kimyasal özellikler ve biyolojik aktivitesi ile hem kanser tedavisinde hem de lokal uygulamalarda kullanılan önemli bir tedavi ajanıdır. Klinik alanda çeşitli malignitelerin tedavisinde ve özellikle postoperatif skar oluşumunu azaltma gibi lokal uygulamalarda yararlı sonuçlar elde edilmiştir (Shokrzadeh ve Ghassemi-Barghi., 2018; Rashed & El-Guindi, 2019). Genetik hasar mekanizması bakımından ise, mitomisin-C, hücresel redüksiyon süreçleri ile aktive olunarak DNA'da çapraz bağlar oluşturan alkile edici gruplar ürettiği için, DNA replikasyonu ve hücre bölünmesi üzerinde ciddi hasarlar meydana getirmekte, bu da özellikle kanser hücrelerinin apoptozunu indüklemekte önemli bir rol oynamaktadır (Abbas Naji ve ark., 2018). Ayrıca, bu mekanizma, DNA tamir yollarında bulunan bozuklukların da etkilerinin artmasına yol açarak klinik duyarlılığı değiştirmekte, böylece tedavi planlamasında dikkatle izlenmesi gereken bir parametre haline gelmektedir (Bhatt ve ark., 2024; Sheth ve ark., 2025).

3. *In Vivo* Genotoksisite Değerlendirme Yaklaşımları

In vivo genotoksisite, bir maddenin genetik materyale zarar verip vermediğinin canlı organizma üzerinde gerçekleştirilen testler vasıtasıyla belirlenmesidir. Deney hayvanı modellerinin kullanıldığı araştırmalar, mikronükleus testi ve kromozomal aberasyon analizi gibi *in vivo* yöntemlerin genotoksik değerlendirmelerdeki önemini ve uygulanabilirliğini açıkça göstermektedir.

3.1. Deney Hayvanı Modellerinin Kullanımı

Deney hayvanı modelleri, ilaç geliştirme, toksikoloji ve ilaç güvenliği açısından kritik veriler sağlamaktadır. Araştırmalar, özellikle fareler, sıçanlar ve diğer küçük memeliler üzerinde yapılan genotoksisite çalışmalarında, maddenin sistemik etkileri ve potansiyel DNA hasarı incelenmektedir (Wei ve ark., 2019; Won ve ark., 2021). Bu modeller, genetik hasar mekanizmalarını hem mikroskobik hem de makroskobik düzeyde gözlemlemeye olanak tanımakta ve elde edilen veriler, uluslararası düzenleyici otoriteler tarafından kabul gören yöntemlere dayanmaktadır. Bu çalışmalar, potansiyel insan sağlığı risklerinin erken teşhisi ve önlenmesine yardımcı olup, ilaç geliştirme süreçlerinde kritik bir rol oynamaktadır (Wei ve ark., 2019; Won ve ark., 2021).

3.2. Mikronükleus Testi

Mikronükleus testi, kemik iliği veya periferik kan örneklerinden elde edilen hücrelerde, kromozomal kırıklar ve kromozom kayıpları sonucunda oluşan mikronükleusların sayımına dayanan güvenilir bir genotoksisite değerlendirme yöntemidir. Özellikle kemik iliği hücreleri üzerinde uygulandığında, bu test genotoksik etkinin doğrudan bir göstergesi olarak kabul edilmektedir (Wei ve ark., 2019; Mathur ve ark., 2023). Yapılan çalışmalarda, bitkisel kökenli özlerin mikronükleus testi kapsamında genotoksik bir etki oluşturmadığı gösterilmiş ve bu bulgu, doğal ürünlerin güvenilirliğinin değerlendirilmesinde mikronükleus testinin önemini ortaya koymuştur (Wei ve ark., 2019). Ayrıca *in vivo* genotoksisite çalışmalarında, mikronükleus testinin farklı hayvan modelleri kullanılarak elde edilen sonuçlarının diğer genotoksisite testleriyle uyumlu olduğu bildirilmiştir (Won ve ark., 2021). Bu paralellik, mikronükleus testinin hassas ve güvenilir bir metodoloji olduğunu desteklemektedir (Won ve ark., 2021; Mathur ve ark., 2023).

3.3. Kromozomal Aberasyon Analizi

Kromozomal aberasyon analizi, hücre kültürlerinde veya canlı organizmalarda kromozomlarda meydana gelen yapısal değişikliklerin belirlenmesine yönelik olarak kullanılan *in vivo* ve *in vitro* bir genotoksisite test yöntemidir. Bu analiz, kromozomal kırıklar, kromatid kırılmaları ve diğer yapısal anomaliler gibi genetik hasarların saptanmasında temel bir araç olarak kabul edilmektedir (Won ve ark., 2021; He & Xu, 2022). He ve Xu tarafından yürütülen çalışmalarda, *Camellia euphlebia* yaprak özlerinin genotoksik potansiyeli çeşitli genotoksisite testleri kullanılarak değerlendirilmiş ve elde edilen bulguların farklı metodolojilerle tamamlayıcı nitelikte olduğu gösterilmiştir (He & Xu, 2022). Bu tür çalışmalar, test edilen maddelerin genetik yapı üzerindeki etkilerinin bütüncül bir yaklaşımla değerlendirilmesine olanak sağlayarak, potansiyel mutajenik risklerin erken dönemde belirlenmesine önemli katkılar sunmaktadır (Won ve ark., 2021; He & Xu, 2022).

3.4. *In Vivo* Genotoksisite Çalışmalarının Önemi

In vivo genotoksisite değerlendirmeleri, maddelerin insan sağlığı üzerindeki potansiyel etkilerinin ortaya konulması açısından büyük önem taşımaktadır. Bu tür çalışmalar, klinik geliştirme süreçlerinde kullanılan bileşiklerin güvenlik profillerinin kapsamlı ve sistematik bir biçimde değerlendirilmesine olanak sağlamaktadır (Şen ve ark., 2018). Özellikle terapötik ajanlar ile çevresel toksinlerin genetik materyal üzerindeki etkilerinin aydınlatılması, olası risklerin erken dönemde belirlenmesi ve uygun müdahale stratejilerinin geliştirilmesi açısından kritik bir gerekliliktir (Mathur ve ark., 2023). Yeni ilaç geliştirme süreçlerinde düzenleyici otoriteler, genotoksisite testlerinden elde edilen verilerin uluslararası standartlar doğrultusunda değerlendirilmesini zorunlu kılmaktadır (Şen ve ark., 2018). Bu kapsamda, kullanılan hayvan modelleri test yöntemlerinin geçerliliğini ve sonuçların güvenilirliğini artırarak potansiyel halk sağlığı risklerinin en aza indirilmesine katkı sağlamaktadır (Wei ve ark., 2019; Won ve ark., 2021).

In vivo genotoksisite değerlendirme yaklaşımları, deney hayvanı modellerinin kullanımı ile birlikte mikronükleus testi ve kromozomal aberasyon analizi gibi tamamlayıcı metodolojilerle desteklenmektedir. Bu yöntemler, test edilen maddelerin genetik yapı üzerindeki etkilerinin sistematik olarak ortaya konulmasını sağlamakta ve ilaç geliştirme ile toksikoloji alanlarında temel araçlar arasında yer almaktadır. Mikronükleus testinin yüksek hassasiyetli tespit kapasitesi ile kromozomal aberasyon analizinin birlikte kullanıldığı *in vivo* çalışmalar, maddelerin güvenlik profillerinin oluşturulmasında kritik veriler sunarak uluslararası düzenleyici gerekliliklerin karşılanmasına önemli katkılar sağlamaktadır (Şen ve ark., 2018; Wei ve ark., 2019; Won ve ark., 2021; He ve Xu, 2022; Mathur ve ark., 2023).

4. Bitkisel Ekstraktların Özellikleri ve Fenolik Bileşiklerin Rolü

Bitkisel ekstraktlar, bitkisel dokularda doğal olarak bulunan ve biyolojik aktivitesi yüksek çeşitli sekonder metabolitleri içeren kompleks karışımlar olarak tanımlanmaktadır. Bu ekstraktlar başlıca fenolik bileşikler, flavonoidler, alkaloidler, terpenoidler ve diğer düşük moleküler ağırlıklı bileşenlerden oluşmakta olup, sahip oldukları bu zengin kimyasal içerik bitkisel kaynaklı ürünlerin biyolojik etkilerinin temelini oluşturmaktadır (Topalović ve ark., 2019; Elbouzidi ve ark., 2023). Söz konusu bileşik grupları, bitkisel ekstraktların yaygın olarak

bildirilen antioksidan, antigenotoksik, antiinflamatuar ve antikanserojen özellikleriyle doğrudan ilişkilidir (Araujo ve ark., 2019).

Fenolik bileşikler ve flavonoidler, bitkisel sekonder metabolitler arasında en yaygın bulunan ve güçlü antioksidan aktivite sergileyen gruplar arasında yer almaktadır. Yapısal özellikleri sayesinde serbest radikalleri nötralize edebilmekte ve oksidatif stresin azaltılmasında kritik bir rol üstlenmektedirler (Topalović ve ark., 2019; Jukić ve ark., 2024). Fenolik bileşiklerce zengin ekstraktların hücresel düzeyde DNA hasarını azaltıcı etkiler göstermesi, büyük ölçüde bu bileşiklerin radikal süpürücü kapasitelerine atfedilmektedir (Araujo ve ark., 2019; Peredo Pozos ve ark., 2020). Bunun yanı sıra flavonoidlerin, hücresel sinyal yolaklarını modüle ederek DNA tamir mekanizmalarını aktive edebildiği ve bu yolla artmış oksidatif stres koşullarında antigenotoksik etki gösterebildiği bildirilmektedir (Topalović ve ark., 2019; Ignjatijević ve ark., 2025).

Bununla birlikte, bitkisel ekstraktlarda yer alan aktif bileşenlerin sinerjistik veya antagonistik etkileşimleri, biyolojik aktivite ve sitotoksisite üzerinde doza bağlı farklılıkların ortaya çıkmasına neden olabilmektedir. Nitekim bazı flavonoidlerin düşük dozlarda DNA onarım süreçlerini destekleyici etki gösterirken, yüksek konsantrasyonlarda pro-oksidan özellik kazanarak genetik materyal üzerinde zararlı ve hatta mutajenik etkiler oluşturabildiği rapor edilmiştir (Viel ve ark., 2019; Elbouzidi ve ark., 2023; Ignjatijević ve ark., 2025). Bu durum, bitkisel ekstraktların potansiyel terapötik ve koruyucu kullanım alanlarının değerlendirilmesinde doz optimizasyonunun ve kapsamlı güvenlik analizlerinin zorunlu olduğunu ortaya koymaktadır (Yıldız ve ark., 2025).

5. Bitkisel Ekstraktların Genotoksik/Antigenotoksik Profili

Bitkisel ekstraktların genotoksik ve antigenotoksik profilleri; kullanılan bitki türü, tercih edilen ekstraksiyon yöntemi ve uygulanan doz gibi çeşitli faktörlere bağlı olarak önemli farklılıklar gösterebilmektedir. Yapılan çok sayıda çalışma, bazı bitkisel ekstraktların belirli konsantrasyonlarda DNA hasarını azaltıcı ve koruyucu (antigenotoksik) etki sergilediğini, ancak daha yüksek dozlarda genotoksik potansiyel ortaya koyabildiğini göstermektedir (Ignjatijević ve ark., 2025; Yıldız ve ark., 2025). Bu bağlamda, flavonoid ve fenolik asitler bakımından zengin bazı bitkisel ekstraktların, benzo[a]piren ve siklofosfamid gibi DNA hasarına neden olan ajanlara karşı hücresel düzeyde koruyucu etki oluşturduğu rapor edilmiştir (Araujo ve ark., 2019). Benzer şekilde, zeytin yaprağı özütü gibi bazı bitkisel ekstraktların hücre içi reaktif oksijen türleri düzeylerini düşürerek estradiol ve dietilstilbestrol kaynaklı DNA hasarını azalttığı bildirilmiştir (Topalović ve ark., 2019).

Öte yandan, ultrason destekli ekstraksiyon gibi optimize edilmiş yöntemler kullanılarak elde edilen bazı bitkisel özütlerin, güçlü antioksidan kapasitelerinin yanı sıra belirgin antigenotoksik etkilere sahip olduğu belirlenmiştir (Peredo Pozos ve ark., 2020). Bu bulgular, bitkisel ekstraktların genetik materyal üzerindeki etkilerinin çift yönlü olduğunu; düşük dozlarda koruyucu ve destekleyici etkiler sergilerken, doz artışıyla birlikte potansiyel olarak zararlı ve mutajenik sonuçlar doğurabildiğini ortaya koymaktadır (Ignjatijević ve ark., 2025; Yıldız ve ark., 2025).

Bitkisel ekstraktlar, sahip oldukları kompleks kimyasal yapılar nedeniyle genetik materyal üzerinde hem koruyucu hem de potansiyel olarak zararlı etkiler oluşturabilmektedir. Fenolik bileşikler ve flavonoidler, ekstraktların antioksidan ve antigenotoksik etkilerini destekleyen temel bileşenler olarak öne çıkmakta; ancak yüksek doz maruziyetlerinde pro-oksidan özellik kazanarak genetik hasar riskini artırabilmektedirler (Topalović ve ark., 2019; Elbouzidi ve ark., 2023). Bu nedenle, bitkisel ekstraktların terapötik veya koruyucu amaçlarla kullanımının, kapsamlı *in vitro* ve *in vivo* çalışmalarla desteklenmesi ve güvenli kullanım için optimal doz aralıklarının dikkatle belirlenmesi gerekmektedir (Araujo ve ark., 2019; Peredo Pozos ve ark., 2020; Ignjatijević ve ark., 2025).

6. Bitkisel Ekstraktların Mitomisin-C Kaynaklı DNA Hasarı Üzerindeki Koruyucu Potansiyeli

Mitomisin-C (MMC), DNA'da çapraz bağlar oluşturarak kromozomal anormalliklere ve belirgin genetik hasara yol açabilen güçlü bir alkaloid olup, klinik kullanımı sırasında ciddi genotoksik yan etkilerle ilişkilendirilmektedir. Bu bağlamda, MMC kaynaklı genetik hasarın azaltılmasına yönelik tamamlayıcı yaklaşımlar büyük ilgi görmekte; özellikle bazı bitkisel ekstraktların antioksidan ve antimutajenik özellikleri sayesinde koruyucu etki gösterebileceği bildirilmektedir. Nitekim *in vivo* ve *in vitro* çalışmalarda, flavonoid ve polifenolik bileşikler bakımından zengin bitkisel ekstraktların MMC'ye bağlı DNA hasarını anlamlı düzeyde azalttığı rapor edilmiştir (Milošević-Djordjević ve ark., 2018; Khalil ve ark., 2019).

Özellikle *Nitraria retusa* yaprak ekstraktının, MMC uygulanan erkek farelerde genetik toksisiteyi ve oksidatif stresi azalttığı; bu etkinin antioksidan savunma sistemlerinin desteklenmesiyle ilişkili olduğu gösterilmiştir (Khalil ve ark., 2019). Benzer şekilde, *Teucrium polium* ve *Teucrium scordium* türlerinden elde edilen ekstraktların, insan periferik kan lenfositlerinde MMC kaynaklı kromozomal hasarı azalttığı ve bu etkinin büyük ölçüde ekstraktların polifenolik içeriğine bağlı olduğu bildirilmiştir (Milošević-Djordjević ve ark., 2018). Bu bulgular, bitkisel ekstraktların içerdiği antioksidan bileşiklerin MMC kaynaklı DNA hasarına karşı önemli bir koruyucu rol üstlenebileceğini ortaya koymaktadır.

Bitkisel ekstraktların koruyucu etkilerinin belirlenmesinde doz–yanıt ilişkilerinin kritik öneme sahip olduğu da vurgulanmaktadır. Yapılan deneysel çalışmalar, düşük dozlarda sınırlı düzeyde koruma sağlanırken, doz artışıyla birlikte antigenotoksik etkinliğin belirgin şekilde arttığını göstermektedir (Khalil ve ark., 2019). Benzer şekilde, *Teucrium* türlerine ait ekstraktlarda, biyolojik aktif bileşenlerin konsantrasyonu ile antimutajenik etki arasında doğrudan bir ilişki olduğu bildirilmiş; bu durum, güvenli ve etkili kullanım açısından optimum doz aralığının belirlenmesinin gerekliliğini ortaya koymuştur (Milošević-Djordjević ve ark., 2018).

MMC ile bitkisel ekstraktların birlikte uygulanmasına ilişkin bulgular, kombine kullanımın genetik hasarı azaltmada tek başına MMC uygulamasına kıyasla daha etkili olabileceğini göstermektedir. *In vivo* modellerde, MMC'ye bağlı DNA hasarının ve oksidatif stres göstergelerinin, koruyucu bitkisel ekstraktların eşzamanlı uygulanmasıyla anlamlı ölçüde baskılandığı rapor edilmiştir (Khalil ve ark., 2019). Bu kombinasyon yaklaşımı, MMC'nin terapötik etkinliğini korurken genotoksik yan etkilerinin azaltılmasına katkı sağlayabilecek potansiyel bir strateji olarak değerlendirilmektedir.

Buna ek olarak, bazı bitkisel ekstraktların MMC uygulanmayan koşullarda dahi genetik stabiliteyi destekleyici ve antioksidan savunma mekanizmalarını güçlendirici etkiler sergilediği bildirilmiştir. *Nitraria retusa* ve *Teucrium* türlerinden elde edilen ekstraktların, farklı genotoksik ve oksidatif stres etmenlerine karşı hücresel koruyucu mekanizmaları desteklediği ve bu yönüyle tek başına potansiyel koruyucu ajanlar olarak değerlendirilebileceği ifade edilmektedir (Milošević-Djordjević ve ark., 2018; Khalil ve ark., 2019).

Genel olarak, mevcut bulgular MMC kaynaklı genetik hasara karşı bitkisel ekstraktların doza bağlı ve çok yönlü bir koruyucu etki sergilediğini ortaya koymaktadır. Bu koruyucu etkinin; antioksidan savunma sistemlerinin güçlendirilmesi, DNA hasarının önlenmesi ve onarım süreçlerinin desteklenmesi ile hücre döngüsü ve apoptozun düzenlenmesi gibi mekanizmalar aracılığıyla gerçekleştiği düşünülmektedir (Pascal, 2018; Angelis ve ark., 2021; Ramarao ve ark., 2022). Bu doğrultuda, MMC içeren tedavi protokollerinde bitkisel ekstraktların yardımcı koruyucu ajanlar olarak değerlendirilmesi, ileri preklinik ve klinik çalışmalar için umut verici bir yaklaşım sunmaktadır.

7. Bitkisel Ekstraktların DNA Hasarı ve Hücresel Koruyucu Mekanizmalar Üzerindeki Etkileri

Genotoksisite, hücresel DNA'nın yapısal bütünlüğünün bozulması sonucu mutasyonlar, kromozomal aberasyonlar ve genomik instabilite ile karakterize edilen kritik bir toksikolojik süreçtir. Bu süreçte, reaktif oksijen türlerinin (ROS) aşırı üretimi, DNA baz modifikasyonları, tek ve çift iplikçikli kırıklar ile mikronükleus oluşumu gibi genetik hasarların başlıca tetikleyicileri arasında yer almaktadır (Pascal, 2018; Petr ve ark., 2020). Bitkisel ekstraktlar, içerdiği fenolik bileşikler ve flavonoidler aracılığıyla oksidatif stresin sınırlandırılmasında rol oynayarak genotoksik etkilerin baskılanmasına katkı sağlayabilmektedir.

Antioksidan savunma mekanizmalarının güçlendirilmesi, bitkisel ekstraktların genotoksisite üzerindeki koruyucu etkilerinin temelini oluşturmaktadır. Süperoksit dismutaz, katalaz ve glutatyon gibi antioksidan sistemlerin aktivasyonunun artırılması, ROS kaynaklı DNA hasarının ve kromozomal kırıkların azaltılmasında önemli rol oynamaktadır (Srinivas ve ark., 2019; Lee ve ark., 2022). Astaksantin ve α-lipoik asit gibi doğal antioksidanların, oksidatif stres aracılı protein yıkımını ve apoptotik sinyalleri baskılayarak DNA onarım proteinlerinin fonksiyonel bütünlüğünü koruduğu bildirilmiştir (Lee ve ark., 2022; Park ve ark., 2022).

Bitkisel ekstraktların genotoksisite üzerindeki etkileri, yalnızca serbest radikal süpürücü özellikleriyle sınırlı olmayıp, DNA onarım mekanizmalarının düzenlenmesiyle de ilişkilidir. Baz eksizyon onarımı (BER) başta olmak üzere nükleotid eksizyon onarımı ve homolog rekombinasyon yollarının aktivasyonu, oksidatif baz lezyonlarının ve DNA iplik kırıklarının giderilmesinde kritik öneme sahiptir (Waters ve Spratt, 2024; Merlin ve ark., 2025). PARP-1 ve Ku70/Ku80 gibi onarım proteinlerinin oksidatif stres koşullarında korunması, genetik stabilitenin sürdürülmesine katkı sağlamaktadır (Pascal, 2018; Park ve ark., 2022).

DNA hasarının onarılamadığı durumlarda ise hücre döngüsü kontrol noktaları ve apoptoz mekanizmaları devreye girerek genetik olarak hasarlı hücrelerin çoğalmasını engellemektedir. p53 aracılı hücre döngüsü arresti ve kaspaz-3 aktivasyonu ile gerçekleşen apoptoz, mutasyon taşıyan hücrelerin elimine edilmesini sağlayarak genotoksik riskin sınırlandırılmasında önemli

bir savunma hattı oluşturmaktadır (Valeri ve ark., 2021; Ramarao ve ark., 2022). Bu süreç, özellikle kronik oksidatif stres ve kimyasal genotoksin maruziyetlerinde genomik bütünlüğün korunması açısından kritik öneme sahiptir.

Sonuç olarak, bitkisel ekstraktlar antioksidan savunmanın desteklenmesi, DNA hasarının azaltılması ve onarım süreçlerinin düzenlenmesi ile hücre döngüsü ve apoptozun kontrollü aktivasyonu yoluyla genotoksisiteyi çok yönlü olarak modüle edebilmektedir. Bu mekanizmalar, bitkisel kökenli bileşiklerin mikronükleus testi, kromozomal aberasyon analizi ve Comet testi gibi genotoksisite değerlendirme yöntemlerinde gözlenen koruyucu etkilerini biyolojik olarak açıklamaktadır (Petr ve ark., 2020; Angelis ve ark., 2021; Ramarao ve ark., 2022).

8. Bitkisel Ekstraktların Güncel Uygulama Alanları ve Geleceğe Yönelik Araştırma Perspektifleri

Bitkisel ekstraktlar, sahip oldukları zengin biyoaktif bileşik içeriği sayesinde farmakoloji, tarım, kozmetik ve biyoteknoloji başta olmak üzere birçok alanda geniş bir uygulama potansiyeline sahiptir. Farmakolojik açıdan değerlendirildiğinde, *Arnebia euchroma* gibi bitkilerden elde edilen fitoaktif bileşiklerin antioksidan, antimikrobiyal, antikanser ve antiülseröz özellikler sergilediği; bu yönüyle çeşitli kronik hastalıkların tedavisinde tamamlayıcı ajanlar olarak değerlendirilebileceği bildirilmektedir (Kazybekov ve ark., 2024). Benzer şekilde, *Stachys pilifera* gibi geleneksel tıpta uzun süredir kullanılan bitkilerin romatizma, enfeksiyon ve solunum yolu hastalıklarında terapötik potansiyel sunduğu, bu durumun modern farmasötik araştırmalar için yeni ilaç adaylarının geliştirilmesine zemin hazırladığı ifade edilmektedir (Sadeghi ve ark., 2022).

Tarım ve bitki sağlığı alanında, bitkisel ekstraktların ve esansiyel yağların nematikasitik özellikleri, çevre dostu ve sürdürülebilir alternatifler olarak öne çıkmaktadır. Özellikle bazı bitkisel kökenli ürünlerin, tarımsal üretimde ekonomik kayıplara yol açan nematod türlerine karşı etkili olduğu ve sentetik kimyasalların yerine kullanılabileceği bildirilmektedir (D'Addabbo & Avato, 2021). Bununla birlikte, bitkisel nematikasitlerin etkinliğinin artırılması ve sahada güvenilir şekilde uygulanabilmesi için standardizasyon ve kalite kontrol süreçlerinin geliştirilmesi gerektiği de vurgulanmaktadır (Mwamula ve ark., 2022).

Kozmetik ve anti-aging uygulamalar açısından bakıldığında, botanik ekstraktların cilt yaşlanmasının geciktirilmesi ve cilt bütünlüğünün korunması üzerinde olumlu etkiler sunduğu gösterilmiştir. Özellikle flavonoid ve antioksidan aktiviteye sahip bitkisel bileşiklerin, oksidatif strese bağlı DNA hasarını azaltarak anti-aging kozmetik ürünlerin geliştirilmesine katkı sağladığı bildirilmektedir (Ferreira ve ark., 2021). Bu alanda, bitkisel aktif maddelerin stabilitesini ve biyoyararlanımını artırmaya yönelik nanoteknoloji temelli ve akıllı taşıma sistemlerinin geliştirilmesi, ürün etkinliğini artıran önemli bir strateji olarak öne çıkmaktadır (Shishir ve ark., 2021).

Nanoteknoloji tabanlı uygulamalar, bitkisel ekstraktların kullanım alanlarını daha da genişletmektedir. *Annona* türlerinden elde edilen ekstraktların, nanomalzemelerin sentezi ve stabilizasyonunda biyouyumlu ajanlar olarak kullanılabildiği ve bu yaklaşımın biyomedikal uygulamalarda yeni ve daha etkili tedavi stratejilerinin geliştirilmesine olanak tanıdığı

bildirilmektedir (Gutiérrez-Pinzón ve ark., 2025). Bu tür yaklaşımlar, bitkisel ürünlerin yalnızca geleneksel kullanım alanlarıyla sınırlı kalmadığını, ileri teknolojilerle entegre edildiğinde daha geniş bir uygulama yelpazesi sunduğunu göstermektedir.

Geleceğe yönelik araştırmalar açısından değerlendirildiğinde, bitkisel ekstraktların biyolojik etkilerinin moleküler düzeyde daha ayrıntılı biçimde aydınlatılması büyük önem taşımaktadır. Özellikle baicalin gibi spesifik bileşiklerin AMPK/Nrf2 gibi hücresel sinyal yolakları üzerindeki etkilerinin detaylı olarak incelenmesi, oksidatif stresin kontrolü ve hücresel bariyer bütünlüğünün korunmasına ilişkin mekanizmaların daha iyi anlaşılmasını sağlayacaktır (Liang ve ark., 2023). Bunun yanı sıra, farklı bitki türlerinden elde edilen ekstraktlar arasındaki biyolojik etkinlik farklılıklarının azaltılması için standart ekstraksiyon protokollerinin geliştirilmesi, hem farmasötik hem de tarımsal uygulamalar açısından kritik bir gereklilik olarak değerlendirilmektedir (Mwamula ve ark., 2022).

Ayrıca, nanoteknoloji ve akıllı taşıma sistemlerinin bitkisel ekstraktlarla entegrasyonu, hedefe yönelik ve kontrollü salınım sağlayarak biyoyararlanımı artırma potansiyeli sunmaktadır. Bu yaklaşım, farmasötik uygulamalarda daha etkili ve güvenilir tedavi stratejilerinin geliştirilmesine katkı sağlayabilir (Shishir ve ark., 2021; Gutiérrez-Pinzón ve ark., 2025). Laboratuvar ortamında elde edilen bulguların klinik ve uygulama odaklı çalışmalara taşınması ise, bitkisel ekstraktların insan ve hayvan sağlığı üzerindeki gerçek etkilerinin doğrulanması açısından büyük önem taşımaktadır; özellikle kozmetik ve antimikrobiyal alanlarda klinik temelli verilerin artırılması gerekmektedir (Ferreira ve ark., 2021).

Sonuç olarak, literatür bulguları bitkisel ekstraktların antioksidan, antienflamatuar, antimikrobiyal ve nematikasitik gibi çok yönlü biyolojik aktivitelere sahip olduğunu ve bu özelliklerin sağlık, tarım, kozmetik ve biyoteknoloji alanlarında önemli uygulama potansiyelleri sunduğunu ortaya koymaktadır. Ancak bu potansiyelin tam anlamıyla değerlendirilebilmesi için moleküler mekanizmaların daha iyi anlaşılması, standardizasyon sorunlarının giderilmesi ve multidisipliner iş birliklerine dayalı araştırma yaklaşımlarının benimsenmesi gerekmektedir. Bu doğrultuda yürütülecek çalışmalar, bitkisel ekstraktların klinik ve endüstriyel uygulamalara güvenli ve etkili biçimde entegre edilmesine katkı sağlayarak hem insan sağlığını hem de çevresel sürdürülebilirliği destekleyecektir (D'Addabbo & Avato, 2021; Ferreira ve ark., 2021; Shishir ve ark., 2021; Mwamula ve ark., 2022; Sadeghi ve ark., 2022; Liang ve ark., 2023; Ndung'u ve ark., 2024; Kazybekov ve ark., 2024; Gutiérrez-Pinzón ve ark., 2025; López-Abán ve ark., 2025; Mamand & Saleh, 2025).

9. Genel Değerlendirme

Bu derlemede, mitomisin-C'nin (MMC) DNA üzerinde çapraz bağlar oluşturarak ve oksidatif stres süreçlerini tetikleyerek ortaya çıkardığı genetik hasar, *in vivo* genotoksisite değerlendirme yaklaşımları (mikronükleus testi ve kromozomal aberasyon analizi) çerçevesinde ele alınmıştır. Literatür bulguları, fenolik bileşikler ve flavonoidler bakımından zengin bazı bitkisel ekstraktların, MMC'ye bağlı DNA hasarını ve oksidatif stres belirteçlerini azaltabildiğini; bununla birlikte etkinliğin bitki türü, ekstraksiyon yöntemi ve özellikle doz–yanıt ilişkisine bağlı olarak değişkenlik gösterebildiğini ortaya koymaktadır. Bu nedenle, bitkisel ekstraktların koruyucu/antigenotoksik etkilerinin değerlendirilmesinde yalnızca antioksidan kapasiteye

odaklanmak yerine, genomik stabiliteyi belirleyen DNA onarımı, hücre döngüsü kontrol noktaları ve apoptoz gibi süreçlerle birlikte bütüncül bir yaklaşım benimsenmesi gerekmektedir.

10. Sonuçlar

Mevcut kanıtlar, uygun doz ve uygulama koşulları altında kullanılan bitkisel ekstraktların MMC kaynaklı genetik hasara karşı tamamlayıcı koruyucu ajanlar olarak umut vadettiğini göstermektedir. Bununla birlikte, bitkisel ekstraktların bazı koşullarda yüksek dozlarda pro-oksidan özellik kazanabilmesi ve potansiyel genotoksik risk oluşturabilmesi, güvenlik değerlendirmelerinin ve standartlaştırılmış ekstraksiyon/kalite kontrol süreçlerinin zorunluluğunu ortaya koymaktadır. Dolayısıyla, MMC ile kombine kullanımın klinik açıdan anlamlı bir faydaya dönüşebilmesi için, iyi tanımlanmış içerik profiline sahip ekstraktlarla, çoklu doz düzeylerini içeren, uygun kontrol gruplarıyla desteklenmiş ileri *in vivo* çalışmaların yürütülmesi; elde edilen bulguların translasyonel düzeyde klinik araştırmalara taşınması gereklidir.

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TÜKETİCİLERİN MEYVE-SEBZE ALIŞVERİŞİNDE ÇEVRİMİÇİ KANALLARI KULLANIM DURUMU

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ÖZET

Son yıllarda dijitalleşmenin hız kazanmasıyla birlikte, tüketicilerin gıda alışveriş alışkanlıklarında önemli değişimler yaşanmıştır. Özellikle çevrimiçi alışveriş kanallarının yaygınlaşması, taze gıda ürünlerinin dolayısıyla meyve ve sebze kategorisinin de dijital perakende sistemine entegrasyonunu hızlandırmıştır. Pandemi döneminde artan çevrimiçi alışveriş eğilimi, dünya genelinde kalıcı bir davranış dönüşümüne yol açmış ve gıda perakendeciliğinde dijital platformlar yeni bir oluşum haline gelmiştir. Dünyada birçok ülkede çevrimiçi gıda ticareti büyüme göstermekte, meyve ve sebze alışverişi bu gelişim içinde dikkat çekici bir paya sahip olmaktadır. Tüketiciler, çevrimiçi kanalları zaman tasarrufu, ürün çeşitliliği, fiyat karşılaştırma kolaylığı ve hızlı teslimat gibi avantajları nedeniyle tercih etmektedir. Ancak, taze ürünlerin kalite güvencesi ve teslimat süresi konusundaki endişeler, bu alışveriş türünün yaygınlığını sınırlayan başlıca unsurlar arasında yer almaktadır. Türkiye'de de benzer bir eğilim gözlemlenmekte olup, özellikle büyükşehirlerde yaşayan tüketicilerin çevrimiçi market uygulamaları aracılığıyla taze ürün temin etme oranı son yıllarda belirgin biçimde artmaktadır. Artan internet erişimi, mobil uygulama kullanımının yaygınlaşması ve tüketicilerin dijital kanallara olan güveninin güçlenmesi, çevrimiçi meyve-sebze ticaretinin gelişimini desteklemektedir. Bu bildirinin amacı, tüketicilerin taze meyve ve sebze alışverişinde çevrim içi kanalları kullanım durumlarını e-ticaretin genel dinamikleri, taze ürünlerin özellikleri ve tüketici davranışları çerçevesinde değerlendirmektir. Türkiye'de tüketicilerin meyve ve sebze alışverişinde çevrim içi kanalları kullanma eğilimleri, dijitalleşmenin etkisiyle gıda perakendeciliğinde köklü bir dönüşüm sürecini tetiklemektedir. Araştırma bulguları, bu dönüşümün taze ürün kategorisinde giderek daha belirgin hâle geldiğini ve tüketici tercihlerini şekillendirdiğini göstermektedir. Çevrim içi meyve-sebze alışverişinin sürdürülebilir gelişimi, güven temelli dijital ekosistemlerin oluşturulması, lojistik ve altyapı yatırımlarının güçlendirilmesi ile tüketici ihtiyaçlarının dinamik biçimde izlenmesine bağlıdır.

Anahtar Kelimeler: Çevrim içi alışveriş, meyve-sebze, taze gıda ürünleri, tüketici davranışları

ABSTRACT

In recent years, with the acceleration of digitalization, significant changes have occurred in consumers' food purchasing habits. The widespread adoption of online shopping channels has accelerated the integration of fresh food products—particularly the fruit and vegetable category—into the digital retail system. The increase in online shopping during the pandemic period led to a lasting transformation in consumer behaviour worldwide, and digital platforms have emerged as a new formation in food retailing. In many countries around the world, online food trade has exhibited notable growth, with fruit and vegetable purchases accounting for a remarkable share of this development. Consumers prefer online channels due to advantages such as time savings, product variety, ease of price comparison, and fast delivery. However concerns regarding quality assurance and delivery time for fresh products remain among the main factors limiting the widespread adoption of this type of shopping. A similar trend is observed in Türkiye, where the rate of procuring fresh products through online grocery applications particularly among consumers living in metropolitan areas has increased significantly in recent years. The expansion of internet access, the widespread adoption of mobile applications, and the enhancement of consumer trust in digital channels collectively foster the growth of online fruit and vegetable trade. The aim of this study is to evaluate consumers' use of online channels for purchasing fresh fruits and vegetables within the framework of general e-commerce dynamics, the characteristics of fresh products, and consumer behaviour. In Türkiye, consumers' increasing tendency to use online channels for fruit and vegetable purchases is triggering a profound transformation process in food retailing driven by digitalization. The research findings indicate that this transformation is becoming increasingly evident in the fresh product category and is shaping consumer preferences. The sustainable development of online fruit and vegetable shopping depends on the establishment of trust based digital ecosystems, the strengthening of logistics and infrastructure investments, and the dynamic monitoring of consumer needs.

Keywords: Online shopping, fruits and vegetables, fresh food products, consumer behaviour

1. GİRİŞ

Tüm dünyada dijital teknolojilerin gelişmesi ve özellikle elektronik ticaretin (E-ticaret) yaygınlaşması, tüketici davranışlarında köklü değişimlere yol açmıştır. E-ticaret, satıcı ve alıcının fiziksel olarak karşı karşıya gelmediği dijital platformlar üzerinden gerçekleştirilen; işletmeler arası (B2B) ve işletmeden tüketiciye (B2C) olmak üzere iki temel yapıda şekillenen bir ticaret türüdür (Narcı, 2021). Günümüzde e-ticaret, ekonomik ve sosyal yaşamın önemli bileşenlerinden biri hâline gelmiştir. Bu bağlamda, internet ve dijital teknolojilerin sunduğu olanaklar sayesinde tüketiciler, geleneksel alışveriş yöntemlerinden uzaklaşarak eş zamanlı olarak birden fazla satıcıya ulaşım imkânı elde etmektedirler (Özer & Erdem, 2024).

Pandemi süreci, tüketicilerin fiziksel mağazalardan çevrimiçi platformlara yönelimini hızlandırmış ve alışveriş davranışlarında köklü bir dönüşüme sebep olmuştur (Kaynak, 2020; Güngördü Belbağ & Belbağ, 2024). Bu süreçte, tüketicilerin edindikleri çevrimiçi alışveriş tecrübeleri ile işletmelerin dijital pazarlama kanallarına olan yönelimi, bu alışveriş

platformlarının kullanımını önemli ölçüde yaygınlaştırmıştır (Bozacı, 2025). Bu doğrultuda, geniş demografik yapısı ve coğrafi çeşitliliğiyle dikkat çeken Türkiye'de, tüketicilerin meyve ve sebze alışverişinde çevrimiçi kanalları tercih etme eğilimlerinin analiz edilmesi, dijital tüketim dinamiklerinin anlaşılması açısından önem arz etmektedir. E-ticaretin genel yayılımı değerlendirildiğinde, Türkiye'de bireylerin çevrimiçi alışverişe katılım düzeyleri ile bu davranışı şekillendiren faktörler üzerine çeşitli araştırmaların yapıldığı görülmektedir (Önder & Demirel, 2022). Yılmaz ve Erdem (2021) tarafından yapılan bir çalışmada, Türkiye'de bireylerin e-ticareti kullanma olasılığını etkileyen değişkenler arasında eğitim düzeyi, gelir seviyesi, yaş, cinsiyet, sosyal medya kullanımı, çevrimiçi ürün ve hizmet arama davranışı ile çevrimiçi bankacılık kullanımı yer almaktadır. Çalışma, ayrıca bireylerin yaşadığı bölgenin gelişmişlik düzeyine bağlı olarak e-ticaret kullanımının farklılaştığını ortaya koymaktadır.

Gıda sektörü, genel olarak "kırılgan ürünler" kategorisinde yer aldığından, taze meyve ve sebzelerin çevrimiçi ortamda pazarlanması lojistik süreçler, tazelik kontrolü ve tüketici güveni açısından temel zorluklar barındırmaktadır (Fuentes & Fuentes, 2022). Öte yandan, taze ürünlerin çevrimiçi satışına ilişkin olarak tüketicilerin bu kanalı tercih etme ya da etmeme nedenlerini inceleyen çalışmalar dikkat çekmektedir. Türkiye özelinde yapılan bir araştırmada, tüketicilerin içsel ve dışsal motivasyonlarının (kolaylık, zaman tasarrufu, ürün çeşitliliği ve risk algısı gibi) çevrimiçi gıda alışverişine yönelimde etkili olduğu tespit edilmiştir. Bu motivasyonlar kapsamında, özellikle ürün tazeliği, teslimat hızı, güvenilirlik ve ödeme güvenliği gibi faktörlerin belirleyici olduğu vurgulanmıştır (Arslan & Turan, 2022). Dünyada, çevrimiçi gıda alışverişi üzerine yapılan çalışmalarda benzer tutum ve davranışlar gözlemlenmektedir. Frank ve Peschel (2020) çalışmalarında, çevrimiçi satış kanallarının benimsenmesinde tüketicilerin teslimat, hizmet güvencesi, fiyat ve kolaylık gibi unsurların belirleyici olduğunu ortaya koymuştur. Seçer ve ark. (2023), yapmış oldukları benzer bir çalışmada çevrimiçi gıda alışverişi eğilimlerini incelemişler ve tüketicilerin tercihlerini etkileyen temel değişkenler arasında algılanan değer, geleneksel alışkanlıklar, çevrimiçi kaynaklardan gelen normlar ve teknolojik becerilerin önemli rol oynadığını tespit etmişlerdir. Söz konusu değişkenlerin, fiziksel mağazalardan dijital platformlara geçiş sürecinde kritik öneme sahip olduğunu bildirmişlerdir.

Türkiye'de tüketicilerin çevrimiçi meyve-sebze satın alma davranışı, hem e-ticaretin genel dinamikleri hem de gıda ve lojistik alanına özgü koşullar tarafından şekillenen çok boyutlu bir araştırma alanı olarak değerlendirilmektedir. Bu bildirinin amacı, tüketicilerin çevrimiçi meyve-sebze satın alma davranışlarını ikincil veriler ışığında incelemektir. Bu kapsamda, Türkiye İstatistik Kurumu (TÜİK) ve Elektronik Ticaret Bilgi Sistemi (ETBİS) verileri ile sektörel raporlar gibi resmî kaynaklardan elde edilen bilgiler ve akademik çalışmalardan sağlanan bulgular birlikte değerlendirilmiştir.

2. ÇEVRİM İÇİ GIDA ALIŞVERİŞİNE GENEL BAKIŞ

2.1.Çevrim İçi Alışverişin Yükselişini Harekete Geçiren Dinamikler

İnternetin yaygınlaşması, mobil cihazların kullanımındaki artış ve e-ticaret platformlarının erişilebilirliğinin yükselmesi, çevrim içi alışverişin günlük yaşamın vazgeçilmez bir parçası haline gelmesine yol açmıştır (Laudon & Traver, 2023). Bu dönüşüm yalnızca teknolojik

gelişmelerle değil, aynı zamanda değişen yaşam tarzları, zaman kısıtları ve kolaylık arayışı gibi sosyoekonomik faktörlerle desteklenmektedir (Ramus & Nielsen, 2005). Tüketicilerin çevrim içi kanallara yönelmesinde en önemli itici güçlerden biri kolaylık unsurudur. Çevrim içi alışveriş, fiziksel mağazalara gitme zorunluluğunu ortadan kaldırarak zaman tasarrufu sağlamaktadır (Verhoef ve ark., 2017). Özellikle çalışan bireyler için bu kolaylık faktörü, satın alma kararlarında belirleyici bir rol oynamaktadır. Mobil uygulamaların kullanıcı dostu arayüzleri ve kişiselleştirilmiş öneri sistemleri, tüketicilerin çevrim içi alışverişe olan ilgisini her geçen gün artırmıştır (Gao & Su, 2017). Bir diğer önemli dinamik, dijital güven ve algılanan risk kavramlarıdır. Başlangıçta çevrim içi alışverişte güven eksikliği önemli bir engel teşkil ederken, gelişmiş güvenlik sistemleri ve tüketici koruma düzenlemeleri sayesinde bu engel büyük ölçüde azaltılmıştır (Gefen ve ark., 2003). Özellikle pandemi döneminde fiziksel temastan kaçınma eğilimi, çevrim içi alışverişe yönelik güvenin artmasına katkı sağlamıştır (Pantano ve ark., 2020). Bununla birlikte, demografik faktörler de çevrim içi alışverişin yükselişinde etkili olmuştur. Genç kuşakların dijital teknolojilere yatkınlığı ve çevrim içi ortamlara olan aşinalığı, e-ticaret platformlarının hızlı benimsenmesine olanak tanımıştır. Ayrıca, artan kentleşme oranı ve internet altyapısındaki gelişmeler, özellikle gelişmekte olan ülkelerde çevrim içi gıda alışverişinin yaygınlaşmasını hızlandırmıştır (Huang & Oppewal, 2006). Bunlara ek olarak, sosyal medya ve dijital pazarlamanın etkisi de çevrim içi alışverişin yükselişini hızlandıran önemli bir diğer faktör olarak öne çıkmaktadır. Markaların sosyal medya üzerinden yürüttükleri etkileşim temelli kampanyalar, tüketicilerin çevrim içi kanallar üzerinden alışveriş yapma eğilimini güçlendirmiştir (Hudson ve ark., 2016). Bu durum, yalnızca ürün bilinirliğini artırmakla kalmayıp, aynı zamanda tüketici güvenini ve sadakatini de pekiştirmektedir. Sonuç olarak, çevrim içi alışverişin yükselişini harekete geçiren dinamikler çok boyutludur ve teknolojik ilerlemeler, tüketici davranışındaki değişimler, güven unsuru, demografik yapı ve dijital pazarlama stratejilerinin etkileşimiyle şekillenmektedir.

2.2. Dünyada ve Türkiye'de Taze Ürünlerin Çevrim İçi Satışı ve Eğilimler

Dünya genelinde e-ticaretin gelişimiyle birlikte gıda perakendeciliği dijital dönüşüm sürecine girmiştir. Özellikle meyve ve sebze gibi taze ürünlerin çevrim içi satışı lojistik, soğuk zincir yönetimi ve tüketici güveni gibi faktörlerin etkisi altında şekillenmektedir (Hand ve ark., 2009). Taze gıda ürünlerinin çevrim içi kanallarda satışa sunulması, başlangıçta kalite algısı ve ürün tazeliği konusundaki endişeler nedeniyle sınırlı bir büyüme göstermiştir. Ancak, son yıllarda teknolojik altyapı ve teslimat sistemlerindeki gelişmeler, bu segmentin hızlı bir şekilde genişlemesine olanak tanımıştır. Uluslararası ölçekte yapılan araştırmalar, çevrim içi taze ürün alışverişinin özellikle gelişmiş ülkelerde yaygınlaştığını göstermektedir. Avrupa ve Asya pazarlarında perakendeciler, tüketici memnuniyetini artırmak amacıyla teslimat hızını ve ürün tazeliğini iyileştiren lojistik modellerine yönelmiştir (Campo & Breugelmans, 2015). Örneğin, İngiltere ve Güney Kore gibi ülkelerde çevrim içi gıda perakendeciliği, tüketicilerin haftalık gıda alışverişinde kalıcı bir alışkanlık haline gelmiştir (Fernie ve ark., 2010). Gelişmekte olan ülkelerde ise çevrim içi taze gıda pazarlarının büyümesi daha yavaş olmakla birlikte, genç nüfusun dijital kanallara ilgisi ve mobil ödeme sistemlerinin yaygınlaşması bu büyümeyi desteklemektedir (Morepje, 2024).

Türkiye'de çevrim içi gıda alışverişi 2020 sonrası dönemde belirgin biçimde artış göstermiştir. Özellikle büyükşehirlerde faaliyet gösteren perakendeciler, taze meyve-sebze teslimatı için özel dağıtım ağları oluşturmuşlardır (Kaya & Ceylan, 2023). Genel olarak değerlendirildiğinde, dünyada ve Türkiye'de taze meyve-sebze satışının çevrim içi ortama taşınması, dijitalleşme sürecinin tarımsal ürün tedarik zincirine entegrasyonunu hızlandırmıştır. Teknolojiye dayalı izlenebilirlik sistemleri, soğuk zincir lojistiği ve veri tabanlı stok yönetimi uygulamaları, bu alandaki büyümenin sürdürülebilirliğini desteklemekte, tüketici beklentilerine daha hızlı ve güvenli biçimde yanıt verilmesini mümkün kılmaktadır.

3.ÇEVRİM İÇİ MEYVE SEBZE ALIŞVERİŞİNDE TÜKETİCİ DAVRANIŞLARI

3.1. Tüketici Profilleri ve Alışveriş Alışkanlıkları

Çevrim içi meyve-sebze alışverişi, tüketicilerin demografik, sosyo-ekonomik özelliklerine göre farklılık göstermektedir. Literatürde, çevrim içi alışveriş yapan tüketicilerin genel olarak genç, eğitim düzeyi yüksek, şehirli ve dijital teknolojiye uyumlu bireylerden oluştuğu ifade edilmektedir (Clemes ve ark., 2014). Bu tüketici grubu, çevrim içi platformlardan zaman tasarrufu, fiyat karşılaştırma imkânı ve kolay erişim gibi avantajlardan daha fazla yararlanma durumuna sahiptirler (Sreeram ve ark., 2017). Tüketici profilleri yalnızca demografik ya da sosyo-ekonomik özelliklerle değil, aynı zamanda yaşam tarzı ve değer yönelimleri ile de şekillenmektedir. Araştırmalar, sağlıklı yaşam bilincine sahip bireylerin taze ve organik ürünleri çevrim içi platformlardan temin etme eğilimlerinin daha yüksek olduğunu göstermektedir (Hsu, 2023). Bununla birlikte gelir seviyesi yüksek bireylerin, çevrim içi meyve-sebze alışverişinde kalite güvencesi sunan markaları tercih etme olasılığının daha yüksek olduğu belirtilmiştir (Yeo ve ark., 2017). Bu durum, çevrim içi taze gıda pazarında markaya duyulan güvenin ve algılanan değer kavramlarının belirleyici faktör olduğunu göstermektedir. Taze ürün kategorisinde özellikle teslimatın zamanında yapılması ve ürünün beklenen şekilde ulaşması, tüketici memnuniyetini doğrudan etkilemektedir (Nguyen ve ark., 2018). Bu nedenle, çevrim içi meyve-sebze alışverişinde lojistik hizmetlerin kalitesi, tüketici sadakatini sürdürülebilir hale getiren kritik bir unsur olarak değerlendirilmektedir. Ayrıca, dijital ortamda alışveriş yapan tüketiciler arasında mobil uygulamaları giderek artan bir paya sahiptir. Mobil tabanlı alışverişin tercih edilme nedenleri arasında, anlık indirim bildirimleri, kişiselleştirilmiş ürün önerileri ve kullanıcı dostu tasarımlar öne çıkmaktadır (Bilgihan ve ark., 2016). Bu gelişmeler, çevrim içi meyve-sebze alışverişinde dijital etkileşimin ve kullanıcı deneyiminin önemini artırmıştır.

Türkiye'de yapılan çalışmalar, çevrim içi gıda alışverişi yapan tüketicilerin çoğunlukla kadın, orta yaşlı ve orta gelir grubuna mensup bireylerden oluştuğunu göstermektedir (Özdemir & Doğan, 2024). Bu tüketim alışkanlığının sürdürülmesinde, özellikle pandemi sonrası dönemde dijital kanallara ilişkin güven ile dijital platformların sunduğu satış sonrası müşteri hizmetleri politikaları önemli bir rol oynamaktadır. Çevrim içi meyve-sebze alışverişinde tüketici profilleri, demografik, sosyo-ekonomik ve psikolojik faktörlerin yanı sıra dijital deneyim ve güven unsurlarıyla şekillenmektedir. Ayrıca, tüketicilerin alışveriş alışkanlıklarının kalıcı hale gelmesi, platformların hizmet kalitesi, teslimat güvenirliği ve markaya duyulan güvenle doğrudan ilişkilidir.

3.2. Satın Alma Motivasyonları ve Engelleri

Tüketicilerin çevrim içi meyve-sebze alışverişine yönelmesinde hem kolaylaştırıcı hem de kısıtlayıcı unsurlar birlikte rol oynamaktadır. Çevrim içi alışverişin temel motivasyonları arasında zaman tasarrufu, ürün çeşitliliğine erişim, fiyat karşılaştırma imkânı ve kapıya teslimat kolaylığı ön plana çıkmaktadır (Lee & Kim, 2021). Özellikle yoğun şehir yaşamı, çalışan bireylerin taze gıda alışverişini planlamada yaşadığı zaman sınırlılığını artırmakta ve çevrim içi kanallar bu açığı kapatan alternatif bir çözüm olarak karşımıza çıkmaktadır (Li ve ark., 2022). Buna ek olarak, kişiselleştirilmiş öneriler ve kullanıcı dostu mobil uygulamalar, tüketicilerin alışveriş deneyimini daha pratik hale getirerek memnuniyet düzeyini yükseltmektedir (Ramus & Nielsen, 2005). Öte yandan, taze ürün kategorisinde çevrim içi satın alma davranışı, güven eksikliği ve kalite belirsizliği gibi bazı engellerle karşılaşmaktadır. Meyve ve sebze gibi ürünlerde fiziksel temasın olmaması, ürün tazeliği, görünüm ve ağırlık gibi duyusal özelliklerin kontrolünü güçleştirmekte; bu durum tüketicilerin kalite algısını olumsuz etkileyebilmektedir (Albors-Garrigós & García-Segovia, 2023). Ayrıca teslimat sürecinde yaşanan gecikmeler, lojistik hatalar veya soğuk zincir kırılmaları, tüketici güvenini zedeleyen önemli faktörler arasında yer almaktadır (Seçer ve ark., 2023). Psikolojik unsurlar da çevrim içi alışveriş davranışını şekillendirmede etkili olmaktadır. Özellikle gıda güvenliği konusundaki endişeler, taze ürün alışverişinde çevrim içi platformlara yönelik tereddütleri artırabilmektedir (Nguyen ve ark., 2023; Sarı & Aydın, 2021).

Çevrim içi meyve-sebze alışverişine yönelik satın alma motivasyonları ile engeller arasındaki denge, tüketici karar süreçlerini doğrudan etkilemektedir. Bu denge teknolojik altyapı, lojistik hizmet kalitesi ve dijital güven mekanizmalarının etkinliği gibi faktörlere bağlı olarak farklı pazarlarda değişiklik göstermektedir. Bu nedenle, çevrim içi taze ürün pazarlarının sürdürülebilir büyümesi, tüketici güveninin tesis edilmesi ve ürün kalitesiyle ilgili belirsizliklerin azaltılmasına yönelik stratejilerin geliştirilmesini gerektirmektedir.

4. SONUÇ

Bu çalışmada, tüketicilerin taze meyve ve sebze alışverişinde çevrim içi kanalları kullanım durumları; e-ticaretin genel dinamikleri, taze ürünlerin özellikleri ve tüketici davranışları çerçevesinde değerlendirilmiştir. Bulgular, dijitalleşmenin etkisiyle birlikte gıda perakendeciliğinin önemli bir dönüşüm süreci yaşadığını ve bu dönüşümün taze ürün kategorisine giderek daha fazla yansıdığını göstermektedir. Özellikle pandemi dönemi sonrasında hız kazanan çevrim içi alışveriş alışkanlığı, tüketicilerin zaman tasarrufu, erişim kolaylığı ve ürün çeşitliliği gibi faktörlere verdiği önemin artmasıyla birlikte kalıcı bir davranış biçimine dönüşmüştür. Araştırma sonuçları, çevrim içi meyve-sebze alışverişinin gelişiminde en belirleyici etmenlerin teknolojik altyapı, lojistik hizmet kalitesi, dijital güven ve tüketici deneyimi olduğunu ortaya koymaktadır. Bu kapsamda, güvenli ödeme sistemleri, ürünlerin tazelik garantisi ve kullanıcı dostu ara yüzler gibi faktörler, tüketici memnuniyetini artıran temel unsurlar arasında yer almaktadır. Fakat ürünlerin duyusal özelliklerine ilişkin kontrol eksikliği, teslimat sürecinde yaşanan belirsizlikler ve kalite standardizasyonundaki yetersizlikler, çevrim içi taze ürün satışında önemli sınırlılıklar olarak öne çıkmaktadır.

Taze ürünlerin çevrim içi satışına ilişkin fırsatlar, özellikle dijitalleşmenin sunduğu izlenebilirlik teknolojileri, akıllı lojistik çözümleri ve veri temelli kişiselleştirilmiş pazarlama stratejileriyle yakından ilişkilidir. Bu teknolojiler, hem tedarik zincirinin şeffaflığını artırmakta hem de tüketicilerin ürün güvenine katkı sağlamaktadır. Ayrıca, sürdürülebilirlik odaklı yaklaşımlar örneğin yerel üreticilerin çevrim içi platformlara entegrasyonu veya çevre dostu paketleme uygulamaları tüketici tercihlerini olumlu yönde etkileyebilecek potansiyele sahiptir. Türkiye özelinde değerlendirildiğinde, çevrim içi meyve-sebze alışverişinin büyükşehir merkezlerinde daha yaygın olduğu, ancak bölgesel farklılıkların bu alandaki potansiyelin tam anlamıyla kullanılmasını sınırladığı görülmektedir.

Sonuç olarak, çevrim içi meyve-sebze alışverişi, hem tüketici beklentilerinin hem de dijital pazarın gerekliliklerinin kesiştiği stratejik bir alan haline gelmiştir. Bu alanın sürdürülebilir biçimde gelişebilmesi, güven temelli bir dijital ekosistemin oluşturulmasına, altyapı yatırımlarının güçlendirilmesine ve tüketici ihtiyaçlarının dinamik biçimde takip edilmesine bağlıdır.

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TÜRKİYE'DE TARIM ÜRÜNLERİ DIŞ TİCARETİNE YÖNELİK BİR DEĞERLENDİRME

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ÖZET

Tarım ürünleri dış ticareti, Türkiye ekonomisinde hem tarımsal üretim yapısının sürdürülebilirliği hem de yabancı sermaye kazandırıcı faaliyetlerin artırılması açısından stratejik bir öneme sahiptir. Son yıllarda bazı tarımsal ürün üretiminde gözlenen miktar artışı, ürün deseninde meydana gelen çeşitlenme ve dış pazarlara erişim imkânlarının genişlemesi, Türkiye'nin ihracat performansını olumlu yönde etkilemektedir. Bununla birlikte, dış ticaretin dinamikleri yalnızca üretim hacmindeki artışla sınırlı kalmamakta uluslararası piyasalardaki talep eğilimleri, ticaret anlaşmaları, gıda güvenliği ve kalite standartları, iklim değişikliğinin üretim üzerindeki etkileri ile sürdürülebilirlik kriterleri gibi çok boyutlu faktörlerle yakından ilişkili bir yapı sergilemektedir. Bu çalışmanın temel amacı, dış ticaret dinamikleri çerçevesinde Türkiye'nin tarım ürünleri dış ticaretinde son yıllarda yaşanan yapısal değişimleri analiz etmek ve özellikle öne çıkan ürün grupları ile hedef pazarlar açısından son dönemdeki eğilimleri değerlendirmektir. Çalışmada elde edilen bulgular, Türkiye'nin tarım ihracatında hububat-bakliyat, yaş meyve-sebze, fındık ve zeytin-zeytinyağı gibi geleneksel ürün gruplarının belirleyici bir paya sahip olduğunu göstermiştir. Ayrıca Avrupa Birliği ülkeleri, Orta Doğu ve Asya pazarlarının başlıca dış ticaret bölgeleri olarak öne çıktığı saptanmıştır. Sonuç olarak, Türkiye'nin tarım ürünleri ihracatında son dönemde kayda değer bir büyüme gözlenmekte, ancak bu büyümenin uzun vadede sürdürülebilirliği için üretim verimliliği, lojistik altyapı, ihracat standartları ve pazarlama stratejilerinin güçlendirilmesine yönelik politikaların geliştirilmesi gerekmektedir.

Anahtar Kelimeler: Tarım ürünleri, dış ticaret, ticaret dinamikleri, ticaret eğilimleri

ABSTRACT

Foreign trade in agricultural products holds strategic importance for the Turkish economy in terms of both the sustainability of the agricultural production structure and the expansion of foreign exchange–earning activities. In recent years, increases in the production volume of certain agricultural products, diversification in cropping patterns, and improved access to

international markets have positively influenced Türkiye's export performance. However, the dynamics of foreign trade are not limited solely to growth in production volume rather, they are closely associated with multidimensional factors such as international demand trends, trade agreements, food safety and quality standards, the impacts of climate change on production, and sustainability criteria. The main objective of this study is to analyse the structural changes observed in Türkiye's foreign trade of agricultural products in recent years within the framework of foreign trade dynamics, and to evaluate recent trends with particular emphasis on prominent product groups and target markets. The findings indicate that traditional product groups such as cereals and pulses, fresh fruits and vegetables, hazelnuts, and olives and olive oil continue to play a decisive role in Türkiye's agricultural exports. In addition, the European Union, Middle Eastern, and Asian markets have emerged as the principal foreign trade regions. In conclusion, while a notable growth has been observed in Türkiye's agricultural exports in recent years, the long-term sustainability of this growth requires the development of policies aimed at strengthening production efficiency, logistics infrastructure, export standards, and marketing strategies.

Keywords: Agricultural products, foreign trade, trade dynamics, trade trends

1.GİRİŞ

Dış ticaret, geçmişten günümüze ülkelerin ekonomik büyümesinde ve dışa açılma stratejilerinde her zaman merkezi bir rol oynamıştır. Dış ticarette, ülke içinde üretilen ürünlerin diğer ülkelere pazarlanması söz konusu iken, ülke içinde üretilemeyen farklı ürünlerin iç pazarda dolaşımına imkân tanınmaktadır. Teknolojinin gelişmesiyle birlikte ülkeler arası ticaret ciddi bir ivme kazanmış ve Dünya Ticaret Örgütü (WTO), Ekonomik Kalkınma İşbirliği Örgütü (OECD) gibi uluslararası ticaret örgütlerinin kurulmasıyla dış ticaretin gelişmesi kaçınılmaz bir durum almıştır (Kara ve ark., 2024). Dış ticarette önemli bir pay alan tarımsal üretim, özellikle gelişmekte olan ülkelerde, kırsal istihdamın önemli bir kısmını oluşturmakta ve bu sayede döviz geliri, bölgesel kalkınma ile ulusal gelirin büyümesinde etkili olmaktadır (Osabohien ve ark., 2019). Türkiye coğrafik konumu, ekolojik yapısı ve geniş ürün yelpazesi sayesinde uzun süredir uluslararası tarımsal ticarette etkin bir aktör konumundadır (Kızıltuğ & Akkaya, 2020). Son yıllarda Türkiye'nin tarımsal ürün ihracatında hem niceliksel artışlar hem de niteliksel dönüşümler gözlenmektedir. Özellikle son yirmi yılda tarımsal ürün ihracatında miktar ve çeşitlilik açısından önemli bir artış söz konusudur. 2000'li yılların başında ihracatın önemli payını yaş meyve-sebze ve fındık gibi geleneksel ürünler oluştururken, son yıllarda bu pay hububat-bakliyat, yağlı tohumlar ve zeytinyağı gibi ürün gruplarının eklenmesiyle çeşitlenmiştir (Uydacı & Değerli, 2024). Nitekim, 2010 yılı sonrası dönemde tarımsal ihracat hacminde istikrarlı bir büyüme eğilimi görülmüş ve ürün kompozisyonunda yaşanan değişim, Türkiye'nin hem Avrupa Birliği (AB) ülkelerine hem de Ortadoğu ve Asya pazarlarına yönelik dış ticaret stratejilerinde önemli bir rol oynamıştır (Özenç, 2023). Türkiye'nin tarımsal ürün dış ticaretindeki değişimi, aynı zamanda küresel dinamiklerle doğrudan bağlantılıdır. Küresel ölçekte artan gıda talebi, sürdürülebilir tarımsal üretim ihtiyacı ve ticaret politikalarındaki değişimler, Türkiye'nin dış ticaret yapısında değişikliklere sebep olmuştur. Altay (2024a)

tarafından yapılan bir çalışmada belirtildiği gibi, Türkiye'nin 2016–2022 döneminde tarımsal ürün ihracatında özellikle hububat ve meyve-sebze gruplarında düzenli bir artış yaşanmıştır.

Kalite, sertifikasyon ve sürdürülebilirlik standartları ihracat performansını etkileyen diğer kritik unsurlar olarak karşımıza çıkmaktadır. AB ülkeleri başta olmak üzere gelişmiş uluslararası pazarlar, gıda güvenliği ve çevresel standartlar giderek daha fazla önemsemektedirler. Bu durum, özellikle yaş meyve-sebze gibi hızla bozulabilen ürünlerde rekabet gücünü belirleyen temel faktörlerden biri olmuştur (Kızıltuğ & Akkaya, 2020). Özenç (2023) çalışmasında, Türkiye'nin geleneksel olarak güçlü olduğu meyve-sebze ihracatında pazar payı kayıplarının büyük ölçüde kalite standartları ve sertifikasyon süreçlerindeki yetersizliklerden kaynaklandığını vurgulamaktadır. Son yıllarda yapılan çalışmalarda, tarımsal ürün dış ticaretinin ekonomik boyutunun yanı sıra tarımsal üretimin çevresel etkileri de ön plana çıkmaktadır. Turan (2021), Türkiye'de tarımsal ihracat artışının karbon emisyonları üzerindeki etkisini analiz etmiş ve ihracatın uzun vadede verimlilik artışları aracılığıyla çevresel baskıları azaltabileceğini ve kısa vadede ise yoğun girdi kullanımına dayalı üretim artışının çevresel olumsuzluklara yol açabileceğini çalışmasında ortaya koymuştur. Bu çerçevede, Türkiye'nin dış ticaret stratejilerinin belirlenmesinde çevresel sürdürülebilirliğin dikkate alınmasının önemli olduğu anlatılmaktadır.

Türkiye'de tarımsal ürün ihracatında bölgesel farklılıklar da dikkat çekmektedir. Akdeniz ve Ege Bölgeleri, ağırlıklı olarak zeytin ve zeytinyağı, Karadeniz Bölgesi fındık, Güneydoğu Anadolu Bölgesi ise hububat, bakliyat ve yağlı tohum ihracatıyla dış ticarette önemli katkılar sağlamaktadır (Öztürk ve ark., 2021). Bu durum, Türkiye'nin coğrafi çeşitliliğinin dış ticaret yapısının oluşmasında etkili olduğuna işaret etmektedir. Türkiye'nin tarım ürünleri dış ticaretinde etkili olan bir diğer faktör ise, ulusal destekleme politikaları, uluslararası anlaşmalar ve ticaret politikası araçlarıdır. Türkiye'deki tarım politikaları, özellikle doğrudan destek ödemeleri ve ihracat teşvikleri tarımsal dış ticaret performansında direk etki göstermekte olup, bu politikalar hem ürün desenini hem de dış pazarlara yönelimi şekillendirmektedir (Kızıltuğ & Akkaya, 2020).

Bu çalışmanın amacı, literatürdeki bulgular doğrultusunda son yıllarda Türkiye'nin tarım ürünleri dış ticaretindeki eğilimlerini nicel ve nitel boyutlarıyla analiz etmektir. Çalışmanın analitik odağını; (i) ihracat hacmi ve değerindeki değişimler, (ii) ürün kompozisyonunda gözlenen dönüşümler, (iii) pazarlardaki kaymalar ve (iv) ihracatı biçimlendiren dinamikler oluşturmaktadır. Bu analiz, politika yapıcılar, ihracatçılar ve araştırmacılar açısından mevcut durumu ortaya koymakta ve sürdürülebilir dış ticaret stratejilerine yönelik değerlendirmelere temel oluşturmaktadır.

2.TÜRKİYE'DE TARIM ÜRÜNLERİ DIŞ TİCARETİNİN GENEL GÖRÜNÜMÜ

2.1. Tarım Ürünleri İhracat ve İthalatının Yıllara Göre Seyri

Tarım sektörü, bir ülkenin gıda arz güvenliğinin sağlanması ve ekonomik sürdürülebilirliğinin desteklenmesi açısından stratejik bir öneme sahiptir. Bu bağlamda, tarım ürünleri dış ticaret performansı hem üretim kapasitesinin düzeyini hem de dış pazarlarla olan entegrasyonun gelişimini yansıtan temel göstergelerden biri olarak değerlendirilmektedir. Türkiye'nin tarım

ürünleri ihracat ve ithalatının yıllar itibarıyla seyri incelendiğinde, dış ticaret dengesinin uzun bir dönem boyunca dalgalı bir yapı sergilediği görülmektedir. Söz konusu dalgalanmalarda, işlenmiş ve işlenmemiş tarım ürünleri arasındaki yapısal farklılıkların dış ticaret performansı üzerinde belirleyici bir etkisi bulunduğu ifade edilebilir. Literatürde, özellikle işlenmiş tarım ürünleri ihracatındaki artışın önemli ölçüde Dahilde İşleme Rejimi (DİR) uygulamalarıyla ilişkilendirildiği görülmektedir. Parlakay ve Duru (2017), 1996 yılından itibaren uygulanan DİR teşvik sisteminin, işletmelere ithal girdileri dünya fiyatlarından temin etme imkânı sağlayarak maliyet avantajı yarattığını, bu durumun ise firmaların uluslararası pazarlardaki rekabet gücünü artırarak ihracat performansını olumlu yönde etkilediğini ortaya koymuştur. Bu bağlamda, işlenmiş tarım ürünleri özelinde DİR uygulamaları, tarım ürünleri dış ticaret hacminin şekillenmesinde önemli bir mekanizma olarak öne çıkmaktadır. Yurt dışından ithal edilen tarımsal hammaddelerin iç piyasada işlenerek yeniden ihraç edilmesi, hem ithalat hem de ihracat değerlerini doğrudan ve eş zamanlı biçimde etkilemektedir (Erdal ve ark., 2012). Benzer şekilde, Gençosmanoğlu (2016), DİR kapsamında kullanılan ithal girdilerin sağladığı maliyet avantajının, ihracat değerlerini ve sanayi kapasite kullanım oranlarını anlamlı düzeyde artırdığını belirtmektedir.

Resmî istatistikler, Türkiye'nin tarım ürünleri ihracatında son yirmi yılda kayda değer bir artış yaşandığını göstermektedir. Ticaret Bakanlığı verilerine göre, 2002 yılında 3,7 milyar dolar olan tarım ürünleri ihracatı, 2012 yılında 15,2 milyar dolara yükselmiştir. Çizelge 1'de yer alan veriler incelendiğinde, Covid-19 pandemisinin küresel ölçekte olumsuz etkilerinin hissedildiği 2020 yılında bile, tarım ürünleri ihracatının bir önceki yıla göre %4,9 oranında artarak yaklaşık 20,7 milyar dolara ulaştığı ve bu dönemin ihracat açısından görece yüksek seviyelerin gözlendiği yıllardan biri olduğu anlaşılmaktadır. 2022 yılı ise yaklaşık 30 milyar dolar düzeyindeki tarım ürünleri ihracatıyla incelenen dönem içerisinde en yüksek ihracat değerinin kaydedildiği yıl olarak öne çıkmaktadır. Türkiye'nin toplam tarım ürünleri ihracatı ise 2023 yılında 26,49 milyar dolar olarak gerçekleşmiştir (TGDF, 2024).

Tarım ürünleri ithalatı, ihracat verileriyle birlikte ele alındığında, yıllar itibarıyla belirgin bir artış eğilimi sergilemektedir. Çizelge 1'de sunulan veriler incelendiğinde, tarım ürünleri ithalatının 2022 yılında yaklaşık 23 milyar ABD doları ile en yüksek düzeyine ulaştığı görülmektedir. Bu durum, ithalat ve ihracat değerlerinin birbirine oldukça yakın seyrettiğini ve tarım sektöründe dış ticaret dengesinin kırılgan bir yapıya sahip olduğunu göstermektedir. Tarım ve Orman Bakanlığı ile Ticaret Bakanlığı tarafından yayımlanan raporlarda da belirtildiği üzere, özellikle üretim maliyetleri yüksek olan ve iklim koşullarına duyarlılığı fazla olan ürün gruplarında dışa bağımlılığın devam etmesi, söz konusu görünümün temel nedenleri arasında yer almaktadır. Tarım sektöründe 2023 yılında gözlenen olumlu gelişmeler, Türkiye'nin tarımsal üretim kapasitesini artırma ve ihracat ürün desenini çeşitlendirme potansiyeline sahip olduğuna işaret etmektedir (Ege İhracatçı Birlikleri, 2023). Ancak, ihracatta kaydedilen artışların uzun vadede sürdürülebilirliği konusunda literatürde farklı değerlendirmeler bulunmaktadır. Bu kapsamda, dönemsel olarak ortaya çıkan dış ticaret fazlalarının, yapısal ve kalıcı bir rekabet avantajından ziyade belirli ürün gruplarındaki fiyat avantajları, döviz kuru hareketleri veya kısa vadeli dış talep artışları gibi geçici faktörlerle ilişkili olduğu ifade edilmektedir (TGDF, 2024). Dolayısıyla, tarım ürünleri ihracatındaki

olumlu görünüme rağmen, yem hammaddeleri ve yağlı tohumlar başta olmak üzere temel girdilerdeki ithalat bağımlılığı, sektörün dış şoklara karşı kırılganlığını artırmaktadır.

Çizelge 1. Türkiye'nin Tarım Ürünleri İthalat ve İhracatı (Milyon ABD Doları)

Yıllar	İhracat		İthalat	
	Genel	DİR	Genel	DİR
2013	16 977	7 931	11 200	3 992
2014	17 995	8 189	12 418	4 111
2015	16 789	7 277	11 243	3 472
2016	16 249	7 234	11 038	3 296
2017	16 912	7 356	12 672	3 273
2018	19 276	7 279	14 414	3 021
2019	19 276	6 909	14 687	4 000
2020	20 706	7 306	15 214	3 318
2021	25 001	8 608	17 791	3 995
2022	29 891	10 569	23 210	5 707
2023	29 490	9 890	21 013	4 990

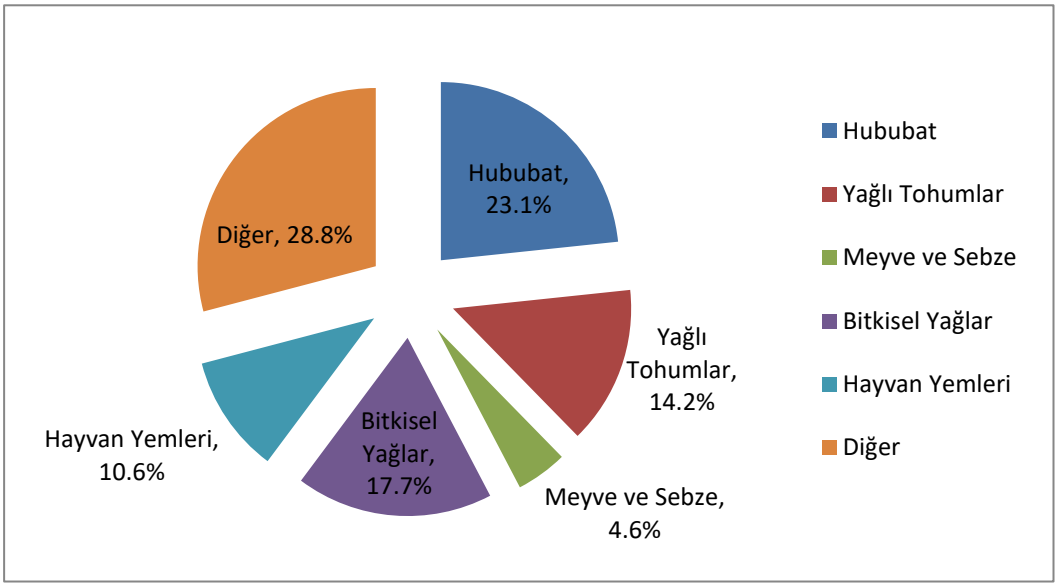
Kaynak: Ticaret Bakanlığı, 2022

2.2. Tarım Ürünleri Dış Ticaretinde Ürün Bazlı Gelişmeler

Bu bölümde tarım ürünleri dış ticareti ürün bazında incelenmiştir. Grafik 1, tarım ürünleri ithalatının ürün grupları itibarıyla dağılımını göstermekte ve Türkiye'nin tarımsal ithalat yapısına ilişkin bazı veriler sunmaktadır. Grafikten anlaşıldığı üzere, **"**Diğer" ürün grubu %28,8 pay ile toplam ithalat içinde en yüksek paya sahiptir. Bu durum, tarım ürünleri ithalatının belirli birkaç ürün grubunda yoğunlaşmakla birlikte, çok sayıda alt ürün grubunu da kapsayan parçalı ve çeşitlenmiş bir yapıya sahip olduğunu göstermektedir. Söz konusu grup, spesifik olarak sınıflandırılamayan veya daha küçük paylara sahip ürünleri içermesi bakımından ithalat kompozisyonunun heterojen niteliğine işaret etmektedir. İkinci sırada yer alan hububat ithalatı (%23,1), Türkiye'nin temel tarımsal girdiler açısından dışa bağımlılığının sürdüğünü göstermektedir. Hububatın stratejik bir ürün grubu olması, bu yüksek payın gıda arz güvenliği ve fiyat istikrarı açısından kritik sonuçlar doğurduğunu ortaya koymaktadır. Bitkisel yağlar (%17,7) ve yağlı tohumlar (%14,2) ithalatının toplam payının oldukça yüksek olması, özellikle yağlı tohum üretimindeki yetersizliklerin ve işlenmiş tarım ürünlerine yönelik talebin ithalat yoluyla karşılandığını göstermektedir. Bu durum, tarımsal üretimde katma değer zincirinin belirli halkalarında yapısal açıklar bulunduğuna işaret etmektedir. Hayvan yemleri (%10,6) ithalatı ise hayvancılık sektörünün önemli ölçüde dış girdilere bağımlı olduğunu ortaya

koymakta ve yem hammaddelerinde ithalata dayalı yapı, üretim maliyetleri ve sektörün rekabet gücü üzerinde belirleyici bir unsur olarak öne çıkmaktadır. Buna karşılık, meyve ve sebze ithalatının (%4,6) görece düşük bir paya sahip olması, Türkiye'nin bu ürün grubunda üretim kapasitesi ve rekabet avantajının daha güçlü olduğunu anlatmaktadır. Genel olarak Grafik 1, Türkiye'nin tarım ürünleri ithalatında özellikle hububat, yağlı tohumlar ve bitkisel yağlar gibi stratejik ürün gruplarında dışa bağımlılığın baskın olduğunu, buna karşın meyve-sebze gibi alanlarda daha güçlü bir üretim yapısına sahip olduğunu ortaya koymaktadır.

Grafik 1. Tarım ürünleri ithalatının ürün grupları itibarıyla dağılımı

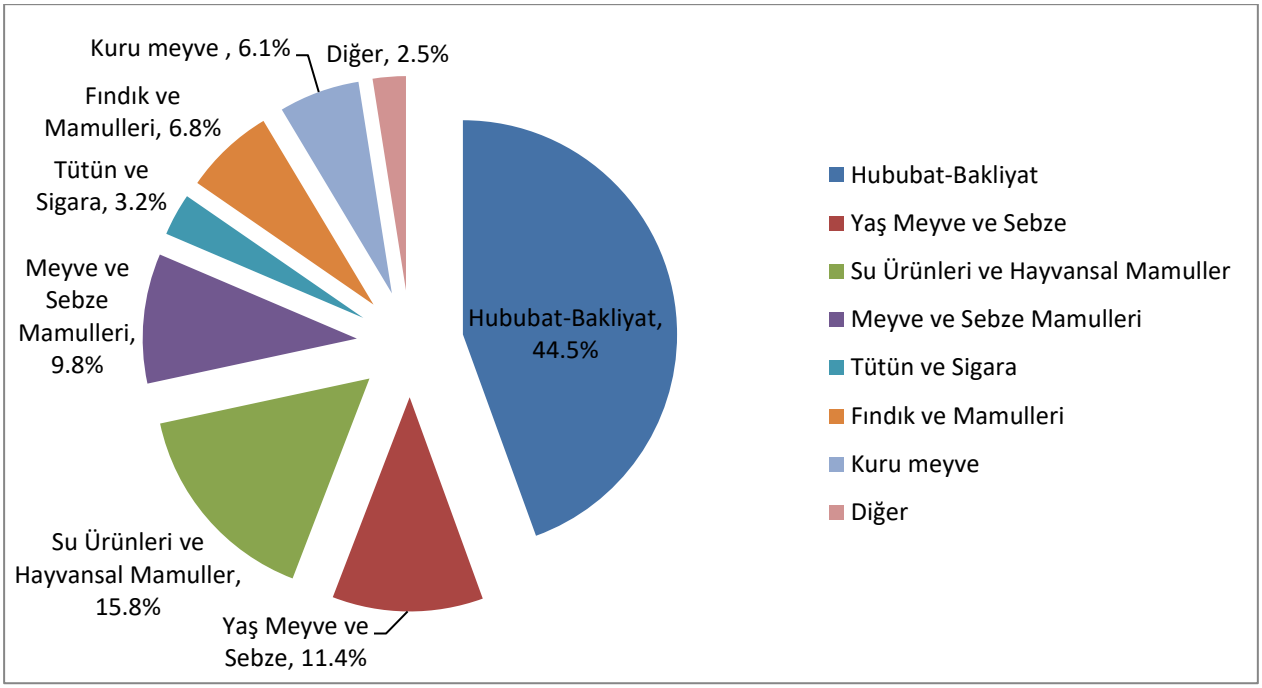


Kaynak: Ticaret Bakanlığı, 2022

Grafik 2'de, tarımsal ürün gruplarının toplam tarımsal ihracat içindeki oransal dağılımı gösterilmiştir. Grafik incelendiğinde, Hububat-Bakliyat grubunun %44,5 ile en yüksek paya sahip olduğu görülmektedir. Bu sonuç, hububat ve bakliyat ürünlerinin hem temel beslenme unsurları olmaları hem de depolanabilirlik, işlenebilirlik ve ticari süreklilik açısından stratejik bir konuma sahip olmalarıyla açıklanabilir. Söz konusu grubun toplam tarımsal ihracat içerisindeki yüksek payı, mevcut tarımsal üretim ve ticaret yapısının büyük ölçüde bu ürünler etrafında şekillendiğini göstermektedir. Grafikte ikinci sırada yer alan Su Ürünleri ve Hayvansal Mamuller (%15,8), hayvancılık ve su ürünlerine dayalı faaliyetlerin önemli bir ekonomik değer oluşturduğunu ortaya koymaktadır. Bu oran, protein temelli gıda ürünlerine olan talebin ve bu alandaki üretim kapasitesinin kayda değer bir düzeyde olduğunu anlatmaktadır. Yaş Meyve ve Sebze (%11,4) ile Meyve ve Sebze Mamulleri (%9,8) birlikte değerlendirildiğinde, taze ve işlenmiş meyve-sebze ürünlerinin toplam payının %21'in üzerinde olduğu görülmektedir. Bu durum, tarımsal üretimde çeşitliliğin bulunduğunu ve katma değeri yüksek işlenmiş ürünlerin önemli bir yer tuttuğunu göstermektedir. Daha düşük oranlara sahip olan gruplar incelendiğinde, Fındık ve Mamulleri (%6,8) ile Kuru Meyve (%6,1) dikkat çekmektedir. Bu ürün grupları, özellikle ihracat potansiyeli yüksek, ancak üretim hacmi sınırlı olan özel tarım ürünlerini temsil etmektedir. Tütün ve Sigara (%3,2) ile Diğer (%2,5) kategorileri ise toplam yapı içerisinde görece düşük bir paya sahiptir. Bu durum, söz konusu ürünlerin ya sınırlı üretim hacmine sahip olduğunu ya da daha dar bir pazar yapısına hitap

ettiğini düşündürmektedir. Genel olarak değerlendirildiğinde, Grafik 2 tarımsal ve gıda temelli sistemin ağırlıklı olarak hububat-bakliyat ve hayvansal ürünler üzerine kurulu olduğunu, buna karşın işlenmiş ve özel ürün gruplarının daha sınırlı oranlarda temsil edildiğini ortaya koymaktadır. Bu dağılım, katma değeri yüksek ürünlerin payının artırılmasının ekonomik çeşitlilik ve sürdürülebilirlik açısından önemli bir potansiyel taşıdığını göstermektedir.

Grafik 2. Tarım ürünleri ihracatının ürün grupları itibarıyla dağılımı



Kaynak: Ticaret Bakanlığı, 2022

2.3. Pazar ve Katma Değerli Ürünler Açısından Dış Ticaretteki Gelişmeler

Son yıllarda Türkiye'nin tarım ve tarıma dayalı ürün ihracatında pazar yapısı ve ürün bileşimi açısından dikkat çekici bir dönüşüm eğilimi gözlenmektedir. Bir yandan, Türkiye'nin tarımsal ihracatında Batı Avrupa ülkeleri başta olmak üzere geleneksel pazarlara olan bağımlılık büyük ölçüde devam ederken diğer yandan Rusya, Orta Doğu ve Kuzey Afrika ülkeleri gibi alternatif pazarlara yönelme eğiliminin güçlendiği görülmektedir. Bu gelişme, tarım ürünleri ihracatında belirli coğrafyalara aşırı bağımlılığın azaltılması ve dış ticaret ilişkilerinin çeşitlendirilmesi açısından önemli bir stratejik kazanım olarak değerlendirilmektedir (Altay, 2024b).

Pazar çeşitlenmesi eğilimi yalnızca ulusal düzeyde değil, aynı zamanda bölgesel ölçekte de farklılaşmalar göstermektedir. Türkiye'de tarımsal ihracat performansının iller arasında belirgin biçimde ayrışması üretim desenleri, tarıma dayalı sanayi altyapısı, lojistik olanaklar ve dış pazarlara erişim kapasitesi gibi faktörlerin bölgesel kalkınma üzerinde belirleyici rol oynadığını ortaya koymaktadır. İller düzeyinde yapılan ampirik çalışmalar, tarım ürünlerinde ürün ve pazar çeşitliliğinin artmasının bölgesel ekonomik büyümeyi desteklediğini, yerel ekonomilerin ihracat yoluyla güçlenmesine katkı sağladığını göstermektedir (Benli ve ark., 2023). Yapılan çalışmalarda, Türkiye'nin tarım ihracatı, ürün çeşitliliği ve katma değer yaratma kapasitesi bakımından önemli bir gelişme potansiyeline sahip olmakla birlikte, bu potansiyelin

henüz tam anlamıyla değerlendirilemediği sıklıkla vurgulanmaktadır. Özellikle küresel değer zincirleri (Global Value Chains – GVC) perspektifinden bakıldığında, Türkiye'nin tarım ve gıda ürünleri ihracatında ağırlıklı olarak ham veya düşük düzeyde işlenmiş ürünlerle yer aldığı, dolayısıyla zincirin orta-alt segmentlerinde konumlandığı görülmektedir. Bu durum, tarımsal ihracatta ürünlerin çoğunlukla düşük katma değerli nitelikte olmasına bağlı olarak, hem birim ihraç fiyatlarının görece düşük seviyelerde kalmasına hem de ihracatın teknoloji, işleme düzeyi ve çeşitlilik açısından sofistikasyonunun sınırlı olmasına yol açmaktadır (Yücel, 2023; Duman, 2025).

Tarım sektöründe katma değer kavramı yalnızca ileri teknoloji kullanımına bağlanmamaktadır. Ürünlerin işlenme düzeyi, kalite ve gıda güvenliği standartları, paketleme, markalaşma, coğrafi işaretleme, izlenebilirlik ve sertifikasyon gibi unsurlar aracılığıyla şekillenmektedir. Türkiye'nin zeytinyağı, fındık, kuru meyve, hububat ürünleri ve süt ürünleri gibi rekabet avantajına sahip olduğu alanlarda, işlenmiş ve markalı ürün ihracatının artırılması, tarımsal dış ticaret gelirlerinin yükseltilmesi açısından kritik öneme sahiptir. Ancak mevcut ihracat yapısında taze ve düşük katma değerli ürünlerin payının yüksek olması, bu potansiyelin yeterince değerlendirilemediğini göstermektedir. Özetle, Türkiye'nin tarım ürünleri dış ticaretinde pazar çeşitlenmesi yönünde kaydedilen ilerlemeler, sektörün dış şoklara karşı dayanıklılığını artırmakta ve ihracatın sürdürülebilirliğini desteklemektedir. Bununla birlikte, uzun vadeli rekabet gücü açısından belirleyici unsur, tarımsal ihracatın katma değer bileşiminin yükseltilmesidir. Bu doğrultuda, tarıma dayalı sanayinin geliştirilmesi, Ar-Ge ve inovasyon faaliyetlerinin desteklenmesi, coğrafi işaretli ve markalı ürünlerin teşvik edilmesi ile sürdürülebilir ve kaliteli üretim standartlarının yaygınlaştırılması, Türkiye'nin tarım sektörünün küresel değer zincirlerinde daha üst basamaklara çıkmasına katkı sağlayacaktır. Dolayısıyla, pazar çeşitlenmesi ile katma değerli tarımsal üretimin eş zamanlı olarak desteklenmesi, Türkiye'nin tarımsal dış ticarette sürdürülebilir büyüme hedeflerine ulaşması açısından stratejik bir gereklilik olarak değerlendirilmektedir (OECD, 2024; World Bank, 2024).

3. DIŞ TİCARET DİNAMİKLERİ ÇERÇEVESİNDE TARIM ÜRÜNLERİ

3.1. Talep Eğilimleri ve Küresel Ticaret Akımlarına Türkiye'nin Uyumu

Uluslararası tarım ürünleri ticaretinde talep yapısı, son yıllarda belirgin bir dönüşüm sürecine girmiştir. Sağlıklı ve organik gıdalara yönelik artan tüketici eğilimleri, sürdürülebilir üretim süreçlerinin yaygınlaşması ve işlenmiş gıda ürünlerine olan talebin güçlenmesi, küresel tarım ürünleri ticaretinin yönünü önemli ölçüde etkilemektedir (Direk, 2025; Yavuz & Hatırlı, 2019). Bu dönüşüm, küresel ticaret akımlarının nicelikten çok nitelik ve katma değer odaklı bir yapıya dönüşmekte özellikle gelişmiş ülkelerde yüksek kalite, izlenebilirlik ve çevresel standartlara sahip ürünlere olan talep artışı ile kendini göstermektedir. Benzer şekilde, Asya ve Orta Doğu pazarlarında nüfus artışı, kentleşme ve yükselen gelir düzeyleri, işlenmiş ve katma değeri yüksek tarım ve gıda ürünlerine yönelik talebi hızlandırmaktadır. Bu bölgelerdeki talep artışı, küresel tarım ticaret akımlarının coğrafi olarak çeşitlenmesine ve gelişmekte olan ülkeler için yeni ihracat fırsatlarının ortaya çıkmasına katkı sağlamaktadır (UkrAgroConsult, 2025).

Dolayısıyla, küresel tarım ürünleri ticareti, hem gelişmiş ülkelerin kalite odaklı talebi hem de yükselen pazarların hacim ve çeşitlilik talebi doğrultusunda yeniden şekillenmektedir.

Türkiye'nin tarım ürünleri ihracatı, söz konusu küresel talep eğilimleri ve ticaret akımları ile uyum sağlama kapasitesi açısından değerlendirildiğinde, seçici ve kısmi bir uyum sürecinin varlığı dikkat çekmektedir. Zeytin ve zeytinyağı, fındık, kuru meyve ile bazı taze sebze ve meyve türleri, kalite, ürün çeşitliliği ve pazarlama kabiliyeti açısından uluslararası talep standartlarıyla daha yüksek düzeyde örtüşmekte ve bu ürünler özellikle Avrupa Birliği ve yüksek gelirli pazarlara yönelik ticaret akımlarına daha başarılı biçimde uyum sağlayabilmektedir (Eren & Sezgin, 2021). Bu durum, Türkiye'nin belirli ürün gruplarında küresel talep dönüşümünü avantaja çevirebildiğini göstermektedir. Buna karşılık, hububat ve baklagiller gibi temel tarım ürünlerinde ihracatın ağırlıklı olarak düşük işlenmiş ve düşük katma değerli ürünlerden oluşması, Türkiye'nin bu segmentlerde küresel ticaret akımlarına sınırlı ölçüde uyum sağlayabildiğine işaret etmektedir. Bu ürün gruplarında birim ihraç fiyatlarının görece düşük olması ve rekabetin büyük ölçüde maliyet temelli yürütülmesi, Türkiye'nin bazı rakip ülkelere kıyasla dezavantajlı bir konumda kalmasına neden olmaktadır (Yavuz & Hatırlı, 2019). Dolayısıyla, Türkiye'nin tarım ürünleri dış ticareti içinde farklı ürün gruplarının küresel talep ve ticaret akımlarına uyum düzeyleri arasında belirgin bir ayrışma söz konusudur. Uluslararası tarım ticaretine uyum, yalnızca ürün kalitesi ve çeşitliliği ile sınırlı olmayıp lojistik altyapı, gıda güvenliği, sertifikasyon süreçleri ve sürdürülebilir üretim uygulamaları gibi tamamlayıcı unsurlarla da yakından ilişkilidir. Son yıllarda Türkiye, özellikle Avrupa Birliği gıda güvenliği mevzuatı ve organik tarım standartları ile uyumlu üretim ve ihracat süreçlerini geliştirmeye yönelik önemli adımlar atmış bu sayede Avrupa ve Orta Doğu pazarlarındaki rekabetçi konumunu korumayı hedeflemiştir (Kara & Demir, 2022). Ancak bu uyum sürecinin tüm ürün gruplarına yaygınlaştırılamamış olması, küresel ticaret akımlarından elde edilen katma değerin sınırlı kalmasına yol açmaktadır.

Sonuç olarak, Türkiye'nin tarım ürünleri dış ticaretinin küresel talep eğilimleri ve ticaret akımlarına kısmen uyum sağladığı söylenebilir. Yüksek katma değerli ürünlerin üretiminin artırılması, sürdürülebilirlik ve kalite standartlarının daha geniş ölçekte entegrasyonu ile lojistik ve pazarlama kapasitesinin güçlendirilmesi, Türkiye'nin küresel tarım ticaret akımları içindeki konumunu ileriye taşıyacak temel stratejik alanlar olarak öne çıkmaktadır. Bu alanlarda sağlanacak ilerlemeler, Türkiye'nin tarım ürünleri ihracat performansını uzun vadede güçlendirecek ve dış ticarette rekabet gücünün artırılmasına katkı sağlayacaktır (Altay, 2024c; Duman, 2025).

3.2. İklim Değişikliği, Sürdürülebilirlik, Lojistik, Kalite ve Gıda Güvenliğinin Türkiye'nin Tarım Ürünleri Dış Ticaretine Etkileri

Uluslararası literatürde iklim değişikliğinin tarım ürünleri üretimi ve gıda güvenliği üzerinde önemli baskılar yarattığı yaygın biçimde kabul edilmektedir. Artan sıcaklıklar, mevsimsel dalgalanmalar ve su kaynaklarındaki azalma, tarımsal üretim süreçlerini doğrudan etkilemekte; bu gelişmeler, tarım ürünlerinin arz istikrarı ve kalite sürekliliği açısından küresel ölçekte çeşitli riskler doğurmaktadır (Tchonkouang ve ark., 2024). Buna paralel olarak, iklim değişikliğine

bağlı üretim ve mevsimsel belirsizliklerin, tarım ve gıda tedarik zincirlerinde aksamalara ve maliyet artışlarına yol açtığına ilişkin bulgular literatürde sıklıkla vurgulanmaktadır (Rojas-Reyes ve ark., 2024).

Küresel düzeyde yapılan çalışmalar, iklim değişikliğinin taşıma sürelerinin uzaması, altyapı üzerinde artan baskılar ve lojistik süreçlerde yaşanan aksamalar yoluyla gıda güvenliği risklerini artırabildiğini ortaya koymaktadır. Özellikle uygun depolama koşulları, taşıma sürelerinin yönetimi ve sıcaklık kontrollü lojistik sistemlerinin yetersizliği, tarım ürünlerinin kalite kaybına uğramasına ve tedarik zincirlerinde kırılganlıkların derinleşmesine neden olabilmektedir (Smith & Delgado, 2023; Tchonkouang ve ark., 2024). Bu bağlamda, lojistik altyapı ve sürdürülebilir tedarik zinciri uygulamaları, gıda güvenliğinin korunmasında küresel ölçekte kritik unsurlar arasında yer almaktadır.

Bu genel bulgular, doğrudan ülke bazlı genellemeler yapılmasını gerektirmemekle birlikte, tarım ürünleri dış ticaretinde iklim koşullarına, lojistik performansa ve kalite standartlarına duyarlı ülkeler açısından önemli çıkarımlar sunmaktadır. Türkiye açısından değerlendirildiğinde, tarım ürünleri ihracatının önemli bir bölümünün taze ve işlenmiş gıda ürünlerinden oluşması, lojistik süreçler, soğuk zincir altyapısı ve gıda güvenliği standartlarının dış ticaret performansı üzerindeki rolünü daha da belirgin hale getirmektedir. Bu nedenle, küresel literatürde ortaya konulan iklim değişikliği ve lojistik temelli risklerin, Türkiye'nin tarım ürünleri dış ticareti açısından potansiyel bir kırılganlık alanı oluşturduğu söylenebilir. İklim değişikliği, sürdürülebilirlik, lojistik altyapı, ürün kalitesi ve gıda güvenliği arasındaki etkileşimler, küresel ölçekte tarım ve gıda sistemlerinin dayanıklılığını belirleyen temel unsurlar arasında yer almaktadır. Türkiye bağlamında ise bunlar, tarım ürünleri dış ticaretinin sürdürülebilirliği ve rekabet gücü açısından dikkatle yönetilmesi gereken stratejik alanlar olarak öne çıkmaktadır. Bu çerçevede, iklim uyumlu üretim uygulamalarının yaygınlaştırılması, lojistik ve depolama altyapısının güçlendirilmesi ve kalite ile gıda güvenliği standartlarının bütüncül bir yaklaşımla ele alınması, Türkiye'nin tarım ürünleri dış ticaretinde karşılaşabileceği risklerin azaltılmasına katkı sağlayacaktır (Scott ve ark., 2024; Tchonkouang ve ark., 2024; Rojas-Reyes ve ark., 2024).

3.3. Ticaret Anlaşmalarının Türkiye'nin Tarım Ürünleri Dış Ticaretine Etkisi

Türkiye'nin tarım ürünleri dış ticareti, uluslararası ticaret anlaşmalarının kapsamı ve uygulama düzeyiyle yakından ilişkilidir. Avrupa Birliği ile yürürlükte olan Gümrük Birliği Anlaşması, özellikle işlenmiş tarım ürünleri ihracatında Türkiye'ye belirli avantajlar sağlamakla birlikte, tarımsal hammaddelerde sınırlı bir serbestlik tanımaktadır (Demir & Aksoy, 2022). Son yıllarda yürürlüğe giren Serbest Ticaret Anlaşmaları (STA), Türkiye'nin ihracat pazarlarını çeşitlendirmesinde önemli bir rol oynamış, özellikle Orta Doğu, Kuzey Afrika ve Güneydoğu Asya ülkelerine yönelik tarımsal ihracatı artırmıştır (OECD, 2023). Bununla birlikte, bazı anlaşmaların teknik düzenlemeler, bitki sağlığı ve gıda güvenliği standartları gibi alanlarda getirdiği uyum zorunlulukları, ihracatçı firmalar açısından ilave maliyet unsurları oluşturabilmektedir (WTO -World Trade Organization , 2024).

Bu nedenle, ticaret anlaşmalarının etkileri yalnızca tarife indirimleri ve gümrük kolaylıklarıyla sınırlı kalmamakta kalite standartlarının yükseltilmesi, sürdürülebilir üretim uygulamalarının benimsenmesi ve kurumsal kapasitenin güçlendirilmesi gibi çok boyutlu unsurları da kapsamaktadır. Bu durum, Türkiye'nin tarımsal ihracat yapısında hem üretim hem de pazarlama süreçlerinin uluslararası standartlara uyumlu hâle getirilmesini zorunlu kılmaktadır. Söz konusu dönüşüm süreci yalnızca özel sektör inisiyatifleriyle değil, aynı zamanda kamu kurumlarının koordineli uygulamalarıyla desteklenmelidir. Türkiye'nin uzun vadede tarımsal dış ticarette rekabet gücünü koruyabilmesi ticaret anlaşmalarının öngördüğü teknik ve idari düzenlemelere uyum sağlayacak yapısal reformların, kapasite geliştirme programlarının ve sürdürülebilir üretim modellerinin etkin biçimde uygulanmasına bağlıdır (Yıldız & Erkan, 2023).

4. SONUÇ

Türkiye'nin tarım ürünleri dış ticareti, son yirmi yılda hem miktar hem de ürün çeşitliliği bakımından önemli bir gelişim göstermiştir. Bu süreçte tarımsal üretim kapasitesinin artışı, ihracat pazarlarının çeşitlenmesi ve işlenmiş ürün ihracatının güçlenmesi, Türkiye'nin uluslararası ticaretinde daha görünür bir aktör hâline gelmesini sağlamıştır. Ancak bu olumlu gelişmelere rağmen, ithalat bağımlılığının özellikle hammadde ve yem girdilerinde devam etmesi, dış ticaret dengesinin sürdürülebilirliğini sınırlayan temel faktörlerden biri olmaya devam etmektedir.

Küresel ölçekte değişen talep eğilimleri, sürdürülebilir üretim ve kalite standartlarına dayalı bir dış ticaret modelinin zorunluluğunu ortaya koymaktadır. Türkiye'nin ihracat kompozisyonunda geleneksel ürünlerin yanı sıra yüksek katma değerli, çevresel standartlara uyumlu ve izlenebilirliği yüksek ürünlerin payının artırılması gerekmektedir. Özellikle organik tarım, iyi tarım uygulamaları ve coğrafi işaretli ürünlerin teşvik edilmesi, uluslararası pazarlarda Türkiye'nin rekabet gücünü güçlendirecektir. İklim değişikliğinin üretim ve lojistik süreçleri üzerindeki olumsuz etkileri, tarımsal tedarik zincirlerinin kırılganlığını artırmaktadır. Bu nedenle, iklim değişikliğine uyumlu üretim tekniklerinin yaygınlaştırılması, su kaynaklarının verimli kullanımı ve lojistik altyapının modernizasyonu öncelikli politika alanları arasında yer almalıdır. Gıda güvenliği, kalite kontrolü ve sertifikasyon sistemlerinin uluslararası normlarla uyumlu biçimde geliştirilmesi, Türkiye'nin ihracat ürünlerinin marka değerini artıracaktır. Diğer yandan, uluslararası ticaret anlaşmaları Türkiye'nin dış ticaret pozisyonunu belirleyen stratejik unsurlardan biridir. Bu anlaşmaların sadece tarife indirimleri değil, aynı zamanda teknik düzenlemeler, sürdürülebilirlik standartları ve kurumsal kapasiteyi güçlendirme boyutları dikkate alınmalıdır. Dolayısıyla, Türkiye'nin tarımsal dış ticarette uzun vadeli rekabet gücü, bu anlaşmalara uyum sağlayacak yapısal ve teknik dönüşümlerin hayata geçirilmesine bağlıdır. Türkiye'nin tarım ürünleri dış ticaretinde sürdürülebilir büyüme ve rekabet avantajı elde edebilmesi için üretimden pazarlamaya kadar bütüncül bir yaklaşım benimsenmesi gerekmektedir. Tarımsal Ar-Ge yatırımlarının artırılması, ihracat odaklı üretim planlamasının güçlendirilmesi ve kamu–özel sektör iş birliği bu sürecin temel yapı taşlarını oluşturacaktır. Bu doğrultuda geliştirilecek politikalar, hem dış ticaret dengesinin iyileştirilmesine hem de

Türkiye'nin uluslararası tarımsal gıda üretiminde sürdürülebilir bir konum edinmesine katkı sağlayacaktır.

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FARKLI KİREÇ DOZLARININ 'VİKİNG' ARONYA ÇEŞİDİNİN VERİM VE POMOLOJİK ÖZELLİKLERİ ÜZERİNE ETKİLERİ

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ÖZET

Türkiye için yeni bir meyve türü sayılabilecek aronya hem birim alandaki getirisi hem de sağlık açısından sahip olduğu faydalar sayesinde dünya çapında çok aranan bir meyvedir. Türkiye'de son yıllarda çok sayıda aronya bahçeleri tesis edilmekte, yetiştiriciliği günden güne artmakta ve artan iç talep ürün değerini artırmaktadır.

Tarımsal üretimin diğer alanlarında olduğu gibi aronya yetiştiriciliğinde de verimli, kaliteli, amaca uygun bir üretim yapmayı etkileyen unsurların başında iklim, arazi ve diğer ekolojik şartlar gelmektedir. Aronya bahçesinin kurulacağı yerin toprak özellikleri kârlı bir üretim için son derece önem arz etmektedir. Türkiye'de Karadeniz Bölgesi hariç diğer bölgelerimizin hemen tamamı yüksek kireçli toprak özellikleri göstermektedir. Kireçli toprak, bitki besin alımına bağlı olarak bitki büyümesini sınırlayabilir. Yüksek kireçli topraklarda apoplastik pH değişimi ve besin elementlerinin yetersizliği klorofil sentezi, kök gelişimi, enzim sentezi ile bitki gelişimini olumsuz etkiler.

Bu çalışmada, farklı kireç dozlarının 'Viking' aronya çeşidinin verim ve pomolojik özellikleri üzerindeki etkileri incelenmiştir. Bunun için aronya fidanları farklı kireç dozları içeren (%30 (kontrol), %20 ve %10) ortamlar ile doldurulmuş saksılara dikilmiştir. Kontrol grubu, bahçe toprağı olup toprak analizi sonucunda %30 kireç içerdiği belirlenmiştir. Çalışmada bazı pomolojik gözlem ve verim değerleri incelenmiştir. Çalışma sonunda, kireç dozlarının aronya bitkisinin verim ve pomolojik özellikleri üzerinde önemli farklılıklar oluşturduğu belirlenmiştir. Meyve tutum oranında en yüksek değer %30 (kontrol) dozunda kaydedilmiş olmasına rağmen, en yüksek salkım sayısı (11.27 adet) ve bitki başına verim (80.25 g) %20 kireç dozunda tespit edilmiştir. Salkımdaki çiçek (22.08 adet) ve meyve sayısı (9.27 adet), meyve eni (13.42 mm), boyu (12.56 mm) ve ağırlığında (1.33 g) en yüksek değer %10

dozunda kaydedilmiştir. Çekirdek sayısı (18.67 adet) ve çekirdek ağırlığında (0.08 g) tüm uygulamalarda benzer sonuçlar alınmıştır.

Adaptasyon kabiliyetinin yüksek olması sayesinde aronya bitkisi çok geniş toprak tiplerinde yetiştirilebilse de yüksek kireçli toprakların aronya yetiştiriciliğini sınırlayabiliceği tespit edilmiştir.

Anahtar kelimeler: aronya, büyüme, gelişme, kireç, stres, verim

ENDEMİK HUŞ GÖVDELİ KIZILAĞACIN (*Alnus glutinosa* subsp. *betuloides* Ansin) POPULASYON ANALİZİ

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ÖZET

Bu çalışma ile ülkemize özgü endemik bir odunsu takson olan Huş gövdeli kızılağacın (*Alnus glutinosa* subsp. *betuloides* Ansin) yayılış alanlarındaki popülasyon durumu taksonun çap-boy değerlerinin ve yaş tayininin yapılması amaçlanmıştır. 2024 yılı vejetasyon döneminde taksonun doğal yayılış alanları olan Bitlis ili Hizan ilçesi, Erzurum ili Hınıs ilçesi ve Bingöl ili Genç ilçesinde saha çalışmaları gerçekleştirilmiştir. Çalışmalarda taksonun bulunduğu bölgelerin koordinatları, yükseltisi ve yaklaşık olarak taksonun kapladığı alan tespit edilmiştir. Ayrıca popülasyon analizi için her alanı temsil edecek belirli sayıda bireyden çap ve boy ölçüsü alınmıştır. Çalışma alanlarındaki ağaçların ortalama yaşını belirlemek amacıyla, türlerin normal gelişimini temsil edebilecek baskı altında kalmamış seçilen ağaçlardan ve göğüs yüksekliğinden (d1,30) artım burgusu kullanılarak artım kalemleri alınmıştır. Çalışma alanlarından alınan artım kalemleri üzerindeki yıllık halkalar sayılarak yaş tahminleri yapılmıştır. Araştırma sonucunda endemik alt tür olan huş gövdeli kızılağacın yayılış gösterdiği lokasyonlarda suya bağımlı olduğu, ağaç köklerinin su içinde kaldığı, nehir kenarından iç bölgelere türün yayılışının olmadığı tespit edilmiştir. Taksonun çalışma alanı olan Bingöl ili Genç ilçesinde yaklaşık olarak 1100 m, Bitlis ili Hizan ilçesinde 1500 m ve Erzurum ili Hınıs ilçesinde 1700 m yükseltilerde yayılış gösterdiği belirlenmiştir. Ölçüm yapılan bireylere göre Bingöl ilinde ortalama ağaç çapı 13,1 cm ve ortalama ağaç boyu 10,5 m; Bitlis ilinde ortalama ağaç çapı 11,2 cm ve ortalama ağaç boyu 8,5 m ve Erzurum ilinde ortalama ağaç çapı 9,9 cm ve ortalama ağaç boyu 8,1 m olarak tespit edilmiştir.

Anahtar Kelimeler: Huş gövdeli kızılağaç, endemik, popülasyon analizi

POPULATION ANALYSIS OF ENDEMIC BIRCH-BARKED ALDER (*Alnus glutinosa* subsp. *betuloides* Ansin)

ABSTRACT

This study aimed to determine the distribution of the Birch-barked alder (*Alnus glutinosa* subsp. *betuloides* Ansin), an endemic woody taxon unique to Türkiye, and to determine the diameter-height values and age of the taxon. Field studies were conducted in the Hizan district of Bitlis province, Hınıs district of Erzurum province, and Genç district of Bingöl province, which are the natural distribution areas of the taxon during the 2024 vegetation period. In the studies, the

coordinates, altitude, and approximate area covered by the taxon in the regions were determined. In addition, diameter and height measurements were taken from a certain number of individuals representing each area for population analysis. To determine the average age of the trees in the study areas, increment cores were taken from selected trees that were not under pressure and could represent the normal development of the species, using an increment borer at breast height (d1.30 cm). Age estimates were made by counting the annual rings on the increment cores taken from the study areas. The research revealed that the endemic taxon, the birch-barked alder, is water-dependent in its distribution areas, and that the species does not spread from riverbanks to inland regions. The taxon was found to be distributed at approximately 1100 m altitude in Genç district of Bingöl province, 1500 m in Hizan district of Bitlis province, and 1700 m in Hınıs district of Erzurum province. Based on the measured individuals, the average tree diameter was 13.1 cm and the average tree height was 10.5 m in Bingöl province; 11.2 cm and the average tree height was 8.5 m in Bitlis province; and 9.9 cm and the average tree height was 8.1 m in Erzurum province.

Keywords: Birch-barked alder, endemic, population analysis

1. GİRİŞ

Küresel iklim değişikliği günümüzde biyolojik çeşitlilik, türlerin hayatta kalması ve çeşitli biyomlardaki ekosistemlerin istikrarı için en önemli tehditlerden biri olarak kabul edilmektedir (Zeraatkar ve ark., 2025). Özellikle endemik türler, dar yayılış alanları ve yüzyıllar boyunca geçirdikleri gelişim süreçlerinde oluşturdukları belirli iklimsel adaptasyonları nedeniyle diğer geniş yayılışlı taksonlara nazaran bu tehditten daha olumsuz etkilenmektedir. Pek çok endemik tür, sınırlı yayılış alanları, küçük popülasyon büyüklükleri, benzersiz genetik rezervleri, belirli habitat gereksinimleri ve düşük yayılma kapasiteleri gibi özelliklerin bir kombinasyonuna sahiptir (Sękiewicz ve ark., 2024). Bu özelliklerinden dolayı endemik türler özellikle de ağaçlar ve çalılar iklimde meydana gelen değişikliklere ve çevresel farklılıklara ayak uyduracak kadar hızlı adapte olamayabilir; aşırı sıcaklık ve uzun kuraklık stresleri bu türlerin fizyolojik mekanizmalarını, büyümelerini ve dağılımlarını etkileyebilir (Lavergne vd. 2004; Zeraatkar ve ark., 2025). Bu nedenle, bölgelerin evrimsel mirasını temsil eden bu benzersiz türlerin korunması, değişen bir çevrede uzun vadeli sürdürülebilirliklerini sağlamak için koruma önceliklerinin oluşturulması son derece önemlidir.

Ülkemize özgün endemik bir takson olan *Alnus glutinosa* subsp. *betuloides* Ansin Türkiye'deki altı adet doğal Kızılağaç taksonundan biridir. Kızılağaçlar (Alnus spp., Betulaceae), And Dağları'nda yayılan iki türü haricinde (A. acuminata Kunth ve A. jorullensis Kunth) kuzey yarımkürenin ılıman bölgelerindeki kıyı ve dağlık yaşam alanlarının öncü türlerinden olan ağaç veya çalılardır. Avrasya'dan Amerika'ya kadar yaklaşık 35 Kızılağaç türü bilinmektedir. Kızılağaçlar, dış çaprazlama üreme sistemine sahip, rüzgarla tozlaşan tek evcikli ağaçlardır ve alt cins Alnus, alt cins Clethropsis (Spach) Regel ve alt cins Alnobetula (W. D. J. Koch) Peterm. olmak üzere üç alt cinsle sınıflandırılmaktadır. Bunlardan Alnus alt cinsi, 20'den fazla tür içerdiği ve Alnus glutinosa gibi bazı üyelerin yaygın olarak dağıldığı başlıca kızılağaç alt cinsidir. Altcins Alnus türleri saplı sürgün tomurcuklarına sahiptir ve kış sonu veya ilkbaharda

tozlaşırlar (Vanden Heuvel 2011; Vít ve ark., 2017; Gryta ve ark., 2017). Ülkemizde yetişen doğal kızılağaç taksonları da bu alt cinse dahildir ve Türkiye'de iki türe ait altı takson doğal olarak yayılış göstermektedir. Bunlar;

- *Alnus orientalis* Decne. (Doğu kızılağacı)
  - *Alnus orientalis* var. *orientalis* (Doğu kızılağacı)
  - *Alnus orientalis* var. *pubescens* Dippel (Tüylü Doğu kızılağacı) (Endemik IUCN: LC)
- *Alnus glutinosa* (L.) Gaertn. (Yaygın kızılağaç)
  - *Alnus glutinosa* subsp. *glutinosa* (Yaygın kızılağaç)
  - *Alnus glutinosa* subsp. *barbata* (C.A.Mey.) Yalt. (Sakallı kızılağaç)
  - *Alnus glutinosa* subsp. *antitaurica* Yalt. (Toros kızılağacı) (Endemik IUCN: NT)
  - *Alnus glutinosa* subsp. *betuloides* Ansin (Huş gövdeli kızılağaç) (Endemik IUCN: NT)

(Ekim ve ark., 2000)

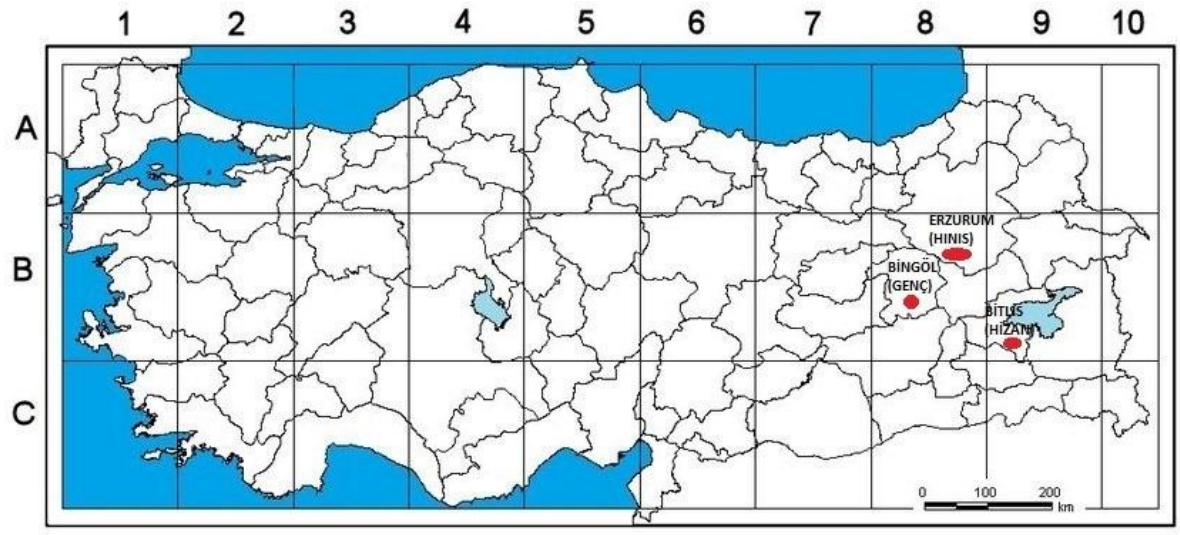
Kızılağaçlar, sahil, dere içleri ve nemli-serin yamaçlarda, deniz kıyısından yaklaşık 1800 m'ye kadar yetişir; toprak nemi yüksek ve rutubetli alanlarda, özellikle dere kenarları, bataklıklar ve derelerin rutubet etkisine sahip alt/orta yamaçlarında yüksek üreme potansiyeline sahiptir. Öncü tür olarak yaprak dökümüyle toprağı organik maddece zenginleştirir; havanın azotunu bağlayan yumruları sayesinde fakir toprakların ıslahında da etkilidir. Hızlı büyüyüp kolay adapte olan kızılağaç, heyelan/erozyon sonrası öncü ağaç olarak ıslah çalışmalarında önemli rol oynar; iklim koşulları açısından su açığı olmayan alanlarda varlık gösterir. Odunu dayanıklı, temiz işlenebilir ve cilalanabilirdir; ancak hava değişimlerinde çürüme sorunuyla karşılaşabilir. Hammadde olarak kontrplak, mobilya, tornacılık, deri sanayi için tanen, boya maddesi ve ambalaj gibi çeşitli alanlarda kullanılır. Kızılağaç, zararlılara dayanıklı ve kısa üretim periyodunda yüksek odun verimi sağlar; sel ve dere yataklarının stabilizasyonunda ve nehir ekosistemlerinin ıslahında önemli rol oynar (Kaya, 2014; Yıldırım ve ark., 2020)

Bu çalışmaya konu olan Huş gövdeli kızılağaç (*Alnus glutinosa* subsp. *betuloides*); Doğu Anadolu Bölgesinde lokal bir yayılışa sahiptir. Erzurum-Hınıs, Bingöl-Genç, Bitlis-Hizan yörelerinde dere içlerinde bulunur. Endemik bir alttürdür. Diğer kızılağaç taksonlarından gövde kabuğunun beyaz renkli olması ve uzun yıllar çatlamadan ağaç üzerinde kalması ile kolayca ayrılır. Bu özelliğiyle Huşlara (Betula spp.) benzer. Diğer yandan, yaprak ayasının dip kısmı geniş ve köşeli değil, çoğunlukla dar kama şeklinde sonuçlanır. Dişi çiçek kozalaklarının 3-5'i bir arada topluluklar halinde kışın ağaç üzerinde kalır (Anşin ve Özder, 1993; Aksoy, 2018). Ülkemize özgü endemik bir ağaç türü olan *Alnus glutinosa* subsp. *betuloides* taksonu ülkemizin de içerisinde yer aldığı üç önemli biyoçeşitlilik sıcak noktasından biri olan Iran-Anadolu sıcak noktasından yalnızca üç lokasyondan bilinmektedir. Taksonun bilim dünyasına tanıtılması ilk kez 1993 yılında yapılmış ve üstünden geçen 32 yılda hiçbir bilimsel çalışmaya konu olmamıştır. Taksonun botanik özelliklerinden başka literatürde hiçbir bilgi yer almamaktadır. Türkiye Bitkileri Kırmızı Listesine (Ekim ve ark., 2000) göre takson NT (Tehdite Açık) tehlike kategorisinde yer almaktadır. Yapılan bu çalışma ile türe ait lokasyonlarda yapılan ölçüm ve sayımlarla türün popülasyonu hakkında detaylı bilgiye sahip olunması ve yöre halkı tarafından kullanımı ve varsa üzerindeki baskıların saptanması amaçlanmıştır.

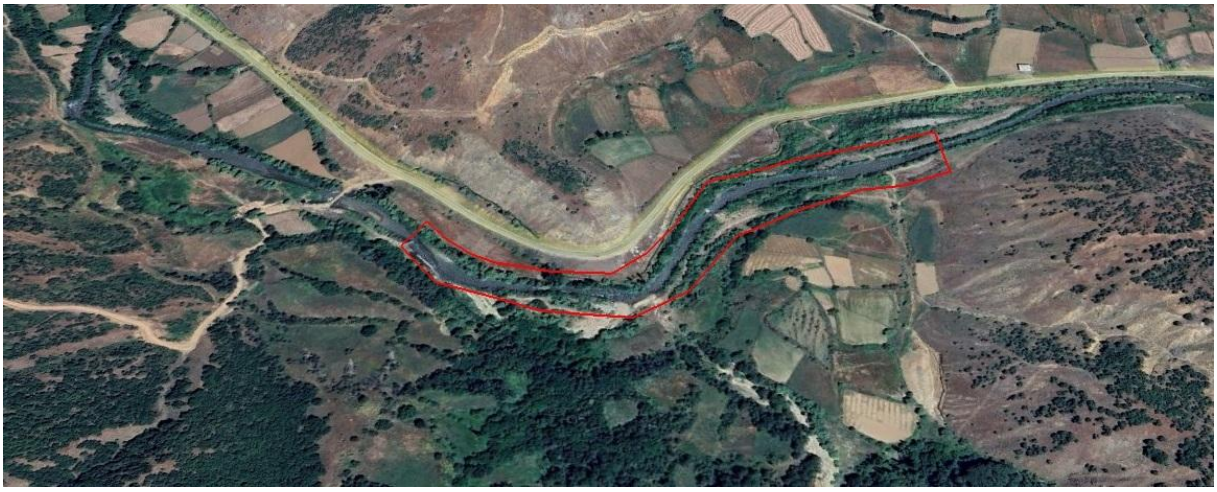
2. MATERYAL VE METOD

2.1. Çalışma alanı

Çalışma alanı Bitlis ili Hizan ilçesi, Bingöl ili Genç ilçesi ve Erzurum ili Hınıs ilçesi sınırları içerisinde bulunan üç lokasyondan oluşmaktadır. Taksonun yayılış alanlarından ilki Bitlis ili Hizan ilçesi yönünde giderken şehir merkezine yaklaşık 30 km uzaklıkta ilin güneydoğusunda, ikincisi Bingöl ili Genç ilçesinin güneyinde ilçe merkezine yaklaşık 5 km uzaklıkta ve üçüncü nokta Erzurum ili Hınıs ilçe merkezi yakınlarından yer almaktadır. Aynı zamanda alanlar Davis (1965)'in grid sistemine göre incelenecek olursa Bingöl ve Erzurum illerinden seçilen alanlar B8 karesinde, Bitlis ilinden alınan nokta ise B9 karesinde bulunmaktadır.



Görsel 1. Çalışma alanları



Görsel 2. Bitlis-Hizan çalışma alanının uydu görüntüsü



Görsel 3. Bingöl-Genç çalışma alanının uydu görüntüsü



Görsel 4. Erzurum-Hınıs çalışma alanının uydu görüntüsü

2. 2. Materyal

Araştırmanın ana materyalini, Erzurum, Bitlis ve Bingöl illerinde yayılış gösteren tehdit altındaki *Alnus glutinosa* subsp. *betuloides* taksonuna ait bireyler ve bu taksonun yayılış alanlarından toplanan herbaryum örnekleri oluşturmaktadır. Çalışılacak taksonun yayılış alanları Anşin ve Özder (1993) "Yeni bir kızılağaç taksonu-*Alnus glutinosa* subsp. *betuloides* (Betulaceae)" isimli makaleden elde edilen lokasyonlara gidilerek belirlenmiştir.

Çalışmaya konu olan Alnus glutinosa türüne ait taksonun tanıtımı

Alnus glutinosa (L.) Gaertner, Yaygın Kızılağaç

Çoğunlukla 20–30 m boylarında bir ağaç, bazen de boylu çalı halinde yaprak döken odunsu bir türdür. Genç dallar ve yapraklar yapışkandır. Yaprakları ters yumurtamsı ila yuvarlak şekilli, parlak koyu yeşil renkli, kenarları çift sıralı dişli ve uçları küt ya da bazen çentiklidir. Çiçekler tek evciklidir. Sarkık erkek kedicikler sonbaharda oluşur ve kışı ağaçta geçirirler. Dişi çiçekler, yapraklar çıkmadan önce mart ayında açar. Çiçeklenmeden sonra dişi kedicikler, içlerinde kanatlı tohumlar oluşan 1-2 cm uzunluğunda odunsu meyve kurulları (strobiller) dönüşür.

Tohumlar sonbaharda olgunlaştığında dağılır, ancak odunsu meyve kurulları genellikle kış boyunca ağaçta kalır ve sonraki büyüme mevsimine kadar varlığını sürdürür. Nus meyve koyu veya kırmızımsı kahverengi, 2-3 mm, dar kanatlıdır. Ağaç köklerindeki nodüllerde Fabaceae (Baklagiller) familyasında olduğu gibi azot sabitleyici mikroorganizmalar gelişir (Davis 1965-85; Davis vd. 1988, Anşin ve Özder, 1993; Güner vd., 2000; Aksoy, 2018).

Yaygın kızılağaç; gövde kabuğu, yaprak biçimi, yaprağının tüylü olup olmayışı gibi botanik özelliklerine göre dört alttüre ayrılır;

1. Tomurcuklar ve yaprak sapları beyaz tüylü; yaprakların altı boz tüylü……..……..….**subsp. antitaurica**

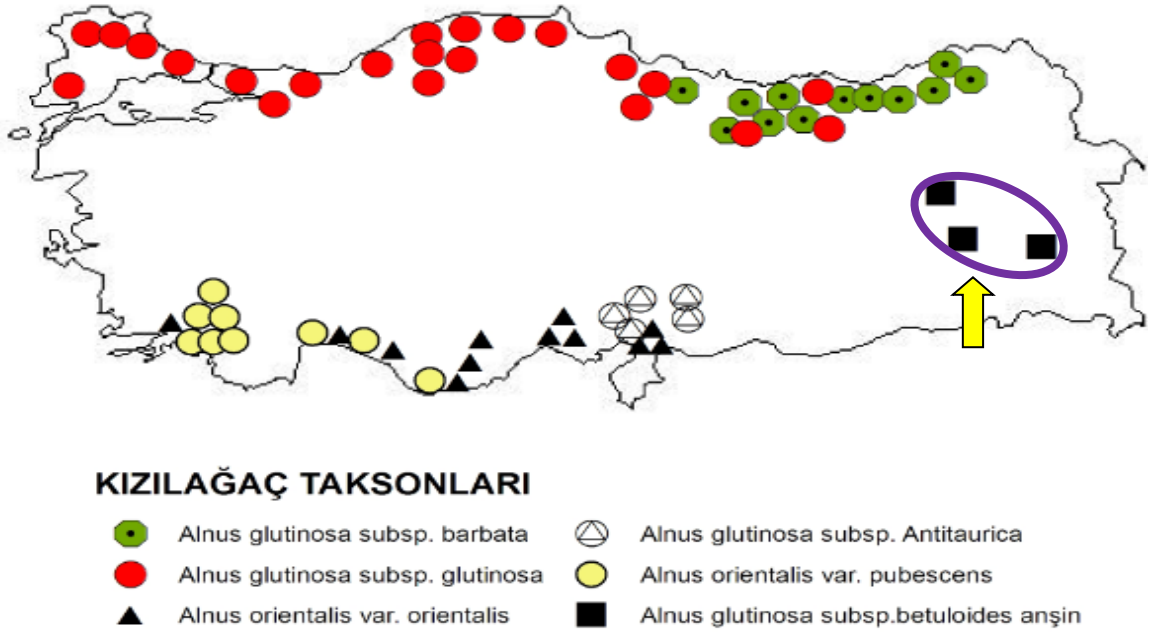
1. Tomurcuklar, yaprak sapları ve yapraklar az-çok tüysüz

2. Gövde kabuğu, sürgünler ve yaşlı tomurcuklar beyaz veya yeşilimsi-beyaz renkte……...……....**subsp. betuloides**

2. Gövde kabuğu, sürgünler ve yaşlı tomurcuklar beyaz değildir

3. Yapraklar 4-8(-9) çift yan damarlı, ters yumurtamsı-yarı dairesel, tepesi içe girintili……..….**subsp. glutinosa**

3. Yapraklar 8-11 çift yan damarlı, geniş yuvarlak eliptik, dairemsi yavaşça ucu keskin, düz……..……..…....**subsp. barbata**



Görsel 5. Türkiye'de kızılağaç taksonlarının dağılımı (Aydın vd. 2019'dan düzenlenerek)

2.3. Metod

Arazi çalışmaları kapsamında belirlenen lokasyonlarda popülasyonu temsil edecek sayıda bireyde ölçümler gerçekleştirilmiştir. Öncelikle bulunan alanın yükseltisi ve konumu konum belirle cihazı (GPS) ile belirlenmiştir. Ardından Bitlis-Hizan'da 119 adet gövdede, Erzurum-Hınıs'ta 115 adet gövdede ve Bingöl-Genç'te 119 adet gövdede ağaç çapı ve ağaç boyu ölçülmüştür. Bireylere ait çap ve boylar standart ölçüm tekniklerine göre yapılmıştır. Çap ölçümleri cm bölümlü metal kumpas yardımıyla ağaçların göğüs yüksekliğinden ($d_{1.30}$ seviyesi) yapılmıştır. Boy ölçümlerinde ise ormancılıkta kullanılan klasik bir hipsometre olan Blume-

Leiss kullanılmıştır. Ağaçların boyu ölçülürken ağacın toprakla birleştiği noktadan en üstünde görülen yapraklı kısma kadar olan bölümün uzunluğu olarak belirlenmiştir. Ardından her üç lokasyondaki (Erzurum-Hınıs; Bingöl-Genç ve Bitlis-Hizan) dere içlerinde türlerin normal gelişimini temsil edebilecek, baskı altında kalmamış seçilen ağaçlardan artım kalemleri alınmıştır. Huş gövdeli kızılağaç taksonlarının yaş tayininin yapılabilmesi için canlı ağaçlardan 40 cm'lik artım burgusu ile göğüs hizası seviyesinden (130 cm yükseklikten) ağacın merkezine doğru artım kalemleri alınmıştır. Seçilen her bir ağaç iki yönlü olarak (Kuzey-Güney ve Doğu-Batı) örneklenmiştir. Alınan örnekler (artım kalemleri), laboratuvarda incelenene kadar zarar görmemeleri için daha önce hazırlanmış plastik borulara konulmuştur.

3. BULGULAR

Alnus glutinosa subsp. *betuloides* taksonuna ait popülasyon analizinin yapılması amacıyla 2024 yılı vejetasyon periyodunda lokasyonlar ziyaret edilerek gerekli ölçümler gerçekleştirilmiştir. Saha çalışmalarında ağaçların dere yataklarında, su içinde geliştiği ve sudan uzaklaşıldığında taksonun yetişmediği gözlemlenmiştir. Sahadaki örnekler bazı bireylerde dipten tek gövde olarak büyümüşken bazı bireylerde dipten itibaren çok gövdeli olduğu gözlenmiştir. Çok gövdeli bireylerde her gövdenin çapı ve boyu ayrı ayrı ölçülerek kayıt edilmiştir. Ölçümlerin yapılacağı bireylerin sağlıklı olanlardan seçilmesine özen gösterilmiştir. Aşağıda ölçüm yapılan bireylerin genel görünümlerine ve habitatlarına ait görseller verilmiştir (Görsel 6, Görsel 7 ve Görsel 8).



Görsel 6. Bitlis-Hizan yöresinde taksonun genel görünüşü ve habitatı

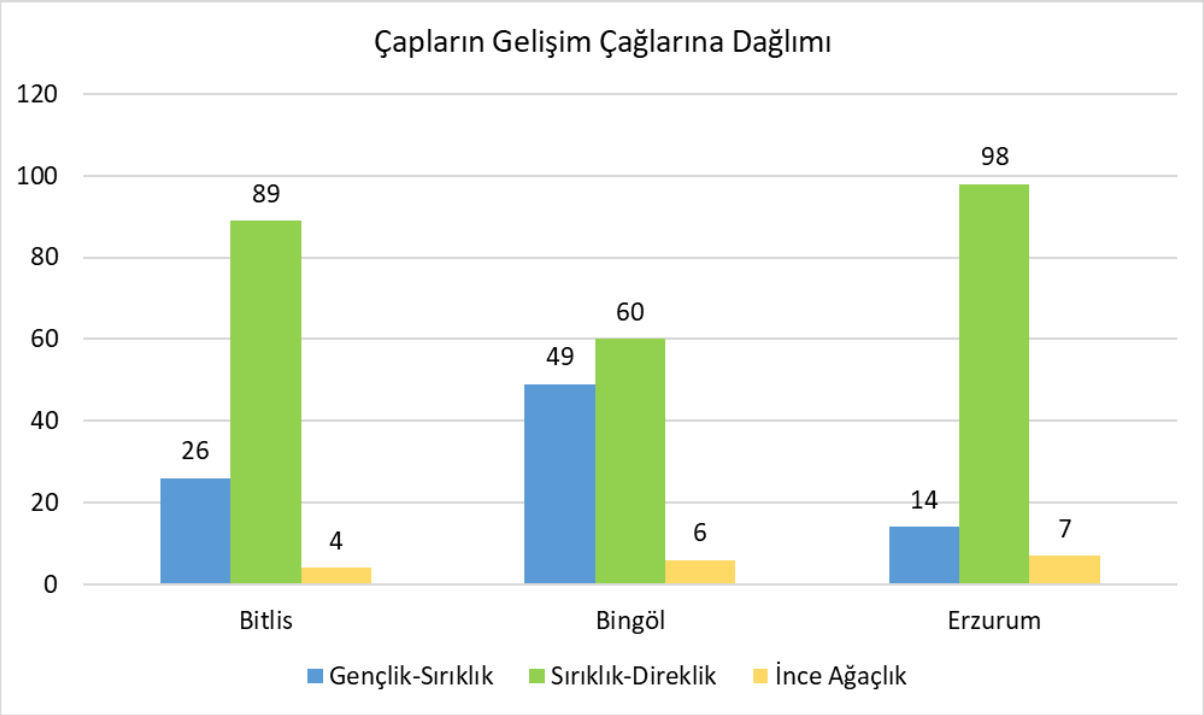


Görsel 7. Bingöl-Genç yöresinde taksonun genel görünüşü ve habitatı



Görsel 8. Erzurum-Hınıs yöresinde taksonun habitatı ve genel görünüşü

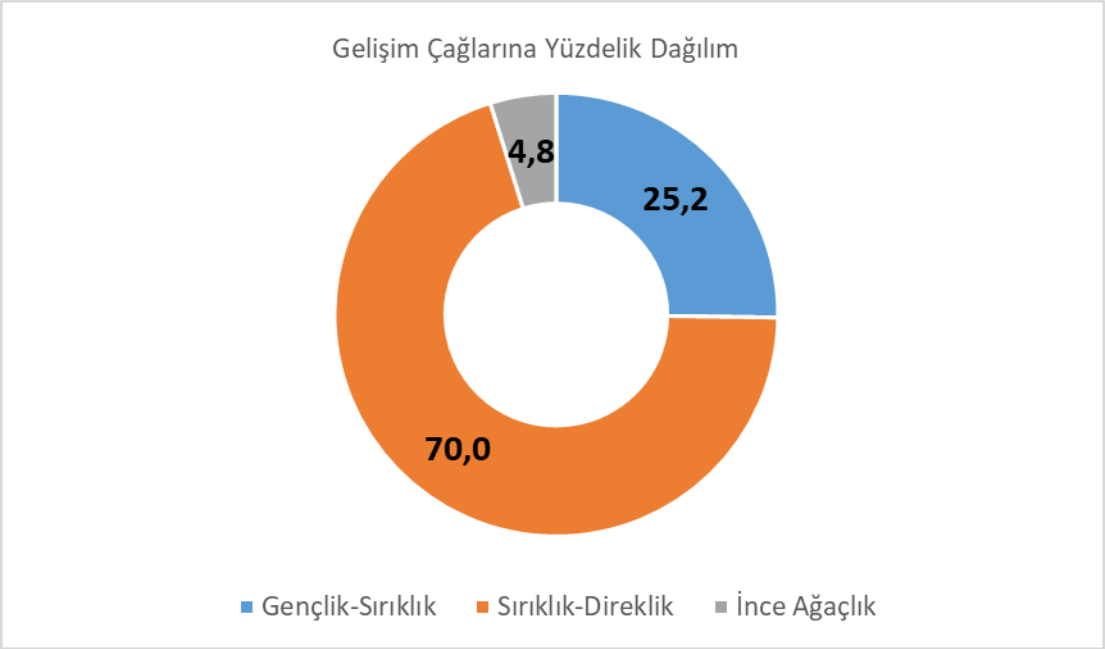
Çap ölçümü yapılan Huş gövdeli kızılağaç bireylerinin gelişim çağlarına göre sayısal dağılışı lokasyonlara göre ayrı ayrı olacak şekilde aşağıdaki görselde verilmiştir (Görsel 9). Yapılan analizler sonucunda her üç lokasyonda da en fazla bireyin Sırıklık-Direklik Çağı'nda (8-19,9 cm çap aralığı) olduğu tespit edilmiştir. Bunu sırasıyla Gençlik-Sırıklık (0-7,9 cm çap aralığı) ve İnce Ağaçlık çağları (20-35,9 cm çap aralığı) takip etmiştir.



Görsel 9. Ölçüm yapılan ağaç çaplarının gelişim çağlarına dağılımı

Huş gövdeli Kızılağaç taksonlarının her üç yörede de çoğunlukla sırıklık-direklik çağında olması faydalanmanın çok fazla olduğunu göstermektedir. Arazi çalışmaları sırasında yerel halkla yapılan görüşmelerde türden çeşitli şekillerde faydalandıklarını belirtmişlerdir. Bitlis-Hizan yöresinde genellikle yakacak odun olarak; Erzurum-Hınıs yöresinde palet ve mobilya ayakları yapımında; Bingül-Genç ilçesinde ise kereste, yakacak odun, mezar tahtası ve evlerin dışında dekor amaçlı kaplama olarak kullandıklarını belirtmişlerdir. En fazla faydalanmanın Bingöl yöresinde olması türlerin gelişim çağlarına dağılımına da etki etmiştir. Bu yörede sırıklık direklik çağında olduğu kadar gençlik-sırıklık çağında da çok sayıda bireyin olduğu görülmektedir (Görsel 9). Ayrıca Uzun ve Keçe (2024) yapmış oldukları çalışmada endemik diğer bir kızılağaç taksonu olan *Alnus glutinosa* subsp. *antitaurica*'nın Adana-Kozan yöresindeki gen ormanında popülasyonunu incelemişlerdir. Yapılan bu çalışmada da benzer sonuçlara ulaşılmış olup en fazla birey sırıklık-direklik çağında tespit edilmiştir.

Taksona ait her üç loasyonda ölçülen bireyler birarada ele alındığında çaplara ilişkin yüzdelik dilim dağılımları aşağıdaki görselde görülmektedir (Görsel 10). En fazla yüzdelik dağılıma sahip Huş gövdeli kızılağaç bireyleri %70 ile Sırıklık-Direklik (8-19,9 cm çap aralığında) çağında olup, en az yüzdelik dağılıma sahip bireylerin ise %4,8 ile İnce Ağaçlık (20-35,9 cm çap aralığında) çağında olduğu tespit edilmiştir.



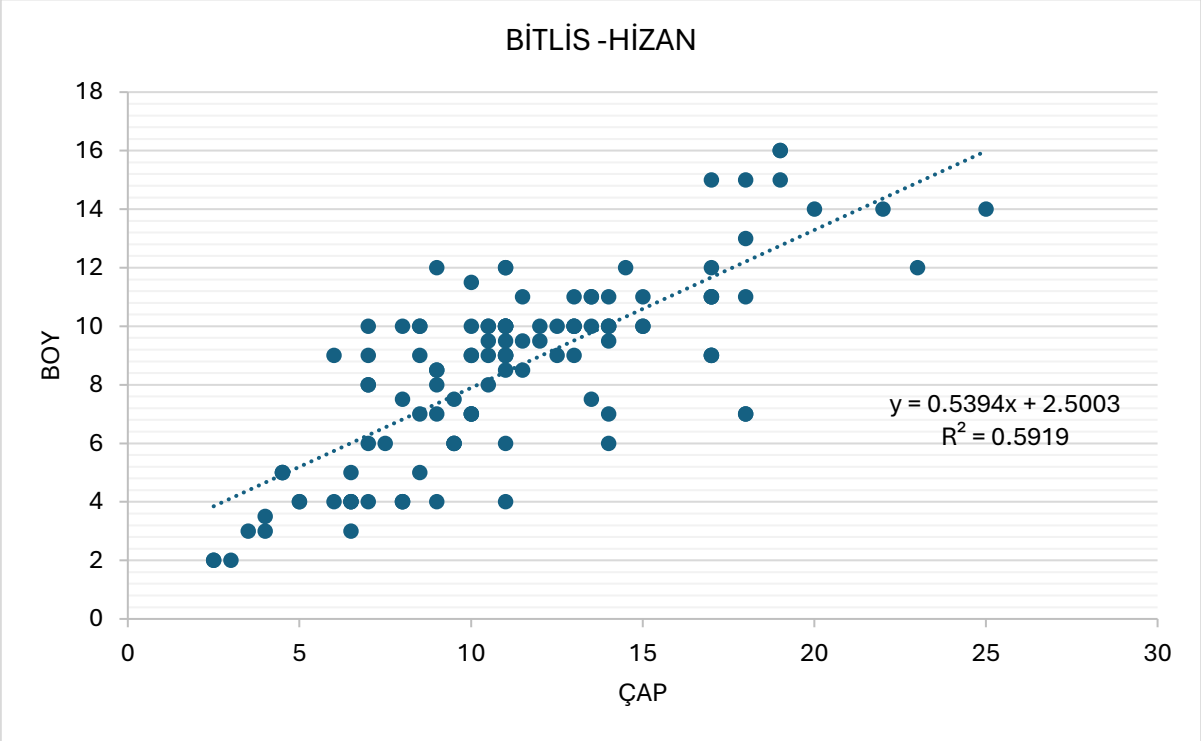
Görsel 10. Ağaç çaplarının gelişim çağlarına göre yüzdelik dağılımı

Çalışma alanları olan Erzurum-Hınıs; Bingöl-Genç ve Bitlis-Hizan yörelerinde ağaçların yaşlarının belirlenmesi amacıyla dere içlerinde türlerin normal gelişimini temsil edebilecek, baskı altında kalmamış ağaçlardan artım kalemleri alınmıştır. Artım kalemleri alınan bireylerden göğüs yüksekliğinden ağaçların kabuklu çevresi ve göğüs çapları da kaydedilmiştir. Ölçüm yapılan ağaçlara ait ortalama değerler Çizelge 1'de verilmiştir. Bireylerden kuzey-güney ve doğu-batı olmak üzere iki yönlü artım kalemi alınmıştır. Alınana artım kalemleri korunaklı plastik borular içerisinde muhafaza edilerek KSÜ Orman Fakültesi Herbaryumuna (Herbaryum KASOF) getirilmiş ve burada stereomikroskop yardımıyla üzerlerindeki yıllık halkalar sayılmak suretiyle yaş tespiti yapılmıştır.

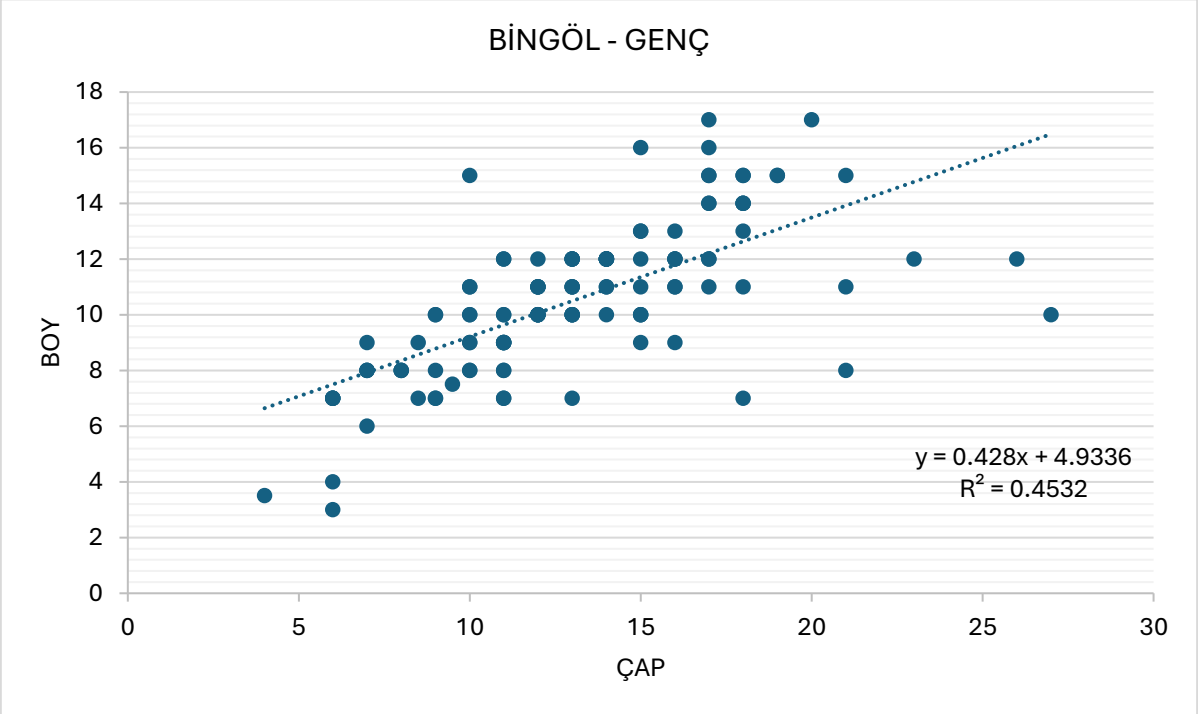
Çizelge 1. Yaş tespiti yapılan bireylere ait ortalama değerler

	Ağaç Yaşı Ortalama Değeri	Göğüs Çapı Ortalaması (cm)	Kabuklu Göğüs Çevresi Ortalaması (cm)
Bitlis	14	17,10	55,50
Bingöl	16	16,66	53,66
Erzurum	18	18,42	60,33

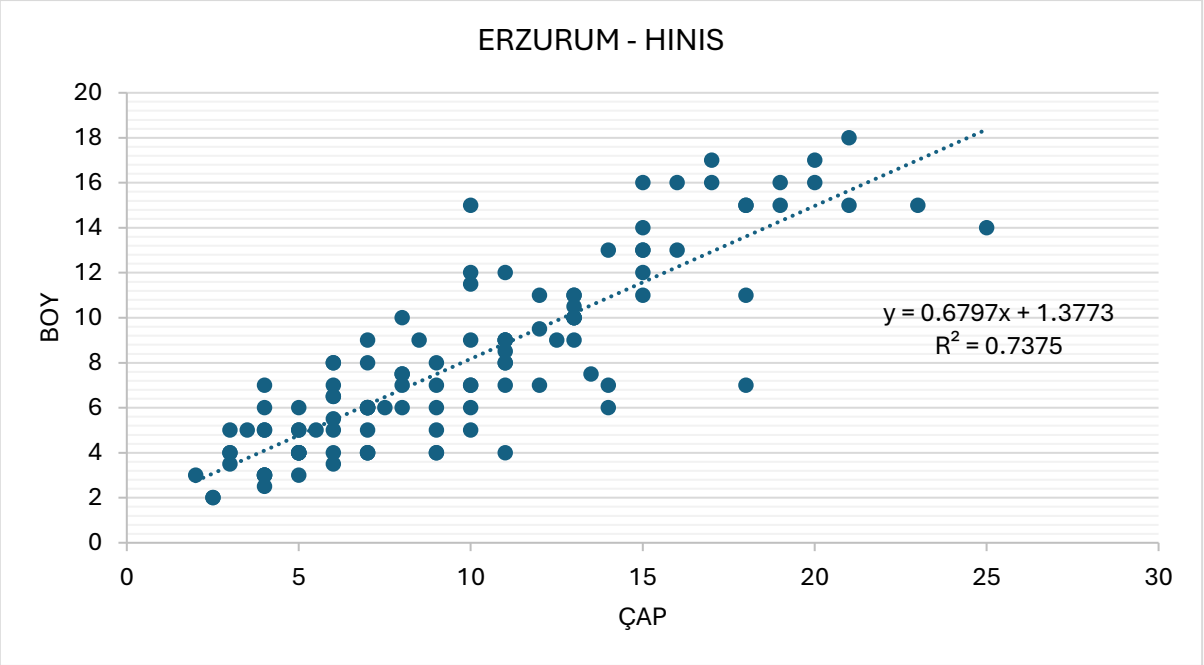
Çalışma alanları olan Bitlis-Hizan, Bingöl-Genç ve Erzurum-Hınıs yörelerinde ölçüm yapılan sırasıyla 119, 115 ve 119 adet Huş gövdeli kızılağaç taksonlarına ait çap ve boy değerlerinin grafikleri Görsel 11, Görsel 12 ve Görsel 13'te verilmiştir. Görsellerde her üç lokasyonda da göğüs çapının 15 cm'yi aşmasından sonra birey sayısında azalma olduğu gözlenmektedir.



Görsel 11. Bitlis-Hizan yöresi Çap ve Boy değerlerinin dağılımı



Görsel 12. Bingöl-Genç yöresi Çap ve Boy değerlerinin dağılımı



Görsel 13. Erzurum-Hınıs yöresi Çap ve Boy değerlerinin dağılımı

4. SONUÇLAR VE DEĞERLENDİRMELER

Ilıman kuşakta yer alan ülkeler arasında önemli bir bitkisel zenginliğe sahip olan Türkiye florası barındırdığı endemik taksonlarca da oldukça büyük bir öneme haizdir. Türkiye florasının ve nesli tehdit altındaki taksonlarının korunması ve gelecek nesillere aktarılması giderek bozulan ekosistemlerde önemli bir sorun halini almıştır. Yapılan bu çalışma ile ülkemizde hakkında çok az bilgi sahibi olduğumuz ve ne yazık ki yoğun bir faydalanmaya konu olan endemik bir ağaç taksonumuz olan Huş gövdeli kızılağacın güncel durumunun ve karşı karşıya olduğu dar boğazların ortaya konulması amaçlanmıştır.

Sahada yapılan çalışmalarda ve ölçümlerde Huş Gövdeli Kızılağacın 15-18 metrelere kadar boylandığı, sınırlı yayılışa sahip popülasyonlarının genellikle genç bireylerden oluştuğu ve nehir kenarında yetiştiği gözlemlenmiştir. Yerel halk ile yapılan görüşmelerde ağaçların yaygın olarak yakacak odun olarak kullanımından dolayı genç bireylerden oluştuğu belirlenmiştir. Takson yerel halk tarafından Bingöl yöresinde Gendar olarak Erzurum yöresinde ise Sorındar olarak adlandırılmaktadır. Bu yörelerde yakacak odun olarak tüketiminin yanı sıra palet yapımında ve renginden dolayı mobilya ayakları yapımında da kullanıldığı tespit edilmiştir.

Huş Gövdeli Kızılağaç her ne kadar suyun içinde yaşıyor olsa da kesildikten sonra su ve nemden olumsuz etkilenmektedir. Bu nedenle halk arasında “susuz yaşamaz kesildikten sonra suyu hiç sevmez” denilmektedir.

Yapılan çalışmalar sonucunda Huş Gövdeli Kızılağacın halk arsında yoğun kullanımı olmasından dolayı bu duruma karşı önlemler alınması ve koruma faaliyetlerinin arttırılarak meşcere özelinde Huş gövdeli kızılağaç taksonunun lehine silvikültürel uygulamaların planlanması acil önem arz etmektedir.

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REVEALING THE DEVELOPMENTAL CHANGES OF PHENOLIC COMPOUNDS IN TEA FLOWERS BY HPLC ANALYSIS

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ABSTRACT

In this study, the phenolic compound profile of tea flower (*Camellia sinensis* L.) samples harvested at different altitudes and during three growth stages (bud, mid-bud, and full bloom) from the Fındıklı district of Rize province was determined using the HPLC method. The levels of phenolic compounds (GC, EGC, catechin, EGCG, EC, caffeine, caffeic acid, p-coumaric acid, and rutin) found in tea flowers were analyzed to evaluate the effects of altitude and growth stage on chemical composition. It has been determined that phenolic compounds undergo significant changes depending on the growth stage, with EGCG, EGC, and rutin levels reaching their highest levels, particularly during the middle bud stage. Additionally, it has been determined that tea flowers grown at high altitudes are richer in phenolic content. As a result, the phenolic composition of tea flowers varies significantly depending on altitude and growth stage, with the bud middle stage emerging as the most productive period in terms of bioactive compounds. As a result of these findings, it is possible to state that tea flowers have significant potential in the development of functional, phytocosmetic, and phytopharmaceutical products.

Keywords: *Camellia sinensis* L., phenolic compounds, HPLC, growth period, altitude

1. INTRODUCTION

Tea, one of the most widely consumed beverages worldwide, is produced by processing the leaves of the tea plant (*Camellia sinensis* L.) (Chen et al., 2018). The chemical composition and biological effects of teas obtained from leaves have been extensively studied. In contrast, the chemical content and functional properties of tea plant flowers have long been overlooked, but in recent years they have become the focus of research due to their bioactive components (Chen et al., 2020).

Tea flowers, with their hermaphroditic structure containing both pistils and stamens, are the generative reproductive organs of the tea plant (*Camellia sinensis* L.), and seed formation occurs through these reproductive organs. For many years, it was believed that tea flowers negatively affected the plant's development. For this reason, tea flowers were often removed or suppressed using chemical methods. However, the scientific basis for these practices regarding tea flowers has been reevaluated in recent years, and studies have shown that tea flowers are an important plant resource that should be evaluated due to the bioactive compounds they contain. Previously largely considered industrial waste, tea flowers are now the subject of growing scientific and industrial interest (Chen et al., 2020).

Although the chemical composition of tea flowers is generally similar to that of tea leaves, it has been reported that there are differences in the type and amount of certain components (Chen et al., 2018; Gao and Chen, 2022). Studies have shown that tea flowers provide significant bioactive content in terms of polyphenols, flavonoids, alkaloids, amino acids, polysaccharides, and saponins (Chen et al., 2020). Tea flowers contain important bioactive components such as phenolic acids, flavonoids, and caffeine, primarily catechin derivatives (Wang et al., 2019).Recent studies have demonstrated that tea flower extracts exhibit a wide range of biological activities, including gastroprotective, hypoglycemic, antioxidant, hypolipidemic, and antiproliferative effects (Chen et al., 2020a). In addition, tea flowers have been reported to possess significant anti-inflammatory properties and exhibit potent antioxidant effects (Chen et al., 2012).It has been reported that bioactive compounds, which underlie these biological effects and exhibit various biological activities, particularly antioxidant activity, make tea flowers a potential plant source for the development of functional products (Wang, 2019; Chen et al., 2020).

Although tea cultivation is carried out over large areas in the Black Sea Region of Turkey, the flowers of the tea plant are still not collected in a planned and organized manner. In practice, this material is mostly considered waste, meaning that a plant resource with high biological potential is not being sufficiently utilized (Yurteri and Sarıkaya, 2025). For these reasons, examining the chemical composition of tea flowers is important in order to contribute to scientific research.This study aimed to determine the chemical composition of tea flower samples (unopened buds, half-open buds and fully open flowers) harvested from different altitudes in the Fındıklı district of Rize province using the HPLC method. Within this scope, the levels of major bioactive components such as GC, EGC, catechin, EGCG, EC, caffeine, caffeic acid, p-coumaric acid, and rutin in tea flowers were analyzed, and the effects of elevation and growth stage differences on the bioactive component profile were evaluated.



Figure 1. An image of the flower of the tea plant (*Camellia sinensis* L.) (Original Photo, S. Sedatcan SARIKAYA, 2025)

2. MATERIALS AND METHODS

2.1. MATERIALS

The tea (*Camellia sinensis* L.) flower samples used in this study were obtained from Sümer Village and Armoni Neighborhood in Fındıklı district of Rize province and consist of flower samples from three different stages of development: unopened bud, half-open bud, and fully open flower (Figure 2.,Table 1).



Figure 2. Tea (*Camellia sinensis* L.) plant flower (a), unopened bud (b), half-open bud (c) (Original Photo)

Table 1. Sampling areas for tea flower samples: location, coordinates, and elevation

Sample Number	Location	Coordinates (Latitude/Longitude)	Altitude
1	Rize / Fındıklı Sümer Village	41.17.05.64 N 41.14.34.64 E	30 Meters
2	Rize / Fındıklı Armoni Neighborhood	41.17.41.06 N 41.15.49.69 E	249 Meters

2.2. METHODS

The harvested tea flower samples were dried in an oven at 35 °C and then ground. 0.10 g of the ground samples were weighed and transferred to Falcon tubes, and 10 mL of 100% methanol was added . The prepared samples were subjected to extraction in an ultrasonic water bath for 1 hour. After extraction, the samples were centrifuged at 4000 rpm for 7 minutes, the upper phase was filtered through a syringe filter with a pore size of 0.45 µm, and the samples were transferred to vials for HPLC analysis (Figure 3.).



Figure 3. Submitting samples prepared for HPLC analysis to the device for analysis (Original Photo)

3. RESULTS AND DISCUSSION

When evaluating the phenolic compound contents obtained from HPLC analysis of tea flower (*Camellia sinensis* L.) samples harvested at 30 m elevation from Sümer Village, Fındıklı District, Rize Province, according to different stages of development, the quantities of phenolic compounds in the full bloom stage were highest to lowest, respectively: epigallocatechin gallate

(EGCG), caffeine, epicatechin (EC), epigallocatechin (EGC), rutin, gallocatechin (GC), caffeic acid, catechin, and p-coumaric acid. The highest value in this stage was found in EGCG (9,620 mg/g), while the lowest value was found in p-coumaric acid (0.088 mg/g).The buds in the middle stage showed the same trend in terms of the amount of phenolic compounds, and the compounds were again ranked as EGCG, caffeine, EC, EGC, rutin, GC, caffeic acid, catechin, and p-coumaric acid, with the highest phenolic compound in this stage being EGCG (13.027 mg/g), while the lowest component was p-coumaric acid (0.090 mg/g). In the unopened bud stage, the phenolic compounds were identified in descending order of quantity as epigallocatechin gallate (EGCG), caffeine, epicatechin (EC), epigallocatechin (EGC), rutin, gallocatechin (GC), caffeic acid, catechin, and p-coumaric acid, with the highest value found in EGCG (17,150 mg/g) and the lowest value found in p-coumaric acid (0.053 mg/g) (Table 2).

Table 2. Phenolic compound contents (mg/g) of tea flower (*Camellia sinensis* L.) samples harvested from Sümer Village, Fındıklı District, Rize Province, determined by HPLC according to different stages of development

Component		GC	EGC	Catechin	Caffeine	EGCG	EC	Caffeic Acid	p-Coumaric Acid	Rutin
Stages of Development	Full Bloom	0,399	1,018	0,138	3,430	9,620	2,736	0,285	0,088	0,664
	Bud Middle	0,350	1,056	0,154	5,683	13,027	2,854	0,329	0,090	0,608
	Unopened Bud	0,380	0,925	0,125	8,231	17,150	2,192	0,377	0,053	0,549

When evaluating the phenolic compound contents obtained from HPLC analysis of tea flower (*Camellia sinensis* L.) samples harvested from Armoni Mahallesi, Fındıklı district, Rize province, according to different stages of development, the highest to lowest amounts of phenolic compounds in the full bloom stage were, respectively: epigallocatechin gallate (EGCG), caffeine, epicatechin (EC), epigallocatechin (EGC), rutin, gallocatechin (GC), caffeic acid, catechin, and p-coumaric acid, in descending order. At this stage, the highest value was found in EGCG (16.135 mg/g), while the lowest value was found in p-coumaric acid (0.034 mg/g). It was determined that the ranking of buds in the middle stage according to the amounts of phenolic compounds showed the same trend, and the compounds were again ranked as EGCG, caffeine, EC, EGC, rutin, GC, caffeic acid, catechin, and p-coumaric acid. At this stage, the highest phenolic compound was EGCG (17.954 mg/g), while the lowest component was p-coumaric acid (0.052 mg/g). In the unopened bud stage, the phenolic compounds were determined to be, in descending order from highest to lowest: epigallocatechin gallate (EGCG), caffeine, epicatechin (EC), epigallocatechin (EGC), rutin, gallocatechin (GC), caffeic acid, catechin, and p-coumaric acid, respectively. In this stage, the highest value was determined in EGCG (11.989 mg/g), and the lowest value was determined in p-coumaric acid (0.103 mg/g) (Table 3).

Table 3. Phenolic compound contents (mg/g) of tea flower (*Camellia sinensis* L.) samples harvested from Armoni Mahallesi, Fındıklı district, Rize province, determined by HPLC according to different stages of development

Component		GC	EGC	Catechin	Caffeine	EGCG	EC	Caffeic Acid	p-Coumaric Acid	Rutin
Stages of Development	Full Bloom	0,277	1,037	0,201	5,517	16,135	3,983	0,431	0,034	0,902
	Bud Middle	0,373	1,515	0,167	6,477	17,954	3,609	0,363	0,052	1,817
	Unopened Bud	0,194	0,788	0,095	7,628	11,989	1,881	0,294	0,103	1,078

When comparing the phenolic compound contents of tea flower (*Camellia sinensis* L.) samples harvested from Sümer Village and Armoni Neighborhood according to different stages of development, epigallocatechin gallate (EGCG) and caffeine were determined to be the dominant compounds in all stages of development at both locations. In the examples from Sümer Village, the EGCG content was determined to be 9,620 mg/g, 13,027 mg/g, and 17,150 mg/g, respectively, in the examples from Sümer Village. The highest EGCG accumulation was observed in the unopened bud stage, while the lowest value was observed in the full bloom stage. In contrast, EGCG levels in the Armoni Mahallesi samples were determined to be 16.135 mg/g, 17.954 mg/g, and 11.989 mg/g, respectively, at the same stages; it was found that the highest EGCG content at this location was in the middle bud stage, while the lowest value was in the unopened bud stage. This situation indicates that EGCG accumulation followed a different metabolic trend at both locations depending on the stage of development.
Similarly, when caffeine content was evaluated, it was determined that caffeine levels changed depending on the stage of development at both locations. In the examples from Sümer Village, caffeine content reached its highest level in the pre-bud stage, while in the examples from Armoni Neighborhood, caffeine levels were found to be higher, particularly in the pre-bud and mid-bud stages. This difference suggests that caffeine biosynthesis is sensitive not only to the phenological period but also to location-specific environmental and physiological factors. Furthermore, p-coumaric acid stood out as the component with the lowest concentration at both locations and throughout all stages of development.

The presence of catechins and caffeine in the flowers of the tea plant (*Camellia sinensis* L.) has previously been demonstrated by HPLC-based studies. One study reported that the total catechin content in different tea flower samples could vary between 10–38 mg/g, while caffeine content could vary between 3–8 mg/g. When comparing our study with the tea flower samples harvested from Sümer Village and Armoni Neighborhood, the phenolic compound contents were compared according to different growth stages. It was determined that epigallocatechin gallate (EGCG) and caffeine were the dominant compounds in all stages at both locations. In our study, caffeine levels ranging from 3,430–8,231 mg/g in Sümer Village and 5,517–7,628 mg/g in Armoni Neighborhood are generally consistent with the caffeine range reported in the

literature on tea flowers. The absence of all catechins and their derivatives in their study makes it unsuitable for comparing catechins and their derivatives (Lin et al., 2003).

A study conducted on tea flower samples originating from the Azores reported EGCG, EC, and caffeine contents as 68.94 mg/g, 10.34 mg/g, and 6.15 mg/g, respectively. When compared to our study, the levels of EGCG (9,620–17,954 mg/g) and EC (1,881–3,983 mg/g) were below the values in question. This difference between the two studies may be related to the genetic material/variety used, the harvest period, environmental conditions, and the post-harvest processing steps of the samples. Additionally, changes in the protocols applied during the extraction and sample preparation stages can significantly affect the amounts of catechin fractions. In contrast, it is noteworthy that caffeine values were closer in range between the two studies. This suggests that caffeine may be a component that is less affected by environmental and methodological variables than catechins under certain conditions (Paiva et al., 2021).

In detailed polyphenol profile studies using HPLC, the buds and leaf tissue of the tea plant are among the most frequently studied materials in the literature. A study reported that EGCG levels in bud/leaf samples could reach 70.21–73.98 mg/g. Consistent with these findings, which suggest that catechin accumulation may be higher in young and photosynthetic tissues, the EGCG levels identified in tea flowers in this study (9,620–17,954 mg/g) were found to be lower; thus providing a comparative framework for the distribution of metabolites across organs and tissues (Civelekoğlu and Yurteri, 2024).

4. CONCLUSION

In this study, the phenolic compound profile of tea flower (*Camellia sinensis* L.) samples collected at three different stages of development from two different locations in the Fındıklı district of Rize province was determined using the HPLC method. The findings indicate that EGCG and caffeine are the predominant components at both locations and throughout all stages of development. In the examples from Sümer Village, the EGCG content increased from the full bloom stage to the unopened bud stage, and the highest value was detected in the unopened bud stage. In the Armoni Mahallesi samples, it was determined that EGCG reached its highest level in the mid-bud stage, while the lowest value was observed in the unopened bud stage. In both locations, p-coumaric acid stood out as the component with the lowest level. As a result, it has been demonstrated that the accumulation of bioactive compounds in tea flowers changes significantly depending on the stage of development and location. This situation demonstrates that the harvest time of tea flowers can be planned according to target components and that samples rich in EGCG/caffeine, in particular, have the potential to serve as raw materials that can be evaluated for functional products, phytocosmetics, and phytopharmaceutical applications.In terms of converting tea flowers, which are often considered waste in tea production, into added value, it is recommended to increase studies supported by systematic collection and advanced biological activity analyses at different locations and stages of development, and to increase the number of studies on tea flowers.

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DETERMINATION OF AROMA COMPOUNDS OF *CALAMINTHA NEPETA* (L.) COLLECTED FROM DERİNDERE PLATEAU, TRABZON

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ABSTRACT

Calamintha nepeta (L.), one of the aromatic species of the *Lamiaceae* family, is a plant rich in volatile constituents and is traditionally used as an herbal tea and a spice due to its characteristic aroma. The fact that the volatile profile may vary depending on altitude and phenological stage highlights the importance of chemical characterization of the species across different ecologies. In this study, it was aimed to determine the volatile constituents of *C. nepeta* samples collected from Derindere Plateau located at an altitude of 2260 m in the Çaykara district of Trabzon Province during the full flowering period. The essential oil yield of the plant harvested at full flowering and the aromatic constituents in its essential oil were determined using the Solid Phase Microextraction (SPME) method coupled with Gas Chromatography–Mass Spectrometry (GC–MS). As a result of the analyses, a total of 40 different aroma constituents were identified; the major constituents were determined as spathulenol (%14.52), β-bourbonene (%11.65), germacrene D (%9.05) and thymol (%7.23). The obtained data demonstrate that *C. nepeta* growing under the conditions of Derindere Plateau possesses an aromatically rich volatile constituent composition; contributing to the regional chemical characterization of the species, it provides a scientific basis for evaluating its potential for food flavoring and phytocosmetic applications.

Keywords: *Clinopodium nepeta*, GC-MS, lesser calamint, SPME

1. INTRODUCTION

Essential oils obtained from aromatic and medicinal plants are defined as complex mixtures produced from different plant parts such as flowers, leaves, seeds, bark roots and composed of numerous natural compounds with polar and non-polar characteristics (Masango, 2005). This complex nature provides a basis for essential oils to exhibit wide diversity in terms of both chemical composition and biological activity. In particular, the antimicrobial and antioxidant potentials of essential oils support their use as flavoring agents in foods and allow them to be considered within the scope of natural additives and preservative components (Božović and Ragno, 2017; Zaoui et al., 2024). In addition, essential oils remain important as sources of raw materials/active constituents for pharmaceutical applications and the fragrance industry due to the aromatic and bioactive components they contain (Božović and Ragno, 2017; Zaoui et al., 2024).

Calamintha nepeta (L.) (Figure 1), one of the aromatic genera belonging to the *Lamiaceae* family, is a perennial herbaceous species with a wide distribution across the Mediterranean basin. In Türkiye, *Calamintha* is referred to by names such as “Güzel Nane, Dağ Nanesi, Miskotu, Tıbbi Miskotu, Yabani Oğulotu” (Alan and Ocak, 2013). The plant is characterized by small, oval (ovate) leaves and can grow up to approximately 60 cm in height (Ceker et al., 2013; Abbad and Abbad, 2023). Traditional knowledge and ethnobotanical sources report that the species is used both as a food and in folk medicine, being employed with attributed antiseptic, antispasmodic, diuretic and antitussive effects. Moreover, various studies have reported the traditional use of *C. nepeta* as a supportive agent in the management of depression-related complaints, cramps, convulsions, insomnia, as well as gastroenterological and respiratory disorders (Marongiu et al., 2010; Božović et al., 2017).



Figure 1. General appearance of *Calamintha nepeta* (L.) plant

1. MATERIALS AND METHODS

Plant samples were collected from Derindere Plateau (2260 m) in the Çaykara district of Trabzon Province, Türkiye, during the full flowering period (Figure 1). The aerial parts of *Calamintha nepeta* (L.) were used as plant material and harvesting was performed by cutting the plants approximately 10–15 cm above the soil surface. After the samples were dried, 100 g of the dried drug material was weighed and subjected to hydrodistillation using a Neo-Clevenger apparatus. Essential oil yield was calculated as the volume of essential oil obtained from 100 g of dry sample and expressed as ml/100 g.

The chemical composition of the essential oil was determined using a Shimadzu GC–MS system (GC MS-2010 Plus) at Recep Tayyip Erdoğan University. Volatile constituents were analyzed by the solid-phase microextraction (SPME) technique. The resulting chromatographic data were evaluated through comparison with relevant mass spectral libraries and the identified compounds were reported accordingly.

2. RESULTS AND DISCUSSION

Following GC–MS analysis of *Calamintha nepeta* samples collected from Derindere Plateau (2260 m), a total of 40 volatile constituents were identified and the profile was found to be particularly rich in sesquiterpenes and oxygenated sesquiterpenes (Table 1). The major volatile constituent detected in the samples was spathulenol (14.52%), followed by β-bourbonene (11.65%) and germacrene D (9.05%). Among the phenolic monoterpenes, thymol (7.23%) was noteworthy and caryophyllene oxide (7.02%), an oxygenated sesquiterpene, was also present at a high level. Together, these five major constituents accounted for approximately 49.5% of the total profile and emerged as the main components defining the chemical character of the sample. Secondary constituents present at relatively high levels included aromadendrene (4.85%), α-terpinyl acetate (3.52%), pinocarvone (3.32%), nonanoate (3.20%) and phytone (3.05%).

Table 1. Volatile compounds detected in Calamint (*Calamintha nepeta*) by GC-MS analysis (%)

Compound Name	**Derindere Plateau**
α-Pinene	2.73
β-Pinene	1.98
Linalool	0.39
trans-Pinocarveol	0.22
Pinocarvone	3.32
Myrtenal	0.52
Pulegone	0.21
Carvone	1.04
Linalyl acetate	0.53
Thymol	7.23
Isomenthol acetate	1.28
Carvacrol	0.74
α-Terpinyl acetate	3.52
β-Bourbonene	11.65

Dihydrojasmone	0.76
Aromadendrene	4.85
β-Cedrene	1.32
α-Humulene	2.22
Germacrene D	9.05
Bicyclogermacrene	1.56
Pentadecane	1.21
α-Muurolene	2.1
β-Bisabolene	1.1
γ-Cadinene	1. 2
Δ-Cadinene	2.21
Nerolidol	0.58
Nonanoate	3.2
Germacrene-B	0.27
Spathulenol	14.52
Caryophyllene oxide	7.02
Humulol	0.03
Cedrol	2.71
α-epi-Muurolol	0.11
α-Santalol	1.25
Bergamotol	1.42
Farnesal	1.5
Phytone	3.05
methyl-Palmitate	1.4
Heneicosane	1.2

In the study conducted by Zeynalova (2018), thymol (19.81%), 1,1-diethyl-cyclopropane, 3-vinyl-3-methyl-cyclohexanone, D-limonene and caryophyllene were identified as the major constituents of *Calamintha nepeta* essential oil. In our study, however, the thymol content was determined as 7.23%, which was lower than the value reported in the literature. In contrast, the dominance of the volatile profile in our samples by sesquiterpenes such as spathulenol (14.52%), β-bourbonene (11.65%) and germacrene D (9.05%) indicates a clear difference in chemical profiles between the two studies.

Mancini et al. (2013) identified a total of 42 constituents in the essential oil obtained by hydrodistillation from the aerial parts of *Calamintha nepeta* collected in the Campania region and reported that the oil was dominated by the sesquiterpene fraction (80.8%). The major constituents were reported as 1,10-di-epi-cubenol, allo-aromadendrene epoxide and cadalene. These findings are generally consistent with our results in terms of our volatile profile being rich in sesquiterpenes and oxygenated sesquiterpenes. However, in our study, the dominance of sesquiterpenes/oxygenated sesquiterpenes was mainly represented by spathulenol, β-bourbonene, germacrene D and caryophyllene oxide, indicating a different distribution of major constituents compared to those reported by Mancini et al. (2013).

Overall, the sesquiterpene/oxygenated sesquiterpene dominance observed in the Derindere samples may be associated with the ability of geographical origin and ecological conditions to shape the distribution of volatile constituents. When these environmental factors are considered together with variations in harvest period, material standardization, drying conditions and analytical workflow, it becomes evident that the consistencies and discrepancies observed across studies have a multifactorial basis. Accordingly, our findings support that the chemical profile of *C. nepeta* can shift sensitively in response to environmental and methodological variables and they indicate that inter-study comparisons can be made more robustly only when sampling, processing and analytical parameters are reported in detail and in a comparable manner.

3. CONCLUSIONS

The volatile constituents of *Calamintha nepeta* (L.) samples collected during the full flowering period from Derindere Plateau (Trabzon/Çaykara) were determined by GC–MS and a total of 40 constituents were identified. The marked enrichment of the volatile profile in sesquiterpenes and oxygenated sesquiterpenes was supported by the high proportions of spathulenol (14.52%), β-bourbonene (11.65%), germacrene D (9.05%) and caryophyllene oxide (7.02%). Among the phenolic monoterpenes, thymol (7.23%) was also among the secondary dominant constituents. These data indicate that *C. nepeta* growing under the conditions of Derindere Plateau possesses an aromatically rich volatile composition with a sesquiterpene/oxygenated sesquiterpene-oriented profile, thereby making a concrete contribution to the regional chemical characterization of the species.

This chemical profile, rich in sesquiterpenes and oxygenated sesquiterpenes, supports that the plant may offer potential for food and phytocosmetic applications beyond its traditional uses. Moreover, considering the variable compositions reported across different ecologies, our findings provide a reliable reference framework for future comparative studies aimed at standardizing the volatile profile of the species.

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SUSTAINABLE VALORIZATION OF TEXTILE WASTE THROUGH HYBRID NATURAL–SYNTHETIC FIBER COMPOSITES: MECHANICAL AND DYNAMIC PERFORMANCE OPTIMIZATION

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ABSTRACT

In this study, a sustainable approach was adopted to valorize textile industry waste by developing hybrid fiber-reinforced composites combining natural and synthetic fibers (glass) within a polyester matrix. The objective was to minimize synthetic fiber usage while achieving optimal mechanical performance through hybridization. Textile waste, which possesses significant potential as a low-cost and renewable reinforcement source for polymer composites, was pretreated via enzymatic desizing and alkaline scouring to enhance fiber–matrix adhesion. The composites were fabricated using a vacuum bag molding technique under controlled fiber volume fractions. Tensile, flexural, and dynamic mechanical analyses were conducted to evaluate mechanical integrity and viscoelastic response. Results revealed that while single natural fiber composites exhibited inferior strength, hybrid combinations demonstrated comparable tensile and flexural performance to all-glass composites. Dynamic mechanical analysis confirmed improved interfacial bonding and modulus stability with increasing glass fiber ratio. The findings highlight that utilizing pretreated textile waste in hybrid composites not only improves resource efficiency but also offers a viable, sustainable pathway for high-performance, lightweight structural materials.

Keywords: textile waste, hybrid composites, natural fibers, mechanical properties, dynamic mechanical analysis, sustainability

DEAD TIME ANALYSIS USING A NaI(Tl) DETECTOR IN GAMMA SPECTROSCOPY: EFFECTS OF MATERIAL AND THICKNESS

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ABSTRACT

Dead time in nuclear radiation detectors is one of the main factors that limit measurement accuracy, reduce the reliability of measurements, and cause deviations in the taken data. Therefore, accurate determination of dead time is very important to increase the efficiency of measurement systems. In this study, gamma photons emitted at 662 keV energy from a ^{137}Cs radioactive source were directed onto different absorber materials, and measurements were taken with a 1.5 × 2 inch NaI(Tl) scintillator detector. Dead time analyses of the detector were performed using the gamma attenuation law and generalized dead time models. As absorbing materials, four different thicknesses of lead (^{82}Pb) and iron (^{26}Fe) plates, as well as copper (^{29}Cu), zinc (^{30}Zn), tungsten (^{74}W), cadmium (^{48}Cd), aluminum (^{13}Al), tantalum (^{73}Ta), gold (^{79}Au), titanium (^{22}Ti) elements, and PMMA compound were used as absorber materials. The results were found to be in the range of 10^{-4} - 10^{-6} seconds. In measurements taken with lead and iron sheets, a decrease in dead time values was observed as the material thickness increased. No correlation was found between the thicknesses of the other absorber sheets and the dead time values. The results of this study contribute to the more accurate modelling of dead time values and the development of correction algorithms, enabling more reliable results in environmental radiation measurements and nuclear safety applications.

Keywords: Dead time, NaI(Tl) detector, Gamma spectroscopy.

1. INTRODUCTION

Detectors are the most important components of gamma spectroscopy systems. They play a crucial role in achieving accurate measurement and reliable results when determining radiation levels. Furthermore, the responsiveness of these gamma spectroscopy systems is directly proportional to several key detector parameters. The accuracy of counting values depends on minimizing photon losses to the detector. This, in turn, limits the time required for the detector to remeasure after detecting an event. This parameter, known as dead time, represents the temporary period of insensitivity during which the detector fails to record the next event. Correcting dead time losses is crucial for obtaining accurate measurement results, particularly when operating at high count rates [1]. In gamma spectroscopy systems, the dead time values of the detector may originate from physical parameters such as the system's geometric structure, material, and operating conditions, as well as from electronic circuit components. The combined effect of these parameters negatively affects the total number of events recorded, leading to counts that are lower than what actually occurs.

In the literature, various mathematical models and corrections are proposed to correct this parameter or minimize its effects. The two most commonly used approaches are paralyzable and non-paralyzable dead time models, which define the detector's response to events under different assumptions. In the non-paralyzable model, after an event is recorded, the detector is unable to process new events for a certain period of time.

That is, the dead time remains unchanged until a new event is recorded. After this period ends, the system becomes live. The non-paralyzable model is expressed by Eq. (1). Here, n is the true count rate, m is the recorded count rate, and τ is the dead time.

$$m = \frac{m}{1+n\tau} \tag{1}$$

In the paralyzed model, no new events are recorded during the dead time, and the dead time is reset and restarted. In this case, the dead time value increases due to events that cannot be recorded. In this model, the system may fail to record any events at extremely high counting rates. Eq. (2) is used for paralysis model calculations [1,2]. Here, n is the true count rate, m is the recorded count rate, and τ represents the dead time.

$$m = ne^{-n\tau} \tag{2}$$

For both models, the losses due to dead time are of the form m < n. This situation arises because the number of photons passing through the absorber material is lower than the number of photons detected without the absorber material.

2. MATERIALS AND METHODS

This study was conducted at the Environmental Radioactivity Measurement and Research Laboratory in the Division of Nuclear Physics at Istanbul University. The measurements were

performed using a 1.5‘ x 2’ NaI(Tl) scintillation detector attached to the gamma spectroscopy system. Measurements were taken using a ^{137}Cs radioactive source emitting gamma photons with an energy of 662 keV. Thin sheets of lead (^{82}Pb), iron (^{26}Fe), copper (^{29}Cu), zinc (^{30}Zn), tungsten (^{74}W), cadmium (^{48}Cd), aluminium (^{13}Al), tantalum (^{73}Ta), gold (^{79}Au), and titanium (^{22}Ti) elements, and thin materials such as PMMA compound were used as the absorber material. As shown in Figure 1, the experimental setup includes a ^{137}Cs source, an absorber material, a gamma spectroscopy system which consists of NaI(Tl) scintillation detector, a spectroscopy amplifier (Canberra 2020), a multi-channel analyser (MCA 8000D), and a high-voltage source.

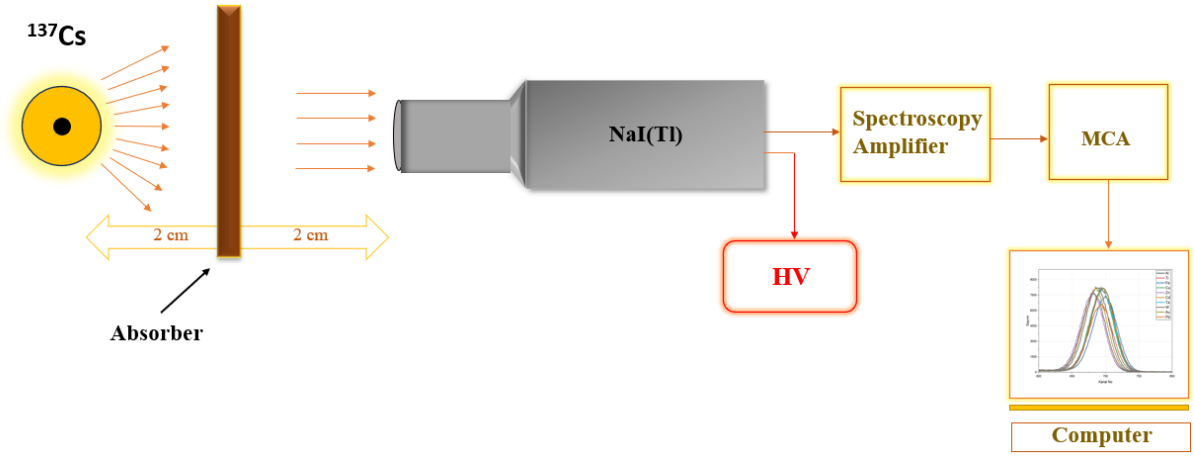


Figure 1. A gamma spectroscopy measurement system.

Measurements were made with a total distance of 4 cm between the radioactive source and the detector, 2 cm between the radioactive source and the absorber material, and 2 cm between the detector and the absorber material. All measurements were taken for 300 seconds. Specific information about the radioactive ^{137}Cs source used in the measurements is given in Table 1.

Table 1. Information on the radioactive ^{137}Cs source.

Radioactive Source	Energy (keV)	Half Life $t_{1/2}$ (years)	Current Activity (kBq)	Emission Probability (%)
^{137}Cs	661.6	30.17	51.3	85.1

Figure 2 shows an example spectrum of a ^{137}Cs radioactive source. The spectrum was plotted using the Origin Pro 2025b analysis programme [5].

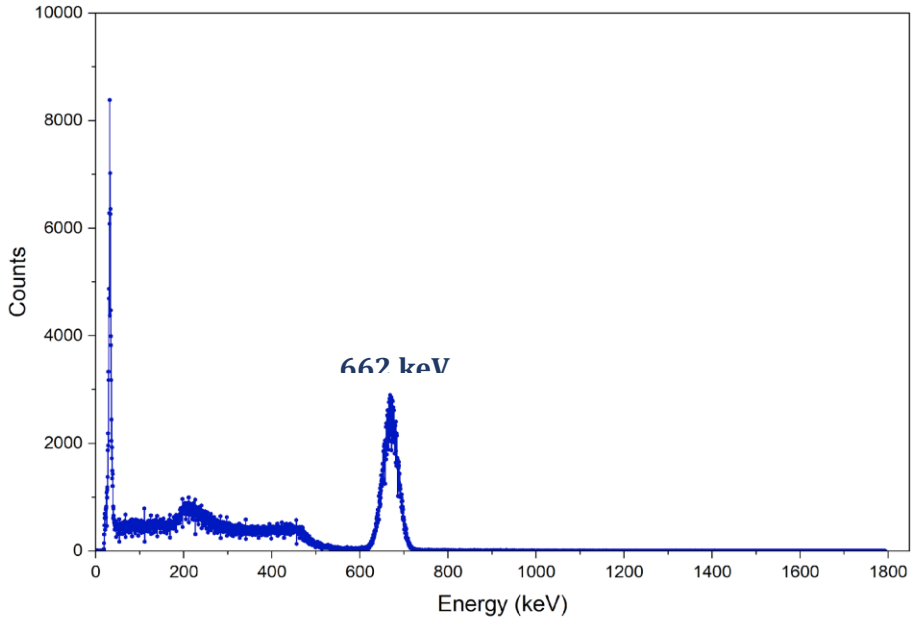


Figure 2. Spectrum of the ^{137}Cs radioactive source.

Background radiation values were subtracted from the count values obtained during the measurement. Measurements were taken three times to reduce statistical errors, and the average count values were used in the calculations.

Two source methods, imposed dead time, the pulser method, and live-time correction are commonly used for experimentally determining dead time values. In this study, however, an analytical method involving formulas derived from the gamma attenuation law was used to determine the dead time parameter [3].

$$I = I_0 e^{-\mu x} \tag{3}$$

Measurements were performed based on the principle of systematically altering the actual counts reaching the detector by using different absorber materials. Measurements were taken first without an absorber material and then with an absorber material using the same radioactive source. By comparing the measurement ratios, the observed decrease in the counting rate was directly related to the attenuation law. The gamma attenuation law in Eq. 3 states that the gamma photons reaching the detector decrease exponentially with thickness (x) and attenuation coefficient (μ). In the equation, I_0 represents the incoming photon intensity, μ represents the linear attenuation coefficient, x represents the thickness, and I represents the intensity of gamma rays passing through the material. The actual count rate (n) reaching the detector was obtained using Eq. 4.

$$n_1 = n_0 e^{-n_0 \tau} \tag{4}$$

For the non-paralyzed model, replacing the parameters m and n in Eq. 1 with m_0 and n_0 and n_1 and m_1 yields Equations 5 and 6. Here, n_0 is the number of actual events emitted from the

gamma source, while n_1 is the number of gamma rays passing through the absorbing material positioned between the source and the detector [2].

$$m_0 = \frac{n_0}{1+n_0\tau} \tag{5}$$

$$m_1 = \frac{n_1}{1+n_1\tau} \tag{6}$$

Equation 7 is obtained by dividing equation 5 by equation 6.

$$n_0\tau = \frac{m_1 - m_0 * e^{-\left(\frac{\mu}{\rho}\right)*(\rho x)}}{m_0 * e^{-\left(\frac{\mu}{\rho}\right)*(\rho x)} - m_1 * e^{-\left(\frac{\mu}{\rho}\right)*(\rho x)}} \tag{7}$$

Equation 7 is used to calculate the $n_0\tau$ values. Subsequently, equation 5 is used to find the dead time values (τ) for the non-paralyzed model.

$$m_0 = n_0 e^{-n_0\tau} \tag{8}$$

$$m_1 = n_1 e^{-n_1\tau} \tag{9}$$

Dead time values are also available for the paralysis model using the same calculation steps. Equation 10 is obtained by dividing Equation 8 by Equation 9 [2, 4].

$$n_0\tau = \frac{lnln\left(\frac{m_0}{m_1}\right) - \left(\frac{\mu}{\rho}\right)*(\rho x)}{e^{-\left(\frac{\mu}{\rho}\right)*(\rho x)} - 1} \tag{10}$$

In the calculations, the build-up factor has not been taken into account due to the very thin plates used in the measurements.

3. RESULTS AND DISCUSSION

The thickness, density, and mass attenuation coefficient (μ/ρ) values of the absorber materials used in the experiment are given in Table 2. To observe the effect of material thickness on the dead time value, iron and lead plates of four different thicknesses were used.

Equations 5 and 7 were used to calculate the non-paralyzed dead time values, while equations 8 and 10 were used for the paralyzed dead time. In both models, the results obtained were in the range of 10^{-4} – 10^{-6} seconds, reflecting the characteristic response times of the detector system.

Table 2. Thickness, mass attenuation coefficient, and density values of absorbent materials.

Absorber Materials	Thickness (cm)	Mass Attenuation Coefficient (Cm^2/G)	Density (g/cm^3)
Au	0.005	0.1059	19.32
Al	0.01	0.07466	2.7
Ta	0.02	0.09644	16.65
Pb (1)	0.02	0.1001	11.35
Cd	0.045	0.7536	8.65
W	0.05	0.09776	19.254

Cu (1)	0.065	0.07259	8.96
Ti	0.035	0.07191	4.51
Fe (1)	0.1	0.07346	7.86
PMMA	0.098	0.08331	0.95
Pb (2)	0.1	0.1001	11.35
Cu (2)	0.165	0.07259	8.96
Fe (2)	0.166	0.07346	7.86
Pb (3)	0.16	0.1001	11.35
Fe (3)	0.216	0.07346	7.86
Zn	0.194	0.07322	7.14
Pb (4)	0.21	0.1001	11.35
Fe (4)	0.296	0.07346	7.86

Absorber Materials	Atomic Number (Z)	Non-Paralyzed Dead Time	Paralyzed Dead Time
Al	13	2.64×10^{-4}	2.12×10^{-4}
Ti	22	3.85×10^{-4}	2.81×10^{-4}
Fe	26	1.05×10^{-4}	9.63×10^{-5}
Fe	26	9.76×10^{-6}	9.69×10^{-6}
Fe	26	7.82×10^{-6}	7.77×10^{-6}
Fe	26	3.35×10^{-6}	3.31×10^{-6}
Cu	29	8.51×10^{-5}	7.96×10^{-5}
Cu	29	2.82×10^{-4}	2.25×10^{-4}
Zn	30	8.51×10^{-5}	7.96×10^{-5}
Cd	48	9.71×10^{-4}	4.45×10^{-4}
Ta	73	1.17×10^{-4}	1.06×10^{-4}
W	74	5.49×10^{-5}	5.26×10^{-5}
Au	79	5.63×10^{-5}	5.38×10^{-5}
Pb	82	5.63×10^{-4}	3.55×10^{-4}
Pb	82	6.32×10^{-5}	6.01×10^{-5}
Pb	82	5.60×10^{-5}	5.37×10^{-5}
Pb	82	2.45×10^{-5}	2.41×10^{-5}
PMMA	(C5O2H8)n	2.61×10^{-5}	2.56×10^{-5}

The calculated dead time values for different absorbent materials are given in Table 3.

Table 3. Dead time values for absorbent materials in paralyzed and non-paralyzed models.

The average dead time value for the non-paralyzed model was found to be 1.75 $\times 10^{-4}$, while the average value for the paralyzed model was 1.21 $\times 10^{-4}$. Dead time values obtained from other studies on the subject in the literature are given in Table 4.

Table 4. Dead time values calculated using the gamma attenuation law.

Detector	Size	Paralyzed model	Non-paralyzed model	Reference
Na(I)Tl	1.5” x 2”	1.20589 $\times 10^{-4}$	1.75475 $\times 10^{-4}$	This study
Na(I)Tl	unspecified	13.57×10^{-6}	13.71×10^{-6}	[2]
Na(I)Tl	2" x 2”	3.63×10^{-5}	2.22×10^{-4}	[4]

The graphs showing the relationship between the thickness values of the iron plates used in the study and the dead time values for paralyzed and non-paralyzed conditions are presented in Figure 4.

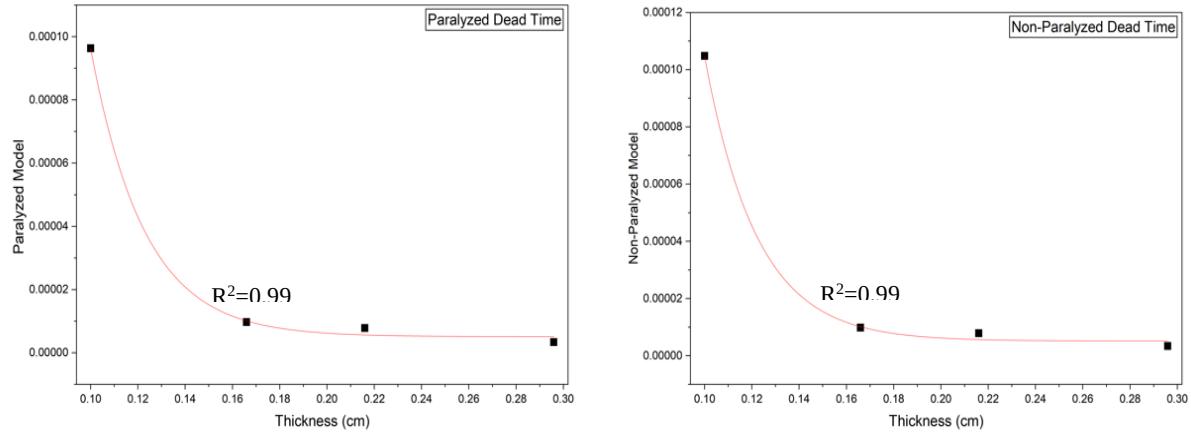


Figure 4. Change in the calculated paralyzed and non-paralyzed dead time values for iron (Fe) plates with thickness.

As shown in Figure 4, the dead time values decrease significantly with the increase in the thickness of the iron plates in both dead time models. This decrease is due to the reduction in the number of gamma rays reaching the detector as the absorber thickness increases. As the rate of counts received by the detector decreases, the probability of consecutive events coinciding also decreases, which reduces the dead time of the system. Although the data obtained show a similar trend for both models, the dead time values in the paralysis model were found to be systematically slightly lower. This variation is because the paralysis model represents the detector's reactive behaviour in a more restrictive manner at high count rates.

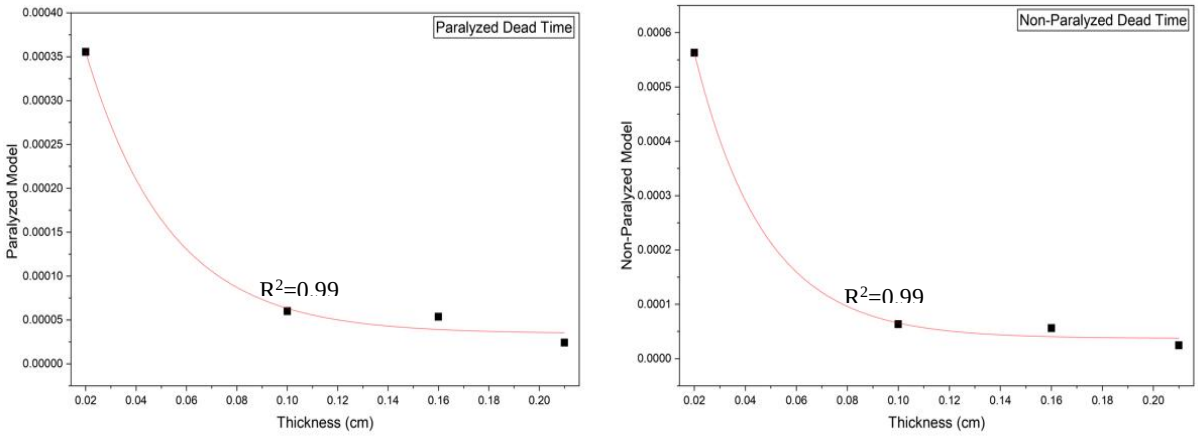


Figure 5. Change in dead time values calculated for paralyzed and non-paralyzed lead (Pb) plates with thickness.

For lead plates, a significant decrease in dead time values was observed as the thickness increased. The results derived from both models show a strong correlation with the exponential decay curve. This result is related to the strong absorption of gamma photons by lead, which has a high atomic number (Z = 82). In other words, increasing thickness reduces the number of photons reaching the detector, thereby decreasing the counting rate.

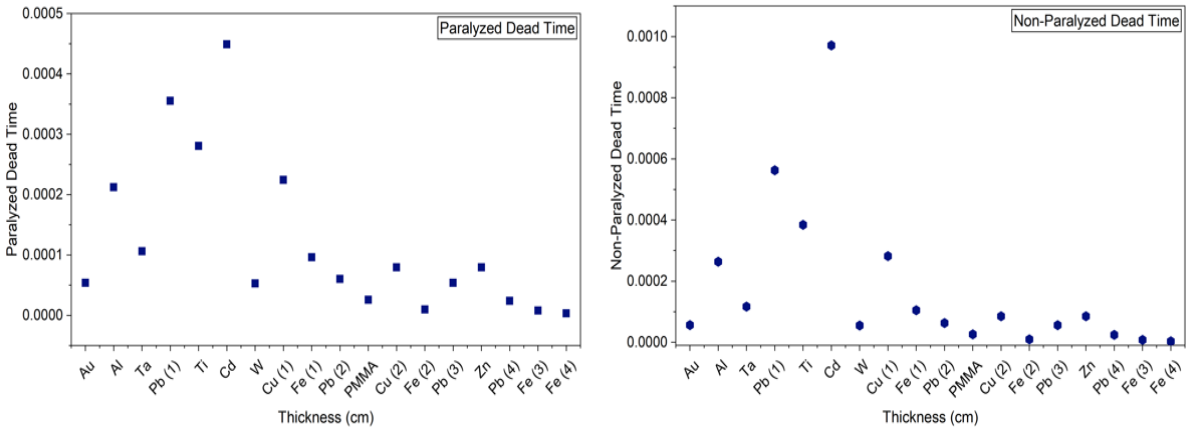


Figure 6. Changes in dead time values, both paralyzed and non-paralyzed, were calculated for various absorber plates of different thicknesses.

As shown in Figure 6, no correlation is observed between the dead time values for plates of different materials and thicknesses. The fundamental reason for this is that the dead time values calculated using the gamma attenuation law depend not only on the thickness parameter but also on the material's atomic number (Z), density (ρ), and mass attenuation coefficient (μ/ρ).

The distribution formed in these graphs indicates that the dead time value cannot be reduced to a single parameter and must be evaluated together with the structural and atomic properties of the material. These results expresses that not only geometric factors but also the interaction of the absorbing material with radiation are effective in the dead time durations of the system.

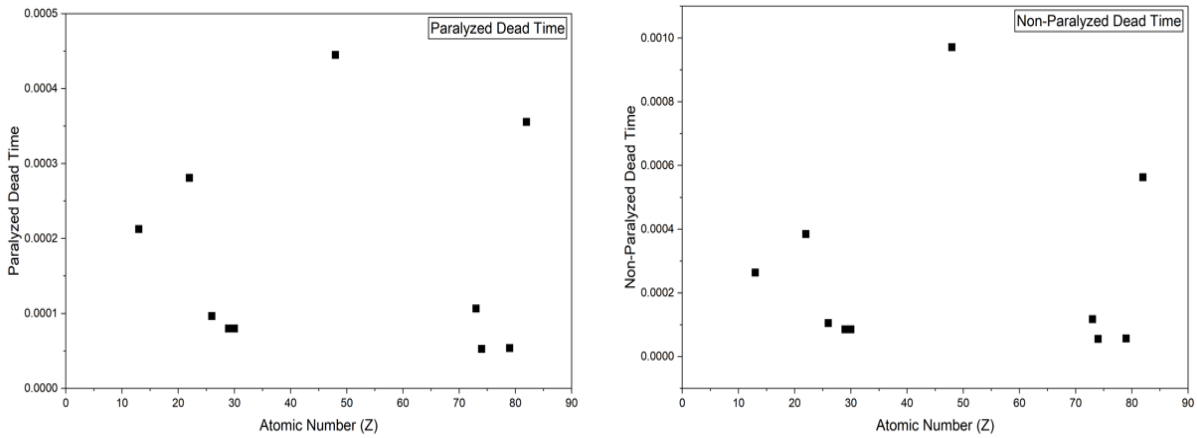


Figure 7. Calculated dead time values for paralyzed and non-paralyzed states corresponding to the atomic numbers (Z) of the materials.

The graphs in Figure 7 show the variation of dead time values for paralyzed and non-paralyzed samples with respect to atomic numbers. No clear linear or monotonic trend was observed in the graphs. This indicates that the dead time parameter is not solely dependent on atomic numbers; rather, it is determined by the combined effects of the material's thickness, density, and mass attenuation coefficient (μ/ρ). While materials with high atomic numbers are expected to absorb gamma photons more effectively, no general correlation could be established due to different thickness and density values. In both models, the wide range of dead time values in materials with low and high atomic numbers reflects the multiple variables present in the system.

4. CONCLUSION

In this study, the effects of different absorber materials and thicknesses on the dead time in gamma spectroscopy systems were experimentally investigated. Thus, a ^{137}Cs radioisotope source and a gamma spectroscopy system with 1.5" × 2" NaI(Tl) scintillator detector were used.

Measurements were evaluated separately for paralyzed and non-paralyzed models; dead time parameters were determined using equations derived from the gamma attenuation law. The results obtained are in agreement with values in the literature.

It was demonstrated that the dead time value decreases exponentially with increasing thickness of the absorbing material. This trend can be explained by the decrease in the probability of pulse collisions in the system due to the attenuation of the gamma ray reaching the detector with increasing material thickness. No significant correlation was observed between the dead time values calculated using the atomic number (Z) of the materials. This conclusion indicates that the dead time values calculated using the gamma attenuation law also vary depending on the material's density, thickness, and mass attenuation coefficient (μ/ρ). This study is crucial for accurately estimating the dead time parameter to improve the precision of counting systems,

reduce uncertainties in environmental radiation measurements, and optimize detectors. The results of this study provide an experimental basis for dead time corrections and data analysis in measurement systems characterized by low count rates.

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SOĞUK VE SICAK DÖVME TEKNİĞİ İLE OTOMOTİV PARÇALARI ÜRETİMİNDE GÖRÜNTÜ İŞLEME DESTEKLİ ÖLÇÜM MAKİNESİ TASARIMI VE UYGULAMASI: ÜRETİM HÜCRESİ İÇİ ÖLÇÜSEL KALİTE KONTROL İÇİN AKILLI BİR YAKLAŞIM

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ÖZET

Bu çalışmada; soğuk ve sıcak dövme gibi plastik şekil verme teknikleri ile kritik elemanlar üretiminde, üretim hattı koşullarında çalışabilecek, görüntü işleme tekniği temelli hücre içi ölçüm makinesinin tasarlanıp, pres makineleri ile iletişim kurarak presli üretimi gerçekleştiren presleri ölçüsel kararlılık limitleri içerisinde kontrol altında tutacak fonksiyonlara sahip şekilde devreye alınması hedeflenmiştir. Tasarım faaliyetleri kapsamında; ölçümlenecek dövme parçaların boyutsal özellikleri ve ölçüsel tolerans limitleri bazında görüntü işleme kamerası ve lens sistemi teorik hesaplamaları ile seçimleri gerçekleştirilmiş ardından ise görüntü işleme sistemi makinesine ait yapısal tasarım ve tasarım optimizasyon faaliyetleri yürütülerek optimum tasarım gerçekleştirilerek görüntü işleme sistemi destekli kameralı ölçüm sistemi makinesi imal edilmiştir. Pres çevrim süresi ile senkronize çalışan ve her dövme çevriminde 20 mikron hassasiyet ile ölçüm yaparak prese üretime devam etme veya üretimi durdurma sinyali vererek üretimi kontrol altında tutabilen bir prototip sistem devreye alınmıştır. Gerçekleştirilen saha doğrulama testlerinde sistemin parça başına ortalama 0,3 saniye altında işlem süresiyle doğru ve hatalı bölgeleri ±5 mikron hassasiyetle ölçümleyerek presli üretim prosesini sürekli kontrol altında tutabildiği ve hurda ile yeniden işleme oranlarını %3 seviyelerinden %0 a indirgediği, ölçüsel kalite kontrol süresinin %75 azaldığı belirlenmiştir. Bu sonuçların, yüksek hızlı soğuk ve sıcak dövme süreçlerinde tam otomatik kalite kontrol uygulamaları açısından önemli bir yenilik olarak değerlendirilebileceği ve sistemin Endüstri 4.0 ilkeleriyle uyumlu, akıllı üretim vizyonuna katkı sunacak bir sistem olacağı belirlenmiştir.

Anahtar Kelimeler : Görüntü işleme, soğuk dövme, kameralı ölçüm sistemi, otomotiv

DESIGN AND IMPLEMENTATION OF AN IMAGE PROCESSING-ASSISTED MEASURING MACHINE IN AUTOMOTIVE PARTS PRODUCTION BY USING COLD AND HOT FORGING TECHNIQUES: A SMART APPROACH FOR DIMENSIONAL QUALITY CONTROL IN-PRODUCTION CELL

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ABSTRACT

This study aimed to design and manufacture an image processing technique-based in-production cell measuring machine that is capable of operating under production field conditions in the production of critical components by using plastic forming techniques such as cold and hot forging. Additionally, the image processing machine is planned to communicate with the press machine within the production cell and perform functions that will control the presses performing the press production within dimensional stability limits. Within the scope of design activities, the image processing camera and lens system are selected based on theoretical calculations and dimensional tolerance limits of the forged parts to be measured. Subsequently, structural design and design optimization activities are realized for the image processing system-supported measuring machine. Based on the optimal design of image processing system-supported camera measuring system, measurement machine is manufactured. A prototype system has been implemented that works synchronously with the cycle time of the press and keeps production under control by measuring with ±5 micron precision in each forging cycle and giving the press a signal to keep up or stop the production. In field validation tests, it is determined that the image processing machine continuously monitors the forging process by measuring correct and defective areas with an average processing time of less than 0.3 seconds per part with an accuracy of 20 microns. It also reduces scrap and rework rates from 3% to 0% and reduces dimensional quality control time by 75%. These results are evaluated as an important innovation in terms of fully automatic quality control applications for high-speed cold and hot forging processes, and it is determined that the system would be an adaptive application that would contribute to the smart production vision, compatible with Industry 4.0 principles.

Keywords : Image processing, cold Forging, camera based measurement system, automotive

1. GİRİŞ

Plastik şekil verme, kuvvet, sıcaklık veya kuvvet-sıcaklık etkileşimleri uygulanarak hacim sabitliği ilkesi ile şekil değişiminin sağlandığı bir üretim yöntemidir[1]. Modern imalat endüstrisinin yüksek verimli ve önemli bir parçası olan plastik şekillendirme, yüksek ölçüsel hassasiyet, yüksek şekillendirme verimliliği ve düşük malzeme firesi gibi önemli avantajlara sahiptir. Havacılık, otomotiv ve savunma sanayii gibi birçok alanda yüksek performanslı parçaların üretimi için etkili bir yöntemdir[2].

Soğuk dövme, oda sıcaklığı koşullarında basma kuvvetleri etkisi altında şekillendirme prensibine dayanan, yüksek hassasiyetli bir üretim yöntemidir. Yüksek üretim hızına rağmen, kalıp, hammadde, sürtünme veya pres parametrelerindeki küçük varyasyonlar nihai ürün ölçülerinde belirlenebilir düzeyde sapmalara yol açabilir [3-5]. Plastik şekil verme ile üretilen parçaların boyutsal doğruluğu, ürünün montaj edilebilirlik kabiliyeti ve performansı açısından kritik bir kalite göstergesi olup özellikle otomotiv sektöründe kullanılan bağlantı elemanları ve kritik güvenlik elemanlarında fonksiyonel uyumsuzluk veya montaj hatalarına neden olabilir.

Geleneksel kalite kontrol yöntemleri, üretimden alınan numunelerin ölçüm aparatları veya mastarlar ile kumpas, mikrometre veya mihengirler vasıtasıyla ölçülmesine dayanır. Ancak bu yöntemin üretim hızı ile eşit olmaması, her parçanın %100 kontrol edilmesini imkansız hale getirir. Bu nedenle, hat içi ölçüm ve otomatik karar verme prensibine dayalı sistemlerin geliştirilmesi, modern üretim hatlarının en önemli gerekliliklerinden biridir.

Son yıllarda makine görüşü ve endüstriyel görüntü işleme teknolojilerinde kaydedilen gelişmeler, mikron seviyesinde doğrulukla çalışan otomatik kontrol sistemlerinin önünü açmıştır[6]. Ancak mevcut optik sistemlerin çoğu Görsel 1'de gösterildiği üzere laboratuvar tipi kullanıma uygundur; yüksek titreşim, sıcaklık ve tozumanın bulunduğu üretim ortamlarında uzun süreli kararlılık sağlayamamaktadır [7,8]. Ayrıca piyasada bulunan ithal sistemler yüksek maliyetlidir ve pres kontrol üniteleriyle doğrudan veri alışverişi yapacak şekilde altyapıya sahip değildir.



Görsel 1. Laboratuvar Tipi Optik Ölçüm Sistemleri [9]

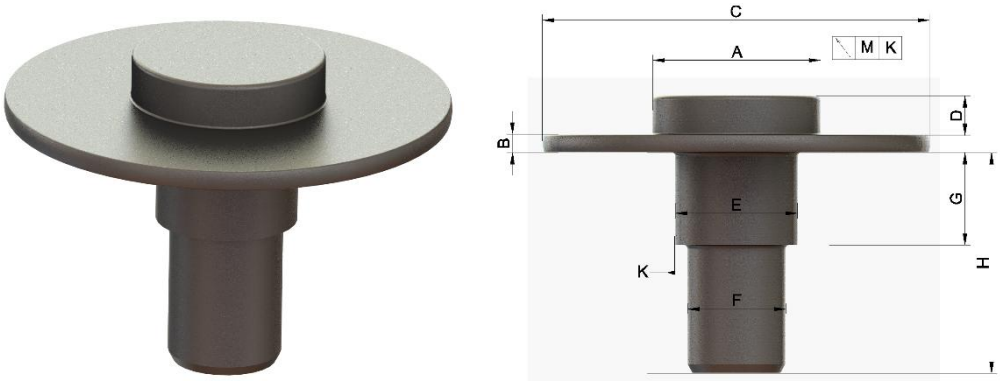
Bu çalışmada, soğuk dövme üretim hattında doğrudan çevrimiçi ölçüm yapabilen, optik görüntüleme, gerçek zamanlı veri işleme ve presle çift yönlü haberleşme kabiliyetine sahip,

üretimi durdurma ve devam ettirme kararı vererek pres makinesini ölçüsel olarak kontrol altında tutan bir ölçüm sisteminin tasarımı ve devreye alınması amaçlanmıştır.

2. MATERYAL VE YÖNTEM

2.1. Materyal

Bu çalışmada otomobillerde süspansiyon yataklama elemanı olarak kullanılan ve soğuk dövme tekniği ile üretilmekte olan flanşlı kesite sahip düşük karbonlu çelik malzemeli soğuk dövme ürün ele alınmıştır. Çalışma kapsamında Görsel 2' de gösterilmekte olan ürünün dövme operasyonuna ait Çizelge 1' de gösterilen 9 adet kontrol noktasının görüntü işleme teknikleri ile max 6 sn içerisinde ölçümlenmesi hedeflenmiştir.



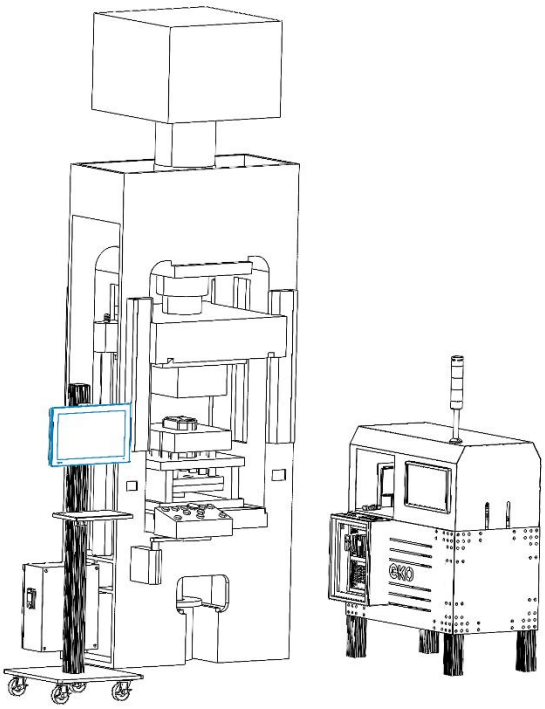
Görsel 2. Ölçümlenecek Referans Parça

Çizelge 1. Ölçümlenecek Referans Parçaya Ait Ölçü Bölgeleri ve Toleransları Çizelgesi

Ölçü Bölgesi	Tolerans
A	±0,5
B	±0,2
C	-1/+4
D	-0,2/+0,5
E	±0,3
F	±0,2
G	-0,15/+0,2
H	-0,4/+0,6
K	0,3

2.2. Yöntem

Çalışma konusu sistem, Görsel 3' de gösterildiği üzere görüntü işleme, ölçüm algoritması ve mekanik tasarım destekli otomasyon kontrolü modüllerinden oluşmaktadır.



Görsel 3. Çalışma Konusu Prototip Üretim Hücresi

Kameranın, pres çevrimine entegre tetikleme sinyaliyle eşzamanlı olarak görüntüyü alması ve geometrik özellikleri analiz ederek nominal tanımlı ölçü ve toleransları ile karşılaştırarak; pres ile kameralı ölçüm sistemi arasındaki iletişim protokolü üzerinden prese üretime devam etmesi veya üretimi durdurması yönünde sinyal aktararak presi durdurmasının sağlanması hedeflenmiştir.

2.2.1. Sistem Genel Tasarımı

Sistem tasarımını meydana getiren yapılar ve bileşenler aşağıda verilmektedir.

1. Görüntü İşleme Sistemi: Görüntü işleme kamerası ve telesentrik lensten meydana gelen görüntü işleme sistemidir.
2. Mekanik yapı: Titreşim sönümleyicili alüminyum – çelik şase ile taşınabilir modüler bir yapıdır. Yapı içerisinde ölçümlenecek iş parçasının mesnetleneceği bir parmak tutuculu sistem ve kendi ekseni etrafında 360 derece dönebilen servo motor destekli ölçüm tablası sisteminden meydana gelir.
3. Kontrol Ünitesi: Siemens PLC, Modbus TCP/IP üzerinden pres ile çift yönlü iletişim protokolü sağlayan otomasyon sistemidir.

2.2.2. Görüntü İşleme Sistemi Tasarımı

Görüntü işleme sistemi Eşitlik 2' de gösterilen genel eşitlik doğrultusunda hesaplama yapan bir algoritmayı kullanmaktadır.

$$\Delta L = |L_{ölçülen} - L_{nominal}| \quad \text{(Eşitlik 1.)}$$

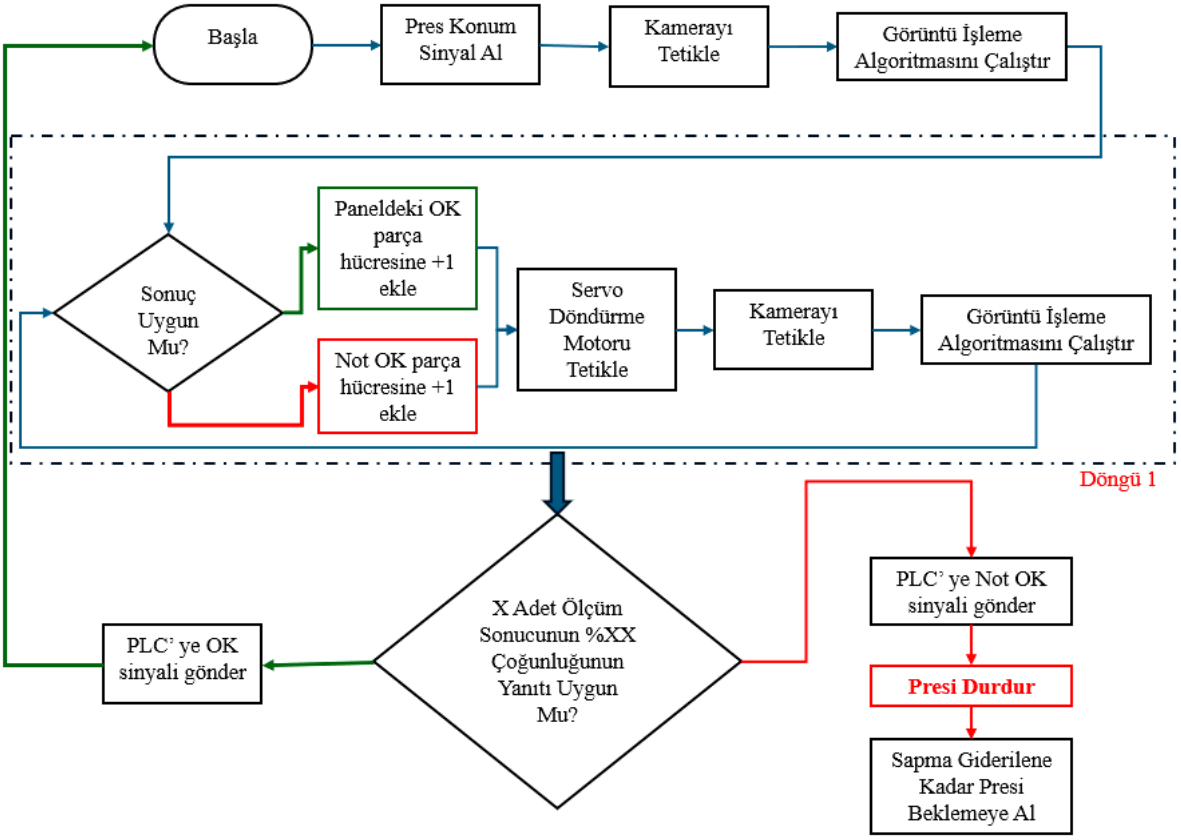
$\Delta L \leq T_{tolerans}$ ise OK, $\Delta L > T_{tolerans}$ ise Not OK (Eşitlik 2.)

$L_{ölçülen}$ görüntü işleme sisteminin elde ettiği ölçüm sonucu, $L_{nominal}$ teknik resimde verilen nominal ölçü ve $T_{tolerans}$ ise tolerans limitidir.

Eşitlik 2' de belirtilen ana kural doğrultusunda aşağıda detaylandırılan görüntü işleme algoritması oluşturulmuştur.

1. Görüntü Edinimi: Endüstriyel Kamera ile görüntünün alınması
2. Aydınlatma farklarının giderilmesi için ön işleme
3. Kenar ve kontur tespiti
4. Ölçüm noktaları tespiti
5. Piksel – mm kalibrasyonu
6. Tolerans kontrolü
7. Karar sinyali üretimi

Sistem; endüstriyel kamera, görüntü işleme bilgisayarı (IPC), PLC ve pres kontrol ünitesinden oluşmaktadır. Kamera, üretim çevrimi sırasında parçanın görüntüsünü alır ve görüntü işleme algoritması ölçüsel kontrol yapar. Tolerans dışı bir parça algılandığında, IPC dijital veya endüstriyel haberleşme sinyali ile PLC'ye "Not OK" komutu gönderir. PLC bu komutu pres kontrol sistemine ileterek presi durdurur.



Görsel 4. Görüntü İşleme Sistemi Mimarisi

2.2.3. Görüntü İşleme Sistemi Seçim Kriterleri

Makine görüsüne dayalı sisteme ait kamera seçimi, optik, elektronik ve uygulama gereksinimlerinin dengeli bir hesabına dayanır. Kamera seçimi yalnızca çözünürlük değil; piksel boyutu, kare hızı (fps), görüş alanı (FOV), mesafe, lens, ışık koşulu, hareket hızı ve hedef detay gibi faktörlerin tamamı birlikte değerlendirilir.

Gereken çözünürlük, iş parçasının ölçüleri ve toleransları dahilinde ölçüm yapabilecek hatta toleransın %10 u hassasiyetinde ölçüm gerçekleştirebilmesi gerekmektedir [10].

Çözünürlük (Piksel) = Nesne Boyutu (FOV) / Hedeflenen Hassasiyet [11] (Eşitlik 3.)

Pratikte, teorik çözünürlüğün 3–5 katı çözünürlükte kamera seçilmesi önerilir.

Objenin doğrusal hızı v ise ve pozlama süresi t ise, obje pozlama sırasında:

Pozlama Süresi (t)= $\Delta x/v$ [12] (Eşitlik 4.)

Bu değer, algılanabilir en küçük detaydan (feature size) küçük olmalıdır.

Hareketli ölçümlerde hareketten kaynaklı bulanıklık değeri hesabı ve kontrolü aşamasında pozlama süresi ile hız parametreleri irdelenir.

Motion Blur = v x t mikron. [13] (Eşitlik 5.)

Bu değer hedef ölçüm hassasiyeti değerinden mutlaka küçük olmalıdır.

Lens seçiminin ilk aşaması olarak görüntü genişliği (Kameranın yatay piksel sayısı x piksel adımı) elde edilmelidir. Ardından diğer hesaplamalar gerçekleştirilebilir.

Gerekli Büyütme:

M_Req= sensör genişliği/obje genişliği = piksel_adımı* kamera yatay piksel sayısı/obje genişliği [14] (Eşitlik 6.)

eşitliğinden bulunan değer, lensin karakterizasyon aralığı içerisinde olması gerekmektedir.

Standart Lens odak uzaklığı -Focal Length- (f):

f= (sensör genişliği x ölçüm mesafesi D) / FOV (Eşitlik 7.)

Yaklaşık optik büyütme (M) = Sensör genişliği / Görüntülenen alan genişliği

Telesentrik Lens odak uzaklığı -Focal Length- (f):

f= Çalışma Mesafesi / (1+Mreq) [14] (Eşitlik 8)

Lens sistemlerinde piksel bazında hassasiyet: Piksel adımı / Mlens (Eşitlik 9.)

Bu çalışmada, ölçümlenecek parça boyutları ve hedeflenen görüntü işleme destekli sisteme ait tasarım parametreleri Çizelge 2’ de gösterilmiştir.

Çizelge 2. Görüntü İşleme Sistemi Destekli Ölçüm Sistemi Tasarım Parametreleri

Nesne Boyutları	100 mm x 100 mm
Hedeflenen Ölçüm Hassasiyeti	30 mikron
Obje Dönüş Hızı	30 mm/sn
Çalışma Mesafesi	250 mm

Çizelge 2' de gösterilmiş olan parametreler doğrultusunda Eşitlik 3' den gerekli çözünürlük 3,3 MP bulunmuş olup, pratik seçim olarak 12 MP kamera seçilmiştir. 12 MP Kamera teknik datalarından yatay piksel sayısı 4000 piksel verisi elde edilmiştir.

Piksel bazında çözünürlük Eşitlik 3 ve 4000 piksel olan kamera verisi kullanılarak 25 mikron olarak elde edilmiştir. İstenen 30 mikron hassasiyeti tek kare ile sağlar. Piksel adımı yeterlidir.

Pozlama süresinin hesaplanması amacı ile Eşitlik 4 kullanılmış ve kamera için gerekli pozlama süresi 0,1 ms olarak elde edilmiştir.

Eşitlik 5 kullanılarak Çizelde X de belirtilen obje dönüş hızından kaynaklı bulanıklık yani Motion blur hesaplanmış be 3 mikron olarak elde edilmiştir. Hedef ölçüm hassasiyeti 30 mikron olduğu için hareketten kaynaklı bulanıklık değeri çok iyidir.

Çözünürlükteki hassasiyeti artırmak amacı ile Lens seçimi yapılacaktır. Kameraya ait görüntü genişliği 7.4mm olarak bulunur.

Standart Lens odak uzaklığı için Eşitlik 7 kullanılır. Belirtilen eşitlik yalnızca sabit odakta ve görüntünün ölçüm mesafesine göre değiştiği lenslerde kullanılır. Eşitlik 7 kullanılarak 22,2 mm standart lens kullanılabileceği belirlenmiştir.

Bu çalışmada parçaların boyutları ve kamera – lens sisteminin ölçüm mesafelerinin değiştirilebileceğinden dolayı Telecentric lens kullanılacaktır. Bu sebeple 7,4 mm genişlikli endüstriyel kamera için Telecentric Lens seçiminde Eşitlik 6 kullanılarak gerekli büyütme oranı 0,074 olarak elde edilir. Telecentric Lens teknik verileri incelenerek uygun lens için çalışma aralığı 0,029x – 0,1 x arası karakterize edilebilen VS-TLS200 Telecentric Lens seçimi gerçekleştirilmiştir.

Telecentric Lenslerde Focal Length (f) yani lens odak uzaklığı Eşitlik 8 ile hesaplanabilir.

Çalışma mesafesi VS-TLS200 için 200–500 mm aralığında olur. Çizelge 2' de belirtilen çalışma mesafesi olan 250 mm değeri ile Eşitlik 8 hesaplandığında Lens odak uzaklığı 232 mm olarak elde edilir. Seçilen lens uygundur.

Standart kamera-lens sisteminde tek karedeki çözünürlük 25 mikron bulunmuştu. Kamera seçiminde ise piksel pitch 1,85 mikron idi. Telecentric lens kullanarak 0,1 x rear unit magnification kullanılırsa (M=0,1 alınır) Eşitlik 9 dan piksel bazında hassasiyet 18,5 mikron/pixel olur. Telecentric lens seçimi ile standart durumda 25 mikron çözünürlük yani ölçüm hassasiyeti 18,5 mikrona iyileştirilmiştir.

2.2.4. Kameralı Ölçüm Sistemi Makinesi Mekanik Tasarımı

Otomotiv kritik güvenlik parçasının ölçüsel özellikleri ve tolerans limitleri kapsamında ölçüm işlemlerini gerekli hassasiyetle gerçekleştirecek kamera-lens sisteminin seçim işlemleri sonunda görüntü işleme sistemi çalışma limitleri referans alınarak mekanik tasarım aşamasına yönelik faaliyetler gerçekleştirilmiştir. Bu doğrultuda ise öncelikli olarak görüntü işleme sisteminin montajlanacağı üst yapı tasarım faaliyetleri yürütülmüştür. Çalışma konusu makinenin üst yapı tasarım faaliyetlerinde;

Farklı ebatlardaki numunelerin ölçümlenebilmesi amacı ile işleme sistemi ve iş parçası mesafesi hassas ayarlama mekanizması tasarımı,

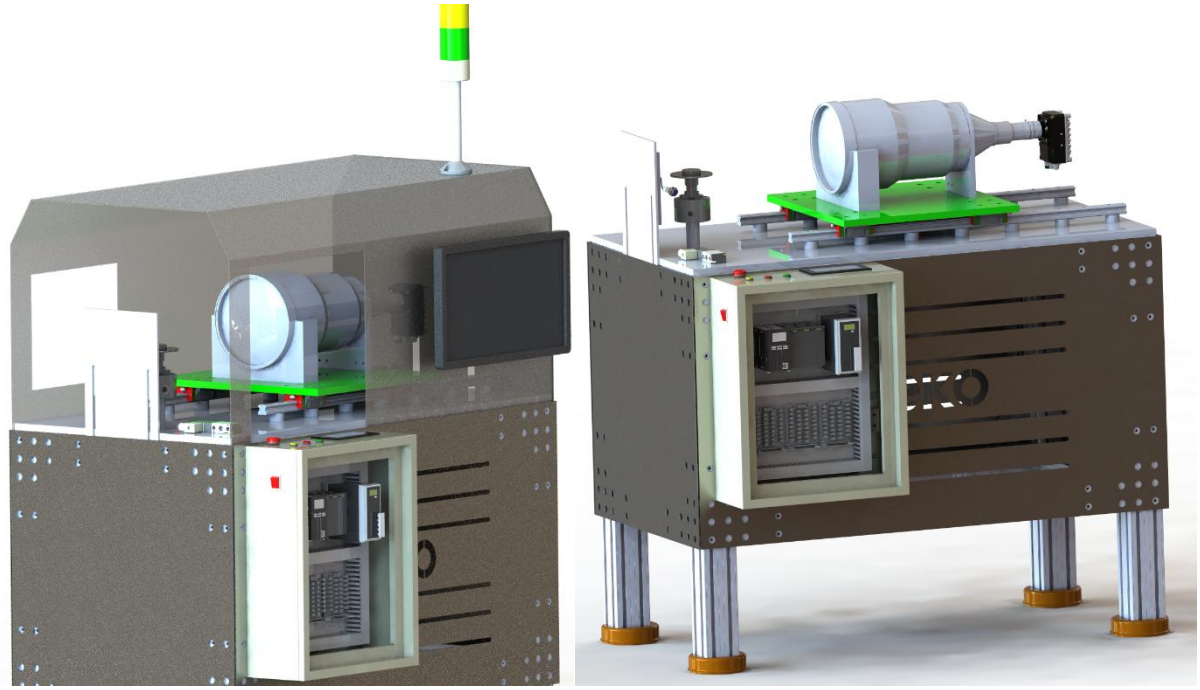
Ölçüm tekrarlanabilirliğini sağlamak amacı ile rijit sabitleme mekanizması tasarımı,

Ölçümü gerçekleştirilen numunenin radyal salgı ve eşmerkezlilik gibi geometrik toleranslarının da belirlenebilmesine olanak sağlayan döner tip gripper mesnetleme sistemi tasarımı ve tahrik sistemi seçimi faaliyetleri yürütülmüştür.

Çalışma konusu makinenin alt yapı tasarım faaliyetlerinde ise;

Taşıma operasyonlarında meydana gelen ani darbeleri sönümleme kabiliyeti için yüksek emniyet katsayılı ve hafif yapılı kompakt tasarım faaliyetleri,

Çalışma ortamı etkenlerine karşı (tozuma, titreşim vb.) muhafaza ve sönümleme sistemleri entegrasyonu faaliyetleri yürütülmüştür. Yürütülen tasarım faaliyetleri kapsamında Görsel 5’ de gösterilmekte olan makine tasarımı ortaya konmuştur. Görsel 5’ de görüntü işleme sistemi destekli kameralı ölçüm sistemine ait üst yapı detayları, Görsel 6’ da ise imalat faaliyetleri sonucunda montaj süreci tamamlanmış sistem gösterilmektedir.

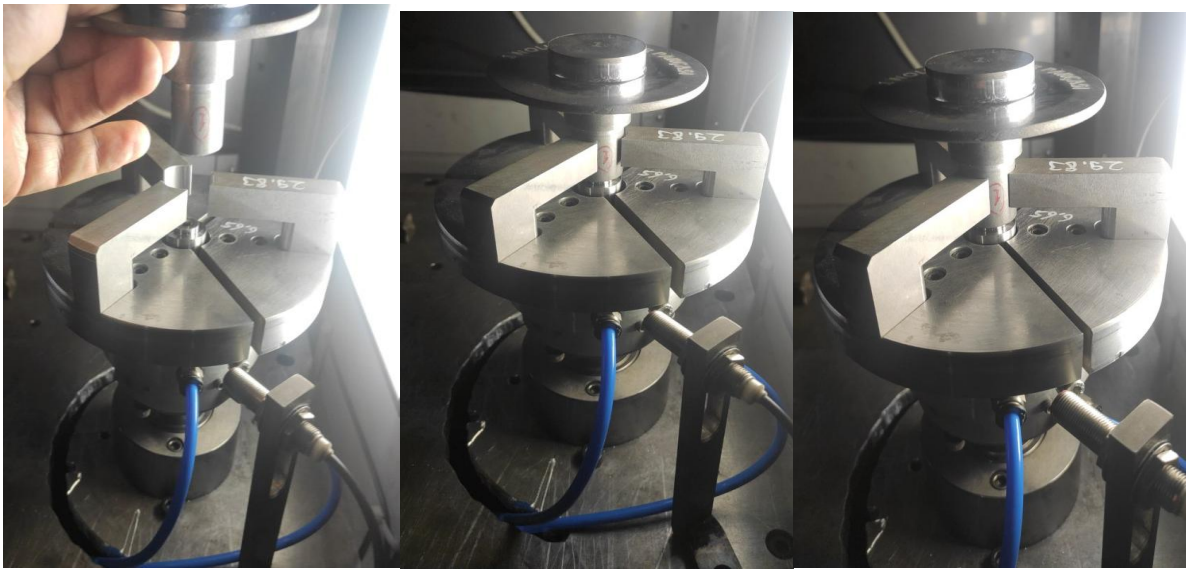


Görsel 5. Kameralı Ölçüm Sistemi Üst Yapı Tasarım Detayları



Görsel 6. Görüntü İşleme Sistemi Destekli Ölçüm Makinesi

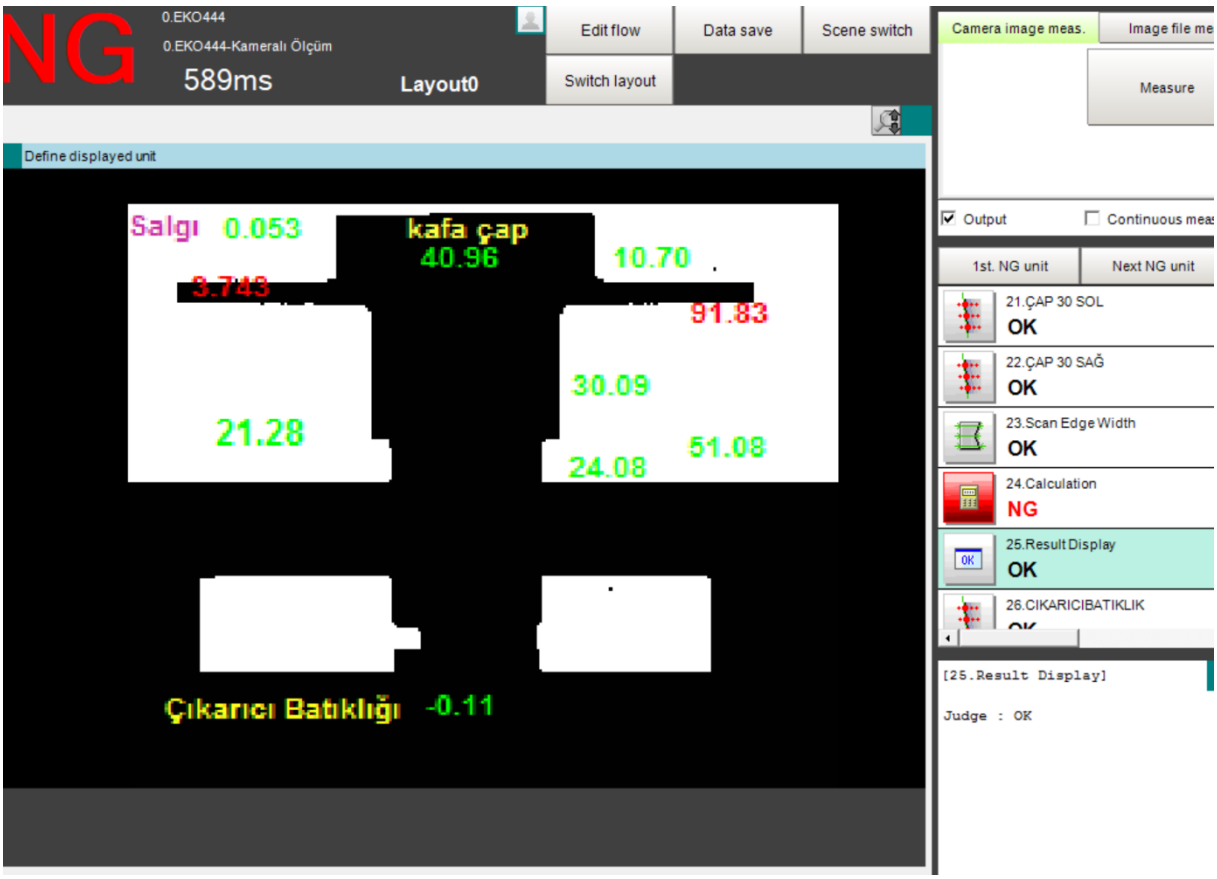
Ölçüm parçasının ölçüm tekrarlanabilirliğini, pozisyon sabitliğini ve radyal salgı ile eşmerkezliliğini ölçümleyebilmek amacı ile servo motor ile tahrik edilerek ayarlanabilir hız özelliği ile ayarlanabilir dönüş açısı yeteneği kazandırılmış olan döner gripper mesnetleme sistemine ait örnekler Görsel 7' de gösterilmiştir.



Görsel 7. Ölçüm Makinesi Döndürülebilir Gripper Mekanizması

Tasarım ve imalat faaliyetlerinin ardından sistem devreye alınmış ve ölçüm programı hazırlanarak Görsel 8' de gösterilen ölçüm sistemi devreye alınmıştır. Ölçüm sistemi 10 farklı

ölçüm karakteristiğini her bir dönüş ve ölçüm çevrimini 2 sn içerisinde gerçekleştirecek şekilde programlanmıştır.



Görsel 8. Görüntü İşleme Sistemi Destekli Ölçüm Makinesi Ölçüm Sonuç Görüntüleme Ekranı

3. SONUÇLAR VE DEĞERLENDİRME

Bu çalışmada, otomotiv ve havacılık endüstrisi gibi kritik güvenlik elemanlarının üretiminin gerçekleştirildiği soğuk ve sıcak dövme gibi plastik şekil verme endüstrilerinde kullanılmak üzere görüntü işleme sistemi temelli kameralı ölçüm sistemi tasarımı ve imalatı gerçekleştirilmiştir. İmal edilen sistemin PLC kontrol donanım ve yazılımları aracılığı ile üretimin gerçekleştirildiği pres makinelerine sinyal iletip sinyal alabilmesine olanak sağlayan altyapı tasarımı gerçekleştirilmiştir. Bu sayede preste şekillendirilen iş parçasının şekillendirme işlemi sonrasında ölçüm makinesine yerleştirilmesi ve 6 saniye içerisinde en az 2 kez kendi ekseninde dönme hareketi yaparak farklı kesitlerden ölçüm gerçekleştirmesinin ardından ölçüm sonucunun tolerans limitleri içerisinde ise prese sinyal göndererek bir sonraki parçanın üretilebilmesi için onay vermesi, ölçüm sonucunun tolerans limitleri dışında olması durumunda ise kırmızı renkli andon yakarak presi durdurma sinyali göndererek üretimi uygunsuzluk çözümlenene kadar durdurması sağlanmıştır.

Çizgelde 3, Çizelge 4 ve Çizelge 5'de gösterildiği üzere preste ardışık olarak üretilen parçalardan alınan rastgele örnekler kameralı ölçüm sisteminde ölçümlenmiş ve ardından ise CMM ölçüm sisteminde ölçümlenerek Kameralı ölçüm sisteminin tekrarlanabilirlik ve ölçüm hassasiyeti gibi kritik performans kriterleri doğrulanmıştır. CMM ölçüm sistemi ile kameralı ölçüm sisteminin ölçüm değerlerini arasında en fazla 20 mikron sapma meydana geldiği

dolayısıyla kameralı ölçüm sisteminin üretim sahasında güvenilir şekilde kullanılabilecek bir alternatif olduğu görülmüştür.

Çizelge 3. Parça 1' e Ait CMM ve Kamera Ölçüm Sistemleri Kıyaslama Çizelgesi

Ölçü Bölgesi	1. Ölçüm CMM	1. Ölçüm CAM	2. Ölçüm CMM	2. Ölçüm CAM	3. Ölçüm CMM	3. Ölçüm CAM
G	21,34	21,328	21,363	21,338	21,375	21,391
G	21,31	21,324	21,369	21,367	21,412	21,408
G	21,327	21,318	21,413	21,411	21,489	21,463
G	21,363	21,347	21,38	21,388	21,415	21,409
H	51,012	51,023	51,035	51,058	51,047	51,045
H	51,04	51,184	51,099	51,11	51,141	51,153
H	51,086	51,102	51,172	51,098	51,248	51,236
H	51,066	51,0574	51,108	51,102	51,144	51,138
D	10,316	10,322	10,34	10,358	10,37	10,328
D	10,363	10,371	10,406	10,422	10,452	10,461
D	10,346	10,358	10,361	10,36	10,384	10,392
D	10,305	10,32	10,301	10,296	10,3	10,28
B		3,96				

Çizelge 4. Parça 2' ye Ait CMM ve Kamera Ölçüm Sistemleri Kıyaslama Çizelgesi

Ölçü Bölgesi	1. Ölçüm CMM	1. Ölçüm CAM	2. Ölçüm CMM	2. Ölçüm CAM	3. Ölçüm CMM	3. Ölçüm CAM
G	21,315	21,327	21,34	21,365	21,356	21,372
G	21,279	21,265	21,345	21,347	21,396	21,392
G	21,3	21,309	21,391	21,393	21,47	21,444
G	21,316	21,332	21,362	21,354	21,404	21,398
H	50,977	50,966	51,001	50,978	51,017	51,015
H	51,006	50,862	51,072	51,061	51,123	51,135
H	51,052	51,036	51,143	51,217	51,222	51,21
H	51,035	51,0436	51,081	51,087	51,123	51,117
D	10,531	10,525	10,519	10,501	10,508	10,466
D	10,586	10,578	10,6	10,584	10,615	10,624
D	10,546	10,534	10,543	10,544	10,539	10,547
D	10,491	10,476	10,462	10,467	10,435	10,415
B		3,77				

Çizelge 5. Parça 3' e Ait CMM ve Kamera Ölçüm Sistemleri Kıyaslama Çizelgesi

Ölçü Bölgesi	1. Ölçüm CMM	1. Ölçüm CAM	2. Ölçüm CMM	2. Ölçüm CAM	3. Ölçüm CMM	3. Ölçüm CAM

G	21,018	21,03	21,044	21,069	21,076	21,092
G	20,972	20,958	21,066	21,068	21,143	21,139
G	21,018	21,027	21,085	21,087	21,151	21,125
G	21,04	21,056	21,081	21,073	21,104	21,098
H	50,997	50,986	51,023	51	51,055	51,053
H	51,049	50,905	51,143	51,132	51,22	51,232
H	51,086	51,07	51,153	51,227	51,22	51,208
H	51,01	51,0186	51,051	51,057	51,074	51,068
D	10,94	10,934	10,12	10,102	10,145	10,103
D	10,039	10,031	10,059	10,043	10,085	10,094
D	10,054	10,042	10,061	10,062	10,07	10,078
D	10,079	10,064	10,099	10,104	10,12	10,1
B		3,96				

Standart seri üretim aşamasında gerçekleştirilen operatöre dayalı proses kalite kontrol faaliyetlerine ilişkin süreç ile kameralı ölçüm sistemi devreye alındıktan sonra gerçekleştirilen süreç analizlerinde Çizelge 6' da gösterilmiş olan kalite kontrol faaliyetleri süreci iyileştirme performansı verileri elde edilmiştir.

Çizelge 6. Kameralı Ölçüm Sistemi Performansının Konvansiyonal Kalite Kontrol Sistemleri ile Kıyaslanması

Parametre	Konvansiyonel Kalite Kontrol Sistemleri	Kameralı Ölçüm Sistemi	Değişim
Ortalama ölçüm süresi	20 sn	6 sn	-70%
Ölçüm doğruluğu	30 µm	30 µm	+60%
Hurda oranı	%3.2	%0.0	-100%
Operatör sayısı	2	1	-50%

Çizelge 6' da gösterilen veriler kapsamında ölçüm süresinin %70 oranında düşüş gösterdiği ve kalite kontrol personelinin yürüttüğü ölçüm süreçlerinin kameralı ölçüm sistemine aktarılması ile hat üzerinde çalışan üretim personeli tarafından hem üretim hem de kalite kontrol faaliyetlerini yürütebilmesi sağlanmıştır. Benzer şekilde sıkı frekansiyel kontrol (5 parçada 1 adet ölçüm) süreci ile yürütülen üretim sürecinin otomatik şekilde %100 kontrol ile yürütülmesine olanak sağlanmıştır. Frekansiyel kontrol aşamasında prosesin yavaşlatılması sebebi ile ortaya çıkan verimlilik düşüşleri ortadan kaldırılmış, vardiya bazında üretim adetleri en az 3 katına çıkarılmıştır. Ek olarak ise kameralı ölçüm sisteminin doğrudan prese durdur/başlat sinyali göstermesi sayesinde hattan hurda parçanın çıkması engellenmiştir.

4. GENEL DEĞERLENDİRME VE SONUÇLAR

Bu çalışma, soğuk ve sıcak dövme başta olmak üzere plastik şekil verme tekniğine göre gerçekleştirilen kritik parça üretiminde tam otomatik, görüntü işleme tabanlı bir ölçüm makinesinin tasarımını, analitik modellemesini ve performans doğrulamasını içeren bir yaklaşım ile sistem entegrasyonunu sunmaktadır. Elde edilen sonuçlar, sistemin endüstriyel ölçekli uygulanabilirliğini göstermektedir.

Geliştirilen görüntü işleme tabanlı ölçüm sistemi, soğuk dövme üretim hatlarında gerçek zamanlı boyutsal kontrol için yüksek güvenilirliğe sahip bir çözüm olarak ortaya çıkmaktadır. Yüksek hızlı optik kontrol, görüntü işleme destekli ölçüm sistematiği ve PLC iletişimi bileşenlerinin entegrasyonu sayesinde sistem, üretim sürecinin kararlılığını sürdürmeye ve sıfır hatalı üretim hedefine katkı sağlayan bir sistemdir. Sistemde kullanılan Telecentric lens sayesinde ölçüm hassasiyeti artırılmış, parça-lens arası mesafe değiştikçe boyutsal ölçüm tutarlığının değişmemesi sağlanmıştır. Görüntüleme alanı içerisinde Telecentric lenslerde her noktada büyütme oranı aynı olduğundan klasik lenslerde oluşan büyütme distorsiyonunun ortadan kaldırılarak dar toleranslı parçaların üretim sahasında otomatik ölçümlenmesi aşamasında ölçüm tutarsızlığı problemi ortadan kaldırılmıştır.

Çalışma konusu sistemin modüler ve kompakt yapısı sayesinde üretim sahası içerisinde farklı üretim makinelerine uyarlanabilmekte ve iletişim kurarak proses güvenliğini üst düzeyde tutabilmektedir. Sistem, yalnızca ölçüm doğruluğunu değil, üretim güvenliğini de artırmıştır. Presin otomatik durdurulması, hatalı üretimden kaçınılmasını sağlamaktadır. Ayrıca, kalite kontrol sürecinin dijitalleştirilmesi sayesinde, ölçüm sonuçları; lot numarası, tarih ve üretim makinesi bazında kaydedilerek izlenebilirlik sağlanabilmekte ve IATF 16949 gibi kalite yönetim sistemleri gereklilikleri desteklenmektedir.

Gelecek araştırmalarda derin pekiştirmeli öğrenme tabanlı hata sınıflandırma çalışmalarının yürütülerek kalıp aşınmasının tespiti ile online kestirimci bakım uygulamalarının kameralı ölçüm sistemlerine adaptasyonu, Endüstri 4.0 tabanlı kalite kontrol ve üretim izlenebilirlik faaliyetlerine katkı sağlayacağı düşünülmektedir.

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NADİR TOPRAK ELEMENTLERİNİN ELEKTRİKSEL, ELEKTRONİKSEL, SAVUNMA, ÇİMENTO ve İNŞAAT SEKTÖRLERİNDE KULLANIMI

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ÖZET

Nadir toprak elementleri (NTE), eşsiz elektriksel, manyetik ve optik özellikleri sayesinde modern teknolojinin vazgeçilmez bileşenleri haline gelmiştir. Bu çalışmada NTE'lerin elektrik ve elektronik endüstrilerinde, savunma sanayinde ve çimento-inşaat sektöründe kullanım alanları kapsamlı şekilde incelenmiştir. NTE'lerin yüksek manyetik permeabilite ve iletkenlik gibi elektriksel özellikleri; güçlü kalıcı mıknatıslar, bataryalar ve süperiletkenler üretiminde kritik rol oynamaktadır. Elektronik uygulamalarda ise NTE'lerin benzersiz luminesans ve doping özellikleri, akıllı telefon ekranlarından fiber optik iletişim sistemlerine dek geniş bir yelpazede kullanılmaktadır. Savunma alanında NTE'ler, gelişmiş silah sistemlerinin, sensörlerin ve motorların performansını artırmakta; bu nedenle ülkeler arasında jeopolitik gerginliklere konu olmaktadır. Çimento ve inşaat sektöründe, özellikle radyasyondan korunma amaçlı beton ve yapı malzemelerine nadir toprak elementleri ilavesinin nötron ve gamma soğurma kapasitesini arttırdığı deneysel olarak gösterilmiştir. Son olarak, son on yıldaki literatür taramasıyla her sektördeki akademik gelişmeler özetlenmiş; NTE'lerin üretiminde bazı ülkelerin dominasyonu ve alternatif kaynak arayışları, geri dönüşüm çabaları ile birlikte değerlendirilmiştir. Bu kapsamlı değerlendirme, NTE'lerin günümüz teknolojileri için stratejik önemini vurgularken sürdürülebilir yönetimi ve tedarik güvenliği konularına da ışık tutmaktadır.

Anahtar Kelimeler : Nadir Toprak Elementleri, NTE Kullanım Alanları, Savunma Sistemleri, Çimento Sektörü, İnşaat Sektörü.

1. GİRİŞ

Nadir toprak elementleri (NTE), periyodik tablonun 57–71 atom numaralı lantanitleri ile skandiyum ve İtriyumdan oluşan toplam 17 metalik elementi tanımlayan bir gruptur[1]. “Nadir” olarak adlandırılsalar da, bu elementler aslında Dünya kabuğunda oldukça bol miktarda bulunur; örneğin seryum yaklaşık 68 ppm ile bakırdan daha yüksek bolluğa sahiptir[2]. Ancak NTE’ler genellikle yüksek saflıkta ve konsantre yataklar halinde bulunmadığından, çıkarılmaları ve rafinajı zahmetli ve masraflıdır[3]. NTE’ler özellikle 4f elektron konfigürasyonlarından kaynaklanan benzersiz manyetik, elektronik ve optik özelliklere sahiptir. Bu özellikler, onları yüksek manyetik akı yoğunluklu mıknatıslar, parlak fosforlar, lazer ortamları ve etkili katalizörler gibi birçok ileri teknolojide vazgeçilmez kılar[1][4]. 2010’lardan itibaren yenilenebilir enerji, elektrikli ulaşım ve savunma teknolojilerindeki atılımlar, NTE’lere ^olan talebi daha da artırmıştır[5][1]. Örneğin elektrikli araçlar, rüzgâr türbinleri, akıllı telefonlar ve savunma sistemleri gibi alanlarda NTE’lerin kullanımı hızla yaygınlaşmıştır.

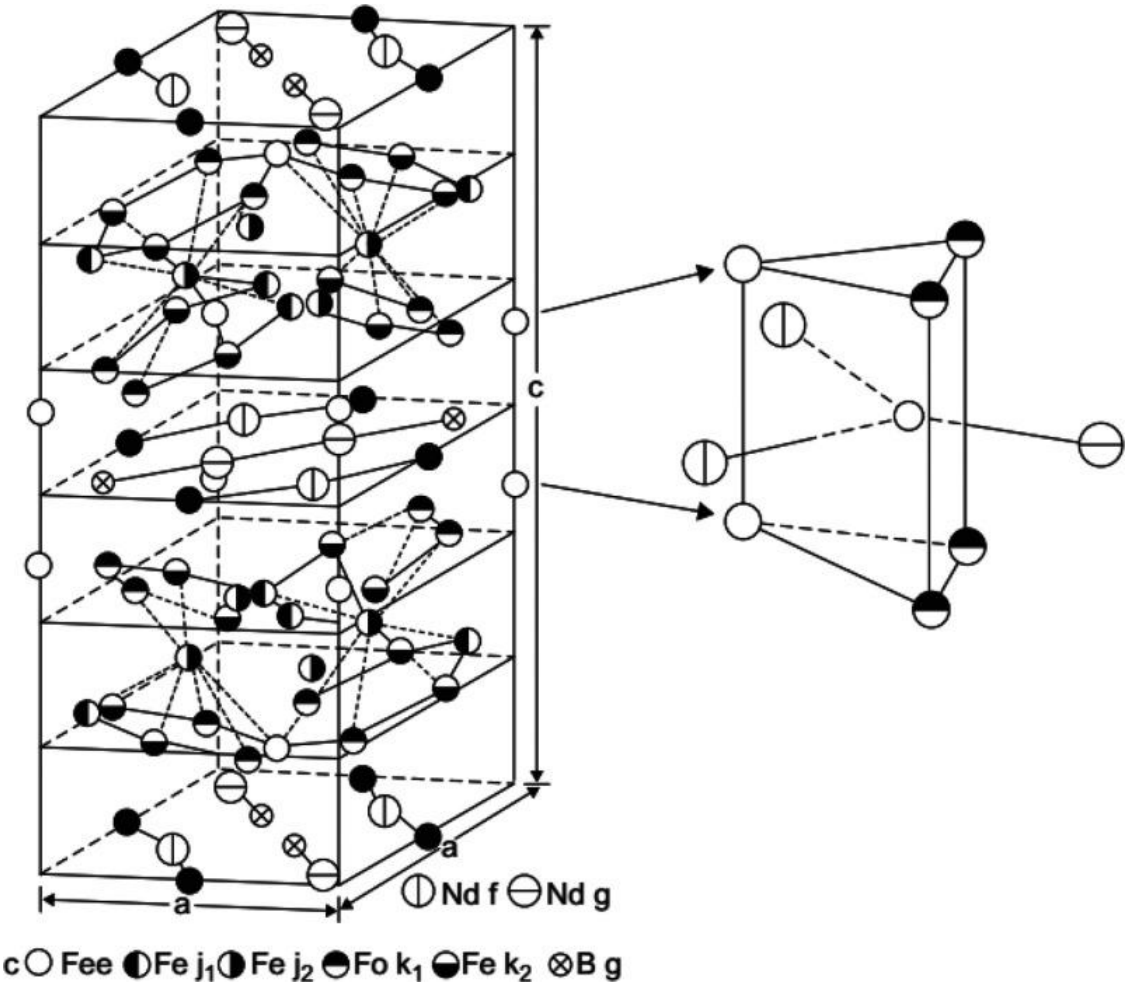
NTE’lerin artan stratejik önemi, küresel ölçekte jeopolitik ve ekonomik etkiler de doğurmaktadır. Dünyadaki NTE üretimi ve rezervleri belirli bölgelere yoğunlaşmıştır; özellikle Çin, 2020’ler itibarıyla global tedarikin büyük kısmını kontrol etmektedir[6]. Bu durum, başta ABD ve Avrupa olmak üzere birçok ülkeyi NTE tedarik zincirlerini güvence altına almaya yönelik politikalara yöneltmiştir. Son yıllarda Türkiye gibi bazı ülkeler de önemli NTE rezervleri keşfettiklerini duyurarak bu stratejik alanda konum edinmeye çalışmaktadır[2]. Tüm bu gelişmeler, NTE’lerin teknolojik ve endüstriyel öneminin yanı sıra jeostratejik bir ham madde olarak dikkat çektiğini göstermektedir.

Bu bildiride, NTE’lerin elektriksel özellikleri ve elektrik sektörü uygulamalarından başlayarak, elektronik sektöründeki kullanım örneklerine, savunma sanayiindeki kritik rollere ve çimento-inşaat sektöründeki özel uygulamalara kadar geniş bir perspektifte ele alınacaktır. Ayrıca dünya genelindeki üretim ve rezerv durumu incelenip bu dağılımın jeopolitik sonuçları tartışılacaktır. Her bir sektör için son 10 yılda yapılan akademik çalışmalardan örnekler verilerek kapsamlı bir literatür taraması sunulacaktır.

2. NADİR TOPRAK ELEMENTLERİNİN ELEKTRİKSEL ÖZELLİKLERİ VE KULLANIMI

NTE’ler, elektriksel açıdan değerlendirildiğinde metaller olmaları nedeniyle iletkenlik gösterse de pratikte saf halleriyle elektrik iletkeni olarak kullanılmazlar. Asıl önemleri, bileşik ve alaşımlarının elektrik enerjisi üretimi, depolanması ve dönüşümündeki kritik rollerinden gelir. Bu elementlerin yüksek manyetik permeabilite ve ani magnetizasyon özellikleri, günümüz elektrik teknolojilerinin merkezinde yer alan güçlü kalıcı mıknatısların temelini oluşturur[5]. Özellikle neodimyum-demir-bor (Nd-Fe-B) mıknatıslar, oda sıcaklığında dünyanın en güçlü mıknatısları olup, elektrik motorlarının ve jeneratörlerin boyutlarını küçültüp verimlerini artırmıştır[5]. Bu sayede rüzgâr türbinleri ve elektrikli araç motorlarında yüksek güç yoğunluğuna sahip manyetik rotörler kullanılabilmektedir. Nitekim ortalama bir elektrikli otomobil, yaklaşık 1–2 kg neodimyum ve praseodimyum elementi içeren mıknatıs

barındırırken, bir 3 MW'lık direkt tahrik rüzgâr türbini jeneratörü yaklaşık 2 ton Nd-Fe-B mıknatıs (yaklaşık %30'u Nd/Pr) içermektedir[1][7]. Bu güçlü mıknatıslar, elektrik üretim ve dönüşüm sistemlerinde daha hafif ve verimli tasarımları mümkün kılmaktadır.



Görsel 9. Kalıcı mıknatısın tetragonal kristal yapısı. Manyetik tane sınırlarında Nd açısından zengin faz tabakası görülmektedir. (Review on he parameters of recycling NdFeB magnets via a hydrogeneration process 2023) [8].

Bunun yanı sıra NTE'ler, elektrik enerjisinin depolanması alanında da kullanılmaktadır. Örneğin lantan (La) içeren metal-hidrit alaşımları, nikel-metal hidrit (NiMH) pillerin elektrotlarında hidrojen depolama malzemesi olarak görev yapar. Toyota Prius gibi ilk nesil hibrit araçlarda NiMH bataryaların yaygın kullanımı, lanthanum talebini önemli ölçüde artırmıştır. Lantan, LaNi_5 alaşımı formunda yüksek döngüsel kararlılık ve enerji yoğunluğu sunarak bataryaların şarj-deşarj performansını iyileştirir. Bunun yanında itriyum (Y) elementinin oksit bileşiği, itriyum oksit stabilizasyonlu zirkonya (YSZ) formunda katı oksit yakıt pilleri ve lambda sensörleri (oksijen sensörleri) için kritik bir elektrolit malzemedir. YSZ, yüksek iyon iletkenliği ve kimyasal kararlılığı sayesinde otomobillerde egzoz gazı sensörlerinde ve enerji santrallerinde yakıt pillerinde kullanılarak elektrik üretiminde verimliliğe katkı sağlar.

Nadir toprak elementlerinin elektriksel uygulamaları arasında bir diğer önemli konu da süperiletkenliktir. Özellikle itriyum barındıran bakır oksit seramikler (örneğin YBa_2Cu_3O_7, YBCO), yüksek sıcaklık süperiletkenleri olarak keşfedilmiştir. YBCO malzemesi, sıvı nitrojen sıcaklıklarında (90 K civarı) süperiletkenlik göstererek manyetik kaldırma (maglev) sistemleri ve kayıpsız güç iletimi konseptleri için potansiyel sunmuştur. NTE katkılı süperiletken malzemeler, ileride dirençsiz enerji iletim hatları ya da güçlü manyetik depolama sistemleri (SMES) gibi elektrik mühendisliği uygulamalarında devrim yaratma potansiyeline sahiptir.

Son olarak, nadir toprak elementleri, elektrik iletim ekipmanlarında ve alaşımlarda tane sınırı düzenleyici ve oksidasyon önleyici katkılar olarak da kullanılır. Örneğin, skandiyum (Sc) ve itriyum, alüminyum ve magnezyum alaşımlarına eklendiğinde bu alaşımların elektriksel ve mekanik özelliklerini iyileştirir; daha hafif ama güçlü iletken alaşımlar elde etmeye imkân tanır. Bazı NTE oksitlerinin yüksek dielektrik sabiti özellikleri, seramik kapasitörlerin üretiminde değerlendirilir; neodimyum oksit katkılı bazı seramikler, elektronik devrelerde yüksek kapasitanslı kondansatörler üretmek için kullanılabilmektedir. Bütün bu örnekler, nadir toprak elementlerinin elektrik enerjisinin üretilmesi, depolanması ve iletilmesindeki vazgeçilmez rollerini gözler önüne sermektedir.

3. NADİR TOPRAK ELEMENTLERİNİN ELEKTRONİKSEL KULLANIMI

NTE'lerin modern elektronik sektöründeki uygulamaları son derece çeşitlidir ve hemen her ileri teknolojik cihazda izlerine rastlamak mümkündür. Bu elementlerin optik ve manyetik özellikleri, elektronik bileşenlerin performansını artırmak ve yeni işlevler kazandırmak için sıklıkla kullanılır. Özellikle manyetik NTE alaşımları ve bileşikleri, tüketici elektroniğinin kalbinde yer almaktadır. Örneğin, neodimyum ve samaryum esaslı kalıcı mıknatıslar, sabit disk sürücülerinin okuma/yazma kafalarını konumlandıran aktüatörlerden akıllı telefonlardaki titreşim motorlarına kadar birçok cihazın içerisinde bulunur. Tipik bir akıllı telefonda, hoparlör ve mikrofon gibi bileşenlerde minyatür Nd-Fe-B mıknatıslar yüksek ses kalitesi sağlarken, cihazın titreşim modülünde de benzer mıknatıslar kullanılarak güçlü fakat kompakt bir mekanizma elde edilir. Bunun sonucunda NTE'ler, mobil cihazların giderek küçülen boyutlarına rağmen artan işlevsellik sunabilmelerinin arkasındaki gizli kahramanlardandır.

Nadir toprak elementlerinin luminesans (ışıldama) özellikleri, ekran teknolojileri ve aydınlatma sektöründe devrim yaratmıştır. Özellikle avrupa (Eu) ve terbiyum (Tb) elementlerinin iyonları, farklı matrisler içinde parlak renkli fosforlar oluşturarak elektronik ekranların gelişimine katkı sunmuştur. Kırmızı renkli fosforlarda genellikle Eu^3+ iyonları (örneğin YVO_4:Eu veya Y_2O_2S:Eu bileşiklerinde) kullanılırken, yeşil fosforlarda Tb^3+ iyonları (ör. oksisülfür matrislerde) yaygın olarak kullanılır[9]. Günümüzde LED ekranlar ve kompakt floresan lambalarda, üçlü bant fosfor sistemleri içerisinde lantan, itriyum, seryum, terbiyum ve avrupa kombinasyonlarıyla istenen beyaz ışık tonu elde edilmektedir[5]. Örneğin beyaz LED'lerde, mavi ışık yayan çip üzerine kaplanan bir fosfor katmanı içinde itriyum-alüminyum garnet:sersiyum (YAG:Ce^3+) kullanılarak mavi ışığın sarımsı beyaz ışığa dönüştürülmesi sağlanır[5]. Bu sayede enerji verimli ve uzun ömürlü aydınlatma ve görüntüleme cihazları geliştirilebilmiştir.

NTE'lerin bir diğer kritik elektronik uygulaması, lazer ve optik sistemler alanındadır. Yttriyum-alüminyum garnet (Y_3Al_5O_12, YAG) kristaline doping edilen neodimyum (Nd^3+), günümüzün en yaygın katı hâl lazerlerinden Nd:YAG lazerlerinin etkin ortamını oluşturur. Nd:YAG lazerler tıpta (ör. göz cerrahisi), endüstride (malzeme işlemede) ve askeri hedefleme sistemlerinde yaygın olarak kullanılmaktadır. Benzer şekilde, erbiyum (Er^3+)-katkılı fiber lazerler ve amplifikatörler, telekomünikasyon altyapısının belkemiği olan fiber optik hatlarda sinyal güçlendirme işlevini görür. Erbiyum katkılı fiber optik amplifikatörler (EDFA), 1.55 µm dalgaboyunda düşük kayıplı haberleşme imkânı sağlayarak kıtalararası fiber hatlarda tekrarlayıcı gereksinimini azaltmıştır. Holmium (Ho^3+) ve tulyum (Tm^3+) elementleri de sırasıyla ~2.1 µm ve ~1.9 µm dalga boylarında lazerler üretmek üzere lazer kristallerinde doping maddesi olarak kullanılır; bu lazerler tıpta (ör. taş kırma, doku kesimi) ve uzaktan algılama uygulamalarında değerlidir.

Nadir toprak elementlerinin yüksek kırılma indisine sahip camlar üretmedeki rolleri de önemlidir. Lanthanum oksit (La_2O_3) katkılı özel optik camlar, kamera lensleri ve teleskop objektiflerinde kullanılmaktadır. Lanthanum camlar, düşük dağılım (aberrasyon düzeltme) ve yüksek kırılma indisi sağlayarak keskin ve parlak görüntü elde edilmesine imkân tanır[2]. Bu sayede yüksek kaliteli DSLR kamera lenslerinde ve askeri gözetleme sistemlerinde (dürbün, periskop vb.) lanthanum içeren camlar tercih edilir. NTE'ler aynı zamanda camların ve ekran panellerinin üretim süreçlerinde de rol oynar; örneğin serium oksit (CeO_2) ultra ince cam yüzeyleri parlatmak için kullanılan en etkin abrazif malzemelerden biridir. Akıllı telefon ve tablet ekranlarının imalatında, CeO_2 bazlı cilalar sayesinde optik olarak pürüzsüz ve çiziksiz yüzeyler elde edilir.

Modern elektronik devrelerde NTE alaşımlarının manyetostriktif özellikleri de kullanılmaktadır. Terbiyum ve disprosyum elementlerinin demir ile oluşturduğu Terfenol-D alaşımı, uygulanan manyetik alanla boyut değiştirebilme (manyetostriksyon) kabiliyetine sahiptir. Bu alaşım, özellikle denizaltı sonarlarında ve hassas mekanik aktüatörlerde elektrik sinyallerini mekanik titreşimlere dönüştürmek için kullanılmaktadır. Ayrıca disprosyum (Dy) ve terbiyum, neodimyum mıknatıslarında yüksek sıcaklık performansını iyileştirmek için eklenir; bu elementler mıknatısların Curie sıcaklığını yükselterek motorların yüksek ısıl koşullarda da güçlü kalmasını sağlar.

Sonuç olarak, televizyon ekranlarından akıllı telefonlara, lazerlerden yüksek kapasiteli sabit disklere kadar sayısız elektronik cihaz NTE'lerin özel kimyasal ve fiziksel özelliklerinden yararlanmaktadır. Her bir NTE'nin kendine özgü bir kullanım alanı bulunmakta; birçok durumda da birden fazla NTE birlikte kullanılarak istenen teknik özellikler elde edilmektedir. Bu çok yönlü kullanım alanları, elektronik sektörünün NTE'lere olan bağımlılığını açıklamakta ve bu elementlerin stratejik değerini daha da artırmaktadır[2][9].

4. NADİR TOPRAK ELEMENTLERİNİN SAVUNMA SANAYİSİNDE KULLANIMI

Nadir toprak elementleri, modern savunma sanayinin görünmez belkemiğidir. Gelişmiş askeri platformlar ve mühimmatlar, NTE'lerin sağladığı üstün malzeme özellikleri sayesinde yüksek performans göstermektedir. Özellikle kalıcı mıknatıs teknolojisi ve özel optik sistemler, askeri

uygulamalarda NTE'lerin kritik rol oynadığı alanların başında gelir. Örneğin beşinci nesil bir savaş uçağı olan F-35 Lightning II, elektronik harp sistemlerinden hedefleme podlarına ve elektrikli aktüatörlerine kadar yaklaşık 920 pound (≈418 kg) nadir toprak elementi içeren bileşen barındırmaktadır[2]. Bu kapsamda F-35'in manyetik alaşımlarında neodimyum, praseodimyum, disprosyum; optik ve sensör sistemlerinde ise itriyum, europium gibi NTE'ler kullanılmaktadır[10][2]. Benzer şekilde, ABD donanmasına ait bir Virginia sınıfı nükleer denizaltı yaklaşık 9.200 pound (≈4.170 kg) NTE içerikli malzeme kullanırken, bir Arleigh Burke sınıfı güdümlü füze destroyerinde bu miktar 5.200 pound (≈2.360 kg) düzeyindedir[2]. Bu veriler, büyük savaş platformlarının ne denli yüksek miktarda NTE'ye bağımlı olduğunu çarpıcı biçimde ortaya koymaktadır.

Savunma sistemlerinde NTE'lerin en yaygın kullanım alanlarından biri, yüksek performanslı mıknatıslar ve manyetik alaşımlardır. Kalıcı mıknatıslar; jet uçaklarının elektrik sistemlerinde, güdüm kitlerinin kanatçık hareket ettiricilerinde, tank ve gemilerde elektrik motorlarında kritik öneme sahiptir. Özellikle güdümlü füzeler ve akıllı mühimmatların hassas kontrol yüzeyleri, küçük boyutlu ama güçlü Nd-Fe-B mıknatıslar ve Samaryum-Kobalt mıknatıslarla donatılmış elektrik motorları sayesinde çalışır[1][2]. Örneğin bir Tomahawk seyir füzesi veya JDAM güdümlü bomba, içinde bulunan nadir toprak mıknatıslı aktüatörler sayesinde hedefe yönelirken hassas manevralar yapabilir. İnsansız hava araçları (İHA) ve insansız hava araçlarına karşı kullanılan sistemler de hafif ve güçlü manyetik malzemeler olmadan düşünülemez; MQ-1 Predator gibi bir IHA'nın sensör sistemlerinden elektrik motorlarına kadar NTE içeren komponentler bulunur[1].

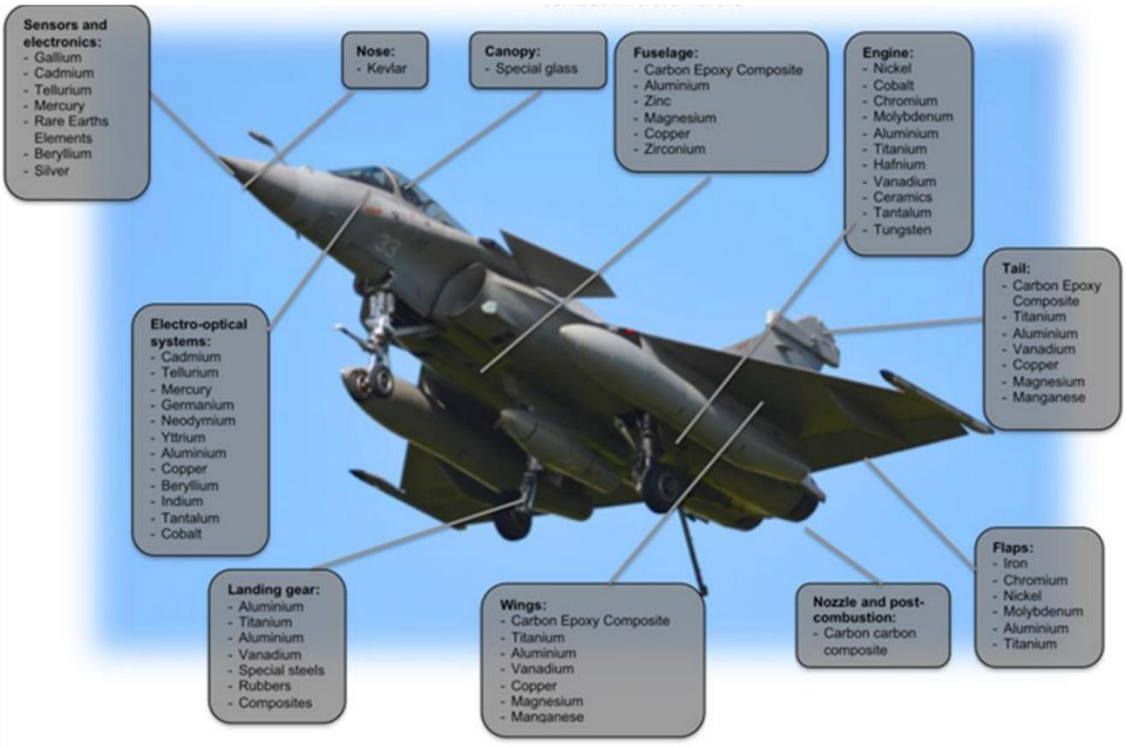
NTE'ler savunma elektroniğinde optik ve elektronik harp alanlarında da kritik rol oynar. Gece görüş gözlükleri ve termal kameralar, görüntüleme tüplerinin fosfor ekranlarında ve kızılötesi dedektörlerinde NTE bazlı malzemeler kullanır[10]. Özellikle europium ve terbiyum katkılı fosfor ekranlar, gece görüş cihazlarında net görüntü sağlamak için ideal dalga boylarında ışık yayarlar. Lazer mesafe bulucular ve hedef işaretleyiciler, genellikle Nd:YAG veya Er:cam lazerleri kullanır ki bu lazer kristallerinin etkinliği doğrudan NTE dopingine bağlıdır. M1A2 Abrams tankı gibi zırhlı araçların lazerli mesafe ölçer sistemlerinde nadir toprak katkılı lazerler bulunmaktadır[2]. Yine aynı tankın gelişmiş kompozit zırh yapısında ve atış kontrol sistemlerinde de NTE içeren sensör ve mıknatıslara rastlanır.

Ağır silah platformlarının yanı sıra, haberleşme ve radar sistemleri de NTE'lerden faydalanır. Modern faz dizinli radarlar, yüksek frekanslı mikrodalga sinyallerini yönlendirmek için itriyum-demir garnet (YIG) rezonatörler ve ferrit devre elemanları kullanır; bu malzemeler radarın tarama hızını ve kararlılığını arttırır. Ayrıca radar gücünü artırmak için kullanılan bazı yüksek güçlü mikrodalga tüplerde (ör. TWT - Traveling Wave Tube) ve manyetronlarda da samaryum-kobalt mıknatıslar tercih edilir[2]. Denizaltı sonar sistemlerinin "transdüser" olarak adlandırılan ses dalgası yayıcıları da Terfenol-D (Tb-Dy-Fe) gibi manyetostriktif NTE alaşımları içerir; bu sayede elektrik sinyalleri güçlü akustik titreşimlere dönüştürülerek sualtında iletişim ve obje tespitine imkân verilir[2].

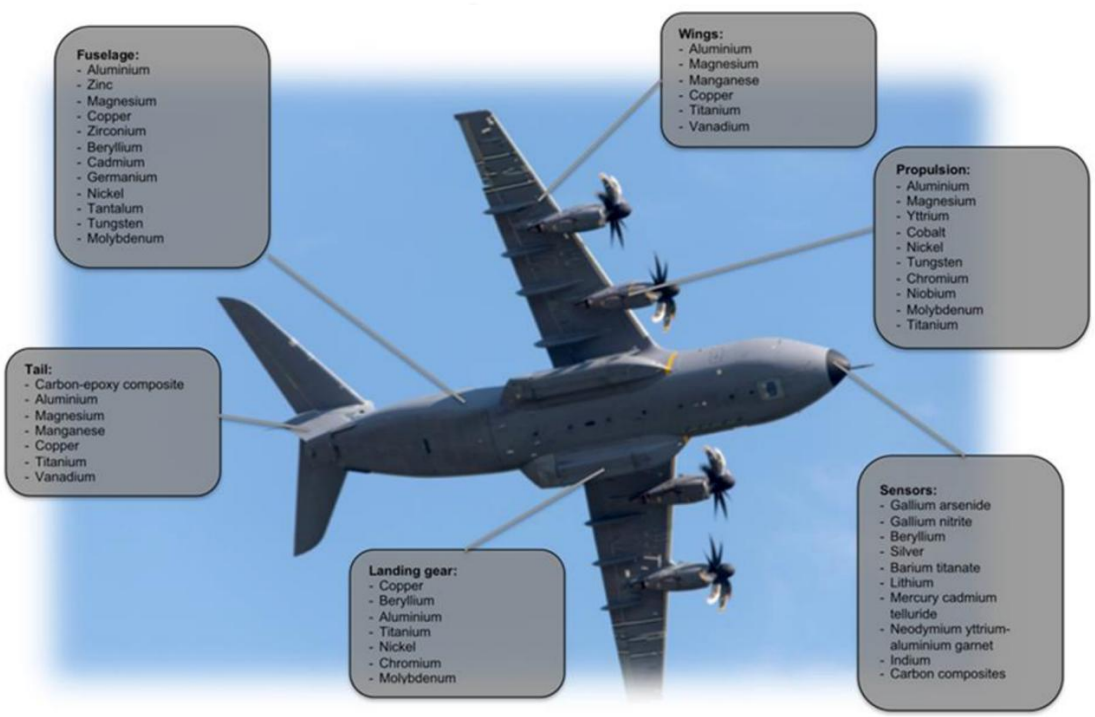
Savunma sanayindeki optik sistemlerde NTE kullanımı bir diğer önemli konudur. Gelişmiş hedefleme sistemleri ve casus uydu kameraları, lantan oksit katkılı özel lenslerle donatılır;

böylece daha hafif lens grupları ile yüksek çözünürlüklü görüntüler elde edilir[2]. Örneğin askeri uydu kameralarında ve keşif uçaklarının objektiflerinde lantanlı camlar, görüntü kalitesini artırarak istihbarat toplama kabiliyetini yükseltir. Ayrıca füze uyarı sistemlerinde kullanılan morötesi ve kızılötesi dedektörlerin filtreleri ve saptayıcı kristalleri de NTE içerebilir (örneğin, gadolinyum oksisülfür bazlı sintilatörler).

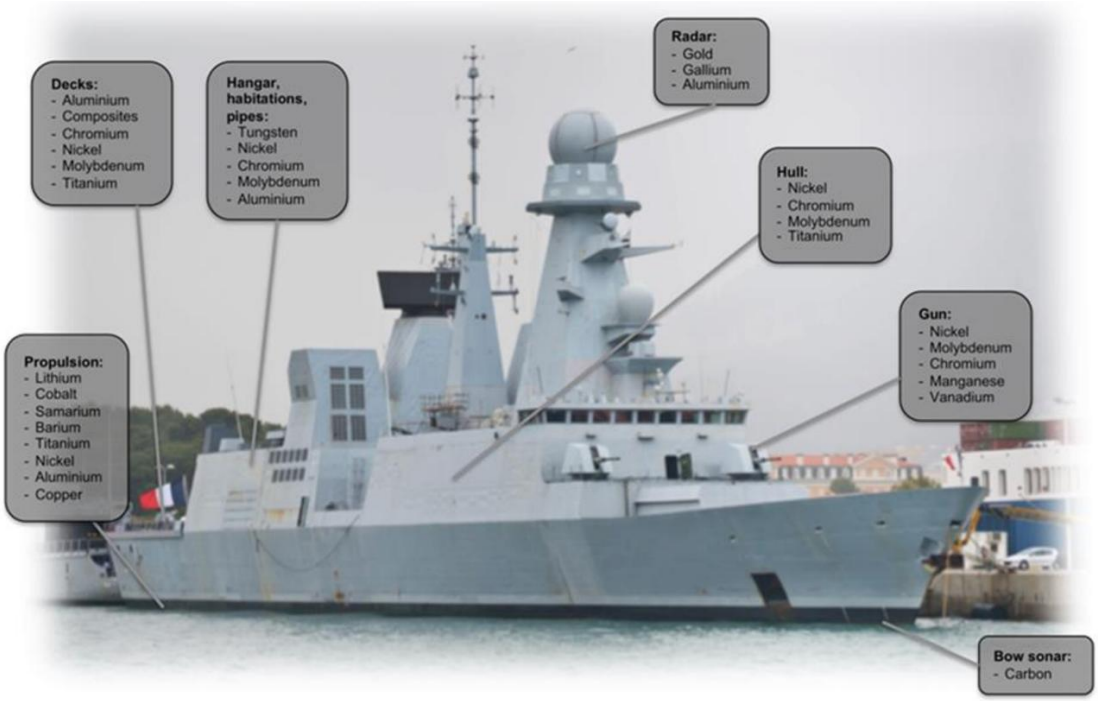
Son olarak ise çeşitli askeri kargo-savaş uçaklarının gerek gövdelerinde gerek ise optik sistemlerinde; denizaltı, fırkateyn ve korvetlerin radar sistemlerinde ve gövdelerinde; tankların haberleşme komponentleri ve gövdelerinde; çeşitli taarruz tüfeklerinde de NTE'lerin kullanımı yaygındır. Görsel 2,3,4,5,6 ve 7'de örnek kullanım alanları gösterilmiştir.



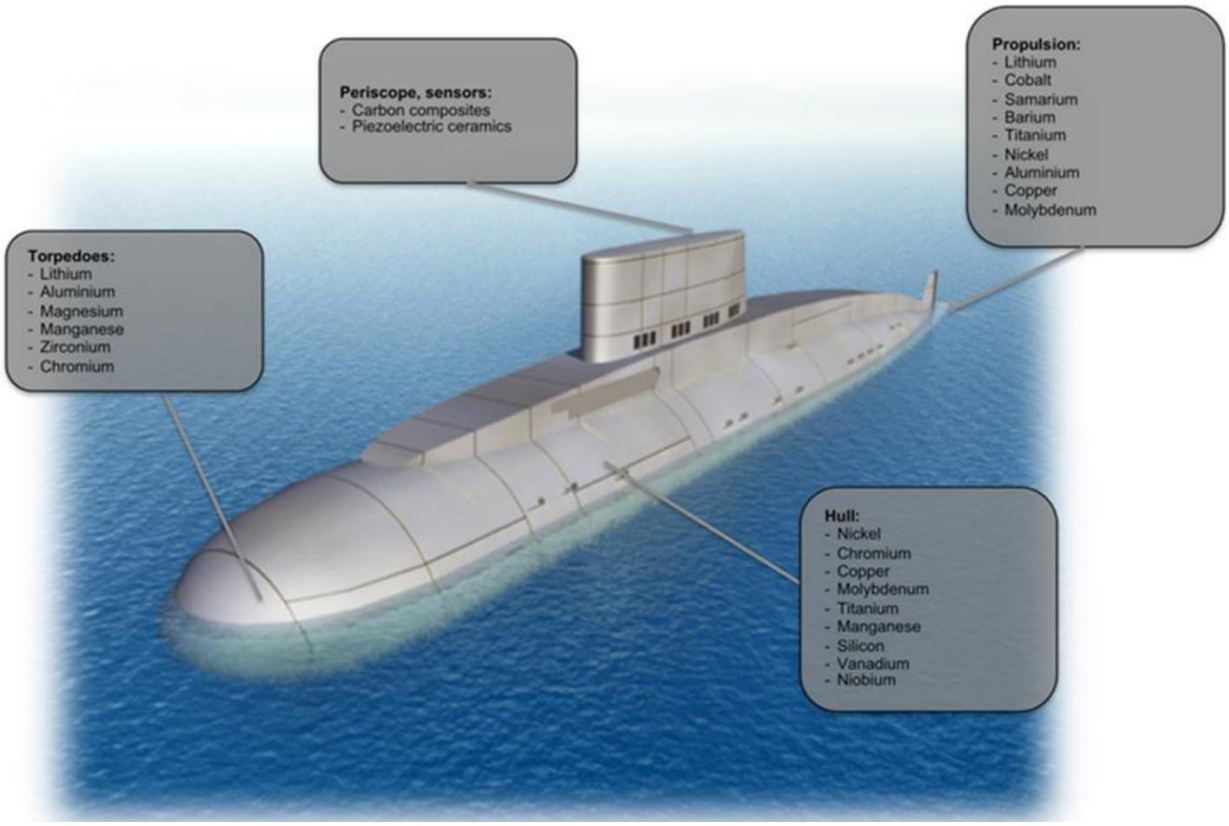
Görsel 10. Dassault Aviation (Fransa) tarafından üretilen Rafale savaş uçağının farklı parçalarında kullanılan bileşenler ve hammaddeler. (Luxembourg: Publications Office of the European Union 2016) [11].



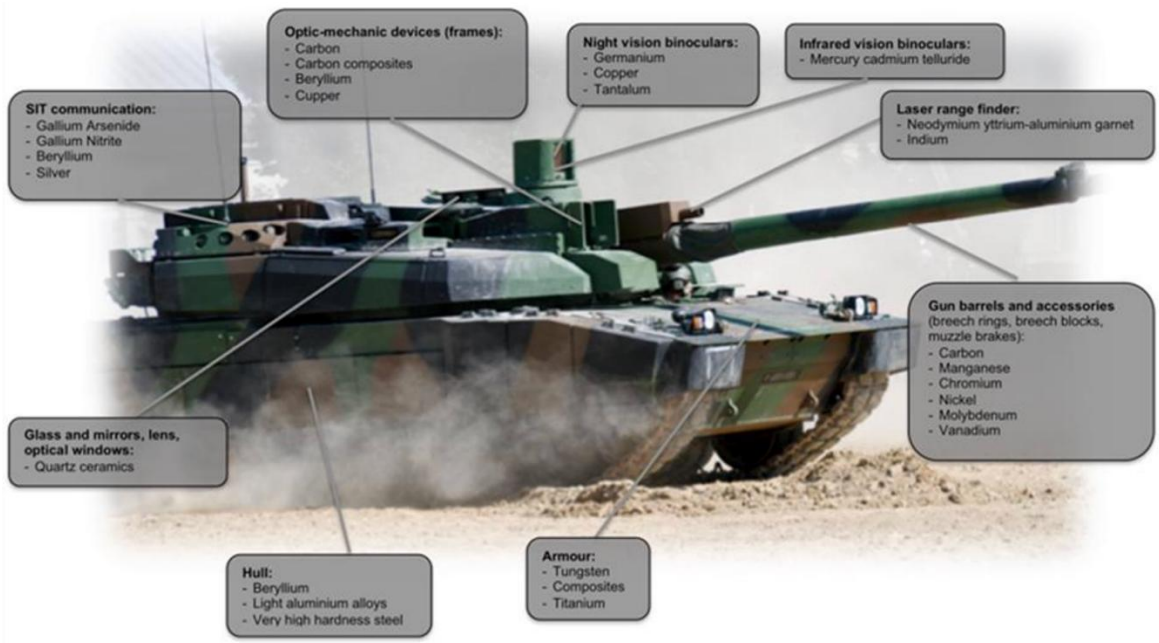
Görsel 11. Airbus D&S tarafından üretilen A400M nakliye uçağının farklı parçalarında kullanılan bileşenler ve hammaddeler. (Luxembourg: Publications Office of the European Union 2016) [11].



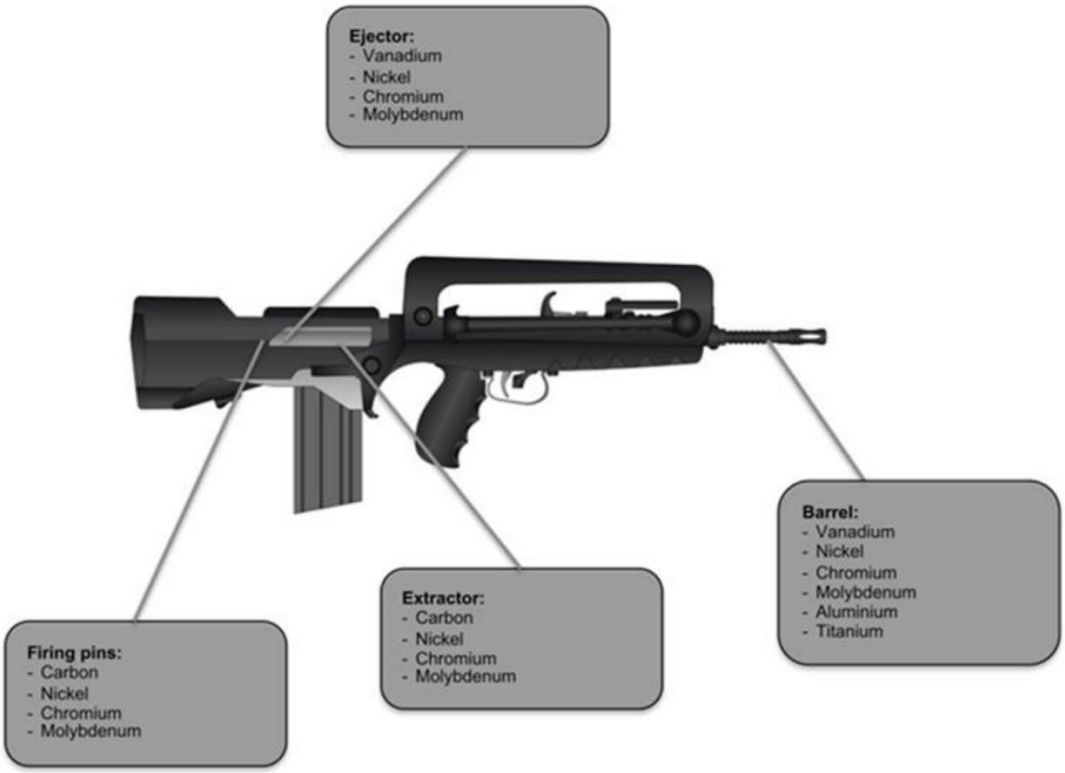
Görsel 12. Korvet'te kullanılan bileşenler ve hammadeler. (Luxembourg: Publications Office of the European Union 2016) [11].



Görsel 13. Denizaltında kullanılan bileşenler ve hammadeler. (Luxembourg: Publications Office of the European Union 2016) [11].



Görsel 14. Ana muharebe tankında (örneğin Leclerc) kullanılan bileşenler ve hammaddeler, ayrıca piyade ve zırhlı savaş araçlarını da temsil eden bileşenler ve hammaddeler. (Luxembourg: Publications Office of the European Union 2016) [11].



Görsel 15. Taarruz tüfeğinde (örneğin Famas, Fransa) kullanılan bileşenler ve hammadeler. (Luxembourg: Publications Office of the European Union 2016) [11].

Tüm bu örnekler, NTE'lerin modern savunma teknolojilerindeki kritik rolünü ortaya koymaktadır. Bu yüzden NTE tedarik zincirindeki herhangi bir aksama, ülkelerin savunma kapasiteleri üzerinde doğrudan etkili olabilmektedir. Özellikle ABD ve Avrupa ülkeleri, savunma sistemlerinde ihtiyaç duydukları NTE'lerin büyük bölümünü Çin'den ithal etmektedir[2]. Bu bağımlılık, NTE'leri bir jeopolitik koz haline getirmekte; Çin'in 2010'da Japonya'ya yönelik geçici ihracat yasağı veya 2025'te duyurduğu mıknatıs teknolojileri ihracat kısıtlamaları gibi hamleler, bu elementlerin stratejik önemini gözler önüne sermektedir[1]. Sonuç olarak, NTE'ler savunma sanayinde hem teknolojik hem de stratejik açıdan kritik bir konumdadır ve bu durum literatürde de geniş yankı bulmaktadır.

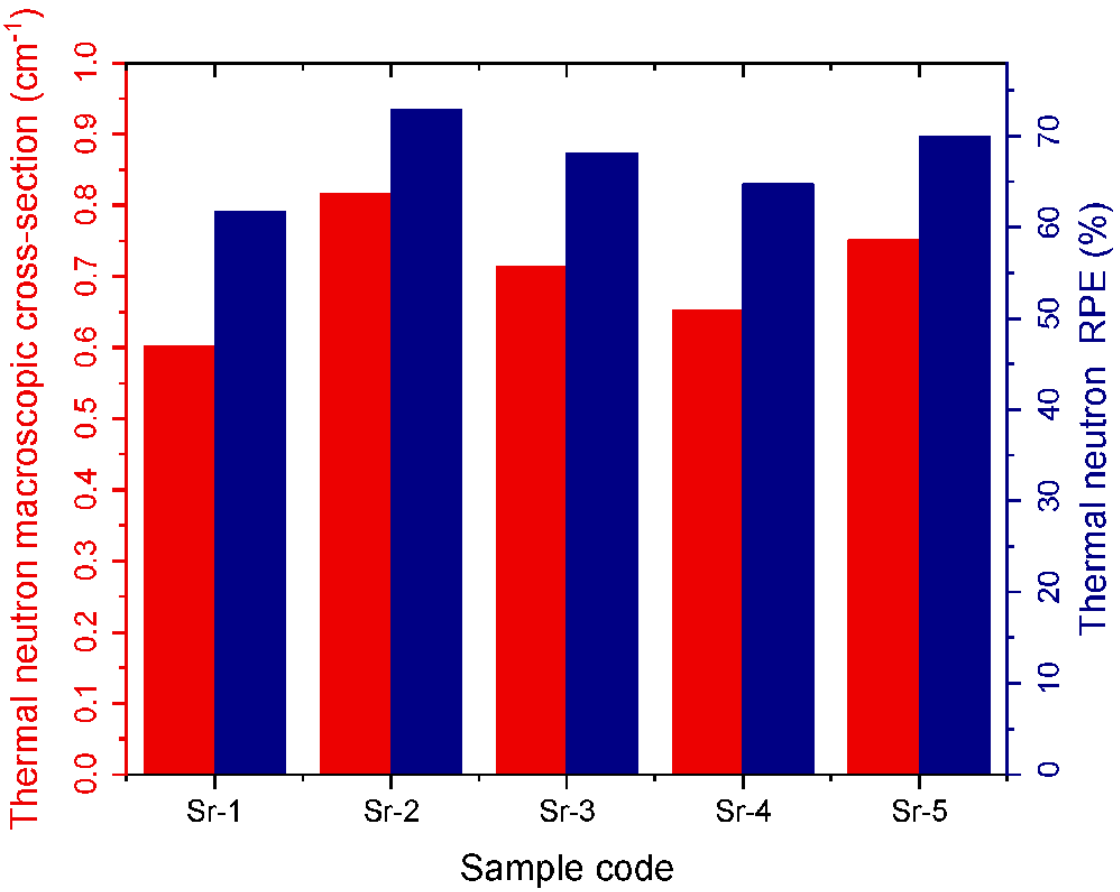
5. NADİR TOPRAK ELEMENTLERİNİN ÇİMENTO ve İNŞAAT SEKTÖRÜNDE KULLANIMI

Nadir toprak elementlerinin alışılmışın dışında bir diğer kullanım alanı, çimento ve inşaat sektöründe, özellikle radyasyondan korunma amacıyla geliştirilmiş özel beton ve yapı bileşenleridir. Nükleer tesisler, radyoterapi merkezleri, sığınaklar ve askeri barınaklar gibi ortamlarda, yapı malzemelerinin gamma ve nötron radyasyonunu etkin bir şekilde soğurması hayati önem taşır. Geleneksel beton, yüksek yoğunluğu sayesinde gama ışınlarının belirli bir kısmını soğurabilse de nötron radyasyonu için etkili değildir. Bu noktada, bazı nadir toprak elementleri yüksek nötron yakalama kesitleriyle devreye girer. Özellikle gadolinyum (Gd), doğadaki elementler arasında en büyük termal nötron yakalama kesitine sahip elementtir (Gd-157 izotopu için ~254.000 barn)[4]. Bu özelliği sayesinde Gd, beton karışımlarına eklendiğinde termal nötronları yakalayarak nötrona karşı kalkanlama performansını çarpıcı biçimde

artırır[3]. Yapılan araştırmalarda Gd içeren beton veya kompozit malzemelerin, özellikle termal nötronlara karşı, bor katkılı malzemelere kıyasla çok daha yüksek soğurma yeteneği gösterdiği saptanmıştır. Bunun nedeni, Gd yakalama reaksiyonu sırasında yüksek enerjili sekonder gamma fotonları üretse de, Gd'nin aynı zamanda yüksek atom numarasından dolayı bu fotonların önemli bir kısmını da soğurabilmesidir[4]. Böylece Gd katkısı, nötron ve ardından oluşan gama radyasyonuna çift etkili bir koruma sağlar.

Gadolinyumun yanı sıra, bazı diğer nadir toprak elementleri de radyasyon kalkanlamada değerlidir. Örneğin samaryum (Sm) ve avrupa (Eu) elementleri, belirli izotopları sayesinde yüksek nötron yakalama kesitleri sergiler. Sm-149 izotopu ~40.000 barn civarında bir kesite sahipken Eu-151 izotopu ~4.500 barn gibi oldukça yüksek bir kesite sahiptir[1]. Bu değerler, konvansiyonel nötron soğurucular olan bora (10B izotopu ~3.840 barn) ve kadmiyuma (113Cd ~20.000 barn) yakın veya daha yüksek seviyelerdedir. Dolayısıyla Sm ve Eu oksitlerinin beton içinde kullanımı da özellikle termal nötronlara karşı ek koruma sağlayabilir. Nitekim bazı deneysel çalışmalarda, beton karışımına europium oksit eklendiğinde nötron zayıflatma katsayısının kayda değer ölçüde arttığı gösterilmiştir. Ayrıca disprosyum (Dy) gibi NTE'ler de orta dereceli nötron soğurma özellikleriyle (Dy-164 izotopu ~2.700 barn) kalkanlama malzemelerinde incelenmektedir[12].

Yapı malzemelerine NTE ilavesi, nötron soğurma yanında gamma radyasyonu zayıflatmada da katkı sunar. Yüksek atom numarasına sahip elementler, fotoelektrik etki mekanizmasıyla gama fotonlarını etkili biçimde soğurur. Örneğin lütesyum (Lu, Z=71), kurşuna yakın atom numarasıyla gama soğuruculuğu yüksek bir elementtir. Yakın tarihli bir çalışmada betona lütesyum oksit (Lu_2O_3) eklendiğinde, betonun hem gama hem de nötron radyasyonuna karşı soğurma performansının belirgin şekilde iyileştiği rapor edilmiştir[13]. Özellikle Lu katkılı beton örneklerinin, aynı kalınlıktaki standart betona kıyasla daha düşük yarı değer kalınlık (HVL) ve daha düşük ortam yolu (MFP) değerlerine ulaştığı, yani radyasyonu daha kısa mesafede yarılayıp soğurabildiği gözlemlenmiştir. Bu da lütesyumun yüksek yoğunluğu ve fotoelektrik soğurma kabiliyetinin bir sonucudur.



Görsel 16. NTE içeren serpantinit numunelerin termal nötron makroskopik kesit ve radyasyon koruma etkinlikleri. (Unfluence of Rare Earth Elements on the Radiation-Shielding Behavior of Serpentinite-Based Materials 2025) [14].

NTE'lerin inşaat malzemelerinde bir diğer uygulaması, nükleer atık depolama ve radyasyona dayanıklı yapısal bileşenler üzerinedir. Bazı doğal mineraller NTE içerir ve bu minerallerin kullanıldığı agregalar, betona benzersiz özellikler kazandırabilir. Örneğin Türkiye'de Elazığ bölgesindeki bir çalışmada, NTE açısından zengin *serpantinit* kayaçlarının betonda agrega olarak kullanımı incelenmiştir[3][4]. Sonuçlar, serpantinit içerisindeki doğal nadir toprak elementlerinin, özellikle gadolinyum konsantrasyonunun, beton numunelerin termal nötron soğurma kesitlerini ciddi oranda artırdığını ortaya koymuştur[4]. Bu tür NTE zengini doğal malzemeler, radyasyona karşı korunma amaçlı duvar ve zemin kaplamalarında, hatta ileride nükleer atık depolama tesislerinin bariyerlerinde değerlendirilebilir. Çalışmada ayrıca NTE içeren kayaçların kullanımıyla çimento tüketiminin azaltılabildiği ve daha çevre dostu, uzun ömürlü radyasyon kalkanlarının elde edilebileceği vurgulanmıştır.

Kısacası, nadir toprak elementleri inşaat sektöründe standart malzemelere eklenerek onlara fonksiyonel bir özellik kazandırma potansiyeline sahiptir. Geliştirilen bu yeni nesil beton ve kompozitler, sadece yapıların mekanik dayanımını sağlamakla kalmayıp aynı zamanda radyolojik koruma görevini de üstlenebilmektedir. Bu alandaki literatür giderek genişlemekte; son 10 yılda NTE katkılı radyasyon kalkanları üzerine çok sayıda araştırma yayınlanmıştır[4].

Özellikle nükleer teknoloji ve uzay radyasyonu gibi konular önem kazandıkça, NTE'lerin inşaat malzemelerine entegrasyonu stratejik bir araştırma alanı olarak karşımıza çıkmaktadır.

6. DÜNYA GENELİNDE ÜRETİM, REZERV DURUMU VE JEOPOLOTİK ETKİLER

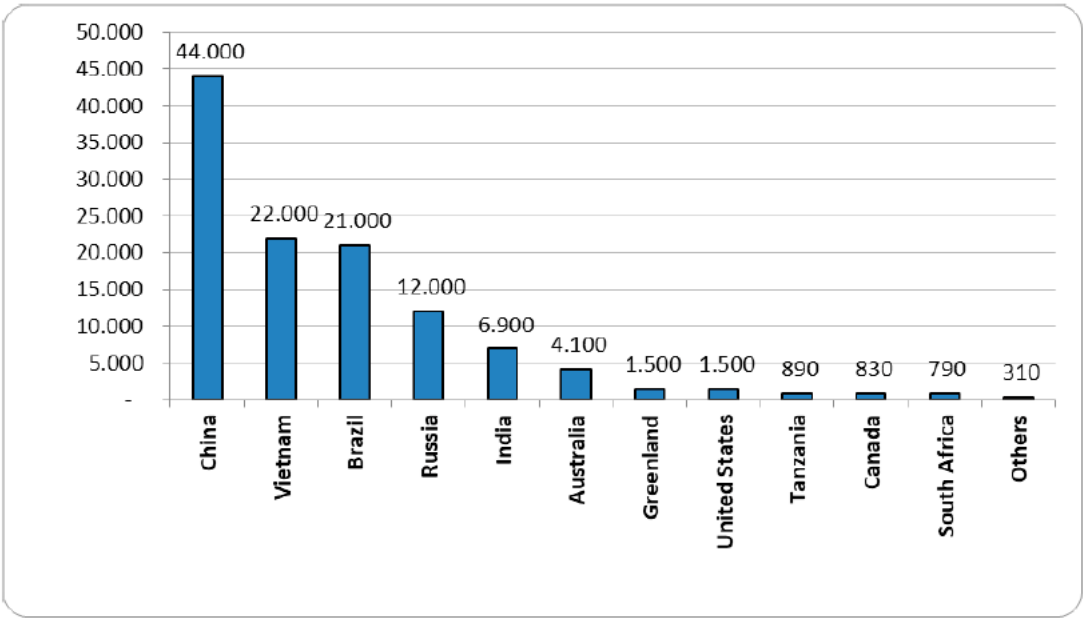
Nadir toprak elementlerinin jeolojik dağılımı ve üretim kapasitesi, küresel tedarik zincirini belirleyen en önemli faktörlerdendir. Dünya genelindeki toplam NTE rezervlerinin 2025 itibarıyla 90 milyon tonun üzerinde nadir toprak oksit (REO) eşdeğerine sahip olduğu tahmin edilmektedir[15]. Bu rezervler coğrafi olarak birkaç ülke ve bölgeye yoğunlaşmıştır. Çin, yaklaşık 44 milyon tonluk teyit edilmiş rezerviyle başı çekmekte olup tek başına dünya NTE rezervlerinin neredeyse yarısını elinde bulundurmaktadır[4]. Çin'i yaklaşık 22 milyon ton civarında potansiyel rezerv ile Brezilya ve 6–7 milyon ton bandında Hindistan takip etmektedir[7]. Amerika Birleşik Devletleri'nin rezervleri ~1.9 milyon ton ile daha sınırlı görünürken, Kanada, Avustralya, Vietnam, Rusya gibi ülkelerin her birinde 1–5 milyon ton arası değişen büyüklükte NTE rezervleri saptanmıştır[15]. 2020'li yıllarda keşfedilen yeni sahalar da dünya rezerv dengesini etkilemeye başlamıştır. Özellikle 2022 yılında Türkiye'nin Eskişehir-Beylikova sahasında açıkladığı 694 milyon ton nadir toprak elementi cevheri (işlenmemiş cevher olarak, yaklaşık 15 milyon ton REO içerdiği tahmin ediliyor) keşfi, literatürde "dünyanın ikinci büyük rezervi" olarak nitelendirilmiş ve dikkatleri üzerine çekmiştir[2]. Her ne kadar bu keşfin ekonomik olarak işletilebilirliği ve gerçek boyutu halen değerlendirme aşamasında olsa da, NTE jeopolitiğinde Türkiye'yi potansiyel bir oyuncu konumuna getirmesi açısından önemlidir.

Dünya NTE üretimine bakıldığında da belirgin bir tek merkezlilik göze çarpar. Çin, 1980'lerden bu yana üretimini istikrarlı biçimde artırarak günümüzde açık ara en büyük üretici olmuştur. 2024 itibarıyla küresel NTE madeni üretimi yaklaşık 390.000 ton REO seviyesine ulaşmıştır; bu üretimin %70'e yakını Çin tarafından gerçekleştirilmiştir[1]. Çin, sadece madencilikte değil, nadir toprakların kimyasal ayrıştırılması ve mıknatıs gibi nihai ürünlere dönüştürülmesi süreçlerinde de dünya lideridir. Dünya NTE ayrıştırma kapasitesinin %85–90'ı ve Nd-Fe-B mıknatıs üretiminin %90'ından fazlası Çin'de bulunmaktadır[1]. Dolayısıyla, küresel değer zincirinin her aşamasında Çin'in hakimiyeti söz konusudur. İkinci büyük üretici konumunda son yıllarda ABD yeniden sahneye çıkmıştır; Kaliforniya'daki Mountain Pass madeni 2018'de üretime yeniden başlayarak 2024'te ~45.000 ton REO üretmiştir[4]. Ayrıca Myanmar, Avustralya ve Tanzanya gibi ülkeler de üretimde pay sahibi olmaya başlamıştır. Özellikle Myanmar, Çin'in sınır komşusu olarak bazı ağır nadir toprakların tedarikinde önemli bir kaynak durumundadır[5]. Bunun yanı sıra, 2023–2024 yıllarında Nijerya ve Tayland gibi ülkelerin de ticari ölçekli NTE üretimine adım attıkları görülmüştür; Afrika ve Güneydoğu Asya'da yeni üreticilerin ortaya çıkması, önümüzdeki yıllarda Çin dışı arzın nispi olarak artabileceğine işaret etmektedir[7].

NTE'lerin bu derece sınırlı coğrafi dağılımı, jeopolitik gerilim ve tedarik riski kavramlarını gündeme getirmektedir. 2010 yılında Çin ile Japonya arasında yaşanan deniz sınırı gerginliği sırasında Çin'in Japonya'ya NTE ihracatını geçici olarak durdurması, dünya çapında endişe yaratmış ve NTE'leri stratejik ham madde olarak ön plana çıkarmıştır[1]. Bunu takiben ABD ve Avrupa Birliği, NTE'leri "kritik ham maddeler" listelerine almış ve tedarik güvenliği

politikaları geliştirmeye başlamıştır. Örneğin ABD Savunma Bakanlığı, 2019'dan bu yana NTE tedarik zincirini güçlendirmek amacıyla yerli üretim ve ayrıştırma tesislerine yatırımlar yapmaktadır[2]. 2023 yılında ABD, "mine-to-magnet" (madenden mıknatısa) yaklaşımıyla tam entegre bir yerli NTE üretim-ekonomi zinciri kurma hedefini ilan etmiş ve 2027 yılına kadar savunma ihtiyaçlarını tamamen karşılayacak kapasiteye ulaşmayı planladığını açıklamıştır[2]. Avrupa Birliği de benzer şekilde, 2020'de yayınladığı "Critical Raw Materials Action Plan" çerçevesinde NTE'ler için tedarik çeşitlendirme ve geri dönüşüm hedefleri koymuştur.

Çin ise NTE alanındaki stratejik üstünlüğünü korumak ve katma değerli ürün üretimine odaklanmak adına zaman zaman politikalar uygulamaktadır. 2021'de nadir toprak endüstrisini konsolide ederek devlete bağlı altı büyük şirket çatısı altında toplayan Çin, 2025 Temmuz ayında ise mıknatıs teknolojileri ihracatına kısıtlama getiren düzenlemeler yapmıştır[1]. Bu düzenlemeye göre, %0.1'den fazla ağır NTE içeren mıknatısların ve ilgili teknolojilerin Çin'den ihracı devlet iznine bağlanmıştır. Pekin yönetimi bu adımın, ulusal güvenliği koruma amacıyla yapıldığını belirtse de, analistler bunu ABD'nin yarı iletken kısıtlamalarına bir karşı hamle ve pazarlık kozu olarak değerlendirmektedir[1]. Sonuç itibarıyla NTE'ler, yüksek teknoloji rekabetinin ve büyük güçler arasındaki ekonomik çekişmelerin merkezinde konumlanmıştır.



Görsel 17. Dünya NTE rezervlerinin ülkelere göre dağılımı. (Energy Security Transition: clean energy, critical minerals and new dependencies 2022) [16].

Jeopolitik etkilerin yanı sıra, NTE'lerin üretimi ve kullanımı çevresel ve ekonomik boyutlarıyla da dikkat çekmektedir. NTE madenciliği ve rafinajı, geleneksel madenciliğe kıyasla daha fazla atık ve çevresel risk barındırır; radyoaktif yan ürünler (thorium, uranium) ve asidik atık sular doğru yönetilmediğinde ciddi kirlilik sorunları doğurabilir[4]. Çin'deki Bayan Obo madeninin çevresinde ve bazı ayrıştırma tesislerinin yakınlarında yaşanan kirlilik hadiseleri, bu sektörün

sürdürülebilirlik kaygılarını artırmıştır. Bu durum, son yıllarda geri dönüşüm ve döngüsel ekonomi yaklaşımlarını NTE'ler için de önemli hale getirmiştir. Artık kullanım ömrünü tamamlamış sabit diskler, mıknatıslar, piller ve fosforlu lambalardan NTE geri kazanım teknikleri üzerine yoğun AR-GE çalışmaları yürütülmektedir[5]. Böylece hem çevresel yük azaltılmaya hem de Çin'e bağımlılık bir nebze kırılmaya çalışılmaktadır.

Özetle, dünya genelindeki NTE üretim ve rezerv durumu son derece dengesiz bir yapı sergilemekte, bu da NTE'leri teknoloji ile jeopolitiğin kesişiminde stratejik bir kaynak haline getirmektedir. Bu alandaki gelişmeler, sadece madencilik veya kimya sektörü değil, küresel diplomasiden milli güvenlik stratejilerine kadar geniş bir yelpazede yankı bulmaktadır.

7. LİTERATÜRDE NATİR TOPRAK ELEMENTLERİNE BAKIŞ

Son on yılda nadir toprak elementleri üzerine yapılan akademik çalışmalar, bu elementlerin hem temel bilimsel özelliklerini hem de endüstriyel uygulamalarını derinlemesine incelemiştir. Literatürdeki eğilimler, her bir sektörde farklı önceliklerin öne çıktığını göstermektedir:

Elektrik ve enerji sektörü literatüründe, NTE bazlı kalıcı mıknatıslar ve batarya malzemeleri başlıca araştırma konuları olmuştur. Özellikle yenilenebilir enerji teknolojilerinin gelişimiyle birlikte, Nd-Fe-B mıknatısların tedariki ve performansı üzerine kapsamlı çalışmalar yapılmıştır. Örneğin Pavel ve arkadaşları (2017), rüzgâr türbinlerindeki Nd-Fe-B mıknatısların malzeme akışını analiz ederek artan talebin uzun vadede sürdürülebilirliğini değerlendirmiştir[1]. Buna paralel olarak, mıknatıslarda kullanılan disprosyum gibi ağır NTE'lerin azaltılmasına yönelik manyetik malzeme araştırmaları dikkat çekmektedir. Batarya alanında ise lantan içeren NiMH pillerin yerini büyük ölçüde lityum-iyon piller alsa da, hidrojen depolamada NTE alaşımlarının potansiyeli üzerine çalışmalar devam etmektedir. Örneğin 2020'lerde yapılan bazı çalışmalar, LaNi_5 alaşımlarının nano-yapı mühendisliği ile iyileştirilerek daha yüksek kapasite ve hızlı tepki verebilir hale getirilebileceğini göstermiştir. Yüksek sıcaklık süperiletkenleri konusunda da YBCO gibi itriyumlu malzemelerin akım taşıma kapasitesini artırmak üzere birçok malzeme bilimi araştırması yayınlanmıştır. Bu alandaki literatür, NTE'lerin enerji teknolojilerinde verimliliği yükseltmedeki rolünü teyit eden bulgular ortaya koymuştur.

Elektronik ve optoelektronik sektörüne dair akademik yayınlar, NTE'lerin optik özellikleri ve bunların cihaz uygulamalarına odaklanmıştır. 2010'lar boyunca LED fosforlarının geliştirilmesi, NTE kimyasının yoğun çalışıldığı bir konu olmuştur[17]. Ce^3+, Eu^2+/Eu^3+ ve Tb^3+ iyonlarını içeren yeni fosfor malzemeleri sentezlenerek daha verimli ve stabil LED aydınlatma fosforları elde edilmeye çalışıldı[4]. Lucas ve arkadaşlarının Rare Earths: Science, Technology, Production and Use (2015) adlı kapsamlı eserinde de vurgulandığı üzere, NTE'lerin 4f elektronu geçişleri onları ışıldama uygulamalarında vazgeçilmez kılmaktadır[5]. Ayrıca fiber optik iletişimde erbiyum katkılı fiber amplifikatörler üzerine hem teorik hem deneysel çalışmalar, bu teknolojinin sınırlarını zorlamıştır. 2015 sonrası literatürde, Tm-doping ile 1.7–2.0 μm bant aralığında yeni fiber lazerler geliştirilmesi ve kuantum kesme (quantum cutting) gibi olgularla UV fotonlarını görünür spektruma çeviren NTE fosforlarının araştırılması dikkat çekmektedir. Tüketici elektroniğinde de akıllı cihazların NTE içerikleri ve geri dönüşümü üzerine araştırmalar mevcuttur. Örneğin, Sprechter ve arkadaşları (2019),

ortalama bir akıllı telefonun içerdiği neodimyum, praseodimyum, gadolinyum gibi elementlerin miktarını analiz ederek milyarlarca cihazdan oluşan elektronik atık havuzunun geri kazanım potansiyelini ortaya koymuştur[18]. Bu tür çalışmalar, NTE'lerin döngüsel ekonomi içindeki yerine ışık tutmaktadır[5].

Savunma ve havacılık sektörü ile ilgili açık literatür, kısmen gizli doğası gereği sınırlı olsa da, NTE'lerin kritik malzeme olarak ele alındığı birçok rapor ve makale yayınlanmıştır. Özellikle ABD'nin resmi dokümanları ve bağımsız strateji raporları, savunma sistemlerindeki NTE bağımlılığına dikkat çekmiştir. ABD Kongre Araştırma Servisi (CRS) tarafından hazırlanan raporlarda, her bir F-35 uçağında ve Virginia sınıfı denizaltıda yüzlerce kilogram NTE kullanıldığı belirtilmiş; bu bağımlılığın ulusal güvenlik riski doğurduğu ifade edilmiştir[2]. Yine RAND Corporation ve CSIS gibi düşünce kuruluşlarının 2010'lar sonu ve 2020'ler başında yayımladığı analizler, Çin'in NTE tedarik zincirindeki tekel pozisyonunu stratejik bir güç olarak kullandığını vurgulamıştır[1]. Teknik akademik literatürde ise, örneğin manyetik tahrik sistemlerinin NTE'siz tasarlanması (ferrit mıknatıslı motorlar veya nadir toprak içermeyen elektrikli silah sistemleri) üzerine AR-GE çalışmaları göze çarpmaktadır. Ayrıca, yüksek güçlü lazer ve radar sistemlerinde NTE bazlı malzemelerin yaşlanma ve dayanıklılık performansı gibi konular da askeri araştırmalarda yer bulmuştur. Bu alandaki literatür, genellikle malzeme bilimi ile güvenlik politikasının kesişim noktasında yer almakta ve NTE'lerin stratejik önemini vurgulamaktadır.

Çimento ve inşaat sektörü odaklı akademik çalışmalar ise özellikle nükleer mühendislik ve radyasyon koruma dergilerinde görülmektedir[19]. 2015 sonrasında, nötron ve gama ışınlarına karşı yeni kalkanlayıcı malzemeler geliştirme çabaları kapsamında NTE bileşikleri incelenmeye başlanmıştır. Örneğin Kılıç ve Yılmaz (2025), NTE içerikli doğal bir malzeme olan serpantinit kayacının radyasyon zırhlamasındaki potansiyelini ortaya koymuş; Gd içeriğinin nötron soğurma üzerindeki belirgin etkisini deneysel verilerle raporlamıştır. Chen ve ekibi (2025) ise gadolinyum bazlı kompozit malzemelere odaklandıkları derleme çalışmalarında, metal, seramik, cam ve polimer esaslı Gd katkılı malzemelerin üretim yöntemlerini ve koruyuculuk performanslarını kapsamlı şekilde özetlemiştir[4]. Bu tür derlemeler, gadolinyumun geleneksel kurşun ve bor bazlı kalkanlara alternatif veya tamamlayıcı olabileceğini dile getirmektedir. Ayrıca simülasyon tabanlı çalışmalarda lütesyum, samaryum gibi elementlerin farklı enerji düzeylerindeki radyasyon için soğurma katsayıları hesaplanmış; Monte Carlo yöntemleriyle NTE katkılarının beton içinde nasıl bir doz azaltımı sağlayacağı incelenmiştir. Literatür taraması, NTE'lerin radyasyondan korunma malzemeleri konusunda yeni bir araştırma dalgası başlattığını göstermektedir[4]. Bu alanda yayınlanan makaleler, ileriye dönük olarak nükleer atık bertarafı, uzay radyasyon kalkanları ve radyoloji odaları gibi uygulamalarda NTE katkılı betonların ciddi bir alternatif olabileceğini işaret etmektedir.

Özetlemek gerekirse, son on yılda nadir toprak elementleri üzerine yapılan çalışmalar, temel bilimden uygulamalı mühendislğe kadar geniş bir alanı kapsamış ve her sektörde bu elementlerin önemini pekiştiren bulgular ortaya koymuştur. Literatürde sıklıkla altı çizilen ortak nokta, NTE'lerin ikame edilebilirliğinin düşük oluşu ve kritik uygulamalarda "oyun

değiştirici" rol oynadığıdır[5][2]. Bu durum, araştırmacıları hem NTE'lerin daha verimli kullanılmasına hem de geri kazanım ve ikame malzemeler geliştirilmesine sevk etmektedir. Son yıllarda artan yayın sayısı, NTE'lerin bilimsel ve teknolojik açıdan ne denli canlı bir araştırma konusu olduğunun açık bir göstergesidir.

8. SONUÇ

Nadir toprak elementleri, sahip oldukları özgün fiziksel ve kimyasal özellikler sayesinde günümüzün yüksek teknoloji dünyasında stratejik bir konuma sahiptir. Bu bildiride, NTE'lerin elektrik üretimi ve depolanmasından elektronik cihazların imalatına, savunma sistemlerinin kritik bileşenlerinden inşaat sektöründeki özel uygulamalara kadar geniş bir yelpazedeki kullanımları detaylı bir şekilde incelenmiştir. Her bir sektördeki örnekler, NTE'lerin genellikle vazgeçilmez nitelikte olduğunu göstermektedir: Örneğin neodimyum ve samaryum olmasa bugünün güçlü elektrik motorları ve jeneratörleri aynı performansa ulaşamayacak; europium ve terbiyum olmasa ekranlarımız bu denli parlak ve renkli olamayacak; gadolinyum olmasa nükleer tesislerde ve hastanelerde gereken radyasyon korumasını sağlamak güçleşecekti.

Bu elementlerin kritikliği, onların jeopolitik ve ekonomik önemini de beraberinde getirmektedir. Dünya NTE üretiminin ve işleme kapasitesinin büyük bir bölümünü elinde bulunduran Çin, bu alandaki üstünlüğünü hem ekonomik kalkınma hem de diplomatik koz olarak kullanmaktadır[1]. Bu durum, diğer ülkeleri alternatif tedarik kaynakları geliştirmeye, kendi rezervlerini harekete geçirmeye ve döngüsel kullanım stratejileri benimsemeye yöneltmiştir. Türkiye'nin açıkladığı büyük rezerv potansiyeli gibi gelişmeler, önümüzdeki yıllarda NTE tedarik haritasının kısmen çeşitlenebileceğine işaret etse de, orta vadede Çin'in baskın konumunun devam edeceği öngörülmektedir. Dolayısıyla uluslararası platformda NTE'ler konusunda iş birliği ve stratejik stoklama çabaları artarak sürecektir.

NTE kullanımının yaygınlaşması, aynı zamanda sürdürülebilirlik tartışmalarını da beraberinde getirmektedir. NTE madenciliğinin çevresel etkileri, geri dönüştürülebilirlik konusunu gündeme getirmiş ve bu alanda teknolojik yeniliklere kapı aralamıştır. Geri dönüşüm teknolojilerindeki ilerlemeler, elektronik atıklardan ve endüstriyel hurda malzemelerden NTE kazanımını kademeli olarak ekonomik hale getirebilir. Bu sayede hem çevre koruma sağlanacak hem de bir miktar tedarik güvenliği elde edilecektir. Ayrıca malzeme bilimi alanındaki araştırmalar, NTE'lerin daha verimli kullanılmasını veya kısmen ikame edilmesini hedefleyen çalışmalarla ivme kazanmıştır. Örneğin, bazı uygulamalarda praseodimyumun neodimyum yerine kullanımı veya demir-nitrojen bileşiklerinin mıknatıslarda NTE oranını azaltacak şekilde geliştirilmesi gibi yenilikçi yaklaşımlar test edilmektedir.

Sonuç olarak, bu bildiride ele alınan bulgular ve literatür ışığında, nadir toprak elementlerinin 21. yüzyıl teknolojik uygarlığının temel taşları arasında yer aldığı söylenebilir. Elektrikten elektroniğe, savunmadan inşaata kadar kritik öneme sahip bu elementlerin bilinçli, verimli ve sürdürülebilir şekilde kullanımı büyük önem taşımaktadır. Gelecekte artan taleple birlikte, NTE'lerin temininde yaşanabilecek güçlükleri aşmak için uluslararası işbirliği, yenilikçi araştırmalar ve sorumlu kaynak yönetimi şart görünmektedir. Bilim insanları ve mühendisler, bir yandan NTE'lerin sunduğu benzersiz fırsatları en iyi şekilde değerlendirirken, diğer yandan da bu değerli elementlerin gelecek nesiller için erişilebilir olmasını sağlamak gibi zorlu fakat önemli bir göreve sahiptir.

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1.35 BAR İÇ BASINCA DAYANIKLI BİR ŞÖNT REAKTÖR TANKININ TASARIMI VE ANSYS TABANLI YAPISAL ANALİZİ

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ÖZET

Şönt reaktörler, yüksek gerilimli güç iletim ve dağıtım sistemlerinde reaktif güç kompanzasyonu amacıyla kullanılan kritik ekipmanlar arasında yer almaktadır. Bu tür sistemlerde reaktörlerin güvenli ve sürdürülebilir şekilde çalışabilmesi, onları çevreleyen tank yapısının mekanik dayanımına doğrudan bağlıdır. İç basınca maruz kalan tanklarda yapısal bütünlüğün korunması işletme güvenliği, arıza riskinin azaltılması ve ekipman ömrünün uzatılması açısından son derece önemlidir. Bu çalışma kapsamında, 1.35 bar iç basınca dayanabilecek şekilde tasarlanmış bir şönt reaktör tankının yapısal tasarımı ve ANSYS tabanlı sonlu elemanlar analizi ayrıntılı biçimde ele alınmıştır. Tasarım aşaması, ilgili endüstri standartlarına bağlı kalınarak yürütülmüş ve basınç gereksinimini karşılayabilmek için tank geometrisine ve malzeme seçimine odaklanılmıştır. Özellikle malzeme kullanımının optimize edilmesi, maliyet etkinliğinin artırılması ve üretim sürecinin sadeleştirilmesi, tasarımın temel hedefleri arasında yer almıştır. Çalışmada geliştirilen tasarımın doğrulanması amacıyla ANSYS yazılımı kullanılarak kapsamlı bir sonlu elemanlar analizi gerçekleştirilmiştir. Analiz aşamasında tankın üç boyutlu modeli oluşturulmuş, servis koşullarını temsil eden sınır şartları tanımlanmış ve iç basınç yüklemesi altında tankın mekanik davranışı detaylı olarak incelenmiştir. Elde edilen sonuçlar kapsamında maksimum von Mises gerilmesi, toplam deformasyon değerleri ve malzemenin akma dayanımı esas alınarak hesaplanan güvenlik

katsayısı değerlendirilmiştir. ANSYS simülasyon sonuçları, önerilen tank tasarımının çalışma basıncı altında yapısal bütünlüğünü başarıyla koruduğunu göstermektedir. Maksimum von Mises gerilmesinin seçilen malzemenin (örneğin yapısal çelik) akma dayanımının oldukça altında kalması, tasarımın güçlü bir güvenlik payına sahip olduğunu ortaya koymuştur. Ayrıca toplam deformasyonun kabul edilebilir sınırlar içinde olması, tasarımın yeterli rijitliğe sahip olduğunu göstermektedir.

Anahtar Kelimeler : Şönt reaktör, ANSYS, Mekanik dayanım, Yapısal analiz.

INVESTIGATION OF SURFACE ROUGHNESS DEPENDING ON POWER AND FREQUENCY AFTER FIBER LASER PROCESSİNG OF ASA SAMPLES PRODUCED BY FDM METHOD

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ABSTRACT

In recent years, the rapid development of three-dimensional (3D) printing technologies has provided significant advantages in the production of engineering components with complex geometries. Among these technologies, Fused Deposition Modeling (FDM) is widely preferred in the industry due to its low-cost production, design freedom, and compatibility with thermoplastic materials. However, the layered structure of FDM-produced parts can increase surface roughness, limiting aesthetic appearance and functional surface properties. Therefore, laser surface processing methods aimed at improving surface quality after additive manufacturing have become a significant research area in recent years.

In this study, the surface roughness values resulting from processing samples produced using F123 ASA thermoplastic filament using the FDM method with a fiber laser at different power and frequency parameters were investigated. A total of 11 samples, measuring 10x10x4 mm, were processed with lasers at different frequencies (25–3000 kHz) and five at different power (10–50%). One sample was evaluated without any treatment as a reference. Surface roughness measurements were repeated three times for each sample, and average Ra values were determined. Fiber laser parameters have shown that they have a significant effect on surface morphology. Specimen (F2), processed at a frequency of 50 kHz, in particular, reached the lowest roughness with Ra = 21.386 µm. An increase in roughness was observed with increasing power, with the lowest average roughness being achieved in sample G1 (18.213 µm). Furthermore, decreasing the scanning speed increased the interaction time of the laser on the sample surface, leading to increased roughness.

Consequently, it was determined that fiber laser processing performed at low power, high frequency, and appropriate scanning speed significantly improved the surface quality of ASA-based FDM parts. These findings demonstrate that fiber laser processing can be an effective method for improving the functional surface properties of thermoplastic parts produced by FDM

Keywords: 3D printer, Fiber laser, Roughness, Laser Marking

1. INTRODUCTION

3D printing technology is an additive manufacturing (AM) technology that allows the production of complex geometries and structures from computer-aided three-dimensional model data. This advanced manufacturing method enables the creation of physical 3D objects by adding material layer by layer under computer control. Generally, the additive manufacturing (AM) process begins with converting a three-dimensional model created in a computer-aided design (CAD) environment into the Standard Tessellation Language (STL) format. The resulting STL file is then transferred to the 3D printer, and the appropriate process parameters for printing are determined. Following these stages, the object is built step by step according to predefined layer thicknesses in an automated production process that prepares the machine with the necessary materials. The completion time of the additive manufacturing process can vary from a few hours to several days, depending on the technology used, the type of material, the printing parameters, and the size of the object to be produced [1–3]. AM techniques offer a significant advantage in the production of a wide variety of engineering components with complex geometries [4].

While additive manufacturing (AM) was initially a developing technology, it has now become a largely mature and advanced manufacturing process. With this transformation, AM technology is increasingly being adopted across various industrial sectors. A significant increase in its use is anticipated in the coming years, particularly in strategically important areas such as aerospace, defense, automotive, and healthcare. Furthermore, this technology is expected to find broader application in other industrial sectors and be more strongly integrated into manufacturing processes [5].

There are different forms of AM techniques, such as Stereolithography (SLA), Selective Laser Sintering (SLS), Fusion Deposition Modeling (FDM), Digital Light Processing (DLP), Electron Beam Melting (EBM), Selective Laser Melting (SLM), Multijet/Polyjet 3D printing, Laminated Object Manufacturing (LOM), etc. Furthermore, these techniques utilize different materials such as plastic, metal, ceramic, liquid, powder, and even living cells [6,7].

Fused Deposition Modeling (FDM) is based on the principle of melting thermoplastic-based filaments (e.g., Polylactic Acid (PLA) or Acrylonitrile Butadiene Styrene (ABS) under controlled heating and extruding them layer by layer through a heated nozzle. In this process, the extruded material is deposited in successive layers to create a three-dimensional (3D) object. Ensuring proper adhesion and precise alignment between layers is critical for achieving the desired mechanical strength and dimensional accuracy of the manufactured part. Therefore,

parameters such as temperature control, extrusion speed, and layer thickness must be carefully optimized in the FDM process [8,9].

Acrylonitrile Styrene Acrylate (ASA) shares similar structural properties with Acrylonitrile Butadiene Styrene (ABS), but its superior ultraviolet (UV) and weather resistance make it a thermoplastic material more suitable for outdoor applications. Highly resistant to chemical and environmental influences, ASA largely retains its mechanical properties even under prolonged exposure to sunlight and harsh atmospheric conditions, providing a much longer-lasting performance compared to ABS. These properties make ASA an ideal engineering material for prototyping, production aids, outdoor components, and particularly automotive applications. Thanks to its high UV stability, strong interlayer adhesion, and thermal resistance, the material maintains its structural integrity and aesthetic appearance even under prolonged environmental exposure. However, manufacturing challenges such as warping and moisture absorption during the printing process require careful optimization of process parameters to fully realize the potential performance of ASA. Besides ASA, other polymeric materials commonly used in additive manufacturing methods include Polylactic Acid (PLA), Acrylonitrile Butadiene Styrene (ABS), Polyamides (PA; e.g., PA12), High Density Polyethylene (HDPE), Polycarbonate (PC), Thermoplastic Polyurethane (TPU), and Polypropylene (PP). These materials are suitable for a variety of engineering and industrial applications thanks to their distinct mechanical, thermal, and chemical properties [10,11].

Laser processing systems are currently used in various fields such as welding, cutting, and marking. Laser marking processes are preferred in many areas due to their high processing speed, minimal human intervention, and contactless precision marking. Process parameters such as laser power, scanning speed, and pulse frequency in laser processing play an important role in the quality of material marking [12]. Parts produced using the FDM method in 3D printers are prone to gaps between layers. Due to the fundamental nature of the FDM technique, poor surface quality is observed on the outer surface [13]. Studies have aimed to develop various finishing methods to address this problem. Some of these methods include chemical treatments, vapor rectification and polishing, heat treatments, and laser polishing. The surface roughness of FDM-produced parts increases due to the step effect created by the printer nozzle [14,15]. There are studies aimed at reducing the roughness of a sample produced with FDM. One of these studies examined the roughness change of an FDM-produced part using the barrel finishing method. At the end of the study, they observed that the barrel finishing process reduced surface roughness by 72% [16]. Another study concluded that the chemicals used to

reduce the roughness of FDM printed ABS parts reduced the surface roughness but reduced tensile strength [17]. A study using the chemical vapor method emphasized that ABS parts achieved a smooth surface after 30 minutes of interaction with ethyl acetate vapor [18]. Compared to these methods, laser polishing has many superior features, such as shorter processing time, no tool wear problems, and its applicability even to parts with complex surfaces [19]. It has been reported that the surface quality of FDM-produced parts is improved by melting and abrading the material during the laser process [20]. Studies have been conducted to develop pulsed laser surface treatment for parts manufactured using FDM using ASA filament. The study monitored the tribological and mechanical behavior of these parts treated with lasers at different parameters. The most significant result emphasized that laser treatment improved the surface quality of the samples without affecting their mechanical properties [21]. Studies have shown that laser marking parameters significantly affect surface texture. Key variables include laser power, scanning speed, and the marking step, which can cause partial or complete material melting. For example, laser marking on polyamide samples caused surface roughness and color changes, and the roughness varied depending on the specific marking modes [22].

In this study, samples produced with FDM using F123 ASA thermoplastic filament on a 3D printer were subjected to surface treatment using a fiber laser at different frequencies and power parameters, and roughness measurements were evaluated. Based on the results, the optimum laser parameter was determined based on the roughness.

2. MATERIAL AND METHOD

In this study, a Stratasys/F170 brand and model 3D printer was used to produce the samples using the FDM method. Before printing, the samples were designed with dimensions of 10x10x4mm using SolidWorks 2025. The design was saved in STL format for transfer to the printer. After transferring the design to the printer, F123 ASA, a thermoplastic, was used as the filament. The samples were printed perpendicular to the table without any support. A visual representation of the produced samples is shown in Figure 1.



Fig. 1. Image of the sample produced with the FDM method

The produced samples were laser surface treated with two different features using Ezcad2 software on a fiber laser marking device, shown in Figure 2. In the first case, the scanning speed, power, and Q-pulse values were kept constant and applied at five different frequencies (25-50-100-200-3000). In the second case, the scanning speed, frequency, and Q-pulse values were kept constant and applied at different power values (10-20-30-40-50%). The process values are shown in Table 1. To describe the samples, those with different frequencies are named F1, F2, F3, F4, and F5, while samples with different strengths are named G1, G2, G3, G4, and G5. The process parameters are detailed in Table 1.

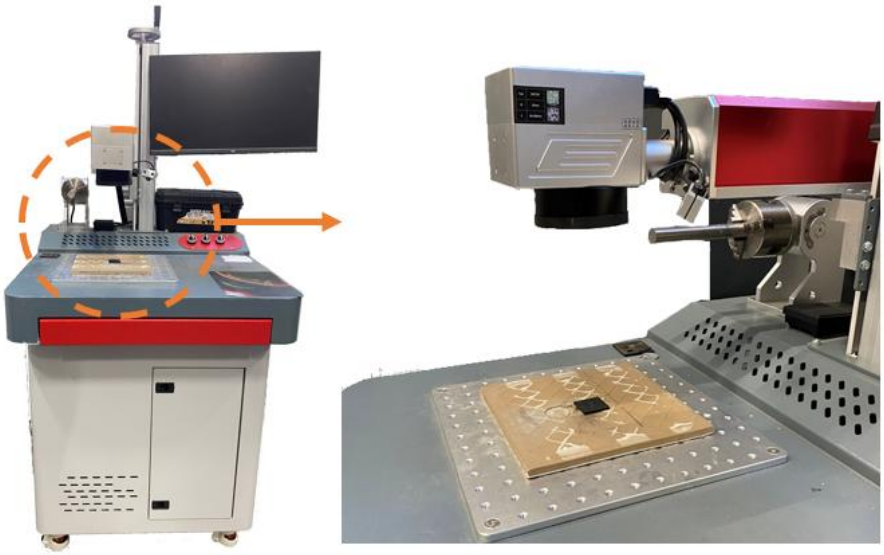


Fig. 2. Fiber laser marking device used in the study

Table 1. Sample parameters of fiber laser marking at different frequencies (a) and different power (b) values.

	Sample	**F1**	**F2**	**F3**	**F4**	**F5**
a)	Speed (mm/sec.)	2500	2500	2500	2500	2500
	Power %	50	50	50	50	50
	Frequency (KHz)	25	50	100	200	3000
	Q pulse Width (ns)	2000	2000	2000	2000	2000
	Sample	**G1**	**G2**	**G3**	**G4**	**G5**
b)	Speed (mm/sec.)	1250	1250	1250	1250	1250
	Power %	10	20	30	40	50
	Frequency (KHz)	200	200	200	200	200
	Q pulse Width (ns)	2000	2000	2000	2000	2000

Images of samples from the F and G series that underwent surface treatment with a fiber laser are shown in Figure 3. Here, first the 5 samples from the F series are shown, followed by the 5 samples from the G series.

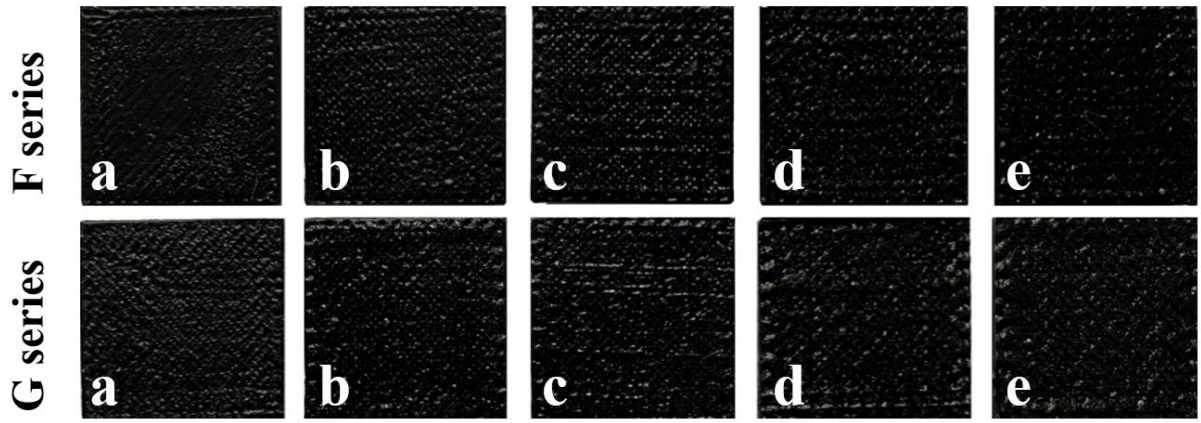


Fig. 3. Images of samples from F and G series

Following laser treatment, samples were subjected to roughness measurements using the device shown in Figure 4. After placing the samples on the device table in order, measurements were taken at 4 mm intervals. Roughness was measured three times for each sample, and the average was calculated. The average roughness values were obtained from the measurement results.

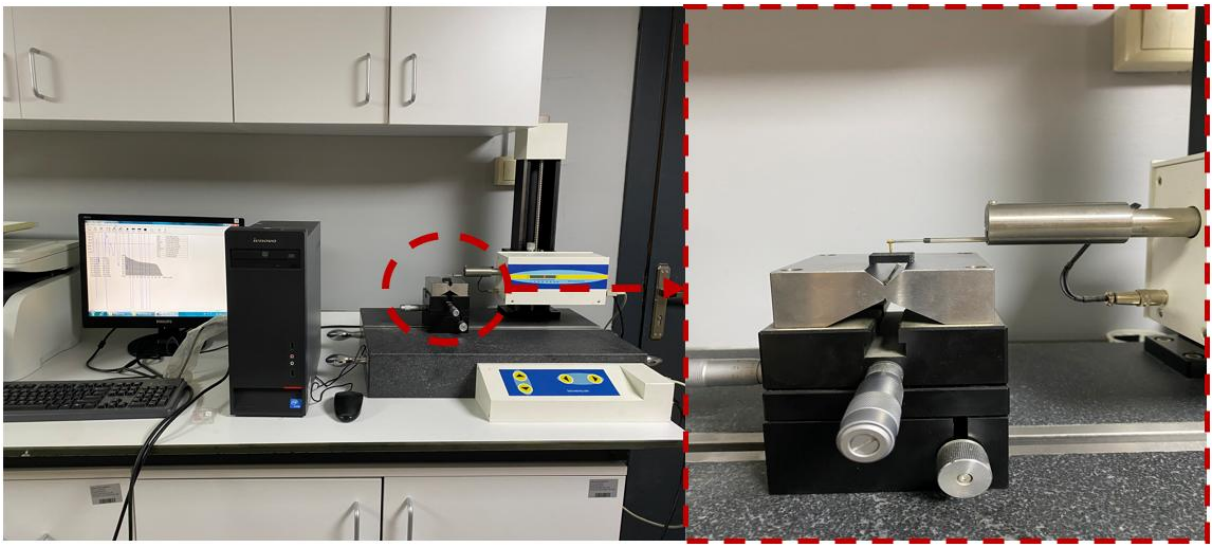


Fig. 4. Roughness measuring device used in the study

3. RESULTS

The roughness values obtained after fiber laser marking of samples produced using the FDM method on a 3D printer at different frequencies are given in Table 2. The average roughness (Ra) value for each sample was measured three times, and the arithmetic mean value was calculated. The untreated sample was not subjected to laser marking. This value is only the roughness value obtained as produced by the 3D printer. The reason for this high value is due to the bumps and grooves formed by the printer's stepwise advancement, as seen in Figure 1.

Table 2. Average roughness values of samples laser marked at different frequencies

Sample	Untreated	F1	F2	F3	F4	F5
Ra (µm)	116,24	113,023	21,386	23,908	30,47	21,324

When samples were examined with varying frequency (scanning speed, power, and Q pulse constant), no significant change in roughness was observed in the sample with a frequency of 25 kHz. Under these conditions, it was observed that the laser did not affect the ASA material. However, at a frequency of 50 kHz, the roughness value reached Ra = 21.386 µm. This suggests that increasing the frequency from 25 kHz to 50 kHz affected the laser process, and the thermoplastic material, especially at its peaks, became completely planar. However, higher frequencies increased the roughness value again, as seen in samples F3 and F4. This suggests that the laser intensity caused the pitted areas in the sample to create deeper cavities. However, when the frequency reached 3000 kHz, the roughness of sample F5 reached its lowest value.

This clearly demonstrates that even the pits formed in the pitted areas melted and filled in the peaks under the laser effect. The average roughness values for samples varying depending on laser power are given in Table 3. Considering the results (scanning speed, frequency, and Q pulse constant), sample G1 at 10% power yielded the lowest roughness value in this series. Increasing the power value increased the roughness value. Furthermore, when looking at samples F4 and G5, the only difference between the two is the scanning speed. Halving the scanning speed increased the roughness value. This proves that the longer the laser remains on the sample, the roughness increases on the sample surface. Similarly, the scanning speed of all samples in the G series was 1250 mm/sec. This increase in roughness compared to the F series was due to the scanning speed. The reduced scanning speed, the frequency being constant at 200 kHz, and the lower power value contributed to the reduction in roughness.

Table 3. Average roughness values of samples marked with laser at different Powers

Sample	Untreated	G1	G2	G3	G4	G5
Ra (µm)	116,24	18,213	19,396	21,814	32,598	44,112

Even when the scanning speed was low, increasing the power value created irregularities on the sample surface and increased roughness (G5). Generally, smoother surfaces were obtained at lower scanning speeds, higher frequencies, and lower power values.

4. CONCLUSION

In this study, the surface roughness values of samples produced with F123 ASA filament using a 3D printer using the FDM method were evaluated using a fiber laser device at different power and frequency levels. Eleven 10x10x4mm samples were produced, five of which were processed with fiber lasers at different frequencies and five with different power levels. The surface roughness values resulting from the power and frequency changes were measured and evaluated three times with a roughness measuring device. Based on the obtained results,

•The roughness value of the sample prepared according to the design (Ra = 116.24 µm) was the highest compared to the laser-processed samples.

•The 25 kHz frequency did not change the roughness value of the sample during the fiber laser marking process at different frequencies.

•The lowest roughness value in the frequency-dependent process was observed in sample F2, at 21.386 µm. This shows that the frequency change from 25 kHz to 50 kHz affected

the laser process, and the thermoplastic material, especially at its peaks, became completely flat.

•When examined in terms of laser power, the continuous increase in power increased in direct proportion to the roughness value.

•The lowest roughness value among all samples was observed in sample G1, at 18.213 µm.

•The common connection between the samples in terms of frequency and power is the F4 and G5 samples. While all values are constant between these samples, only the scanning speed differs. This demonstrates that the scanning speed affects the roughness value of the thermoplastic Asa material.

•As the scanning speed decreases, the time the fiber laser dwells on the sample increases. This, in turn, increases the roughness value due to the sample being subjected to more surface treatment.

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AISI 1060 KARBON ÇELİĞİNDEN İMAL EDİLEN YATAK YAYLARININ GERİLME DAĞILIMI VE MEKANİK DAVRANIŞ ANALİZİ

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ÖZET

Bu çalışmada, AISI 1060 karbon çeliğinden imal edilen yatak tipi helisel baskı yaylarının mekanik davranışı ve gerilme dağılımları incelenmiştir. Çalışma kapsamında, farklı sarım sayısı (spin), yay yüksekliği, ortalama yay çapı ve tel kalınlığına sahip yay geometrileri modellenerek sayısal analizler gerçekleştirilmiştir. Yayların üç boyutlu geometrik modelleri SolidWorks ortamında oluşturulmuş, doğrusal elastik varsayımlar altında statik yükleme koşulları için sonlu elemanlar yöntemi kullanılarak gerilme analizleri yapılmıştır. Analizlerde, özellikle maksimum eşdeğer (von Mises) gerilme değerleri, gerilme yoğunlaşma bölgeleri ve geometrik parametrelerin mekanik davranış üzerindeki etkileri değerlendirilmiştir.

Elde edilen sonuçlar, tel kalınlığı ve yay çapının gerilme dağılımı üzerinde belirleyici bir etkiye sahip olduğunu, sarım sayısı ve yay yüksekliğindeki değişimlerin ise yük taşıma kapasitesi ve elastik deformasyon karakteristiğini doğrudan etkilediğini göstermektedir. Farklı geometrik kombinasyonlar altında oluşan gerilme seviyelerinin karşılaştırılması, yatak sistemlerinde kullanılan Bonnell tipi yayların yorulma dayanımını artırmaya yönelik tasarım optimizasyonları için önemli veriler sunmaktadır. Çalışma sonuçları, AISI 1060 karbon çeliğinden üretilen yatak yaylarının mekanik performansının iyileştirilmesine ve uzun servis ömrüne sahip yay sistemlerinin geliştirilmesine katkı sağlamayı amaçlamaktadır.

Anahtar kelimeler: Yatak yayları, 1060 çeliği, von mises gerilmesi

STRESS DISTRİIBUTION AND MECHANICAL BEHAVIOUR ANALYSIS OF MATTRESS SPRINGS MANUFACTURED FROM AISI 1060 CARBON STEEL

ABSTRACT

In this study, the mechanical behaviour and stress distributions of bedding-type helical compression springs manufactured from AISI 1060 carbon steel were investigated. Within the scope of the study, numerical analyses were performed by modelling spring geometries with different numbers of coils (turns), spring heights, mean spring diameters, and wire diameters. Three-dimensional geometric models of the springs were created in the SolidWorks environment, and stress analyses were conducted under static loading conditions using the finite element method based on linear elastic assumptions. In the analyses, particular emphasis was placed on maximum equivalent (von Mises) stress values, stress concentration regions, and the effects of geometric parameters on mechanical behaviour.

The results indicate that wire diameter and spring diameter have a decisive influence on stress distribution, while variations in the number of coils and spring height directly affect load-carrying capacity and elastic deformation characteristics. Comparing stress levels obtained under different geometric combinations provides important data for design optimisation aimed at increasing the fatigue strength of Bonnell-type springs used in mattress systems. The outcomes of this study aim to contribute to the improvement of the mechanical performance of mattress springs manufactured from AISI 1060 carbon steel and to the development of spring systems with long service life.

Keywords: Mattress springs, AISI 1060 steel, von Mises stress

1. GİRİŞ

Helezon bobin (sarım) yaylar, çalışma koşulları altında bağlantı bölgelerinde oluşan çekme ve basma kuvvetleri nedeniyle esas olarak dikey eksenel yüklere maruz kalmaktadır. Karmaşık geometrik yapıları nedeniyle bu yaylar, özellikle döngüsel yükleme rejimleri altında, hareketlerine bağlı olarak kesme gerilmesi, normal gerilme ve burulma momenti gibi farklı iç gerilme bileşenleri üretmektedir (Nishimura vd., 2018). Bu mekanik tepkiler, çelik helezon yayların taşıma kapasitesi, elastik geri kazanım yeteneği ve uzun süreli yapısal performansını belirleyen temel unsurlar arasında yer almaktadır. Söz konusu özellikler, helezon yayların yatak endüstrisi ve otomotiv koltuk sistemleri başta olmak üzere birçok mühendislik uygulamasında temel destek elemanı olarak kullanılmasını mümkün kılmaktadır. Yatak sistemlerinde çekirdek yay yapısı, en yüksek yük seviyelerine maruz kalan ve sistemin genel mekanik davranışını belirleyen ana bileşen niteliğindedir. Yay çekirdeğinin geometrik tasarımı ve malzeme kalitesi, yüklerin omurgaya uygun biçimde dağıtılmasını sağlayarak uyku ergonomisi ve kullanıcı konforu üzerinde doğrudan etkili olmaktadır (Vlaović vd., 2010). Helisel baskı yayları, yatak sistemleriyle sınırlı kalmayıp mekanik mühendisliğin farklı alanlarında da yaygın olarak kullanılan kritik yapısal elemanlardır. Yük emilimi, kuvvet iletimi ve kinetik enerjinin depolanması gibi temel işlevleri sayesinde otomotiv süspansiyon sistemlerinden ağır yük taşıyan yapısal uygulamalara kadar geniş bir yelpazede sistem güvenilirliğini doğrudan

belirlemektedirler (Nya vd., 2018; Mulla, 2016). Özellikle otomotiv süspansiyon sistemlerinde dinamik şokları ve yer değiştirmeleri kontrol eden helisel yaylar, yorulma ömrü ve dayanım açısından tasarımın en kritik bileşenleri arasında yer almaktadır. Benzer biçimde Bonnell yayları, yatak ve döşeme sistemlerinde yüksek frekanslı ve sürekli çevrimsel yüklemelere maruz kalmakta olup, bu yükleme koşulları malzeme dayanımı ve geometrik kararlılık açısından önemli gereksinimler oluşturmaktadır. Yay elemanları genel olarak statik (sabit deformasyon), dinamik (zamanla değişen yük) ve çevrimsel (tekrarlanan gerilme döngüleri) olmak üzere üç temel gerilme rejimi altında çalışmaktadır. Bonnell yaylarında baskın olan çevrimsel yükleme koşulları, yüksek yorulma direncinin yanı sıra geometrik bütünlüğün uzun süre korunmasını zorunlu kılmaktadır. Bu nedenle üretim süreçlerinde, yüksek akma dayanımına ve üstün yorulma performansına sahip karbon çelikleri veya krom alaşımlı özel çelikler tercih edilmektedir (Mulla, 2016). Yayların servis ömrü ve güvenilirliği, çoğu uygulamada sistemin genel dayanıklılığını sınırlayan başlıca faktör olarak kabul edilmektedir. Bir helisel baskı yayının mekanik performansı; sertlik, yük taşıma kapasitesi ve dayanıklılık açısından büyük ölçüde geometrik parametrelerine bağlıdır. Yay tel çapı (d), ortalama bobin çapı (D_m), toplam yay yüksekliği (H) ve bobin aralığı (P) gibi tasarım değişkenleri, yayın gerilme dağılımını ve elastik davranışını belirleyen temel faktörlerdir. Özellikle tel çapı, yayın sertliğini ve mukavemet sınırını doğrudan etkileyerek kritik bir rol oynamaktadır. Tel çapındaki artış yük taşıma kapasitesini artırmakla birlikte, yorulma ömrü üzerindeki etkisi doğrusal değildir; aşırı sertlik, üretim zorlukları ve gerilme yığılmaları gibi olumsuz sonuçlar doğurabileceğinden, optimum dayanıklılığın sağlanması dikkatli bir tasarım dengesi gerektirmektedir (Jain vd., 2017).

Literatürde, yaylı döşeme sistemlerinin yalnızca köpük esaslı sistemlere kıyasla daha dayanıklı ve uzun ömürlü olduğu rapor edilmiştir. Bu bağlamda, özellikle helezon yaylar üzerine yürütülen yorulma ömrü ve hasar mekanizması analizleri giderek artmaktadır. Abdullah vd. (2021), bir yayın dayanıklılığını değerlendirmek üzere güvenilirlik–çevrim sayısı–hata oranı ilişkisini tanımlayan üç boyutlu bir dağılım modeli önermiştir. Yan vd. (2019), yüksek gerilme seviyeleri altında helezon yaylarda gözlenen erken kırılma mekanizmalarını incelemiş; Zhou vd. (2019) ise anormal titreşimlerin yay arızaları üzerindeki etkilerini analiz etmiştir. Pytell vd., farklı malzemelerden üretilmiş helezon baskı yayları üzerinde uzun süreli yorulma testleri gerçekleştirerek, yayların yorulma davranışlarını karşılaştırmalı olarak değerlendirmiştir. Plastik deformasyon, yayın elastik sınırlarının aşılmasıyla geri dönüşü olmayan boyutsal değişimlere ve sistemde kalıcı çökme oluşumuna yol açmaktadır. Yorulma hasarı ise, çevrimsel yükleme altında malzeme içerisinde mikroskobik çatlakların oluşup ilerlemesiyle ortaya çıkan kümülatif bir arıza mekanizmasıdır (Kong vd., 2018). Çelik yaylar, özellikle değişken yük koşullarında çalıştıklarında, yorulmaya bağlı mukavemet azalması ve tel kırılması riskleriyle karşı karşıya kalmaktadır. Bu tür hasar mekanizmaları, uzun vadede hem kullanıcı konforunun azalmasına hem de sistemin yapısal bütünlüğünün zayıflamasına neden olmaktadır. Bu nedenle, Bonnell yaylarının geometrik tasarım parametrelerinin optimize edilmesi, mekanik performansın iyileştirilmesi ve yorulma ömrünün uzatılması açısından kritik öneme sahiptir. Yay yüksekliği, sarım sayısı, spiral çapı ve tel kalınlığı gibi parametrelerin uygun kombinasyonları sayesinde gerilme dağılımları dengelenerek yorulma hasarının geciktirilmesi mümkün olmaktadır. Özellikle 10^4 çevrimi aşan yükleme koşullarında meydana gelen kırılma

kaynaklı yorulma arızaları, helisel yaylar için en yaygın ve kritik hasar modlarından biri olarak tanımlanmaktadır. Yorulma çatlaklarının oluşumu; yüksek gerilme aralıkları, üretim sırasında oluşan takım izleri, yüzey pürüzlülüğü ve içsel malzeme kusurları gibi faktörlerle hızlanmaktadır (Llano vd., 2006).

2. Materyal ve Metot

2.1.Materyal

Bu çalışmada incelenen helisel baskı yayları, yatak sistemlerinde yaygın olarak kullanılan AISI 1060 karbon çeliğinden imal edilmiştir. Orta karbon içeriğine sahip olan AISI 1060 çeliği, yeterli akma dayanımı, elastik modül ve uygun yorulma performansı sunması nedeniyle yatak yayları için tercih edilen bir malzemedir. Sayısal analizlerde malzemenin izotropik ve doğrusal elastik davranış sergilediği kabul edilmiş; plastik deformasyon ve hasar oluşumu bu çalışma kapsamında dikkate alınmamıştır. Malzemenin mekanik özellikleri, literatürde verilen standart değerler esas alınarak tanımlanmıştır (Bauccio, M.).

Tablo 1. AISI 1060'ın mekanik özellikleri (Bauccio, M.).

Özellik	Değer	Birim
Çekme dayanımı	620	MPa
Akma dayanımı	485	Mpa
Young modülü	200	GPa
Poisson oranı	0,29	-

Tablo 2. AISI 1060'ın kimyasal bileşimi (Bauccio, M.).

Element	Ağırlıkça %
C	0,55-0,65
Mn	0,60-0,90
Si	0,15-0,35
P	≤0,040
S	≤0,050

Yatak sistemlerinde kullanılan Bonnell tipi helisel baskı yayları temel alınarak, yayların mekanik davranışını belirleyen başlıca geometrik parametreler sarım sayısı (spin), yay yüksekliği (H), ortalama yay çapı (D_m) ve tel kalınlığı (d) olarak belirlenmiştir. Bu parametrelerin etkilerini incelemek amacıyla, her biri farklı geometrik kombinasyona sahip yay modelleri oluşturulmuş ve parametrik bir yaklaşım benimsenmiştir. Parametre seviyeleri, endüstriyel uygulamalarda yaygın olarak kullanılan boyut aralıklarını temsil edecek şekilde seçilmiştir. Böylece, geometrik değişkenlerin gerilme dağılımı ve mekanik davranış üzerindeki etkileri karşılaştırmalı olarak değerlendirilmiştir.

2.2.Sayısal Modelleme ve Sonlu Elemanlar Analizi

Tüm yay geometrilerinin üç boyutlu modelleri SolidWorks yazılımı kullanılarak oluşturulmuştur. Helisel yapıların geometrik doğruluğunu sağlamak amacıyla helis ve süpürme (sweep) tabanlı modelleme yöntemleri kullanılmıştır. Elde edilen modeller, SolidWorks

Simulation modülüne aktarılmış ve sonlu elemanlar yöntemi ile sayısal analizler gerçekleştirilmiştir. Sonlu eleman ağ yapısı tetrahedral elemanlardan oluşturulmuş, özellikle gerilme yoğunlaşmasının beklendiği bölgelerde ağ inceltmesi uygulanmıştır. Ağ bağımsızlığı sağlamak amacıyla gerekli mesh iyileştirme kontrolleri yapılmıştır.

Analizlerde doğrusal statik çözüm yaklaşımı benimsenmiş ve yayların çalışma prensibini temsil eden eksenel basma yükü uygulanmıştır. Yayın alt ucu tamamen sabitlenmiş, üst uçtan eksenel yönde tekil bir yük uygulanarak sınır koşulları tanımlanmıştır. Temas, sürtünme etkileri ve geometrik doğrusal olmayanlıklar analiz kapsamı dışında bırakılmıştır. Bu yaklaşım, farklı geometrik tasarımların mekanik tepkilerinin karşılaştırılmasına olanak tanıyan tutarlı bir analiz ortamı sağlamıştır.

Her bir yay geometrisi için maksimum eşdeğer (von Mises) gerilme değerleri, gerilme yoğunlaşma bölgeleri ve toplam elastik deformasyon miktarları belirlenmiştir. Elde edilen sayısal sonuçlar, geometrik parametrelerin mekanik davranış üzerindeki etkilerini ortaya koymak amacıyla karşılaştırmalı olarak analiz edilmiştir. Bu kapsamda, AISI 1060 karbon çeliğinden imal edilen yatak yaylarının mekanik performansını iyileştirmeye yönelik tasarım eğilimlerinin belirlenmesi hedeflenmiştir.

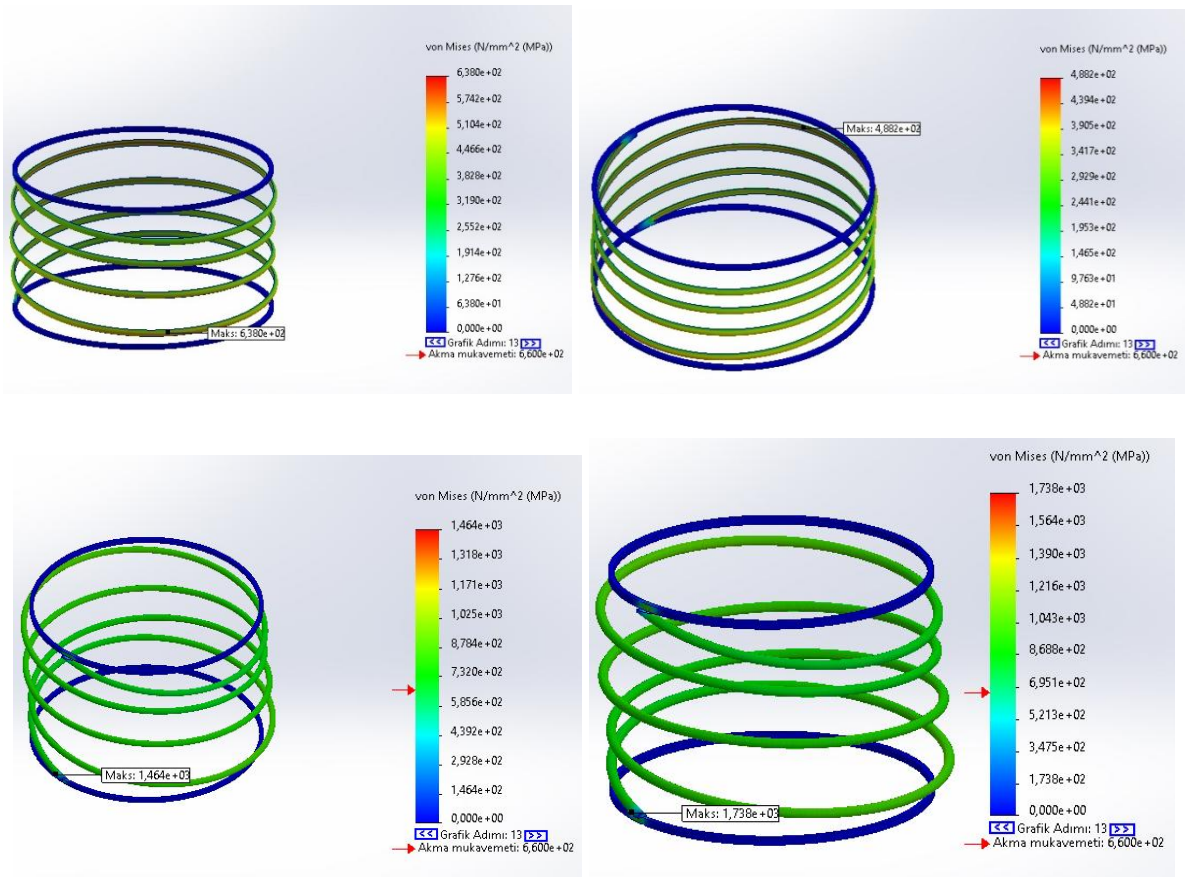
3. DENEYSEL SONUÇLAR

Bu bölümde, farklı geometrik konfigürasyonlara sahip AISI 1060 karbon çeliğinden imal edilmiş helisel yatak yayları için gerçekleştirilen sonlu elemanlar analizlerinden elde edilen deneysel sonuçlar sunulmaktadır. FEM tabanlı analizler kapsamında yayların gerilme ve gerinim dağılımları, akma dayanımı esas alınarak hesaplanan güvenlik faktörleri ile yorulma hasarı ve yorulma ömrü tahminleri değerlendirilmiştir. Ayrıca, yay geometrisinin neden olduğu bükülme etkileri ayrıntılı olarak incelenmiştir. Elde edilen sonuçlar, farklı geometrik parametrelerin mekanik davranış üzerindeki etkisini ortaya koymak amacıyla karşılaştırmalı olarak ele alınmış; kritik bölgelerde oluşan maksimum değerler ve bunların yapısal bütünlük, güvenli çalışma koşulları ve servis ömrü açısından anlamı tartışılmıştır.

3.1.Gerilme-Gerinim ve Güvenlik Faktörü Analizi

Gerilme ve gerinim kavramları, yayların mekanik davranışının değerlendirilmesinde birbirini tamamlayan iki temel parametre olarak ele alınmıştır. Gerilme, uygulanan dış yükler sonucunda malzeme içerisinde oluşan birim alan başına düşen iç kuvveti temsil ederken, gerinim bu gerilmeler altında malzemenin maruz kaldığı şekil değişimini ifade etmektedir. Şekil 1'de AISI 1060 karbon çeliğinden imal edilmiş dört farklı helisel yatak yayı geometrisi için (n=6) elde edilen von Mises eşdeğer gerilme dağılımları karşılaştırmalı olarak değerlendirildiğinde, gerilmenin tüm konfigürasyonlarda yay telinin aktif boğumlarında belirginleştiği; maksimumların ise çoğunlukla uç boğum–oturma/bağlama bölgesine komşu geçiş kesitlerinde oluştuğu görülmektedir. Bu kritik bölgeler, helisel yaylarda saf burulma varsayımından sapmaya neden olan sınır şartları kaynaklı ikincil eğilme bileşenlerinin (uç kısıtlamaları, temas rijitliği, eksen kaçıklığı hassasiyeti) burulma gerilmesine süperpoze olduğu alanlar olup, tel kesitinde gerilme yığılmasını artırarak eşdeğer gerilmenin tepe değerini belirlemektedir. Nitekim tüm görsellerde renk skalasının sıcak renge yaklaştığı lokal bölgeler, aktif boğum

boyunca yayılmış bir “ortalama” seviyeden ziyade, uçlara yakın küçük hacimli alanlarda yoğunlaşmaktadır; bu durum yapısal bütünlüğün esasen bu lokal kritik noktalara bağlı olduğunu göstermektedir.



Şekil 1. Farklı parametrelere sahip AISI 1060 çeliği yatak yaylarının gerilme analizi. (a) H=180 mm, D=65 mm, d=1.8 mm, (b) H=140 mm, D=65 mm, d=1.8 mm, (c) H=180 mm, D=55 mm, d=1.5 mm, (d) H=150 mm, D=44 mm, d=1.5 mm

Sayısal tepe değerleri dikkate alındığında, (a) H=180 mm, D=65 mm, d=1.8 mm konfigürasyonunda maksimum eşdeğer gerilme $\sigma_{max} \approx 6.38\times10^{2}$ MPa olup, görselde verilen akma mukavemeti $\sigma_y \approx 6.60\times10^{2}$ MPa değerine oldukça yakındır ($\sigma_{,max}/\sigma_y \approx 0.97$). Bu sonuç, ilgili yükleme altında yayın büyük ölçüde elastik bölgede kalmakla birlikte, uç boğum çevresindeki kritik bölgelerde akma sınırına yaklaşan bir çalışma rejimine girdiğini; dolayısıyla küçük bir yük artışı, montaj eksenelliği bozulması veya yüzey kusuru gibi etkilerle lokal plastikleşmenin başlayabileceğini düşündürmektedir. (b) H=140 mm, D=65 mm, d=1.8 mm konfigürasyonunda ise maksimum gerilme $\sigma_{max} \approx 4.88\times10^{2}$ MPa düzeyinde kalmakta ($\sigma_{max}/\sigma_y \approx 0.74$) ve elastik sınırlar içerisinde daha belirgin bir emniyet payı sunmaktadır. Aynı tel çapı ve ortalama çapa sahip iki konfigürasyonun tepe gerilmelerinin farklılaşması, serbest yükseklik/pitch değişiminin rijitlik ve deformasyon şekli üzerinden iç kuvvet dağılımını etkilediğini; özellikle uç bölgelerdeki eğilme katkısının konfigürasyona duyarlı olduğunu göstermektedir. Buna karşılık tel çapı 1.5 mm olan konfigürasyonlarda gerilme düzeyleri belirgin biçimde yükselmiştir. (c) H=180 mm, D=55 mm, d=1.5 mm için $\sigma_{max} \approx 1.464\times10^{3}$ MPa ($\sigma_{max}/\sigma_y \approx 2.22$) ve (d) H=150 mm, D=44 mm, d=1.5 mm için $\sigma_{max} \approx 1.738\times10^{3}$ MPa (σ_{max}/σ_y

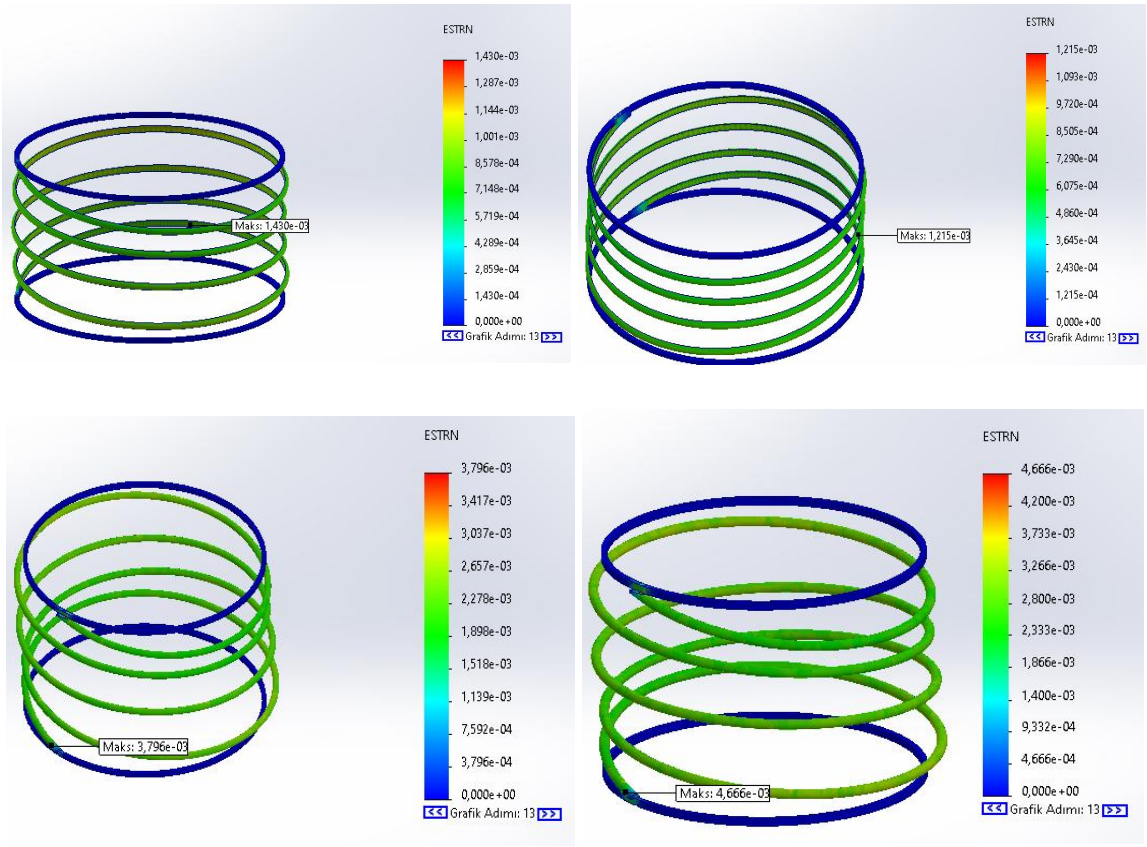
≈ 2.63) elde edilmiştir. Bu iki durumda eşdeğer gerilmenin akma dayanımını çok büyük bir oranla aşması, kritik bölgelerde malzemenin elastik sınırın dışına çıktığını ve belirgin plastik deformasyonun kaçınılmaz hâle geldiğini ortaya koymaktadır. Helisel yaylarda tel çapındaki azalma, kesitin polar ataletini ve dolayısıyla burulma/ eğilme taşıma kapasitesini düşürdüğü için gerilmeleri keskin biçimde yükseltir; ayrıca ortalama çapın küçülmesiyle yay indeksinin azalması (özellikle D=44 mm, d=1.5 mm için) tel kesitinde gerilme yoğunlaşmalarını artırarak tepe değerleri büyütür.

Mekanik anlamı açısından, σ_vm,max değerinin σ_y'yi aşması, yalnızca anlık bir gerilme fazlalığı olarak değil; yayda kalıcı şekil değişimi, rijitlik kaybı ve servis sırasında geometrik uyumsuzluk gibi sonuçlara kapı aralayan bir durum olarak değerlendirilmelidir. Özellikle uç boğumlara yakın lokal plastikleşme, çevrimsel yüklemelerde gerinim birikimini hızlandırarak hasarın bu bölgelerde başlamasına neden olur ve eşdeğer gerilme haritasında görülen sıcak noktalara karşılık gelen alanlar pratikte çatlak başlatma açısından en elverişli bölgeler hâline gelir. Dolayısıyla 1.5 mm tel çaplı konfigürasyonlarda gözlenen yüksek tepe gerilmeler, yapısal bütünlük açısından kabul edilebilir bir emniyet aralığının dışında bir çalışma rejimine işaret etmektedir. Buna karşılık 1.8 mm tel çaplı konfigürasyonlar, özellikle H=140 mm olan durumda elastik çalışma açısından daha dengeli bir tablo sunmakta; H=180 mm, D=65 mm, d=1.8 mm durumunda ise akma sınırına yakın çalışma nedeniyle uç bölge tasarımı/oturma koşulları ve montaj eksenelliği gibi parametrelerin kritikleştiği anlaşılmaktadır.

Sonuç olarak, karşılaştırmalı von Mises dağılımları AISI 1060 çeliğinin akma dayanımı ile birlikte ele alındığında; D=65 mm ve d=1.8 mm konfigürasyonlarının mevcut yükleme altında elastik sınırlar içinde veya sınıra yakın bir rejimde çalıştığı, d=1.5 mm olan konfigürasyonların ise σ_y'yi 2–2.6 kat aşan tepe gerilmeler nedeniyle statik açıdan dahi güvenli olmadığı ve lokal plastikleşme kaynaklı bütünlük kaybına açık olduğu bilimsel olarak ortaya konmaktadır. Bu bulgular, emniyetli tasarım için tel çapının artırılması, yay indeksinin yükseltilmesi, uç boğum/oturma geometrisinin ikincil eğilmeyi azaltacak biçimde optimize edilmesi ve sınır şartlarının (temas/kısıt) gerçek montaj koşullarını doğru temsil edecek şekilde modellenmesinin kritik olduğunu göstermektedir.

Şekil 2'de AISI 1060 karbon çeliğinden imal edilmiş, boğum sayısı 6 olan dört farklı yatak yayına ait eşdeğer toplam gerinim (ESTRN) dağılımları karşılaştırmalı olarak değerlendirildiğinde, maksimum gerinim değerlerinin geometriye güçlü biçimde duyarlı olduğu görülmektedir. İncelenen konfigürasyonlarda tepe gerinimler (a) için 1.430×10^{-3} ve (b) için 1.215×10^{-3}, (c) için 3.796×10^{-3} ve (d) için 4.666×10^{-3} olarak elde edilmiştir. Gerinim alanlarının uzaysal dağılımı, tüm modellerde aktif sarımlar boyunca görece daha düşük ve daha homojen bir seviyede seyrederken, uç sarım–aktif sarım geçişlerinde ve özellikle yükleme/mesnetleme koşullarının etkisinin belirginleştiği bölgelerde yerel gerinim yığılmalarının oluştuğunu göstermektedir. Bu kritik bölgeler, helisel yaylarda baskın deformasyon modunun torsiyon olmasına karşın, uç koşullar ve sarım geometrisi nedeniyle ortaya çıkan ikincil eğilme bileşenlerinin yerel gerinimi artırmasıyla uyumludur; dolayısıyla maksimum gerinimlerin uçlara yakın sarımlarda işaretlenmesi, sınır şartı kaynaklı gerinim gradyenlerinin ve kesit içi gerinim yoğunlaşmasının bir sonucudur. Geometrik parametrelerin

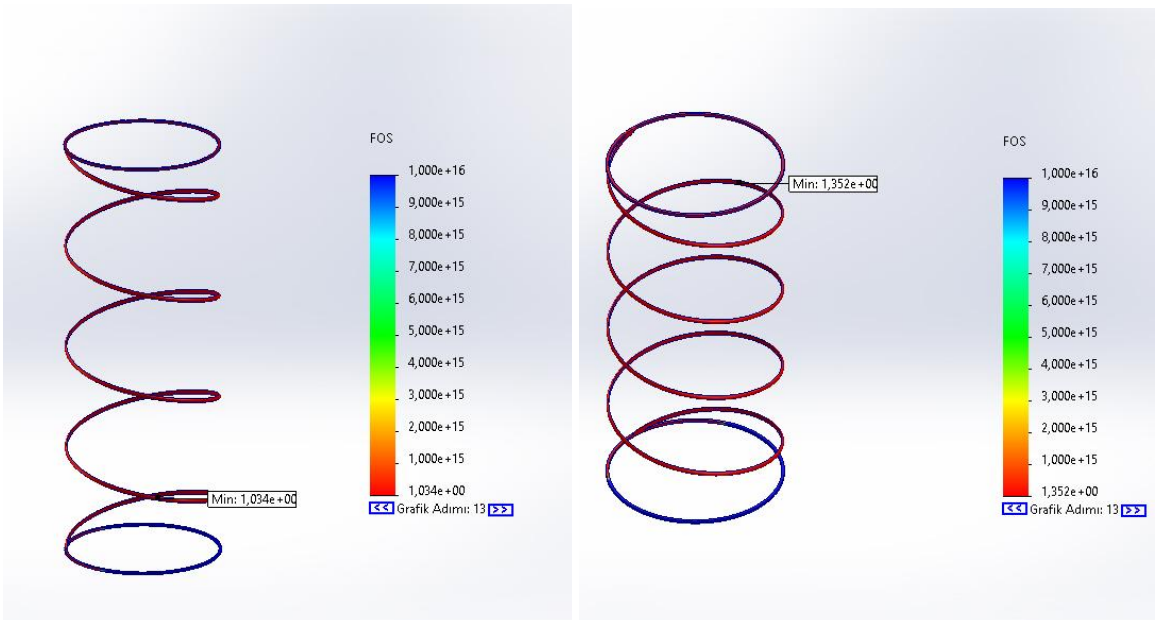
etkisi incelendiğinde, tel çapının artmasının (1.5 mm → 1.8 mm) kesit rijitliğini yükselterek gerinim seviyesini belirgin şekilde düşürdüğü; buna karşılık ortalama yay çapının azalmasının (65 mm → 55 mm → 44 mm) yay indeksini küçülterek (C = D/d) aynı yükleme koşulları altında tel kesitinde daha yüksek eşdeğer gerinimlere yol açtığı anlaşılmaktadır. Nitekim tel çapı 1.5 mm olan iki model arasında D=44 mm değerine sahip konfigürasyonun en yüksek gerinimi üretmesi, küçük yay indeksine bağlı olarak teldeki kesme gerinimi ve eğilme kaynaklı gerinim katkısının büyümesiyle tutarlıdır. Malzemenin elastik sınırları açısından yorumlandığında, AISI 1060 için verilen akma dayanımı ~660 MPa dikkate alınıp çeliğin elastisite modülü mertebesinde (E≈200–210 GPa) bir değerlendirme yapıldığında, akma gerinimi yaklaşık $\varepsilon_y \approx \sigma_y/E \approx 3.1\times10^{-3}$ düzeyindedir. Bu bağlamda (d) ve (c) modellerinde raporlanan maksimum eşdeğer gerinimlerin bu eşiği aştığı, dolayısıyla kritik bölgelerde yerel akma/plastikleşme riskinin bulunduğu; buna karşılık (a) ve (b) modellerinin maksimum gerinimlerinin akma geriniminin altında kalarak tam elastik davranış bölgesinde çalıştığı söylenebilir.

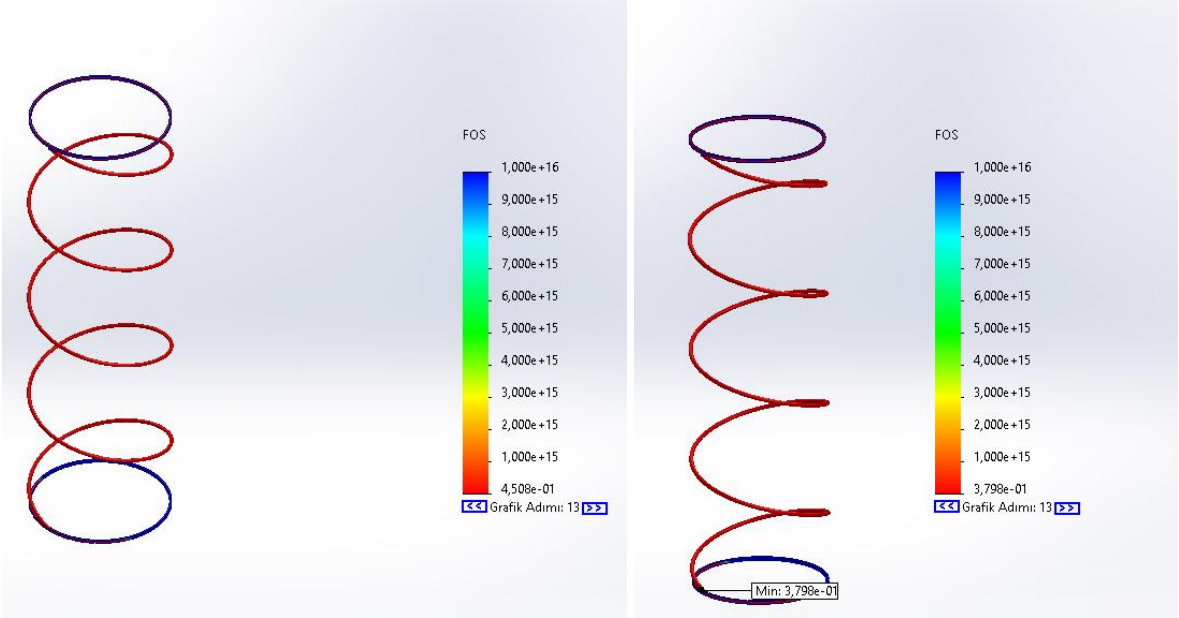


Şekil 2. Farklı parametrelere sahip AISI 1060 çeliği yatak yaylarının gerinim analizi. (a) H=180 mm, D=65 mm, d=1.8 mm, (b) H=140 mm, D=65 mm, d=1.8 mm, (c) H=180 mm, D=55 mm, d=1.5 mm, (d) H=150 mm, D=44 mm, d=1.5 mm

Sonuç olarak, gerinim dağılımı açısından yapısal bütünlük ve güvenli çalışma koşulları, özellikle küçük çaplı ve ince telli yaylarda uç bölge gerinim yığılmalarının kontrol edilmesine bağlıdır; bu nedenle tasarım iyileştirmesi (yay indeksinin artırılması, tel çapının büyütülmesi) servis koşullarında kalıcı şekil değişimi ve buna bağlı performans kaybı riskini azaltacaktır.

Şekil 3'de verilen güvenlik faktörü (FOS) haritaları, AISI 1060 karbon çeliği için akma dayanımı esas alınarak (model çıktılarında $\sigma_y \approx 660$ MPa) statik akma güvenliğini doğrudan okumaya imkân vermektedir. Dört farklı geometri için minimum FOS değerleri sırasıyla (a) yayında $FOS_{min} \approx 1.03$, (c) yayında $FOS_{min} \approx 0.45$, (d) yayında $FOS_{min} \approx 0.38$ ve (b) yayında $FOS_{min} \approx 1.35$ olarak elde edilmiştir. Bu dağılım, von Mises gerilme sonuçlarıyla tutarlı biçimde, ilgili modellerdeki maksimum eşdeğer gerilmelerin yaklaşık olarak 638 MPa, 1464 MPa, 1738 MPa ve 488 MPa seviyelerine ulaştığını; dolayısıyla FOS'un yaklaşık olarak σ_y/σ_{max} oranını yansıttığını göstermektedir. Kritik bölgeler tüm konfigürasyonlarda benzer karakterdedir: FOS minimumları, yük aktarımının ve sınır şartlarının yoğunlaştığı uç sargılar/oturma yüzeyine yakın geçiş bölgelerinde ve helis eğriliği nedeniyle lokal gerilme yığılmasının arttığı kesitlerde ortaya çıkmaktadır. Bu durum, basma altında helisel yaylarda hâkim olan burulma gerilmesine ek olarak uç kısımlarda kısıtlamaya bağlı ikincil eğilme bileşenlerinin oluşması ve temas/mesnetleme etkileriyle gerilmenin homojen dağılmaması ile açıklanabilir.





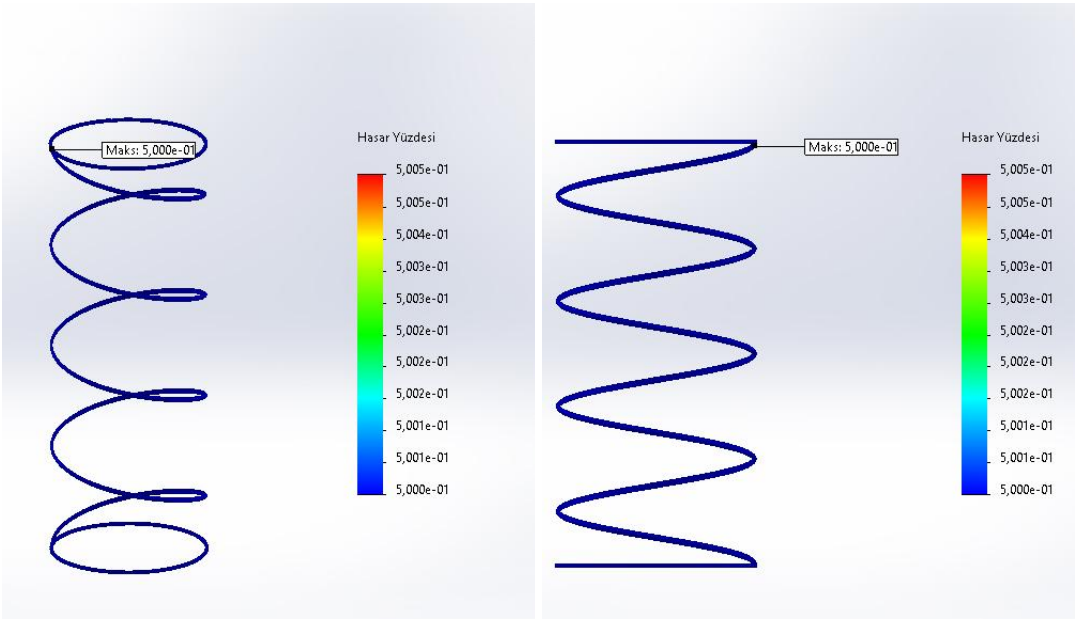
Şekil 3. Farklı parametrelere sahip AISI 1060 çeliği yatak yaylarının gerilme analizi. (a) H=180 mm, D=65 mm, d=1.8 mm, (b) H=140 mm, D=65 mm, d=1.8 mm, (c) H=180 mm, D=55 mm, d=1.5 mm, (d) H=150 mm, D=44 mm, d=1.5 mm

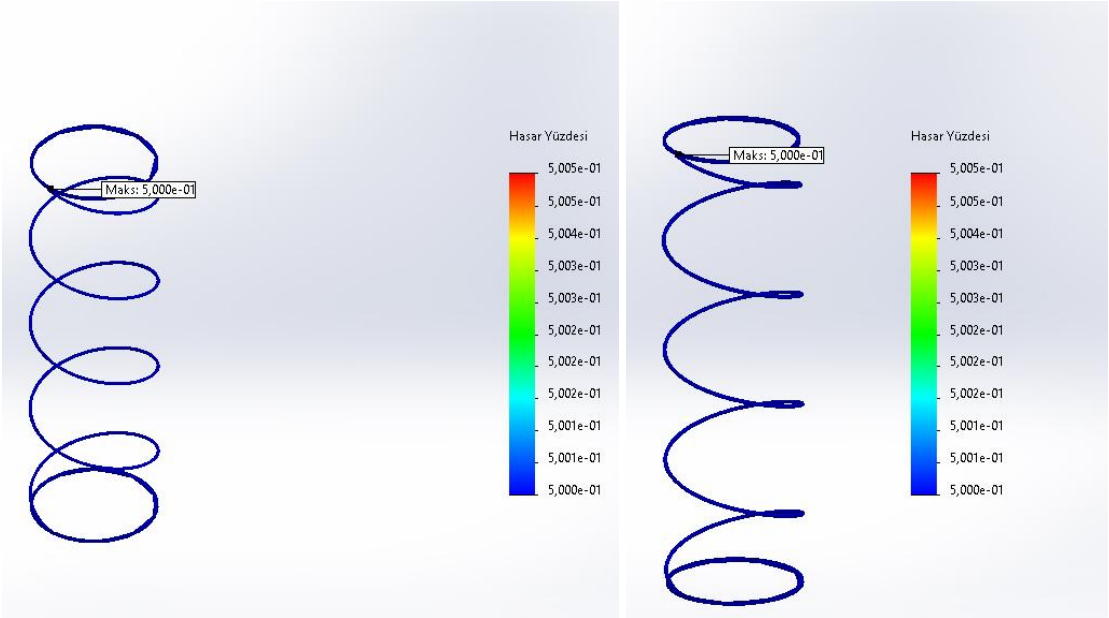
Elastik sınır açısından değerlendirildiğinde, AISI 1060 için elastik modülün tipik mertebesi (E≈200 GPa) dikkate alındığında akma gerilmesine karşılık gelen elastik birim uzama yaklaşık $\varepsilon_y \approx \sigma_y/E \approx 0.0033$ düzeyindedir. Gerinim haritaları bu yorumu desteklemektedir: d=1.8 mm olan iki konfigürasyonda maksimum gerinimler ~1.43×10^{-3} ve ~1.22×10^{-3} mertebesinde kalarak elastik bölgede kalırken, d=1.5 mm olan ve özellikle daha küçük ortalama çapa sahip geometrilerde maksimum gerinim ~3.80×10^{-3} ve ~4.67×10^{-3} seviyelerine çıkarak elastik sınırın aşıldığını işaret etmektedir. Buna paralel olarak FOS<1 veren (c) ve (d) tasarımlarında beklenen davranış, kritik bölgelerde lokal plastikleşme, yayda kalıcı şekil değişimi, rijitlik ve serbest boy kaybı, ve servis sırasında erken hasar riskinin artmasıdır. Özellikle (d) konfigürasyonunda hem ortalama çapın küçülmesi hem tel çapının düşük kalması, burulma gerilmesi seviyesini yükselterek FOS'u en olumsuz seviyeye taşımıştır; bu sonuç, geometrik oranların (D_m/d ve yay indeksi) yay güvenliğinde belirleyici olduğunu göstermektedir. Buna karşılık (b) konfigürasyonunda minimum FOS'un ~1.35 olması, seçilen yükleme altında akma açısından güvenli bir çalışma penceresine işaret eder; ancak uç bölgelerde FOS'un yine minimuma düşmesi, tasarım iyileştirmelerinin (uç sargı geometrisinin iyileştirilmesi ve gerekiyorsa tel çapı/ortalama çap optimizasyonu) güvenlik marjını arttırmada etkili olacağını göstermektedir. Sonuç olarak, analizler AISI 1060 malzeme sınırlarıyla karşılaştırıldığında, d=1.8 mm kullanılan tasarımların statik akma bütünlüğü açısından daha güvenli olduğunu; d=1.5 mm ve özellikle küçük ortalama çaplı tasarımların ise aynı yükleme koşulunda akma sınırını aştığı için yapısal bütünlük ve güvenli çalışma koşulları açısından kritik olduğunu ortaya koymaktadır.

3.2.Yorulma (hasar ve ömür) Analizi

Yorulma (hasar) analizinden elde edilen dağılımlar incelendiğinde (Şekil 4), tüm geometriler için hasar göstergesinin yaklaşık 5.00×10^{-1} (≈0,50) mertebesinde ve yorulma ömrünün

~1.0×10⁶ çevrim seviyesinde raporlanması ve renk skalasının çok dar bir aralıkta toplanması nedeniyle yay gövdesinin büyük bölümünde nispeten homojen bir hasar alanı oluştuğu görülmektedir. Bununla birlikte, maksimum hasarın konumu geometriden bağımsız olarak belirgin şekilde uç boğum/oturma bölgesine yakın ilk aktif sarımın başlangıcında (uç sarım–aktif sarım geçişi ve yerel temas/mesnet etkilerinin baskın olduğu bölgeler) yoğunlaşmaktadır. Helisel yaylarda eksenel yükleme altında hakim gerilme bileşeninin burulma kaynaklı kayma gerilmesi olmasına karşın, uç sarımların kısmi kısıtlanması (olası temas ve yerel rijitlik artışı) nedeniyle bu bölgede ikincil eğilme bileşenleri devreye girmekte; böylece gerilme/gerinim genliği yerel olarak yükselerek yorulma hasarı kritik hale gelmektedir. Bu bulgu, yorulma çatlağı başlatma eğiliminin helisel yaylarda çoğunlukla uçlara yakın yüksek eğrilik ve kısıtlanma gradyanının bulunduğu kesitlerde ortaya çıkacağına işaret eder.



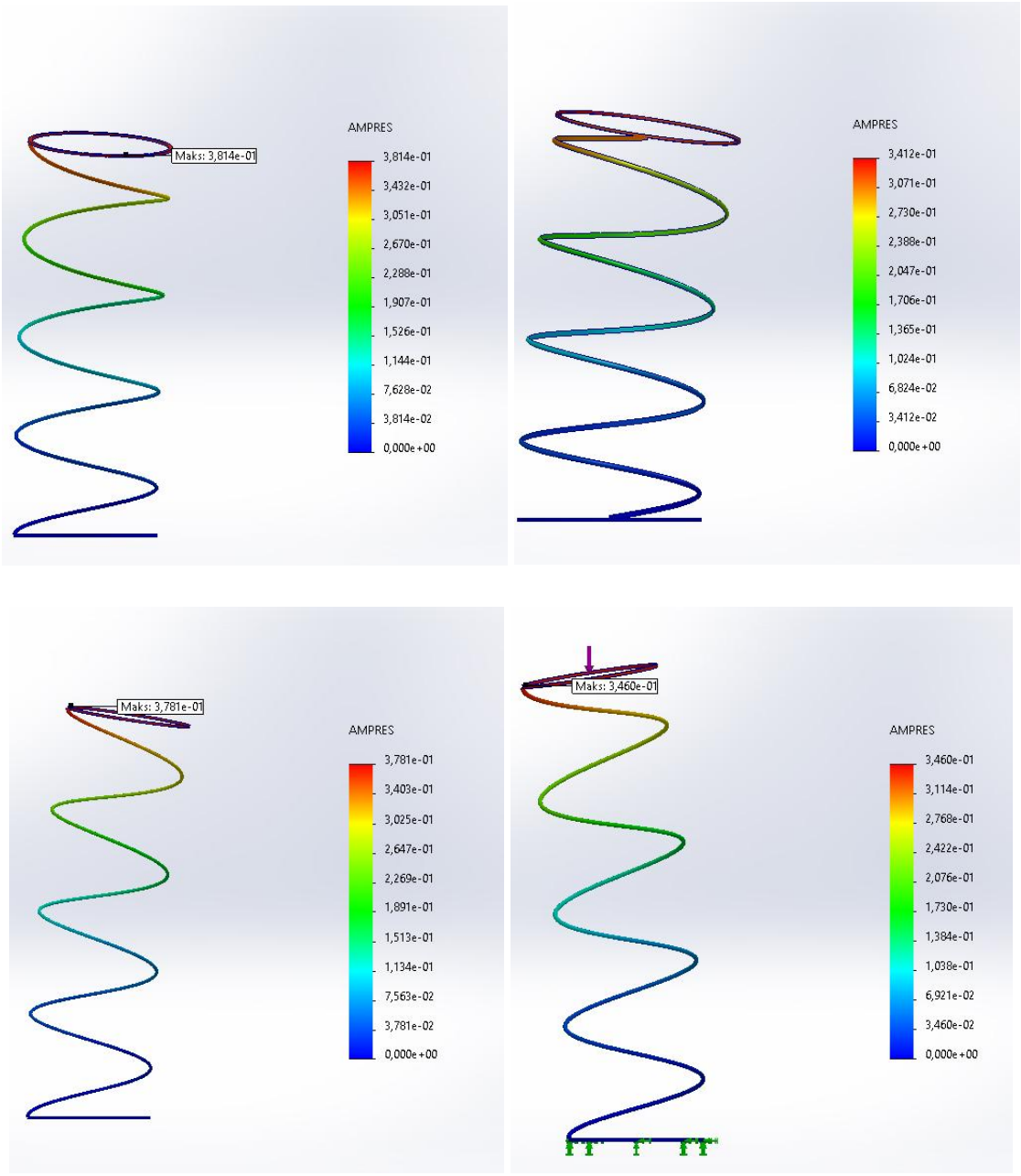


Şekil 4. Farklı parametrelere sahip AISI 1060 çeliği yatak yaylarının gerilme analizi. (a) H=180 mm, D=65 mm, d=1.8 mm, (b) H=140 mm, D=65 mm, d=1.8 mm, (c) H=180 mm, D=55 mm, d=1.5 mm, (d) H=150 mm, D=44 mm, d=1.5 mm

Geometrik parametrelerin yorulma hasarına etkisi, hasarın mutlak değerinden ziyade hasar gradyanı ve kritik bölgenin belirginliği üzerinden okunmaktadır. Tel çapı ve ortalama yay çapı birlikte ele alındığında (yay indeksi (C=D/d)), tel çapının azalması ve/veya ortalama çapın artması, etkin gerilme seviyelerini yükseltme eğilimi taşır; bu durum özellikle (c) ve (d) konfigürasyonlarında uç bölge yakınındaki hasar tepe noktasının daha keskinleşmesiyle uyumludur. Elde edilen hasar ≈0,50 seviyesi, seçilen yükleme-spektrumu altında AISI 1060 karbon çeliği için tanımlanan yorulma sınırının yaklaşık yarısının tüketildiği bir çalışma durumuna karşılık gelecek şekilde yorumlanabilir; bu, tasarım ömrü perspektifinde yayların tam hasara ulaşmadan önce belirli bir emniyet marjı barındırdığını, ancak uç boğum yakınındaki kritik bölgenin servis ömrünü sınırlayan birincil aday olduğunu göstermektedir. Yapısal bütünlük açısından sonuçlar, global ölçekte yay gövdesinin yorulma açısından stabil bir davranış sergilemesine rağmen, uzun süreli çevrimsel çalışmada hasarın birikerek ilk olarak uç bölge kaynaklı çatlak başlatma ile kendini gösterebileceğini düşündürür. Bu nedenle güvenli çalışma koşulları için; uç sarım geçişinin daha yumuşak tasarlanması, temas/mesnet koşullarının iyileştirilmesi önerilebilir.

3.3.Bükülme Analizi

Bükülme davranışı (bükülme genliği) sonuçları tüm konfigürasyonlarda yay boyunca artan bir trendle özellikle yükün uygulandığı üst uç yakınında maksimuma ulaşmakta; maksimum bükülme genlikleri sırasıyla yaklaşık 3.814×10^{-1}, 3.781×10^{-1}, 3.460×10^{-1} ve 3.412×10^{-1} mertebelerinde raporlanmaktadır. Maksimumun üst bölgede toplanması, yük aktarımının uç sarımda oluşturduğu ek moment bileşenleri ve uç koşullarına bağlı dönme kısıtlarıyla açıklanabilir; bu durum, helisel yay geometrisinin ideal eksenel yükleme altında dahi uçlarda eğilme etkilerine hassas olduğunu göstermektedir. Bükülme genliği seviyeleri birbirine görece yakın görünse de, gerilme–FOS sonuçları ile birlikte değerlendirildiğinde, bazı geometrilerde bükülmeye eşlik eden kesit zorlanmasının akma sınırını aştığı ve bu nedenle bükülme kaynaklı lokal etkilerin yapısal bütünlüğü belirleyen kritik mekanizmalardan biri haline geldiği anlaşılmaktadır. Bu bağlamda, uç sarım tasarımının (aktif sarım sayısı dağılımı, uç şekli, oturma yüzeyi koşulları) ve yükleme hizasının iyileştirilmesi, bükülme bileşenini azaltarak hem akma emniyetini hem de yorulma dayanımını artırmaya yönelik temel tasarım adımları olarak öne çıkmaktadır.



Şekil 5. Farklı parametrelere sahip AISI 1060 çeliği yatak yaylarının gerilme analizi. (a) H=180 mm, D=65 mm, d=1.8 mm, (b) H=140 mm, D=65 mm, d=1.8 mm, (c) H=180 mm, D=55 mm, d=1.5 mm, (d) H=150 mm, D=44 mm, d=1.5 mm

4. SONUÇLAR

Bu çalışmada, AISI 1060 karbon çeliğinden imal edilmiş dört farklı helisel yatak yayı geometrisinin mekanik davranışları sonlu elemanlar yöntemi (FEM) kullanılarak ayrıntılı biçimde incelenmiştir. Farklı serbest yükseklik, ortalama yay çapı ve tel çapı kombinasyonlarının gerilme, gerinim, güvenlik faktörü, yorulma hasarı, yorulma ömrü ve bükülme davranışı üzerindeki etkileri karşılaştırmalı olarak değerlendirilmiştir.

Gerilme analizleri sonucunda, maksimum von Mises gerilmelerinin tüm konfigürasyonlarda ağırlıklı olarak yay uçlarına yakın boğum bölgelerinde yoğunlaştığı belirlenmiştir. Bu durum,

helisel yay geometrisinde yük aktarımının düzgün olmaması ve uç bölgelerde oluşan geometrik süreksizlikler ile ilişkilidir. Tel çapının azalması ve ortalama yay çapının küçülmesiyle birlikte maksimum gerilme seviyelerinin arttığı gözlemlenmiş, bazı konfigürasyonlarda gerilme değerlerinin AISI 1060 karbon çeliğinin akma dayanımına yaklaştığı veya aştığı tespit edilmiştir. Gerinim analizleri, gerilme dağılımı ile uyumlu sonuçlar vermiş ve en yüksek gerinim değerlerinin yine uç boğumlarda ve yük uygulama bölgelerinde oluştuğunu göstermiştir. İncelenen konfigürasyonlar arasında daha ince tel çapına sahip yayların daha yüksek elastik şekil değiştirme sergilediği belirlenmiştir. Bu durum, tel çapının azalmasının yay rijitliğini düşürdüğünü ve elastik deformasyonları artırdığını ortaya koymaktadır. Güvenlik faktörü analizleri, geometrik parametrelerin yapısal güvenilirlik üzerindeki etkisini açık biçimde ortaya koymuştur. Tel çapının küçük olduğu ve yay çapının daraldığı konfigürasyonlarda minimum güvenlik faktörlerinin 1'in altına düştüğü gözlemlenmiş, bu durum söz konusu yayların güvenli çalışma koşullarını sağlamadığını göstermiştir. Buna karşılık, daha büyük tel çapına ve uygun yay oranına sahip konfigürasyonların daha yüksek güvenlik faktörleri sunduğu ve yapısal açıdan daha emniyetli olduğu belirlenmiştir.

Yorulma hasarı analizleri, hasarın tüm konfigürasyonlarda yay uçlarına yakın bölgelerde yoğunlaştığını göstermiştir. Bu bölgeler, hem maksimum gerilme hem de maksimum gerinim değerlerinin oluştuğu alanlar olup, yorulma çatlaklarının başlama noktaları açısından kritik öneme sahiptir. Yorulma ömrü analizleri ise, geometrik parametrelerin yorulma performansı üzerinde belirleyici rol oynadığını ortaya koymuştur. Özellikle tel çapının artırılması ve uygun yay oranlarının seçilmesiyle, yayların yorulma ömrünün belirgin şekilde uzadığı görülmüştür.

Bükülme analizleri, helisel yay geometrisinin doğası gereği eksenel yükleme altında dahi önemli eğilme etkilerinin oluştuğunu göstermiştir. Maksimum bükülme etkilerinin yine üst boğum ve yük uygulama bölgelerinde meydana geldiği belirlenmiş olup, bu durum gerilme ve yorulma analizleriyle tutarlı sonuçlar vermiştir. Bükülme davranışı, yay stabilitesi ve uzun vadeli performans açısından kritik bir parametre olarak öne çıkmaktadır.

Genel olarak elde edilen sonuçlar, helisel yatak yaylarının performansının yalnızca malzeme özellikleriyle değil, büyük ölçüde geometrik parametrelerin doğru seçimiyle belirlendiğini ortaya koymuştur. Tel çapı, ortalama yay çapı ve serbest yükseklik gibi parametrelerin birlikte optimize edilmesi, hem güvenli çalışma koşullarının sağlanması hem de uzun servis ömrü elde edilmesi açısından zorunludur. Bu çalışma kapsamında sunulan FEM tabanlı analiz yaklaşımı, helisel yay tasarımında yapısal güvenilirlik ve yorulma performansının öngörülmesi için etkin ve güvenilir bir yöntem sunmaktadır.

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PERLİT KATKILI RİJİT SÜNGERLERDE GÖZENEK MORFOLOJİSİ VE MEKANİK ÖZELLİKLER ARASINDAKİ İLİŞKİNİN İNCELENMESİ

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ÖZET

Bu çalışmada, perlit katkılı rijit süngerlerin gözenek morfolojisi ile mekanik özellikleri arasındaki ilişki deneysel olarak incelenmiştir. Farklı perlit oranları (%5-10-15) içeren rijit sünger numuneleri üretilmiş ve perlit katkısının sünger yapısı üzerindeki etkileri ayrıntılı biçimde değerlendirilmiştir. Gözenek yapısı; hücre boyutu ve hücre dağılımı üzerinden analiz edilmiş, elde edilen morfolojik özelliklerin mekanik davranış üzerindeki etkileri ortaya konmuştur. Mekanik karakterizasyon kapsamında numunelere basma testleri uygulanarak basma mukavemeti ve elastik davranışları belirlenmiştir. Sonuçlar, perlit katkısının rijit süngerlerin gözenek morfolojisini belirgin şekilde etkilediğini ve hücre yapısındaki değişimlerin mekanik özellikler üzerinde doğrudan rol oynadığını göstermiştir. Artan perlit içeriğiyle birlikte gözenek yapısında daha homojen bir dağılım ve hücre boyutlarında belirgin değişimler gözlemlenmiş, bu morfolojik farklılıkların basma mukavemeti ve elastik modül değerlerinde anlamlı değişimlere yol açtığı tespit edilmiştir. Elde edilen bulgular, perlit katkılı rijit süngerlerde mekanik performansın, gözenek morfolojisi ile yakından ilişkili olduğunu

ortaya koymaktadır. Bu çalışma, perlit katkılı rijit süngerlerin yapı–özellik ilişkisini ortaya koyarak, hedeflenen mekanik özelliklere sahip hafif ve yüksek performanslı sünger malzemelerin tasarlanmasına yönelik önemli katkılar sunmaktadır.

Anahtar Kelimeler: Rijit süngerler, Perlit katkısı, Mekanik özellikler

INVESTIGATION OF THE RELATIONSHIP BETWEEN PORE MORPHOLOGY AND MECHANICAL PROPERTIES IN PERLITE-FILLED RIGID FOAMS

ABSTRACT

In this study, the relationship between pore morphology and the mechanical properties of perlite-filled rigid foams was experimentally investigated. Rigid foam samples containing different perlite contents (5, 10, and 15 wt%) were produced, and the effects of perlite addition on the foam structure were evaluated in detail. The pore structure was analysed in terms of cell size and cell distribution, and the influence of the obtained morphological characteristics on mechanical behaviour was elucidated. For mechanical characterisation, compression tests were conducted to determine the compressive strength and elastic behaviour of the samples. The results demonstrated that perlite addition significantly affects the pore morphology of rigid foams and that changes in the cellular structure play a direct role in determining their mechanical properties. With increasing perlite content, a more homogeneous pore distribution and noticeable variations in cell size were observed, leading to significant changes in compressive strength and elastic modulus values. The findings reveal that the mechanical performance of perlite-filled rigid foams is closely related to their pore morphology. This study provides important contributions to the design of lightweight, high-performance foam materials with tailored mechanical properties by clarifying the structure–property relationships in perlite-filled rigid foams.

Keywords: Rigid foams, Perlite addition, Mechanical properties

1. GİRİŞ

Poliüretanlar, iki veya daha fazla izosiyanat grubu (di- veya triizosiyanatlar) içeren bileşiklerin, hidroksil (poliol) veya amino grupları içeren bileşiklerle ardışık poliadisyon reaksiyonu sonucu elde edilir ve ana zincirlerinde [-O-CO-NH-] yapısında üre grubu oluşur [1]. Poliüretan köpükler (PUF'ler), geniş uygulama alanına sahip çok yönlü polimer malzemeler sınıfını oluşturur. Bu köpükler; inşaat, otomotiv gibi pek çok endüstri alanında yaygın şekilde kullanılmaktadır [2,3]. Rijit PUF'ler, yarı rijit PUF'ler (SrPUF'ler) ve esnek PUF'ler, farklı uygulamalar ve özellikler sergileyen belirgin bir PUF alt grubunu temsil eder [4]. PUR ürünleri modern endüstride vazgeçilmez hâle gelmiş olup, küresel üretimi yıllık 21,3 milyon tonu aşarak sentetik malzemeler arasında dünya çapında altıncı sırada yer almaktadır. 2021 yılı itibarıyla PUR pazarının tahmini değeri 77,9 milyar ABD dolarıdır ve bu değerin 2026 yılında 105,3 milyar ABD dolarına ulaşacağı öngörülmektedir [5].

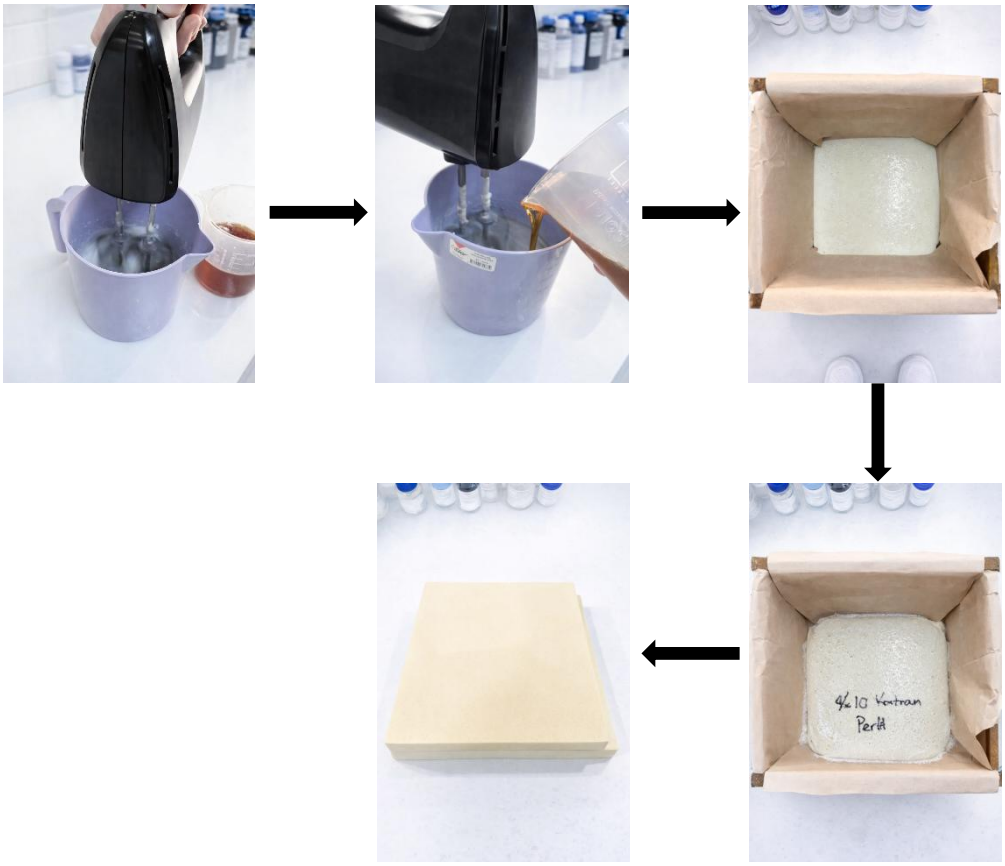
Perlit (P), çok düşük yoğunluğa sahip amorf cam benzeri volkanik bir kayadır. Perlit esas olarak SiO_2, Na_2O, Al_2O_3, K_2O ve sudan oluşur ve Türkiye (%16) dünyanın önde gelen perlit üreticilerinden biridir [6-8]. Perlit 760–1100 °C arasındaki sıcaklıklara ısıtıldığında hacmi 10–20 kat artar. Kimyasal olarak inerttir ve çeşitli malzemelerde ve süreçlerde dolgu veya filtrasyon yardımcı maddesi olarak kullanılabilir [9]. Perlit, yüksek gözenekliliğe sahiptir ve akustik ve termal yalıtkan olarak işlev görebilir. Harç, tuğla ve blok gibi termal yalıtım malzemelerinde yaygın olarak kullanılır [10]. Bazı çalışmalarda, belirli katkı maddelerinin düşük seviyelerde (%1,5'in altında) eklenmesiyle mekanik özelliklerde iyileşmeler sağlandığını bildirmiştir. Ancak katkı konsantrasyonu %1,5 ile %2 arasına yükseldiğinde performansta ani bir düşüş gözlemlenmiştir [11]. Bu düşüş, dolgu parçacıkları ile matris arasındaki güçlü ara yüzey yapışmasının etkili gerilme transferini teşvik ederek basma dayanımını artırmasına karşın, daha yüksek dolgu oranlarında parçacıkların hücre duvarlarına nüfuz etmesi ve zarar vermesiyle hücre yapısında anormalliklere ve çökme meydana gelmesine bağlanabilir [12]. Bu nedenle, mekanik performansı optimize etmek ve yapısal hasarı önlemek için dolgu miktarı dikkatle dengelenmelidir. Valipour ve ark. [13], PUR köpük kompozitlerinin mikro yapısal özelliklerini ve ısıl yalıtım performansını artırmak için umut verici dolgu malzemeleri olarak nanokilleri incelemiştir. Araştırmacılar, ısı yalıtımında %22–26 oranında iyileşme elde edildiğini bildirmiştir. Ai ve ark. [14], mekanik performans değişmeden ısıl iletkenliği daha düşük PUR köpük kompozitlerinin elde edilebileceğini göstermiştir. Araştırmacılar genişletilmiş perlit ve poliüretanı karıştırarak poliüretan rijit köpük/genişletilmiş perlit kompozitleri hazırlamıştır. Perlit içeriğinin, elde edilen perlit ısı yalıtım kompozitlerinin termal ve mekanik özellikleri üzerindeki etkisi incelenmiştir. Bulgular, perlit ısı yalıtım kompozitlerinin basma dayanımının arttığını ve böylece etkili ısı yalıtımı sağlandığını göstermiştir [15]. Ancak bu çalışma, perlitin alev geciktirici özelliklerini araştırmamıştır. Diğer çalışmada, poliüretan rijit köpük/genişletilmiş perlit ısı yalıtım kompozitleri hazırlanmıştır. Perlit içeriğinin bu ısı yalıtım kompozitlerinin yangına dayanıklılık performansı üzerindeki etkileri, küçük ölçekli bir brülör testi kullanılarak maksimum alev yüksekliğine göre değerlendirilmiştir. Sonuçlar, genişletilmiş perlitin ısı yalıtım kompozitlerinin alev geciktirici özellikleri üzerinde önemli bir etkiye sahip olduğunu göstermiştir [16].

2. MATERYAL VE METOTLAR

2.1.Perlit Katkılı Rijit Poliüretan Sünger Üretimi

KIMrigid RW 026 poliol sistemi ile İzokim RW 003 izosiyanat kullanılarak gerçekleştirilen rijit poliüretan sünger üretiminde, dolgu maddesi olarak perlit tozu kullanılmıştır. Perlit ilavesi, toplam poliol sistemi üzerinden ağırlıkça %5, %10 ve %15 olmak üzere üç farklı oranda uygulanmıştır. Bu sayede perlit oranının sünger yapısı ve özellikleri üzerindeki etkilerinin gözlemlenmesi hedeflenmiştir. KIMrigid RW 026, rijit sünger üretimi için özel olarak formüle edilmiş bir poliol sistemidir ve bünyesinde katalizör, şişirici ajan, hücre düzenleyici ve yardımcı katkılar içermektedir. İzokim RW 003 ise MDI bazlı bir izosiyanat olup poliol sistemi ile reaksiyona girerek süngerin sert ve kapalı hücreli yapısını oluşturmaktadır. Üretim öncesinde tüm hammaddelerin sıcaklığı 20–25°C aralığında sabitlenmiş, karıştırma ekipmanlarının ve kalıpların temiz ve kuru olmasına dikkat edilmiştir. Ortam neminin düşük tutulması sağlanmış, izosiyanatın nem ile reaksiyona girmesinin önüne geçilmiştir. Şekil 1'de de gösterildiği gibi

üretim aşamasında öncelikle KIMrigid RW 026 karıştırma kabına alınmıştır. Ardından perlit tozu, belirlenen oranlara göre (%5, %10 ve %15) kademeli olarak poliol sistemine eklenmiştir. Perlit ilavesi sırasında topaklanma oluşmaması ve dolgunun poliol içerisinde homojen şekilde dağılması için ön karıştırma yapılmıştır. Bu adım, sünger yoğunluğunun ve mekanik özelliklerinin dengeli olması açısından kritik öneme sahiptir. Perlitin homojen dağılımı sağlandıktan sonra, reçetede belirtilen oranda İzokim RW 003 izosiyanat karışıma ilave edilmiştir. İzosiyanat ilavesinin ardından karışım, yüksek devirli bir mikserle kısa sürede homojen hale gelinceye kadar karıştırılmış ve karışım bekletilmeden kalıba dökülmüştür. Döküm sonrasında poliol ve izosiyanat arasında kimyasal reaksiyon başlamış, oluşan gazın etkisiyle karışım köpürerek hacim kazanmıştır. Reaksiyon sürecinde karışım sırasıyla kremleşme, yükselme ve jelleşme evrelerinden geçmiş ve perlit dolgulu kapalı hücre yapısına sahip rijit poliüretan sünger oluşmuştur.



Şekil 1. Rijit poliüretan sünger üretimi

Sünger, ilk sertleşmesini birkaç dakika içerisinde tamamlamıştır. Nihai mekanik dayanım, boyutsal stabilite elde edilebilmesi için ürünler kürleme sürecine alınmıştır. Kürleme işlemi oda sıcaklığında yaklaşık 24 saat süresince gerçekleştirilmiştir. Bu yöntemle üretilen ve farklı oranlarda (%5, %10 ve %15) perlit içeren rijit poliüretan süngerler, yüksek basma dayanımı, iyi boyutsal stabilite ve ısı yalıtım özellikleri sunmaktadır. Perlit oranındaki artışın sünger

yoğunluğu, mekanik dayanım ve hücre yapısı üzerindeki etkileri karşılaştırmalı olarak değerlendirilmiştir.

2.2.Perlit Katkılı Rijit Poliüretan Sünger Karakterizasyonu

Perlit katkısı ile üretilen rijit poliüretan sünger köpüklerin fiziksel ve mekanik özellikleri, üretim sürecinin tamamlanmasının ardından sistematik bir şekilde karakterize edilmiştir. Malzemelerin performansını ortaya koymak amacıyla yoğunluk, elastik özellikler, basma dayanımı ve hücresel yapı gibi temel parametreler dikkate alınmıştır. Yoğunluk ölçümleri, belirlenen geometrik boyutlarda hazırlanan numunelerin kütlelerinin hassas terazi yardımıyla ölçülmesi ve elde edilen değerlerin numune hacmine oranlanması suretiyle gerçekleştirilmiştir. Hücresel yapı incelemeleri ile elastikiyet ve basma dayanımı deneyleri, standartlara uygun şekilde hazırlanan numuneler üzerinde, ilgili mekanik test ve analiz cihazları kullanılarak yürütülmüştür. Deneysel çalışmalar sonucunda elde edilen veriler, perlit katkılı rijit poliüretan sünger köpüklerin mekanik davranışlarının ve potansiyel uygulama alanlarına uygunluklarının değerlendirilmesinde temel bir referans oluşturmuştur.

3. DENEYSEL SONUÇLAR

3.1.Perlit Katkılı Rijit Poliüretan Süngerlerin Fiziksel Testleri

Bu çalışmada, perlit katkısının rijit poliüretan süngerlerin fiziksel özellikleri üzerindeki etkileri incelenmiştir. Bu kapsamda, farklı oranlarda perlit ilavesiyle üretilen rijit poliüretan sünger numunelerinin yoğunluk, elastikiyet ve basma dayanımı gibi temel fiziksel ve mekanik özellikleri belirlenmiştir. Elde edilen test sonuçları, perlit katkısının sünger yapısına ve performansına olan etkilerini ortaya koymak amacıyla değerlendirilmiştir. 3 µm perlit tozu ile takviye edilmiş rijit poliüretan süngerlerin yoğunluk değerleri Tablo 1'de sunulmuştur. Sonuçlar, perlit katkı oranının artmasıyla birlikte sünger yoğunluğunda düzenli bir artış meydana geldiğini göstermektedir. Katkısız numunede yoğunluk 0,126 g/cm³ olarak ölçülürken, bu değer %5, %10 ve %15 perlit içeren numunelerde sırasıyla 0,132 g/cm³, 0,137 g/cm³ ve 0,140 g/cm³ seviyelerine yükselmiştir. Gözlenen yoğunluk artışı, perlit ilavesiyle birlikte sünger yapısında birim hacimde bulunan katı faz miktarının arttığını göstermektedir. İnorganik perlit parçacıklarının poliüretan matrise dâhil edilmesi, hücresel yapıda daha fazla yük taşıyıcı malzemenin bulunmasına yol açmış ve bu durum yoğunluğun artmasıyla sonuçlanmıştır. Ayrıca artan perlit içeriğinin, hücre duvarları ve strut bölgelerinde katı faz oranını artırarak yapının daha kompakt bir hâl almasına katkı sağladığı söylenebilir. Yoğunluktaki bu artış, süngerlerin mekanik performansında gözlenen iyileşmelerle uyumlu bir eğilim sergilemektedir. Rijit poliüretan süngerlerde yoğunluğun artması, genellikle basma altında yük taşıma kapasitesinin ve yapısal rijitliğin artmasıyla ilişkilendirilmektedir. Bu bağlamda, perlit katkı oranına bağlı olarak yoğunlukta meydana gelen artışın, basma kuvveti ve basma gerilmesi değerlerinde gözlenen yükselişi destekleyen önemli bir yapısal etken olduğu değerlendirilmektedir.

Tablo 1. Perlit katkılı rijit süngerlerin yoğunluk değerleri

Parametreler	
Birim	g/cm^3
Katkısız	0,126
%5	0,132
%10	0,137
%15	0,140

3 µm perlit tozu ilavesiyle üretilmiş rijit poliüretan süngerlerin elastikiyet değerleri Tablo 2'de sunulmuştur. Sonuçlar, perlit katkı oranının artmasıyla birlikte süngerlerin elastik modülünde belirgin bir artış meydana geldiğini göstermektedir. Katkısız numunenin elastikiyet değeri 6,23 N/mm² olarak ölçülürken, bu değer %5, %10 ve %15 perlit içeren numunelerde sırasıyla 6,73 N/mm², 7,41 N/mm² ve 9,40 N/mm² seviyelerine yükselmiştir. Gözlenen bu artış, perlit ilavesinin sünger yapısının rijitliğini artırdığını ortaya koymaktadır. İnorganik perlit parçacıklarının poliüretan matrise dâhil edilmesi, birim hacimde yer alan katı faz oranını artırarak hücre duvarları ve taşıyıcı strut bölgelerinin elastik deformasyona karşı direncini yükseltmiştir. Bu durum, süngerin düşük şekil değiştirme bölgesinde daha yüksek gerilmeler altında elastik davranışını sürdürebilmesine olanak tanımış ve elastik modül değerlerinde artışa yol açmıştır. Elastikiyet değerlerindeki artış eğiliminin, perlit oranıyla birlikte artan yoğunluk ve basma dayanımı sonuçlarıyla uyumlu olduğu görülmektedir. Rijit poliüretan süngerlerde elastik modülün artması, genellikle daha kompakt bir hücresel yapı ve daha etkin yük aktarımı ile ilişkilendirilmektedir. Bu bağlamda, perlit katkısının süngerlerin elastik davranışını güçlendirerek mekanik performansını iyileştirdiği değerlendirilmektedir.

Tablo 2. Perlit katkılı rijit süngerlerin elastikiyet değerleri

Parametreler	
Birim	N/mm^2
Katkısız	6,23
%5	6,73
%10	7,41
%15	9,40

%0, %5, %10 ve %15 oranlarında 3 µm perlit tozu ile takviye edilmiş rijit poliüretan süngerlerin basma deneyi sonuçları Tablo 3'de özetlenmiştir. Elde edilen sonuçlar, perlit içeriğinin süngerlerin basma performansı üzerinde belirgin bir etkiye sahip olduğunu, özellikle maksimum kuvvet ve maksimum basma gerilmesi açısından ortaya koymaktadır.

Tablo 3. Perlit katkılı rijit süngerin basma deneyi sonuçları

	Max Kuvvet	**Max Gerilme**	**Max Uzama**	**Max Yüzde Uzama**
Parametreler	Tüm Alan Hesaplaması	Tüm Alan Hesaplaması	Tüm Alan Hesaplaması	Tüm Alan Hesaplaması
Birim	N	N/mm^2	mm	%
Katkısız	5668,75	2,26750	20,0000	40,0000
%5	5821,88	2,32875	20,0010	40,0020
%10	6421,88	2,56875	19,9950	39,9900
%15	6498,44	2,59938	20,0000	40,0000
Ortalama	6402,74	2,44110	19,9990	39,9980
Standart Sapma	418,592	0,16744	0,00271	0,00541
Aralık	829,690	0,33188	0,00600	0,01200

Katkısız sünger numunesinde maksimum basma kuvveti 5668,75 N olarak ölçülmüş olup, bu değer perlit içeriğinin artmasıyla birlikte düzenli bir artış göstererek %5, %10 ve %15 perlit içeren numunelerde sırasıyla 5821,88 N, 6421,88 N ve 6498,44 N seviyelerine ulaşmıştır. Benzer şekilde maksimum basma gerilmesi, katkısız numunede 2,2675 N/mm^2 iken %15 perlit ilavesiyle 2,59938 N/mm^2 değerine yükselmiştir. Bu bulgular, perlit parçacıklarının rijit poliüretan süngerlerin basma altında yük taşıma kapasitesini artırdığını göstermektedir. Perlit oranının artmasıyla maksimum basma kuvveti ve maksimum basma gerilmesinde gözlenen artış, perlit ilavesinin sünger yapısının hem yoğunluğunu hem de yük taşıma kapasitesini artırmasına bağlanabilir. Perlit katkısının artmasıyla birlikte sünger yoğunluğunun yükselmesi, birim hacimde yer alan yük taşıyıcı katı faz miktarının artmasına neden olmuş; bu durum hücre duvarları ve taşıyıcı strut bölgelerinin basma deformasyonuna karşı direncini artırmıştır. Böylece sünger yapısı, basma altında daha yüksek kuvvetleri taşıyabilmiş ve maksimum basma kuvveti değerleri yükselmiştir. Buna ek olarak, poliüretan matris içerisinde dağılan perlit parçacıkları, daha yüksek elastik modülleri sayesinde basma yükü altında gerilmenin bir kısmını üstlenerek yük aktarımına katkı sağlamıştır. Bu mekanizma, yalnızca taşınabilen toplam kuvvetin artmasına değil, aynı zamanda hücre duvarlarının daha yüksek gerilmelere dayanabilmesine olanak tanımış ve maksimum basma gerilmesi değerlerinde de artışa yol açmıştır. Maksimum uzama ve yüzde uzama değerlerinin perlit oranına bağlı olarak belirgin bir değişim göstermemesi, gözlenen artışların süneklik kaybından ziyade yapısal dayanım ve rijitlik artışından kaynaklandığını desteklemektedir.

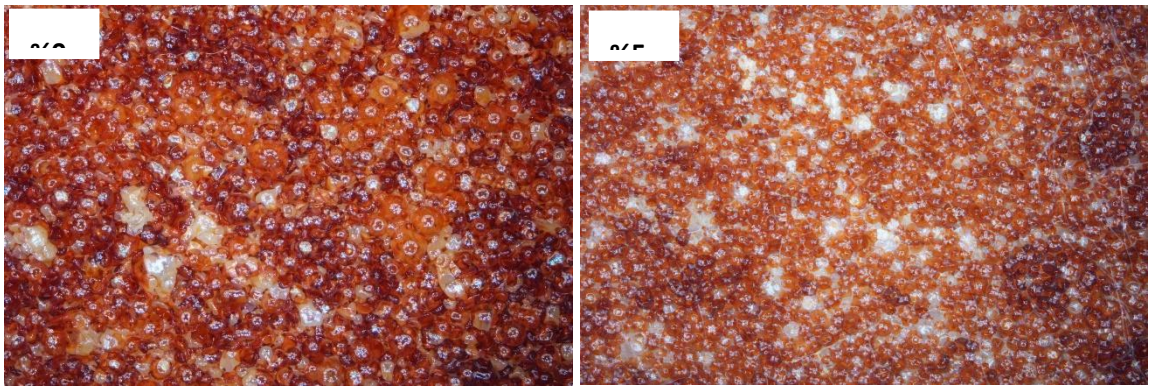
Buna karşılık maksimum uzama ve maksimum basma şekil değiştirmesi değerleri tüm bileşimlerde yaklaşık olarak sabit kalmış; maksimum uzama yaklaşık 20 mm, maksimum yüzde uzama ise %40 civarında ölçülmüştür. Bu sınırlı değişim, perlit ilavesinin süngerin basma altındaki deformasyon kapasitesini önemli ölçüde etkilemediğini ve gözlenen iyileşmenin esas

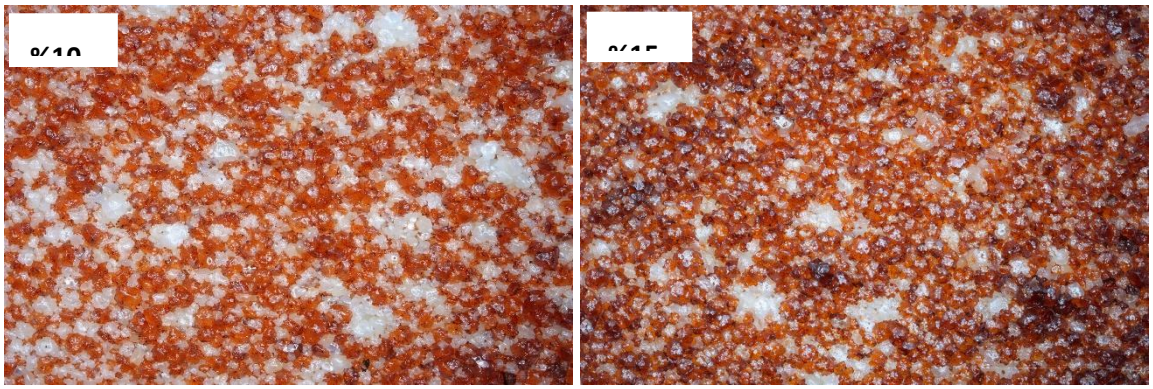
olarak dayanım ve rijitlik artışından kaynaklandığını düşündürmektedir. Uzama ve şekil değiştirme parametrelerinde elde edilen düşük standart sapma değerleri, tüm formülasyonlar için basma altında tutarlı bir deformasyon davranışı sergilendiğini göstermektedir. Buna karşın maksimum kuvvet ve maksimum gerilme değerlerinde gözlenen artış eğilimi, perlit parçacıklarının sünger yapısının mekanik tepkisine etkin bir katkı sağladığını ortaya koymaktadır. Maksimum uzama ve maksimum basma şekil değiştirmesi değerlerinin tüm bileşimlerde yaklaşık olarak sabit kalması, perlit ilavesinin sünger yapısının temel deformasyon mekanizmasını değiştirmediğini göstermektedir. Rijit poliüretan süngerlerde basma altındaki deformasyon, ağırlıklı olarak hücre duvarlarının elastik deformasyonu ve strut bölgelerinin kontrollü burkulması yoluyla gerçekleşmekte olup, perlit katkısı bu mekanizma üzerinde belirgin bir değişime neden olmamıştır. Ayrıca uzama ve şekil değiştirme parametrelerinde elde edilen düşük standart sapma değerleri, tüm formülasyonlar için basma altında tutarlı ve tekrarlanabilir bir deformasyon davranışı sergilendiğini ortaya koymaktadır.

Genel olarak elde edilen sonuçlar, 3 µm perlit tozu ilavesinin rijit poliüretan süngerlerin basma dayanımını artırırken, basma şekil değiştirme kapasitesini olumsuz yönde etkilemediğini ve perlitin rijit poliüretan sünger sistemleri için etkili bir takviye dolgu malzemesi olarak değerlendirilebileceğini göstermektedir.

3.2.Perlit Katkılı Rijit Poliüretan Süngerlerin Gözenek Analizi

Şekil 2'de verilen rijit köpük numunelerinde, perlit katkı oranının hücresel morfoloji üzerindeki etkisi optik görüntüler aracılığıyla değerlendirilmiştir. Katkısız (%0 perlit) numune, yüksek oranda kapalı hücreli bir yapı sergilemekte olup hücre boyutları görece küçük ve dağılımı büyük ölçüde homojendir. Hücrelerin küresel formunu koruduğu, hücre duvarlarının sürekliliğinin yüksek olduğu ve belirgin hücre birleşmelerinin bulunmadığı gözlenmektedir.





Şekil 1. %0-5-10-15 oranlarında perlit katkılı rijit köpük numunelerinin optik görüntüleri

%5 oranında perlit katkısı içeren numunede, genel kapalı hücre karakteri korunmakla birlikte hücre boyutlarında sınırlı bir artış ve dağılımda hafif bir heterojenlik oluştuğu gözlenmektedir. Perlit parçacıklarının köpürme sırasında heterojen nükleasyon merkezleri olarak davranması, hücre oluşum sayısını artırırken bazı bölgelerde hücre boyutlarının yerel olarak büyümesine neden olmuştur. Buna rağmen hücre duvar bütünlüğü büyük ölçüde korunmuş olup, hücresel yapı yapısal stabilitesini muhafaza etmektedir. Bu katkı oranı, perlitin mikroyapıyı belirgin şekilde bozmadığı ancak hücre oluşum mekanizmasını etkilediği bir geçiş bölgesi olarak değerlendirilebilir. Perlit oranının %10'a çıkarılmasıyla birlikte hücresel yapıda daha belirgin değişimler gözlenmektedir. Hücre boyutlarının genel olarak büyüdüğü, hücre boyutu dağılımının belirgin biçimde heterojenleştiği ve bazı bölgelerde hücre duvarlarının inceldiği görülmektedir. Yer yer hücre birleşmeleri ve kısmi açık hücre oluşumları dikkati çekmektedir. Bu durum, artan perlit içeriğinin sistemin reolojik özelliklerini ve reaksiyon kinetiğini değiştirerek hücre stabilitesini azalttığını göstermektedir. Hücresel yapı hâlen büyük oranda kapalı hücreli olmakla birlikte, mikroyapısal bütünlükte bozulma eğilimi başlamıştır. %15 perlit katkısı içeren numunede ise hücresel morfolojideki bozulma daha belirgin hale gelmektedir. Hücre boyutları önemli ölçüde artmış, hücre dağılımı belirgin biçimde düzensizleşmiş ve hücre duvarlarında yaygın incelme ve süreksizlikler oluşmuştur. Birçok bölgede hücre birleşmeleri ve açık hücre yapıları gözlenmektedir. Bu yapı, yüksek perlit içeriğinin köpürme sırasında hücre büyümesini kontrolsüz hale getirdiğini ve hücre stabilitesini ciddi ölçüde azalttığını göstermektedir.

Genel olarak değerlendirildiğinde, perlit katkı oranının artmasıyla birlikte rijit köpüğün hücresel yapısında hücre boyutunun kademeli olarak arttığı, hücre boyutu dağılımının heterojenleştiği ve hücre duvar bütünlüğünün azaldığı görülmektedir. Düşük perlit oranlarında (%5'e kadar) perlit, hücre oluşumunu etkileyen bir dolgu/nükleasyon ajanı gibi davranırken, daha yüksek oranlarda (%10 ve %15) hücre stabilitesini bozarak açık hücre oluşumunu ve hücre birleşmelerini artırmaktadır. Bu bulgular, perlit katkısının rijit poliüretan köpüklerde dikkatli biçimde optimize edilmesi gerektiğini ortaya koymaktadır.

SONUÇLAR

Bu çalışmada, 3 µm boyutunda perlit tozu ile %0, %5, %10 ve %15 oranlarında takviye edilmiş rijit poliüretan süngerlerin fiziksel, mekanik ve hücresel özellikleri sistematik olarak

incelenmiştir. Elde edilen bulgular, perlit katkı oranının süngerlerin yoğunluğu, elastik davranışı, basma performansı ve hücresel morfolojisi üzerinde belirgin ve birbirini destekleyen etkiler oluşturduğunu ortaya koymuştur. Yoğunluk ölçümleri, perlit katkı oranının artmasıyla birlikte rijit poliüretan süngerlerin yoğunluğunda düzenli ve kademeli bir artış meydana geldiğini göstermiştir. Bu durum, perlit ilavesiyle birlikte sünger yapısında birim hacimde yer alan katı faz miktarının artmasına bağlanmıştır. İnorganik perlit parçacıklarının poliüretan matrise dâhil olması, hücre duvarları ve strut bölgelerinde daha fazla yük taşıyıcı malzemenin bulunmasına yol açmış ve yapının daha kompakt bir hâl almasını sağlamıştır. Elastikiyet deneyleri, perlit katkısının süngerlerin elastik modülünü belirgin biçimde artırdığını göstermiştir. Artan perlit oranıyla birlikte elastik modül değerlerinde gözlenen yükseliş, sünger yapısının rijitliğinin arttığını ortaya koymuştur. Bu artış, perlit parçacıklarının poliüretan matrise mekanik olarak katkı sağlaması ve hücre duvarlarının elastik deformasyona karşı direncini artırmasıyla ilişkilendirilmiştir. Elastik modül sonuçlarının yoğunluk ve basma dayanımı bulgularıyla uyumlu olması, perlit katkısının yapısal rijitliği güçlendirdiğini doğrulamaktadır. Basma deneyi sonuçları, perlit ilavesinin rijit poliüretan süngerlerin basma altında yük taşıma kapasitesini önemli ölçüde artırdığını ortaya koymuştur. Maksimum basma kuvveti ve maksimum basma gerilmesi değerleri, perlit oranı arttıkça düzenli bir artış eğilimi göstermiştir. Bu durum, artan yoğunlukla birlikte hücre duvarları ve taşıyıcı strut bölgelerinin basma deformasyonuna karşı direncinin yükselmesine bağlanmıştır. Ayrıca perlit parçacıklarının, yüksek elastik modülleri sayesinde basma yükünün bir kısmını üstlenerek yük aktarımına katkı sağladığı değerlendirilmiştir. Buna karşılık, maksimum uzama ve maksimum basma şekil değiştirmesi değerlerinin tüm bileşimlerde yaklaşık olarak sabit kalması, perlit ilavesinin süngerlerin basma altındaki temel deformasyon mekanizmasını önemli ölçüde değiştirmediğini göstermektedir. Rijit poliüretan süngerlerde basma altındaki deformasyonun ağırlıklı olarak hücre duvarlarının elastik deformasyonu ve strut bölgelerinin kontrollü burkulması yoluyla gerçekleştiği; perlit katkısının bu mekanizma üzerinde belirgin bir olumsuz etki oluşturmadığı sonucuna varılmıştır. Düşük standart sapma değerleri, basma davranışının tüm formülasyonlarda tutarlı ve tekrarlanabilir olduğunu göstermektedir. Hücresel morfolojiye ilişkin optik incelemeler, perlit katkı oranının artmasıyla birlikte hücre boyutunun büyüdüğünü, hücre boyutu dağılımının heterojenleştiğini ve hücre duvar bütünlüğünün kademeli olarak azaldığını ortaya koymuştur. Katkısız ve düşük perlit oranlı (%5) numunelerde kapalı hücre yapısının büyük ölçüde korunduğu ve yapısal stabilitenin yüksek olduğu gözlenirken, daha yüksek perlit oranlarında (%10 ve %15) hücre birleşmeleri ve kısmi açık hücre oluşumlarının arttığı belirlenmiştir. Bu durum, artan perlit içeriğinin köpürme sırasında hücre stabilitesini olumsuz yönde etkilediğini ve mikroyapısal bozulmalara yol açtığını göstermektedir.

Genel olarak elde edilen sonuçlar, 3 µm perlit tozu ilavesinin rijit poliüretan süngerlerin yoğunluk, elastik modül ve basma dayanımını artırarak mekanik performansı iyileştirdiğini; buna karşılık yüksek katkı oranlarında hücresel morfolojide bozulmaların ortaya çıkabildiğini göstermektedir. Bu bağlamda, perlitin rijit poliüretan sünger sistemleri için etkili bir takviye dolgu malzemesi olduğu, ancak optimum performansın sağlanabilmesi için katkı oranının dikkatli biçimde optimize edilmesi gerektiği sonucuna varılmıştır. Özellikle mekanik dayanım artışı ile hücresel bütünlüğün korunması arasında bir denge kurulmasının, yalıtım amaçlı rijit poliüretan sünger uygulamaları açısından kritik öneme sahip olduğu değerlendirilmektedir.

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MİNİBAR YÜZEYİNDE YERLİ HAMLE PROJESİ: YÜZEY KAPLAMA TEKNOLOJİLERİNDE YERLİ ÜRETİM VE SÜRDÜRÜLEBİLİRLİK YAKLAŞIMI

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ÖZET

Firmamız, enerji tasarrufu ve sürdürülebilirlik odaklı yeni nesil soğutma teknolojileri ile minibar üretimi gerçekleştirmektedir. Bu çalışmada, minibar üretiminde yüzeyde kullanılan PVC kaplı sacın yerine yerli üretim **Polyester–Polyamid (PEPA) Sistem Boyalı Sac** geliştirilmesi ve ticarileştirilmesi amacıyla yürütülen "Minibar Yüzeyinde Yerli Hamle Projesi" ele alınmaktadır. Projenin çıkış noktası; ithal PVC kaplı sacın sürdürülebilirlik, tedarik riski ve geri dönüşüm zorlukları gibi kritik dezavantajları ile Türkiye'de yerli üretici sayısının sınırlı olması sonucu oluşan dışa bağımlılığın azaltılması ihtiyacıdır. Çalışma kapsamında elde edilen maliyet iyileştirmeleri ise teknik çözümün doğal bir çıktısı olarak ek bir kazanım niteliği taşımaktadır.

Proje kapsamında mevcut durum analizi, SWOT çalışmaları, malzeme ve boya alternatiflerinin teknik değerlendirmesi, laboratuvar testleri (Cross-cut, yapışma, tuz testi 400–600–800 saat), planlı deney yöntemi ve fizibilite analizleri gerçekleştirilmiştir. Farklı renk ve yüzey tiplerinde geliştirilen numuneler hem ISM üretim operasyonlarında hem de tedarikçi laboratuvarlarında dayanım, kozmetik kalite ve kimyasal direnç açısından doğrulanmıştır.

Elde edilen sonuçlar, PEPA Sistem Boyalı Sacın; PVC kaplı sacın dezavantajlarını ortadan kaldırdığını, daha yüksek çizilme dayanımı sunduğunu, geri dönüşüm sürecine uygun olduğunu ve global standartlara (EN13523, EN10169) uyum sağladığını göstermiştir. Ayrıca ürün maliyetlerinde %3–5 arası iyileşme, satınalma hacminde ithalat oranının %35'ten %25 seviyelerine gerilemesi ve tedarik riskinin belirgin şekilde azalması sağlanmıştır.

Proje, Ekim 2025 itibarıyla ticarileşmiş olup, elde edilen yerli yüzey teknolojisi yalnızca minibar ürünlerinde değil, karavan ve marin projelerinde de uygulanabilir bir altyapı sunmaktadır. Bu yönüyle çalışma, yerli üretimi güçlendiren, sürdürülebilirliği artıran ve sektörde inovatif malzeme gelişimine katkı sağlayan kapsamlı bir iyileştirme modeli niteliğindedir.

Anahtar Kelimeler: Boyalı Galvanize Sac - Sürdürülebilir Malzeme Geliştirme - Yerli Üretim

YAPAY ZEKA DESTEKLİ OTONOM TARIM ROBOTUNUN GELİŞTİRİLMESİ

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ÖZET

Tarım sektöründe insan gücünün azalması ve kırsal alanlardan şehirlere göç nedeniyle tarımda istihdam edilecek iş gücünün bulunamaması, mevcut iş gücünün maliyetlerinin de yükselmesi gibi sorunlar giderek artmaktadır. Bu bağlamda, tarımsal verimliliği artırmak amacıyla emek yoğun sistemlerden otomasyonlu sistemlere geçiş yapılması elzem hâle gelmiştir. Tarımda, ürünün tarlaya ekimi kadar; ürünün filizlenmesinden itibaren tüketiciye gönderilmek üzere tarladan hasat edilinceye kadar geçen bakım süreçlerinin de iyi yönetilmesi gereklidir. Tarımsal ürünlere uygulanması gereken bakım işleri arasında gübreleme, çapalama ve ilaçlama gibi işlemler yer almaktadır. Geleneksel tarım yapılan çiftliklerde çapalama işlemleri için onlarca emekçi tarlada gün boyu çalışmaktadır.

Bu çalışmada, emek yoğun çapalama işlemini otomasyonlu hâle getirmek üzere geliştirilen otonom tarım robotu ele alınmıştır. Tarım robotunda enerji depolarının daha verimli

kullanılması için hafifletme çalışmaları kapsamında optimizasyonlar yapılmıştır. Geliştirilen otonom tarım robotuna sensörler ve emniyet elemanları eklenerek, rota üzerindeki engellere çarpmadan istenen noktaya ulaşması sağlanmıştır.

Bu çalışmada, tarım sektöründeki mevcut sorunlara yenilikçi çözümler sunarak gelecekte daha verimli bir tarım sistemi oluşturulması hedeflenmektedir. Geliştirilen otonom robot; gelişmiş sensörler ve yapay zekâ teknolojileri sayesinde tarımsal ürünlere ait verileri analiz ederek çapalama işlemlerini gerçekleştirmektedir. Otonom tarım robotu sıra boyunca ilerlerken yabani otları ana üründen ayırıp imha ederek çapalama işlemi yapmaktadır. Yabani otları yetiştirilmek istenen bitkiden ayırt etmek için yapay zekâ tabanlı yöntemlerden yararlanılmaktadır. Çalışmada YOLOv8 modeli kullanılarak ürün tanıma ve sınıflandırma konularında yüksek doğruluk oranlarına ulaşılmıştır.

Anahtar Kelimeler : çapalama, tarım robotu, otonom robot,

Liquid-Dependent Wettability Behavior of Lotus-Inspired Surfaces Fabricated by FDM

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ABSTRACT

This study aims to adapt functional surfaces found in nature to engineering applications using additive manufacturing technologies. Inspired by the self-cleaning and water-repellent properties of the lotus leaf, four different microgeometric models were produced using the Fused Deposition Modeling (FDM) method. A model with a flat surface was also produced for comparison. The wettability behavior of these biomimetic surfaces was examined in detail using contact angle (CA) measurements. The study evaluated the effect of different geometric models on surface energy. Furthermore, the effect of different droplets (water, oil, and milk) on the contact angle of the liquid was also investigated. The findings showed that surfaces designed at the micro scale using the FDM method can exhibit wetting behavior similar to the lotus effect. Furthermore, it was observed that the contact angle measurement with different liquids had a significant effect on the contact angle value. This approach, thanks to the controllability of both surface morphology and production parameters, offers a new research area for the functional design of FDM-based biomimetic surfaces..

Keywords: Additive manufacturing, FDM, Lotus effect, Wettability, biomimetic

INTRODUCTION

In recent years, additive manufacturing (AM) has made significant progress, evolving from a rapid prototyping method into a versatile production platform. Unlike traditional manufacturing methods, which rely on tools such as molds and machining, AM technology provides high design freedom and dimensional accuracy by producing layers directly from digital models. AM enables the production of complex structures even in very small-sized materials. For this reason, it has become a popular field that enables the production of geometrically precise, functionally reliable, and economically viable components by providing control over microstructure and surface properties (Ngo et al. 2018; Solomon et al. 2021).

The additive manufacturing process is based on converting a three-dimensional (3D) virtual model created in a computer environment into a physical product using a layer-based approach. In this process, the desired part is first modeled in a digital environment using computer-aided design (CAD) software. Then, this 3D model is divided into two-dimensional (2D) sections using slicing software, and the production data for each layer is transferred to the additive manufacturing system. During the production phase, the machine uses this data as a reference to build up the material in successive layers according to the specified production parameters. Thus, the model designed in the digital environment is converted into a physical part (Abdulhameed et al. 2019; Ashley 1991; Gibson et al. 2021; Kruth 1991; Mueller 2012; Wohlers et al. 2016).

In additive manufacturing techniques, Fused Deposition Modeling (FDM), Laminated Object Manufacturing (LOM), and Selective Laser Sintering (SLS). Among these methods, systems such as SLA, SLS, and FDM have become more widely preferred (Wang et al. 2017). Fused Deposition Modeling (FDM) has become one of the most widely used and economically accessible methods among additive manufacturing technologies. In this technique, a thermoplastic filament is heated to a specific temperature until it becomes semi-molten and then extruded layer by layer through an extrusion head. Following a roadmap obtained from computer-aided design (CAD) data, the material is extruded in a controlled manner onto the production platform to create three-dimensional structures. The most commonly used materials in the process include thermoplastics such as ABS, PLA, PETG, and PCL. There are many studies in the literature related to FDM. In particular, there are many studies on the surface properties (Anitha et al. 2001; Thrimurthulu et al. 2004) and mechanical performance (Bertoldi et al. 1998; Popescu et al. 2018; Rodríguez et al. 2003; Zaldivar et al. 2017) of FDM production parameters.

The FDM method not only enables the production of complex geometries but also allows for the controlled design of surface morphology and roughness. Production parameters (nozzle temperature, layer thickness, scanning speed, infill density, etc.) have a direct effect on surface roughness, porosity, and material deposition behavior (Dey and Yodo 2019). These micro- and nano-scale topographical changes play a critical role, particularly in determining the wettability properties of the surface. Wettability defines a liquid's tendency to spread on a solid surface and is primarily determined by surface energy and roughness (Donaldson and Alam 2013). Hydrophobicity and hydrophilicity are among the most fundamental surface properties that

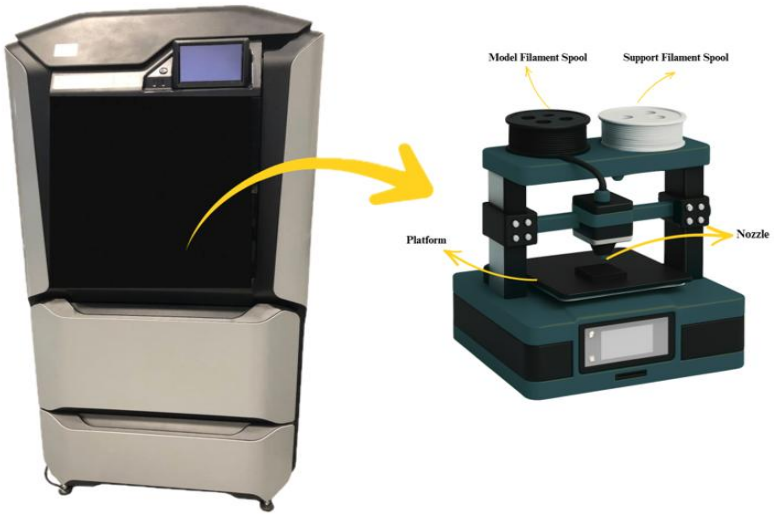
determine a surface's interaction with liquids. These two concepts are of critical importance in many fields, particularly surface engineering, biomaterials, tribology, and corrosion control. On hydrophilic surfaces, liquid droplets spread out, and the contact angle is typically below 90°. Surface energy is high on such surfaces; therefore, liquid molecules adhere to the surface. In contrast, hydrophobicity is observed on surfaces with low surface energy. In this case, the liquid droplet remains spherical rather than contacting the surface; the contact angle is above 90° (Gao and Yan 2012). Hydrophobicity is a surface's tendency to repel water molecules or, when in contact with water, to cause water droplets to roll off the surface in a spherical form without wetting it (Law 2014; Marmur et al. 2017). Hydrophobic surfaces are important for practical applications such as self-cleaning, corrosion prevention, improved heat transfer, or chemical protection (Blossey 2003; Pan et al. 2013; Vakarelski et al. 2012; Wang et al. 2006).

With the advancement of technology, surfaces with improved performance have been developed using materials that exist in nature and are widely preferred. Biomimicry refers to the process of imitating, adapting, or attempting to derive similar structures from biologically active systems found in nature. In nature, there are numerous examples that exhibit excellent hydrophobic and superhydrophobic behavior thanks to the interaction between the chemical composition of the surface and its micro/nano-scale morphology. Scientists inspired by nature have produced biomimetic hydrophobic surfaces by drawing inspiration from different types of living organisms such as lotus leaves, spider webs, rice leaves, or butterfly wings (Guo et al. 2011; Hwang et al. 2015). The lotus effect of hydrophobic surfaces has been studied theoretically and experimentally for many years (He et al. 2022; Parvate et al. 2020; Si et al. 2018; Yang et al. 2015). Wang et al. (2009) proposed that the superior water-repellent property of the lotus leaf arises from the combined action of micro- and nano-topographies, where micro-pillars provide air entrapment and the “plastron” effect on the surface, while nano-pillars optimize surface energy. While the lotus front surface is classified as a true superhydrophobic surface, the back surface, despite having a high contact angle, is considered a metastable hydrophobic surface rather than an ultra-hydrophobic one due to its high hysteresis. In another study, silica particles were deposited onto the surface using spray coating to achieve a lotus effect, resulting in a micro- and nano-scale surface. The produced surfaces exhibited a pronounced lotus effect with a contact angle (CA) of 166–168° and a contact angle hysteresis (CAH) of 1–2° (Ebert and Bhushan 2012).

In this context, this study aims to investigate the wettability behavior of different surface geometries produced by Fused Deposition Modeling (FDM) inspired by the self-cleaning and superhydrophobic properties of the lotus leaf. The effects of different microgeometric models (five different surface patterns) on surface energy, contact angle, and contact angle hysteresis were systematically evaluated. With this approach, by mimicking hierarchical surface structures found in nature using FDM technology, the study aims to offer a new perspective on the effects of production parameters and surface topography on wettability. The study aims to establish a guiding framework for the functional design of FDM-based biomimetic surfaces.

EXPERIMENTAL DETAILS

In this study, five different lotus models were examined using the Fused Deposition Modeling (FDM) method on a Stratasys F170 machine. The lotus models were designed using the Solidworks 2025 computer-aided design (CAD) program. All models were produced in 30x30x3mm3 dimensions. The designed models were also saved in Stereolithography (.Stl) format for 3D printing.



Visual 1. Device in the Fused Deposition Modeling (FDM) method

F123 ABS (Acrylonitrile Butadiene Styrene) material was used in this study. This material is a type of thermoplastic material frequently used in functional prototyping or engineering applications, in addition to its high impact resistance, mechanical strength, and heat resistance. The properties of the parameters used are given in Table 1.

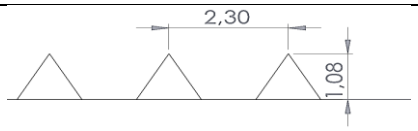
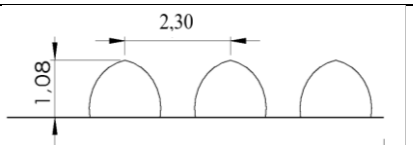
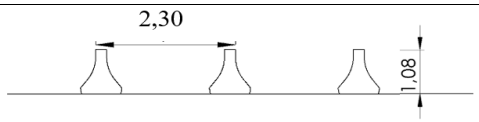
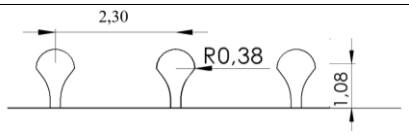
Table 1. FDM device parameters and features

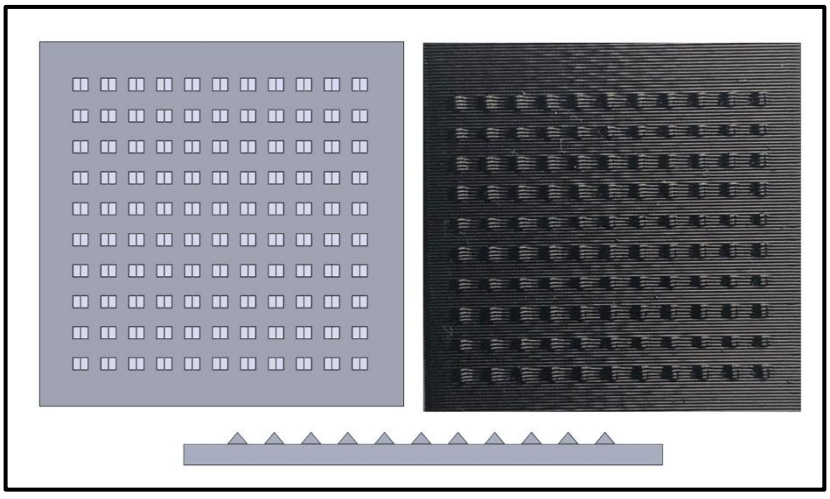
Parameters	**Properties**
Materials	F123 ABS
Support Materials	QSR Support
Nozzle temperature (°C)	230-260°C
Build plate temperature (°C)	90-110°C
Nozzle diameter	0.4 mm

Lotus models were designed in Solidworks 2025. Details of the samples planned for production are shown in Visual 2, Visual 3, Visual 4, Visual 5 and Visual 6. All models were created with dimensions of 30x30x3mm³. A total of 110 textures were obtained with a count of 11x10, and

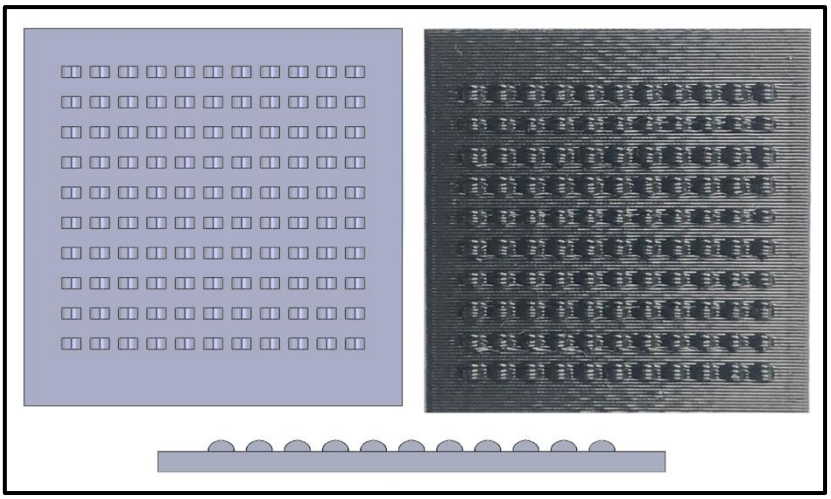
all textures were drawn with the same width and height. These specifications are also provided with technical drawings in Table 2.

Table 2. Specifications for the dimensions of Lotus models

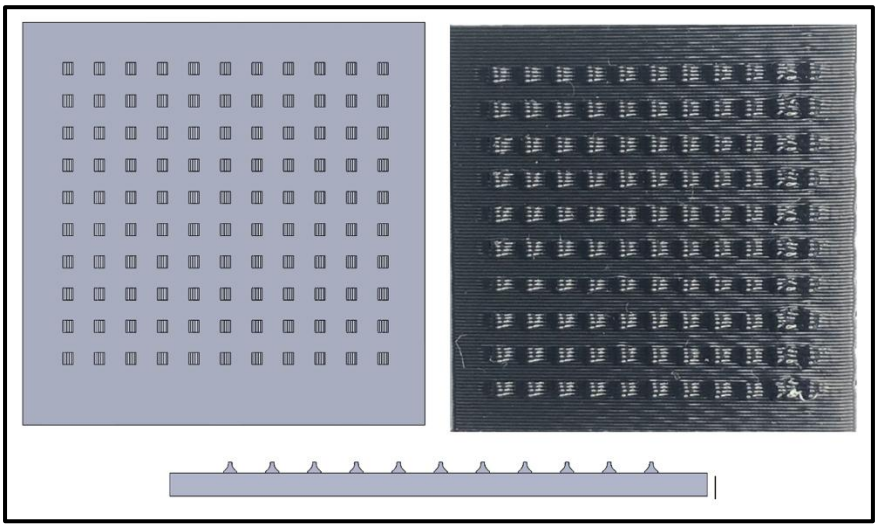
Lotus modeli (L1)	
Lotus modeli (L2)	
Lotus modeli (L3)	
Lotus modeli (L4)	



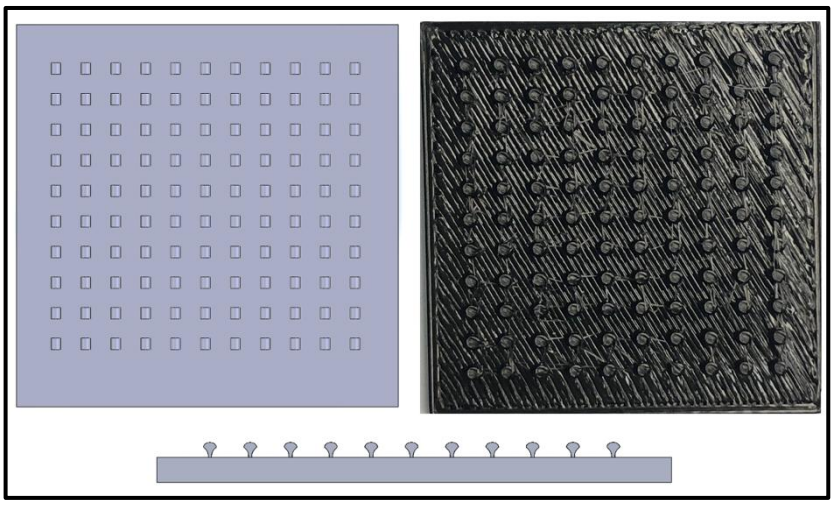
Visual 2. Lotus model (L1)



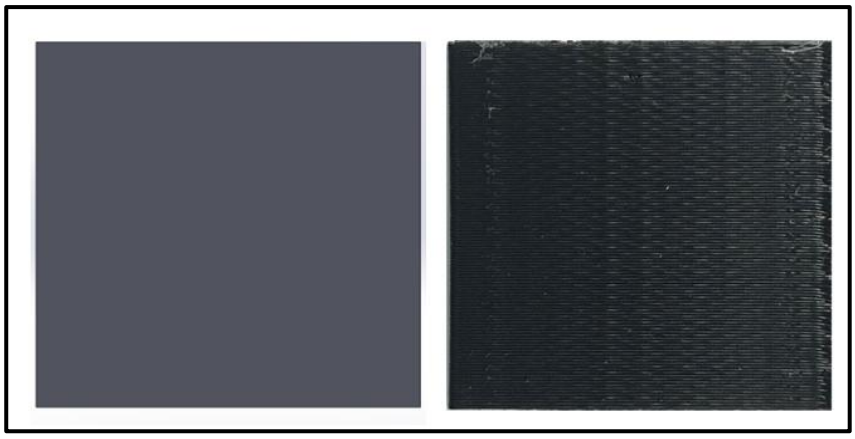
Visual 3. Lotus model (L2)



Visual 4. Lotus model (L3)



Visual 5. Lotus model (L4)



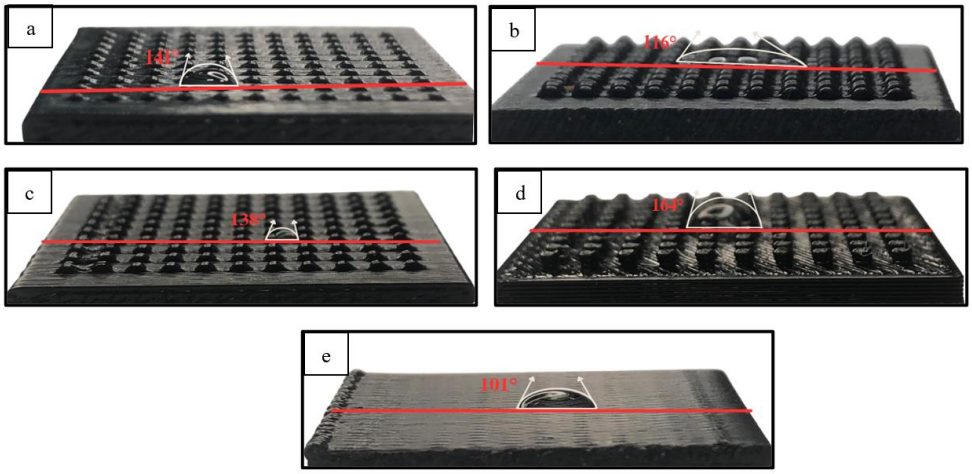
Visual 6. Lotus model (L5)

RESULTS AND DISCUSSION

In this study, inspired by the self-cleaning and superhydrophobic properties of lotus leaves, four different model designs were created using the FDM method. In the L1 model (Visual 2), the contact area was limited by using a sharp-edged triangular-like structure. In the L2 model (Visual 3), a curved geometry was obtained by providing a rounded transition on the surface. This structure is rounded dome-like and increases the contact area between the liquid and the surface. In the L3 model (Visual 4), a mushroom-like structure was created to provide the model most similar to a lotus leaf, and liquid flow into the micro-pockets was prevented by the indented structure. Finally, the L4 model (Visual 5) obtained a wide-headed surface, which is the opposite of the L3 model.

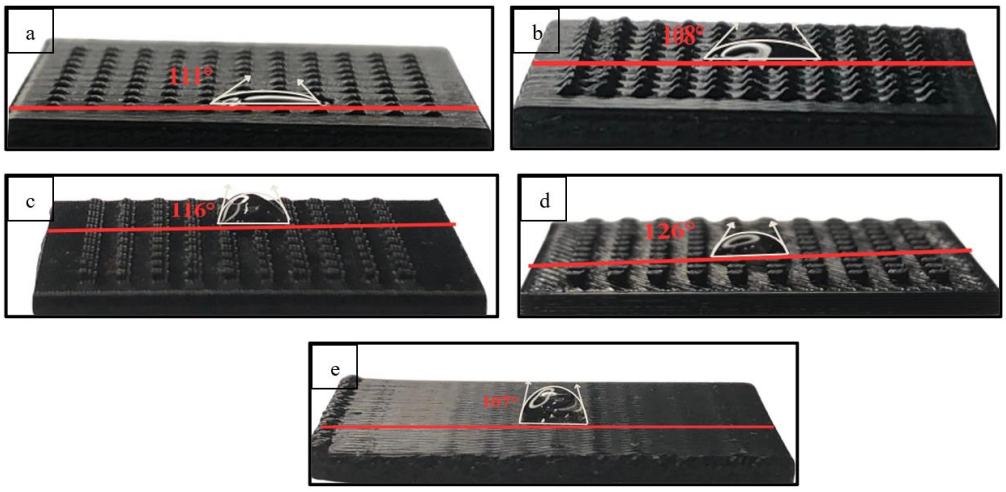
As is well known, the lotus leaf structure consists of randomly distributed micropillar structures. These micro pillars reduce surface contact and cause air to become trapped in micro voids due to their indentation structure. Thus, instead of spreading over the entire surface of the material, the liquid interacts with the peaks of the roughness (Zhang et al., 2016). The fundamental reason for this behavior is the Cassie–Baxter type wetting regime that occurs on the surface. In this regime, the liquid does not contact the entire surface. Air pockets are trapped between the peaks of the micro-protrusions, and the droplet remains suspended on the surface. Contact angle measurements were performed with water, oil, and milk on the structures obtained in this study, and the results are detailed in Visual 7-8-9. As a result of contact angle measurements performed on lotus models, it was observed that the wettability behavior exhibited by surface models towards different liquids changed significantly.

Visual 7 shows the contact angle values obtained from the water contact angle measurement. Based on the data obtained, the contact angle of all models created with FDM was higher than that of the flat model (L5). The contact angle was 164° in the L4 model and 101° in the L5 model. This result shows that the pillar-like models created on the surface significantly contribute to hydrophobic behavior and even lead to superhydrophobic behavior. Furthermore, the highest contact angle was obtained from the L4 model, and the lowest contact angle value was obtained in L5. The L4 model features structures with air pockets, similar to the lotus structure. This contributed to the reduction in contact.



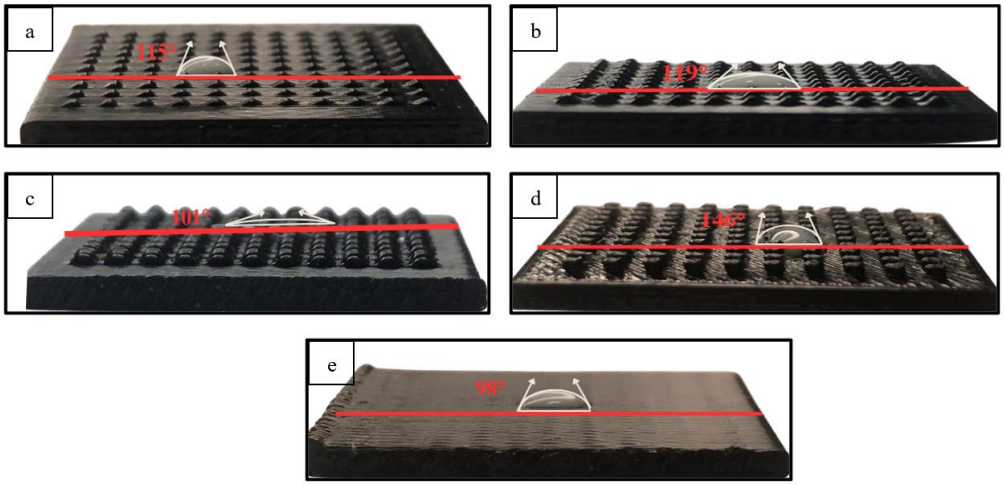
Visual 7. Contact angles of Lotus models with water a.) L1 b.) L2 c.) L3 d.) L4 and e.) L5

Visual 8 shows the results of the contact angle measurement with oil. Lower values were obtained in the contact angle measurement with oil than in the measurement with water. This situation is explained in terms of surface tension. Under normal conditions, the viscosity of oil is considerably higher than that of water. The viscosity of oil is between 50 and 90 mPa·s (Anand et al. 2010; Yalcin et al. 2012), while the viscosity of water is between 0.9 and 1.0 mPa·s (Tørklep 1993). However, surface energy is more important than viscosity in contact angle here. The viscosity value provides information about the spreading speed of the liquid. During the contact angle test, the oil droplet reached the final spreading area on the surface more slowly than water due to its high viscosity. However, the contact angle of the oil droplet decreased compared to the water droplet. As in the contact angle measurement with water, the highest contact area was obtained in sample L4 with 126°. The lowest contact angle was obtained in the L5 model. Interestingly, the L2 model yielded almost the same contact angle value as L5. This indicates that this geometric model does not support oleophobic behavior in terms of contact angle with oil. However, the L4 model exhibited oleophobic behavior compared to the flat model.



Visual 8. Contact angles of Lotus models with oil a.) L1 b.) L2 c.) L3 d.) L4 and e.) L5

Visual 9 shows the data obtained from the contact angle measurement with milk. The complex composition of milk is reflected in the contact angle measurement on the surface. Milk has a complex composition of water, protein, and fat (Walstra et al., 2005). In this case, a higher contact angle value was obtained than with oil. The contact angle value for the L4 model is 146°, while the contact angle for L5 is 98°. The protein and fat structure in milk exhibited a partially more spreading tendency behavior compared to water.



Visual 9. Contact angles of Lotus models with milk a.) L1 b.) L2 c.) L3 d.) L4 and e.) L5

Table 3 summarizes the data obtained from contact angle measurements with all liquids. Based on the results obtained, the L4 model was found to be the most similar to the lotus leaf in terms of geometry. In the L4 model, the indented grooves create air pockets, reducing the adhesion force between the liquid and the surface. Furthermore, the geometry on the upper surface of the model contributed to the reduction in the contact area. The contact angle includes not only surface-liquid contact but also solid-gas and liquid-gas contact. Therefore, the formation of air pockets is crucial in terms of the contact angle. Subsequently, it was observed that the contact angle value of the L1 model was generally high. This can be explained by the reduction in the liquid-solid contact area. At the same time, it was observed that the contact angle measurements obtained with water were higher than those obtained with other liquids. This can be explained by the surface tension of water droplets.

Table 3. Comparison of contact angles of lotus models with water, oil, and milk

Lotus Model Code	Contact Angle Water (°)	Contact Angle Milk (°)	Contact Angle Oil (°)
L1	141°	115°	111°
L2	116°	119°	108°
L3	138°	101°	116°
L4	164°	146°	126°
L5	101°	98°	107°

CONCLUSION

This study investigated the wettability behavior of materials with lotus-inspired surface geometries produced by the FDM method in liquids with different chemical properties such as water, oil, and milk. The results obtained are presented below:

- The results indicate that the contact angle depends not only on liquid-surface (solid) interaction but also on liquid-gas and surface-gas interfaces.
- The L4 geometric model, thanks to the indented channels it creates in the neck region, supports the formation of air pockets, resulting in the structure most similar to a lotus leaf.
- The highest contact angle value for wettability behavior in all liquids was obtained in L4, while the lowest value was obtained in L5.
- In the L4 geometric model, air pockets and surface texture reduced the contact area between the liquid and the surface, contributing to the contact angle.
- In the L1 geometric model, the contact angle value was observed to be the highest after L4, especially due to the reduction in the contact surface area.
- Due to the high surface tension of water, a high contact angle behavior was obtained compared to other liquid droplets.

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SÜRDÜRÜLEBİLİR KALKINMA HEDEFLERİNİN KÜLTÜREL MİRAS YÖNETİMİNE ETKİSİ: KAYSERİ KALESİ ÖRNEĞİ

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ÖZET

Sürdürülebilir kültürel miras yönetimi, kültürel miras, toplum ve çevre arasındaki ilişkinin uzun süreli olarak korunmasını sağlayarak sadece günümüz değil, gelecek kuşakların da mirası deneyimlemesine imkân tanır. Bu çalışmada, Roma, Bizans ve Selçuklu dönemlerinden günümüze ulaşan çok çeşitli bir tarihi dokuya sahip Kayseri Kalesi ele alınarak, sürdürülebilir kalkınma hedeflerinin (SKA) kültürel miras yönetimiyle kesişim noktaları değerlendirilmiştir.

Kent merkezinde yer alan Kayseri Kalesi, Roma döneminde bir savunma yapısı olarak inşa edilmiş; Bizans döneminde güçlendirilmiş ve Selçuklu döneminde ise kentsel yaşamla daha bütünleşik bir kimlik kazanmıştır. Bu tarihsel süreç, kalenin farklı dönemlerde değişen toplumsal ve siyasi ihtiyaçlara uyum sağlayarak yeniden biçimlendiğini göstermektedir. Bu bağlamda Kayseri Kalesi, yalnızca bir savunma yapısı olmaktan çıkıp kentin kimliğini ve hafızasını temsil eden, çeşitli kültürel etkinliklerin düzenlendiği önemli bir kültürel miras unsuruna dönüşmüştür.

Özellikle SKA 11'in 4. hedefi, "kültürel ve doğal mirasın korunması ve güçlendirilmesi" çerçevesinde, Kayseri Kalesi'nde yürütülen uygulamalar ve mevcut eksiklikler üzerinde değerlendirildiğinde, bu çerçevede önemli bir alan ortaya çıkmaktadır. Ayrıca, turizmle doğrudan ilişkisi olan SKA 8'in kültürel miras temelli sürdürülebilir turizmi teşvik eden alt hedefleri eklendiğinde, kalenin ekonomik canlanmaya katkısı ve istihdam üzerindeki etki ettiği görülmüştür. Bunlara ek olarak eklenecek birkaç SKA ile birlikte çalışmada bu hedeflerin uygulanabilirliği, miras yönetimi süreçlerine yön verdiği noktalar ve mevcut uygulamaların sürdürülebilirlik boyutları genel bir yaklaşımla değerlendirilmiştir. Kayseri Kalesi üzerinden yapılan bu değerlendirme, sürdürülebilir kalkınma hedeflerinin kültürel miras yönetiminde yalnızca mevcut uygulamaları geliştirmekle kalmayıp, gelecekte daha kapsayıcı, toplum odaklı ve çevresel açıdan duyarlı bir miras politikası geliştirilmesine de yön verebilecek bir çerçeve sunduğunu ortaya koymaktadır.

Anahtar Kelimeler : Sürdürülebilir Kalkınma, Kültürel Miras Yönetimi, Kayseri Kalesi, Sürdürülebilir Kalkınma Hedefleri

THE IMPACT OF SUSTAINABLE DEVELOPMENT GOALS ON CULTURAL HERITAGE MANAGEMENT: THE CASE OF KAYSERI CASTLE

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ABSTRACT

Sustainable cultural heritage management ensures the long-term preservation of the relationship between cultural heritage, society, and the environment, enabling not only present but also future generations to experience this heritage. In this study, Kayseri Castle, which has a diverse historical fabric dating from the Roman, Byzantine, and Seljuk periods to the present, is examined, and the intersection points between the Sustainable Development Goals (SDGs) and cultural heritage management are evaluated.

Kayseri Castle, located in the city center, was built as a defensive structure during the Roman period, strengthened in the Byzantine period, and gained a more integrated identity with urban life during the Seljuk period. This historical process demonstrates that the castle was reshaped by adapting to changing social and political needs in different periods. In this context, Kayseri Castle has transformed from merely a defensive structure into an important cultural heritage element representing the identity and memory of the city, where various cultural events are held.

Especially when SDG 11.4, which focuses on the “protection and strengthening of cultural and natural heritage,” is considered together with the practices carried out in Kayseri Castle and the existing deficiencies, a significant field emerges within this framework. Additionally, when the sub-targets of SDG 8, which promote cultural heritage-based sustainable tourism and are directly related to tourism, are taken into account, the castle's contribution to economic revitalization and its impact on employment become evident. Along with a few other SDGs to be added, the applicability of these goals, the points at which they guide heritage management processes, and the sustainability dimensions of current practices have been evaluated with a general approach. The evaluation based on Kayseri Castle reveals that the Sustainable Development Goals not only improve current practices in cultural heritage management but also provide a framework that can guide the development of a more inclusive, community-oriented, and environmentally sensitive heritage policy in the future.

Keywords: Sustainable Development, Cultural Heritage Management, Kayseri Castle, Sustainable Development Goals

1. GİRİŞ

Sürdürülebilirlik, doğal, sosyal ve ekonomik kaynakların gelecek kuşakların ihtiyaçlarını düşünerek uzun vadeli biçimde yönetilmesini hedefleyen genel bir yaklaşımdır. Günümüzde bu yaklaşım, farklı disiplinlerde olduğu gibi kültürel miras alanında da giderek daha fazla önem kazanmaktadır. Birleşmiş Milletler tarafından geliştirilen ve küresel ölçekte benimsenen Sürdürülebilir Kalkınma Amaçları (SKA), sürdürülebilirlik ilkelerinin kültürel, sosyal ve çevresel boyutlarla birlikte ele alınmasına olanak sağlamaktadır.

Kültürel miras; tarihsel yapılar, arkeolojik alanlar ve anıtlar gibi somut değerlerin yanı sıra, gelenekler, beceriler ve toplumsal hafıza gibi somut olmayan unsurları da kapsayan, toplumların kimliğini ve sürekliliğini yansıtan önemli bir kaynaktır. Bu bağlamda kültürel mirasın korunması ve yönetimi, yalnızca geçmişin korunması değil; aynı zamanda kentsel planlama, mimarlık ve çevresel sürdürülebilirlik ile birlikte ele alınması gereken bütüncül bir süreçtir (Hoşkara, Lombardi & Doğaner, 2021).

BM 2030 Gündemi kapsamında kültür ve miras, özellikle SKA 11'in 4. hedefi ile doğrudan ilişkilendirilmekte; kültürel ve doğal mirasın korunması sürdürülebilir kentlerin temel bileşenlerinden biri olarak ele alınmaktadır. Bunun yanı sıra SKA 8, 4, 12 ve 17 gibi hedefler, kültürel mirasın ekonomik, eğitsel ve yönetişim boyutlarıyla dolaylı ilişkiler kurmaktadır (Soykök Ede & Taş, 2025).

Bu çalışma, söz konusu ilişkileri tarihsel sürekliliği ve güncel işlevlendirme süreçleriyle dikkat çeken Kayseri Kalesi üzerinden değerlendirmektedir. Roma döneminde savunma yapısı olarak inşa edilen ve farklı uygarlıklar tarafından onarılarak günümüze ulaşan kale, günümüzde kültürel ve kamusal kullanımlarla kentsel belleğin önemli bir parçası hâline gelmiştir. Bu yönüyle Kayseri Kalesi, sürdürülebilir kültürel miras yönetiminin SKA'lar bağlamında tartışılabileceği özgün bir örnek sunmaktadır.

2.KAYSERİ KALESİ: TARİHSEL SÜREÇ VE MEKÂNSAL GELİŞİM

Bu bölümde, Kayseri Kalesi'nin tarihsel süreç ve mekânsal gelişimi ele alınmaktadır. İlk olarak kalenin kentsel konumu ve kent içindeki önemi, Mazaka/Eusebeia'dan Kaisareia'ya uzanan yerleşim süreci üzerinden değerlendirilmiştir. Ardından kalenin mimari kurgusu ve yapı malzemeleri, iç ve dış kale düzeni, sur sistemi, burçlar ve onarım süreçlerinde kullanılan malzemeler açıklanmıştır. Son olarak ise Kayseri Kalesi'nin tarihsel gelişimi, Roma, Bizans, Selçuklu ve Osmanlı dönemleri boyunca geçirdiği yapısal ve işlevsel değişimler çerçevesinde incelenmiştir ve savunma yapısından kentsel miras alanına dönüşümü, yeniden işlevlendirme çalışmaları ve güncel kültürel kullanımlar bağlamında ele alınarak yapının günümüz kent yaşamıyla kurduğu ilişki ortaya konulmuştur.

2.1. KAYSERİ KALESİ'NİN KENTSEL KONUMU VE ÖNEMİ

Kayseri'de ilk yerleşimin, Erciyes Dağı'nın eteklerinde konumlanan ve antik kaynaklarda Mazaka ya da Eusebeia olarak anılan eski şehir çevresinde başladığı bilinmektedir. Kaniş'in yıkılışından (MÖ 1200) yüzyıllar sonra kurulan Mazaka, zamanla Kapadokya Krallığı'nın başkenti hâline gelmiş ve kenti çevreleyen savunma surlarıyla tanımlanan bir yerleşim karakteri kazanmıştır. MÖ 2. yüzyıl ortalarında V. Ariarathes döneminde inşasına başlanan ve MS 4. yüzyıl başlarına kadar çeşitli onarımlarla kullanılan bu surlar, kentin erken dönem savunma sistemini oluşturmaktadır (Erkiletlioğlu, 2024). Mazaka'nın kesin konumu konusunda tarihçiler arasında görüş birliği bulunmamakla birlikte, genel kabul, yerleşimin Erciyes'in eteklerinde, günümüz Kayseri kent merkezinin yaklaşık iki kilometre güneybatısında yer alan tepeler üzerinde geliştiği yönündedir. Bu bölge, tarihsel kaynaklarda "Eski Şehir" ya da "Eski Kayseri" olarak anılmakta; farklı dönemlerde Ermeni kaynaklarında "Zorzat" veya "Zorzot" isimleriyle de tanımlanmaktadır(Erkiletlioğlu, 2024). Antik Dönem'in en önemli coğrafya kaynaklarından biri olan Strabon'un Geographika adlı eserinde, MS 1. yüzyıl başlarında kentin adının Mazaka/Eusebeia'dan Kaisareia'ya dönüştüğü belirtilmekte ve yerleşimin bu erken çekirdeğinin, sonraki kentsel gelişimin temelini oluşturduğu ifade edilmektedir (Strabon, 1987). Günümüzde Kayseri Kalesi'nin konumu genelden özele doğru bir anlatımla aşağıdaki görselde sunulmuştur (Görsel 1).



Görsel 1. Kayseri Kalesi'nin Kentteki Konumu, 2025

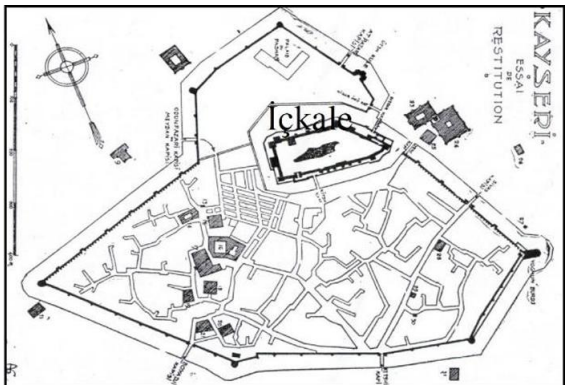
Kentin önemli bir konumunda ve ilk yerleşim bölgesinde bulunan Kayseri Kalesi'nin çevresinde de şehri temsil eden önemli yapılar, anıtlar, caddeler ve sokaklar bulunmaktadır. Kayseri için geçmişten gelen öneme sahip Cumhuriyet Meydanı ve kapalı çarşının yanında konumlanan kalenin etrafında Kayseri Ulu Cami, Hunat Cami ve Bürüngüz Cami gibi Kayseri halkı için önemli camiler de bulunmaktadır. Ayrıca Sivas bulvarı, Seyyid Burhannettin bulvarı, Park bulvarı gibi şehrin önemli bulvarlarının kesişim noktasında konumlanmaktadır. Harita üzerinde kale ve çevresi sunulmuştur (Görsel 2).

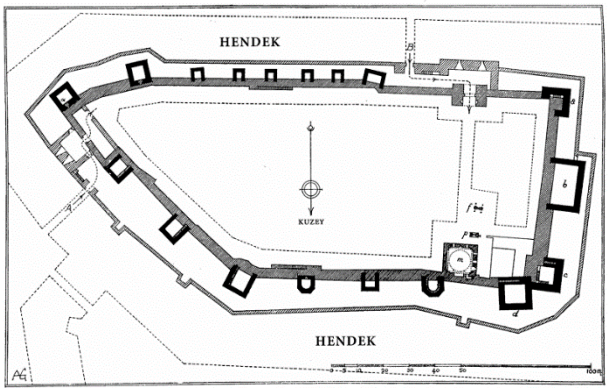


Görsel 2. Kayseri Kalesi ve Çevresi, 2025

2.2. KAYSERİ KALESİ'NİN MİMARİ KURGUSU VE YAPI MALZEMELERİ

Kayseri Kalesi, kentin tarihine tanıklık eden en önemli yapılardan biridir. İç ve dış kale olmak üzere iki bölümden oluşan yapı kent merkezinde yer almaktadır. Dış kale surlarının büyük bölümü günümüze ulaşamamış olsa da ayakta kalan burçlar sur hattının kısmen okunmasına olanak tanımaktadır. İç kale ise günümüzde tamamen ayakta olup savunma yapısı niteliğini korumaktadır (Eldek, 2021). Korunmuş olan iç kale ise beden duvarlarıyla birlikte bu duvarlara entegre edilmiş farklı boyutlarda 18 burçtan ve burçlar üzerinde konumlanan iki kapıdan oluşmaktadır (Akşehirlioğlu & Kaderli & Kozlu). Ayrıca Osmanlı döneminde alınan ilk kayıtlarda yapılan tamir işlerinde kullanılan malzemeler kayıt altına alınmıştır. Demir, kömür, ağaç, kum ve köylerden getirilen yapı taşları tamirde kullanılan malzemelerden bir kaçını oluşturmaktadır (İnbaşı, 2000). Kayseri Kalesi'nin eski yerleşimini gösteren planları Albert Gabriel tarafından çizilmiştir (Görsel 3 ve Görsel 4).

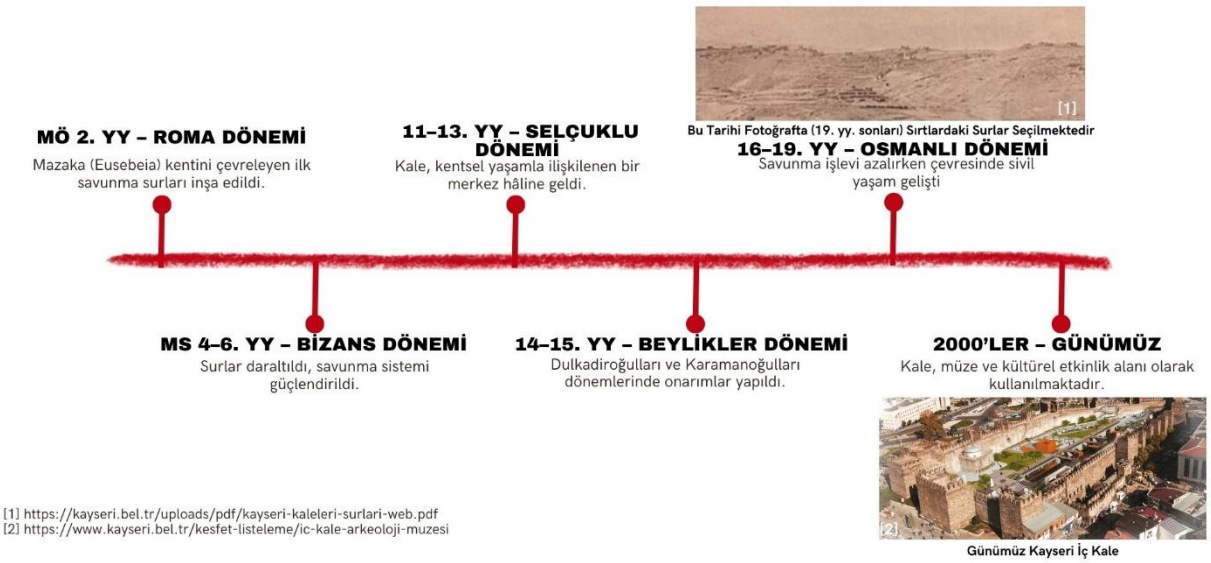




Görsel 3. Kayseri Eski Kent Planı (Gabriel, 1931) **Görsel 4. Kayseri Kale'nin Planı(Gabriel, 1931)**

2.3. KAYSERİ KALESİ'NİN TARİHSEL GELİŞİMİ VE KENTSEL MİRAS ALANINA DÖNÜŞÜMÜ

Yazılı kaynaklar, Kayseri Kalesi'nin tarihsel gelişiminin, erken dönemlerde yerleşimi tam anlamıyla tanımlamayan ve daha çok çevresel unusurları kapsayan savunma hatlarıyla başladığını, bu savunma kurgusunun zaman içinde kentin büyümesi ve değişen askeri ihtiyaçlar doğrultusunda daha genel bir kale yapısına dönüştüğünü ortaya koymaktadır (Prokopius, 1940). Roma döneminde biçimlenen sur örgüsü, Bizans döneminde gerek daraltılarak gerekse yeniden tahkim edilerek kentin güvenlik gereksinimlerine uyum sağlamıştır. Bu bağlamda, Bizans döneminde gerçekleştirilen müdahalelerle savunma açısından yetersiz kalan erken dönem surlarının yeniden düzenlendiği ve kentin askeri denetimini güçlendiren daha tanımlı bir kale kurgusunun oluşturulduğu anlaşılmaktadır (Gabriel, 1931). 11. yüzyıl ve sonrasında Danişmendliler ile Anadolu Selçukluları zamanında kale, özellikle I. Alaeddin Keykubat döneminde kapsamlı onarımlar görmüş, iç ve dış kalelerin çevresindeki savunma sistemleri güçlendirilmiştir. Farklı dönemlerde Osmanlı egemenliği altında da tamirat ve değişimlere uğrayan yapı, özellikle Osmanlı döneminde kentin savunma ihtiyacının azalmasıyla ikincil yaşamsal fonksiyonlar kazanmıştır. Kayseri Kalesi'nin Roma döneminden günümüze uzanan tarihsel süreci aşağıda verilen zaman çizelgesinde gösterilmiştir (Görsel 5).



Görsel 5. Kayseri Kalesi Zaman Çizelgesi, 2025

Bu uzun tarihsel süreç, kalenin mimari bileşenlerinin farklı uygarlıklar tarafından yeniden biçimlendirilmesine ve çevresel bağlamla ilişkilenmesine imkân tanımıştır. Bu tarihsel gelişim süreci, Kayseri Kalesi'ni yalnızca bir savunma yapısı olmaktan çıkarıp kentin sürekliliğini ve kimliğini temsil eden bir kültürel miras öğesine dönüştürmektedir (Görsel 6 ve Görsel 7).

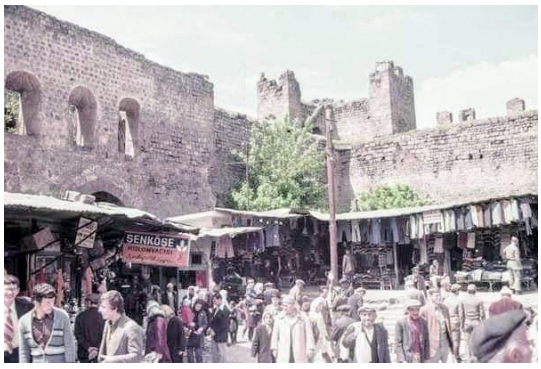


Görsel 6. Kayseri Kalesi, Walter Becke, 1930



Görsel 7. Kayseri Kale İçi, 2013

İlk inşa edildiği dönemlerde surları, burçları ve kontrollü girişleriyle kentsel savunma sisteminin temel unsurlarından biri olan kale, zamanla savunma stratejilerinin değişmesi ve kent yaşamının dönüşmesiyle birlikte bu özgün işlevini büyük ölçüde yitirmiştir. Savunma amaçlı inşa edilen surların işlevsiz hâle gelmesi, yapının kent içindeki rolünün yeniden değerlendirilmesini gerekli kılmıştır. Yakın geçmişte çarşı işleviyle kentsel yaşama dâhil edilen kale, günümüzde ise gerçekleştirilen mimari proje ve müdahaleler sonucunda yeni işlevlerle tekrardan kente kazandırılmıştır. Aşağıdaki görsellerde kale içinin çarşı olarak kullanıldığı zamandan görseller sunulmuştur (Görsel 8 ve Görsel 9).



Görsel 8. Kayseri Kale İçi, 2008



Görsel 9. Kayseri Kale İçi, 2008

İç Kale'nin günümüz kültür–sanat kullanımlarına dönüştürülmesi için 2008 yılında açılan ulusal mimarlık yarışması sonucunda seçilen proje uygulanmış olup, bu kapsamda kültürel etkinlik mekânları ve kamusal alanlar yaratılmıştır (Muş & Kevseroğlu, 2023). Yapılan proje kapsamında iç kalede arkeoloji müzesi, sergi alanları ve kamusal kullanımı destekleyen kafe gibi mekânlar oluşturulmuş, bu alanlar sayesinde yapı, kültürel üretim ve sosyal etkileşim odaklı bir mekâna dönüşmüştür. Ayrıca kale içerisinde düzenlenen sergiler, festivaller ve çeşitli kültürel etkinlikler, yapının yalnızca korunmasını değil, aktif biçimde kullanılmasını da sağlayarak kentsel yaşamla kurduğu bağı güçlendirmektedir. Bu bağlamda Kayseri Kalesi, tarihsel kimliğini koruyarak günümüz ihtiyaçlarına uyum sağlayan, yaşayan bir kentsel miras alanı niteliği kazanmıştır. Kayseri Kalesinde 2025 yılında yapılmış olan mimarlık festivali (Görsel 10 ve Görsel 11).





Görsel 10 ve Görsel 11. Kayseri Kalesi, Mimarlık Festivali, 2025

3. SÜRDÜRÜLEBİLİR KÜLTÜREL MİRAS YÖNETİMİ VE SÜRDÜRÜLEBİLİR KALKINMA AMAÇLARI

Bu bölümde sürdürülebilir kültürel miras yönetimi kavramı, kavramsal çerçevesiyle ele alınmaktadır. İlk olarak sürdürülebilirlik kavramı ile kültürel miras arasındaki ilişki, mirasın korunması, yönetimi ve gelecek kuşaklara aktarılması bağlamında değerlendirilmiştir. Ardından Sürdürülebilir Kalkınma Amaçlarının kültürel mirasla ilişkisi, özellikle SKA 11.4 başta olmak üzere doğrudan ve dolaylı bağlantılar kuran hedefler üzerinden incelenmiştir. Bu çerçeve doğrultusunda, sürdürülebilir kültürel miras yönetimi yaklaşımlarının, tarihsel savunma işlevini yitirmiş ancak kentsel bellekteki önemini koruyan Kayseri Kalesi'nin güncel kullanım kararlarının değerlendirilmesi için nasıl bir zemin oluşturduğu ortaya konulmuştur.

3.1. SÜRDÜRÜLEBİLİRLİK KAVRAMI VE KÜLTÜREL MİRAS

Sürdürülebilirlik özellikle kültürel mirasın yönetiminde kritik bir rol üstlenmekte; mirasın korunmasını ve gelecek kuşaklara aktarılmasını sağlayarak toplumsal ve kültürel deneyimlere uzun vadeli katkıda bulunmaktadır. Bu bağlamda Sürdürülebilirlik ile kültürel mirasın, kapsamları ve amaçları bakımından birbirleriyle güçlü bir ilişki içinde olduğu bilinmektedir. Ancak bazı araştırmalarda kültürel miras ile sürdürülebilir kalkınma ayrı kavramlar olarak ele alınsa da, her iki kavramın doğal ve yapılı çevreye ilişkin disiplinlerle doğrudan ilişkili olduğu görülmektedir. Bu bağlamda kültürel mirasın korunması ve yönetimi, yalnızca tarihsel değerlerin sürdürülmesine yönelik bir süreç değil; aynı zamanda bölgesel ve kentsel planlama, kentsel tasarım ve mimarlık gibi alanlarla birlikte ele alınması gereken bütüncül bir disiplin alanı olarak değerlendirilmektedir. Dolayısıyla, kültürel mirasın sürdürülebilir biçimde

korunması, yapılı ve doğal çevrelerin planlanması, tasarlanması ve geleceğe yön verilmesi açısından temel bir bileşen niteliği taşımaktadır (Hoşkara, Lombardi & Doğaner, 2021).

Sürdürülebilir Kalkınma Amaçlarının bazı hedefleri kültürel mirasla doğrudan ilişkilendirilebilirken, bazıları ise dolaylı düzeyde bağlantı kurmaktadır. Bu çerçevede, BM 2030 Gündemi'nde kültür ve mirasın özellikle SKA 11 kapsamında ele alındığı, Hedef 11.4 ile kültürel ve doğal mirasın korunmasına yönelik doğrudan bir yaklaşım benimsendiği görülmektedir (Soykök Ede & Taş, 2025). Bu doğrudan ilişkinin yanı sıra, kültürel mirasla dolaylı olarak bağlantı kuran hedefler de sürdürülebilirlik çerçevesinin önemli bir parçasını oluşturmaktadır. Bu kapsamda SKA 8 (İnsana Yakışır İş ve Ekonomik Büyüme), SKA 12 (Sorumlu Üretim ve Tüketim), SKA 4 (Nitelikli Eğitim), SKA 2 (Açlığa Son), SKA 15 (Karasal Yaşam) ve SKA 17 (Amaçlar İçin Ortaklıklar) kültürel mirasla çeşitli düzeylerde ilişkilendirilen amaçlar arasında gösterilmektedir (Soykök Ede & Taş, 2025).



Görsel 12. Sürdürülebilir Kalkınma İçin Küresel Amaçlar, 2015

Bu bağlamda ele alınan sürdürülebilir kültürel miras yönetimi yaklaşımları ve sürdürülebilir kalkınma amaçları, tarihsel savunma işlevini yitirmiş ancak kentsel bellekteki önemini koruyan Kayseri Kalesi'nin güncel kullanım biçimlerinin değerlendirilmesi açısından önemli bir zemin oluşturmaktadır. Kale üzerinde gerçekleştirilen restorasyon, yeniden işlevlendirme ve kamusal kullanım kararları, bu kuramsal çerçeve doğrultusunda ele alınarak sürdürülebilirlik bağlamında incelenebilir.

4. TARİHİ KALE YAPILARINDA SÜRDÜRÜLEBİLİR YENİDEN İŞLEVLENDİRME ÖRNEKLERİ

Dünya'nın farklı ülkelerinde de geçmişte savunma amaçlı yapılmış olan tarihî kale yapılarında sürdürülebilir yeniden işlevlendirme yaklaşımları bu yapıların kültürel miras değerlerini koruyarak güncel sosyal, kültürel ve kamusal ihtiyaçlara uyum sağlamasını hedefleyen birçok

kale yapısı örneği vardır. Dünyada önde gelen örneklerden biri olarak, yeniden işlevlendirme projesi Carlo Scarpa'ya ait olan Castelvecchio Kalesi günümüzde müze olarak kullanıma hizmet veren bir kale yapısı olup, sürdürülebilirlik açısından önemli örneklerden biridir (Görsel 13). Küresel anlamda önemli olan bir diğer büyük örnek ise İskoçya'da bulunan Edinburgh Kalesidir. 19. yüzyılın yarısından itibaren kale, askerî savunma işlevinden ziyade ulusal kimliğin temsil edildiği, turizm ve tarih yazımıyla desteklenen kamusal bir kültür mekanı olarak yeniden kurgulanmıştır ve günümüzde müze, sergi alanı ve tören alanı gibi hizmetlerde bulunmaktadır. (Görsel 14).



Görsel 13. Castelvecchio Kalesi



Görsel 14. Edinburgh Kalesi

Türkiye'de de birçok örnek bulunmakta olup, bunlardan biri Antalya'da yer alan Alanya Kalesi'dir, günümüzde açık hava müzesi olarak kullanılan kale, konumuyla birlikte turistlerin önemli ilgi odaklarından biridir (Görsel 15). Benzer şekilde Türkiye'de Ege bölgesinde bulunan Bodrum Kalesi de yeniden işlevlendirildikten sonra açık hava müzesi olarak kullanılan önemli örneklerden biridir (Görsel 16). Bu örnekler turistlerin odak noktası olup ülkelerde ekonomik kalkınmaya destek olmaktadır. Bu bağlamda Türkiye'de kültürel miras sürdürülebilirliğinin ekonomik kavramla, SKA 8 amacıyla yakından ilişkili olduğunu ortaya koymaktadır.



Görsel 15. Alanya Kalesi



Görsel 16. Bodrum Kalesi

5. SONUÇLAR VE DEĞERLENDİRME

Kayseri Kalesi, savunma yapısı olarak inşa edilmiş olmasına rağmen tarihsel süreç içerisinde işlevini yitirerek günümüz kent yaşamına uyum sağlayan bir kültürel miras alanına dönüşmüştür. Gerçekleştirilen restorasyon ve yeniden işlevlendirme çalışmaları, yapının özgün kimliğini tamamen ortadan kaldırmadan, güncel ihtiyaçlara cevap verecek biçimde ele alınmıştır. Bu durum, kültürel mirasın korunması ile kullanımının birlikte düşünülmesine olanak tanıyan sürdürülebilir bir yaklaşımı ortaya koymaktadır.

Kalenin günümüzde arkeoloji müzesi, sergi alanları ve kamusal kullanım mekânlarıyla değerlendirilmesi, SKA 11.4 kapsamında kültürel mirasın korunması hedefiyle doğrudan ilişkilidir. Bunun yanı sıra, kültürel etkinlikler ve turizm odaklı kullanımlar aracılığıyla SKA 8 (İnsana Yakışır İş ve Ekonomik Büyüme) ve SKA 4 (Nitelikli Eğitim) hedeflerine dolaylı katkılar sağlandığı görülmektedir. Yapı, bu yönüyle yalnızca korunması gereken bir tarihsel unsur değil, aynı zamanda kentsel yaşamı destekleyen aktif bir kamusal mekân niteliği kazanmıştır.

Bunaların yanı sıra Kayseri Kalesi özelinde yapılan değerlendirmeler, uluslararası koruma tüzüklerinde vurgulanan temel ilkelerle önemli ölçüde uyuşmaktadır. Venedik Tüzüğü'nün 5. Maddesinde (Venice Charter,1964), tarihi yapıların toplumsal yaşamla uyumlu yeni işlevlerle kullanılmasının, yapının korunmasının en etkili yollarından biri olduğunu belirtilmektedir. Kayseri Kalesi'nin günümüzde kültürel etkinlikler, sergiler ve kamusal kullanımlarla yaşama entegre edilmesi, bu ilkenin somut bir yansıması olarak değerlendirilebilir.

Kayseri Kalesi'nde gerçekleştirilen müdahalelerin büyük ölçüde geri alınabilir ve yapının tarihsel gelişimini okunabilir kılacak biçimde tasarlanmış olması, sürdürülebilir miras yönetimi açısından olumlu bir örnek sunmaktadır. Savunma işlevini yitirmiş olsa da, kale kentin hafızasındaki yerini koruyarak geçmiş ile günümüz arasında süreklilik kuran bir yapı olarak varlığını sürdürmektedir. Bu bağlamda Washington Tüzüğünde (Washington Charter, 1987) tarihi kent alanlarında yapılan müdahalelerin, alanın özgün kimliğini koruması gerekirken çağdaş yaşamın gereksinimlerini de karşılaması gerektiği ifade edilmektedir, kalede düzenlenen etkinlikler bu ilke ile yakından ilişkilendirilebilir.

Türkiye'de, tarihi kale yapıları büyük bir potansiyele sahiptir ancak bu potansiyel çoğu zaman yeterince değerlendirilememektedir. Bu yapıların, fiziksel bütünlüğüne zarar vermeden kültürel etkinlikler, süreklilik arz eden araştırma ve üretim ortamları ile desteklenmesi, hem kültürel mirasın korunmasına hem de sürdürülebilir kalkınma hedeflerine çok boyutlu katkılar sunabilir.

KAYNAKÇA

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GELENEKSEL YAPILARDA YENİDEN KULLANIM VE ÇAĞDAŞ EK: TUMO YARATICI TEKNOLOJILER MERKEZİ ÖRNEĞİ

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ÖZET

Tarihî yapıların korunması, kültürel mirasın gelecek kuşaklara aktarılmasında önemli bir sorumluluktur. Bu yapıların aktarılabilmesi ise, özgün niteliklerine zarar vermeden güncel gereksinimlere uyarlanmasını gerektirir. Yeniden işlevlendirme ve çağdaş ekler yapının güncel yaşama uyumunu sağlayan tamamlayıcı araçlardır. Bu çalışma, Ermenistan'ın Gyumri kentinde bulunan ve Bernard Khoury tarafından tasarlanan TUMO Yaratıcı Teknolojiler Merkezi'nin yeniden işlevlendirme sürecini mimari, mekânsal ve koruma odaklı açılardan ele almaktadır. 1850'li yıllarda inşa edilen ve 1988 depreminden sonra terk edilen tiyatro binası, mevcut taş kabuğu korunarak çağdaş bir eğitim yapısına dönüştürülmüştür. Projede tarihî cepheler restore edilirken, iç mekânda yeni işlevlere yanıt verecek şekilde özgün bir mekânsal kurgu geliştirilmiş; amfi-formundaki ortak alanlar, üretim ve gösterim işlevlerini bütünleştiren bir yapı oluşturmuştur.

Yeni müdahaleler, malzeme ve dil açısından özgün yapıdan bilinçli olarak ayrışmakta; kırmızı tonlu sıva ve çelik yapı elemanları tarihî dokuya aykırı değil, onunla diyaloğa giren bir okunabilir farklılık üretmektedir. Bu yaklaşım, bir çok tüzük ve bildiride başta Venedik ve Burra Tüzüğü olmak üzere uluslararası koruma ilkeleriyle örtüşmekte, hem özgün öğelerin korunmasını hem de çağdaş eklerin ayırt edilebilirliğini sağlamaktadır.

Yapının mekânsal organizasyonu, zemin katta kullanılan mekanlar, üst kotta yer alan idari ve kamusal birimler ile kapsayıcı bir biçimde ele alınmıştır. Yerel yapı teknikleri sürece entegre edilerek kültürel süreklilik sağlanmış olup yapı yalnızca fiziksel değil, toplumsal bağlamda da yeniden işlevlendirilmiştir. Bu bildiri, Gyumri TUMO Yaratıcı Teknolojiler Merkezi örneği üzerinden tarihî yapılarda çağdaş ek uygulamalarının tasarımsal niteliğini, yeniden işlevlendirme sürecini, tarihî yapı kabuğunun korunmasını, çağdaş mimari müdahalenin niteliği ve uluslararası koruma ilkeleriyle uyumu üzerinden değerlendirerek, projenin nasıl bir dönüşüm modeli ortaya koyduğunu açıklamayı amaçlamaktadır.

Anahtar Kelimeler : Yeniden işlevlendirme, Çağdaş ek, Adaptif yeniden kullanım

REUSE AND CONTEMPORARY ADDITIONS IN HISTORIC BUILDINGS: THE CASE OF THE TUMO CENTER FOR CREATIVE TECHNOLOGIES

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ABSTRACT

The preservation of historic buildings represents a significant responsibility in sustaining cultural heritage for future generations. Ensuring this continuity requires adapting such structures to contemporary needs while maintaining their authentic architectural qualities. Within this framework, adaptive reuse and contemporary additions function as strategies that enable historic buildings to remain active components of urban life. This study examines the adaptive reuse of the TUMO Center for Creative Technologies in Gyumri, Armenia—designed by Bernard Khoury—from architectural, spatial, and conservation-oriented perspectives. Originally constructed in the 1850s and abandoned after the 1988 earthquake, the theater house was transformed into a contemporary educational facility while its existing stone shell was preserved.

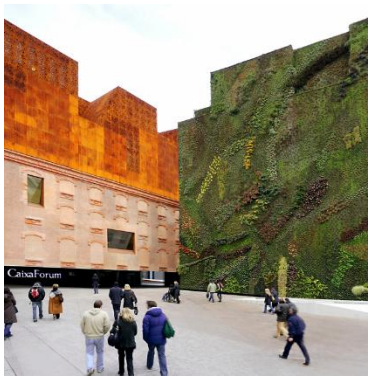
In the project, the historic façades were restored, and a new spatial configuration was introduced to accommodate updated programmatic requirements. Amphitheater-like communal areas established a flexible interior that integrates production and performance functions. Contemporary interventions intentionally diverge from the original structure in terms of materiality and expression; the use of red-toned plaster and steel elements generates a contrasting yet coherent dialogue with the historic fabric. This design attitude aligns with core international conservation principles, particularly those articulated in the Venice Charter and the Burra Charter, which emphasize both the safeguarding of authentic components and the recognizability of new additions.

The spatial organization, including ground-level public spaces and upper-level administrative units, was designed holistically to support circulation and programmatic clarity. By incorporating local construction techniques, the project reinforces cultural continuity and ensures a transformation that is not only physical but also social. Through the case of the Gyumri TUMO Center, this paper evaluates how contemporary additions, adaptive reuse strategies, and the preservation of the historic shell collectively form a coherent model of architectural intervention that respects international conservation standards.

Keywords: Adaptive reuse, Contemporary addition, Architectural conservation

1. GİRİŞ

Kültürel kimliği gelecek nesillere aktarmak için tarihi yapılar çok önemlidir. Tarihi binaların orijinal amacını artık yerine getiremediği durumlarda, tarihi binaların önemini korumak için yeni bir işlev önerilmesi kaçınılmaz bir durumdur (Mısırlısoy & Günçe, 2016). Tarihî yapıların günümüz ihtiyaçlarına uyarlanması sürecinde çoğu zaman yeni işlevler eklenir; ancak bu işlevlerin gerektirdiği mekânsal program, yapının özgün kurgusu ve kapasitesiyle her zaman örtüşmeyebilir. Bu uyumsuzluk ortaya çıktığında, yapının yeni kullanımlarını desteklemek ve mekânsal yetersizliği gidermek için ek mekânlara ihtiyaç duyulabilir (Zeren, 2010). Ancak bu ekler, hiçbir koşulda yapının mekânsal kurgusunu, strüktürünü ve tarihsel kimliğini örtecek ölçekte olmamalıdır (Ahunbay, 2017). Ayrıca tarihi yapılara ya da çevrelerine eklenen yeni yapıların, tek başına ele alınması mümkün değildir çünkü çağdaş ekler, kentin bütünlüğünü bozacak ölçüde olduğunda tarihî çevre bilincine aykırı bir müdahaleye dönüşmektedir (Erder, 1977). Günümüzde yeniden işlevlendirme, yalnızca kültürel mirasın korunmasıyla sınırlı bir yaklaşım olmaktan çıkmış; kentlerde artan atıl yapı stoğuna, ekonomik ve kültürel sorunlara çözüm üreten stratejik bir tasarım aracı olarak görülmeye başlanmıştır (Lanz & Pendlebury, 2022). Bu bilgiler yapılan çağdaş eklerin ve yeniden işlevlendirme kararlarının pek çok farklı alanda öneme sahip olduğunu göstermektedir. Dünyada çağdaş ek ve yeniden işlevlendirmenin çok fazla örneği bulunmaktadır. Endüstriyel binaların müzelere, sanat stüdyolarına, yaşa-çalış birimlerine, ofislere, konutlara, okullara ve ticari alanlara dönüştürülmesi en yaygın dönüşüm türleridir (Cantell, 2005). Farklı işlevler verilerek yeniden canlandırılan pek çok yapı vardır (Görsel 1, Görsel 2 ve Görsel 3).



Görsel 1. CaixaForum Madrid Sanat Merkezi / Herzog & de Meuron (URL



Görsel 2. Moritzburg Müzesi Eklentisi / Nieto Sobejano Arquitectos



Görsel 3. Zeitz MOCAA / Heatherwick Stüdyosu

(URL 3)

Venedik Tüzüğü'ne göre (The Venice Charter, 1964), restorasyon, varsayıma dayanmamalı, modern ekler ayırt edilebilir olmalı ve mimari kompozisyonun bir parçası olarak gözlemlenebilmelidir. Amsterdam Bildirgesi'ne göre (Amsterdam Declaration 1975), Tarihi binaların korunması, onları modern yaşamın gereksinimleri ile uyumlu bir şekilde yeniden

işlevlendirilmesin gerektirmektedir. Burra Tüzüğü'ne göre ise (Burra Charter 1999 / 2013) Kültürel önem, yalnızca fiziksel değil, sosyal ve tarihsel değerleri de kapsayan bir alandır. Eğer yapılarda yeniden işlevlendirme projesi söz konusuysa bu maddelere dikkat edilmesi gerekmektedir.

Bu bağlamda söz konusu çalışmada, Gümrü Eski Tiyatro Binası'nın TUMO Yaratıcı Teknolojiler Merkezi olarak yeniden işlevlendirilme süreci araştırma yöntemleriyle analiz edilmiştir. Çalışmada, yapının tarihsel gelişimi, deprem sonrası geçirdiği yapısal dönüşümler ve çağdaş ek yaklaşımını incelemek amacıyla Bernard Khoury Architects tarafından yayımlanan proje dokümanları, ICOMOS ve UNESCO çerçevesindeki uluslararası koruma tüzükleri, ayrıca yapının mimarlık platformlarında yer alan çizim, kesit ve görsel materyalleri üzerinden mekânsal analizi yapılmıştır. Bu çerçevede çalışmanın amacı, yapının korunmuş tarihî taş kabuğu ile içine yerleştirilen çağdaş çelik ve cam strüktür arasındaki ilişkiyi; mekânsal ayrışma, ayırt edilebilirlik ve karşıtlık üzerinden değerlendirmek ve bu müdahalenin yeniden işlevlendirme ilkeleriyle kurduğu ilişkiyi ortaya koymaktır.

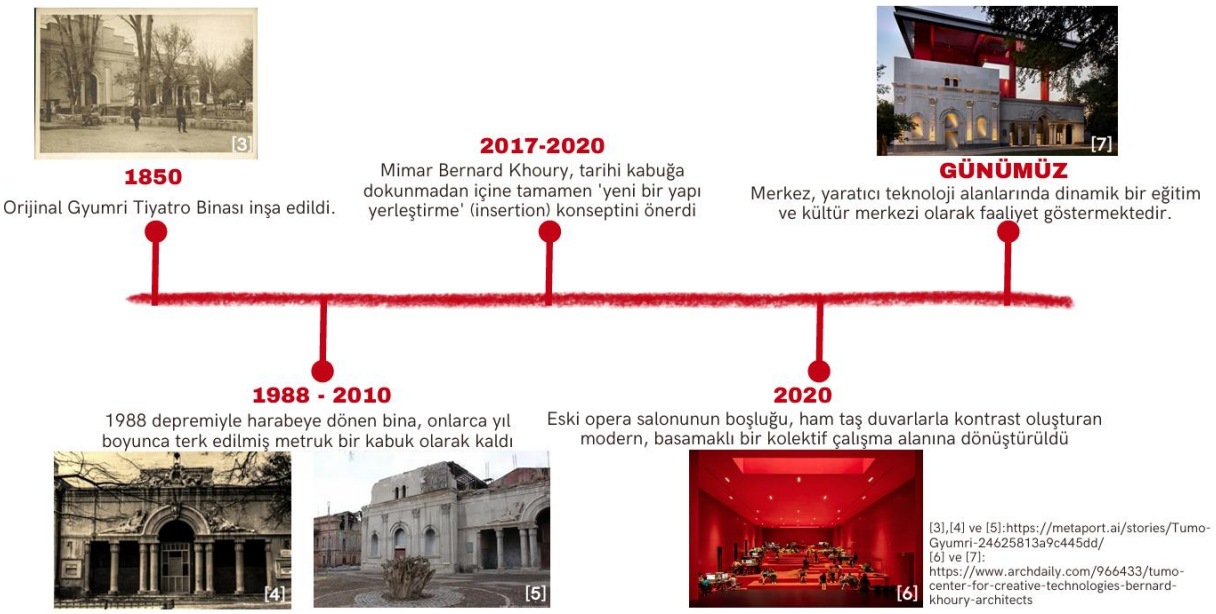
2. ARAŞTIRMA VE BULGULAR

Günümüzde Yaratıcı Teknolojiler İçin Tumo Merkezi olarak bahsedilen yapının ilk isminin Aleksandropol Halk Evi olduğu bilinmektedir (Vardanyan, 2021). Gyumri Tiyatrosu, adını bir dönem bünyesinde barındırdığı opera binasından almıştır, bu kapsamda ana salon, yapının en karakteristik mekânı hâline gelecek şekilde, döner sahneye sahip bir tiyatroya dönüştürülmüştür (URL 4). Aleksandropol Halk Evi, şehrin tarihi tiyatro binalarından biri olup, tarihi kısımda, şehir parkının bitişiğindeki bölgede inşa edilmiştir. 1850'lerde inşa edilmiş, çeşitli yeniden yapılanmalardan geçerek işlevlerini Halk Sarayı'ndan bir Televizyon Kurumu'na, İnşaatçılar Sarayı'na gibi birçok farklı şekilde hizmet ederek değiştirmiştir. Bina, Armen Tigranyan'ın "Anuş" operasının 1912'deki prömiyeriyle ünlüdür (Vardanyan, 2021). Aşağıdaki görselde TUMO Yaratıcı Teknolojiler Merkezi'nin şehir parkı ve kentin diğer bölümüyle konum olarak ilişkisi gösterilmektedir (Görsel 4).



Görsel 4. TUMO Yaratıcı Teknolojiler Merkezi'nin Konumu

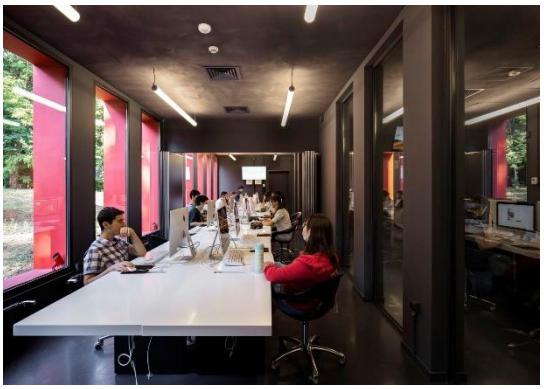
Yapı iki depreme ve bir yangına dayanmış ve harap bir durumda günümüze ulaşmıştır (Vardanyan, 2021). İki büyük deprem kente ciddi zararlar vermesine rağmen, Gyumri hâlâ tarihi mimarisinin kalıntılarını ve koruma altındaki binalarını görmek isteyen ziyaretçileri kendine çekmektedir, bu nedenle, ayakta kalan yapıların mümkün olduğunca korunması çok önemli bir tercihtir (URL 4). Gyumri kenti gelişmekte olan ülkelerdeki tarihi alanlar için ortak olan birçok zorlukla karşı karşıyadır bunlar nüfus azalması, en eski kent alanlarının bozulması, sakinleri arasında iş istikrarsızlığı, düşük gelir ve yetersiz planlama politikalarıdır. Yapılan çalışmalara dayanarak, şehrin tarihi binalarını koruyarak ve bunları belirli yeniden canlandırma süreçlerinin odak noktası haline getirerek şehrin geleceğini geliştirebilecek çeşitli işlevler verilmiştir (Giambruno & Pistidda & Petrosyan, 2024). Şehrin tarihi yapılarından biri olan bu tiyatro binasını yeniden işlevlendirme projesi önemli koruma tercihlerinden biridir. Geçmişten bugüne bir çok işlev kazanmış bu önemli tarihi yapının bugüne kadar hangi aşamalardan geçtiğini gösteren bir zaman çizelgesi sunulmuştur (Görsel 5).



Görsel 5. TUMO Yaratıcı Teknolojiler Merkezi Zaman Çizelgesi

Görsel, orijinal olarak ArchDaily kaynaklı veriler esas alınarak oluşturulmuş ve yazar tarafından düzenlenmiştir

Tumo Yaratıcı Teknolojiler Merkezi, yenilikçi, ücretsiz ve açık bir dijital medya öğrenme merkezidir. Şu anda Ermenistan'da altı TUMO merkezi bulunmaktadır, Bunlar Erivan, Dilijan , Gümri , Koghb , Kapan ve Yeghegnadzo şehirlerindedir (URL 5). Tumo Mayıs 2015'te Ermenistan'ın ikinci büyük kenti olan Gyumri'de yeni bir şube olan bu merkezi açarak şube sayısını artırmıştır (URL 4). Orijinal Tumo'ya benzer şekilde, bu 2.500 metrekarelik merkezin ders programı aynı dört odak alanını kapsar bu odak alanları animasyon, dijital medya, video oyunları ve web geliştirmedir (URL 4). Yeniden işlevlendirilen merkezin içindeki mekanlar dört odak noktasını sağlayarak öğrenciler tarafından aktif olarak kullanılmaktadır (Görsel 6 ve Görsel 7).



Görsel 6. Dijital Üretim Alanı (URL 4)



Görsel 7. Çok Amaçlı Ortak Alan(URL 4)

Yapıdaki asıl çalışma mekânı, eski opera binasının tiyatro salonu içinde kurgulanmıştır ve basamaklı çok amaçlı çalışma alanı, 3D yazıcı laboratuvarı olarak tasarlanmıştır aynı zamanda

gösterimler ve performanslar için eski 200 kişilik tiyatro düzenine dönüştürülebilecek esnek bir mekân niteliği taşımaktadır (Görsel 7). Önerilen proje, iki farklı topografik seviyeyi birleştirerek şehrin sosyal ve kültürel dokusu üzerindeki etkisini vurgulamayı hedefleyen bir projedir (URL 4).

Etkileyici bir kemer ve ortak toplanma alanlarını içeren çatı, iç ve dış mekanlarda gerçekleşebilecek etkinlikleri birbirine bağlar. Çatının aynalı alt yüzeyi sayesinde merkezin aktifliğini çevredeki şehre yansıtabilmektedir (Görsel 8 ve Görsel 9).



Görsel 8. Aynalı çatı yüzeyi (URL 4)



Görsel 9. Aynalı çatı yüzeyi (URL 4)

Yapının iki ana girişi bulunmaktadır bunların girişleri batı ve doğu yönlerinden sağlanmaktadır; doğu girişi bir alt kottan açılmakta ve buradan öğrenci sirkülasyonu ön plana alınarak organize edilmiştir. Batı girişi ise idari işlevler ve kamusal etkinliklere hizmet etmekte olup, bu giriş üzerinden sinema salonuna erişim sağlanmaktadır (Vardanyan, 2021). Aşağıdaki görselde planların ve kesitlerin çağdaş ek olan bölümleri ve özgün yapı olan bölümleri belirtilerek sunulmuştur (Görsel 10).



Görsel 10. TUMO Yaratıcı Teknolojiler Merkezine ait Planlar ve Kesitler

Görsel, orijinal olarak ArchDaily kaynaklı veriler esas alınarak oluşturulmuş ve yazar tarafından düzenlenmiştir

Düz bir topografyaya yerleşmeyen yapının kotlarının kullanımı da detaylı bir biçimde düşünülüp projelendirilmiştir. Öğrencilerin kullanacağı ana alanlar, alt park kotundaki doğu cephesinden erişilen zemin katta konumlandırılmıştır, ana lobi, yönetim birimleri ve halka açık amfitiyatro gibi öğrenci kullanımına doğrudan dâhil olmayan kamusal işlevler ise zemin kat alanının çatısı üzerinden, batı cephesi boyunca üst cadde kotundan erişim sağlanmaktadır (URL 4). Bu doğrultuda, kullanıcı profilleri dikkate alınarak bir tasarım yaklaşımı geliştirilmiş ve planlarda mekansal yerleşimler bu veriler esas alınarak düzenlenmiştir.

Yapının tüzük ve kartalarla en güçlü biçimde kesiştiği nokta projenin cephesinde yapılan müdahalelerde ortaya çıkmaktadır, projeye eklenen çağdaş müdahalenin tarihî yapıdan belirgin bir şekilde ayırt edilebilir olması ve dışarıdan anlaşılabilir bir nitelik taşıması tüzüklerde bahsedilen önemli bir noktadır. Bu yaklaşım, Venedik Tüzüğü'nün 9. maddesinde geçen yeni yapılan eklerin özgün yapıdan ayırt edilebilir olması gerektiği ilkesiyle doğrudan ilişkilidir (The Venice Charter, 1964). Yapının cephelerinde sadece Güney ve Doğu cepheleri restore edilip korunmuştur (Vardanyan, 2021). Korunan cephelerin eski ve yeni durumları aşağıdaki görsellerde sunulmuştur (Görsel 11 ve Görsel 12).



Görsel 11. TUMO Yaratıcı Teknolojiler Merkezi Restore Edilen Güney Cephe (URL 6)



Görsel 12. TUMO Yaratıcı Teknolojiler Merkezi Restore Edilen Güney-Doğu Cephe (URL 6)

Kuzey ve batı cephelerinde ise yapıyla bilinçli olarak ayrışan, parlak kırmızı renkli çağdaş ekler eklenmiştir (Görsel 13, Görsel 14 ve Görsel 15). Kentin tek renkli renk paletine karşı bir renkle yeniden işlevlendirme projesi olarak tasarlanmıştır (URL 4). Bu bağlamda tarihi taş cephelere temas etmeyen, bağımsız çelik ve cam strüktür; doğal ışığın iç mekanda kolay bir biçimde dolaşmasına olanak sağlarken, eski yapının dokusunun sürekli olarak algılanmasını sağlamaktadır.



Görsel 13, Görsel 14 ve Görsel 15. TUMO Yaratıcı Teknolojiler Merkezi'nin Cephesine Yapılan Çağdaş Ekler (URL 4)

3. SONUÇLAR VE DEĞERLENDİRME

Bu çalışma, Gyumri'de bulunan TUMO Yaratıcı Teknolojiler Merkezi'nin yeniden işlevlendirilme sürecini, tarihî taş kabuğun belirli cephelerde korunması ve buna eklenen çağdaş müdahalelerin mekânsal, yapısal ve koruma ilkeleri bağlamındaki ilişkisi üzerinden değerlendirmiştir. 19. yüzyıla tarihlenen ve birçok dönemsel afetlere ve olaylara şahit olmuş, uzun süre atıl durumda kalan tiyatro yapısının, özgünlüğüne çok müdahale edilmeden modern bir eğitim yapısına dönüştürülmesi, tarihî yapılarda yeniden kullanımın yalnızca işlevsel bir gereklilik değil, aynı zamanda kültürel sürekliliği destekleyen bir tasarım yaklaşımı olduğunu ortaya koymaktadır. Bunlara ek olarak yeniden işlevlendirme perspektifinden bakıldığında büyük ölçekte kentlere olan etkisini gösteren örnek bir projedir. Tarihi yapıların yeniden kullanımı, yalnızca fiziksel müdahale ile ilişkili değil kentin hafızası, kamusal kullanımıyla ilişkili bir süreçtir (Akın 2007). Bu nedenle yeniden işlevlendirme projeleri, kentsel ölçekte anlam ve etki üretir. Proje, iç mekanda uygulanan yeni strüktürel kurgu ve kot farklılıklarıyla oluşturulan güncel gereksinimlere göre yapılmış mekanlar, tarihî yapının günümüz zamanına adapte olduğunu göstermektedir.

Venedik Tüzüğü'nün (The Venice Charter, 1964) ayırt edilebilirlik ve tarihî değere saygı ilkeleri doğrultusunda, çağdaş eklerin özgün yapıdan bilinçli biçimde ayrıştırılması; Burra Tüzüğü'nde (Burra Charter 1999/2013) vurgulanan kültürel ve toplumsal değerlerin korunmasıyla birlikte ele alınmıştır. Tarihi cephelere zarar vermeyen bağımsız çelik ve cam strüktür, hem eski yapının görünürlüğünü sürdürmekte hem de yeni kullanımın gerektirdiği mekânsal koşulları sağlamaktadır. Bunlara ek olarak, iç mekânda özgün tiyatro hacminin dönüştürülerek çok amaçlı bir ortak alan olarak kullanılması, Dublin İlkeleri'nde (ICOMOS–TICCIH, 2011) vurgulanan yapı mirasında mekansal bütünlüğün korunması tartışmaları açısından eleştirel bir değerlendirme alanı da sunulduğu bilinmektedir.

Sonuç olarak TUMO Yaratıcı Teknolojiler Merkezi, tarihî yapılarda çağdaş ek ve yeniden işlevlendirme yaklaşımlarının, doğru koruma yaklaşımlarıyla bir araya geldiğinde mimari, toplumsal ve kentsel ölçekte nitelikli mekansal çözümler üretebileceğini göstermektedir. Proje, tarihî kabuk ile modern müdahale arasındaki zıtlığı bir çatışma olarak değil, bilinçli bir tasarım olarak ele alması bakımından, uluslararası koruma ilkeleriyle uyumlu ve tartışmaya açık bir model sunmaktadır. Ayrıca TUMO Yaratıcı Teknolojiler Merkezi'ne ilişkin çalışmaların ulusal ve uluslararası literatürde kısıtlı olması ve yapının yeniden işlevlendirilme sürecinin özellikle çağdaş ek yapı yaklaşımıyla birlikte akademik olarak ele alınmamış olması çalışmanın önemini arttırmaktadır. Bu bağlamda çalışma geleneksel yapılarda çağdaş ek uygulamalarının değerlendirilmesine yönelik literatüre katkı sağlamakta ve benzer yeniden işlevlendirme projeleri için önemli bir referans oluşturmaktadır.

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SÜRDÜRÜLEBİLİR KALKINMA AMAÇLARI ÇERÇEVESİNDE KAYSERİ ERKİLET ARKEOLOJİK SİT ALANI ÜZERİNE BİR DEĞERLENDİRME

A STUDY ON THE KAYSERİ ERKİLET ARCHAEOLOGİCAL SİTE WİTHİN THE FRAMEWORK OF THE SUSTAİNABLE DEVELOPMENT GOALS

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ÖZET

Kültürel mirasın korunması ve sürekliliğinin sağlanmasına yönelik gereksinim günümüzde giderek artmaktadır. Özellikle sit alanlarında yer alan tarihî yapıların sürdürülebilirliğinin güvence altına alınması, koruma politikalarının temel bir bileşeni olarak öne çıkmaktadır. Sürdürülebilir kalkınma yaklaşımı, ekonomik gelişmenin doğal ve kültürel değerlerle uyum içinde gerçekleşmesini esas alan bütüncül bir çerçeve sunmakta; bu doğrultuda kültürel mirasın rolünü güçlendirecek yenilikçi stratejilere duyulan ihtiyaç artmaktadır. Bu çalışma kapsamında Kayseri, Kocasinan ilçesine bağlı Erkilet Mahallesi'nde bulunan eski yerleşim dokusunu içeren arkeolojik sit alanı ele alınmıştır. Hıdırellez Tümülüsü yakınında, eğimli bir topografya üzerinde konumlanan alan, mescitler, kaya oyma kilise, hamam kalıntıları ve geleneksel konut dokusu gibi kültürel varlıkları barındırması nedeniyle korunması gereken hassas bir konumdadır. Nüfus mübadelesi sonrası ortaya çıkan terk edilmişlik, heyelan ve jeolojik riskler, vandalizm, kaçak müdahaleler ve kontrolsüz yapılaşma gibi tehditler alanın özgün karakterini kaybetme tehlikesini artırmaktadır. Bu nedenle alanın mevcut durumunun kapsamlı değerlendirilmesi ve Sürdürülebilir Kalkınma Amaçları (SKA) doğrultusunda iyileştirme stratejilerinin geliştirilmesi gerekmektedir. Erkilet Arkeolojik Sit Alanı, kent içindeki tarihî dokuların korunmasının kentsel kimlik ve toplum yararına katkısını ortaya koyarken, alanın özgün niteliklerine dayanan bütüncül koruma politikaları, kültürel mirasın sürdürülebilirliği ve gelecek kuşaklara aktarımı açısından önem taşımaktadır. Bu bağlamda Erkilet örneği; SKA 11 (tarihî çevrenin korunması), SKA 4 (kültürel miras bilincinin güçlendirilmesi), SKA 8 (yaratıcı ekonomi olanaklarının desteklenmesi), SKA 13 (iklim ve afet risklerine karşı dayanıklılığın artırılması) ve SKA 15 (doğal–kültürel peyzajın korunması) hedefleriyle doğrudan ilişkilidir; bu bağlamda alan, arkeolojik mirasın sürdürülebilir kalkınmanın çok boyutlu hedefleriyle bütünleştirilebileceğini ortaya koyan örnek bir model sunmaktadır.

Anahtar Kelimeler: Erkilet, Sürdürülebilir Kalkınma Hedefleri, Kültürel Miras, Arkeolojik Sit Alanı

ABSTRACT

The need to protect cultural heritage and ensure its continuity has been increasingly emphasized in recent years. Safeguarding the sustainability of historical structures located within designated conservation areas has become a fundamental component of contemporary preservation policies. The sustainable development approach provides an integrated framework that prioritizes economic growth in harmony with natural and cultural values, thereby amplifying the need for innovative strategies that strengthen the role of cultural heritage. This study examines the archaeological site encompassing the historic settlement pattern in Erkilet, a neighborhood of Kocasinan district in Kayseri. Situated on a sloped topography near the Hıdırellez Tumulus, the area contains significant cultural assets—including mescits, a rock-cut church, remains of a bathhouse, and traditional residential fabric—rendering it a sensitive zone requiring careful conservation. Post–population exchange abandonment, landslide and geological hazards, vandalism, unauthorized interventions, and uncontrolled construction threaten the integrity of the site. Accordingly, a comprehensive assessment of the existing conditions and the development of improvement strategies aligned with the Sustainable Development Goals (SDGs) are essential. Erkilet Archaeological Site demonstrates the contribution of conserving historical urban fabric to urban identity and societal benefit; holistic conservation policies grounded in the site's inherent qualities are crucial for safeguarding cultural heritage and transmitting it to future generations. In this context, the Erkilet case is directly related to SDG 11 (protection of historical environments), SDG 4 (strengthening cultural heritage awareness), SDG 8 (supporting opportunities in the creative economy), SDG 13 (enhancing resilience to climate and disaster risks), and SDG 15 (conservation of natural–cultural landscapes). Thus, the site presents an exemplary model demonstrating how archaeological heritage can be integrated into the multidimensional objectives of sustainable development.

Keywords: Erkilet, Sustainable Development Goals, Cultural Heritage, Archaeological Site

1. GİRİŞ

Hızlanan kentleşme dinamikleri ve değişen yaşam pratikleri, kültürel miras alanlarında işlev kaybına yol açarak bu alanlar üzerinde ciddi bir yok olma baskısı oluşturmaktadır. Bu bağlamda, harap durumdaki miras yapılarının yeniden kullanımı; ekonomik, sosyal, çevresel ve kültürel boyutlarıyla sürdürülebilir kalkınmanın önemli araçlarından biri olarak değerlendirilmektedir. Bu çalışma, kuramsal çerçevesini oluşturan "sürdürülebilirlik" ve "süreklilik" kavramlarını, nitel araştırma yöntemi kapsamında mimarların saha deneyimlerine dayalı olarak irdelemeyi amaçlamaktadır. Elde edilen bulgular doğrultusunda, kültürel mirasın korunmasına yönelik stratejilerin geliştirilmesi ve kentsel alanların kent belleğiyle ilişkili biçimde yeniden canlandırılması yoluyla, koruma politikalarının sürdürülebilir kalkınma hedefleriyle bütünleştirilmesinin gerekliliği vurgulanmaktadır.

Bu yaklaşımın, özellikle Erkilet gibi arkeolojik sit niteliği taşıyan kentsel alanlarda tarihî yapıların yeniden işlevlendirilmesi ve yeniden kullanım süreçlerine yön vererek, bölgenin

özgün kültürel birikiminin gelecek kuşaklara aktarılmasına önemli katkılar sunması beklenmektedir. Bununla birlikte, kültürel mirasın korunması süreci; mimarlık, jeoloji, kentsel tasarım, ekonomi ve kent sosyolojisi gibi disiplinler arası iş birliğini zorunlu kılmakta ve bütüncül yaklaşımlar temelinde yeni planlama ve politika üretim modellerine duyulan ihtiyacı ortaya koymaktadır.

Erkilet Arkeolojik Sit Alanı'nın korunması ve değerlendirilmesi sürecinde uluslararası koruma ilke ve bildirgeleri de önemli bir kuramsal dayanak oluşturmaktadır. Venedik Tüzüğü (1964), tarihî anıt ve sit alanlarının özgünlük ve bütünlük ilkeleri doğrultusunda korunmasını esas alarak, Erkilet'te yer alan kaya oyma yapılar, mescitler ve geleneksel konut dokusunun özgün malzeme, plan şeması ve mekânsal bağlamlarıyla ele alınmasını gerekli kılmaktadır. Burra Tüzüğü (1979; 2013) ise kültürel mirası yalnızca fiziksel özellikleriyle değil, sosyal, tarihsel ve sembolik değerleriyle birlikte değerlendiren "kültürel önem" kavramını ön plana çıkarmakta; bu yaklaşım Erkilet'te yerleşim sürekliliği, gündelik yaşam pratikleri ile su ve üretim kültürü gibi somut olmayan değerlerin de koruma sürecine dâhil edilmesini zorunlu kılmaktadır. Ayrıca UNESCO Dünya Mirası Sözleşmesi (1972) ve ICOMOS'un tarihî kentsel peyzaj yaklaşımı, Erkilet'in doğal topoğrafyası, kaya oluşumları ve tarihî yapıların oluşturduğu bütüncül peyzajın korunmasını destekleyerek, sit alanı ve çevresinin birlikte ele alınmasını öngörmektedir (URL 2).

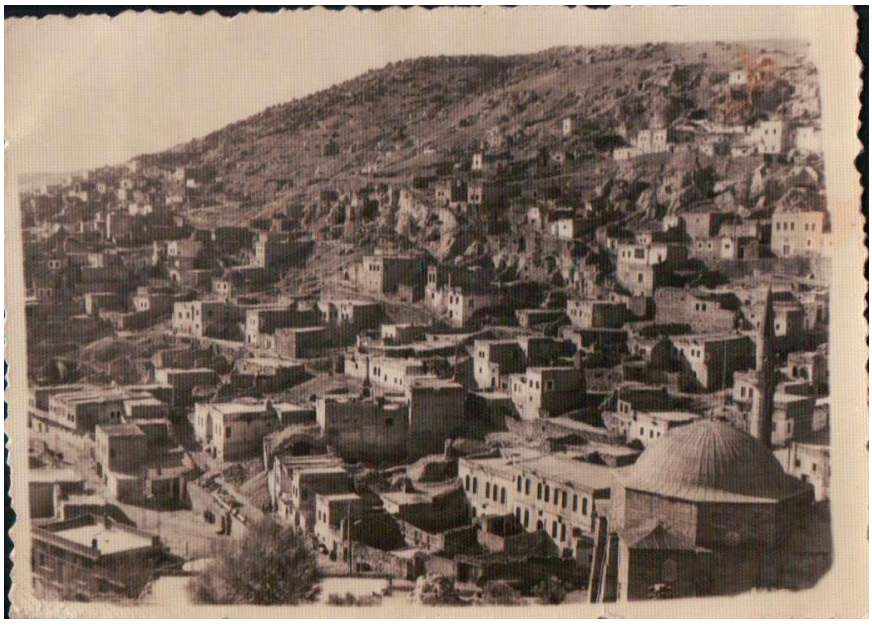
Arkeolojik sit alanlarına ilişkin koruma ve kullanma koşulları, Türkiye'de 14.07.1998 tarihli ve 594 sayılı İlke Kararı ile belirlenmiş; uygulamada ortaya çıkan sorunlar ve Danıştay 6. Dairesinin 11.11.1997 tarihli kararları doğrultusunda yeniden düzenlenmiştir. Bu kapsamda arkeolojik sitler, eski uygarlıklara ait kültür varlıklarının bulunduğu alanlar olarak tanımlanmış ve I., II. ve III. derece olmak üzere sınıflandırılmıştır. I. derece arkeolojik sitler, bilimsel çalışmalar dışında aynen korunacak alanlar olup yapılaşmaya kapalıdır; yalnızca zorunlu altyapı müdahaleleri ve kurul izniyle sınırlı düzenlemelere izin verilmektedir. II. derece arkeolojik sitlerde yeni yapılaşma yasak olmakla birlikte, mevcut tescilsiz yapıların basit onarımlarına izin verilmektedir. III. derece arkeolojik sitlerde ise koruma–kullanma dengesi gözetilerek, geçiş dönemi yapılanma koşulları çerçevesinde kontrollü müdahaleler kurul kararıyla mümkün olabilmektedir (URL 1).

Bu çerçevede Erkilet Arkeolojik Sit Alanı, anıtsal ve sivil mimarlık örneklerinin yanı sıra doğal–kültürel peyzaj bütünlüğü ve toplumsal belleğiyle değerlendirilmesi gereken çok katmanlı bir miras alanı niteliği taşımaktadır. Alana yönelik müdahalelerin, geri döndürülebilirlik, asgari müdahale ve sürdürülebilir kullanım ilkeleri doğrultusunda ele alınması; hem kültürel mirasın korunmasını hem de sürdürülebilir kalkınma hedefleriyle uyumlu biçimde yaşatılmasını mümkün kılacaktır.

2. TARİHSEL SÜREÇ İÇERİSİNDE ERKİLET

Erkilet, Kayseri ili Kocasinan ilçesinde, kültürel sürekliliği Eski Anadolu Uygarlıklarına kadar uzanan önemli bir yerleşim alanıdır. Yerleşim tarihine ilişkin kesin arkeolojik veriler sınırlı olmakla birlikte, bölgedeki kültürel geçmişin Hitit dönemine dayandığı, çevrede bulunan doğal kaya oluşumlarının Roma ve Bizans dönemlerinde kullanılmış olmasının ise alanın Kapadokya yerleşimleriyle benzerlik taşıdığını gösterdiği kabul edilmektedir (Gelb, 1939; Erkilet Vakfı, 2025). M.Ö. 1. yüzyıl ile M.S. 2. yüzyıllar arasına tarihlenen büyük tümülüs, Erkilet'in bilinen

en erken arkeolojik kalıntıları arasında yer almaktadır. Yerleşim adının, bazı kaynaklarda Oğuz boylarına mensup "Erkil Ata" ile ilişkilendirildiği ifade edilmektedir (Erkilet Vakfı, 2025).
Osmanlı arşivlerinde "Erkilât" olarak geçen yerleşim, 16. yüzyılda Sahra Nahiyesi'ne bağlı bir köy konumundaydı. Bu dönemde 435 Müslüman ve 144 gayrimüslim olmak üzere toplam 579 haneden oluşan bir yerleşim birimi olduğu belirtilmektedir (Erkiletlioğlu, 1996). 18. yüzyıl başlarında Sadrazam Nişancı Mehmet Paşa tarafından vakfedilmesiyle birlikte bölgede kapsamlı bir imar faaliyetinin başladığı, bu süreçte cami, külliye ve çeşitli vakıf yapılarının inşa edildiği bilinmektedir (Erkilet Vakfı, 2025). Yerleşimin adının, Antik Çağ'da "Arkalla" ya da "Archalla" olarak anıldığı ve bu adın Kapadokya Kralı Arkhelaus ile ilişkilendirildiği çeşitli kaynaklarda belirtilmektedir (Maraşlıoğlu, 2014). Osmanlı döneminde ise yerleşimin "Erkilat/Erkilet" adıyla anılmaya başlandığı, bu adlandırmanın Nişancı Mehmet Paşa tarafından verildiği ve bazı araştırmacılar tarafından "Erkatlar" adlı Türk boyuyla ilişkilendirildiği aktarılmaktadır (İnbaşı, 2010; Yinanç & Elibüyük, 2009; Özdoğan, 1948; Tali, 2022).
Erkilet'in mekânsal gelişimi üç temel dönemde incelenmektedir. İlk evrede yerleşim, savunma amaçlı olarak kayalık yamaçlarda yoğunlaşmış; ikinci evrede 18. yüzyıldaki vakfiye düzenlemeleriyle güneye doğru genişlemiştir. Üçüncü evre ise 1980'ler sonrası kaya düşmesi ve heyelan riskleri nedeniyle ova kesimine yönelimi içermektedir. Bu dönemde afet konutları ve kooperatif yerleşimleri ortaya çıkmıştır (Yinanç, 1984; Erkilet Vakfı, 2025). Bölgenin tarihsel sürekliliğini destekleyen önemli bulgulardan biri de 1932'de keşfedilen ve bugün Kayseri Müzesi'nde korunan iki Hitit hiyeroglif yazıtıdır (Gelb, 1939).



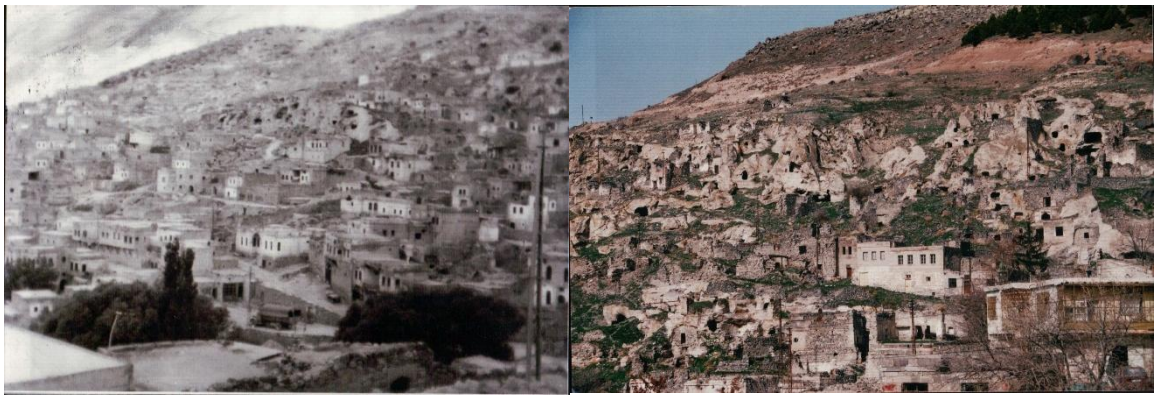
Görsel 1. 1955 Yılı Hanönü'nden Hastek ve Zade Mahaleleri (Erkilet Vakfı, 2025)

Erkilet'in mimari mirası Selçuklu ve Osmanlı dönemlerine ait çok sayıda yapıyı barındırmaktadır. Özellikle Selçuklu dönemine tarihlenen Hızırilyas Tepesi Köşkü, bölgedeki

nadir sivil mimarlık örneklerinden biridir ve II. Gıyaseddin Keyhüsrev döneminde inşa edilmiştir (Eravşar, 2000; Erkiletlioğlu, 2006). Osmanlı dönemine ait en önemli yapılar arasında ise Nişancı Mehmet Paşa tarafından yaptırılan cami ve külliye yer almaktadır (Erkilet Vakfı, 2025).

Depremler ve kaya düşmeleri gibi doğal afetler, yerleşimin tarihsel gelişimini etkileyen unsurlar arasında yer almaktadır. 1618'de büyük bir kaya parçasının koparak yapıların üzerine düşmesi, 1717 ve 1835 depremlerinin bölgedeki mimari dokuya zarar verdiği çeşitli kaynaklarda belirtilmiştir (Eravşar, 2000; Erkiletlioğlu, 2006). Tüm bu veriler, Erkilet'in tarihsel kimliğinin uzun dönemli bir kültürel birikim, coğrafi koşullar ve farklı dönemlerdeki yönetimsel müdahalelerle şekillendiğini göstermektedir.

Erkilet yerleşimi, Orta Asya'dan gelen Türk toplulukları tarafından kurulmuş olup tarihsel süreçte tarım ve hayvancılığa dayalı bir ekonomik yapıya sahip olmuştur. Türk yerleşimi öncesinde bölgede Rum ve Ermeni nüfusun yoğun olduğu, özellikle ticari faaliyetlerin bu grupların kontrolünde bulunduğu; demiryolunun 1926'da Kayseri'ye ulaşması ve 1936'da Sümer Bez Fabrikası'nın açılmasıyla birlikte Erkilet'te iş olanaklarının ve ekonomik hareketliliğin arttığı anlaşılmaktadır. Ancak sanayi ve ticarette elde edilen birikimin büyük kentlere yönelmesi, yerel ölçekte üretim ve istihdamın sınırlı kalmasına neden olmuştur. Günümüzde Erkilet'te tahıl tarımı ağırlıklı olmak üzere sınırlı ölçekte şeker pancarı, üzüm ve meyve yetiştiriciliği yapılmakta; sebze üretimi ise çoğunlukla hane içi tüketime yöneliktir. Tarımda makineleşme yaygın olmakla birlikte, tarım ve hayvancılık ekonomik yapı içinde ikincil bir konuma gerilemiş; nüfusun büyük bölümü işçi, esnaf ve memur kesiminden oluşmuştur. (Erkilet Vakfı, 2025).



Görsel 2. 1963 Yılı (Hanönü) ve Eski Erkiletin Genel Görünüşü (Erkilet Vakfı, 2025)

Erkilet, Kayseri kent merkezinin kuzeybatısında, yaklaşık 8–10 km uzaklıkta yer alan; ilk yerleşimi Hıdırellez Tümülüsü çevresinde oluşmuş, zamanla aşağı kotlara doğru genişlemiş tarihî bir yerleşimdir. Erkilet Arkeolojik Sit Alanı, Yamula Barajı'nın doğu–güneydoğusunda, kentin kuzeybatı yönünde konumlanmaktadır. Alan, baraj havzası ile Kayseri şehir merkezi arasında yer almakta, topoğrafik olarak eğimli kaya yamaçları ve tüf oluşumları üzerinde gelişmiştir. Sit alanı içerisinde, kaya oyma mekânlar, Adak Kilisesi ve çeşitli sivil mimarlık örnekleri yer almaktadır. Buna karşılık, Erzade ve Arabidin mescitleri, Nişancı Mehmet Paşa Camii ile geleneksel konut dokusunu oluşturan sivil mimari örnekleri ve çeşme yapılarının önemli bir bölümü, mevcut sit sınırlarının dışında kalmaktadır. Bu durum, koruma–kullanma

bütünlüğünü zedeleyen parçalı bir mekânsal yapı ortaya çıkarmış; sit alanı dışında kalan tarihî yapıların, koruma süreçlerinden yeterince yararlanamaması sonucunda fiziksel bozulma ve işlev kaybı süreçleri hızlanmıştır.

Erkilet Arkeolojik Sit Alanı'nda gözlenen terk edilme ve bozulma süreci, yalnızca bu yerleşime özgü bir durum olmayıp, kırsal alanlarda yer alan pek çok yerleşimde benzer biçimde yaşanan yapısal ve mekânsal dönüşümlerin bir parçası olarak değerlendirilmelidir. Özellikle heyelan riski ve Yamula Barajı'nın su tutmasıyla birlikte, Taşhan, Boyacı ve Çevril gibi yakın çevredeki yerleşimlerde önemli değişimler yaşanmış; nüfus, daha güvenli ve yüksek kotlarda konumlanan yeni yerleşim alanlarına taşınmıştır. Bu süreç sonucunda, eski yerleşim alanları büyük ölçüde boşalmış; anıtsal mimari yapılar ile sivil mimari örnekleri terk edilerek yoğun fiziksel tahribata maruz kalmıştır. Eski Erkilet'te de benzer bir mekânsal dönüşüm süreci yaşanmış, tarihsel yerleşim dokusunun zamanla aşağı kotlara doğru kayması, eski yerleşim alanlarında işlev kaybını ve yapısal bozulmayı hızlandıran temel etkenlerden biri olmuştur.

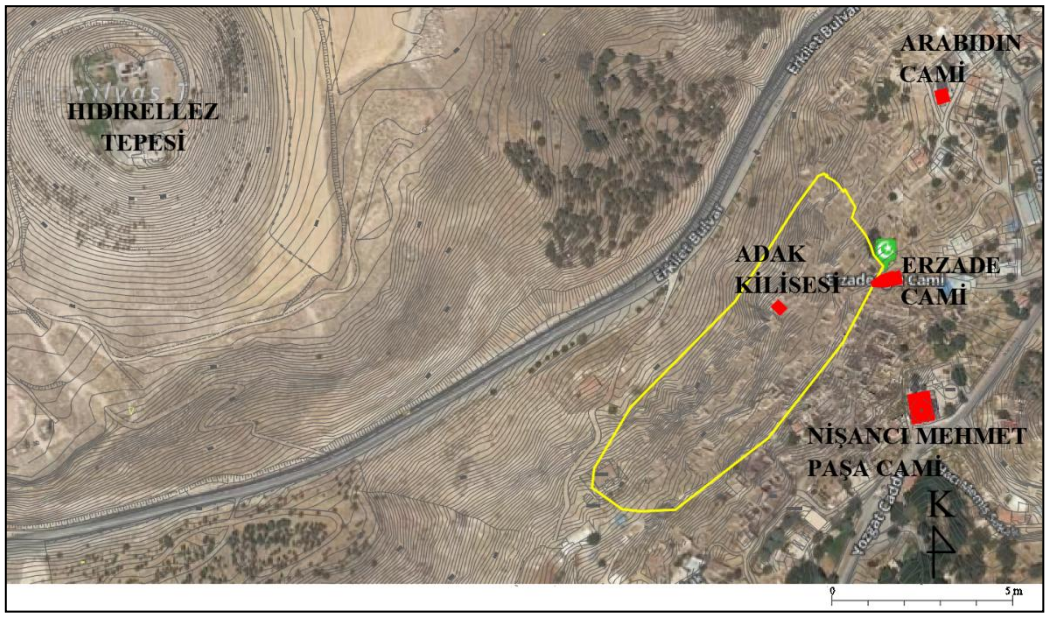


Görsel 3. 1990lı Yıllar le Günümüz Erkilet ve Erciyes Manzarası (Erkilet Vakfı, 2025; Güler, 2025).

2020 tarihli ve 4556 sayılı karar ile "kaya oyma mekânlar ve yerleşim alanı" niteliği kapsamında II. derece arkeolojik sit alanı olarak tescil edilen Erkilet'te, farklı dönemlere ait çok katmanlı bir kültürel miras birikimi bulunmaktadır. Sit alanında ve çevresinde kaya oyma mekânlar (Adak Kilisesi, kaya oyma kiliseler ve mezarlar), geleneksel konut dokusu, mescitler, bezirhaneler ve hamam kalıntıları yer almakta; ayrıca dönemin su kültürünü yansıtan çeşmeler, şadırvanlar, köprüler ve yunaklar gibi yapılar da bulunmaktadır. Osmanlı dönemine tarihlenen Nişancı Mehmet Paşa Camii ile Erzade ve Arabidin mescitleri, bu bütünün önemli bileşenleri arasında yer almaktadır. Söz konusu yapı çeşitliliği, Erkilet'in yerleşim sürekliliğini ve üretim ile su kültürü etrafında şekillenen gündelik yaşam pratiklerini ortaya koymakta; alanın tarihsel, mimari ve kültürel katmanlarının bütüncül biçimde ele alınmasını gerekli kılmaktadır.



Görsel 4. Erkilet Arkeolojik Sit Alanının Konumu



Görsel 5. Arkeolojik Sit Alanı Sınırı ve İncelenen Yapılar (Kocasinan belediyesinden alınan halihazır harita üzerinden yazar tarafından yeniden işlenmiştir.)

Bununla birlikte, arkeolojik sit alanı sınırlarının belirlenmesinde tüm tarihî yapıların ve sivil mimari örneklerinin yeterince dikkate alınmadığı anlaşılmaktadır. Köy merkezindeki kaya oyma yapılar ve çevresindeki geleneksel konut dokusunun bir bölümünün sit alanı sınırları içinde, bir bölümünün ise dışında kalması; koruma–kullanma bütünlüğünü zedeleyen parçalı bir mekânsal yapı ortaya çıkarmıştır. Sit sınırları dışında kalan yapıların da terk edilmiş olması, bu alanların koruma süreçlerinden yeterince yararlanamamasına ve fiziksel bozulmanın artmasına neden olmuştur.

Sit alanının üst kotlarında yer alan Hıdırellez Tümülüsü (Hızır İlyas Köşkü) çevresinde gerçekleştirilen peyzaj düzenlemeleri ve rekreasyon amaçlı millet bahçesi uygulamaları, bölgenin kamusal kullanım potansiyelini artırmış olsa da, bu düzenlemelerin arkeolojik sit alanı

ve çevresindeki tarihî yerleşim dokusuyla bütüncül bir planlama yaklaşımı içinde ele alınmadığı görülmektedir. Bu durum, Erkilet'te kültürel mirasın korunması, yeniden işlevlendirilmesi ve sürdürülebilir biçimde değerlendirilmesi açısından kapsamlı ve bütüncül bir koruma stratejisine duyulan ihtiyacı açıkça ortaya koymaktadır.



Görsel 6. Günümüz Arkeolojık Sit Alanı (Güler, 2025).



Görsel 7. Erkilet İmar Planı (URL 4)

2.1. Erkilet Arkeolojik Sit Alanı ve Çevresindeki Önemli Yapılar

Adak Kilisesi

Adak Kilisesi, arkeolojik sit sınırı içerisinde, yerleşime hâkim bir konumda, tüf kaya içine oyularak inşa edilmiş kaya oyma bir yapıdır. Kuzeydoğu–güneybatı doğrultusunda uzanan kilise, sade ve işlevsel bir mekân düzenine sahip olup geniş bir giriş açıklığı, nişler ve kubbeli bir tavan ile tanımlanmaktadır. İç mekânda fresk veya boya izlerine rastlanmamakta, yüzeylerin büyük ölçüde ateş kullanımına bağlı oluştuğu düşünülen siyah bir tabaka ile kaplı olduğu görülmektedir. El aletleriyle gerçekleştirilen kaba yontma izleri, yapının inşa tekniğini ortaya koymaktadır. Adak Kilisesi, Göreme Vadisi ve çevresindeki kaya oyma kiliselerle benzer biçimde tüf kayaya oyulmuş olmakla birlikte, süsleme açısından daha yalın bir karakter sergilemekte; bu durum yapının mütevazı bir dini işleve sahip olabileceğine ya da bezemelerin zamanla tahrip olduğuna işaret etmektedir (Kaderli & Arık, 2025)

Erzade Mescidi

Arkeolojik sit sınırının hemen dışında yer alan Erzade mesciti, günümüzde büyük ölçüde harap hale gelmiş, uzun süredir işlevsiz ve korunmasız durumdadır. Kitabesi bulunmadığından kesin inşa tarihi bilinmemekle birlikte, mimari özellikleri ve benzer örnekler dikkate alındığında 19. yüzyılın ikinci yarısına tarihlenebileceği değerlendirilmektedir. Doğu–batı doğrultusunda uzanan dikdörtgen planlı, tek mekânlı bir mahalle mescidi olan yapı, basık kemerli taş giriş açıklığı, mazgal pencereleri, ahşap direklerle taşınan düz toprak dam örtüsü ve sade iç mekân düzeniyle geleneksel Anadolu mescit mimarisinin karakteristik özelliklerini yansıtmaktadır. Güney cephede yer alan, palmet ve rumi motifleriyle süslenmiş mihrap yoğun tahribata uğramış; özgün köşk minaresi günümüze ulaşmamış ve yerine yakın dönemde yapının tarihsel kimliğiyle uyumsuz bir müdahale gerçekleştirilmiştir. Yapının doğu cephesinde, geçmişte medrese olarak kullanıldığı aktarılan ek bir mekânın kalıntıları bulunmakta ve genel olarak yapı hem yapısal hem de estetik açıdan ciddi bozulmalar göstermektedir (Kaderli & Güler, 2025).



Görsel 8. Adak Kilisesi ve Erzade Mesciti (Kaderli & Arık, 2025; Kaderli & Güler, 2025).

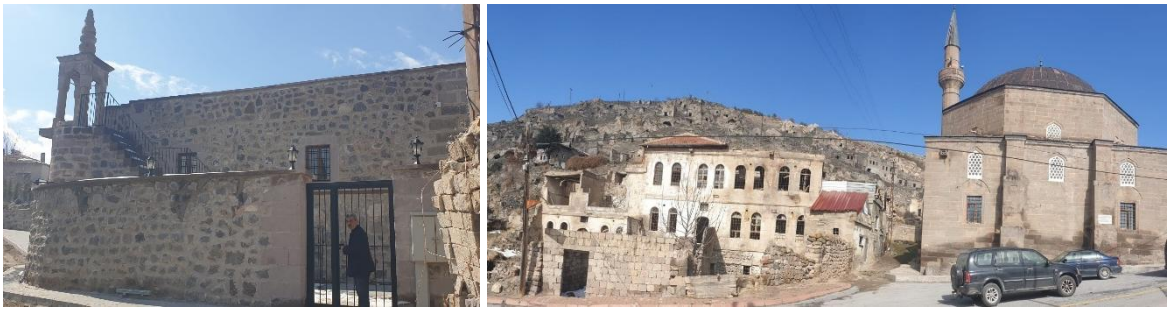
Arabıdın (Arabidin) Mescidi

Sit alanının dışında yer alan Arabidin Mescidi, H.1253/M.1837–38 yılında el-Hac Mustafa tarafından inşa edilmiştir. Günümüzde restore edilmiş ve ibadete açık olan yapı, tek mekânlı mahalle mescidi tipolojisinde kurgulanmıştır. Kaba yonu moloz taş malzeme ile inşa edilen yapıda, kuzey cephede yer alan girişten ulaşılan harimde güney duvarın ortasında yarım daire formlu, dilimli sivri kemerle çerçevelenmiş bir mihrap bulunmaktadır. Güney ve doğu cephelerde simetrik pencere açıklıkları, batı cephede ise küçük nişler yer almaktadır. Yapının güneydoğusunda, silindirik kaideli ve kesme taştan inşa edilmiş köşk minaresi konumlanmakta; minare, dört çokgen sütun üzerine oturan kemerciğin taşıdığı külahla sonlanmaktadır. Genel mimari özellikleriyle Erzade Mescidi ile benzerlik gösteren yapı, 19. yüzyıl Osmanlı taşra mescit mimarisinin sade plan anlayışını ve sınırlı bezeme geleneğini yansıtmaktadır (Özbek & Aslan, 2008;268).

Nişancı Mehmet Paşa Cami

Kurşunlu Camii, Cami Kebir veya Merkez Camii olarak da bilinen yapı, H.1130/M.1718 yılında Erkiletli Hacı Ali Ağa oğlu Nişancı Mehmet Paşa tarafından, depremde yıkılan Musa Ağa Camii'nin yerine inşa ettirilmiştir. Kesme taş malzemeyle yapılan cami, arazinin eğimine bağlı olarak payandalarla desteklenmiş, kuzeyde üç bölümlü son cemaat yeri ve tek mekânlı, tromplarla geçilen kubbeli harim düzenine sahiptir. Basit ve dengeli plan kurgusu, sade mihrap

ve taş minberiyle 18. yüzyıl Osmanlı taşra cami mimarisinin karakteristik özelliklerini yansıtan yapı, günümüzde sağlam durumda olup ibadete açıktır (Özbek & Aslan, 2008;210).



Görsel 9. Arabıdın (Arabidin) Mescidi ve Nişancı Mehmet Paşa Cami (Güler, 2025)

Sivil Mimari (Konutlar)

Sit alanında ve çevresinde yer alan sivil mimari örnekleri, çoğunlukla küçük ölçekli, geleneksel konut tipolojisini yansıtan yapılardan oluşmaktadır. Bu konutlarda alt katlar genellikle ahır, mutfak ve depo gibi hizmet mekânlarına ayrılmış; üst katlar ise yaşam alanı olarak düzenlenmiştir. Teras çatı uygulaması yaygın kullanılmakla birlikte, plan kurgusu, mekânsal organizasyon ve yapı tekniği açısından Kayseri ve çevresinde görülen geleneksel konut mimarisinin sürekliliğini ortaya koymaktadır. Bu özellikleriyle söz konusu yapılar, bölgenin yerel yaşam biçimini ve kırsal–kentsel geçiş karakterini yansıtan önemli sivil mimarlık örnekleri niteliğindedir.



Görsel 10. Sivil Mimari Örnekleri (Güler, 2025)

3. SÜRDÜRÜLEBİLİR KALKINMA KAVRAMI

Sürdürülebilir kalkınma kavramı, ilk olarak Meadows ve arkadaşlarının (1972) dünya sisteminin ekolojik sınırlarına dikkat çeken çalışmalarıyla gündeme gelmiş; 1987 yılında Dünya Çevre ve Kalkınma Komisyonu'nun Our Common Future (Ortak Geleceğimiz) raporuyla kuramsal ve politik bir çerçeve kazanmıştır (Meadows vd., 1992; WCED, 1987). Brundtland Raporu'nda sürdürülebilir kalkınma, "mevcut kuşakların gereksinimlerini, gelecek kuşakların kendi gereksinimlerini karşılama olanaklarını tehlikeye atmadan karşılayan kalkınma" olarak tanımlanmış; bu tanım Macmillan Çevre Sözlüğü ve Brackley (1988) tarafından da benimsenmiştir (Bozlağan, 2010). Literatürde kavram, yenilenebilir kaynakların

tükenmesini önleyen, çevresel tahribatı sınırlayan ve ekosistemlerin taşıma kapasitesini gözeten bir büyüme modeli olmanın ötesinde; yaşam kalitesinin artırılması, sosyal eşitliğin sağlanması ve doğal-kültürel değerlerin korunmasını içeren çok boyutlu bir yaklaşım olarak ele alınmaktadır (Barton vd., 1993; Blowers, 1993). Decleris (2000) ise sürdürülebilir kalkınmayı, kuşaklar arası adalet, biyolojik çeşitliliğin korunması, kültürel mirasın sürekliliği ve mekânsal planlama yoluyla insan yapımı sistemler ile ekolojik sistemler arasında denge kurulmasını esas alan hukuki ve etik bir sorumluluk olarak değerlendirmektedir. Bu bağlamda sürdürülebilir kalkınma, ekonomik, sosyal, kültürel ve çevresel boyutları bütüncül biçimde ele alan, uzun vadeli yaşam kalitesini merkeze alan bir kalkınma anlayışını ifade etmektedir (Decleris, 2000).

3.1. Sürdürülebilir Kalkınmanın Kültürel Mirasla İlişkisi

1970'lerden itibaren hızlanan kentleşme ve serbest piyasa ekonomisinin yol açtığı çevresel sorunlar, sürdürülebilir kalkınma arayışlarını uluslararası düzeyde zorunlu kılmış; bu doğrultuda kavram, 1972 Birleşmiş Milletler Stockholm İnsan Çevresi Konferansı'nda çevresel bozulma ile ekonomik kalkınmanın uyum içinde yürütülmesi gerekliliğinin vurgulanmasıyla ilk kez küresel gündeme taşınmış, raporda gelecek kuşakların ihtiyaçlarını gözeten bir kalkınma anlayışının önemi belirtilmiş ve sosyal-kültürel programlara ilişkin tavsiyeler sunulmuştur (Stokholm, 1973, 3; 24). Bu yaklaşım, 1987 Dünya Çevre ve Kalkınma Komisyonu tarafından yayımlanan ve sürdürülebilir kalkınmayı "gelecek nesillerin kendi ihtiyaçlarını karşılama becerilerinden ödün vermeden bugünün ihtiyaçlarının karşılanması" olarak tanımlayan Brundtland Raporu ile kuramsal bir çerçeveye kavuşturulmuş; rapor, sürdürülebilirliğin çevresel, ekonomik ve sosyal olmak üzere üç boyutunu açık biçimde ortaya koymuştur (Brundtland, 1987, 1; Nocca, 2017, 2).

1992 Rio Dünya Zirvesi ise Brundtland Raporu'nun etkisiyle sürdürülebilir kalkınmayı kurumsallaştırmış, Rio Bildirgesi ve bu bildirgenin uygulanmasına yönelik kapsamlı bir eylem planı niteliğindeki Gündem 21'i kabul ederek kavramın yönetişim boyutunu güçlendirmiştir (Rio, 1992). 2002 Johannesburg Dünya Zirvesi, sürdürülebilir kalkınma tartışmalarında çevresel odaktan sosyal ve ekonomik boyutlara doğru bir yönelme olduğunu göstermiş; zirve sonucunda yayımlanan Siyasi Bildiri ve Uygulama Planı, bu dönüşümün politik ve uygulamalı altyapısını oluşturmuştur (Johannesburg, 2002). 2010 Birleşmiş Milletler Küresel Kalkınma Yüksek Düzey Paneli, sürdürülebilir kalkınmanın ekonomik büyüme, sosyal eşitlik ve çevresel korumanın dengeli bütünleşmesine dayandığını resmi olarak teyit etmiş; 2012 Rio+20 Konferansı ise "yeşil ekonomi/yeşil büyüme" kavramlarını benimseyerek sürdürülebilir kalkınmanın yeni küresel kalkınma paradigmasıyla uyumunu sağlamayı hedeflemiştir (Rio de Janeiro, 2012). Son olarak, 2015'te kabul edilen 2030 Sürdürülebilir Kalkınma Gündemi, önceki tüm girişimlerin yerini alarak 17 küresel amaç ve 169 hedef içeren kapsamlı bir eylem planı ortaya koymuş ve sürdürülebilir kalkınmayı uluslararası politika çerçevesinin temel ekseni haline getirmiştir (Gündem 30, 2015).



Görsel 11. Sürdürülebilir Kalkınma Amaçları (URL 3)

3.2. Sürdürülebilir Kalkınma Amaçları Bağlamında Erkilet Arkeolojik Sit Alanı

Erkilet Arkeolojik Sit Alanı, sahip olduğu çok katmanlı kültürel miras birikimi, geleneksel yerleşim dokusu ve doğal peyzaj özellikleriyle başta Sürdürülebilir Kalkınma Amacı 11 (Sürdürülebilir Şehirler ve Topluluklar) ile doğrudan ilişkilidir. Özellikle 11.4 maddesi kapsamında tarihî ve kültürel mirasın korunması ve yaşatılması hedefi doğrultusunda, kaya oyma mekânlar, mescitler, geleneksel konutlar ve anıtsal yapılar kentsel kimliğin sürekliliğini sağlayan temel unsurlar olarak öne çıkmaktadır. Alanın bütüncül bir koruma yaklaşımıyla ele alınması, tarihî çevrenin kentsel yaşamla entegrasyonunu güçlendirmekte ve yerel kimliğin sürdürülebilirliğine katkı sunmaktadır.

Alan, doğal topoğrafyası, kaya oluşumları ve kültürel peyzaj bileşenleriyle birlikte değerlendirildiğinde Sürdürülebilir Kalkınma Amacı 15 (Karasal Yaşam) ile de doğrudan ilişkilidir. Özellikle 15.1 ve 15.4 maddeleri, doğal ve kültürel peyzajın birlikte korunmasını ve sürdürülebilir biçimde yönetilmesini öngörmekte; Erkilet örneği, insan yerleşimi ile doğal çevre arasındaki hassas dengenin korunmasının önemini ortaya koymaktadır.

Erkilet Arkeolojik Sit Alanı, Sürdürülebilir Kalkınma Amacı 4 (Nitelikli Eğitim) ile de doğrudan bağlantılıdır. Özellikle 4.7 maddesi kapsamında kültürel miras bilincinin geliştirilmesi, tarihî çevrelerin eğitim ve farkındalık amaçlı kullanımı açısından alan önemli bir açık hava öğrenme ortamı niteliği taşımaktadır. Arkeolojik ve mimari değerlerin belgelenmesi, tanıtılması ve akademik çalışmalara konu edilmesi, kültürel mirasın kuşaklar arası aktarımını destekleyen temel unsurlar arasında yer almaktadır.

Alan, Sürdürülebilir Kalkınma Amacı 8 (İnsana Yakışır İş ve Ekonomik Büyüme) ile de doğrudan ilişkilidir. 8.3 ve 8.9 maddeleri kapsamında, kültürel miras temelli turizm, yaratıcı endüstriler ve yerel ekonominin desteklenmesi açısından önemli bir potansiyel sunmaktadır. Tarihî yapıların korunarak yeniden işlevlendirilmesi, istihdam olanaklarının artırılmasına ve yerel kalkınmanın teşvik edilmesine katkı sağlayabilecek bir araç olarak değerlendirilebilir.

Erkilet örneği aynı zamanda Sürdürülebilir Kalkınma Amacı 13 (İklim Eylemi) ile doğrudan bağlantılıdır. Özellikle 13.1 maddesi doğrultusunda, heyelan, kaya düşmesi ve jeolojik risklere

karşı alınacak önleyici tedbirler, hem kültürel mirasın korunması hem de yerleşim güvenliğinin sağlanması açısından önem taşımaktadır. Tarihî yerleşimlerin afet risklerine karşı dayanıklılığının artırılması, sürdürülebilir koruma politikalarının ayrılmaz bir bileşeni olarak değerlendirilmektedir.

Buna karşılık, alan ile Sürdürülebilir Kalkınma Amacı 3 (Sağlık ve Kaliteli Yaşam) arasında dolaylı bir ilişki kurulabilir. 3.9 maddesi kapsamında, kontrollü rekreasyon alanları, peyzaj düzenlemeleri ve açık alan kullanımları yoluyla tarihî çevrenin sağlıklı yaşam koşullarını desteklemesi mümkündür. Hıdırellez Tümülüsü çevresinde gerçekleştirilen rekreasyon ve millet bahçesi düzenlemeleri bu bağlamda değerlendirilebilecek uygulamalardır.

Benzer şekilde, Sürdürülebilir Kalkınma Amacı 12 (Sorumlu Üretim ve Tüketim) ile de dolaylı bir ilişki söz konusudur. 12.2 ve 12.8 maddeleri kapsamında mevcut yapı stokunun korunarak yeniden kullanılması, kaynakların verimli kullanımı ve sürdürülebilir tüketim bilincinin geliştirilmesi açısından Erkilet Arkeolojik Sit Alanı örnek bir potansiyel sunmaktadır. Bu çerçevede Erkilet Arkeolojik Sit Alanı; SKA 11, 15, 4, 8 ve 13 ile doğrudan, SKA 3 ve 12 ile ise dolaylı ilişkiler kurabilen; kültürel mirasın korunmasını sürdürülebilir kalkınmanın sosyal, ekonomik ve çevresel boyutlarıyla bütünleştiren önemli bir örnek alan niteliği taşımaktadır.

Bu bağlamda Erkilet'in değerlendirilmesi, yalnızca yerel ölçekte değil, uluslararası ölçekte benzer özellikler taşıyan kaya oyma yerleşimler ve tarihî kırsal alanlar üzerinden de okunabilir. Uluslararası örnekler, kültürel miras alanlarında uygulanan farklı koruma ve dönüşüm yaklaşımlarının uzun vadeli etkilerini ortaya koyması açısından önemli karşılaştırma imkânları sunmaktadır. İran'daki Palangan Köyü ile İspanya'daki Setenil de las Bodegas, özgün fiziksel dokuları ve zengin sosyo-kültürel mirasları sayesinde turizm rotalarına dâhil edilmiş; ancak yere özgü koruma politikalarının yetersizliği nedeniyle, turizmin tetiklediği sektörleşme ve kontrolsüz dönüşüm sonucu yerel kimliklerini kaybetme riskiyle karşı karşıya kalmıştır. Buna karşılık, Mali'deki Bandiagara Yerleşkesi ve Çin'deki Mogao Mağaraları gibi UNESCO Dünya Mirası Alanları'nda, kapsamlı yönetim planları doğrultusunda bütüncül koruma yaklaşımları benimsenmiş; yerel toplumun sürece dâhil edilmesi, eğitim, izleme ve kontrollü ziyaretçi yönetimi yoluyla koruma–kullanma dengesi gözetilmeye çalışılmıştır. Ürdün'deki Petra ve İtalya'nın Basilicata Bölgesi'nde yer alan Matera (Sassi di Matera) örnekleri ise etkin koruma ve yönetim planlarına rağmen yoğun turizm baskısının sosyal ve ekonomik yapıyı dönüştürerek yerel yaşamın sürekliliğini zorlaştırdığını göstermektedir. Bu örnekler, kültürel miras alanlarında fiziksel korumanın tek başına yeterli olmadığını; yerel yaşam, sosyal yapı ve ekonomik ilişkileri merkeze alan sürdürülebilir ve yere özgü yönetim modellerinin gerekliliğini ortaya koymaktadır (Asrav, 2021:129-130).

Benzer biçimde, Türkiye'de Nevşehir Kalesi ve çevresi, Ortahisar ve Ürgüp gibi Kapadokya yerleşimleri, Erkilet'le benzer jeomorfolojik özelliklere ve çok katmanlı kültürel miras birikimine sahiptir. Bu alanlarda da kaya oyma mekânlar, geleneksel konut dokusu ve doğal topoğrafya bir arada bulunmakta; ancak turizm odaklı dönüşüm, plansız yapılaşma ve yerel nüfusun mekânsal dışlanması gibi süreçler, özgün yerleşim dokusunun bütünlüğünü tehdit etmektedir. Göreme Vadisi ve Kapadokya bölgesi, 1985 yılında UNESCO Dünya Mirası Listesi'ne dâhil edilmiş olmasına karşın, açık hava müzesi niteliği kazanmasıyla birlikte yoğun turizm baskısı altında kalmıştır. Bu durum, bölgedeki doğal aşınma süreçleri ve kontrolsüz ziyaretçi hareketleri nedeniyle, mirasın fiziksel bütünlüğünü ve özgün karakterini tehdit eden

risklerin devam ettiğini göstermektedir. Bu sebeple, Kapadokya bölgesindeki kültürel peyzaj alanlarında olduğu gibi, Erkilet Arkeolojik Sit Alanı'nda da koruma politikalarının yalnızca fiziksel müdahalelere değil; sosyal, ekonomik ve yönetsel bileşenleri kapsayan bütüncül koruma yaklaşımlarına dayanması gerekmektedir.

4. SONUÇLAR VE DEĞERLENDİRME

Bu çalışma kapsamında ele alınan Erkilet Arkeolojik Sit Alanı, tarihsel sürekliliği, çok katmanlı kültürel miras birikimi ve özgün yerleşim dokusuyla, sürdürülebilir kalkınma hedefleri çerçevesinde bütüncül koruma yaklaşımlarını zorunlu kılan nitelikli bir kentsel miras alanı niteliği taşımaktadır. Erkilet'in tarihsel süreçte Kayseri'den bağımsız, tarım ve bağcılığa dayalı bir yerleşim olarak geliştiği; zamanla kentin kenar yerleşimine dönüşerek havaalanının inşası, eğitim yapılarının yapılması ve ulaşım olanaklarının artmasıyla kentsel sistemle daha güçlü biçimde bütünleştiği görülmektedir. Özellikle son yıllarda, pandemi sonrası değişen yaşam pratikleriyle birlikte alt kotlarda yeni konut ve villa gelişmelerinin artması, alan üzerindeki yapılaşma baskısını belirgin biçimde artırmıştır.

Erkilet, uzun bir tarihsel geçmişe sahip olması ve farklı kültür katmanlarına ait mimari çeşitliliği bünyesinde barındırmasıyla dikkat çekmektedir. Bu yapıların bir bölümünün anıtsal nitelik taşıması, alanın kültürel miras değeri açısından önemini daha da artırmaktadır. Bu bağlamda Erkilet Arkeolojik Sit Alanı; SKA 11 (Sürdürülebilir Şehirler ve Topluluklar), SKA 4 (Nitelikli Eğitim), SKA 8 (İnsana Yakışır İş ve Ekonomik Büyüme), SKA 13 (İklim Eylemi) ve doğal–kültürel peyzaj bütünlüğü çerçevesinde SKA 15 (Karasal Yaşam) ile doğrudan; SKA 3 (Sağlık ve Kaliteli Yaşam) ve SKA 12 (Sorumlu Üretim ve Tüketim) ile ise dolaylı ilişkiler kurmaktadır. Özellikle kaya oluşumları, topoğrafik yapı ve peyzaj unsurlarının korunması, kültürel miras ile doğal çevrenin birlikte ele alınmasını gerektirmekte ve bu yönüyle SKA 15'in hedeflediği ekosistem bütünlüğü ve peyzaj koruma yaklaşımıyla örtüşmektedir. Bununla birlikte, alanın sosyal yapısı, mekânsal potansiyeli ve çok katmanlı karakteri dikkate alındığında, diğer sürdürülebilir kalkınma amaçlarıyla da ilişkilendirilebilecek kapsayıcı bir çerçeve sunduğu söylenebilir.

Alan için hazırlanacak koruma amaçlı imar planı kapsamında, gerekli güçlendirme ve restorasyon çalışmalarının bilimsel ilkelere dayalı biçimde gerçekleştirilmesi halinde, Erkilet'in yeniden değerlendirilmesi ve kentsel yaşama daha etkin biçimde kazandırılması mümkün görünmektedir. Kocasinan Belediyesi'nin, sit alanının korunması ve çevresinin yeniden işlevlendirilmesine yönelik bir planlama çalışması başlattığı bilinmekle birlikte, bu çalışmanın henüz uygulama aşamasına geçmediği görülmektedir. Kente olan yakınlığı ve son yıllarda artan konut ihtiyacı dikkate alındığında, özellikle pandemi ve deprem sonrası süreçte tercih edilen az katlı, bahçeli konut tipolojileri açısından Erkilet önemli bir potansiyel taşımaktadır. Bu doğrultuda, mevcut durumun doğru analiz edilmesiyle birlikte, alanın yeniden istihdam olanakları yaratacak biçimde değerlendirilmesi ya da kültürel miras temelli bir "kültür rotası" içine dâhil edilmesi sorgulanabilir. Sit alanının üst kotlarında yer alan Hıdırellez Tümülüsü'ne uzanan güzergâh boyunca, mevcut patikaların yürüyüş rotalarına dönüştürülmesi ve Erkilet bütününü kapsayan rekreatif düzenlemelerin yapılması, alanın sosyal ve kültürel açıdan canlandırılmasına katkı sağlayabilir. Bu yaklaşım, Matera (İtalya), Petra (Ürdün) ve Bandiagara (Mali) gibi uluslararası örneklerde görüldüğü üzere, kültürel miras alanlarının

bütüncül yönetim planları aracılığıyla koruma–kullanma dengesi gözetilerek kentsel yaşama entegre edilmesine yönelik güncel koruma politikalarıyla da örtüşmektedir.

Bu dönüşüm süreci, Erkilet'te yer alan arkeolojik ve mimari mirasın korunmasını daha kritik hâle getirmektedir. Heyelan ve kaya düşmesi gibi jeolojik riskler, alanın fiziksel sürdürülebilirliğini tehdit eden başlıca unsurlar arasında yer almakta; bu risklerin istinat yapıları, koruyucu sistemler ve kontrollü mühendislik çözümleriyle azaltılması mümkün görünmektedir. Ancak bu müdahalelerin, sit alanının doğal ve görsel bütünlüğünü zedelemeyecek biçimde, bilimsel raporlar ve disiplinler arası çalışmalar doğrultusunda gerçekleştirilmesi gerekmektedir.

Erkilet örneği, kültürel miras alanlarının kısmen yeniden işlevlendirilerek kentsel yaşama entegre edilmesinin, alanın hem korunmasına hem de sosyal ve ekonomik açıdan canlandırılmasına katkı sağlayabileceğini göstermektedir. Buna karşılık, plansız gelişme ve kontrolsüz yapılaşma, tarihî yerleşmenin özgün karakterini geri dönüşü olmayan biçimde tehdit etmektedir. Bu nedenle Erkilet Arkeolojik Sit Alanı için; koruma–kullanma dengesini gözeten, afet risklerini dikkate alan, yerel toplumu ve kültürel belleği merkeze alan sürdürülebilir bir koruma ve planlama yaklaşımının geliştirilmesi gerekmektedir. Bu yönüyle Erkilet, arkeolojik mirasın kentsel kimlik ve sürdürülebilir kalkınma hedefleriyle bütünleştirilebileceğini ortaya koyan önemli bir örnek alan niteliği taşımaktadır.

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TARİHİ KENTLERİN İKLİM DEĞİŞİKLİĞİNE UYUMU: SAFRANBOLU ÖRNEĞİNDE UYUM TEDBİRLERİ

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ÖZET

İklim değişikliği, artan sıcaklıklar, aşırı yağışlar ve su stresi gibi etkiler yoluyla kentlerin fiziksel ve ekolojik yapısını giderek daha fazla zorlamakta; bu durum tarihî kentler için daha karmaşık ve çok boyutlu riskler doğurmaktadır. Bu çalışma, Safranbolu özelinde, iklim değişikliğine uyum kapsamında alınması gereken öncelikli tedbirleri ortaya koymayı amaçlamaktadır. UNESCO Dünya Mirası Listesi'nde yer alan Safranbolu, korunması gereken tarihî dokusu ile iklim değişikliğine uyum gereklilikleri arasındaki hassas denge açısından önemli bir örnek teşkil etmektedir. Çalışmada Safranbolu'nun kentsel ve iklimsel özellikleri dikkate alınarak; sıcaklık artışı ve ısı dalgaları, aşırı yağış ve nem, kuraklık ve su stresi ile kentsel yeşil alan kaybı gibi başlıca iklim riskleri değerlendirilmiştir. Analiz süreci, UNESCO'nun kültürel miras ve iklim değişikliği politikaları ile "Historic Urban Landscape" yaklaşımı temel alınarak yürütülmüştür. Bu çerçevede, yapılı çevre, su yönetimi, kentsel peyzaj, afet ve risk yönetimi, ölçülebilirlik ve yönetişim başlıkları altında Safranbolu için uygulanabilir uyum tedbirleri tanımlanmıştır. Bulgular, Safranbolu'da iklim değişikliğine uyumun; sert ve geri döndürülemez fiziksel müdahaleler yerine, geleneksel mimarinin pasif iklim avantajlarını koruyan, su ve yeşil alan yönetimini güçlendiren ve veri temelli izleme mekanizmalarıyla desteklenen bütüncül bir yaklaşım gerektirdiğini göstermektedir.

Anahtar Kelimeler: İklim değişikliği, tarihi kentler, Safranbolu

1. GİRİŞ

İklim değişikliği, küresel ölçekte artan ortalama sıcaklıklar, aşırı hava olaylarının sıklık ve şiddetindeki artış, yağış rejimlerindeki değişimler ve su kaynakları üzerindeki baskılar yoluyla kentlerin fiziksel, çevresel ve sosyo-ekonomik sistemlerini derinden etkilemektedir (IPCC, 2021). Kentler, yoğun nüfus, yüksek yapılaşma oranı ve karmaşık altyapı sistemleri nedeniyle iklim değişikliğinin etkilerine karşı daha hassas hâle gelmekte; aynı zamanda küresel sera gazı emisyonlarının önemli bir bölümünden sorumlu olmaları nedeniyle bu sürecin hem nedeni hem de sonucu olarak öne çıkmaktadır (Seto et al., 2014; UN-Habitat, 2020).

Tarihî kentler, çağdaş kentlere kıyasla iklim değişikliğine karşı daha kırılgan bir yapı sergilemektedir. Bu kırılganlık, tarihî yapıların özgün malzeme özellikleri, yaşlanmış yapı stokları ve koruma odaklı planlama kısıtlarıyla doğrudan ilişkilidir. Literatürde, artan sıcaklıklar, nem değişimleri, aşırı yağışlar ve don-çözülme döngülerinin tarihî yapılarda fiziksel bozulma süreçlerini hızlandırdığı açıkça ortaya konmuştur (Hughes et al. 2020; Avila-Diaz vd., 2020 , Ummenhofer ve Meehl, 2017; Brimblecombe & Grossi, 2010). Bu bağlamda iklim değişikliği, yalnızca fiziksel hasar riski değil, aynı zamanda kültürel mirasın uzun vadeli sürdürülebilirliği açısından da ciddi bir tehdit oluşturmaktadır (Fatorić & Seekamp, 2017).

Bu çerçevede, Safranbolu, tarihî kentlerin iklim değişikliğine uyumu bağlamında önemli bir örnek teşkil etmektedir. Osmanlı dönemi sivil mimarisinin özgün örneklerini barındıran Safranbolu, tarihî kentsel dokusu, topoğrafik yapısı ve yoğun turizm faaliyetleri nedeniyle iklim değişikliğinin etkilerine karşı çok boyutlu bir kırılganlık sergilemektedir. Aynı zamanda UNESCO Dünya Mirası Listesi'nde yer alması, Safranbolu'da uygulanabilecek uyum önlemlerinin koruma ilkeleriyle uyumlu, geri döndürülebilir ve bütüncül bir yaklaşımla ele alınmasını zorunlu kılmaktadır (UNESCO, 2011).

UNESCO tarafından geliştirilen Historic Urban Landscape (HUL) yaklaşımı, tarihî kentlerin iklim değişikliğine uyum sürecinde yalnızca yapı ölçeğine odaklanılmaması; doğal çevre, peyzaj, sosyal yapı ve ekonomik faaliyetlerin birlikte değerlendirilmesi gerektiğini vurgulamaktadır (UNESCO, 2011; Hosagrahar et al., 2016). Bu yaklaşım, iklim değişikliğine uyumun sert mühendislik çözümleri yerine, yerel bağlama duyarlı, aşamalı ve veri temelli stratejilerle ele alınmasını önermektedir.

Bu çalışma, Safranbolu örneğinde tarihî kentlerin iklim değişikliğine uyum sürecinde alması gereken öncelikli tedbirleri belirlemeyi amaçlamaktadır. Çalışmanın kapsamı; yapılı çevre, su yönetimi, kentsel yeşil alanlar, afet ve risk yönetimi ile yönetişim başlıkları altında değerlendirilen uyum tedbirlerini içermektedir. Bu çerçevede, tarihî kentlerde iklim değişikliğine uyumun, koruma ilkeleriyle çelişmeyen; geleneksel kentsel bilginin bilimsel veriler ve çağdaş planlama araçlarıyla bütünleştirildiği bir yaklaşım gerektirdiği savunulmaktadır.

2. SAFRANBOLU'NUN KENTSEL VE İKLİMSEL ÖZELLİKLERİ

Safranbolu, Batı Karadeniz Bölgesi'nde, Karabük iline bağlı, engebeli topoğrafyaya sahip bir yerleşim olup tarihî kent dokusu büyük ölçüde vadi tabanları ve yamaçlar boyunca gelişmiştir. Kentin bu topoğrafik yapısı, mikroiklim koşullarının oluşmasında belirleyici olmakta; özellikle dar sokaklar, eğimli araziler ve yapı yoğunluğu, hava sirkülasyonu, yüzey akışı ve nem dağılımı üzerinde doğrudan etkili olmaktadır. Topoğrafyanın bu belirleyici rolü, Safranbolu'da aşırı yağışlar sırasında yüzey akışının hızlanmasına ve lokal taşkın risklerinin artmasına neden olabilmektedir.

Safranbolu'nun iklimi, Karadeniz iklimi ile İç Anadolu karasal iklimi arasında bir geçiş özelliği göstermektedir. Yaz ayları nispeten sıcak ve kurak, kış ayları ise soğuk ve zaman zaman kar yağışlı geçmektedir. Türkiye genelinde gözlenen iklim değişikliği eğilimlerine paralel olarak,

bölgede ortalama sıcaklıkların arttığı, aşırı sıcak gün sayısının yükseldiği ve yağışların mevsimsel dağılımında düzensizlikler ortaya çıktığı rapor edilmektedir (MGM, 2021; IPCC, 2021). Bu durum, Safranbolu gibi tarihî kentlerde hem yapı ölçeğinde termal stresin artmasına hem de su yönetimi ve altyapı sistemleri üzerinde ek baskılar oluşmasına yol açmaktadır.
Nüfus yapısı ve turizm faaliyetleri, Safranbolu'nun kentsel dinamiklerini şekillendiren temel unsurlar arasında yer almaktadır. Safranbolu'nun daimi nüfusu sınırlı olmakla birlikte, kültürel miras turizmi nedeniyle yılın belirli dönemlerinde kentte yoğun bir ziyaretçi artışı yaşanmaktadır. Bu mevsimsel nüfus artışı; su tüketimi, atık üretimi ve enerji talebinde ani yükselmelere neden olarak kentsel altyapı üzerinde ilave baskı oluşturmaktadır. Literatürde, turizm yoğunluğu yüksek tarihî kentlerde iklim değişikliğinin etkilerinin, bu geçici nüfus artışları nedeniyle daha da şiddetlendiği vurgulanmaktadır (Scott et al., 2016).
Safranbolu'nun tarihî yapı stoku, büyük ölçüde ahşap karkas sistemli, taş temelli ve geleneksel Osmanlı sivil mimarisinin özgün örneklerinden oluşmaktadır. Bu yapıların kalın duvarlar, saçaklar, avlular ve doğal havalandırma gibi pasif iklimlendirme özellikleri, geçmişte iklim koşullarına uyum sağlayan önemli avantajlar sunmuştur. Ancak günümüzde artan sıcaklıklar, nem oranındaki değişimler ve aşırı yağışlar, ahşap ve taş gibi geleneksel yapı malzemelerinde bozulma süreçlerini hızlandırmakta ve yapıların iklim değişikliğine karşı kırılganlığını artırmaktadır.
Safranbolu'nun UNESCO Dünya Mirası Listesi'nde yer alması, kentsel planlama ve müdahale süreçlerine önemli kısıtlar getirmektedir. Dünya Mirası statüsü, tarihî dokunun özgünlüğünü ve bütünlüğünü korumayı temel ilke olarak benimsemekte; bu durum, iklim değişikliğine uyum kapsamında gerçekleştirilecek fiziksel müdahalelerin sınırlı, geri döndürülebilir ve koruma odaklı olmasını zorunlu kılmaktadır (UNESCO, 2011). Dolayısıyla Safranbolu'da iklim değişikliğine uyum, yalnızca teknik bir çevre sorunu değil; aynı zamanda kültürel mirasın korunması, kentsel planlama ve yönetişim süreçlerini birlikte ele almayı gerektiren çok boyutlu bir planlama problemi olarak ortaya çıkmaktadır (Bandarin & van Oers, 2012).

3. SAFRANBOLU İÇİN ÖNE ÇIKAN İKLİM RİSKLERİ

3.1 Sıcaklık Artışı ve Isı Dalgaları

Safranbolu'nun dar ve yoğun yapılaşmış tarihî merkezi, doğal yüzeylerin azalması ve yapı malzemelerinin ısı tutma kapasitesi nedeniyle Kentsel Isı Adası (KİA) etkisine meyillidir. Küresel sıcaklık artışları ile birleşen KİA etkisi, termal stresi artırarak enerji talebini yükseltir ve kent konforunu olumsuz etkiler (Akbari, 2020). Bu durum, özellikle yaşlı nüfus için ciddi sağlık riskleri oluşturmaktadır. Tahminler, yüzyılın sonuna kadar 7,5°C'ye kadar varan potansiyel ısınmayla birlikte, aşırı sıcaklıklarda önemli bir artışa işaret etmektedir (Gümüş vd., 2024). Safranbolu evlerinin ana yapı malzemeleri olan ahşap karkas ve sıvalı kerpiç/dolgu, yüksek sıcaklık ve termal değişimlere karşı hassastır. Ani ve aşırı sıcaklık dalgaları, ahşapta kuruma, çatlama ve yoğun genleşme/büzülme döngülerine neden olarak yapısal bozulmayı hızlandırır. Bu durum, malzemelerin fiziksel bütünlüğünü tehdit ederek restorasyon maliyetlerini artırmaktadır.

3.2 Aşırı Yağış, Nem ve Taşkın Riski

Karabük bölgesinin genel topoğrafik yapısı ve iklim değişikliğinin tetiklediği şiddetli yağış rejimleri, Safranbolu için taşkın ve heyelan riskini önemli ölçüde artırmaktadır. Safranbolu'nun tarihî merkezi, derin vadilerin tabanına yerleşmiştir. Bu topoğrafik özellik, şiddetli yağışlarda yüzeysel akışı hızlandırır. Eski ve yetersiz kalmış drenaj sistemlerinin bu yüksek akışa cevap verememesi durumunda, sel ve taşkın olayları kaçınılmaz hale gelmektedir. Dere yatakları

yakınındaki tarihî yapılar ve altyapı bu riskten doğrudan etkilenmektedir. Artan nem ve yoğun yağış, tarihî yapı malzemelerinde biyolojik ve kimyasal bozulmaları tetikler. Ahşap elemanlar, yüksek nemin etkisiyle mantar ve böcek zararlarına karşı daha savunmasız hale gelirken, sıva ve taş gibi gözenekli malzemelerde nemlenme ve tuzlanma kaynaklı yüzey dökülmeleri ve erozyon hızlanmaktadır.

3.3 Kuraklık ve Su Stresi

Karadeniz Bölgesi genelinde yağış rejimi dengesizlikleri ve artan buharlaşma, Safranbolu'nun yeraltı ve yüzey su kaynakları üzerinde baskı yaratmaktadır. Uzun süreli kuraklık periyotları, su rezervlerinin azalmasına ve kentsel/tarımsal su ihtiyacının karşılanmasında ciddi kısıtlamalara yol açma potansiyeli taşımaktadır. Safranbolu'nun yoğun turistik faaliyetleri, özellikle yüksek sezonda su talebini doğal kaynaklar üzerindeki baskıyı artıracak şekilde yükseltmektedir. Kuraklık dönemlerinde, artan turizm talebiyle birlikte kısıtlı su kaynaklarının yönetimi, yerel yönetimler için önemli bir sorun haline gelmektedir.

3.4 Ekosistem ve Peyzaj Riskleri

Yüksek sıcaklıklar ve kuraklık, Safranbolu çevresindeki ormanlık alanlar ve doğal peyzaj üzerinde yangın riskini ve ekosistem stresini artırmaktadır. Yeşil alanların kaybı, KİA etkisinin şiddetlenmesine ve kentin ekolojik dengeleme kapasitesinin düşmesine neden olur. Hızlı iklim değişikliği, bölgedeki bitki ve hayvan türlerinin habitatlarını değiştirmekte ve hassas türlerin hayatta kalma şansını azaltmaktadır. Özellikle yerel ekosistemlere özgü olan türler, artan sıcaklıklar ve değişen nem koşullarına adapte olamayarak biyoçeşitlilik kaybına yol açabilir.

3.5. Hava Kirliliği

Safranbolu yakınlarındaki Karabük'te bulunan demir ve çelik sanayisi, Türkiye'nin toplam sera gazı emisyonlarının yaklaşık %7'sine katkıda bulunmaktadır. Hava kalitesi değerlendirmeleri, yüksek düzeyde partikül madde (PM) olduğunu göstermekte olup, halk sağlığını ve turizmi korumak için acil kirlilik azaltma önlemlerinin alınmasını gerektirmektedir (Güllü et al., 2025).

4. SAFRANBOLU İÇİN UYUM TEDBİRLERİ

4.1. Yapılı Çevreye Yönelik Uyum Tedbirleri

Tarihî kentlerde iklim değişikliğine uyum sürecinde yapılı çevreye yönelik tedbirler, yeni ve sert müdahalelerden ziyade mevcut mimari mirasın iklimle kurduğu geleneksel ilişkinin korunması ve güçlendirilmesi esasına dayanmalıdır. Safranbolu'daki geleneksel konut dokusu, kalın duvarlar, ahşap karkas sistemler, geniş saçaklar, avlular ve doğal havalandırmayı destekleyen mekânsal kurgular aracılığıyla geçmişte yerel iklim koşullarına uyum sağlayan pasif iklimlendirme çözümleri sunmuştur. Literatürde, bu tür geleneksel mimari unsurların, günümüz iklim değişikliği koşulları altında dahi enerji talebini azaltma ve iç mekân termal konforunu iyileştirme potansiyeline sahip olduğu vurgulanmaktadır (Ratti et al., 2003). Bu nedenle Safranbolu'da uyum tedbirlerinin ilk adımı, söz konusu pasif iklim avantajlarının korunması ve işlevsel hâle getirilmesi olmalıdır.

Artan sıcaklıklar, nem oranındaki dalgalanmalar ve aşırı yağışlar, Safranbolu'daki tarihî yapıların yapı malzemeleri üzerinde doğrudan olumsuz etkilere yol açmaktadır. Özellikle ahşap elemanlarda biyolojik bozulma, taş yüzeylerde tuzlanma ve çatlama, nemin yoğun olduğu alanlarda ise malzeme yorgunluğu ve yüzey kayıpları gözlenmektedir. İklim değişikliğinin bu

tür bozulma süreçlerini hızlandırdığı, çok sayıda deneysel ve saha çalışmasıyla ortaya konmuştur (Brimblecombe & Grossi, 2009). Bu bağlamda yapı ölçeğinde alınacak önlemler; nem kontrolünün iyileştirilmesi, doğal havalandırmanın sürekliliğinin sağlanması, çatılarda ve cephelerde suyun yapıdan uzaklaştırılmasına yönelik detay çözümleri ve yapı temellerinde drenaj koşullarının izlenmesi gibi düşük müdahaleli fakat etkili uygulamaları içermelidir. Bu tür önlemler, yapıların iklim değişikliğine karşı dayanıklılığını artırırken, özgün malzeme ve mimari karakterin korunmasına da olanak tanımaktadır (ASHRAE, 2011; Camuffo, 2019).
Safranbolu'nun UNESCO Dünya Mirası statüsü, yapılı çevreye yönelik her türlü uyum müdahalesinin koruma ilkeleriyle uyumlu, sınırlı ve geri döndürülebilir olmasını zorunlu kılmaktadır. UNESCO'nun Historic Urban Landscape yaklaşımı, tarihî kentlerde iklim değişikliğine uyumun, özgün kentsel dokuyu bozan kalıcı müdahaleler yerine; izlenebilir, aşamalı ve gerektiğinde geri alınabilir uygulamalarla gerçekleştirilmesini önermektedir (UNESCO, 2011). Bu çerçevede, Safranbolu'da modern yalıtım malzemeleri, mekanik iklimlendirme sistemleri veya cephe müdahaleleri gibi uygulamalar, ancak görsel bütünlüğü bozmadığı, yapıya zarar vermediği ve geri döndürülebilir olduğu ölçüde değerlendirilebilir. Literatürde, geri döndürülebilirlik ilkesinin, tarihî yapıların iklim değişikliğine uyumunda temel bir planlama aracı olduğu ve uzun vadede koruma–uyum dengesini güçlendirdiği belirtilmektedir (Bandarin & van Oers, 2012; Fatorić & Seekamp, 2017).
Sonuç olarak Safranbolu'da yapılı çevreye yönelik iklim uyum tedbirleri; geleneksel mimarinin pasif iklim potansiyelini koruyan, yapı ölçeğinde ısı ve nem kaynaklı riskleri azaltan ve koruma ilkeleriyle uyumlu geri döndürülebilir müdahalelere dayanan bütüncül bir yaklaşım gerektirmektedir. Bu yaklaşım, tarihî kentlerde iklim değişikliğine uyumun, teknik bir yenileme sürecinden ziyade, kültürel mirasın sürekliliğini esas alan bir dönüşüm süreci olarak ele alınması gerektiğini ortaya koymaktadır.

4.2. Su Yönetimi ve Kuraklıkla Mücadele Tedbirleri

İklim değişikliğiyle birlikte yağış rejimlerinde gözlenen düzensizlikler ve artan sıcaklıklar, tarihî kentlerde su kaynakları üzerindeki baskıyı önemli ölçüde artırmaktadır. Özellikle Safranbolu gibi topoğrafik olarak eğimli ve tarihî dokusu yoğun kentlerde, yağmur suyunun hızla yüzey akışına geçmesi hem taşkın riskini artırmakta hem de suyun etkin biçimde değerlendirilmesini engellemektedir. Literatürde, iklim değişikliğine uyum kapsamında yağmur suyunun yerinde yönetimi ve hasadının, tarihî kentler için düşük maliyetli ve etkili bir çözüm sunduğu vurgulanmaktadır (Fletcher et al., 2015). Bu bağlamda Safranbolu'da, avlu sistemleri, bahçeler ve geçirgen yüzeyler aracılığıyla yağmur suyunun toplanması ve depolanmasına yönelik geleneksel uygulamaların yeniden değerlendirilmesi, iklim uyum stratejilerinin temel bileşenlerinden biri olarak ele alınmalıdır.
Su verimliliği uygulamaları, Safranbolu'da kuraklık riskinin azaltılması açısından kritik öneme sahiptir. Artan sıcaklıklar ve yaz aylarında yükselen su talebi, özellikle içme suyu kaynakları üzerinde ciddi baskı oluşturmaktadır. Dünya genelinde yapılan çalışmalar, yapı ölçeğinde su tasarruflu armatürlerin kullanımı, gri suyun yeniden değerlendirilmesi ve kentsel ölçekte su kayıplarının azaltılmasına yönelik altyapı iyileştirmelerinin, su tüketimini önemli ölçüde düşürdüğünü göstermektedir (Gleick, 2014). Ancak tarihî kentlerde bu tür uygulamaların, yapıların özgünlüğünü bozmadan ve geri döndürülebilir biçimde hayata geçirilmesi gerekmektedir. Bu nedenle Safranbolu'da su verimliliği politikaları, teknik çözümler kadar koruma ilkeleriyle uyumlu planlama yaklaşımlarını da içermelidir.
Turizm faaliyetleri, Safranbolu'nun ekonomik sürdürülebilirliği açısından önemli bir rol oynarken, iklim değişikliği bağlamında su tüketimi üzerinde ek baskı oluşturmaktadır. Literatürde, turizm yoğunluğu yüksek tarihî kentlerde kişi başına düşen su tüketiminin yerleşik nüfusa kıyasla belirgin şekilde daha yüksek olduğu ortaya konmuştur (Gössling et al., 2012;

Scott et al., 2016). Bu durum, özellikle yaz aylarında su stresi riskini artırmaktadır. Safranbolu'da turizm kaynaklı su tüketiminin izlenmesi, konaklama tesisleri için su verimliliği standartlarının geliştirilmesi ve farkındalık odaklı uygulamaların teşvik edilmesi, iklim değişikliğine uyum kapsamında öncelikli tedbirler arasında yer almalıdır.

4.3. Kentsel Yeşil Alan ve Peyzaj Tedbirleri

Kentsel yeşil alanlar, iklim değişikliğine uyum sürecinde yalnızca estetik unsurlar değil, aynı zamanda kentlerin iklim altyapısının ayrılmaz bir parçası olarak değerlendirilmektedir. Yeşil alanlar; sıcaklıkların düşürülmesi, yağmur suyunun tutulması, hava kalitesinin iyileştirilmesi ve biyolojik çeşitliliğin korunması gibi çok yönlü ekosistem hizmetleri sunmaktadır (Gill et al., 2007; Kabisch et al., 2017). Safranbolu gibi tarihî kentlerde yeşil alanların korunması ve geliştirilmesi, kentsel ısı adası etkisinin azaltılması ve iklim kaynaklı risklerin hafifletilmesi açısından kritik öneme sahiptir.

Yerel ve iklim koşullarına dayanıklı bitki türlerinin kullanımı, kentsel peyzajın iklim değişikliğine uyum kapasitesini artıran temel unsurlardan biridir. Literatürde, yerel bitki türlerinin daha düşük su ihtiyacı, daha yüksek sıcaklık toleransı ve bakım gereksiniminin azlığı nedeniyle iklim uyum stratejilerinde öncelikli olarak tercih edilmesi gerektiği vurgulanmaktadır. Safranbolu'da peyzaj düzenlemelerinde yerel flora ile uyumlu, kuraklığa dayanıklı bitki türlerinin kullanılması, hem su verimliliğini artıracak hem de tarihî peyzaj karakterinin korunmasına katkı sağlayacaktır.

Kentsel ısı adası etkisi, yapı yoğunluğu yüksek ve yeşil alan oranı sınırlı tarihî kentlerde iklim değişikliğinin etkilerini daha da şiddetlendirmektedir. Yeşil çatılar, gölgeleme sağlayan ağaçlandırma uygulamaları ve geçirgen yüzeylerin artırılması gibi doğa temelli çözümler, ısı adası etkisinin azaltılmasında etkili araçlar olarak öne çıkmaktadır (Bowler et al., 2010). Ancak Safranbolu gibi Dünya Mirası alanlarında bu uygulamaların, görsel bütünlüğü bozmayacak ve geri döndürülebilir nitelikte tasarlanması gerekmektedir. Bu bağlamda kentsel yeşil alan ve peyzaj tedbirleri, iklim değişikliğine uyum ile kültürel mirasın korunmasını birlikte ele alan bütüncül bir planlama yaklaşımını zorunlu kılmaktadır.

4.4. Afet ve Risk Yönetimine Yönelik Tedbirler

Safranbolu gibi tarihî kentlerde iklim değişikliğine uyum, yalnızca uzun vadeli çevresel iyileştirmelerle sınırlı değildir; aynı zamanda taşkın, sıcak dalgası ve kuraklık gibi iklim kaynaklı afetlerin olasılık ve etkilerini azaltmaya dönük sistematik bir risk yönetimi yaklaşımını gerektirir. Bu çerçevede ilk adım, kentin topoğrafyası, drenaj ağı, yapı yoğunluğu, hassas miras varlıkları ve kritik altyapı bileşenlerini birlikte değerlendiren iklim risk haritalarının oluşturulmasıdır; çünkü risk haritalama, tehlike–maruziyet–kırılganlık bileşenlerini bütünleştirerek öncelikli müdahale alanlarının belirlenmesini sağlar (IPCC, 2022; UNDRR, 2015). İkinci adım, Safranbolu'nun yerel koşullarına uygun taşkın, sıcak dalgası ve kuraklık senaryolarının geliştirilmesidir; senaryoların yalnızca meteorolojik değişkenleri değil, aynı zamanda turizm mevsimselliğiyle artan nüfus baskısı ve su talebi gibi sosyo-ekonomik etkenleri de içermesi, risk yönetiminin gerçekçi ve uygulanabilir olmasını güçlendirir (IPCC, 2022; Scott et al., 2016). Üçüncü adım ise erken uyarı ve kriz yönetimi kapasitesinin kurumsallaştırılmasıdır: meteorolojik uyarıların yerel yönetim operasyonlarına bağlanması, sıcak dalgası eylem planları, geçici serinleme alanları, taşkın anında kritik noktalarda hızlı müdahale protokolleri ve tarihî yapı stoğu için olay sonrası hızlı hasar değerlendirme prosedürleri bu bütünün temel parçalarıdır (WMO, 2015; WHO, 2008). Dünya Mirası alanları bağlamında ayrıca, afet risk yönetiminin koruma yaklaşımıyla entegre edilmesi ve

müdahalelerin "özgünlük–bütünlük–geri döndürülebilirlik" ilkeleriyle uyumlu kurgulanması önerilmektedir (UNESCO/ICCROM/ICOMOS/IUCN, 2010; UNESCO, 2011).

4.5. Ölçülebilirlik ve Veri Temelli Yönetim

İklim uyumunun etkili biçimde yönetilebilmesi için Safranbolu'da ölçülebilirlik ilkesi temel alınmalı; karar alma süreçleri yalnızca genel hedeflere değil, düzenli izlenen göstergelere dayandırılmalıdır. Bu kapsamda kent ölçeğinde karbon, su ve enerji ayak izi envanterlerinin oluşturulması, hem iklim değişikliğiyle mücadele (azaltım) hem de uyum önceliklerinin doğru belirlenmesi açısından kritik bir başlangıçtır; özellikle kent emisyon envanteri için uluslararası kabul gören GHG Protocol for Cities yaklaşımı, yerel yönetimlerin karşılaştırılabilir ve denetlenebilir veri üretmesine imkân verir (WRI et al., 2014). Su ayak izi ve su verimliliği tarafında ISO çerçeveleri, kuraklık riskinin arttığı dönemlerde önceliklendirme ve performans takibine yardımcı olur. Enerji performansı için ise ISO 50001 gibi sistematik yaklaşımlar, kamu binaları ve turizm tesislerinde sürekli iyileştirme döngüsü kurulmasını kolaylaştırır. Ölçülebilirlik yaklaşımının sahadaki karşılığı, tarihî kent merkezinde mikroiklim izleme sistemlerinin kurulmasıdır; sıcaklık-nem sensörleri, yüzey sıcaklığı izleme (uygun noktalarda), yağış şiddeti ve kısa süreli taşkın gözlemi gibi veri akışları, risk haritalarının güncellenmesini ve bakım/onarım önceliklerinin kanıta dayalı biçimde belirlenmesini sağlar (Camuffo, 2019; WMO, 2015). Bu altyapı kurulduğunda, karar alma süreçleri "iyi niyetli ama ölçümsüz" yaklaşımdan çıkar; hangi mahallede ısı adası baskısının arttığı, hangi yapı tipinde nem kaynaklı bozulmanın hızlandığı veya turizm sezonunda su talebinin hangi eşikleri aştığı gibi sorular, düzenli raporlama ve hedef güncellemesiyle yönetilebilir hâle gelir (Kitchin, 2014).

4.6.Yönetişim, Politika ve Kurumsal Tedbirler

Safranbolu'da iklim uyum tedbirlerinin kalıcı ve uygulanabilir olması, teknik çözümler kadar yönetişim ve kurumsal kapasiteye bağlıdır. Yerel yönetimler, risk azaltım ve uyum eylemlerinin koordinasyonunda "ana taşıyıcı" aktör olarak; planlama, altyapı yatırımları, bakım-onarım programları, veri toplama-raporlama ve acil durum yönetimini tek bir iklim dayanıklılığı çerçevesinde birleştirmelidir (UNDRR, 2015; IPCC, 2022). Bununla birlikte, tarihî kentlerde başarı, yalnız belediye içi süreçlerle sınırlı kalmaz; paydaş katılımı belirleyicidir. Yerel halkın günlük pratikleri, esnafın işletme kararları ve turizm sektörünün su-enerji tüketim davranışları, iklim uyumunun sahadaki etkisini doğrudan şekillendirir; bu nedenle bilgilendirme-teşvik mekanizmaları, gönüllü taahhüt programları ve sezonluk yoğunluk yönetimi gibi araçlar, uyumun sosyal kabulünü ve sürdürülebilirliğini artırır (Ostrom, 2010; Scott et al., 2016). Son olarak Safranbolu'nun Dünya Mirası statüsü nedeniyle, koruma politikaları ile iklim politikalarının entegrasyonu ayrı bir kurumsal gerekliliktir: koruma amaçlı imar planları, bakım protokolleri ve turizm yönetimi uygulamaları; iklim risk haritaları, envanter verileri ve afet senaryolarıyla birlikte ele alınmalı; müdahaleler "minimum müdahale, geri döndürülebilirlik ve peyzaj bütünlüğü" ilkelerini korurken aynı anda dayanıklılığı artırmalıdır (UNESCO, 2011; Bandarin & van Oers, 2012). Bu entegrasyonun somut çıktısı, Safranbolu için ölçülebilir göstergelere dayanan, paydaşlı bir izleme mekanizması bulunan ve düzenli güncellenen bir İklim Uyum ve Dayanıklılık Eylem Planının kurumsallaştırılmasıdır.

5. TARTIŞMA

Bu çalışmada Safranbolu için önerilen iklim değişikliğine uyum tedbirleri, tarihî kentlerde koruma–uyum dengesini gözeten, düşük müdahaleli ve aşamalı bir yaklaşım üzerine kurulmuştur. Önerilen tedbirlerin uygulanabilirliği değerlendirildiğinde, özellikle pasif mimari

özelliklerin korunması, yağmur suyu yönetimi, kentsel yeşil alanların iklim altyapısı olarak güçlendirilmesi ve veri temelli izleme sistemlerinin kurulması gibi uygulamaların, yüksek maliyetli ve geri döndürülemez yatırımlara kıyasla daha gerçekçi ve kısa vadede hayata geçirilebilir olduğu görülmektedir. Literatürde, tarihî kentlerde iklim uyumunun başarısının, büyük ölçekli mühendislik çözümlerinden ziyade yerel bağlama duyarlı, küçük ölçekli ve birbiriyle uyumlu müdahalelere dayandığı vurgulanmaktadır (Bandarin & van Oers, 2012; IPCC, 2022). Bu bağlamda Safranbolu için önerilen tedbirler, yerel yönetim kapasitesi ve mevcut koruma rejimi dikkate alındığında uygulanabilir bir çerçeve sunmaktadır.

Önerilen yaklaşımın tarihî kentler için genellenebilirliği, çalışmanın önemli tartışma noktalarından biridir. Safranbolu, özgün topoğrafyası, geleneksel yapı stoku ve yoğun turizm baskısı ile kendine has özellikler taşımakla birlikte; iklim değişikliğine karşı karşılaşılan temel riskler (ısı dalgaları, su stresi, aşırı yağışlar) ve uyumda karşılaşılan kısıtlar, birçok tarihî kent için ortak niteliktedir. Bu nedenle çalışmada geliştirilen risk temelli, ölçülebilirlik odaklı ve yönetişimle entegre uyum çerçevesi, benzer nitelikteki tarihî kentlere uyarlanabilir bir model sunmaktadır. Nitekim UNESCO'nun Historic Urban Landscape yaklaşımı da, tarihî kentlerde iklim değişikliğine uyumun yerel bağlama göre uyarlanabilir ancak kavramsal olarak ortak ilkeler üzerine inşa edilmesi gerektiğini ortaya koymaktadır (UNESCO, 2011).

Bununla birlikte, uygulama sürecinde çeşitli sınırlılıklar ve zorluklarla karşılaşılması kaçınılmazdır. İlk olarak, veri eksikliği ve süreklilik sorunu, ölçülebilirlik temelli yönetim yaklaşımlarının önünde önemli bir engel oluşturmaktadır. Mikroiklim izleme, ayak izi envanterleri ve risk haritalarının oluşturulması, teknik kapasite ve kurumsal süreklilik gerektirmektedir (Kitchin, 2014). İkinci olarak, koruma mevzuatı ile iklim uyum gereksinimleri arasındaki potansiyel çatışmalar, özellikle yapı ölçeğinde alınacak önlemlerde karar süreçlerini yavaşlatabilmektedir. Üçüncü olarak, turizm sektörü ve yerel kullanıcı davranışlarının değişimi zaman almakta; bu durum, uyum tedbirlerinin kısa vadeli etkisini sınırlayabilmektedir (Scott et al., 2016). Bu sınırlılıklar, Safranbolu örneğinde iklim uyumunun yalnızca teknik değil, aynı zamanda kurumsal ve toplumsal bir dönüşüm süreci olduğunu göstermektedir.

6. SONUÇ VE ÖNERİLER

Bu çalışma, Safranbolu örneğinde tarihî kentlerin iklim değişikliğine uyum sürecinde alması gereken tedbirleri, yapılı çevre, su yönetimi, kentsel yeşil alanlar, afet ve risk yönetimi, ölçülebilirlik ve yönetişim başlıkları altında bütüncül bir çerçevede ele almıştır. Bulgular, Safranbolu'nun geleneksel mimari ve kentsel peyzaj özellikleri sayesinde belirli bir uyum potansiyeline sahip olduğunu; ancak bu potansiyelin, iklim değişikliğinin artan etkileri karşısında kendiliğinden yeterli olmayacağını ortaya koymaktadır. Özellikle veri temelli izleme mekanizmalarının eksikliği, su ve turizm kaynaklı baskıların artışı ve iklim risklerinin sistematik olarak yönetilmemesi, kentin kırılganlığını artıran temel unsurlar olarak öne çıkmaktadır.

Safranbolu için öncelikli eylem alanları üç başlıkta özetlenebilir;

1. Geleneksel yapıların pasif iklim avantajlarını koruyan ve güçlendiren yapı ölçeği tedbirlerinin yaygınlaştırılmasıdır.
2. Yağmur suyu yönetimi, su verimliliği ve kentsel yeşil alanların iklim altyapısı olarak ele alındığı doğa temelli çözümlerin, koruma ilkeleriyle uyumlu biçimde hayata geçirilmesidir.
3. Karbon, su ve enerji ayak izi envanterlerine dayanan, mikroiklim izleme ile desteklenen ve paydaş katılımını içeren veri temelli bir yönetişim yapısının kurumsallaştırılmasıdır.

Bu alanlarda atılacak adımlar, Safranbolu'nun iklim değişikliğine karşı dayanıklılığını artırırken, kültürel mirasın korunmasına da katkı sağlayacaktır.

Gelecek çalışmalar açısından, Safranbolu'da mahalle ölçeğinde mikroiklim analizleri, yapı tiplerine göre kırılganlık değerlendirmeleri ve turizm sezonlarına özgü su–enerji tüketim

profillerinin detaylandırılması önemli araştırma alanları olarak öne çıkmaktadır. Ayrıca önerilen uyum tedbirlerinin pilot uygulamalar üzerinden izlenmesi ve uzun dönemli performans değerlendirmelerinin yapılması, tarihî kentler için geliştirilecek iklim uyum politikalarının etkinliğini artıracaktır. Bu yönüyle çalışma, Safranbolu özelinde somut öneriler sunmakla birlikte, tarihî kentlerin iklim değişikliğine uyumuna yönelik daha geniş ölçekli karşılaştırmalı araştırmalar için de bir başlangıç noktası niteliği taşımaktadır.

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TARİHİ ÇEVRE ÖZELLİKLERİNİN YENİ YAPILAŞMAYA YANSIMALARININ SAFRANBOLU ÖRNEĞİNDE İRDELENMESİ

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ÖZET

Tarihi çevreler, geçmiş dönemlere ait toplumların mimari, sosyal, kültürel ve ekonomik özelliklerini yansıtan alanlardır. Bu çevreler somut olduğu kadar somut olmayan kültürel miras değerlerine de sahiptir. Değerler bir bütün olarak bulundukları kente kimlik kazandırmakta ve kentlileri ortak duyguda buluşturmaktadır. Eğitici ve öğretici yönlere de sahip tarihi çevreleri anlamak, bunlardan çıkarımlar yapmak günümüz ve geleceğin mimarlığı için yol gösterici olmaktadır/olacaktır. Tarihi yapı ve çevrelerin koruma-kullanma dengesi içerisinde yaşama entegre edilmeleri korunarak geleceğe aktarılmalarını sağlayacaktır. Yapılacak yeni ek/yapı tasarımlarının nasıl olması gerektiği konusu ise mimarlık alanında tartışılmaktadır. Bu konuda farklı yöntem ve yaklaşımlar olmakla birlikte, bağlamdan uzak uygulamalar tarihi değere zarar verebilmektedir. Yaşam koşullarının ve ihtiyaçların giderek değişmesi, nüfus artışı, hızlı kentleşme faaliyetleri, ekonomik çıkar sağlama isteği gibi nedenlerle kentlerde yeni yapılaşma yoğunluğu da hızla artmaktadır. Bu durumdan tarihi dokular olumsuz etkilenebilmektedir. Tarihi dokuların etrafında hızla türeyen yeni yapılaşmalar insan ölçeğinde ve doğayla bütünleşmiş silüeti bozabilmekte, tarihi çevrenin okunurluğunu zayıflatmaktadır.

Çalışmada, tarihi dokuya sahip Safranbolu kenti irdelenmiştir. Günümüze ulaşabilmiş tipik bir Osmanlı şehri örneği olan kent, sahip olduğu değerlerin korunmasına yönelik 1985 yılında kentsel sit alanı ilan edilmiş, 1991'de koruma amaçlı imar planı devreye sokulmuştur. Özgünlük ve bütünlük ana ölçütlerini sağlaması neticesinde ise 1994 yılında UNESCO Dünya Miras Listesi'ne dahil edilmiştir. Kentin eski dokuya komşu alanlarında hızla yeni yapılaşmalar meydana gelmiştir ve bu süreç günümüzde de devam etmektedir. Bu çalışmada, Safranbolu'daki tarihi doku özelliklerinin yeni yapılaşmaya yansımalarını örnekler üzerinden ortaya koymak hedeflenmiştir. Örnekler; sit alanı, etkileme geçiş alanı (geçiş bölgesi) ve bu ikisi dışında kalan kısım olmak üzere farklı noktalardan seçilmiştir. Bunların mimari okumaları yapılarak, tarihi çevre bağlamıyla uyum ve uyumsuzluklarının eleştirisi yapılmıştır. Yapılan

incelemeler sonucunda eski ile yeni arasında anlamsal ilişkinin yeterince kurulmadığı, genellikle uyumun geleneksel öğelerin taklidi şeklinde yakalanmaya çalışıldığı tespit edilmiştir.

Anahtar Kelimeler: Tarihi çevre, Safranbolu, tarihi çevrede ek/yeni yapı tasarımı

1. GİRİŞ

Mimari tasarımda geçmiş ile geleceği ilişkilendirme ve tarihi çevreyi koruma yaklaşımları, eski ve yeni yapıların bir arada var olabileceği ve bu birlikteliğin sürdürülebilir bir mekânsal kimlik üretebileceği varsayımına dayanmaktadır. Yeni yapıların tasarım sürecinde ortaya çıkan kaygılar, tarihsel çevrenin korunmasına yönelik duyarlılıklarla kesiştiğinde, mimari açıdan bütüncül bir sentezin oluşması mümkün hale gelmektedir. Bu bağlamda, mimaride geçmişe değer vermenin ve mevcut yapı dokusu ile çağdaş tasarımı dengeli biçimde bir araya getirmenin temel koşulu, tasarım sürecinde tarihsel bağlamın dikkate alınmasıdır. Bu yaklaşımın sağlıklı biçimde uygulanabilmesi yalnızca mimari kararlarla sınırlı kalmamakta, aynı zamanda toplumsal bilinçle de doğrudan ilişkilendirilmektedir. Toplumun kendi kültürel birikimini benimsemesi, mimari mirası koruma sorumluluğu üstlenmesi ve yaşam çevrelerinin tarihsel değerlerini kavraması, bu sürecin sürdürülebilirliği açısından önem taşımaktadır. Böylelikle mimarlar, tasarım yaklaşımlarını toplumsal ve kültürel değerlerle uyumlu hale getirerek güçlü kimliğe sahip ve kalıcı mekânların üretimine katkı sağlayabilmektedir.

Brandi (1956), modern olanı bütünüyle reddetmeden ve tarihsel olanı tahrip etmeden gelecekle ilişki kurmanın gerekliliğine vurgu yapmaktadır. Tarihi çevrede gerçekleştirilen tasarım süreçlerinde mimarın temel sorumluluğu, geleceğe yönelik nitelikli mekânlar üretmeyi hedeflerken aynı zamanda geçmişin en doğru biçimde korunmasını sağlamaktır. Yapılacak tasarımlarda mimardan beklenen yaklaşım; geçmişi ve bugünü doğru analiz edebilen, süreklilik ve değişim kavramlarını bir arada değerlendirebilen ve çağın gerekliliklerini tasarımına yansıtabilen bir anlayıştır. Bu niteliklere sahip mimarlar, kullanıcılar için daha nitelikli ve yaşanabilir çevreler oluşturabilecektir.

Farklı tarihsel dönemlerde çeşitli kültürlerin etkisiyle biçimlenen mimari anlayışların izlerini barındıran tarihi çevrelerde, yeni yapıların form, malzeme, yapım tekniği ve üslup açısından nasıl ele alınması gerektiği günümüzde tartışmalı bir alan oluşturmaktadır. Bu bağlamda, tarihsel doku içerisinde gerçekleştirilecek yeni yapıların ve çağdaş eklerin, bulundukları dönemin mimari özelliklerini birebir yeniden üretmesi mi, mevcut çevrenin karakteristik niteliklerini referans alarak uyumlu ya da benzeşimci bir yaklaşım sergilemesi mi, yoksa çağdaş mimarlığın güncel ifade biçimlerini yansıtan özgün tasarımlar mı olması gerektiği sorusu, tasarım sürecinde mimarların karşı karşıya kaldığı temel karar alanlarından biri olarak öne çıkmaktadır (Kılıç, 2015). Bu bağlamda bu çalışmada yukarıda açıklanan sorunsalların ele alındığı yaklaşımlar tarihi nitelikleriyle ön plana çıkan Safranbolu özelinde irdelenecektir.

2. TARİHİ ÇEVRE ve KORUMA

Tarihi çevre, geçmiş dönemlerden günümüze taşınan kimlik, hafıza ve yaşam biçimlerinin somutlaştığı bir kültürel miras alanı olarak tanımlanabilir. Miras kavramı 1964 yılında Venedik Tüzüğü ile birlikte anıt ölçeğinden alan, yer boyutuna genişletilmiştir. Soyupak ve Çardak'a

göre, kültürel miras olarak tarihi çevreler, geçmiş dönem yaşam biçimlerini sosyal, kültürel, teknolojik ve ekonomik açıdan yorumlamayı sağlayan alanlardır. Buralar, arka arkaya gelen tarihi dönemlere ve kültür katmanlarına ait taşıdıkları izlerle korunmaya değer görülmektedir (Soyupak ve Çardak, 2023). Tarihi çevreler; değişik zaman dilimi ve coğrafyalarda yaşamış insan topluluklarının yaratmış olduğu uygarlıkların ürünüdür ve bu uygarlıkların mimari, sosyal, kültürel ve ekonomik özelliklerini yansıtan yerleşim yerleri ve bunlara ait kalıntılardır (Özteke, 2004). Bir toplumun geçmişine, yaşanmışlıklarına ve uygarlıklara şahitlik etmiş değerler bütünü olan tarihi çevre, bileşenleriyle birlikte bulunduğu kente karakter vermekte ve kentlilerin ortak duyguda buluşmalarını sağlamaktadır (Karataş, 2021). Bu bağlamda korunarak gelecek nesillere aktarılmaları konusu önem kazanmaktadır.

Korumanın kültürel, ekonomik, toplumsal, gelişimsel, çevresel ve eğitimsel olmak üzere topluma farklı boyutlarda yararları vardır. Kültürel yönden zenginleşme, geçmiş ile bağlantı kurularak koruma konusunda isteğin artması, kültürel gelişimin yaşanması, turizme kazandırılarak ekonomik katkı sağlanması, değerlerin bakımlı hale gelmesi, tarihi çevrenin önemi anlaşılarak kültürel değerlere saygının artması gibi katkılar alınabilecektir (URL 1). Sahip olduğu zenginlikleri ve çeşitlilikleri ile bu çevreler, öğretmekte, eğitmekte ve insanların gelişimini yönlendirebilmektedir (Hatami, 2013).

Amos Rapoport'a göre insanlar mekânı biçimsel niteliklerinden ziyade anlamsal ve simgesel ilişkiler üzerinden algılar (Rapoport, 1982). Bir yerleşme, toplumun değerler sistemi, yaşam biçimi ve inançlarıyla şekillenir. Bu nedenle tarihi çevre, geçmişteki kültürel davranış biçimlerinin ve toplumsal düzenin somutlaşmış bir kültürel metnidir. Tarihi çevrelerin biçimsel özellikleri kadar, onları var eden sosyal normlar ve anlam sistemlerinin de korunması gereklidir. Bu yüzden kültürel miras, yalnızca fiziksel dokunun yaşatılması değil, anlamın sürekliliğinin de sağlanmasıdır (Rapoport, 1969; 1982). Bu süreklilik bozulduğunda fiziksel varlık korunsa bile kültürel mirasın özü kaybolur.

3. TARİHİ ÇEVREDE YENİ YAPI TASARIMI

Tarihi çevrede yeni yapı tasarımı konusundaki tartışmalar koruma kaygısının artmasıyla başlamıştır. Bu konuyla ilgili yaklaşımlar 20. yüzyılın başlarından itibaren uluslararası anlaşma, yönetmelik, tüzük ve bildirgelerde yer almıştır.

1931 tarihli Carta Del Restauro'da anıt çevresinin niteliği, üslubu, kütlesi ve rengi ile rahatsız edici yapılar tarafından sarılmasına engel olunması gerektiği vurgulanmıştır (URL 2). 1933 tarihli Atina Tüzüğü'nde geçmişteki bina tiplerinin estetik kaygılarla tarihi alanlardaki yeni yapılara uygulanmasının yıkıcı sonuçları olacağı ve buna izin verilmemesi gerektiği belirtilmiştir (URL 3). 1964 yılındaki Venedik Tüzüğü'ne göre anıtların korunması çevresini de içine almalı; kütle, renk ilişkilerini değiştirecek yeni eklentiye izin verilmemelidir (URL 4). 1975 tarihli Amsterdam Bildirgesi'nde bütünleşik koruma için yeni yapıların çevreleriyle uyum sağlayacak şekilde hacimsel ve boyutsal kısıtlamaları getirecek yasa hazırlamanın önemli olduğundan bahsedilmiştir (URL 5). Unesco'nun 1976 yılındaki Nairobi Bildirgesi'ne göre yeni bina mimarisinin tarihi bina gruplarının mekânsal organizasyonuna ve çevresine uyumlu şekilde entegre olmasını sağlamak için, yüksekliklerin uyumunu, kullanılan renk, malzeme ve

biçimleri, cephe ve çatı formlarını, bina kütlelerinin parsel içindeki konumlarını, parsellerdeki yapılaşma oranlarını içeren kentsel çevre analiz edilmelidir. Parsellerin yeniden düzenlenmesinin bütünün uyumuna zarar verebilecek kütle değişikliğine neden olabileceği belirtilmiştir (URL 6). 1985 tarihli Granada Sözleşmesi'nde tarihi binaların veya ören yerlerinin özelliklerini bozacak önemli tadilat çalışmaları, binaların yıkımı, yeni binaların yapımı ile ilgili projelerin yetkili makamın iznine sunulması gerekliliği vurgulanmıştır (URL 7). 1987 yılındaki Washington Tüzüğü'nde yeni binalar yapılırken veya eskileri uyarlanırken mevcut mekânsal oluşumlara saygı gösterilmesi, ölçek ve parsel boyutuna dikkat edilmesi, çevreyle uyumlu çağdaş öğelerin yöreyi zenginleştirebileceği için yeni tasarımların engellenmemesi gerektiği konularından bahsedilmiştir (URL 8). 1999 yılındaki Burra Tüzüğü'nde yeni tasarımların mevcut ile uyumlu ancak taklitten kaçınılması gerektiği belirtilmiştir (URL 9). Yine aynı yıla ait ICOMOS Geleneksel Mimari Miras Tüzüğü'nde geleneksel yapı, yapı grubu ve yerleşmelere çağdaş müdahalelerin bunların kültürel değerlerine ve geleneksel karakterlerine saygı göstermesi gerektiği ifade edilmiştir (URL 10). 2011 tarihli Valetta İlkeleri'ne göre yeni binaların yapılması veya eskilerin uyarlanması gerektiğinde, çağdaş mimari tarihi kentin mekânsal oluşumuyla ve kentsel çevrenin tümü ile ahenk içinde olmalıdır ve alanın ölçeğine saygı göstermelidir (URL 11). 2013 tarihli Burra Tüzüğü'nde, yapılacak yeni uygulamaların bulunduğu tarihi çevrenin önemini, parsel düzenini, biçimini, ölçeğini, karakterini, rengini, dokusunu ve malzemesini dikkate alarak yansıtması ve taklitten kaçınılması tavsiye edilmektedir (URL 12).

Rapoport, tarihi çevrede yapılacak müdahalelere kuramsal çerçeve sunmaktadır. Yeni yapı, tarihsel biçimleri taklit etmek yerine onların kültürel mantığını kavrayarak çağdaş bağlama aktarılmalıdır. Bağlam duyarlılığı sadece fiziksel uyumla değil, anlamın yeniden üretilebilmesiyle gerçekleşir (Rapoport, 2000). Yeni yapı, tarihi çevrenin yaşam döngüsüne entegre edilmelidir. Böylece bu yapı çevre tarafından benimsenir ve sürekliliğe katkı sunan unsur haline gelir (Akbıyık, 2013). Kılıç (2015), tarihi çevrede tasarım yapmanın tek bir reçetesinin olmadığına, her tasarımın yer aldığı çevrenin sahip olduğu koşullarına ve kültürel dinamiklerine göre biçimlendiğine vurgu yapmaktadır (Kılıç, 2015). Tarihi çevrede yeni yapı tasarımının nasıl olacağı konusu mimarlık alanında tartışılmaktadır. Bu konuda farklı yaklaşım ve uygulamalar vardır. Bunlar; taklit, uyum, nötr ve zıt yaklaşım olmak üzere dört ana başlıkta birleştirilebilir. Taklit/kopya yönteminde, tarihi yapının biçim, kompozisyon, malzeme, cephe özellikleri vb. tekrar edilmektedir. Ancak bu durumda dönemsel farklılıklar algılanamamaktadır. Uyumlu yaklaşımda, tarihi çevreden referanslar alınarak bunlar yeni tasarımda yorumlanarak kullanılır, dönem farklılıkları okunabilir. Uyumluluk ve farklılaşma arasında denge yakalanmaya çalışılır. Nötr yaklaşımda, yeni yapı tasarımı baskın davranmaz ve bu sayede tarihi yapının ön plana çıkması sağlanır. Bu yöntemde yalın yeni yapı, mevcut yapının yanında ayırt edilir. Zıt yaklaşımda, mevcut mimarinin malzeme, cephe düzeni, kat yüksekliği, hacim, form vb. özelliklerine tezat hareket edilerek yeni yapı/ek tasarımı bilinçli bir şekilde aykırı davranır.

4. SAFRANBOLU TARİHİ

Batı Karadeniz Bölgesi'nde yer alan Safranbolu, Karabük'e bağlı bir ilçedir. Tarihi M.Ö. 3000 yıllarına uzanan Safranbolu'da pek çok uygarlığın izi bulunmaktadır. Kent, Homeros'un İlyada'sında Paphlagonia bölgesinin sınırları içinde yer almaktadır. Safranbolu yöresinde sırasıyla Hititler, Frigler, Lidyalılar, Persler, Helenistik Krallıklar (Pondlar), Romalılar, Selçuklular, Çobanoğulları, Candaroğulları ve Osmanlılar egemenlik kurmuşlardır (URL 13). 1392 yılında Osmanlı ve Candaroğulları'nın savaşı sonucunda bölge Osmanlı Devleti'ne geçmiştir (Karacakaya vd., 2013). Kent, Osmanlı döneminde ekonomik ve kültürel anlamda üst seviyeye ulaşmıştır (Aksoy ve Kuş, 1997). İç Anadolu Bölgesi'ni Karadeniz limanlarına bağlayan tali kervan yollarının ulaşım ağında olduğu için uzun yıllar stratejik önemini korumuştur. 17. yüzyılda imar hareketlerinin hızlandığı kentte, Cinci Hanı, Cinci Hamamı, elli adet dükkân, Köprülü Mehmet Paşa Camisi, Tuzcu Hanı ve Cami bu dönemde inşa edilmiştir (Acar, 2006). 60 oda, depo ve ahır mekanlarına sahip Cinci Han, yapıldığı dönemde Anadolu'daki en büyük hanlardan biri olarak görülmektedir (Başak, 1966). 18. yüzyılda Safranbolu'da önemli iktisadi gelişmeler yaşanmıştır. Yeni meslekler ortaya çıkarken, iktisadi iş bölümü de artmıştır (Acar, 2006). 19. yüzyıl ise kentin ekonomik anlamda en parlak dönemidir. 6 han ve 500 dükkânın olduğu bir yerleşim yeri haline gelmiştir. İstanbul ve Kastamonu'yla kurulan ilişkiler, üretim ve ticaretten kazanılan tecrübe, ekonomik güç kentteki kültürel gelişimi de yönlendirmiştir. Bunun neticesinde konut kalitesi ve kentleşme alanlarında zirveye ulaşılmıştır (Yaşar, 2004). Bunun yanında meslekler ve sanat dalları da artmıştır (Şendil, 2017). Debbağlık, kunduracılık, dericilik, yemenicilik, saraçlık, semercilik, aşçılık, fırıncılık, kasaplık, pamukçuluk, hallaçlık, bez dokumacılığı, urgancılık, terzilik, kalaycılık, sobacılık, hattatlık, manifaturacılık, kereste ticareti, nalbantlık, cambazlık, dülgerlik kentin meslek gruplarındandır (Acar, 2006).

1870 yılında kaza olarak Kastamonu sancağına bağlanan Safranbolu, 1927 yılında Zonguldak'a dahil edilmiştir. Son olarak ise Karabük'ün il olması neticesinde 1995 yılında bu kente bağlanmıştır (URL 14). Safranbolu 1994 yılında Unesco Dünya Miras Listesi'ne alınmıştır. Bu gelişmeden sonra yerli ve yabancı turistlerin giderek ilgisini çeken kent zamanla turizm kentine dönüşmüştür.

5. SAFRANBOLU KENTİNDE TARİHİ DOKUNUN ÖZELLİKLERİ

Safranbolu'da farklı dönemlere ait birçok mimari ürün bulunmaktadır. Kette koruma altına alınmış çok sayıda yapının yanı sıra 21 adet arkeolojik sit, 6 adet kentsel sit, 2 adet doğal sit alanı vardır (Koçan, 2022). Özellikle Osmanlı döneminde ekonomik açıdan en canlı günler yaşanmış, mimari bakımdan birçok nitelikli mekân oluşmuştur. Geleneksel Safranbolu evleri 18. ve 19. yüzyıl Türk hayatının ekonomisini, kültürünü, yaşam biçimini ve mimarisini yansıtmaktadır. Bu sivil mimari yapılarının dışında, cami, türbe, hamam, han, çeşme, köprü gibi çok sayıda kültür varlığı da inşa edilmiştir (Yetiş, 2016). Tipik bir Osmanlı kenti özelliği gösteren Safranbolu'da Han-Hamam-Cami-Çarşı bir arada bulunmaktadır. Arazinin durumuna göre çarşı çukur yerdeyken, evler yamaçlara konumlandırılmıştır. Merkezdeki camilerin etrafında dükkanlar sıralanmaktadır (Bozkurt, 2022; Tuncel, 1980). Eski kent dokusunda hemen

tüm caddeler, han, cami, hamam, arasta dükkanları ve pazaryerinin olduğu bölgeye doğru açılmaktadır (Hacısalihoğlu, 1995). Safranbolu Çarşısı, Lonca düzeninin hüküm sürdüğü dönemlere ait örneklere sahiptir. Yemeniciler arastası bunun en tipik örneğidir (Ulukavak, 1976). Bakırcılık, semercilik, dikicilik, ayakkabıcılık gibi işlenmiş üretime yönelik kolların mekânsal yapıda, eski lonca düzenine uygun biçimde ayrı ayrı sokaklarda, ama hep bir arada yer tuttukları görülür. 17. yüzyılda Safranbolu'da temel üretim kolu dericilik olmuştur. 19. yüzyılın sonunda kentteki tabakhanelerin sayısı ise 84'tür (Aktüre ve Şenyapılı, 1976). Kentteki diğer bazı üretimleri de işlevsel olarak beslemiş olan bu imalathaneler kentin en alt kotunda, derenin kenarında konumlandırılmıştır. Ancak günümüzde deri imalatı yapılmamaktadır. Bazı imalathaneler zamanla yok olurken, bazıları günümüze erişebilmiştir, ancak bunlar atıl durumdadır. Kentte zanaat düzeyindeki diğer geleneksel üretimler ise eski canlılığını büyük ölçüde yitirmiştir.

Safranbolu kent merkezindeki geleneksel yerleşim dokusu Çukur, Kıranköy ve Bağlar olmak üzere üç bölgede yer almaktadır. Bu bölgelerde farklı imparatorlukların etkilerine rastlanmaktadır. Çukur (Eski Çarşı) ve Bağlar, Selçuklu ve Osmanlı sürekliliğini gösterirken, Kıranköy'de ise Roma-Bizans-Osmanlı etkisi görülebilmektedir. Kentin dokusu ve iyi korunmuş konakları Osmanlı'da Müslüman ve Rum-Ortodoks aile ve sosyal yaşamına ait önemli bilgiler vermektedir (Canbulat, 2016). Tarihi dokuda hem bina hem de yerleşim ölçeğinde iklim şartları ve topografik özellikler konumlanmada önemli etken olmuştur. Kentin üretim, ticari ve idari fonksiyonlarını barındırmış Çukur bölgesi, dik yamaçlara sahip, Gümüş ile Akçasu derelerinin geçtiği vadi içinde ve yamaçlarında yer almaktadır. Bu alanda, kanyon duvarlarının sert rüzgarlara set olması ve soğuğa karşı korunaklı konumlanma nedeniyle konutlar daha çok kış ayları için tercih edilmiştir. Bağlar bölgesi ise Çukur ve Kıranköy'e göre daha üst kotlardadır. Yüksek rakımdaki bu bölge rüzgarlara açık ve serin özellikte olup, yazlık yerleşim yeri olarak kullanılmıştır. Çukur'da sıkışık bir yapılaşma dokusu varken, Bağlar'da geniş bahçeler yer almakta ve yapılaşma seyrek düzendedir. Bağlar bölgesi, adından da anlaşılabileceği üzere özellikle üzüm yetiştiriciliğinde ön plana çıkmıştır. Bu üretim faaliyetleri Bağlar'a üretim kimliği kazandırmıştır, ancak günümüzde bu kimliğinden uzaklaşmış durumdadır. Çukur'un üst kotunda, çeperde yer alan Kıranköy'de ise mübadele dönemine kadar Rum azınlıklar yaşamıştır. Buradaki evlerde yer alan şaraphaneler yörede bağcılık faaliyetlerinin gelişmiş olduğunu göstermektedir.

Safranbolu geleneksel yerleşimdeki yapılaşma doğal çevre ile uyum içerisindedir. Az katlı, yalın ve basit geometrili binalar doğayla yarışmadan, ona saygılı şekilde bütünleşmektedir. Eğime uygun hareket edilerek araziye mümkün olduğunca az müdahale edilmiştir (Fidan, 2024). Yamaçlara yerleşmiş binalarda, arazi eğimine bağlı olarak değişik kotlardan girişlerinin sağlandığı veya ön ve arka cephelerinin farklı yükseklikte olduğu da görülebilmektedir. Kentin tarihi dokusundaki mimari ürünlerin büyük çoğunluğunu geleneksel evler oluşturmaktadır. Safranbolu evleri geçmiş dönemlere ait kent kültürünü ve değerleri yansıtan önemli simgelerdir. Topografik özelliklerin iyi değerlendirilmesi sonucunda evler birbirinin güneşini ve manzarasını engellememekte, bu sayede doğal ısı ve ışık kaynağından maksimum derecede faydalanabilmektedir.

Arnavut kaldırımlı sokaklar, kaba taş duvarla sokaktan ayrılmış bahçeler, avluya veya eve açılan çift kanatlı kapılar, kapı tokmağı, içeriye ışığın alınmasını sağlayan ve istifli odunların kurumasını kolaylaştıran gliste adı verilen ahşap kafes, "hayat" mekanı, büyük fırınlar, kiler, ahır, samanlık, ahşap işçiliğinin güzel örneği olan merdivenler, sofa ve buna bağlı odalar, ahşap dolaplar, ahşap raflar, pencere önündeki sedirler, gusülhane (yüklük dolaplarının içindeki küçük banyo), ahşap süslemeli tavanlar, oda büyüklüğüne göre değişen sayıda dar uzun pencereler, muşabak denilen ahşap kafesler, kara kapaklar, cumbalar, payandalar, alaturka kiremitli kırma çatılar geleneksel Safranbolu evlerindeki önemli mimari öğelerdir (Birlik vd., 2025). Evlerin ortak özelliklerinden biri de doğa-insan-ev, sokak-ev, sokak-çarşı ilişkilerinin son derece dengeli ve düzenli kurulmuş olmasıdır (Safranbolu Belediye Başkanlığı, 2007). Doğal peyzajın büyük ölçüde korunmuş olduğu kentte evler bahçeli düzendedir. Bağlar bölgesindeki konutların bahçeleri ise daha büyüktür. Meyve ve sebze yetiştirilen bu mekanlarda iklim koşullarıyla uyumlu ağaçlar gölgeleme elemanı olarak da değerlendirilmiştir. Yüksek tutulan bahçe duvarları ise mahremiyeti sağlamanın yanında soğuk havayı da kesmektedir. Bahçe duvarları, bina yüzeyleri, ağaçlar, çeşmeler, yeşil doku kamusal mekân olarak sokakların tanımlayıcı unsurlarıdır.

Safranbolu evleri kalabalık ailelerin bir arada yaşayabileceği mekânsal kurguya sahiptir. Bu durum dönemin yaşam tarzını ortaya koymaktadır. Az katlı (genellikle 2,3 kat) olmaları sayesinde yerleşim dokusunda insan ölçeği yakalanmıştır. Bahçeli ve az katlı özellikte olmaları sayesinde günümüz kentlerinde eksikliği hissedilen yatay mimariye örnek oluşturmaktadırlar.

Çukur bölgesinde konutlar çoğunlukla vadi ve güney yönüne bakan yamaç eteklerine yayılmış, bu sayede soğuk havadan korunurken güneş ışığından en iyi derecede yararlanılmıştır (Gürel, 2010). Bağlardaki yerleşim ise güneye bakan yamaç ve sırtlarında yer almaktadır ve burada hâkim rüzgâra açık konumlanma ve yönlenme ile yazları serinlenme sağlanabilmiştir. Kentin geleneksel konutlarında kare, kareye yakın kompakt formlar oluşturularak soğuk dönemlerde ısı kayıpları azaltılmıştır. Üst katlarda yapılan çıkmalarla bina yüzey alanı artırılmakta, ısıl denge ve gölgeleme elde edilebilmektedir. Ayrıca bu çıkmalar sokakla bütünleşmeyi, farklı yönlerden ışık almayı ve farklı manzaralara yönlenmeyi de sağlamaktadır.

Geleneksel evlerde kullanılan taş ve kerpiç malzeme ısıl kütle gibi çalışarak iç mekânda uygun sıcaklık konforu oluşturmaktadır. Taş malzemeli ve duvarlarında minimum boşluk açılmış alt katlar tampon görevi de üstlenerek, üst katlardaki yaşam alanlarını zeminin soğuğu ve neminden korumaktadır. Üst katlarda ise manzarayı görme, güneş ışığı ve doğal havalandırmadan faydalanma açısından fazla sayıda pencere kullanılmıştır. Ancak cephelerdeki dolu-boş dengesi duvar malzemesinin taşıyıcı özelliği ve fiziksel çevre denetimi sağlamak amacıyla dengeli kurulmuştur. Pencerelerde sıcak ve soğuğa önlem olarak kara kapak uygulamaları da görülmektedir.

Geleneksel yaşamda günün büyük bölümü sofada geçirilmektedir. Bunun etrafında ise uyuma, oturma, yıkanma, yemek yeme-pişirme gibi çeşitli işlevlerin yapılabildiği esnek mekân özelliğindeki odalar vardır. Sofa, oda ve eyvanlarda çapraz veya karşılıklı konumlandırılan pencere ve kapı açıklıkları sayesinde doğal havalandırma imkânı da yaratılmıştır. Odalardaki ocaklar iç ortamın ısıtılmasında da kullanılmıştır. İklim koşulları referans alınarak binalarda eğimli çatılar uygulanmış, saçakları ise geniş yapılarak yağmur ve güneşin olumsuz etkilerine

karşı önlem alınmıştır. Safranbolu'nun geleneksel mimarisinde yöreden elde edilen taş, ahşap, toprak vb. malzemeler kullanılmıştır. İnsan ve çevre sağlığına zarar vermeyen bu malzemeler, geri dönüştürülebilir oldukları için atık sorunu da yaratmamakta ve enerji tasarrufu sağlamaktadırlar.

Safranbolu'daki bazı geleneksel konutlarda havuz odaları ve havuzlu sofalar bulunmaktadır. Evden bağımsız inşa edilen havuz odalarına da rastlanmaktadır (Bölükbaşı Ertürk, 2010). Bu sayede iç mekânda suyun serinletici özelliğinden faydalanılmıştır. Bağlar bölgesinin bazı sokaklarında üstü açık su arkları mevcuttur. Kaynaktan çıkan sular bahçelerin sulanmasında kullanılmak üzere bu arklarla yönlendirilmiştir.

6. SAFRANBOLU'DA TARİHİ ÇEVRE ÖZELLİKLERİNİN YENİ YAPILAŞMAYA YANSIMALARI

Çalışma kapsamında, önceki bölümde anlatımı yapılan Safranbolu tarihi dokusunun taşıdığı özelliklerin yeni yapılaşmaya yansımaları örnekler üzerinden irdelenmiştir. Bu örnekler kentsel sit alanı, etkileme geçiş alanı (buffer zone) ve kentin diğer noktalarından olmak üzere çeşitli yerlerden seçilmiştir. Kentteki tarihi alanların konumları Görsel 1'de görülmektedir.



Görsel 1. Safranbolu merkezindeki etkileme geçiş ve sit alanı sınırları (Yetiş, 2018)

6.1. Bağlar Bölgesinde Konut Yapısı-1

Safranbolu Değirmenbaşı Mahallesi'nde yer alan konut 1975 yılında inşa edilmiştir (Birlik vd., 2025). Yapı, kentsel sit alanı içerisindedir ve yanında tescilli geleneksel konut bulunmaktadır (Görsel 2). Sokağa bitişik tarihi yapının hizasından yaklaşık 5 m geriye çekilerek konumlandırılması tarihi değere saygılı bir yaklaşımdır. Tescilli konutta ahşap, kerpiç, taş gibi

yöresel malzemelerin kullanılmasına karşın yeni konutta ahşap çatı strüktürü dışında bu malzeme kullanımlarına rastlanmamaktadır. Duvarlar tuğla, pencereler PVC, giriş kapısı çelik, bahçe duvarı korkulukları ise alüminyum malzemelidir. Bahçe kapısı ve duvar üstü korkuluk-küpeşte uygulamalarının tasarım dili ve rengi birbirinden farklı olup bu durum uyumsuzluk yaratmaktadır. Tarihi konutun pencere düzenindeki ritim ve oran yeni yapıda yoktur. Geleneksel dokuda görülen arazi eğimiyle uyum, bu yapıda yoktur. Alt katın ışık alabilmesi için konut önünde yapay bir çukur alan oluşturulmuştur. Cephedeki yatay/dikey silmeler ve pencerelerin üç kenarında yapılan söveler gelenekselin biçimsel taklididir. Bağlar bölgesindeki hâkim yeşil dokunun aksine yeni konutun ön kısmı tamamen sert zemin bırakılmıştır. Yüksekliği (2 kat) ve yataydaki büyüklüğü ise tarihi çevrenin ölçeğine uyum sağlamaktadır. Çatısının üst kotu yanındaki ve sokak üzerindeki tarihi yapılarınkinden düşük tutulmuştur.



Görsel 2. Tescilli konut (solda) ve yeni konut (sağda)

6.2. Bağlar Bölgesinde Konut Yapısı-2

Değirmenbaşı Mahallesi'nde yer alan konut 1971 yılında yapılmıştır (Birlik vd., 2025). Sit alanı içerisinde olan konutun yakın çevresinde tescilli binalar bulunmaktadır. Sokak üzerindeki tarihi binaların hizasından saygılı biçimde 5 m geride konumlanan konut, gabari olarak tarihi çevreyle uyumludur. Ön cephesinde görülen kütlesel çıkma geleneksel yapılara atıf yapmaktadır (Görsel 3). Geleneksel evlerin pencere boyut ve düzeni bu yapıda görülememektedir. Duvarlarda beyaz, PVC pencerelerde ise ahşap rengi tercih edilerek tarihi çevrenin renk dokusuyla uyum yakalanmıştır. Ancak yapının giriş kotuna sonradan eklenen niteliksiz ve özensiz yarı açık mekân uygulaması çevre doku ile uyumsuz görünmektedir. Sokak üzerindeki taş malzeme sürekliliği ise incelemesi yapılan iki konutun (Konut 1,2) olduğu kısımlarda farklı malzeme ve tasarım dili nedeniyle kesintiye uğramaktadır.



Görsel 3. Konut yapısının ön cephesinden görünüm

6.3. Safranbolu Belediyesi Leyla Dizdar Kültür Merkezi

Bağlarbaşı Mahallesi'nde yer alan kültür merkezi binası kentsel sit alanı sınırları içerisindedir. İki katlı bina betonarme taşıyıcı sistemine sahiptir. Cephelerindeki çıkma hareketleri, yatay/dikey bantlar, yer yer ritmik düzende kullanılan pencerelerin formları ve bölüntü özellikleri, geniş saçaklar, ahşap pencereler geleneksel dokudan izler taşımaktadır (Görsel 4). Zemin kattaki büyük pencerelerde sık aralıklı dikey kayıtların kullanılması geleneksel yapılarda görülen glisteye atıf yapmaktadır. Cephelerin beyaz ve kahverengi tonlarında olması tarihi çevrenin renk dokusuyla uyumu sağlamıştır. Bağlar bölgesinde öne çıkan yeşil doku özelliği bu binanın peyzajında da devam etmektedir. Ancak binanın yataydaki büyüklüğü tarihi çevrenin insan ölçeğindeki minimal yapılaşma özelliği ile uyumsuzdur. İç mekanlarda ise geleneksele öykünme olmayıp, modern düzenlemeler yapılmıştır.



Görsel 4. Kültür merkezinin genel görünümü

6.4. Hilton Otel

Bağlar bölgesinin çeperinde konumlanan Hilton Garden Inn Otel etkileme geçiş alanı sınırları içindedir. 2016 yılında inşası tamamlanan otel yapısında, alt katlarda taş kaplama malzemesinin kullanılması, çıkmalar, üst katlarda ritmik düzende giden dikey dikdörtgen pencereler, söveler, geniş saçaklı kırma çatı, kahverengi ve beyaz renklerin kullanımı geleneksel dokuya atıf yapmaktadır (Görsel 5). Binanın bazı yüzeylerinde ahşap çatkı görünümlü uygulamalar, çıkmaların altında payandalar ve yatay/düşey silmeler de görülmektedir. Ancak işlevi olmayan bu unsurlar tarihi yapı bileşenlerini taklit etmektedir. Binanın iç mekân kullanımında geleneksele öykünme yoktur. Yatay ve düşeydeki büyüklüğü ise insan ölçeğindeki tarihi çevre dokusu ile uyumsuzdur.



Görsel 5. Otel binasından görünüm

6.5. Yavuzlar Otel

Atatürk Mahallesi'nde yer alan otel binası etkileme geçiş alanı sınırları içerisindedir. Otelin yakınında geleneksel evler ve 1890 yılında Frengi Hastanesi olarak yapılmış tescilli bina bulunmaktadır. Dört katlı otel binasında kullanılan yatay/dikey ahşap silmeler, ahşap söve ve muşabaklar tarihi dokuya atıf yapmaktadır (Görsel 6). Cephelerin beyaz, pencerelerin ise PVC malzemeli olmasına rağmen ahşap renginde tercih edilmesi tarihi çevrenin renk özelliğine uyumu sağlamıştır. Pencere düzeni ise gelenekselden farklılaşmaktadır. Yataydaki kütle ölçeği çevre ile uyumludur ancak kat sayısı nispeten fazladır. Binanın resepsiyon-lobi kısmındaki ahşap malzeme kullanımı ve sedir düzeni dışında iç mekânda geleneksele öykünme yoktur.



Görsel 6. Yavuzlar Otelin görünümü

6.6. Safranbolu Belediyesi İtfaiye Müdürlüğü Binası

Çukur bölgesinin çeperinde yer alan bina, etkileme geçiş ve doğal sit alanı sınırları içerisindedir. 2018 yılında inşa edilen yapı betonarme taşıyıcı sistemine sahiptir. Yatay ve düşeyde kütle hareketleri yapılarak masif etki kırılmak istenmiştir. Arazi eğiminden de yararlanılarak farklı kotlardan girişler sağlanmıştır. Yapı görünüm olarak geleneksel Safranbolu evlerine benzetilmeye çalışılmıştır. Üst katlarda oluşturulan çıkmalar, kırma çatı uygulaması, ahşap malzemeli söve, pencere, payanda ve yatay/dikey silmelerin yapılması, alt katlarda taş kaplama malzemesinin tercih edilmesi bu benzetme çabalarını göstermektedir (Görsel 7). Bina dış yüzeylerindeki renkler (beyaz, kahverengi) tarihi çevre ile uyumludur. Payandaların ise taşıyıcı özelliği yoktur ve tarihi evlerden taklit edilmiş öğelerdir. İç mekanlarda geleneksele herhangi bir öykünme bulunmamaktadır.



Görsel 7. İtfaiye müdürlüğü binasının görünümü

6.7. Ermersa Siteleri

Safranbolu Barış Mahallesi'nde yer alan Ermersa Sitesi 2006 yılında tamamlanmıştır (Oral, 2019). Etkileme geçiş alanındaki sitede 6 blok yer almaktadır. Betonarme taşıyıcı sisteme sahip binalar bodrum+zemin+3 katlıdır. Son üç katta tek parça halinde yapılan çıkmalar geleneksel Safranbolu evlerine referans vermektedir (Görsel 8). Çıkmaların üzeri üçgen alınlıkla bitirilmiş binalarda kırma çatı kullanılmıştır. Pencere malzemesi, ritmi, boyutu ve bölüntüleri geleneksel konutlardan izler taşımaktadır. Yine eski yapılardaki gibi cephelerde yatay ve düşey ahşap bantlar kullanılmıştır ancak bunlar taklit edilmiş uygulamalardır. İç mekân düzeninde ise geleneksel konutlara öykünme yoktur.



Görsel 8. Sitedeki konut binalarının görünümü

6.8. Akçasu Konakları

Babasultan Mahallesi'nde site olarak inşa edilen Akçasu konakları etkileme geçiş alanı sınırları içerisindedir. 2014 yılında yapımı tamamlanan iki katlı konutlar betonarme taşıyıcı sistemine sahiptir. Bina formunda görülen kütle hareketleri, ahşap malzemeli dikdörtgen pencere düzenleri, ahşap kaplamalı oda çıkmaları, üçgen alınlıkları ve geniş saçaklı kırma çatı uygulamaları geleneksel dokudan izler taşımaktadır (Görsel 9). Tarihi konutlarda sıklıkla görülen beyaz ve kahverengi renkler de bu yapılarda tercih edilmiştir. İç mekânda ise geleneksele öykünme yoktur.



Görsel 9. Villa yapısının görünümü

6.9. Safranbolu Orman İşletme Müdürlüğü

Bağlarbaşı Mahallesi'nde yer alan müdürlük binası etkileme geçiş alanı sınırları içindedir. 2012 yılında inşa edilen yapı, betonarme taşıyıcı sistemine sahiptir. Cephelerde; taş ve ahşap malzemeli kaplama ve sövelerin, ahşap silmelerin, çıkmaların, dikdörtgen ve kemerli pencere formlarının, beyaz ve ahşap renklerinin kullanılması geleneksele öykünme çabalarıdır (Görsel 10). Pencere düzen, boyut ve bölüntüleri de belli ölçüde yine geleneksel izler taşımaktadır. Yakın çevresinde yer alan tarihi Bağlar bölgesinde yeşil doku hakimdir. Bina geniş bahçesi ile bu özelliğe uymaktadır ancak çevredeki ağaç dokusu sürekliliğinin bu kısımda kesintiye uğradığı görülmektedir.



Görsel 10. Müdürlük binasının görünümü

6.10. Abdurrahman Yerlikaya Kız Anadolu İmam Hatip Lisesi

Kirkille Mahallesi'nde yer alan okul binası etkileme geçiş ve sit alanı sınırları dışındadır. 2010 öncesi dönemde inşa edilmiş bina 5 katlı olup, betonarme taşıyıcı sistemine sahiptir. Dik hatlı çıkmalar, üçgen alınlıklı yüzeyler, ritmik düzendeki ahşap pencereler, söveler, yatay/dikey silmeler tarihi çevreye referans vermektedir (Görsel 11). Bahçe duvarlarında geleneksel yerleşimdeki gibi taş kullanılmıştır. Pencere boyut ve bölüntüleri de gelenekselden izler taşımaktadır. Cam mozaik malzemedeki renk ile yapılan silme ve söveler biçimsel olarak taklit edilmiş öğelerdir. Günümüzde binanın deprem güçlendirme ve tadilat çalışmaları devam etmektedir.



Görsel 11. Okul binasının görünümü

6.11. Çimkent Sitesi

Safranbolu Cemalcaymaz Mahallesi'nde yer alan Çimkent Sitesi dört bloktan oluşmaktadır. 2006 yılında inşası tamamlanan site, etkileme geçiş alanı sınırının hemen dışındadır. Dört katlı konut binalarında, üç kat boyunca yapılan çıkmalar, üçgen alınlıklar, moloz taş görünümlü bodrum duvarları, ikili gruplandırılmış ahşap malzemeli pencerelerin boyutları, kırma çatı uygulaması, ahşap muşabak, söve ve yatay/dikey silmeler geleneksel evlere referans vermektedir (Görsel 12). İç mekânda ise geleneksele öykünme yoktur.



Görsel 12. Sitedeki konut bloğu

6.12. Safranbolu Türker İnanoğlu İletişim Fakültesi Binası

Yenimahalle Mahallesi'nde bulunan fakülte binası sit alanı ve etkileme geçiş alanı sınırları dışında konumlanmaktadır. 2020 yılında inşası tamamlanan yapının taşıyıcı sistemi betonarmedir. Simetrik forma sahip binada farklı yükseklikteki kütleler U biçiminde bir araya gelerek avluyu tanımlamaktadır (Görsel 13). Ana girişin yapıldığı orta kısım, yan kollardan bir kat daha yüksek tutularak kütle hareketliliği sağlanmıştır. Bunların kesişim noktalarında ise küçük planlı kütleler yükselmektedir. Binanın cephe tasarımında geleneksel evlere öykünülmüştür. Giriş kısmını tanımlı hale getiren çıkma, payanda, yatay/dikey silmeler, geniş saçaklı kırma çatı, genellikle iki veya üçerli gruplandırılmış pencere düzenleri, avlu ortasındaki su öğesi, pencere boyut ve bölüntüleri gibi özellikleri ile bina tarihi çevreden izler taşımaktadır. Ancak payandaların taşıyıcı özelliği yoktur. Binanın cephesinde geleneksel dokuda sıklıkla görülen beyaz ve kahverengi renkler kullanılmıştır. İç mekanlarda ise geleneksele öykünme yoktur.



Görsel 13. Fakülte binasının görünümü

6.13. Safranbolu Otobüs Terminali

Barış Mahallesi'nde yer alan terminal binası sit alanı veya etkileme geçiş alanı sınırları içerisinde olmamakla birlikte geleneksel dokuya atıfta bulunmaktadır. Betonarme taşıyıcılı bina az katlı ve insan ölçeğindedir. Ritmik pencereler, geniş saçaklar, cephedeki üçgen çatı yüzeyi hareketleri, zemin kat dış duvarında yer yer görülen taş kaplamalar, söveler, ahşap payanda ve muşabak öğeleri ile tarihi dokudan izler taşımaktadır (Görsel 14). Cephesinde kullanılan renkler (beyaz, kahverengi) ise geleneksel evlerle uyumludur.



Görsel 14. Otogar binasının görünümü

6.14. Bağlar Saray Otel

Yenimahalle Mahallesi'nde yer alan ve 2002 yılında inşa edilen Bağlar Saray Otel etkileme geçiş ve sit alanı sınırları dışında kalmaktadır. Beş katlı olan binada, ritmik düzende ikili, üçlü düzenlenmiş ahşap pencereler, pencere boyutları ve bölüntüleri, saçaklı kırma çatı uygulaması, çıkmalar, çıkmaların üzerindeki üçgen alınlıklı yüzeyler, ahşap malzemeli balkon korkulukları, söveler, yatay/dikey silmeler ve payandalar tarihi dokunun mimari unsurlarına benzetilmiştir (Görsel 15). Ancak ahşap payandalar taklit amaçlıdır ve taşıyıcılığı yoktur. Bahçe duvarında tarihi çevredeki gibi taş malzeme kullanılmıştır. İç mekanlardaki düzenlemeler ise belli ölçüde geleneksel evlere öykünmeler içermektedir. Bu düzenlemelerde modern yaşam koşullarına uyarlama söz konusudur. Tavan kaplaması, merdiven ve tefrişlerde yoğun olarak ahşap malzemenin kullanıldığı görülmektedir.



Görsel 15. Otel binasının görünümü

6.15. İsmail Necati Efendi KYK Öğrenci Yurdu

Safranbolu-Kastamonu ve Karabük-Kastamonu ana kara yolu akslarının kesişiminde konumlanan öğrenci yurdu, tarihi çarşı merkezine yaklaşık 3 km mesafededir. Sit alanı ve etkileme geçiş alanı sınırları dışında olan yurt, 2015-2016 yılları arasında inşa edilmiştir. Yüksekliği oldukça fazla tutulan binaların taşıyıcı sistemi betonarmedir. Cephelerde geleneksel yapılara öykünmeye çalışılmıştır. Ancak bileşenlerinde birbirinden farklı anlayışta tasarım dilinin kullanılması ve çok sayıda farklı malzemenin tercih edilmesi cephe bütünlüğünü bozmuş ve karmaşıklığa neden olmuştur (Görsel 16). Geleneksel evlerde görülen kütle çıkmaları yurt binalarında, işlevselliği olmayan küçük çıkıntıya dönüşmüştür. Giydirme cephe olan kısımlarda, gelenekseldeki yoğun ahşap kullanımına referans vermek amacıyla ahşap görünümlü kaplama kullanılmıştır. Yine bazı yüzeylerdeki taş kaplama uygulaması da benzer amaçlıdır. Cam yüzeyler üzerindeki ahşap renkli çapraz elemanlar ise payandaya atıfta bulunmaktadır ancak iki boyutlu taklidin ötesine geçilememiştir. Uzun cephe boyunca birbirini tekrar eden söveli pencerelerin boyut ve düzeni geleneksel evlerdekinden farklılaşmıştır. Eğimli çatının dar tutulan saçaklarına yer yer dekoratif, taşıyıcı özelliği olmayan küçük payandalar yerleştirilmiştir. Binaların gabarisi tarihi ve doğal çevre ile uyumsuzdur.



Görsel 16. Yurt binasının görünümü

SONUÇ VE DEĞERLENDİRME

Bu çalışma, tarihi çevrede yeni yapılaşma sorunsalını Safranbolu örneği üzerinden ele alarak, çağdaş mimari müdahalelerin mevcut tarihsel doku ile kurduğu ilişkiyi değerlendirmeyi

amaçlamıştır. Safranbolu'nun çok katmanlı kültürel mirası ve özgün kentsel silüeti, yeni yapılaşmalar açısından hem önemli bir referans hem de hassas bir tasarım alanı oluşturmaktadır. Çalışma kapsamında elde edilen bulgular, tarihi çevrede yeni yapı üretiminde biçimsel yaklaşımların belirleyici rol oynadığını, ancak bu yaklaşımların çoğunlukla eleştirel bir tasarım sürecinden uzak kaldığını ortaya koymaktadır.

Araştırma bulgularına göre, Safranbolu'da tarihi çevreye yakın alanlarda gerçekleştirilen yeni yapılaşmalarda, geleneksel mimariye yönelik biçimsel öykünme ve taklit eğilimi yaygın biçimde gözlemlenmektedir. Bu taklitçi yaklaşım, çoğu zaman yalnızca cephe düzenlemeleri, çatı formları veya malzeme seçimleri üzerinden sınırlı kalmakta; mekânsal kurgu, işlevsel organizasyon ve çağdaş yaşam gereksinimleri ile bütüncül bir ilişki kuramamaktadır. Bu durum, geleneksel mimarinin özünü ve üretildiği sosyo-kültürel bağlamı yeniden yorumlamak yerine, yüzeysel bir biçim aktarımına indirgenmesine yol açmaktadır.

Bulgular ayrıca, geleneksel mimarinin çağdaş bir yorumla ele alındığı nitelikli örneklerin sayıca oldukça sınırlı olduğunu göstermektedir. Oysa tarihi çevrede yeni yapılaşmanın, geçmişi birebir kopyalamak yerine, tarihsel sürekliliği çağdaş tasarım diliyle yeniden üretmesi beklenmektedir. Safranbolu özelinde mevcut durum, bütüncül bir kültürel peyzaj ve silüet algısının halen izlenebilir olduğunu; ancak plansız ve kontrolsüz yeni yapılaşma baskısı nedeniyle bu bütünlüğün giderek zayıfladığını ortaya koymaktadır. Özellikle yeni yapılaşma alanlarının tarihi dokunun hemen yakınında konumlanması, bu yapıların yalnızca fiziksel değil, görsel ve algısal olarak da kentsel silüetin ayrılmaz bir parçası haline gelmesine neden olmaktadır.

Çalışmanın bir diğer önemli bulgusu, tarihi çevrede tasarım konusunun mimarlık eğitiminde yeterince derinlikli biçimde ele alınmadığına işaret etmektedir. Özellikle mimari proje derslerinde, tarihi çevrede yeni yapı tasarımına ilişkin kuramsal tartışmaların, eleştirel yaklaşımların ve özgün tasarım denemelerinin daha fazla yer bulması gerekmektedir. Bu bağlamda, öğrencilerin yalnızca biçimsel uyuma odaklanan çözümler yerine, bağlam, ölçek, işlev, kullanıcı ve kültürel süreklilik gibi çok boyutlu tasarım kriterleri üzerinden düşünmeleri teşvik edilmelidir.

Sonuç olarak, Safranbolu örneği, tarihi çevrede yeni yapılaşmanın yalnızca koruma refleksiyle değil, bilinçli ve eleştirel bir tasarım yaklaşımıyla ele alınması gerektiğini ortaya koymaktadır. Tarihi çevrede sürdürülebilir ve nitelikli bir mimari üretim için, taklitçi eğilimlerin ötesine geçen, çağdaş mimarlık ile kültürel miras arasında dengeli ve yaratıcı bir ilişki kuran yaklaşımların geliştirilmesi kaçınılmazdır.

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KADINLARIN MUTLULUĞU VE YAŞAM MEMNUNİYETİ ESTETİK CERRAHİ KABULÜNÜN BELİRLEYİCİSİ MİDİR? GİZLİ PROFİL ANALİZİ

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ÖZET

Bu araştırmada; kadınların estetik cerrahiyi kabul etme düzeylerinin mutluluk ve yaşam doyumları ile ilişkisinin incelenmesi amaçlanmıştır. Kesitsel, tanımlayıcı-ilişkisel yürütülen bu araştırmada gizli profil analizi kullanılmıştır. Veriler Kasım 2024 ile Şubat 2025 tarihleri arasında Sosyodemografik Form, Estetik Cerrahi Kabul Ölçeği, Oxford Mutluluk Anketi-Kısa Formu ve Yaşam Memnuniyeti Değerlendirme Ölçeği kullanılarak online olarak toplanmıştır. Araştırmada toplam 422 kadına ait veriler analiz edilmiştir. Analiz sonucunda mutluluk, yaşam doyumu ve estetik cerrahi kabulü için orta düzeyde puanlar elde edilmiştir. Korelasyon analizi, mutluluk ve yaşam doyumu arasında anlamlı ve pozitif bir ilişki olduğunu ortaya koymuştur. Lojistik regresyon analizi, sosyodemografik değişkenlerin estetik cerrahi kabul düzeylerini artırma potansiyeline sahip olduğunu ortaya koymuştur ($p>0.05$). Ayrıca gizli profil analizi kadınları estetik cerrahi kabulünde düşük (Sınıf 1), orta (Sınıf 2) ve yüksek (Sınıf 3) olmak üzere üç farklı gruba ayırmıştır. Tanımlanan üç kabul grubundan yüksek kabul grubunun mutluluk ve yaşam doyumu puanlarının diğer gruplardan daha yüksek olduğu tespit edilmiştir. Sonuç olarak mutluluk ve yaşam memnuniyetinin birbiriyle ilişkili olduğu, estetik cerrahi yüksek oranda kabul gören grubun daha yüksek psikolojik refah sergilediği belirlenmiştir. Ek olarak sosyodemografik değişkenler estetik cerrahiyi kabullenmeyi öngörmemiştir ve sonuçlarımız geleneksel varsayımları sorgulamıştır.

Anahtar Kelimeler: Estetik cerrahi, mutluluk, yaşam doyumu.

IS WOMEN'S HAPPINESS AND LIFE SATISFACTION A DETERMINANT OF COSMETIC SURGERY ACCEPTANCE? LATENT PROFILE ANALYSIS

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Abstract

This study aimed to examine the relationship between women's acceptance of cosmetic surgery and their happiness and life satisfaction. This cross-sectional, descriptive-correlational study utilized latent profile analysis. Data were collected online between November 2024 and February 2025 using the Sociodemographic Form, Aesthetic/Cosmetic Surgery Acceptance Scale, Oxford Happiness Questionnaire-Short Form, and Life Satisfaction Assessment Scale. Data from a total of 422 women were analyzed. The analysis yielded moderate scores for happiness, life satisfaction, and cosmetic surgery acceptance. Correlation analysis revealed a significant and positive relationship between happiness and life satisfaction. Logistic regression analysis revealed that sociodemographic variables have the potential to increase cosmetic surgery acceptance levels ($p>0.05$). Furthermore, latent profile analysis classified women into three groups: low (Class 1), medium (Class 2), and high (Class 3) in terms of cosmetic surgery acceptance. Of the three acceptance groups identified, the high acceptance group was found to have higher happiness and life satisfaction scores than the other groups. Consequently, happiness and life satisfaction were found to be interrelated, with the group with a high acceptance of cosmetic surgery demonstrating higher psychological well-being. Additionally, sociodemographic variables did not predict acceptance of cosmetic surgery, and our results challenged traditional assumptions.

Anahtar Kelimeler: Cosmetic surgery, happiness, life satisfaction.

Hemşirelikte Mesleki Tutumu Belirleyen Temel Faktör: Birinci Sınıf Öğrencileri Üzerine Bir İnceleme

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Özet

Amaç: Bu çalışmada, hemşirelik birinci sınıf öğrencilerinin mesleğe yönelik tutumlarının belirlenmesi ve bu tutumun sosyodemografik özellikler ile hemşirelik mesleğini seçme durumu gibi bazı değişkenlerle ilişkisinin incelenmesi amaçlanmıştır.

Yöntem: Çalışma, 76 birinci sınıf hemşirelik öğrencisi üzerinde yürütülmüştür. Veri toplama aracı olarak "Hemşirelik Mesleğine Yönelik Tutum Ölçeği" kullanılmış ve elde edilen toplam puanlar bağımsız gruplar t-testi ve Spearman korelasyon analizi ile değerlendirilmiştir.

Bulgular: Analizler sonucunda, öğrencilerin tutum puanları ile yaşları arasında anlamlı bir ilişki saptanmamıştır (r=0,022; p=0,849). Cinsiyet açısından yapılan karşılaştırmada, kadın öğrencilerin ortalama puanı (159,98) erkek öğrencilerden (152,07) daha yüksek olmasına rağmen, aralarındaki farkın istatistiksel olarak anlamlı olmadığı tespit edilmiştir. (p=0,369). Benzer şekilde, öğrencinin kendisinde (p=0,548) veya birinci derece yakınlarında (p=0,346) kronik bir hastalık bulunmasının veya birinci derece yakınlarında bir sağlık çalışanı olmasının (p=0,524) tutum puanları üzerinde anlamlı bir etkisi olmadığı belirlenmiştir. Buna karşılık, mesleği isteyerek seçme durumu ile tutum puanları arasında anlamlı bir fark saptanmıştır (p=0,026). Mesleğini isteyerek seçen öğrencilerin tutum puanları (159,67), istemeyerek seçenlere (143,83) göre anlamlı düzeyde daha yüksek bulunmuştur. Bu bulgu, meslek seçiminde gönüllülük düzeyinin öğrencilerin mesleğe yönelik tutumlarını olumlu biçimde etkileyen önemli bir faktör olabileceğini göstermektedir.

Sonuç: Bulgular, hemşirelik öğrencilerinin mesleki tutumlarının demografik ve ailesel faktörlerden bağımsız olduğunu, ancak mesleği isteyerek seçmenin olumlu tutum geliştirmede belirleyici rol oynadığını göstermektedir. Bu nedenle, eğitim sürecinin başında mesleki motivasyonu destekleyici girişimlerin yararlı olabileceği düşünülmektedir.

The Main Factor Determining Professional Attitude in Nursing: A Study on First-Year Students

Abstract

Objective: This study aims to determine the professional attitudes of first-year nursing students and to examine the relationship of these attitudes with certain variables, such as sociodemographic characteristics and the circumstances of choosing the nursing profession.

Method: The study was conducted with 76 first-year nursing students. The "Nursing Profession Attitude Scale" was used as the data collection tool, and the total scores obtained were evaluated using independent samples t-test and Spearman correlation analysis.

Results: The analysis revealed no significant relationship between the students' attitude scores and their age ($r=0.022$; $p=0.849$). In the comparison based on gender, although the mean score of female students (159.98) was higher than that of male students (152.07), the difference was not statistically significant ($p=0.369$). Similarly, it was determined that the presence of a chronic illness in the student themselves ($p=0.548$) or in their first-degree relatives ($p=0.346$), or having a healthcare worker among their first-degree relatives ($p=0.524$) did not have a significant effect on the attitude scores. In contrast, a significant difference was found between the circumstance of choosing the profession willingly and the attitude scores ($p=0.026$). The attitude scores of students who chose the profession willingly (159.67) were significantly higher than those who chose it unwillingly (143.83). This finding indicates that the level of voluntariness in career choice may be an important factor positively influencing students' attitudes towards the profession.

Conclusion: The findings show that nursing students' professional attitudes are independent of demographic and familial factors, but choosing the profession willingly plays a decisive role in developing a positive attitude. Therefore, it is considered that initiatives supporting professional motivation at the beginning of the educational process could be beneficial.

BÖBREK NAKLİ ALICILARINDA KARDİYOVASKÜLER RİSK FAKTÖRLERİ

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ÖZET

Böbrek nakli son dönem böbrek yetmezliğinde optimal tedavi yöntemidir. Böbrek nakli alıcılarında kardiyovasküler hastalıklar graft sağkalımını olumsuz etkilemektedir ve başlıca mortalite nedenidir. Böbrek nakli sonrası kardiyovasküler hastalık patogenezi multifaktöriyeldir. Hipertansiyon, diyabet, dislipidemi ve obezite son dönem böbrek yetmezliğinde yüksek prevalansa sahiptir ve bu risk faktörleri nakil sonrası dönemde de devam etmektedir. İmmünsüpresif tedaviler bu komorbiditelerin şiddetlenmesine neden olabilmektedir. Mevcut kardiyovasküler risk tahmin modelleri ise bu nakle özgü faktörleri dikkate almadığından, en yüksek risk altındaki nakil alıcılarını doğru bir şekilde belirlemek güçleşmektedir. Böbrek nakli alıcılarına özgü müdahale çalışmalarının sınırlı olması nedeniyle, kardiyovasküler riskin azaltılmasına yönelik stratejiler çoğunlukla diğer hasta popülasyonlarından türetilmektedir. Bu nedenle, geleneksel kardiyovasküler risk faktörlerinin agresif yönetimi önlemenin temelini oluşturmakta olup, immünsüpresif rejimlerin etkilerinin bilinmesi ek kardiyovasküler hasarın en aza indirilmesi de potansiyel olarak önemli bir rol oynamaktadır.

Anahtar Kelimeler: Böbrek nakli, Kardiyovasküler risk, İmmünsüpresyon

1. GİRİŞ

Böbrek nakli, diyaliz tedavisine kıyasla fonksiyonel bir allogreftin sağladığı üstünlük nedeniyle optimal renal replasman tedavisidir (1). Böbrek nakli sağkalımın artması ve yaşam kalitesinin anlamlı ölçüde iyileşmesine katkı sağlamaktadır (2). Bu kazanımlara rağmen böbrek nakli son dönem böbrek yetmezliğine bağlı gelişen çok sayıda metabolik bozukluk açısından tam anlamıyla küratif bir yaklaşım değildir.

Düzenli hemodiyaliz uygulanan kronik böbrek hastalarında kardiyovasküler hastalık riski, genel popülasyona kıyasla 10–20 kat daha fazla olduğu tahmin edilmektedir (3). Başarılı bir böbrek nakli bu riski anlamlı ölçüde azaltsa da böbrek nakli alıcılarında yıllık kardiyovasküler

olay insidansı %3,5–5'dir (4). Böbrek nakli alıcılarında, kardiyovasküler hastalık sık görülen morbidite nedenlerinden biridir ve mortalitenin başlıca sebebidir (5). Fonksiyonel greft varken ölüm, greft kaybının başlıca nedeni olarak öne çıkmaktadır (6). Kardiyovasküler hastalık yükünü etkin şekilde azaltmaya yönelik potansiyel stratejiler hem greft hem de hasta sonuçlarının iyileştirilmesi açısından önem taşımaktadır (7).

Nakil bekleme listesine kabul kriterlerinin daha esnek olması nedeniyle, kardiyovasküler hastalık için risk faktörleri taşıyan aday sayısı artmaktadır ve birçok böbrek nakli adayı, sağlık kampanyalarına rağmen sigara içmeye devam etmektedir (8). Bununla birlikte immünsüpresif rejimlerin nakil sonrası etkileri nedeniyle obezite, diyabet, hipertansiyon ve dislipidemi gibi yaygın risk faktörleri daha fazla görülmektedir (9). Son dönem böbrek yetmezliğinde kardiyovasküler risk skorlaması yapılması ve değiştirilebilir risk faktörlerinin şekilde düzeltilmesi, nakil sonrası süreçte de kardiyovasküler morbidite ve mortalite riskini azaltılmasına yardımcı olacaktır. Literatürde böbrek nakli sonrası kardiyovasküler risk faktörleri ile ilgili limitli sayıda derleme çalışması bulunmaktadır. Bu nedenle, bu derlemede sağlık profesyonellerine bilgi sağlamak amacıyla mevcut böbrek nakli literatürünü sentezledik.

2. BÖBREK NAKLİ ALICILARINDA KARDİYOVASKÜLER RİSK FAKTÖRLERİ

2.1. Hipertansiyon

Böbrek nakli öncesinde hastaların %60'ından fazlasında hipertansiyon bulunmakta ve transplant sonrası da çoğunlukla devam etmektedir; kalsinörin inhibitörleri gibi bazı immünsüpresif ilaçlar durumu kötüleştirebilir (10). Kalsinörin inhibitörleri, vasküler tonusu değiştirerek, renal sodyum taşınmasını etkileyerek ve sempatik sistemi uyararak hipertansiyon gelişimine katkıda bulunur; bu etki siklosporin ile takrolimusa göre daha belirgindir (11). Steroidler ise mineralokortikoid etkileri, renin-anjiyotensin sistem aktivasyonu ve vazodilatör üretiminin baskılanması yoluyla kan basıncını yükseltebilir (12). Diğer katkı sağlayan faktörler greft disfonksiyonu ve transplant renal arter stenozudur. Hipertansiyon, greft kaybı, kardiyovasküler hastalık ve mortalite ile ilişkilidir (13).

Ambulatuvar kan basıncı izlemesi, maskele hipertansiyonu ve gece hipertansiyonunu tespit etmek açısından önemlidir; gece kan basıncı, greft kaybının güçlü bir prediktörüdür (14). Hedef kan basıncı kesin olmamakla birlikte, Böbrek Hastalıkları: Küresel Sonuçları İyileştirme kılavuzları <130/80 mmHg, İngiltere kılavuzları ise proteinüri yoksa <140/90 mmHg önermektedir (15, 16).

2.2. Diyabetes mellitus

Avrupa'da son dönem böbrek yetmezliği hastalarının %26'sında primer renal hastalık olarak diyabetik nefropati mevcuttur (17). Nakil öncesi diyabet bulunmayan alıcılar ise post-transplant diyabetes mellitus gelişme riski taşır ve bu durum, kardiyovasküler hastalık ve mortalite açısından önemli bir risk faktörüdür (18).

İmmünsüpresif ilaçlar post-transplant diyabetes mellitus gelişiminde kritik rol oynar. Glukokortikoidler iştahı artırır, leptin direncini teşvik eder ve glikoz alımını azaltır; pankreas β-hücrelerinin fonksiyonunu bozabilir ve apoptozu artırabilir (19). Kalsinörin inhibitörleri, insülin salgısını bozar ve insülin direncine yol açar; takrolimus, siklosporine göre daha diyabetojendir (20). mTOR inhibitörlerinin etkisi daha hafif olup hem insülin duyarlılığı hem direncini etkileyebilir (21). Post-transplant diyabetes mellitus riskini artıran diğer faktörler

arasında yaşlı alıcılar, ölü donör grefti, hipertansiyon, obezite, post-transplant kilo artışı ve etnik köken yer alır.

2.3. Dislipidemi

Böbrek nakli alıcılarında dislipidemi yaygın olup hastaların %60'ından fazlasını etkiler ve kardiyovasküler morbidite ve mortaliteye önemli katkı sağlar (22). Risk faktörleri arasında ileri yaş, obezite, diyabet, sigara, yetersiz fiziksel aktivite, hipotiroidi, proteinüri, yüksek kalori ve doymuş yağ alımı ile bazı ilaçlar sayılabilir. Transplant sonrası immünsüpresif tedaviler, özellikle steroidler, siklosporin ve mTOR inhibitörleri, lipid profili üzerinde olumsuz etkiye sahiptir; düşük yoğunluklu lipoprotein ve trigliserid düzeylerini artırabilir. Takrolimus ise daha az etkili olmakla birlikte bazı hastalarda hipertrigliseridemiye yol açabilir (23).

2.4. Sigara Kullanımı

Sigara, kardiyovasküler olayların gelişiminde önlenebilir en önemli risk faktörlerinden biridir ve böbrek nakli alıcılarında hem bireyi hem de greft sağlığını olumsuz etkiler. Çalışmalar, transplant sırasında veya sonrasında sigara kullanan böbrek nakli alıcılarında kardiyovasküler hastalık riskinin %30 arttığını, tüm nedenlere bağlı mortalitenin ise iki kat veya daha fazla yükseldiğini göstermektedir (24).

Bulgular, sigarayı nakil öncesinde en az 5 yıl önce bırakmış hastalarda olumsuz sonuç riskinin anlamlı şekilde azaldığını göstermektedir. Bu durum, sigara bırakma stratejilerinin kronik böbrek hastalığında, son dönem böbrek yetmezliğine ulaşmadan önce uygulanmasının daha etkili olacağını ortaya koymaktadır (25).

2.5. Obezite

Amerika Birleşik Devletleri verilerine göre, nakil sırasında böbrek nakli alıcılarının yaklaşık %35'i vücut kitle indeksi ≥ 30 kg/m² ile obezdir ve bu oran yıllar içinde artmaktadır (26). Obez son dönem böbrek yetmezliği hastaları nakil sonrası diyalizde kalanlara kıyasla daha iyi yaşam sürelerine sahiptir; ancak obezite, kardiyovasküler hastalık riski ile ilişkilidir. Özellikle her 5 birimlik vücut kitle indeksi artışı, kalp hastalığı riskini %25 oranında artırmaktadır (27).

Nakil sonrası kilo alımı sık görülür; hastaların yarısından fazlası vücut ağırlığının %10'undan fazlasını kazanabilir ve bu durum obezite olmasa bile olumsuz sonuçlarla ilişkilidir (28).

3. SONUÇLAR

Böbrek nakli sonrası kardiyovasküler hastalık, greft ve hasta sağlığı için halen en önemli tehditlerden biridir. Böbrek nakli alıcılarında, immünsüpresif tedavilerin etkisiyle kardiyovasküler risk daha da artar. Kardiyovasküler hastalıkların etkili önlenmesinin temeli, geleneksel risk faktörlerinin agresif yönetimidir. Bunun yanı sıra, optimal greft fonksiyonunu sürdürmeye ve mevcut immünsüpresif rejimlerin olumsuz etkilerini azaltmaya yönelik ek stratejiler de değerlendirilmelidir.

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VISUAL AND QUANTITATIVE INVESTIGATION OF ATMOSPHERIC MICROPLASTICS IN ISTANBUL EUROPEAN SIDE NATURE PARKS THROUGH *Xanthoria parietina* LICHEN MONITORING

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Microplastics (MPs), a significant component of plastic pollution, accumulate in atmospheric, soil, and aquatic ecosystems, posing ecological risks and affecting biodiversity, soil structure, and food chains. Therefore, monitoring environmental MP levels is of critical importance.

This study investigated airborne microplastic particle pollution on the European side of Istanbul using epiphytic lichens as bio-monitoring tools. Specifically, the lichen *Xanthoria parietina* (L.) Th.Fr. was selected due to its wide distribution and morphological characteristics, which allow it to incorporate airborne pollutants into its thallus.

To rapidly screen and visualize MPs in the lichen thallus samples collected from 11 stations, the Nile Red staining protocol and fluorescence microscopy were applied. The characteristic fluorescent signal enabled the observation of microplastic candidates as bright spots.

Image scans performed using ImageJ revealed that the number of MP particles per unit area in the lichen samples across the 11 stations ranged from 30 to 195. MP levels were found to be high in Emirgan Grove (30–195) and Göktürk Pond Nature Park (120–190), and lower in Paşaeli Recreation Area (30–100) and Çatalca National Park (40–70).

These variations likely reflect the impact of anthropogenic pollution. This study is the first to investigate atmospheric MP pollution in the region using the lichen bio-monitoring method, providing new data to the literature and contributing to raising awareness regarding airborne MPs. This study was supported by the Marmara University BAP project, FYL-2024-11423.

Key words: air pollution, airborne microplastics, biomonitoring, environment, lichen

Nanofibriler Protein Eldesi için Kabak Çekirdeği Bazlı Başlangıç Materyali Geliştirmesi

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ÖZET

Bitkisel proteinler, sürdürülebilirlik, beslenme ve fonksiyonel gıda uygulamalarındaki artan önemi nedeniyle son yıllarda yoğun ilgi görmektedir. Bu çalışmada, protein nanofibrili eldesi için uygun bir başlangıç materyalinin geliştirilmesi amaçlanmıştır. Bu kapsamda, bitkisel protein kaynağı olarak kabak çekirdeği seçilmiştir. Kabak çekirdeğinden yağ, süperkritik karbondioksit ekstraksiyonu yöntemiyle uzaklaştırılmış ve bu işlem sonucunda toplam protein içeriği %67 olan posa, protein kaynağı olarak kullanılmıştır. Yağdan arındırılmış kabak çekirdeği posasından protein ekstraksiyonu, alkali ekstraksiyon ve enzim destekli ekstraksiyon olmak üzere iki farklı yöntem kullanılarak gerçekleştirilmiştir. Her iki yöntemle elde edilen protein izolatlarının çözünürlük, su ve yağ tutma kapasitesi, köpük ve emülsiyon oluşturma özellikleri gibi fonksiyonel özellikleri karşılaştırmalı olarak değerlendirilmiştir. Enzimatik ekstraksiyon yöntemiyle elde edilen proteinlerin alkali yöntem ile elde edilen proteinlere göre daha yüksek çözünürlük, su ve yağ tutma kapasitesi ile daha iyi emülsiyon ve köpük oluşturma performansı gösterdiği belirlenmiştir. Elde edilen protein izolatları arasındaki farklılık literatürde enzimlerin proteinler ve hücre yapısı üzerinde yarattığı moleküler etkileşim değişiklikleriyle açıklanmıştır. Bu çalışma, protein nanofibril üretimine yönelik ilerleyen aşamalarda gerçekleştirilecek fibrilasyon çalışmalarına uygun yüksek proteinli başlangıç materyalinin geliştirilmesine katkı sağlamaktadır.

Anahtar Kelimeler : Kabak çekirdeği proteini, Süperkritik CO_2 ekstraksiyonu, Protein nanofibrilleri

AMPELOGRAFİDEN DİJİTAL AMPELOGRAFA: HASSAS BAĞCILIKTA CNN YAKLAŞIMLARI

FROM AMPELOGRAPHY TO DİGİTAL AMPELOGRAPHY: CONVOLUTİONAL NEURAL NETWORK APPROACHES İN PRECİSİON VİTİCULTURE

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Özet

Bağcılık, küresel tarım ekonomisinin en önemli sektörlerinden biri olmasının yanı sıra, kültürel miras ve coğrafi kimliğin de taşıyıcısıdır. Üzüm çeşitlerinin doğru ve güvenilir sınıflandırılması, menşe sertifikasyonu, tüketici güveni ve tarımsal sürdürülebilirlik açısından kritik öneme sahiptir. Geleneksel ampelografi, yaprak morfolojisi ve salkım yapısı gibi fenotipik özelliklerin uzmanlarca görsel incelenmesine dayanmakla birlikte, öznellik, fenotipik plastisite ve ölçeklenebilirlik sorunları nedeniyle modern bağcılığın ihtiyaçlarını karşılamakta yetersiz kalmaktadır. Hassas Bağcılık paradigması, veri odaklı ve otomatik yöntemlerle bağ yönetimini dönüştürürken, Evrişimsel Sinir Ağları (CNN'ler) bu dönüşümün en güçlü katalizörü olmuştur. Bu derleme, CNN tabanlı dijital ampelografi yaklaşımlarını sistematik olarak incelemekte; kullanılan veri setlerini, model mimarilerini, performans metriklerini ve karşılaşılan temel zorlukları değerlendirmektedir. Çalışma, araştırmacılara ve sektör profesyonellerine, geleneksel bilgelik ile yapay zekânın gücünü birleştiren yeni nesil bağcılık sistemlerinin bilimsel temelini ve gelecekteki araştırma yönelimlerini sunmaktadır.

Anahtar kelime: Ampelografi, Dijital Ampelografi, Hassas Bağcılık, Evrişimsel Sinir Ağları (CNN), Derin Öğrenme

*****: Van Yüzüncü Yıl Üniversitesi BAP Koordinasyon Ofisi tarafından FDK-2024-11262 numaralı proje kapsamında desteklenmiştir.

Abstract

Viticulture is not only a cornerstone of the global agricultural economy but also a bearer of cultural heritage and geographical identity. Reliable identification and classification of grapevine cultivars are essential for origin certification, consumer trust, and agricultural

sustainability. Traditional ampelography, based on visual inspection of leaf morphology and cluster traits, has long served this purpose; however, its subjectivity, phenotypic plasticity, and limited scalability restrict its applicability in modern viticulture. Precision Viticulture (PV) introduces data-driven and automated vineyard management, with Convolutional Neural Networks (CNNs) emerging as the most powerful catalyst of this transformation. This review systematically examines CNN-based digital ampelography approaches, analyzing datasets, model architectures, performance metrics, and major challenges such as data imbalance and domain adaptation. The study provides researchers and industry professionals with a scientific roadmap for integrating traditional expertise with artificial intelligence, shaping the future of viticulture through scalable, accurate, and explainable digital systems.

Keywords: Ampelography, Digital Ampelography, Precision Viticulture, Convolutional Neural Networks (CNN), Deep Learning

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1. Giriş

Bağcılık, yalnızca tarımsal bir faaliyet değil, aynı zamanda küresel ekonominin yüz milyarlarca dolarlık dinamosu ve binlerce yıllık kültürel mirasın somutlaşmış halidir (American Association of Wine Economists, 2006). Dünya genelinde üzüm üretimi; şarap endüstrisi, sofralık üzüm, kuru üzüm ve türevleriyle birlikte uluslararası ticaretin ve tüketici güveninin temel taşlarından biridir. Özellikle menşe işaretli bölgeler ve tescilli üretimler için şarap sertifikasyonu, yasal ve kalite kontrol açısından hayati bir süreçtir (Giacomarra vd., 2016). Bu bağlamda, tarladan şişeye kadar izlenebilirlik, bağcılığın küresel ölçekte rekabet gücünü belirleyen kritik bir unsur haline gelmiştir.

Asırlar boyunca üzüm çeşitlerinin kimlik tespiti, Ampelografi adı verilen disiplin aracılığıyla yaprak morfolojisi, salkım yapısı ve sürgün özelliklerinin uzmanlarca görsel ve elle incelenmesine dayanmıştır (Garcia-Muñoz vd., 2011). Ancak bu yöntem doğası gereği özneldir, uzun yıllara dayalı deneyim gerektirir ve geniş bağ alanlarında uygulanması maliyetli ve zaman alıcıdır (Birkhaeuser vd., 1991). Dahası, aynı varyetenin farklı iklim, toprak ve bağ yönetim koşullarında gösterdiği fenotipik esneklik, geleneksel ampelografik sınıflandırmanın güvenilirliğini zorlaştırmaktadır (Stavrakaki & Biniari, 2016). Bu ölçeklenebilirlik ve objektiflik açığı, modern bağcılığın Hassas Bağcılık (Precision Viticulture, PV) felsefesiyle çelişmektedir. PV, bağ yönetimini veri odaklı, hedefe yönelik ve otomatik hale getirmeyi amaçlar (Matese & Di Gennaro, 2015; Mulla & Khosla, 2015).

Bu dönüşümün katalizörü, görüntü tanıma ve sınıflandırma görevlerinde devrim yaratan Derin Öğrenme (Deep Learning, DL) teknolojileri ve özellikle Evrişimsel Sinir Ağları (Convolutional Neural Networks, CNNs) olmuştur (LeCun, Bengio, & Hinton, 2015). CNN'ler, biyolojik görüntü verilerinden hiyerarşik ve karmaşık örüntüleri otomatik olarak öğrenme yeteneği sayesinde uzman bağımlılığını azaltmış ve üzüm çeşitlerinin sınıflandırılması, hastalık tespiti ve verim tahmini gibi PV uygulamalarında insanüstü doğruluk sergilemiştir (Singh vd., 2017; Terzi, Ozguven, & Yagci, 2024).

Bu derleme, bağcılığın bu kritik dönüşüm noktasını ele almaktadır: Geleneksel ampelografiden, objektif ve nicel verilere dayanan Dijital Ampelografi'ye geçiş. Çalışma, mevcut literatürü kapsamlı bir Görselde analiz ederek kullanılan veri setlerini, CNN mimarilerini (ResNet, VGG, MobileNet, Xception), elde edilen performans metriklerini ve bu teknolojilerin önündeki en büyük engelleri (örneğin veri seti dengesizliği, alan transfer edilebilirliği) değerlendirecektir. Nihai hedef, araştırmacılara ve sektör profesyonellerine, geleneksel bilgelik ile yapay zekânın gücünü birleştiren yeni nesil bağcılık sistemlerinin bilimsel temelini ve gelecekteki araştırma yönelimlerini sunmaktır.

Bu çalışma, 2010–2025 yılları arasında yayımlanan makaleler ve derleme çalışmalarını kapsamaktadır. Literatür taraması, Web of Science, Scopus, IEEE Xplore ve ScienceDirect veri tabanlarında "digital ampelography", "precision viticulture", "CNN grape classification" ve "deep learning in agriculture" anahtar kelimeleri kullanılarak yürütülmüştür. Toplam 87 kaynak incelenmiş, bunlardan konu bütünlüğü, metodolojik sağlamlık ve özgün katkı kriterlerine uyan 60 çalışma detaylı analiz edilmiştir. Derleme, bu kaynaklardaki yöntem, veri seti, model mimarisi ve performans metriklerine odaklanmıştır.

2. Geleneksel Ampelografi ve Sınırlılıkları

Ampelografi, asma (*Vitis vinifera* L.) tür ve çeşitlerini tanımlama ve sınıflandırma bilimidir. Tarihsel olarak bu disiplin, yaprak morfolojisi, sürgün özellikleri, salkım yapısı ve tane formu gibi fenotipik karakterlerin dikkatli gözlemlerine dayanmıştır (Garcia-Muñoz vd., 2011). Uzman ampelograflar, yaprakların şekli, lob sayısı, damar yapısı ve kenar dişliliği gibi yüzlerce morfolojik parametreyi değerlendirerek çeşitleri birbirinden ayırmaya çalışmışlardır.

Ancak bu geleneksel yaklaşım, modern bağcılığın ihtiyaçlarını karşılamakta önemli sınırlılıklar taşımaktadır:

- **Öznellik ve uzman bağımlılığı:** Morfolojik karakterlerin değerlendirilmesi büyük ölçüde uzmanın deneyimine ve yorumuna bağlıdır. Bu durum, farklı uzmanlar arasında tutarsızlıklara yol açmakta ve standardizasyonu zorlaştırmaktadır (Birkhaeuser, Löffler, & Larcher, 1991).
- **Fenotipik plastisite:** Üzüm çeşitleri, farklı çevresel koşullar (iklim, toprak, rakım) ve yetiştirme teknikleri (budama, sulama) altında farklı morfolojik özellikler sergileyebilir. Aynı çeşidin farklı bölgelerde farklı görünmesi, görsel tanımlamayı yanıltıcı hale getirmektedir (Stavrakaki & Biniari, 2016).
- **Maliyet ve zaman verimsizliği:** Geniş bağ alanlarında binlerce asmanın tek tek elle incelenmesi, yoğun iş gücü ve uzun süre gerektirir. Bu durum, özellikle endüstriyel ölçekli bağlarda uygulanabilirliği sınırlamaktadır.

Bu sınırlılıklar, bağcılıkta daha **objektif, hızlı ve ölçeklenebilir** tanımlama yöntemlerine duyulan ihtiyacı açıkça ortaya koymaktadır. Geleneksel ampelografi, uzman bilgeliğini yansıtan değerli bir disiplin olmakla birlikte, günümüzde Hassas Bağcılık (Precision Viticulture) paradigmasının veri odaklı ve otomatik yaklaşımıyla çelişmektedir.

Aşağıdaki Çizelge, geleneksel ve dijital ampelografinin temel farklılıklarını özetlemektedir:

Çizelge 1. Geleneksel ve Dijital Ampelografi arasındaki temel farklar.

Kriter	Geleneksel Ampelografi	Dijital Ampelografi
Veri tipi	Nitel, gözlemsel	Nicel, ölçülebilir
Öznellik	Yüksek	Düşük (otomatik)
Deneyim gereksinimi	Uzun yıllar	Transfer öğrenme ile kısa
Hız	Yavaş, manuel	Hızlı, otomatik
Ölçeklenebilirlik	Düşük	Yüksek (geniş alanlar)
Maliyet	Yüksek (uzman iş gücü)	Düşük (operasyonel)
Tekrarlanabilirlik	Düşük	Yüksek
Entegrasyon	Sınırlı	Karar destek sistemleriyle uyumlu

Çizelge 1'de Geleneksel ve dijital ampelografi yaklaşımlarının farklarını özetleyerek, ölçeklenebilirlik ve otomasyonun dijital yöntemlerdeki avantajını ortaya koymaktadır.

3. Hassas Bağcılık ve Dijitalleşme

3.1 Hassas Tarımın Evrimi

Hassas Tarım (*Precision Agriculture, PA*), 1980'lerden itibaren tarımsal üretimde verimliliği artırmak, girdi kullanımını optimize etmek ve çevresel etkiyi azaltmak amacıyla geliştirilmiş bir paradigma olarak tanımlanmaktadır (Mulla & Khosla, 2015). PA'nın temel amacı, tarla içi varyasyonu yöneterek üretim süreçlerini daha verimli, sürdürülebilir ve kârlı hale getirmektir (Bongiovanni & Lowenberg-DeBoer, 2004). Bu yaklaşım, özellikle Akdeniz ülkelerinde tarımsal ekonomiye önemli katkılar sağlamaktadır (Peris-Ortiz vd., 2015).

3.2 Hassas Bağcılığın Doğuşu

Bağcılık özelinde **Hassas Bağcılık (Precision Viticulture, PV)**, 1990'lı yıllardan itibaren Avustralya (Bramley & Lamb, 2003) ve ABD'de (Wample vd., 1999) başlatılan projelerle gelişmiş, günümüzde bağ yönetiminde verim ve kaliteyi artırırken çevresel etkiyi azaltmayı hedefleyen bir uygulama alanı haline gelmiştir (Matese & Di Gennaro, 2015; Santesteban, 2019). PV'nin temel bileşenleri, bağ yönetiminin her aşamasında doğru ve otomatik veri toplama ve analizini gerektiren çok boyutlu teknolojilerden oluşmaktadır.

3.3 Dijitalleşmenin Bileşenleri

PV'nin dijitalleşme süreci üç ana teknoloji alanına dayanmaktadır:

- **Yerinde İzleme Sistemleri**
    - *Toprak sensörleri:* Elektriksel iletkenlik ve rezistivite ölçümleri ile toprak yapısı ve nem durumu belirlenmektedir (Lee vd., 2010; Georgieva vd., 2016).
    - *Bitki sensörleri:* Yaprak nemi, fotosentetik aktivite ve besin eksikliklerini ölçen sistemler, bağın fizyolojik durumunu ortaya koymaktadır (Mahlein vd., 2012).

- *Çevresel sensörler:* Mikroklima verileri (sıcaklık, nem, ışık) bağın fenolojik gelişim evrelerini izlemek için kullanılmaktadır (Pérez-Expósito vd., 2017; Yost vd., 2017).

- **Uzaktan Algılama Teknolojileri**
  - *İnsansız hava araçları (UAV):* Yüksek çözünürlüklü multispektral ve hiperspektral görüntülerle bağların vigor haritaları çıkarılmakta, hastalık ve stres faktörleri erken dönemde tespit edilmektedir (Pádua vd., 2017; Adão vd., 2017).
  - *Uydular:* Landsat serisi gibi platformlar, geniş ölçekli bağ alanlarının sınıflandırılmasında kullanılmıştır. Örneğin, Landsat 1 ile ABD'de tarım alanları %83 doğrulukla sınıflandırılmıştır (Bhatti vd., 1991; Mulla, 2013).
- **Uygulama Teknolojileri**
  - *Verim ve kalite izleme:* Hasat sırasında doğrudan üzüm ağırlığı ölçülerek verim haritaları oluşturulmaktadır (Hall vd., 2002). Taşınabilir cihazlarla üzümün asitlik, şeker ve nem düzeyleri ölçülmekte, olgunluk ve kalite parametreleri belirlenmektedir (Marques & Pitarma, 2018).
  - *Değişken Oranlı Teknolojiler (VRT):* GPS ve sensör verileriyle gübreleme, ilaçlama ve sulama işlemleri otomatik olarak değişken oranlarda uygulanmaktadır (Arnó vd., 2009).
  - *Tarımsal robotlar:* Otonom traktörler ve ilaçlama sistemleri, bağ içi operasyonları insan müdahalesi olmadan gerçekleştirebilmektedir (Noguchi vd., 2004; Oberti vd., 2016).

Çizelge 2. Hassas Bağcılıkta dijitalleşmenin temel bileşenleri.

Teknoloji Alanı	Teknoloji	Uygulama Alanı
Yerinde İzleme Sistemleri	Toprak sensörleri (iletkenlik, rezistivite)	Toprak yapısı ve nem durumu
	Bitki sensörleri (yaprak nemi, fotosentez)	Bitkinin fizyolojik durumu, besin eksiklikleri
	Çevresel sensörler (sıcaklık, nem, ışık)	Mikroklima verileri, fenolojik gelişim takibi
Uzaktan Algılama	UAV (multispektral/hiperspektral görüntüleme)	Vigor haritaları, hastalık/stres tespiti
	Uydular	Geniş ölçekli sınıflandırma, uzun dönem trendler
Uygulama Teknolojileri	Taşınabilir cihazlar	Üzüm kalitesi ve olgunluk izleme

	VRT	Değişken oranlı gübreleme, ilaçlama, sulama
	Tarımsal robotlar	Otonom bağ içi operasyonlar

4. Makine Görme ve Derin Öğrenme Temelleri

4.1 Makine Görme (MV) ve Tarımsal Uygulamalar

Makine görme (*Machine Vision, MV*), bilgisayarların görüntülerden veri çıkararak sınıflandırma, tanıma ve karar destek süreçlerinde kullanmasını sağlayan teknolojidir (Kamilaris & Prenafeta-Boldú, 2018). Tarımsal üretimde MV, bitki morfolojisinin, hastalık belirtilerinin ve verim parametrelerinin otomatik olarak analiz edilmesine olanak tanır.

MV'nin bağcılık ve genel tarım uygulamalarındaki başlıca kullanım alanları:

- **Otonom sistemler ve robotik:** Görsel rehberlik ve engel algılama yetenekleriyle donatılmış tarımsal robotlar, yabancı ot kontrolü, ilaçlama ve hasat gibi görevleri bağımsız Görselde yerine getirebilir (Ball vd., 2016; Adamides vd., 2014).
- **Uzaktan algılama ve İHA uygulamaları:** İnsansız hava araçları (UAV) ile MV birleşerek bağların kanopi yapısı çıkarılabilir, hiperspektral görüntüleme ile hastalık ve stres faktörleri erken dönemde tespit edilebilir (Pádua vd., 2017; Adão vd., 2017).
- **Hastalık ve verim izleme:** MV, yaprak hastalıklarının otomatik tespiti ve meyve sınıflandırması/verim tahmininde kritik rol oynar. Örneğin, mango bahçelerinde yapılan sınıflandırma çalışmaları MV'nin doğrudan ekonomik katkı sağladığını göstermektedir (Sarron vd., 2018).

Bu gelişmeler, MV'nin bağcılıkta yaprak morfolojisi ve salkım yapısının otomatik analizi sayesinde çeşit tanımlama, hastalık erken uyarısı ve verim tahmini için kritik bir araç haline geldiğini göstermektedir.

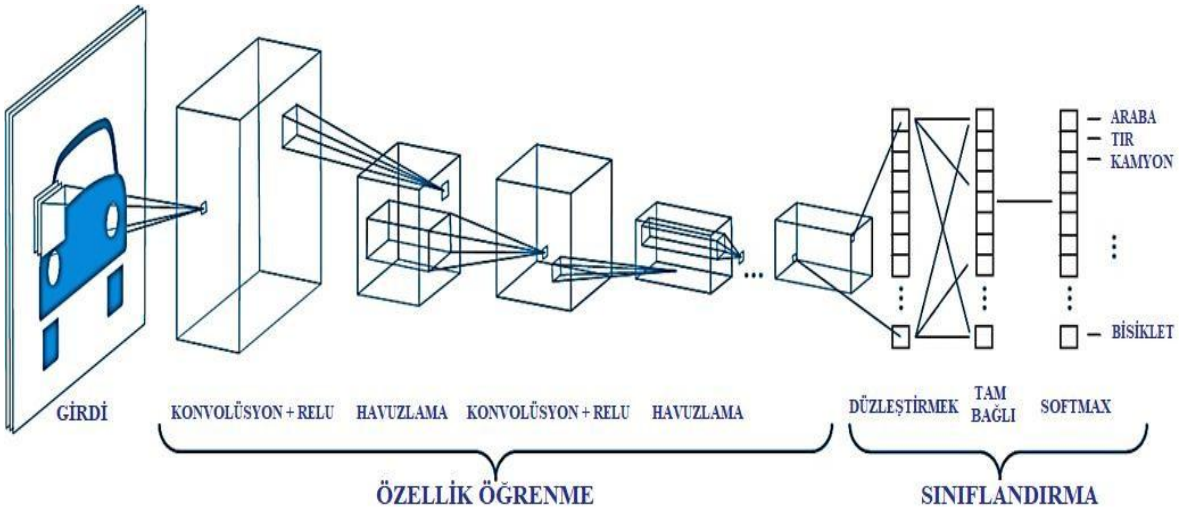
4.2 Derin Öğrenme (DL) ve Evrişimsel Sinir Ağları (CNNs)

Makine görme teknolojilerinin sınırlı genelleme kapasitesi, 2010'lu yıllarda derin öğrenme (*Deep Learning, DL*) mimarilerinin yükselişiyle aşılmıştır. DL, yüksek boyutlu biyolojik verilerden hiyerarşik ve karmaşık örüntüleri otomatik olarak öğrenme yeteneği sayesinde tarımsal görüntü analizinde devrim yaratmıştır (LeCun, Bengio, & Hinton, 2015).

CNN'ler, görsel korteksten ilham alarak tasarlanmış ve üç temel katmandan oluşur:

- **Evrişim (Convolution) katmanı:** Görüntü üzerinde filtrelerin kaydırılmasıyla kenar, doku ve morfolojik örüntüler çıkarılır.
- **Havuzlama (Pooling) katmanı:** Özellik haritalarının boyutunu küçültür, hesaplama yükünü azaltır ve uzamsal varyasyonlara karşı dayanıklılığı artırır.
- **Tam bağlantılı (Fully Connected) katman:** Çıkarılan özellikleri sınıflandırma görevine aktarır; softmax fonksiyonu ile nihai olasılık dağılımı elde edilir.

Bu yapı, CNN'leri bitki hastalık tespiti, yaprak sınıflandırma ve meyve sayımı gibi tarımsal uygulamalarda öne çıkarmaktadır (Mohanty, Hughes, & Salathé, 2016; Singh vd., 2017; Wang vd., 2017).



Görsel 1. Temel Evrişimsel Sinir Ağı (CNN) mimarisi: Özellik öğrenme (konvolüsyon + ReLU + havuzlama) ve sınıflandırma (tam bağlı + softmax) aşamaları (Uyarlanmış from Ergin, 2020)

4.3 Transfer Öğrenme ve Modern CNN Mimarileri

CNN'lerin bağcılık gibi spesifik alanlarda başarılı uygulanmasını kolaylaştıran en önemli yaklaşım **transfer öğrenme**dir. ImageNet gibi devasa veri setleri üzerinde önceden eğitilmiş modeller, üzüm yaprağı gibi küçük ve özel veri setlerine aktarılabilir. Bu sayede daha az veriyle yüksek doğruluk elde edilir (Zoph, Vasudevan, Shlens, & Le, 2018; Hossen, Awrangjeb, Pan, & Mamun, 2025).

Bağcılıkta kullanılan başlıca CNN mimarileri:

- **VGG:** Basit ve derin katmanlı yapısıyla yüksek doğruluk sağlar (Simonyan & Zisserman, 2014).
- **ResNet:** "Skip connections" sayesinde derin ağlarda öğrenme zorluklarını aşar (He vd., 2015).
- **Inception:** Paralel filtrelerle zengin özellik çıkarımı yapar (Szegedy vd., 2016).
- **MobileNet:** Hafif yapısıyla mobil cihazlarda ve saha uygulamalarında kullanılabilir (Howard vd., 2017).
- **Xception:** Derinlemesine ayrılabilir evrişimlerle daha verimli özellik çıkarımı sağlar (Chollet, 2016).

5. Bağcılıkta CNN Uygulamaları

Evrişimsel Sinir Ağları (CNN'ler), bağcılığın pratik sorunlarına yönelik somut çözümler üretme kapasitesiyle öne çıkmaktadır. Geleneksel ampelografinin öznellik ve ölçeklenebilirlik sınırlılıklarını aşarak, üzüm çeşitlerinin sınıflandırılması, hastalıkların erken tespiti, verim tahmini ve olgunluk analizi gibi kritik görevlerde yüksek doğruluk sağlamaktadır.

5.1 Üzüm Çeşidi Sınıflandırması

Dijital ampelografinin en temel uygulaması, üzüm çeşitlerinin yaprak görüntülerinden otomatik olarak sınıflandırılmasıdır. CNN modelleri, insan gözünün ayırt etmekte zorlandığı ince morfolojik farklılıkları ve doku desenlerini öğrenerek, geleneksel yöntemlere kıyasla çok daha yüksek doğruluk sunar.

- Singh ve arkadaşları (2017), VGG ve ResNet mimarilerini kullanarak yaprak lobları ve damar yapılarındaki ince farklılıkları yüksek doğrulukla ayırt edebilmiştir.
- Nasiri, Taheri-Garavand ve Omid (2021), modifiye ettikleri CNN modeli ile %99'un üzerinde sınıflandırma doğruluğu elde etmiştir.
- Terzi, Ozguven ve Yagci (2024), 50 farklı üzüm çeşidini yaprak, salkım ve meyve görüntülerinden sınıflandırarak yeni bir CNN modeli önermiş ve yüksek başarı sağlamıştır.

5.2 Hastalık Tespiti ve Yönetimi

Bağcılıkta verim ve kaliteyi tehdit eden külleme, mildiyö ve kara çürüklük gibi hastalıkların erken tespiti, CNN'lerin en kritik uygulamalarından biridir.

- Mohanty, Hughes ve Salathé (2016), yaprak hastalıklarını renk ve desen analiziyle sınıflandırarak CNN tabanlı sistemlerin gücünü göstermiştir.
- Xie ve arkadaşları (2020), gerçek zamanlı bir CNN tabanlı dedektör ile bağ yaprağı hastalıklarını yüksek doğrulukla izleyebilmiştir.
- Hernandez ve arkadaşları (2025), mildiyö hastalığının erken tespiti için semantik segmentasyon kullanarak hastalıklı bölgeleri sağlıklı dokudan başarıyla ayırmıştır.

Bu sistemler, pestisit kullanımını azaltarak hem ekonomik hem de ekolojik kazanımlar sağlamaktadır.

5.3 Verim Tahmini ve Olgunluk Analizi

Hasat öncesi doğru verim tahmini, lojistik planlama ve kalite kontrol için kritik öneme sahiptir. CNN modelleri, drone veya yer araçlarından elde edilen yüksek çözünürlüklü görüntülerdeki salkımları otomatik olarak tespit edip sayarak daha doğru ve ölçeklenebilir tahminler sunar.

- Wang, Sun ve Wang (2017), CNN tabanlı salkım sayımı ile verim tahmini yapmıştır.
- Di Gennaro ve arkadaşları (2019), UAV ile elde edilen RGB görüntülerini kullanarak düşük maliyetli bir metodoloji ile verim tahmini gerçekleştirmiştir.
- Marques ve Pitarma (2018), renk analizi ile olgunluk seviyesini belirleyerek hasat zamanlamasında karar desteği sağlamıştır.

Çizelge 3. Bağcılıkta CNN uygulama alanları, katkıları ve örnek çalışmalar.

Uygulama Alanı	CNN'in Katkısı	Örnek / Kaynak
Üzüm Çeşitlerini Sınıflandırma	Yaprak lobları ve damar yapılarındaki ince farklılıkları yüksek doğrulukla ayırır.	Singh vd. (2017); Nasiri vd. (2021); Terzi vd. (2024)
Hastalık ve Zararlı Tespiti	Mildiyö ve antraknoz gibi hastalıkların lekelerini renk ve desen analiziyle sınıflandırır.	Mohanty vd. (2016); Xie vd. (2020); Hernandez vd. (2025)
Kantitatif Fenotipleme	Yaprak Alan İndeksi (LAI) ve canopy yoğunluğu regresyon görevleriyle tahmin edilir.	Patil & Thorat (2016); Marques & Pitarma (2018)
Verim Tahmini	Görüntülerden salkım sayımı yaparak verim tahmini sağlar.	Wang vd. (2017); Di Gennaro vd. (2019)
Olgunluk Tespiti	Renk analizi ile olgunluk seviyesini belirler.	Marques & Pitarma (2018)
Gerçek Zamanlı Uygulamalar	Hafif mimariler (MobileNet, Xception) mobil cihazlarda hızlı sınıflandırma sağlar.	Howard vd. (2017); Chollet (2016)

Çizelge 3'de CNN tabanlı bağcılık uygulamalarını karşılaştırmalı biçimde sunarak, hangi mimarilerin hangi görevlerde öne çıktığını göstermektedir.

6. Veri Setleri, Metodolojiler ve Performans

6.1 Veri Kaynakları ve Çeşitlilik

CNN modellerinin başarısı, büyük ölçüde kullanılan veri setlerinin kalitesine, çeşitliliğine ve büyüklüğüne bağlıdır. Literatürdeki çalışmalar, standart RGB görüntülerin yanı sıra, bitkinin fizyolojik durumunu izlemek için multispektral/hiperspektral görüntüler ve su stresi için termal görüntüler gibi farklı sensör verilerini kullanmaktadır (Mahlein vd., 2012; Pádua vd., 2017).

Bağcılık özelinde, veri setlerinin yalnızca yaprak görüntülerinden değil, aynı zamanda salkım ve sürgün görüntülerinden de oluşturulması gerekir. Çünkü çeşitlerin doğru tanımlanması için morfolojik bütünlük şarttır (Garcia-Muñoz vd., 2011). Ayrıca veri setlerinin farklı terroir koşullarını yansıtması, CNN modellerinin saha genellemesi açısından kritik önemdedir.

6.2 Veri Artırma (Data Augmentation)

Veri seti yetersizliği veya sınıflar arası dengesizlik sorununu aşmak için veri artırma teknikleri yaygın olarak kullanılır. Döndürme, çevirme, ölçekleme, parlaklık ayarları ve gürültü ekleme

gibi yöntemler, modelin genelleme yeteneğini artırır ve aşırı öğrenmeyi (overfitting) önler (Pawara vd., 2017).

Son yıllarda, yapay veri üretimi (synthetic data generation) ve GAN tabanlı veri artırma yöntemleri de bağcılıkta kullanılmaya başlanmıştır. Bu yöntemler, küçük veri setlerinde bile CNN modellerinin %85–90 doğruluk oranlarına ulaşmasını sağlamaktadır (Singh vd., 2023).

6.3 Metodolojiler

CNN modellerinin eğitimi sırasında kullanılan metodolojiler, performans üzerinde doğrudan etkilidir.

- **Transfer öğrenme:** ImageNet gibi büyük veri setlerinde önceden eğitilmiş modellerin bağcılık veri setlerine uyarlanması, daha az veriyle yüksek doğruluk sağlar (Zoph vd., 2018; Hossen vd., 2025).
- **Normalizasyon ve dropout:** Eğitim sürecinde aşırı öğrenmeyi azaltmak için yaygın olarak kullanılır.
- **Veri dengesi stratejileri:** Dengesiz veri setlerinde sınıf ağırlıklandırma ve örnekleme teknikleri modelin daha adil öğrenmesini sağlar (Miftahushudur, Sahin, & Grieve, 2025).

6.4 Performans Metrikleri

Bir CNN modelinin etkinliğini değerlendirmek için standart metrikler kullanılır:

- **Doğruluk (Accuracy):** Genel sınıflandırma başarısını gösterir.
- **Hassasiyet (Precision):** Pozitif sınıflandırmaların doğruluğunu ölçer.
- **Duyarlılık (Recall):** Gerçek pozitiflerin ne kadarının yakalandığını gösterir.
- **F1-Skoru:** Hassasiyet ve duyarlılığın harmonik ortalaması, özellikle dengesiz veri setlerinde güvenilir bir ölçüttür.
- **Karışıklık Matrisi (Confusion Matrix):** Modelin hangi sınıflarda hata yaptığını görsel olarak ortaya koyar.

Literatürdeki çalışmalar, doğru metodoloji ve yeterli veri ile CNN modellerinin üzüm çeşidi ve hastalık sınıflandırmasında %95 ila %99 arasında değişen yüksek doğruluk oranlarına ulaşabildiğini göstermektedir (Nasiri vd., 2021; Terzi vd., 2024; Hernandez vd., 2025).

7. Dijital Ampelografinin Pratik Uygulamaları ve Geleceği

7.1 Pratik Uygulamalar

Dijital ampelografi, geleneksel ampelografinin öznellik ve ölçeklenebilirlik sınırlılıklarını aşarak bağcılıkta çok boyutlu kullanım alanları sunmaktadır. CNN tabanlı sistemler, yalnızca çeşit sınıflandırma değil, aynı zamanda fitosaniter uygulamaların çeşitlere özgü optimize edilmesi, verim tahmini, kalite kontrol ve terroir analizi gibi kritik görevlerde kullanılmaktadır (Mohimont, Alin, & Lebeau, 2022).

- **Çeşit sertifikasyonu:** CNN modelleri, yaprak ve salkım görüntülerinden çeşitleri yüksek doğrulukla ayırt ederek menşe işaretli bölgelerde sertifikasyon süreçlerini hızlandırmaktadır (Terzi, Ozguven, & Yagci, 2024; Nasiri, Taheri-Garavand, & Omid, 2021).
- **Hastalık yönetimi:** Mildiyö ve antraknoz gibi hastalıkların erken evrede tespiti, CNN tabanlı semantik segmentasyon ile mümkün hale gelmiştir (Xie vd., 2020; Hernandez vd., 2025). Bu sistemler, pestisit kullanımını azaltarak hem ekonomik hem de ekolojik kazanımlar sağlamaktadır.
- **Verim tahmini:** UAV ve RGB görüntüleriyle salkım sayımı ve verim tahmini, bağ yönetiminde lojistik planlamayı kolaylaştırmaktadır (Di Gennaro vd., 2019; Wang, Sun, & Wang, 2017).
- **Olgunluk analizi:** Renk ve doku tabanlı CNN modelleri, üzüm olgunluk seviyesini belirleyerek hasat zamanlamasında karar desteği sağlamaktadır (Marques & Pitarma, 2018).
- **Gerçek zamanlı uygulamalar:** MobileNet ve Xception gibi hafif mimariler, mobil cihazlarda saha koşullarında hızlı sınıflandırma imkânı sunmaktadır (Howard vd., 2017; Chollet, 2016).

Ezcümle; Son yıllarda İspanya, İtalya ve Türkiye gibi Akdeniz ülkelerinde yürütülen saha projelerinde dijital ampelografi sistemleri pilot ölçekte uygulanmıştır.

İspanya ve İtalya'da yürütülen hassas bağcılık projeleri, görüntü tabanlı otomatik sınıflandırma ve verim tahmini sistemlerinin saha koşullarında başarıyla uygulanabileceğini göstermiştir (Arnó, Martínez-Casasnovas, Ribes-Dasi, & Rosell, 2009; Matese & Di Gennaro, 2015; Di Gennaro vd., 2019).

Türkiye'de Terzi, Ozguven ve Yagci (2024), yaprak ve salkım görüntülerinden üzüm çeşitlerini %96 doğrulukla sınıflandıran CNN tabanlı bir model geliştirmiştir.

Bu çalışmalar, dijital ampelografinin yalnızca teorik bir kavram olmaktan çıkıp pratik bağ yönetiminde uygulanabilir bir araç haline geldiğini göstermektedir.

7.2 Performans ve Küçük Veri Setleri

Küçük veri setlerinde yapılan ön testlerde bile CNN modelleri %85–90 arasında doğruluk oranlarına ulaşabilmektedir (Singh vd., 2023). ResNet ve Inception mimarilerinin VGG'ye kıyasla daha yüksek genelleme kapasitesi sergilediği, MobileNet'in ise mobil uygulamalar için uygun olduğu görülmüştür (He vd., 2015; Szegedy vd., 2016).

7.3 Gelecek Perspektifleri

Dijital ampelografi, bağcılığın iklim değişikliğine adaptasyonunda karar destek sistemlerinin temel bileşeni olarak görülmektedir. Gelecekteki araştırmalar şu alanlara odaklanmalıdır:

- **Multimodal veri entegrasyonu:** RGB, hiperspektral ve termal görüntülerin birlikte kullanımı.
- **Domain adaptation:** Laboratuvar ortamında eğitilen modellerin saha koşullarına uyarlanması (Zhang vd., 2021).

- **Açıklanabilir yapay zekâ (XAI):** CNN modellerinin karar mekanizmalarının şeffaflaştırılması, çiftçi ve uzman güvenini artıracaktır (Mengesha vd., 2025).
- **Kenar bilişim (edge computing):** Mobil cihazlarda ve saha robotlarında gerçek zamanlı CNN uygulamalarının yaygınlaştırılması.

8. Sonuç ve Gelecek Yönelimler

Bu derleme, geleneksel ampelografinin asırlık bilgeliğinden, Evrişimsel Sinir Ağları (CNN'ler) tarafından yönlendirilen dijital ve otomatik bir geleceğe doğru bağcılıkta yaşanan teknolojik evrimi sistematik bir Görselde incelemiştir. Geleneksel yöntemlerin öznellik, maliyet ve ölçeklenebilirlik gibi doğal sınırlamaları, Hassas Bağcılık paradigmasının gerektirdiği objektif, hızlı ve veri odaklı çözümlere olan ihtiyacı doğurmuştur. CNN'ler, bu ihtiyaca cevap vererek üzüm yaprakları, salkımları ve diğer biyolojik verilerden karmaşık desenleri otomatik olarak öğrenme ve bu sayede çeşit sınıflandırması, hastalık tespiti ve verim tahmini gibi kritik görevleri yüksek doğrulukla gerçekleştirme potansiyelini ortaya koymuştur (LeCun, Bengio, & Hinton, 2015; Singh vd., 2017; Terzi, Ozguven, & Yagci, 2024).

Literatür, transfer öğrenme gibi yaklaşımlar sayesinde CNN tabanlı sistemlerin %95–99 doğruluk oranlarıyla üzüm çeşitlerini ayırt edebildiğini, hastalıkları erken evrede tespit ederek hedefe yönelik ilaçlama ile çevresel etkiyi azaltabildiğini ve verim tahminlerini önemli ölçüde iyileştirdiğini göstermektedir (Nasiri, Taheri-Garavand, & Omid, 2021; Hernandez vd., 2025; Di Gennaro vd., 2019). Bu teknolojiler, artık teorik bir olasılık olmaktan çıkıp pratik ve uygulanabilir çözümlere dönüşmektedir.

Ancak, bu teknolojik devrimin tam potansiyeline ulaşması için aşılması gereken kritik engeller bulunmaktadır. Özellikle veri seti dengesizliği ve alan transfer edilebilirliği (*domain adaptation*) sorunları, laboratuvar ortamındaki yüksek başarımların gerçek dünya koşullarına aktarılmasında en büyük kısıtlayıcı faktörlerdir (Miftahushudur, Sahin, & Grieve, 2025; Zhang vd., 2021). Ayrıca, Açıklanabilir Yapay Zekâ (XAI) yöntemlerinin entegrasyonu, "kara kutu" algısını kırarak çiftçilerin ve uzmanların bu sistemlere olan güvenini artırmak için elzemdir (Mengesha vd., 2025).

Son yıllarda, Evrişimsel Sinir Ağları'nın (CNN) yanı sıra Vision Transformer (ViT) tabanlı modeller de dijital ampelografi ve hassas bağcılıkta önemli ilerlemeler kaydetmiştir. Örneğin, ViT ve Masked Autoencoders (MAE) gibi self-supervised yaklaşımlar, sınırlı etiketli veri setlerinde bile yüksek doğruluklarla üzüm çeşidi sınıflandırması sağlamakta olup, geleneksel CNN'lere kıyasla daha robust genelleme kapasitesi sergilemektedir (Carneiro et al., 2025). Benzer Görselde, Xception tabanlı otomatik boru hatları, doğal ortamda çekilen yaprak görüntülerinde %95-98 doğruluk oranları elde ederek, çeşit sertifikasyonu ve fenotipik sınıflandırmada pratik uygulanabilirlik sunmaktadır (Palacios et al., 2024).

Hastalık tespiti alanında ise Transformer çerçeveli hafif modeller, küçük örneklem koşullarında multi-scale özellik yakalama yeteneğiyle öne çıkmakta ve erken müdahale için gerçek zamanlı çözümler vaat etmektedir (Vallabhajosyula et al., 2025). Multimodal veri entegrasyonu (RGB + hiperspektral + termal) ve edge computing ile birleştiğinde, bu teknolojiler pestisit

kullanımını önemli ölçüde azaltarak sürdürülebilir bağcılığı desteklemekte, Türkiye ve Akdeniz ülkeleri gibi bölgelerde pilot uygulamalarda ekonomik ve ekolojik kazanımlar sağlamaktadır (Terzi et al., 2024).

Bu gelişmeler, dijital ampelografinin yalnızca teorik bir araç olmaktan çıkıp, iklim değişikliğine dirençli ve veri odaklı bağ yönetiminin temel taşlarından biri haline geldiğini göstermektedir. Gelecek çalışmalar, açıklanabilir yapay zekâ (XAI) entegrasyonu, domain adaptation teknikleri ve otonom robotlarla multimodal füzyonu önceliklendirmelidir.

Gelecek Yönelimler

Gelecekteki araştırmalar şu alanlara odaklanmalıdır:

- **Multimodal veri entegrasyonu:** RGB, hiperspektral ve termal görüntülerin birlikte kullanımıyla daha zengin fenotipik analizler.
- **Domain adaptation:** Farklı terroir ve iklim koşullarında eğitilen modellerin saha genellemesi için uyarlanması.
- **Açıklanabilir yapay zekâ (XAI):** CNN modellerinin karar mekanizmalarının şeffaflaştırılması, kullanıcı güvenini artıracaktır.
- **Kenar bilişim (edge computing):** Mobil cihazlar ve saha robotlarında gerçek zamanlı CNN uygulamalarının yaygınlaştırılması.
- **Otonom sistemlerle entegrasyon:** Tarımsal robotlar ve UAV'lerle CNN tabanlı karar destek sistemlerinin bütünleştirilmesi.

Teşekkür: Bu çalışma, Van Yüzüncü Yıl Üniversitesi Bilimsel Araştırma Projeleri Başkanlığı tarafından FDK-2024-11262 numaralı proje kapsamında desteklenmiştir. Yazarlar, çalışmanın yürütülmesi sürecindeki değerli katkıları ve destekleri için Van Yüzüncü Yıl Üniversitesi Bilimsel Araştırma Projeleri Koordinasyon Birimine içten teşekkürlerini sunmaktadır.

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BAĞCILIKTA DIJITAL DÖNÜŞÜM: YAPAY ZEKA, UZAKTAN ALGILAMA, IOT VE OTONOM SISTEMLERIN ENTEGRE KULLANIMI *

DIGITAL TRANSFORMATION IN VITICULTURE: INTEGRATED USE OF ARTIFICIAL INTELLIGENCE, REMOTE SENSING, IOT, AND AUTONOMOUS SYSTEMS

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ÖZET

Bu derleme, üzüm yetiştiriciliğinde (bağcılık) dijital dönüşümü Görsellendiren modern teknolojileri bütüncül bir yaklaşımla incelemektedir. Mekansal Karar Destek Sistemleri (MKDS), Yapay Zeka (AI), Makine Öğrenmesi (ML), Derin Öğrenme (DL), Uzaktan Algılama, İnsansız Hava Araçları (İHA), Nesnelerin İnterneti (IoT), otonom robotlar, büyük veri analitiği ve dijital ikiz teknolojisi gibi bileşenlerin bağcılıkta sunduğu olanaklar, güncel uluslararası literatür ışığında değerlendirilmiştir.

Çalışma, öncelikle bağcılığın mekansal değişkenliğe duyarlı yapısını ele alarak MKDS'nin bağ yeri seçimi, terroir analizi ve mekansal karar süreçlerinde sağladığı avantajları ortaya koymaktadır. Ardından, YSA ve CNN gibi derin öğrenme modellerinin hastalık tespiti, salkım sayımı, verim tahmini ve kalite değerlendirmesinde ulaştığı yüksek doğruluk oranları incelenmiştir. Uzaktan algılama indeksleri (NDVI, CWSI vb.) ile İHA görüntülerinin, bitki sağlığı izleme ve stres tespiti için sağladığı katkılar detaylandırılmıştır. IoT sensör ağlarının toprak, iklim ve bitki parametrelerini gerçek zamanlı izleyerek sulama, gübreleme ve hastalık yönetimi kararlarını optimize ettiği; otonom robotların ise budama, ilaçlama, hasat ve izleme gibi operasyonlarda iş gücü verimliliğini artırdığı gösterilmiştir.

Büyük veri analitiği ve dijital ikiz teknolojisi, bağcılıkta çok kaynaklı verilerin bütünleştirilmesi, senaryo simülasyonları ve proaktif yönetim stratejilerinin geliştirilmesi açısından kritik bir yenilik olarak değerlendirilmiştir. Çalışma ayrıca veri kalitesi, ekonomik fizibilite, kullanıcı kabulü ve veri güvenliği gibi uygulama zorluklarını tartışmakta; açıklanabilir yapay zeka, uç bilişim ve blokzincir entegrasyonu gibi gelecekteki araştırma yönelimlerini ortaya koymaktadır.

Sonuç olarak, yapay zeka tabanlı entegre sistemlerin bağcılıkta reaktif yönetimden proaktif, öngörüye dayalı ve sürdürülebilir bir üretim modeline geçişi hızlandırdığı; verim, kalite ve kaynak kullanım etkinliğini önemli ölçüde artırdığı görülmektedir.

Anahtar Kelimeler: Hassas Bağcılık; Yapay Zeka; Mekansal Karar Destek Sistemi; Derin Öğrenme; Verim Tahmini; Hastalık Tespiti; Uzaktan Algılama; IoT; Otonom Robotlar; Dijital İkiz.

*****: Van Yüzüncü Yıl Üniversitesi BAP Koordinasyon Ofisi tarafından FDK-2024-11262 numaralı proje kapsamında desteklenmiştir.

ABSTRACT

This review provides a comprehensive and integrated analysis of the modern technologies driving digital transformation in viticulture. It examines the effectiveness and applicability of Spatial Decision Support Systems (SDSS), Artificial Intelligence (AI), Machine Learning (ML), Deep Learning (DL), Remote Sensing, Unmanned Aerial Vehicles (UAVs), Internet of Things (IoT) sensors, autonomous robots, big data analytics, and digital twin technologies in enhancing productivity, quality, and sustainability.

The study first highlights the spatial variability inherent in vineyard ecosystems and demonstrates how SDSS-integrated with Geographic Information Systems (GIS) and remote sensing-supports vineyard site selection, terroir characterization, and spatial decision-making. It then evaluates the performance of ANN- and CNN-based deep learning models in disease detection, cluster counting, yield prediction, and quality assessment. Remote sensing indices (e.g., NDVI, CWSI) and UAV imagery are shown to significantly improve plant health monitoring and stress detection. IoT sensor networks enable real-time monitoring of soil, climate, and plant parameters, optimizing irrigation, fertilization, and disease management, while autonomous robots enhance labor efficiency in pruning, spraying, harvesting, and monitoring tasks.

Big data analytics and digital twin systems are identified as emerging pillars of predictive and scenario-based vineyard management, enabling multi-source data integration, simulation, and proactive decision-making. The review also discusses key challenges-including data quality, economic feasibility, user acceptance, and data security-and outlines future research directions such as explainable AI, edge computing, and blockchain integration.

Overall, the findings demonstrate that AI-driven integrated systems are accelerating the transition from reactive to proactive, predictive, and sustainable vineyard management, significantly improving yield, quality, and resource-use efficiency.

Keywords: Precision Viticulture; Artificial Intelligence; Spatial Decision Support System; Deep Learning; Yield Prediction; Disease Detection; Remote Sensing; IoT; Autonomous Robots; Digital Twin.

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1. GİRİŞ

1.1. Bağcılığın Küresel ve Ulusal Önemi

Bağcılık, binlerce yıllık geçmişiyle yalnızca bir tarımsal faaliyet değil, aynı zamanda birçok kültürün sosyal ve ekonomik yapısında derin izler bırakan bir üretim alanıdır. Dünya genelinde milyonlarca hektarlık alanda yapılan üzüm üretimi; taze tüketim, şarapçılık, kuru üzüm ve pekmez gibi geniş bir kullanım alanına sahiptir. Uluslararası Bağ ve Şarap Örgütü'nün (OIV, 2023) verilerine göre, dünya genelinde üzüm bağları yaklaşık 7.3 milyon hektar alan kaplamakta ve yıllık üretim 78 milyon ton civarında seyretmektedir. Bu üretim, milyarlarca dolarlık ekonomik hacim yaratmakta ve milyonlarca insana doğrudan veya dolaylı istihdam sağlamaktadır.

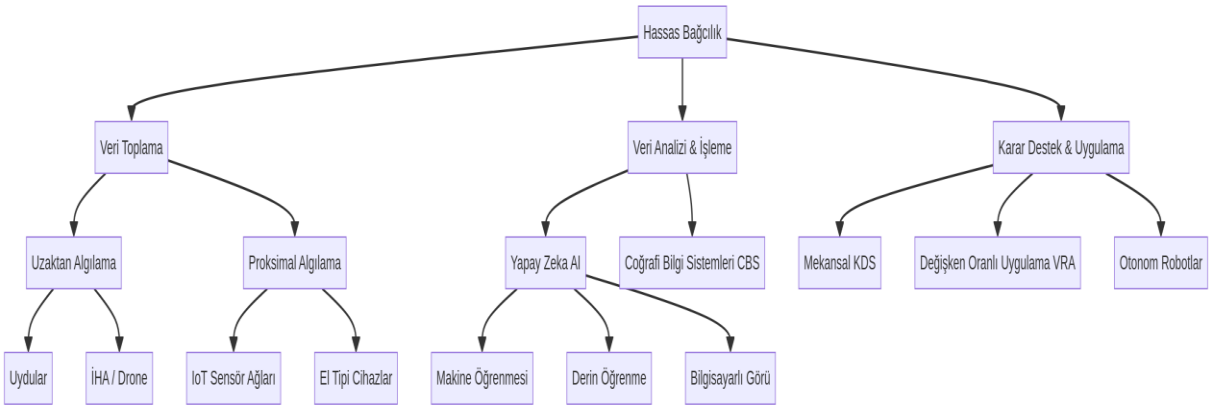
Türkiye, coğrafi konumu ve iklimsel çeşitliliği sayesinde dünyanın önemli bağcılık merkezlerinden biri olarak kabul edilmektedir. Ülke, hem sofralık üzüm üretiminde hem de geleneksel ürünlerde (kuru üzüm, pekmez, pestil) güçlü bir üretim mirasına sahiptir. Türkiye İstatistik Kurumu'nun verileri, Türkiye'nin dünya üzüm üretiminde ilk 10 ülke arasında yer aldığını göstermektedir (TOB, 2023). Ancak artan küresel rekabet, iklim değişikliği ve tüketici beklentilerinin yükselmesi, geleneksel üretim yöntemlerinin sınırlarını zorlamaktadır.

1.2. Hassas Tarım ve Bağcılık

Bu zorluklara yanıt olarak tarım sektörü, son yirmi yılda "Hassas Tarım" veya "Akıllı Tarım" olarak adlandırılan teknoloji odaklı bir dönüşüm sürecine girmiştir. Hassas tarım; verimliliği, sürdürülebilirliği ve kaliteyi artırmak amacıyla modern bilgi ve iletişim teknolojilerini kullanan bir yönetim stratejisidir (Stafford, 2000). Bu yaklaşım, tarlanın her bir bölümünün kendine özgü ihtiyaçlarına göre yönetilmesini, böylece su, gübre ve pestisit gibi girdilerin optimize edilmesini ve çevresel etkinin azaltılmasını hedefler.

Bağcılık, ürün kalitesinin büyük ölçüde "terroir" olarak bilinen toprak, iklim ve topoğrafya gibi mekansal faktörlerin etkileşimine bağlı olması nedeniyle hassas tarım uygulamaları için ideal bir alandır. Bağ içindeki küçük ölçekli değişkenlikler bile üzümün olgunlaşması, şeker-asit dengesi ve aromatik bileşenleri üzerinde önemli farklılıklar yaratabilir. Bu nedenle bağların homojen birimler olarak değil, heterojen alt bölgelerden oluşan bir mozaik olarak yönetilmesi kritik öneme sahiptir (Bramley & Hamilton, 2004; Tisseyre & McBratney, 2008).

Hassas bağcılık teknolojileri, dört ana katmanda organize edilmektedir: veri toplama (uzaktan algılama, proksimal sensörler), veri analizi (AI, CBS), karar destek (MKDS) ve uygulama (VRA, otonam robotlar). Görsel 1'de gösterildiği üzere, bu hiyerarşik yapı, teknolojilerin birbirleriyle nasıl entegre olduğunu ve veri akışını göstermektedir (Tang vd., 2020).



Görsel 1. Hassas bağcılıkta kullanılan teknolojilerin hiyerarşik yapısı

1.3. Derlemenin Amacı ve Kapsamı

Son yıllarda yapay zeka (AI), makine öğrenmesi (ML), coğrafi bilgi sistemleri (CBS) ve uzaktan algılama gibi teknolojiler, hassas bağcılık uygulamalarına yeni bir boyut kazandırmıştır. Bu teknolojiler, büyük veri setlerini analiz ederek karmaşık ilişkileri modelleme, geleceğe yönelik tahminlerde bulunma ve karar vericilere bilimsel temelli öneriler sunma kapasitesine sahiptir.

Bu derlemenin temel amacı, üzüm yetiştiriciliğinde:

- Mekansal Karar Destek Sistemleri (MKDS),
- Yapay Sinir Ağları (YSA),
- Makine Öğrenmesi ve Derin Öğrenme modelleri,
- Uzaktan algılama ve İHA uygulamaları

gibi teknolojilerin etkinliğini ve kullanılma olanaklarını, güncel bilimsel çalışmalar ışığında kapsamlı bir Görselde analiz etmektir.

Bu kapsamda aşağıdaki araştırma sorularına yanıt aranacaktır:

- MKDS, bağ yeri seçimi ve terroir analizinde ne gibi avantajlar sunmaktadır?
- YSA ve derin öğrenme modelleri, hastalık tespiti, verim tahmini ve kalite değerlendirmesinde ne kadar etkilidir?
- Uzaktan algılama, İHA ve IoT sensörleri gibi veri toplama teknolojileri, AI tabanlı sistemleri nasıl beslemektedir?
- Bu teknolojilerin pratik uygulamadaki zorlukları ve ekonomik fizibilitesi nedir?

Bu derleme, belirtilen teknolojilerin teorik temellerini açıklamakla kalmayıp, dünya genelinden ve Türkiye'den güncel vaka çalışmalarıyla pratik uygulamaları somutlaştırmayı hedeflemektedir. Tüm içerik APA 7 formatına uygun olarak hazırlanmış olup, Görsel, Çizelge ve diyagramlarla desteklenmiştir. Nihai hedef, bağcılık sektöründeki üreticilere, araştırmacılara ve politika yapıcılara yapay zeka ve ilişkili teknolojilerin sunduğu fırsatlar ve zorluklar hakkında bütüncül bir bakış açısı sunmaktır.

2. YAPAY ZEKA VE MAKİNE ÖĞRENMESİ TEMELLERİ

2.1. Yapay Zeka Kavramı ve Tarımda Yeri

Yapay zeka (AI), en genel tanımıyla, normalde insan zekâsı gerektiren görevleri yerine getirebilen bilgisayar sistemlerinin geliştirilmesini amaçlayan bir bilim dalıdır (Russell & Norvig, 2020). Bu görevler arasında öğrenme, akıl yürütme, problem çözme, algılama ve doğal dil işleme gibi bilişsel fonksiyonlar bulunmaktadır.
Tarım sektöründe yapay zeka, yalnızca otomasyonun ötesine geçerek karmaşık çevresel verileri analiz etme, desenleri tanıma ve değişken koşullara uyum sağlama yeteneği ile öne çıkmaktadır. AI, çiftçilere daha önce mümkün olmayan bir hassasiyetle kaynakları yönetme, riskleri öngörme ve operasyonel verimliliği artırma imkânı sunmaktadır (LeCun vd., 2015).

2.2. Makine Öğrenmesi Algoritmaları ve Bağcılık Uygulamaları

Makine öğrenmesi (ML), yapay zekânın bir alt dalı olup, bilgisayar sistemlerinin açıkça programlanmadan verilerden öğrenmesini sağlayan algoritmalar geliştirmeyi amaçlar (Alpaydın, 2020). Bağcılıkta kullanılan temel ML yaklaşımları; sınıflandırma, regresyon, kümeleme ve anomali tespiti gibi görevlerde uygulanmaktadır. ML algoritmalarını ve bağcılık uygulamaları Çizelge 1'de verilmiştir.

Çizelge 1. Bağcılıkta kullanılan başlıca makine öğrenmesi (ml) algoritmaları ve uygulama alanları

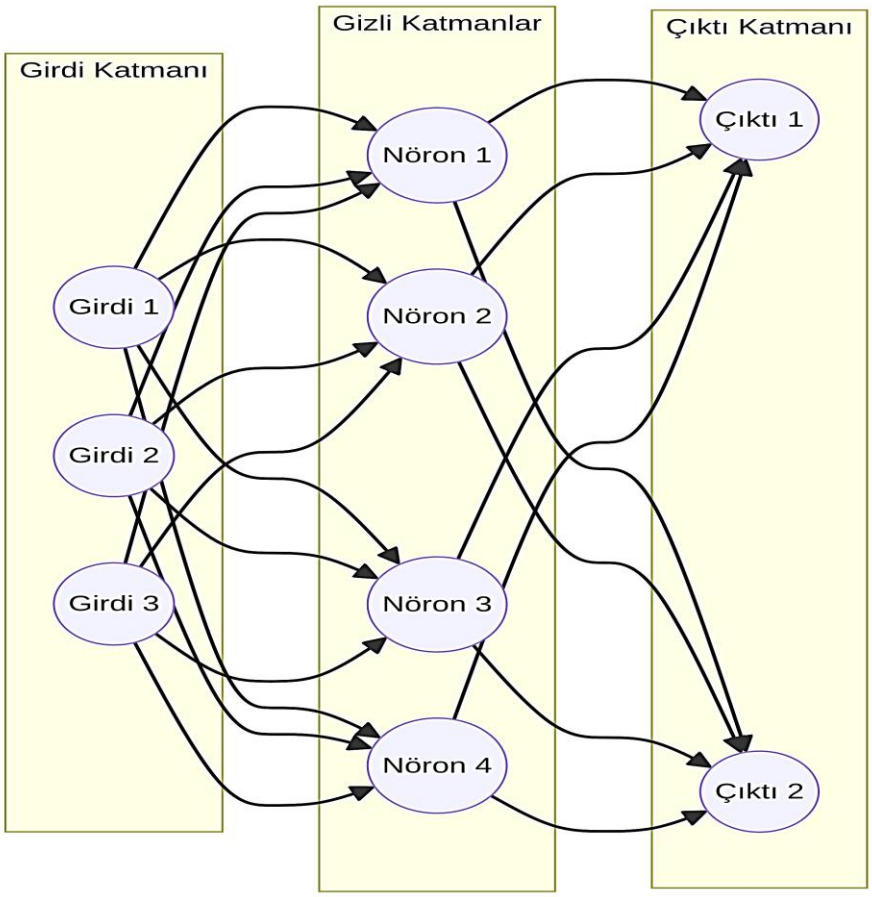
Algoritma	Temel Özellikler	Bağcılıkta Kullanımı	Kaynak
Random Forest	Çoklu karar ağaçlarının birleşimi; yüksek doğruluk; aşırı öğrenmeye dayanıklı	Verim tahmini, hastalık sınıflandırma, kalite tahmini	Breiman (2001)
Support Vector Machines (SVM)	Küçük veri setlerinde yüksek performans; margin maximization	Hastalık tespiti, yaprak sınıflandırma, stres analizi	Vapnik (1999)
Artificial Neural Networks (ANN)	Çok katmanlı öğrenme; doğrusal olmayan ilişkileri modelleme	Verim tahmini, fenolojik aşama tahmini	Alpaydın (2020)
k-Nearest Neighbors (k-NN)	Basit ve etkili; örüntü tanıma	Hastalık sınıflandırma, yaprak görüntü analizi	Russell & Norvig (2020)
Gradient Boosting / XGBoost	Art arda zayıf öğrenicilerin güçlendirilmesi; yüksek doğruluk	Verim tahmini, stres tespiti, kalite modelleme	Mingione vd. (2022)
Naive Bayes	Olasılıksal sınıflandırma; hızlı ve hafif	Hastalık tespiti, erken uyarı sistemleri	Hasan vd. (2020)

Not. *Çizelge 1, bağcılıkta yaygın olarak kullanılan makine öğrenmesi algoritmalarını ve bu algoritmaların temel uygulama alanlarını özetlemektedir.*

2.3. Yapay Sinir Ağları ve Derin Öğrenme

Yapay Sinir Ağları (YSA), insan beynindeki nöronlardan ilham alınarak tasarlanmış matematiksel modellerdir. Bağcılıkta YSA'lar özellikle görüntü işleme, sınıflandırma ve zaman

serisi analizinde kullanılmaktadır. YSA'nın temel yapısı Görsel 3'te gösterilmiştir. Görsel 2'de görüldüğü üzere, tipik bir YSA; girdi katmanı, bir veya daha fazla gizli katman ve çıktı katmanından oluşmaktadır. Her katmandaki nöronlar, bir önceki katmanın nöronlarıyla ağırlıklı bağlantılar aracılığıyla iletişim kurar. Derin Öğrenme (DL), çok sayıda gizli katmana sahip YSA mimarilerini kullanarak karmaşık desenleri öğrenme kapasitesine sahiptir (Simonyan & Zisserman, 2014; He vd., 2016).



Görsel 2. Yapay sinir ağı (YSA) temel yapısı

3. MEKANSAL KARAR DESTEK SİSTEMLERİ (MKDS)

3.1. MKDS Tanımı ve Temel Bileşenleri

Mekansal Karar Destek Sistemi (MKDS), mekansal veriler (haritalar, koordinatlar, coğrafi öznitelikler) ile geleneksel veri analiz yöntemlerini entegre ederek karar vericilere bilimsel temelli öneriler sunan bilgisayar tabanlı sistemlerdir (Sprague & Carlson, 1982). MKDS, özellikle bağcılık gibi mekansal değişkenliğin yüksek olduğu sektörlerde kritik bir rol oynamaktadır. Aşağıda MKDS'nin temel bileşenleri Çizelge 2'de özetlenmiştir.

Çizelge 2. MKDS bileşenleri ve fonksiyonları

Bileşen	Açıklama	Bağcılıkta Kullanımı

Veri Tabanı Yönetim Sistemi (DBMS)	Mekansal ve mekansal olmayan verilerin depolanması ve yönetilmesi	Toprak, iklim, topoğrafya, verim ve hastalık verilerinin saklanması
Model Tabanı (MBMS)	Analitik modellerin çalıştırıldığı bileşen	AHS, uygunluk analizi, verim tahmini modelleri
Kullanıcı Arayüzü (UI)	Kullanıcı ile sistem arasındaki etkileşim	Harita görüntüleme, katman seçimi, raporlama
Bilgi Tabanı	Uzman bilgisi ve kuralların yer aldığı bileşen	Terroir kuralları, bağ yönetim rehberleri

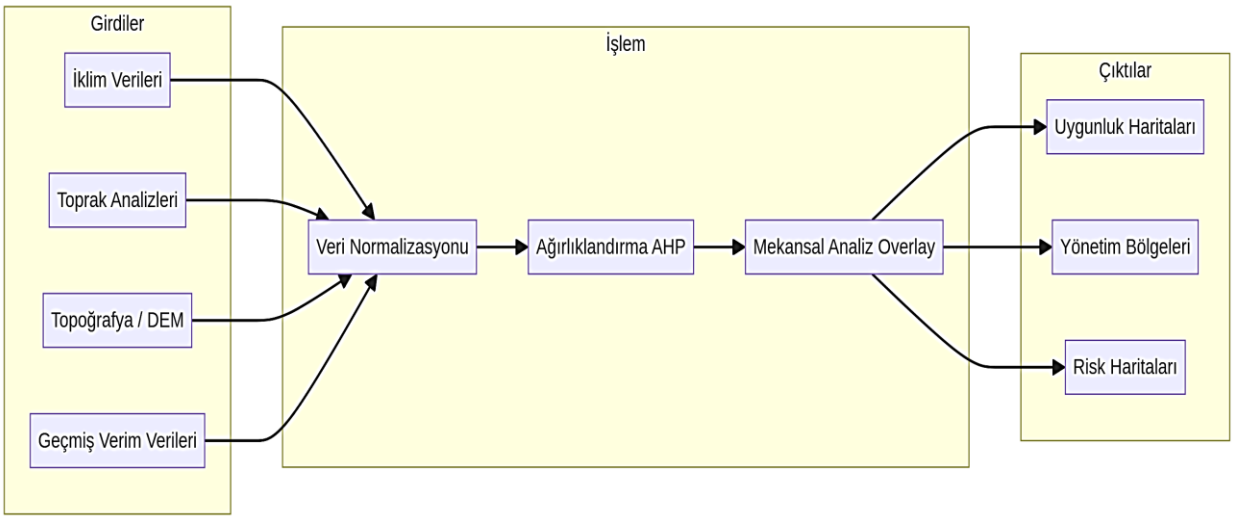
Not. *MKDS'nin dört ana bileşenini ve bu bileşenlerin bağcılık uygulamalarındaki rollerini göstermektedir.*

MKDS Bileşenleri ve Fonksiyonları

Çizelge 2'de görüldüğü üzere MKDS; veri tabanı yönetim sistemi, model tabanı, kullanıcı arayüzü ve bilgi tabanı bileşenlerinden oluşmaktadır. Bu bileşenlerin entegrasyonu, bağcılık uygulamalarında terroir analizinden verim tahminine kadar geniş bir yelpazede kullanılmaktadır (Mulla, 2013; Stafford, 2000).

3.2. MKDS Çalışma Prensibi ve Bağ Yeri Seçimi

MKDS'nin çalışma süreci, veri toplama, veri normalizasyonu, ağırlıklandırma (Analitik Hiyerarşi Süreci – AHS), mekansal analiz (overlay) ve sonuç haritalarının oluşturulması gibi aşamalardan oluşmaktadır (Boehm vd., 2008). MKDS'nin genel iş akışı Görsel 3'te gösterilmiştir.



Görsel 3. MKDS çalışma prensibi akış şeması

Bağ yeri seçimi için değerlendirilen başlıca kriterler şunlardır (Boehm vd., 2008):

- **İklim kriterleri:** Ortalama sıcaklık, yağış miktarı, güneşlenme süresi
- **Toprak kriterleri:** pH, organik madde, drenaj, tekstür
- **Topoğrafik kriterler:** Eğim, bakı, yükseklik
- **Sosyoekonomik kriterler:** Pazara yakınlık, altyapı, işgücü mevcudiyeti

Bu kriterlerin değerlendirilmesi sonucunda bağ yeri uygunluk haritaları oluşturulmaktadır.

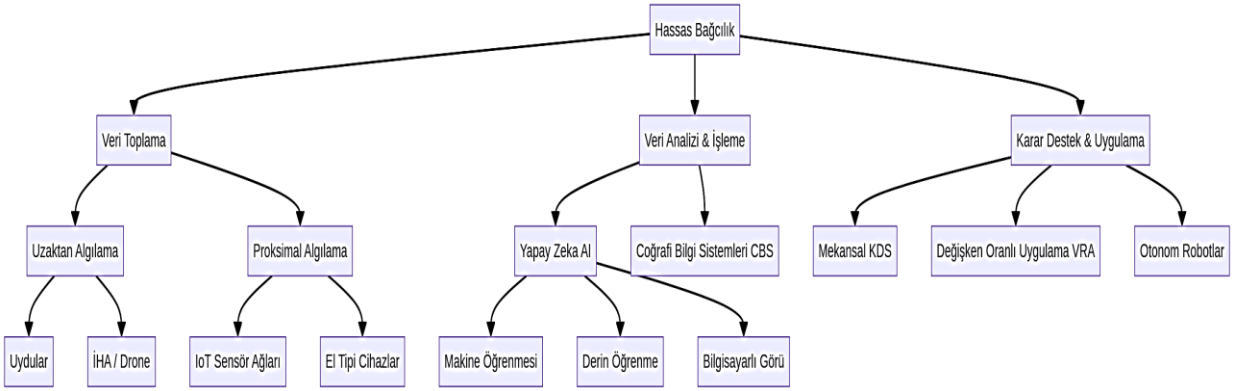
Çizelge 3. Geleneksel Bağcılık ile Hassas Bağcılık Arasındaki Temel Farklar

Kriter	Geleneksel Bağcılık	Hassas Bağcılık
Yönetim Yaklaşımı	Tek tip uygulama	Alan içi değişkenliğe göre yönetim
Veri Kullanımı	Gözleme dayalı	Sensör, İHA ve uydu verileri
Girdi Kullanımı	Sabit oranlı	Değişken oranlı uygulamalar (VRA)
Karar Verme	Deneyime dayalı	Veri ve model tabanlı
Verim Tahmini	Sezon sonu	Sezon içi, çoklu veri kaynağı ile
Çevresel Etki	Daha yüksek	Optimize edilmiş, daha düşük

Not. *Hassas bağcılığın geleneksel bağcılıktan hangi yönlerde ayrıldığını göstermektedir.*

3.3. Hassas Bağcılık Teknolojileri Hiyerarşisi

Hassas bağcılık teknolojileri; veri toplama, veri analizi, karar destek ve uygulama olmak üzere dört ana katmanda organize edilmektedir (Gebbers & Adamchuk, 2010). Bu yapı, teknolojilerin birbirleriyle nasıl entegre olduğunu ve veri akışını göstermektedir. Hassas bağcılık teknolojilerinin hiyerarşik yapısı Görsel 4'te gösterilmiştir.



Not. *Bu Görsel, veri toplama → veri analizi → karar destek → uygulama katmanlarını göstermektedir.*

Görsel 4. Hassas bağcılıkta kullanılan teknolojilerin hiyerarşik yapısı

4. UZAKTAN ALGILAMA VE İHA UYGULAMALARI

4.1. Uzaktan Algılama İndeksleri ve Bitki Sağlığı Analizi

Uzaktan algılama, uydu veya hava araçlarından alınan görüntüler aracılığıyla Dünya yüzeyinin özelliklerini inceleme ve ölçme tekniğidir (Lillesand vd., 2015). Bağcılıkta uzaktan algılama indeksleri; bitki sağlığı, su stresi ve verim potansiyelinin değerlendirilmesinde kritik rol oynamaktadır.Bu bölümde kullanılan yaygın uzaktan algılama indeksleri Çizelge 4'te özetlenmiştir.

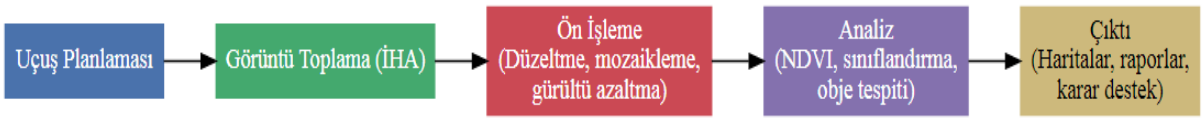
Çizelge 4'te görüldüğü üzere NDVI, bitki sağlığının genel bir göstergesi olarak en yaygın kullanılan indekstir (Rouse vd., 1974). CWSI ise sulama yönetimi kararlarında önemli bir rol oynamaktadır (Jackson vd., 1981).

Çizelge 4. Bağcılıkta kullanılan yaygın uzaktan algılama indeksleri

İndeks	Açıklama	Bağcılıkta Kullanımı
NDVI (Normalized Difference Vegetation Index)	Bitki yoğunluğu ve sağlığını ölçer	Genel bitki sağlığı değerlendirmesi
GNDVI (Green NDVI)	Yeşil bant duyarlılığı yüksek	Azot durumu ve klorofil yoğunluğu
SAVI (Soil Adjusted Vegetation Index)	Toprak etkisini azaltır	Seyrek bitki örtüsünde sağlık analizi
EVI (Enhanced Vegetation Index)	Atmosfer etkilerini azaltır	Yoğun bitki örtüsünde hassas sağlık ölçümü
NDWI (Normalized Difference Water Index)	Su içeriğini ölçer	Su stresi tespiti
CWSI (Crop Water Stress Index)	Bitki su stresini hesaplar	Sulama yönetimi
PRI (Photochemical Reflectance Index)	Fotosentetik verimlilik	Stres ve fizyolojik durum analizi

4.2. İHA Tabanlı Veri Toplama ve Görüntü İşleme

İnsansız Hava Araçları (İHA), bağlarda yüksek çözünürlüklü görüntü toplama ve gerçek zamanlı veri analizi imkânı sunmaktadır. İHA'lardan elde edilen RGB ve multispektral görüntüler, makine öğrenmesi ve derin öğrenme modelleriyle işlenerek hastalık tespiti, salkım sayımı ve verim tahmini yapılmaktadır (Lobell vd., 2015; Vélez vd., 2025). İHA tabanlı görüntü işleme sürecinin genel yapısı Görsel 5'te gösterilmiştir.



Görsel 5. İHA tabanlı veri toplama ve görüntü işleme sürecinin genel akışı.

İHA görüntüleri, özellikle:

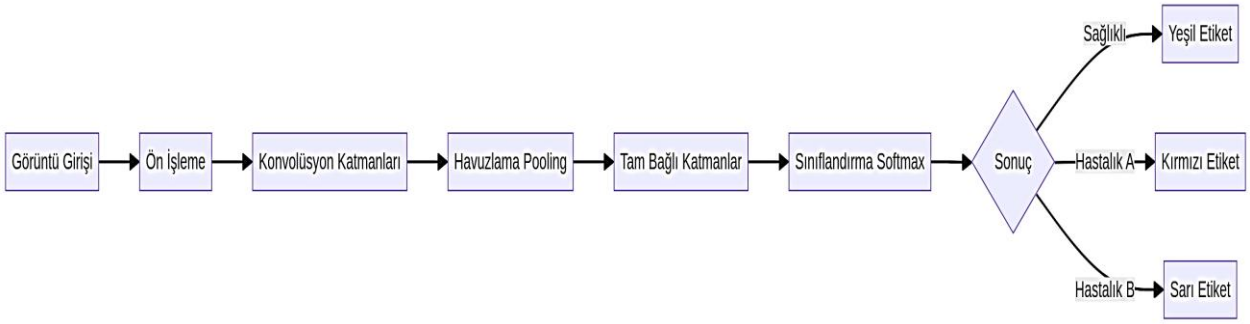
- Hastalık tespiti
- Salkım sayımı
- Verim tahmini
- Su stresi analizi
- Gelişim takibi; gibi uygulamalarda yüksek doğruluk sağlamaktadır.

5. YAPAY ZEKA İLE HASTALIK TESPİTİ

5.1. Derin Öğrenme Modelleri ve CNN Mimarileri

Convolutional Neural Networks (CNN), görüntü işleme alanında en etkili derin öğrenme modellerinden biridir. Bağcılıkta CNN'ler, özellikle üzüm yaprağı hastalıklarının otomatik teşhisinde yaygın olarak kullanılmaktadır. CNN modelleri, görüntülerden özellik çıkarma ve

sınıflandırma görevlerinde yüksek doğruluk oranları sunmaktadır (Hasan vd., 2020; Zhang vd., 2022). CNN tabanlı hastalık tespit süreci Görsel 6'da gösterilmiştir.



Görsel 6. CNN ile hastalık tespiti sürecinin genel akışı.

Görsel 6'da gösterildiği üzere CNN tabanlı hastalık tespiti sistemi beş ana aşamadan oluşmaktadır:

1. Görüntü girişi
2. Ön işleme
3. Konvolüsyon katmanları
4. Havuzlama (pooling)
5. Tam bağlı katmanlar ve sınıflandırma

Son aşamada softmax sınıflandırıcısı, görüntüyü "sağlıklı", "hastalık A" veya "hastalık B" olarak etiketlemektedir (Rayhan vd., 2021; Ateşoğlu vd., 2025).

5.2. Gerçek Uygulamalar ve Doğruluk Oranları

Son yıllarda yapılan çalışmalar, CNN modellerinin üzüm hastalık tespitinde **%90–98** doğruluk oranlarına ulaştığını göstermektedir (Rayhan vd., 2021; Ateşoğlu vd., 2025).

Bu başarı özellikle aşağıdaki hastalıkların erken teşhisinde kritik öneme sahiptir:

- **Downy mildew** (*Plasmopara viticola*)
- **Powdery mildew** (*Erysiphe necator*)
- **Leaf blight**
- **Black rot**

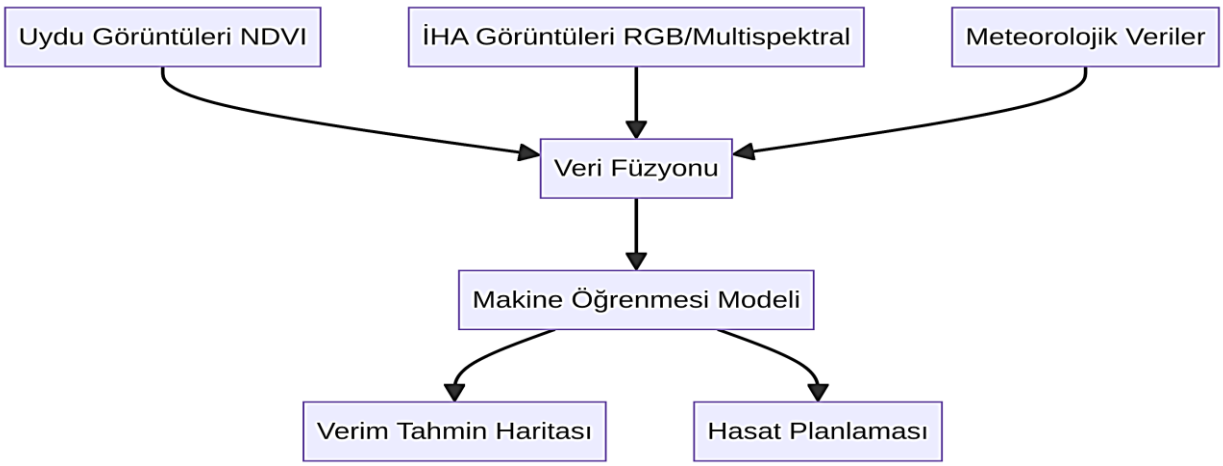
Erken teşhis, hem kimyasal kullanımını azaltmakta hem de verim kayıplarını önlemektedir.

6. VERİM TAHMİNİ VE ZAMAN SERİSİ ANALİZİ

6.1. Makine Öğrenmesi Modelleriyle Verim Tahmini

Verim tahmini, bağcılıkta sezon başında hasat planlaması, pazarlama stratejileri ve kaynak tahsisi kararlarında kritik bir rol oynamaktadır. Makine öğrenmesi modelleri; tarihsel veriler, meteorolojik veriler ve görüntü tabanlı veriler gibi çoklu veri kaynaklarını kullanarak güvenilir verim tahminleri sunmaktadır (Mingione vd., 2022; Orlandi vd., 2025).

Bu modeller, özellikle: Sıcaklık, Yağış, Nem, NDVI gibi uzaktan algılama indeksleri, İHA görüntüleri ve Fenolojik gözlemler; gibi değişkenleri kullanarak sezon sonundaki beklenen verimi tahmin etmektedir. Veri füzyonuna dayalı verim tahmin modeli Görsel 7'de gösterilmiştir.



Görsel 7. Verim tahmini için veri füzyonu modeli. *Not. Bu Görsel, uydu görüntüleri (NDVI), İHA görüntüleri (RGB ve multispektral) ve meteorolojik verilerin makine öğrenmesi modeline entegre edilerek verim tahmini yapılmasını göstermektedir.*

Görsel 7'de gösterildiği üzere verim tahmini sistemi üç ana veri kaynağını entegre etmektedir:

1. Uydu görüntüleri (NDVI)
2. İHA görüntüleri (RGB ve multispektral)
3. Meteorolojik veriler (sıcaklık, yağış, nem)

Bu veriler makine öğrenmesi modeline girdiler olarak sunulmakta ve model, sezon sonundaki beklenen verimi tahmin etmektedir (Lee vd., 2024).

Çizelge 5. Bağcılıkta kullanılan IoT sensör türleri, ölçülen parametreler ve kullanım amaçları

Sensör Tipi	Ölçülen Parametre	Ölçüm Aralığı	Kullanım Amacı
Toprak Nem Sensörü	Toprak su içeriği / Volumetrik su içeriği	0-100%	Sulama zamanlaması ve su stresi yönetimi
Sıcaklık Sensörü	Hava ve toprak sıcaklığı	-40 ila +60 °C	Fenolojik gelişim ve hastalık risk analizi
Yaprak Islaklık Sensörü	Yaprak yüzeyindeki nem	0–12 saat	Mildiyö, külleme ve diğer hastalık risk tahmini
Rüzgâr Sensörü	Rüzgâr hızı ve yönü	-	İlaçlama etkinliği ve mikroklima analizi
pH Sensörü	Toprak pH değeri	-	Besin yönetimi ve toprak sağlığı
EC Sensörü	Elektriksel iletkenlik	-	Tuzluluk ve besin çözeltisi takibi
Işık Sensörü	Güneşlenme süresi ve ışık yoğunluğu	-	Fotosentez kapasitesi ve gelişim analizi
Dendrometre	Gövde çapı değişimi	±0.5 mm	Su stresi takibi

Meteoroloji İstasyonu	Sıcaklık, nem, rüzgâr	-40 ila +60 °C	İklim takibi
Spektral Sensörler	Işık yansıması	400-2500 nm	Bitki sağlığı ve stres analizi

Çizelge 5'te gösterildiği üzere, her sensör türü belirli bir parametreyi ölçmekte ve farklı yönetim kararlarını desteklemektedir (Poblete-Echeverría vd., 2023; Atesoglu vd., 2025)

7. NESNELERİN İNTERNETİ (IoT) VE SENSÖR AĞLARI

7.1. IoT Sensörleri ve Ölçülen Parametreler

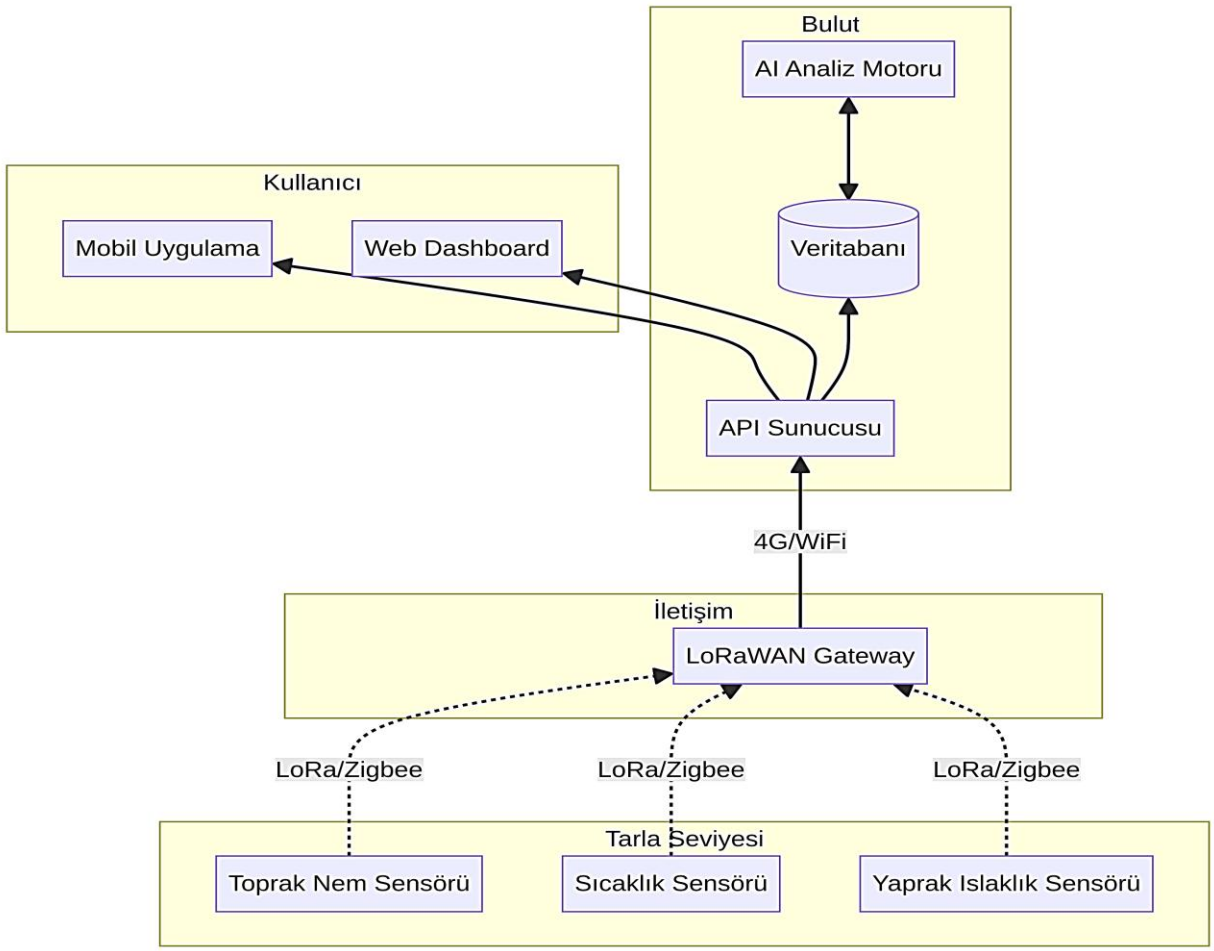
Nesnelerin İnterneti (IoT), bağlarda kurulan sensör ağları aracılığıyla gerçek zamanlı veri toplama imkânı sunmaktadır. Bu sensörler; toprak nemi, sıcaklık, yaprak ıslaklığı, rüzgâr hızı ve diğer kritik parametreleri ölçerek bağ yönetiminde karar destek süreçlerini güçlendirmektedir (Mansoor vd., 2025; Stojanova vd., 2025). Bağcılıkta kullanılan temel IoT sensör türleri Çizelge 5'te özetlenmiştir.

7.2. IoT Mimarisi ve Veri İletişimi

IoT tabanlı bağ izleme sistemleri, sensörlerden toplanan verilerin kablosuz iletişim protokolleri aracılığıyla bulut tabanlı platformlara aktarılması ve burada analiz edilmesi prensibine dayanır. Bu mimari; tarla seviyesi, iletişim katmanı, bulut katmanı ve kullanıcı arayüzü olmak üzere dört ana bileşenden oluşmaktadır (da Costa vd., 2025). IoT tabanlı bağ izleme sisteminin genel mimarisi Görsel 8'de gösterilmiştir.
Görsel 8'de gösterildiği üzere IoT sistemi dört katmandan oluşmaktadır:

1. **Tarla seviyesi:** Toprak nemi, sıcaklık, yaprak ıslaklığı gibi parametreleri ölçen sensörler
2. **İletişim katmanı:** LoRaWAN, Wi-Fi veya GSM tabanlı veri iletimi
3. **Bulut katmanı:** Veritabanı, API, yapay zeka analiz modülleri
4. **Kullanıcı arayüzü:** Mobil uygulama veya web tabanlı dashboard

Sensörlerden toplanan veriler, LoRaWAN protokolü aracılığıyla gateway'e iletilmekte, buradan bulut sunucularına aktarılmakta ve yapay zeka modelleriyle analiz edildikten sonra kullanıcıya raporlanmaktadır (da Costa vd., 2025).



Not. Bu Görsel, sensörler → LoRaWAN iletişim katmanı → bulut sunucusu → kullanıcı arayüzü veri akışını göstermektedir.

Görsel 8. IoT tabanlı bağ izleme sistemi mimarisi.

8. OTONOM ROBOTLAR VE MEKATRONİK UYGULAMALAR

8.1. Robotik Sistemlerin Bağcılıkta Kullanım Alanları

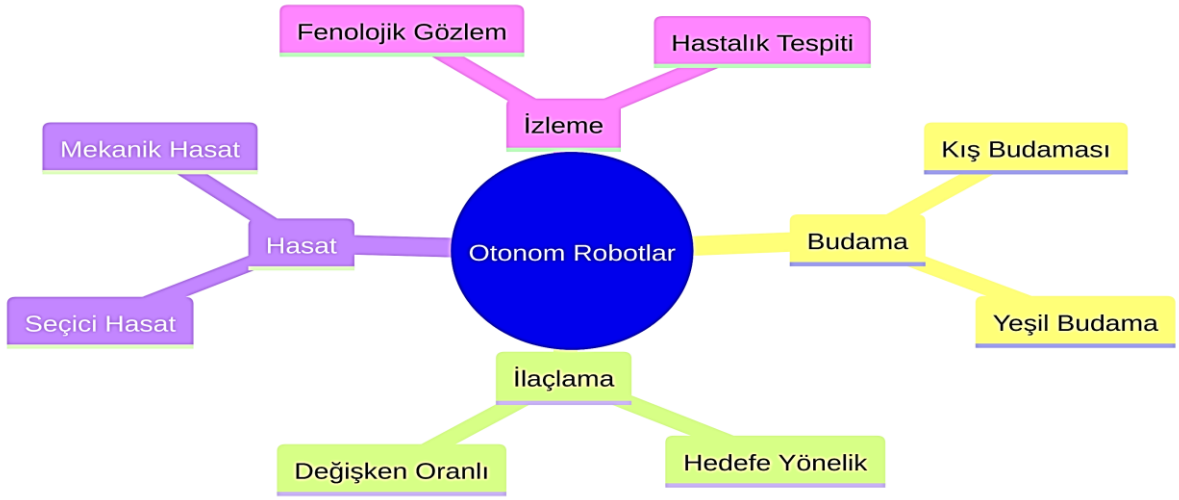
Otonom robotlar, bağcılıkta budama, ilaçlama, hasat ve izleme gibi işlerde insan iş gücünün yerini almaya başlamıştır. Bu robotlar; sensörler, kameralar, yapay zeka algoritmaları ve mekatronik bileşenlerle donatılarak bağ ortamının karmaşık koşullarında otonom olarak çalışabilmektedir (Loggenberg vd., 2024). Robotik sistemlerin bağcılıkta kullanım alanları Görsel 9'da, bağcılıkta robotik sistemlerin karşılaştırılması Çizelge 6'da özetlenmiştir.

Çizelge 6. Bağcılıkta robotik sistemlerin karşılaştırılması

Robotik Sistem	Görev / Kullanım Amacı	Teknolojik Altyapı	Geliştirilme Durumu
Wall-Ye	Budama, yaprak alma, göz sayımı, veri toplama	Görüntü işleme, GPS, robotik kollar	**Ticari kullanımda**; Fransa'da bağlarda aktif olarak kullanılmaktadır
VineScout	Bitki su stresi ölçümü, hassas sulama yönetimi	Termal kamera, multispektral sensörler, GPS, otonom navigasyon	**Ticari kullanımda**; sulama optimizasyonu için bağlarda uygulanmaktadır

Vinbot	Verim tahmini (kg/m²), bağ görüntüleme ve 3D veri analizi	Otonom mobil robot (Summit XL), kamera sistemleri, bulut bilişim	**Araştırma & Geliştirme aşamasında**; AB FP7 projesi kapsamında geliştirilmiştir
GRAPE	Üzüm kalitesi ve hastalık takibi, yaprak analizi	Yapay zekâ algoritmaları, görüntü işleme, mobil robot platformu	**Araştırma & Geliştirme aşamasında**; prototip düzeyinde test edilmektedir

Not. Çizelge 6, bağcılıkta kullanılan robotik sistemlerin görevlerini, teknolojik altyapılarını ve geliştirilme durumlarını göstermektedir. Robotik sistemlerin bazıları (örneğin *Wall-Ye* ve *VineScout*) ticari olarak kullanılmaya başlanmışken, diğerleri (*Vinbot, GRAPE*) hâlâ araştırma ve geliştirme aşamasındadır (Loggenberg vd., 2024; Kumanan vd., 2025).



Not. Bu Görsel, budama → ilaçlama → hasat → izleme görevlerini ve bu görevlerde kullanılan sensör/aktüatör yapılarını göstermektedir.

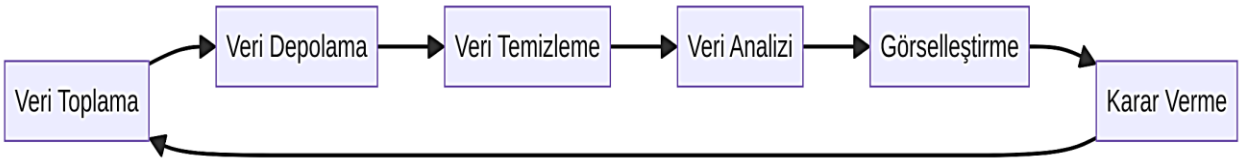
Görsel 9. Otonom robotik sistemlerin bağcılıkta kullanım alanları

Görsel 9'da görüldüğü gibi otonom robotlar bağcılıkta budama için kış budaması ve yeşil budama işlemlerinde robotik kollarla ilaçlama için hedefe yönelik püskürtme ve değişken oranlı uygulamalarda hasat için seçici veya mekanik hasat robotlarında ve izleme için fenolojik gözlem hastalık tespiti ve gelişim takibinde kullanılmakta olup her görev farklı sensör ve aktüatör konfigürasyonları gerektirmektedir.

9. BÜYÜK VERİ ANALİTİĞİ VE DİJİTAL İKİZ TEKNOLOJİSİ

9.1. Büyük Veri Döngüsü ve Entegre Analiz

Büyük veri analitiği, tarımsal üretimde giderek artan veri hacmini anlamlandırmak ve karar destek süreçlerini güçlendirmek için kullanılan çok aşamalı bir süreçtir. Bağcılıkta büyük veri; sensör ağları, İHA görüntüleri, uydu verileri, meteorolojik kayıtlar ve geçmiş verim bilgileri gibi çok çeşitli kaynaklardan elde edilmektedir (Loggenberg vd., 2024). Büyük veri analitiği döngüsü Görsel 10'da gösterilmiştir.



Görsel 10. Büyük veri analitiği döngüsü

Görsel 10'da gösterildiği üzere büyük veri analitiği altı aşamalı bir döngüden oluşmaktadır:

1. **Veri toplama:** Sensörler, İHA'lar, uydu sistemleri
2. **Veri depolama:** Bulut tabanlı veri tabanları
3. **Veri temizleme:** Gürültü giderme, eksik veri tamamlama
4. **Veri analizi:** Makine öğrenmesi, istatistiksel modelleme
5. **Görselleştirme:** Haritalar, grafikler, 3D modeller
6. **Karar verme:** Sulama, gübreleme, hasat planlaması

Bu döngü, bağcılık uygulamalarında sürekli iyileştirme ve adaptif yönetimi mümkün kılmaktadır (Loggenberg vd., 2024).

9.2. Dijital İkiz Teknolojisi

Dijital ikiz, fiziksel bir sistemin (örneğin bir bağın) sanal bir kopyasının oluşturulması ve bu kopyanın gerçek zamanlı verilerle sürekli güncellenmesi prensibine dayanan bir teknolojidir. Bağcılıkta dijital ikiz, bağın fenolojik gelişimi, su stresi, hastalık riski ve verim potansiyeli gibi parametrelerin simülasyonunu mümkün kılmaktadır (Loggenberg vd., 2024). Dijital ikiz teknolojisinin kavramsal modeli Görsel 11'de gösterilmiştir.

Görsel 11'de gösterildiği üzere dijital ikiz sistemi şu bileşenlerden oluşmaktadır:

Diyagramın Katmanları:

Katman 1: Veri Kaynağı (Sarı) - Fiziksel Bağ

- Bağ Parseli
- Bitki Sağlığı
- Toprak Koşulları

Katman 2: Veri Toplama ve Dijital Model (Mavi)

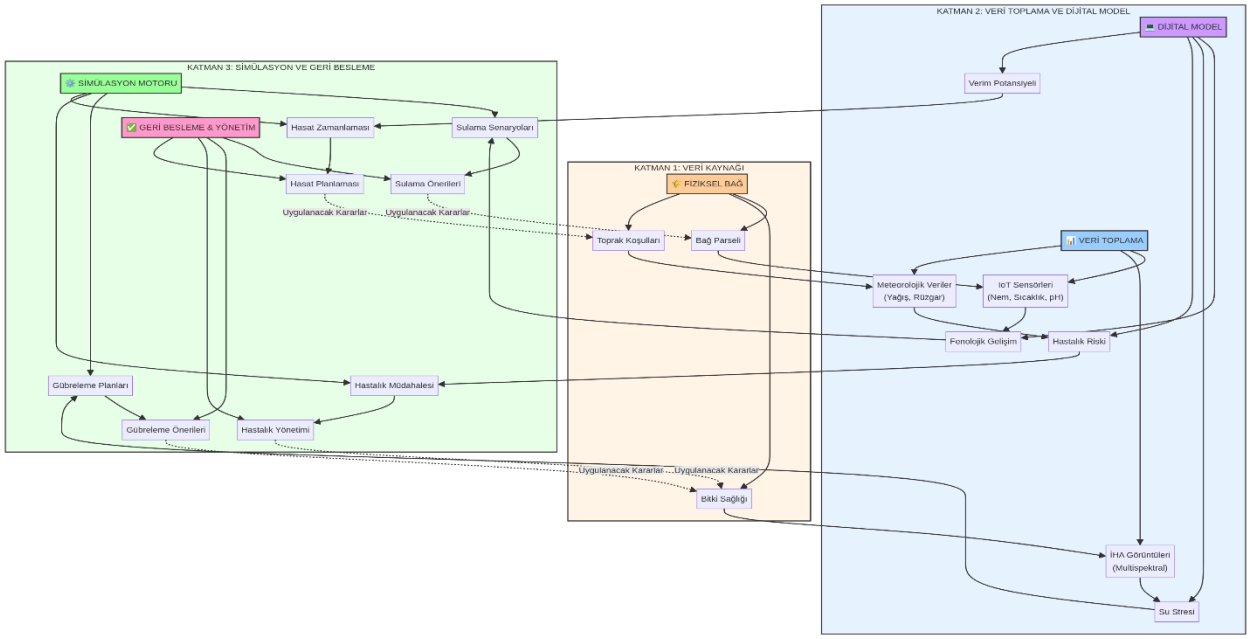
- Veri Toplama: IoT Sensörleri, İHA Görüntüleri, Meteorolojik Veriler
- Dijital Model: Fenolojik Gelişim, Su Stresi, Hastalık Riski, Verim Potansiyeli

Katman 3: Simülasyon ve Geri Besleme (Yeşil)

- Simülasyon Motoru: Sulama Senaryoları, Gübreleme Planları, Hastalık Müdahalesi, Hasat Zamanlaması
- Geri Besleme & Yönetim: Sulama Önerileri, Gübreleme Önerileri, Hastalık Yönetimi, Hasat Planlaması

Döngüsel Yapı: Geri Besleme katmanından Fiziksel Bağ'a geri dönen noktalı çizgiler, sistemin sürekli döngüsel doğasını göstermektedir. Bu yapı sayesinde sistem gerçek zamanlı olarak güncellenir ve iyileştirilir.

Bu yapı sayesinde üreticiler; sulama, gübreleme, hastalık yönetimi ve hasat zamanlaması gibi kritik kararları daha bilimsel ve öngörülebilir bir Görselde verebilmektedir.

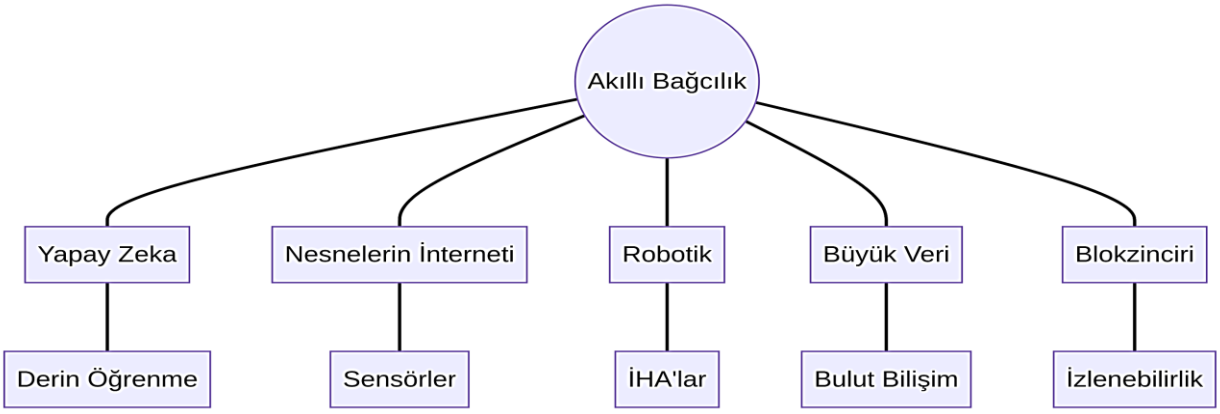


Görsel 11. Dijital ikiz teknolojisi kavramsal modeli

10. GELECEĞİN AKILLI BAĞCILIK EKOSİSTEMİ

10.1. Gelişmekte Olan Teknolojiler

Akıllı bağcılığın geleceği, yapay zeka, nesnelerin interneti, robotik, büyük veri ve blokzinciri teknolojilerinin entegrasyonuna bağlıdır. Bu teknolojiler, bağcılık yönetiminin farklı yönlerini destekleyerek daha verimli, sürdürülebilir ve öngörülebilir bir üretim sistemi oluşturmayı amaçlamaktadır (Loggenberg vd., 2024). Geleceğin akıllı bağcılık ekosistemi Görsel 12'de kavramsal olarak gösterilmiştir.



Not. Bu Görsel, yapay zeka → IoT → robotik → büyük veri → blokzinciri entegrasyonunu ve bu teknolojilerin bağ yönetimindeki rollerini göstermektedir.

Görsel 12. Geleceğin akıllı bağcılık ekosistemi

Görsel 12'de gösterildiği üzere geleceğin akıllı bağcılık ekosistemi şu bileşenlerden oluşmaktadır:

- **Yapay Zeka:** Hastalık tespiti, verim tahmini, karar destek
- **IoT Sensörleri:** Gerçek zamanlı veri toplama
- **Robotik Sistemler:** Otonom budama, ilaçlama, hasat
- **Büyük Veri Analitiği:** Çok kaynaklı veri füzyonu
- **Blokzinciri:** Ürün izlenebilirliği ve kalite sertifikasyonu

Bu teknolojilerin entegrasyonu, bağcılıkta reaktif yönetimden proaktif ve öngörüye dayalı bir yönetim anlayışına geçişi hızlandırmaktadır.

10.2. Ekonomik ve Çevresel Etki

Akıllı bağcılık uygulamaları, hem ekonomik hem de çevresel açıdan önemli faydalar sunmaktadır. Bu etkiler Çizelge 7'de özetlenmiştir.

Çizelge 7. Akıllı bağcılık uygulamalarının ekonomik ve çevresel etkileri

Etki Alanı	Fayda	Açıklama
Ekonomik	Girdi tasarrufu	Su, gübre ve pestisit kullanımında %20–40 azalma
Ekonomik	İş gücü verimliliği	Otonom robotlarla %50'nin üzerinde iş gücü tasarrufu
Ekonomik	Verim artışı	Daha doğru verim tahmini ve stres yönetimi
Çevresel	Kimyasal kullanımının azalması	Hedefe yönelik ilaçlama ile çevresel yükün düşmesi
Çevresel	Su tasarrufu	IoT tabanlı sulama yönetimi ile su kullanımının optimize edilmesi
Çevresel	Karbon ayak izi azalması	Enerji verimli sistemler ve optimize edilmiş operasyonlar

Not. Çizelge 7, akıllı bağcılık uygulamalarının ekonomik ve çevresel etkilerini özetlemektedir.

Akıllı bağcılık teknolojilerinin yaygınlaşmasıyla birlikte:

- Üretim maliyetlerinin azalması,
- Kaynak kullanımının optimize edilmesi,
- Çevresel etkinin azaltılması,
- Ürün kalitesinin artırılması; gibi önemli kazanımlar elde edilmektedir (Loggenberg vd., 2024).

11. SONUÇ VE ÖNERİLER

Bu derleme, üzüm yetiştiriciliğinde mekansal karar destek sistemleri (MKDS), yapay sinir ağları (YSA) ve genel olarak yapay zeka (AI) uygulamalarının etkinliğini ve kullanılma olanaklarını kapsamlı bir Görselde analiz etmiştir. Yapılan inceleme, aşağıdaki temel bulguları ortaya koymaktadır:

1. **MKDS'nin Etkinliği:** Mekansal karar destek sistemleri, bağ yeri seçimi ve terroir analizinde yüksek doğruluk oranlarına ulaşmakta ve stratejik karar vermeyi önemli ölçüde desteklemektedir (Boehm vd., 2008).
2. **AI Tabanlı Hastalık Tespiti:** CNN gibi derin öğrenme modelleri, üzüm hastalıklarının teşhisinde %90–98 doğruluk oranlarına ulaşmakta ve erken müdahale imkânı sunmaktadır (Rayhan vd., 2021; Ateşoğlu vd., 2025).
3. **Verim Tahmini:** Makine öğrenmesi modelleri, çok kaynaktan veri füzyonu yaparak güvenilir verim tahminleri sağlamakta ve hasat planlamasını optimize etmektedir (Orlandi vd., 2025; Lee vd., 2024).
4. **IoT ve Sensör Ağları:** Gerçek zamanlı veri toplama, sulama ve ilaçlama kararlarının optimize edilmesini sağlamakta ve girdi tasarrufu %20–40 arasında değişmektedir (Mansoor vd., 2025).
5. **Otonom Robotlar:** Robotik sistemler, iş gücü verimliliğini %50'nin üzerinde artırma potansiyeline sahip olup tekrarlayan görevlerin otomasyonunu sağlamaktadır (Loggenberg vd., 2024).
6. **Entegre Sistemlerin Gücü:** Yapay zeka, IoT, robotik ve büyük veri teknolojilerinin entegrasyonu, bağcılıkta reaktif yönetimden proaktif ve öngörüye dayalı bir yönetim anlayışına geçişi mümkün kılmaktadır.

Bu teknolojilerin benimsenmesinde aşağıdaki zorluklar öne çıkmaktadır:

- **Veri Kalitesi:** Sensörlerin kalibrasyonu ve veri doğruluğu, sistem başarısının kritik faktörleridir.
- **Ekonomik Fizibilite:** Başlangıç yatırım maliyetleri yüksek olup geri dönüş süresi bölgesel koşullara bağlı olarak 3–5 yıl arasında değişmektedir.
- **Kullanıcı Kabulü:** Geleneksel üreticilerin yeni teknolojileri benimsemesi için eğitim ve teknik destek gerekmektedir.
- **Veri Gizliliği:** Tarım verilerinin güvenliği ve mülkiyeti konusunda yasal çerçevelerin geliştirilmesi gerekmektedir.

Gelecekteki çalışmaların aşağıdaki alanlarda yoğunlaşması önerilmektedir:

1. **Açıklanabilir Yapay Zeka (XAI):** Karar verme süreçlerinin şeffaflığını artırmak ve kullanıcı güvenini güçlendirmek.
2. **Uç Bilişim (Edge Computing):** Bulut bağımlılığını azaltarak gerçek zamanlı veri işleme kapasitesini artırmak.
3. **Dijital İkiz Teknolojisi:** Fiziksel bağların sanal simülasyonlarının geliştirilmesi ve farklı yönetim senaryolarının test edilmesi.
4. **Blokzincir Entegrasyonu:** Ürün izlenebilirliği, kalite sertifikasyonu ve veri güvenliğinin artırılması.

Yapay zeka ve ilişkili teknolojiler bağcılık sektöründe bir paradigma değişimi yaratmakta; sürdürülebilir, verimli ve kaliteli üretim hedeflerine ulaşmada kilit bir rol oynamaktadır. Ancak bu teknolojilerin tam potansiyelinin gerçekleştirilmesi, araştırma kurumları, teknoloji sağlayıcıları ve üreticiler arasında güçlü bir iş birliği ve koordinasyon gerektirmektedir.

Teşekkür Bu çalışma, Van Yüzüncü Yıl Üniversitesi Bilimsel Araştırma Projeleri Başkanlığı tarafından FDK-2024-11262 numaralı proje kapsamında desteklenmiştir. Yazarlar, çalışmanın yürütülmesi sürecindeki değerli katkıları ve destekleri için Van Yüzüncü Yıl Üniversitesi Bilimsel Araştırma Projeleri Koordinasyon Birimine içten teşekkürlerini sunmaktadır.

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ANTIOXIDATIVE INGREDIENTS AND BIOCHEMICAL METABOLISM OF TEA AND GRAPES

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Abstract:

In recent years, researchers have given great place to polyphenolic components in the components of naturally derived fruits and vegetables, which are biologically and pharmacologically effective in the prevention and treatment of diseases. There is a direct relationship between polyphenols and health. Most of the exogen-derived polyphenols have antioxidative properties. Foods with polyphenic components can interact with each other or with some structures in the body (enzymes, membranes, proteins, carbohydrates, lipids and DNA) in the metabolic process, leading to significant changes in antioxidant activity levels and the biological roles of the substances they interact with. In this review, in the light of current research, we bring up how tea and grapes containing flavanols and folic acid carry out their metabolic interactions and their effects on possible antioxidative activity results.

Keywords: Antioxidants, polyphenols, grapes, tea, health

ÇAY VE ÜZÜMÜN ANTİOKSİDAN İÇERİKLERİ VE BİYOKİMYASAL METABOLİZMASI

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Öz:
Son yıllarda araştırmacılar, hastalıkların önlenmesi ve tedavisinde biyolojik ve farmakolojik olarak etkili olan, doğal kaynaklı meyve ve sebzelerin bileşimindeki polifenolik bileşenlere büyük önem vermektedir. Polifenoller ile sağlık arasında doğrudan bir ilişki bulunmaktadır. Dış kaynaklı polifenollerin çoğu antioksidan özellik göstermektedir. Polifenolik bileşenler içeren besinler, metabolik süreçte birbirleriyle veya vücuttaki bazı yapılarla (enzimler, membranlar, proteinler, karbonhidratlar, lipitler ve DNA) etkileşime girerek antioksidan aktivite düzeylerinde ve etkileşimde bulundukları maddelerin biyolojik rollerinde önemli değişikliklere neden olabilir. Bu derlemede, güncel araştırmalar ışığında, flavanoller ve folik asit içeren çay ve üzümün metabolik etkileşimlerini nasıl gerçekleştirdiğini ve olası antioksidan aktivite sonuçları üzerindeki etkilerini ele alıyoruz.

Anahtar Kelimeler: Antioksidanlar, polifenoller, üzüm, çay, sağlık

AMBİYANSIN İZİNDE RICOEUR'CÜ BİR HERMENEUTİK İNCELEME: TRABZON KADINLAR PAZARI'NIN ANLATI KİMLİĞİ[1]

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ÖZET

Bu çalışma, günümüzde kentlerin kimliğini aşındıran müdahalelere karşı, yaşayan kentin otantik dokusunu görünür kılan kentsel mekân ambiyanslarını anlatı kimliği üzerinden tartışmaya açmaktadır. Bu bağlamda araştırma, mekânın dönüşen ve/veya dönüşüme direnen özgün kimliğini, duyusal deneyimlere dayalı anlatı metinlerinden hareketle çözümlemeyi amaçlamaktadır.

Yöntemsel çerçeve, hermeneutik (yorumbilim) kuram doğrultusunda yapılandırılmış; özellikle Ricoeur'cü hermeneutik diyalektiğe dayalı bir analiz yaklaşımı benimsenmiştir. Ricoeur'e göre anlatı, zamanı deneyimlenebilir hâle getiren bir düzenleme biçimidir. Bu nedenle mimarlık, yalnızca mekânı üretmekle kalmaz; onu aynı zamanda 'anlatır' ve mekânı zamansal bir anlatının sahnesine dönüştürür (Ricoeur, 1984). Nitel bir araştırma yöntemi olarak kurgulanan çalışma, hermeneutik süreci oluşturan üç aşama anlama, açıklama ve kavrama üzerinden ilerlemektedir.

Anlama fazı, anlatı metninin anlamını bütüncül ve sezgisel biçimde ortaya koymayı içerir. Açıklama fazı, metnin özerkliğinin belirginleştiği; okurun metne bilinçli bir mesafe koyarak kopma yaşadığı analitik düzeyi ifade eder. Bu aşama, anlama ve kavrama arasında ara bir diyalektik işlev görür. Kavrama fazı ise açıklama sürecinde çözümlenen anlamın okur tarafından yeniden içselleştirilmesi; başka bir deyişle anlamın temellük edilerek okurun ufkuna geri kazandırılmasıdır.

Araştırmanın veri setini, TÜBİTAK tarafından desteklenen ve hâlen yürürlükte olan uluslararası araştırma proje kapsamında, Trabzon Kadınlar Pazarı durak noktasında üretilen anlatı metinleri oluşturmaktadır. Kadınlar Pazarı, kadın emeğini görünür kılan ve yerel pratiklere ayrıcalıklı bir konum tanıyan; buna karşın mekânsal izleri tarihsel süreçte silinen, ancak kentin kolektif hafızasında önemli bir yere sahip bir kentsel mekândır.

[1] Bu çalışma, Türkiye Bilimsel ve Teknolojik Araştırma Kurumu (TÜBİTAK) tarafından 223K212 numaralı proje ile desteklenmiştir. Projeye verdiği destekten ötürü TÜBİTAK'a teşekkürlerimizi sunarız.

Bulgular ve tartışma bölümünde, bir grup mimarlık öğrencisinin seçili mekânı beş gün boyunca farklı duyular aracılığıyla deneyimlemeleri sonucunda ürettikleri anlatı metinleri, önerilen hermeneutik analiz modeli doğrultusunda incelenmiştir. Bu inceleme, metinlerin Ricoeur'cü Ricoeur'cü hermeneutik diyalektiği üzerinden değerlendirilmesini kapsamaktadır.

Sonuç olarak bu çalışma, duyusal deneyimlerin ve hermeneutik yorumlamanın kentsel mekân ambiyanslarını anlamadaki belirleyici rolünü ortaya koymaktadır. Araştırma, kentsel mekân tasarımı ve planlamasında ambiyans odaklı yaklaşımların gerekliliğini vurgulamakta; mekân deneyimlerinin mimarlık disiplinine ve kentsel politika süreçlerine entegrasyonunun önemini akademik bir çerçevede tartışmayı hedeflemektedir.

Anahtar Kelimeler: Kentsel Mekân, Ambiyans, Anlatı Kimliği, Hermeneutik, Trabzon Kadınlar Pazarı.

1. GİRİŞ: ANLATI, AMBİYANS VE MİMARLIK ÜZERİNE

Kent ve kullanıcı ilişkisi geçmişten günümüze değişerek evrilmiştir. Yaşadığımız ve deneyimlediğimiz mekânların yüzü olan kentsel yerler, insan algısının yapıcı bir ürünüdür, dolayısıyla insan katılımı olmadan yer anlamını ve tanımını kaybetmektedir (Havik vd., 2018). Mekânlar deneyim yoluyla anlam kazanarak yer'lere dönüşür. Yerler iç içe geçmiş hikâyelerden oluşur. Çünkü bir yerde olmak demek o yer hakkında anlatılabilecek bir hikâyenin varlığına işaret eder. Benzer şekilde, bütün hikâyeler kendilerini bir yer'e konumlandırır. Kentsel mekânlar ve yerler, onlara bağlanan hikâyelerde anlatı haline gelir (Havik vd., 2018: 5).

Kent insan tarafından deneyimlenen, duyumsanan, karşılıklı etkileşime geçilen bir olgudur (Durmuş Öztürk & Çıraklı, 2023). Kentsel mekân deneyimlerine ilişkin duyumsama biçimlerinin araştırılması kentin yeni ve özgün bir bilgi uzamı olarak yeniden üretilmesi açısından önemlidir. Kentin bu yaklaşımla araştırılması otantik kent imgesini zenginleştirmeye ve derinleştirmeye hizmet eder (Durmuş Öztürk vd., 2023). Kent ve mekân, sanıldığının aksine, fiziksel ya da mekanik değil canlı ve organik bir olgudur ve insanî bir olgu olarak insanla etkileşim dolayımında belirlenim kazanır. Dolayısıyla tıpkı insan gibi sürekli olma, oluş, oluşum, çeşitlilik, değişim ve dönüşüm gösterir. Kentler içinde barındırdığı mekânlar ile anlatı kimliğinin oluşmasına katkı sağlar. Anlatı kimliğinin tanımlanmasında ve kentsel yerler hakkında bilgi edinilmesinde, hermeneutik (yorumbilim) veya anlatıbilimin araçları gündeme gelebilir. Öte yandan anlatı, tasarım fikirleri üretme hakkında bir düşünme biçimidir ve bu nedenle mimari pratiğin parçası olarak tanımlanır. Dolayısıyla mimarlıkta anlatı bir yapıdır, bir düşünme eylemidir ve bir ifadedir denebilir (Durmuş Öztürk, 2021).

Yaşam kalitesini önemli ölçüde etkileyen ve kentsel kimliğin oluşumunda bir güç aracı olan ambiyanslar ise mimarlıkta göz ardı edilmemelidir. Dünya'da 1980'ler itibari ile başlayan paradigma değişimiyle beraber, ambiyans üzerine eğilen çalışmalar önemli ölçüde hız

kazanmıştır. Bu bağlamda kentsel ambiyansa dair bütüncül bir tanımlama henüz benimsenmemiş olsa da atmosfer, ortam veya çevre olarak çeşitli kavramlar üzerinden tanımlama ve açıklamaların üretildiği saptanmıştır. Bu doğrultuda Zumthor, atmosferin tanımını yaparken dokuz alt başlıktan yardım almaktadır ve bu alt başlıkları şu şekilde sıralamaktadır: Mimarinin Bedeni, Malzeme Uyumluluğu, Mekânın Sesi, Mekânın Sıcaklığı, Çevreleyen Nesneler, Dinginlik ve Baştan Çıkarma Arasında, İç ve Dış Mekân Arasındaki Gerilim, Yakınlık Düzeyleri, Nesneler Üzerindeki Işık (Zumthor, 2006). Benzer şekilde, mimarların metinlerinde atmosfer kavramının tanımına bakıldığında bu tanımlamaların genellikle mekânın materyal ve immateryal boyutları üzerinden başka bir deyişle mimarlığın tektonik kavrayışı üzerinden yapıldığı görülmektedir. Bu noktada Böhme'ye (2016) göre atmosfer, algılanabilir bir ortamın bireyde yarattığı duyusal ve duygusal etkidir. Atmosfer yalnızca fiziksel özelliklerin toplamı değil, aynı zamanda bu özelliklerin duyusal algıyla nasıl ilişkilendirildiğinin bir sonucudur. Atmosferler duygusal bir etki olarak deneyimlenir. Bu nedenle, onları üretme sanatı aynı zamanda bir güç kullanımıdır (Böhme, 2016). Atmosferler, özneler ile nesneler arasındaki aracı alanlardır. Onlar hem dış dünyada vardır hem de öznel deneyim ile sıkı sıkıya bağlantılıdır. Bu tanımlamalar ışığında, kentsel ambiyans kavramı, materyal ve immateryal etkileşimleri bir bütün olarak kente davet eden –Hill (2006), mimarlıkta bu iki kavramın örülü olması gerektiğini savunur- aynı zamanda, bireylerin duyusal ve duygusal deneyimleri sonucu şekillenen ve anlatı kimliğini besleyen bir güç alanı olarak gündeme gelmektedir.

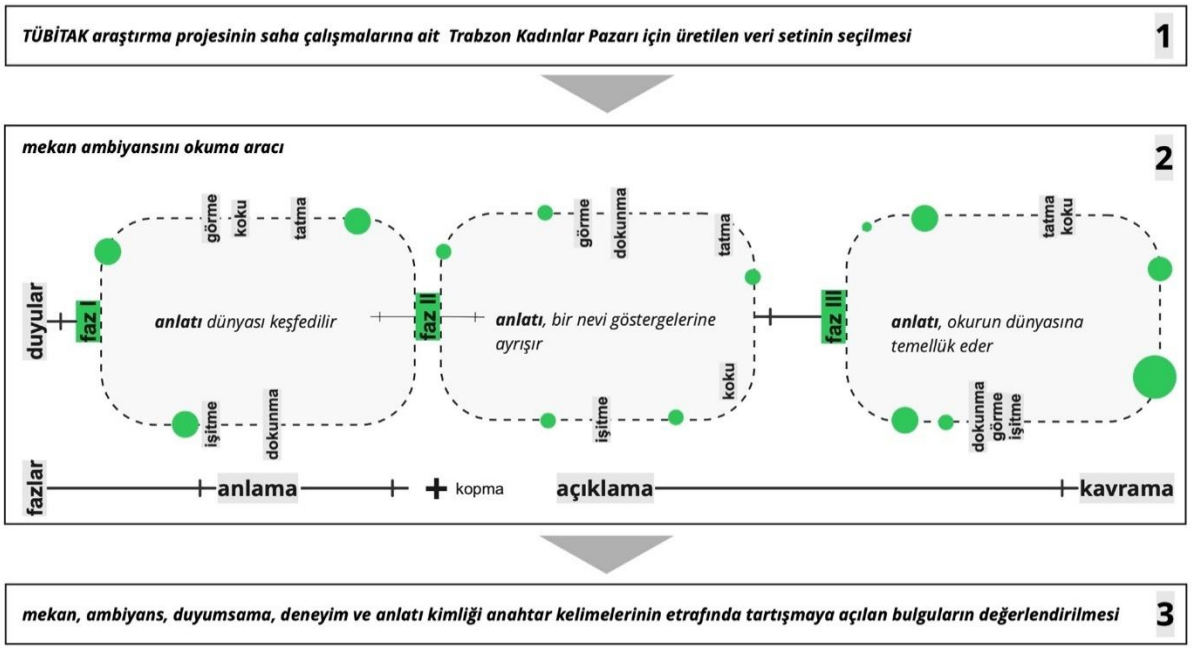
Bu bağlamda anlatı, kentsel mekânın deneyimle harmanlanmış anlam katmanlarını bir yorumlama aracı; ambiyans ise bu anlatıların duyumsal zeminini kuran etkin bir güç alanı olarak ele alınmaktadır. Mimarlıkta ambiyansı yalnızca tasarlanmış bir çıktı değil, beden, duyular ve anlatılar aracılığıyla sürekli yeniden üretilen bir olgu olarak okumak, mekânın anlatı kimliğini çok katmanlı biçimde kavramaya imkân tanır (Durmus Ozturk, 2025). Bu çalışma, kentsel bir pazar yeri olarak Trabzon'daki Kadınlar Pazarı'nı duyu odaklı anlatılar üzerinden inceleyerek, ambiyansın mimari ve kentsel anlam üretimindeki kurucu rolünü tartışmaya açmayı amaçlamaktadır.

2. YÖNTEMSEL ÇERÇEVE

Ricoeur'a (2007: 93) göre "bütünü yorumlamak ayrıntıları yorumlamaktır. Neyin önemli olduğu ve neyin önemsiz olduğuna dair hiçbir zorunluluk, hiçbir delil yoktur. Önem yargısının kendisi bir tahmindir". Bu yaklaşımdan hareketle, bireyin mimarlıkla kurduğu biricik ilişkide, öznel olarak ayrıcalık atfettiği deneyim anlatıları, o mekâna dair kapsayıcı bir ambiyans kavrayışı için belirleyici hâle gelmektedir. Bu çalışma, tam da bu öznel seçiciliği görünür kılmayı amaçlayarak, deneyim sonucu kaleme alınan duyusal verilerin yorumlanmasına ve bu verilerin mekânsal anlatı kimliğini nasıl kurduğuna odaklanmaktadır.

Bu çalışma kapsamında yapılan okuma, başka bir ifadeyle yorumlama modeli, anlama, açıklama ve kavrama olmak üzere Ricoeur'ün tanımladığı üç fazdan oluşmaktadır (Ricoeur, 2007). Anlama fazı, anlatı metnine bütüncül ve sezgisel bir düzeyde yaklaşmayı ifade

etmektedir. Bu fazın amacı, mekânı deneyimleyen öznenin duyu temelli ürettiği anlatıda neyi ortaya koyduğunu görünür kılmaktır. Bu noktada anlama, metnin sunduğu dünyaya müdahale etmeden yapılan bir gezintidir. Açıklama fazı ise, okurun metne bilinçli bir mesafe koyarak analitik bir tavır gösterdiği aşamayı tariflemektedir. Okuyucunun metinle teması kopma eylemi üzerinden kurgulanarak, anlatıdaki duyusal verilerin mekân deneyimini nasıl örgütlediğinin açıklığa kavuşturulması ön görülmektedir. Son faz olan kavrama, metinle düşünsel bağ kurma aşamasıdır; anlam okurun dünyasına taşınarak yeniden üretilmektedir. Böylece anlam, yaşanan kopmanın ardından okur tarafından temellük edilerek içselleştirilmektedir. Bu çerçevede anlama fazı, metnin dünyasına sezgisel bir yakınlık kurarak açıklamayı mümkün kılan önkoşulu üretmektedir; açıklama bu yakınlıktan beslenerek analizci bir mesafe kazandırmaktadır ve her iki fazın gerilimli birlikteliği kavrama fazında okurun dünyasında yeniden bütünleşir. Bu nedenle fazlar, doğrusal olarak birbirini izleyen aşamalar değil; birbirini besleyen, her birinin diğerine düşünsel bir zemin hazırladığı devingen bir yorumlama süreci olarak ele alınmaktadır (Şekil 1).



Görsel 1. Ricoeur'cü okuma modeli

Bu çalışma, her bir duyu için tekil bir anlatı üzerinden genelleme yapmak yerine, aynı duyunun farklı mekânsal anlatılar üretme kapasitesini görünür kılmak amacıyla ikili anlatı setleri üzerinden ilerlemektedir. Bu doğrultuda gerçekleştirilen yeniden okuma sürecinde ambiyans anlatıları, önce naif bir kavrayış düzeyinde sezgisel olarak ele alınmış, ardından kopma aracılığıyla yapısal bir çözümlemeye tabi tutulmuş ve son aşamada mimarlık disiplininin kavramsal çerçevesi içerisinde sofistike bir anlama seviyesine ulaştırılarak değerlendirilmiştir.

3.TRABZON KADINLAR PAZARI'NIN TARİHSEL SÜREKLİLİĞİ VE MEKÂNSAL AMBİYANSI

Karadeniz'in önemli liman kentlerinden biri olan Trabzon, coğrafi konumu sayesinde tarih boyunca çok yönlü ticaret ilişkilerinin ve farklı kültürlerin kesişim noktası olmuştur (Faroqhi, 2004; İnan, 2013). Antik dönemlerden günümüze Doğu ile Batı arasındaki ticaret güzergâhlarının Karadeniz'deki kesişim noktası olan şehir; Roma İmparatorluğu, Bizans ve Osmanlı egemenlik dönemlerinde sadece siyasi ve askeri öneme sahip olmamış, bunun yanı sıra ekonomik hareketliliğin, toplumsal etkileşimin ve kültürel alışverişin yoğun biçimde yaşandığı kentsel bir sahne işlevi görmüştür. Yüzyıllar boyunca devam eden bu süreç, Trabzon'un kentsel yapısına hanlar, bedestenler, çarşı alanları ve sokak düzeyinde yaşanan gündelik alışkanlıklar üzerinden izlenebilen zengin bir ticari ve toplumsal bellek kazandırmıştır. Şehrin günümüzdeki fiziksel ve sosyal düzeni de bu köklü geçmişin etkilerini barındırmakta; kamusal mekânlar, süregelen pratikler aracılığıyla belirli odak noktaları tarihi sürekliliği somut bir şekilde yansıtmaktadır.

Trabzon'un tarihsel kent dokusu içerisinde gündelik yaşam pratikleriyle şekillenen ve kolektif hafızasının sürekliliğini taşıyan odak noktalarından biri Trabzon Kadınlar Pazarı'dır. Osmanlı döneminden itibaren gelişen pazar kültürü, Trabzon gibi liman kenti kimliği güçlü yerleşimlerde sadece ticari merkezi olmaktan öte, kültürel iletişimin ve gündelik yaşamın mekânsal organizasyonu olarak işlev görmüştür. Kadınlar Pazarı, bu bağlamda kentin ticari hafızasında kadın emeğinin görünür olduğu kamusal mekânlardan biri olarak öne çıkmaktadır (Şekil 2).



Görsel 2. Trabzon Kadınlar Pazarı'na ait dış ve iç mekân görselleri (Bali, 2017)

Tarihsel açıdan değerlendirildiğinde, Osmanlı kentlerindeki pazar yerleri yalnızca alışveriş alanı değil; toplumsal hiyerarşilerin, cinsiyet rollerinin ve kültürel pratiklerin mekâna yansıdığı kentsel katmanlardır (Faroqhi, 2004). Trabzon Kadınlar Pazarı'nın özgünlüğü ise üretici ile tüketici arasında doğrudan ilişki kuran yapısında ve kadınların hem üretici hem de mekânın öznesi olarak kamusal alanda varlık gösterebilmesinde yatmaktadır.

Kadınlar Pazarı'nın konumlandığı alan, Trabzon'un tarihi ticaret aksları, hanlar ve çarşılarla kurduğu mekânsal bağlantı sayesinde kentsel dolaşımın organik bir unsuru hâline gelmiştir. Osmanlı kent planlamasında pazar yerlerinin han, mescit ve bedestenlerle yakın ilişki içinde kurgulanması, ticaretin sosyal yaşamla bütünleşmesini sağlamıştır (Tuluk & Düzenli, 2010).

Bu bağlamda Kadınlar Pazarı, Sakız Meydanı ve etrafındaki ticari binalarla birlikte değerlendirilmesi gereken şehir öğesi olarak ele alınabilir (Şekil 3).



Görsel 3. Günümüzde Kadınlar Pazarı ve çevresi (Unarcode Arşivi, 2025)

Zaman içerisinde değişen ekonomik koşullar, üretim şekilleri ve alışveriş alışkanlıklarına karşın Kadınlar Pazarı, yerel üretim temelli karakterinin büyük ölçüde korumuştur. Günümüzde pazarda satışa sunulan tarımsal ürünler, ev yapımı gıdalar ve el emeği ürünler, yalnızca ekonomik bir değer değil; kırsal-kentsel ilişkilerin, yerel bilginin ve gündelik rutinlerin sürekliliğini temsil eden kültürel işaretler olarak yorumlanabilir. Bu durum, pazarın fiziksel mekânının ötesinde, yaşayan bir kültürel doku olarak ele alınmasını gerekli kılmaktadır.

Bu çalışma kapsamında Trabzon Kadınlar Pazarı, yalnızca tarihi bir pazar mekânı olarak değil; kadın emeğinin mekânsal temsili, gündelik yaşamın duyusal katmanları ve kentsel hafızanın sürekliliği bağlamında ele alınmaktadır. Pazarda kurulan tezgâh düzenleri, sesler, kokular ve bedensel dolaşım pratikleri, mekânın deneyimlenme biçimini şekillendiren önemli unsurlar olarak öne çıkmaktadır. Bu çok-duyulu yapı, pazarın tanımlı mimari sınırlarına rağmen güçlü bir mekânsal kimlik/ambiyans üretmesine olanak sağlamaktadır. Böylece Kadınlar Pazarı, Trabzon kentinin tarihsel sürekliliğini gündelik pratikler aracılığıyla günümüze taşıyan canlı bir kamusal mekân olarak kentsel anlatının önemli bir bileşeni hâline gelmektedir.

4. BULGULAR VE TARTIŞMA

Duyusal deneyimi odağına alan ve kentin otantik dokusunu keşfe çıkan bu çalışmanın bulguları, "Yaşayan Kent İmgesinin Kentsel Anlatı Kodları İle Araştırılması (Unarcode©)" adlı TÜBİTAK araştırma projesinin saha çalışmalarına ait ve Trabzon Kadınlar Pazarı için üretilen

anlatılarına analizine odaklanmaktadır. Kadınlar Pazarı'na ilişkin, beş turdan oluşan ve her biri altı gün süreyle planlanmış saha çalışmalarından elde edilen anlatılar arasından, tur ayrımı gözetilmeksizin ve anonim biçimde, beş duyuyu temsilen seçilen ikişer örnekle toplamda on anlatıdan oluşan bir veri seti oluşturulmuştur. Bu seçimin amacı, Kadınlar Pazarı'nın anlatı kimliğini duyuların izinde tartışmaya açmaktır. Bu doğrultuda, Ricoeur'cü diyalektiğin önderliğinde belirlenen yöntemsel çerçeve, söz konusu veri setini yorumlama aracı olarak seçilmiştir. Nitekim görme, koklama, işitme, tatma ve dokunma duyuları odağında üretilen anlatıların; anlama, açıklama ve kavrama fazlarından geçirilmesiyle hermeneutik yorumlamaları yapılmıştır.

4.1. Görme Duyusu

John Berger 'Görme Biçimleri' adlı kitabında, her imgede bir görme biçimi olduğunu ifade etmektedir. Fotoğrafların sanıldığı gibi mekanik kayıtlar olmadığını; aksine fotoğraflarda, fotoğrafçının sınırsız görünüm olanakları arasından kendi seçkisini öne çıkardığını belirtmektedir (Berger, 2020). Bu noktadan hareketle mekânı görme, farklı bedenlerin aynı mekâna dair oluşturduğu muhtelif imgeler bütünü olarak tariflenebilir. Tam da bu nedenle, mekâna dair sunulan imge fragmanlarını görünür kılmak o mekânın bütüncül ambiyansını anlamak, nelerin tekrar edildiğini ve/veya ardıl bırakıldığını tartışabilmek adına oldukça elzemdir. Bu amaç doğrultusunda, görme duyusunu odağına alan ve iki farklı özne tarafından deneyimlenen Kadınlar Pazarı'na dair iki anlatı örneği aşağıdaki gibidir (Unarcode Arşivi, 2025);

> [GD-1] Kadınlar Pazarı, Trabzon'un kalabalık sokaklarında bir nefes gibi hayat buluyor. Burası, sadece ticaretin değil, aynı zamanda insanların buluşma noktası. Kalabalığın arasında dolaşırken, meyvelerin tatlı kokusu burnumu okşuyor ve yeşilliklerle süslenmiş tezgâhlar gözlerimi büyülüyor. Ticari alanlar ise yaşamın nabzını tutarken, insanlar arasında bir bağ kuruyor. Bu mekân, sadece meyve ve sebzelerin satıldığı bir yer değil, aynı zamanda, toplumun bir araya gelerek birlikte yaşama arzusunu gösterdiği şehrin kalbi, ruhu ve tarihini yansıtan bir simgedir.

> [GD-2] Kentin içinde fakat kente ait ol(a)mayan, insanları duraksatarak bir şeyler aldırtmaya yönelik eylemleri teşvik eden, sonu gelmeyecekmiş gibi hissettiren, kahverengi tonlarında koca bir boşluk gibi duran, camlarıyla devasa uzun bu yapı, kentte kendine bir yer edinme çabası içinde öylece duruyor; insanların ona uğrayıp etkileşim içinde olmasını bekler gibi…

Görme duyusu odağında kurulan bu iki anlatı, birbirlerinden farklı iki imge üretmektedir. GD-1 anlatısında Kadınlar Pazarı, hareketin yoğun olduğu bir bölgede önemli bir buluşma, nefes alma noktası olarak görülmektedir. Koku duyusundan da beslenerek ifade edilen tezgâhların etkileyiciliği vurgulanmakta; ayrıca aidiyet, toplumsal bellek ve merkeziyetçilik temaları ön plana çıkartılmaktadır. Buna karşın GD-2 anlatısında, pazar mekânı büyük ölçekli bir boşluk tanımlayan, cam cepheli ve kahverengi bir yapı olarak betimlenir. Yapının çevresiyle kurduğu ilişki uyumsuz bulunmakla birlikte, insan ile etkileşim kurmakta zorlanan, bedenin eylemlerini

kısıtlayan ve yönlendiren bir yapı olarak ifade edilmektedir. Pazar, kent içinde edilgen bir nesne olarak konumlandırılmıştır.

Anlatılar arasındaki fark, görme duyusunun mekânla kurduğu etkileşimin farklı biçimlerde örgütlenmesinden kaynaklanmaktadır. GD-1 anlatısında mekân, ortam üzerinden başka bir ifadeyle yaşama dair eylemler ve toplumsal etkileşimler vasıtasıyla imgeleştirilmiştir; ancak GD-2 anlatısında boyut, renk, malzeme gibi mekânın fiziksel özellikleri ön plana çıkartılmıştır. GD-1'de Kadınlar Pazarı için kullanılan 'nefes', 'şehrin kalbi', 'şehrin ruhu', 'tarihsel simge' gibi metaforlar mekâna ayrıcalıklı bir önem atfederek canlılık, yaşanmışlık ve tarihsellik nitelikleri kazandırmaktadır.

Pazar yeri için üretilen bu iki anlatı birlikte değerlendirildiğinde, görme duyusunun mekânı tekil ve sabit bir gerçeklik olarak değil, öznenin konumlanışıyla sürekli yeniden kurulan bir deneyim alanı olarak biçimlendirdiği görülmektedir. GD-1'de görme, toplumsal aidiyet ve gündelik yaşam pratikleriyle birleşerek mekânı canlı, davetkâr ve kapsayıcı bir yer hâline getirirken; GD-2'de aynı mekân, fiziksel özellikleri üzerinden okunarak yabancılaşma, mesafe ve kopukluk duygularına sebebiyet vermektedir. Dolayısıyla Kadınlar Pazarı, görme duyusu üzerinden hem toplumsal bağların taşıyıcısı hem de kent içinde fiziksel olarak dışlanan bir yapı olarak eşzamanlı kavranır. Bu dışlanma, yakın geçmişte yeniden inşa edilen ve yerel mimariye atıfta bulunan özgün ahşap karkaslı eski pazar mekânın mimari izlerinin silinmesi ile açıklanabilir. Dolayısıyla günümüzde pazarın ambiyansı, bu karşıt görsel imgelerin bir aradalığıyla okunmaktadır.

4.2. Koku Duyusu

Mekâna dair en güçlü hafızanın koku deneyimi olduğunu ifade eden Pallasmaa, özgün bir kokunun görsel hafızadan tamamen silinmiş bir mekâna dahi tekrar gitmeye yardımcı olabileceğini vurgulamaktadır (Pallasmaa, 2006). O halde koku duyusu, mekânın yalnızca fiziksel varlığına değil, zamansal sürekliliğine ve deneyimlenmiş geçmişine de nüfuz eden bir algı biçimi olarak değerlendirilebilir. Kadınlar Pazarı'nı koku duyusuyla deneyimleme yoluyla üretilen anlatılar, mekânın gündelik yaşam içindeki deneyimlenme biçimini ve bellekte nasıl yer ettiğini görünür kılmaktadır. Bu doğrultuda, koku duyusu için türetilen deneyim anlatıları aşağıda sunulmaktadır (Unarcode Arşivi, 2025);

> [KD-1] Araçlardan salgılanan kötü kokulardan kaçmak için bir sığınak olan kadınlar pazarı içine girildiği anda birçok kokunun karışımıyla beni karşıladı. Manav tezgâhlarından gelen taze çilek kokuları, keskin limon kokuları, sanki dalından yeni koparılmış gibi kokan domates kokuları bir bahçede gibi hissettirirken; yoğun mısır unu kokusu beni bir değirmene götürdü. Çiğ tavuk ve et kokuları bir kasaptaymış hissi verirken; acı zeytin ve küflenmiş peynir kokuları diğer kokularla birleşti. Yeşilliklerin birbirine baskınlık kurmaya çalışan kokuları ortama ferah bir koku yayarken baharatların ağır kokularıyla karıştı. Her koku farklı bir tanım oluştururken bu kokuların birleşimi ile Kadınlar Pazarı adeta bir köye dönüşmüş ve bütünleşmişti.

> [KD-2] Kadınlar Pazarı renkli meyve ve sebzeleriyle göze hitap ettiği gibi buruna da hitap etmektedir. Önünden geçerken parfümünü sürmüş çilekler, cazibeleriyle yanından geçen herkesi hipnotize ediyor. Karşı reyonda ekşi, tuzlu ama lezzetli kokusuyla bulunan peynirler meyvelerle rekabeti bırakmamakta ısrarcılar. Emekçisinin toprak kokusunun hissedildiği bu pazarda taze ürünler kişiyi kapısından içeri girmeye zorluyor.

Koku duyusu yoluyla üretilen yukarıdaki iki anlatı, Kadınlar Pazarı'nı koku duyusu anlamında çeşitliliği bol bir yer olarak betimlemektedir. KD-1'de pazar, dış çevredeki olumsuz kokulardan kaçılan bir sığınak olarak tanımlanırken; meyve, sebze, et, peynir ve baharat kokularının bir arada var oluşu ön plana çıkarılmaktadır. Anlatı, farklı kokuların çağrıştırdığı imgeler aracılığıyla pazarı bahçe, değirmen ve kasap gibi başka mekân türlerinin bir bileşkesi olarak nitelendirmektedir. KD-2'de ise türlü kokular ve emekçilerin taze ürünleri pazar yerine davet edici nitelik üstlenmektedir. İlaveten meyve, peynir ve toprak kokuları pazarın canlı ve çekici ambiyansını tanımlayan unsurlar olarak vurgulanmıştır.

Her iki anlatıda kokular, mekânsal deneyime yön veren başat öğeler olarak işlev görmektedir. KD-1'de anlatı göstergelerine bakıldığında, taze, keskin, yoğun, ferah, ağır gibi temel koku çeşitliliği üzerinden örgütlenmektedir ve anlatı, kokuların birbiriyle karışması veya baskınlık kurma hâli üzerinden mekânsal bütünlük üretmektedir. KD-2'de ise, anlatı içindeki renk vurgusu ve çoklu duygulanımlar koklama eylemini perçinlenmektedir. KD-1'deki 'sığınak', 'bahçe', 'köy', 'değirmen', 'kasap' metaforları ile KD-2'deki 'çileğin parfüm sürmesi', 'yapının kapıdan girilmesi için zorlaması' gibi kişileştirme örnekleriyle koku duyusunun anlatılarda soyutlanarak özneleştiğini; böylece kokunun mekânı pasif bir arka plan olmaktan çıkarıp anlatı içinde etkin, yönlendirici ve anlam kurucu bir unsur hâline getirdiğini göstermektedir.

Bu iki anlatı birlikte değerlendirildiğinde kokular, pazarı kentsel bağlamdan koparak kırsal, tanıdık ve aidiyet duygusu üreten bir ortam inşa etmektedir. Böylece koku, mekânın bellekte yer etmesini sağlayan, bedeni mekâna geri çağıran ve mekânsal bütünlüğü duyusal düzlemde kuran/devam ettiren bir eşik işlevi görmektedir. Bu bağlamda koku, mekânın pasif bir niteliği değil, aktörleri yönlendiren, pazar yeri ambiyansının önemli kurucu ortaklarından biri haline gelmiştir denebilir.

4.3. İşitme Duyusu

Ses, mekân içerisinde hareket edebilen ve farklı zamanlarda başka türlü vuku bulan biricik duyumsamalardır. Schafer (1994: 80), sesi oluşturan öğelerin yakalanması gerektiğini vurgulamaktadır; çünkü sesler, kentsel müdahalelerin ve sosyal değişimlerin sonucu ebediyen kaybolmaya mahkûmdur. Dolayısıyla, mekânda var olan sesleri işitmek dahası tüm bu sesleri kaydetmek ambiyansın devingenliğini gözlemleme ve sürdürülebilirliğini sağlama açısından oldukça kıymetlidir. Bu bağlamda, işitme duyusu odağında üretilen anlatı örnekleri aşağıdaki gibidir:

> [İD-1] Sokağın başından aşağıya doğru inmeye başlarken pazarcıların sesleri nerede olduğumu açık ediyordu. Davetkâr ve yönlendirici olan bu sesler pazar yerleri için vazgeçilmezdi. Başka yerde olsa, kulak tırmalayacak olan bu seslerin burada olması olağan düzendi. Yerler yöreler değişse de bu sesler her yerde aynıydı. Öte yandan zamansızlığın da sembolü gibiydi. Çocukluğum da nasılsa bugün de aynıydı ve muhtemelen yıllar sonra da aynı kalacak. Ancak bu sesler bir aradayken zamansızdı, odaklı dinleyip sesleri seçmeye başladığımda farklı yörelere ait sesler ortaya çıkıyordu. Pazardaki farklı gurupların bir arada olma hali gibi seslerde bir arada iken ahenkli ve zamansızdı. Cami kubbesinden balıkçıların üzerine doğru yükselen martı sesleri ise pazarcılara eşlik ederek bu ahenge dâhil oluyordu.
>
> [İD-2] İçeriye girerken giriş katında çoğu dükkân açılmadığı için sessizlik hâkimdi. Üst kata ulaştığımda ise pazarcılar ve müşteriler etraftaydı. Satıcıların ‘Buyurun! Buyurun!’ sesleri arasında, müşterilerin ürünler hakkındaki soruları kulağıma çalınıyordu. Ortam pek kalabalık değildi fakat bulunan insan sayısına göre ses yoğunluğunun azlığı başka pazar yerlerinde olan deneyimlerime göre beni şaşırtmıştı. Yaşlı teyzelerin tezgâhlarının olduğu tarafa geçtiğimde ise ses neredeyse iki kat artmıştı. Bu ses yoğunluğu alışverişten değildi. Teyzelerin aralarında samimi bir ortam oluşturup gelen müşteriler ile birlikte kurdukları sohbet sesleriydi.

İşitme duyusu ile deneyimlenen pazar mekânın aktarıldığı İD-1 anlatısında, kısmen rahatsız edici olarak algılanabilecek olan esnaf sesleri, pazar bağlamında bilakis olağan bir niteliğe bürünmektedir. Anlatıda bu seslerin yönlendirici ve tanıtıcı potansiyeline işaret edilmektedir. İD-2 anlatısında ise, sessizlikten sesliye ve sonrasında çok sesli bir ortama doğru yaşanan işitsel geçiş, farklı kotlarda yer alan mekân iç organizasyonunu duyulur kılmaktadır. Her iki anlatıda da var olan esnaf sesi, müşteri sesi, arka plandan gelen sohbet sesleri vs. pazar yeri olmanın özünde var olan işitsel duyumlar olarak betimlenmektedir.

İşitme duyusu üzerinden kurulan bu iki anlatı, Kadınlar Pazarı’nda sesin yalnızca arka plan uğultusu olmadığını, mekânsal örgütlenmeyi ve toplumsal ilişkileri görünür kılan bir düzenleyici olduğunu ortaya koymaktadır. İD-1’de esnaf sesleri, bedeni mekâna yönlendiren ve pazar yerine yaklaşmayı işitsel olarak haber veren bir eşik işlevi görmektedir. Bu seslerin tekrar eden ve tanıdık yapısı, anlatıda zamansızlık vurgusuyla ilişkilendirilerek pazar yerini farklı bağlamlarda dahi süreklilik arz eden bir deneyim alanı hâline getirmektedir. İD-2’de ise işitsel deneyim, sessizlikten çok sesliliğe doğru kademeli bir geçiş üzerinden örgütlenmekte; farklı katlarda ve tezgâh yoğunluklarında değişen ses düzeyleri, mekânın içsel hiyerarşisini ve kullanım biçimleri hakkında ipuçları vermektedir. Anlatıda sesler, zamansızlık, toplumsal birlik ve mekânsal aidiyet gibi soyut kavramları taşıyan örtük metaforlar ve kişileştirmeler aracılığıyla pazar deneyimini derinleştirmektedir.

Bu anlatılar birlikte değerlendirildiğinde, anlatılarda işitildiği öne sunulan sesler şunu göstermektedir: Emekçilerin kendi içlerinde samimiyet duygusunun hâkim olduğu kolektif gruplar oluşturması ve ticaret eylemini müşteri ile kurduğu kuvvetli ilişkiler üzerinden

sürdürmesi, pazar yerinin yalnızca ekonomik bir değişim alanı değil, işitsel ve toplumsal ambiyans aracılığıyla süreklilik kazanan bir aidiyet mekânı olarak kavranmasına olanak tanımaktadır. Bu ambiyans, bedeni yönlendiren, mekânda kalma süresini ve hareket biçimini etkileyen bir düzen kurmaktadır. Dolayısıyla işitme, mekânın pasif bir niteliği değil; pazar yerinin sosyal dokusunu, zamansal sürekliliğini ve kolektif deneyimini kuran temel duyumsama biçimlerinden biri olarak kavranmaktadır.

4.4. Tatma Duyusu

Tatma duyusu mekânı bellek, aidiyet, kültür ve haz üzerinden okumaya imkân veren güçlü bir duyumsama aracıdır. Tatmanın toplumsal ve kültürel boyutlarına odaklanan Sutton (2010), bu duyuyu öznel bir duyumsama biçimi olarak görmenin ötesinde, geçmiş deneyimleri yansıtan ve yer duygusunu harekete geçiren kültürel bir pratik olarak ele almaktır ve tatma eyleminin mekân kurucu potansiyeline değinmektedir. Bu bakış açısı ile tatma, mekâna ait bir takım kültürel kodların sürdürülebilirliğini sağlayan etkin bir algı biçimidir. Tatma duyusu üzerinden üretilen aşağıdaki iki anlatı örneği, Kadınlar Pazarı'nın anlatı kimliğini, mekânsal aidiyetin birlikte üretildiği bir deneyim alanı olarak tartışmaya açmaktadır.

> [TD-1] Bütün renkleri ve gürültüsüyle davetkâr bir yer olan bu pazar, kentin içinde herkesin köyünde gibi hissettiği büyülü bir yer. Girişinden başlayan peynir kokusu, bize kent kargaşası içinde kaybettiğimiz özümüzü hatırlatıyor. İlerledikçe artan, canlanan renkler, sesler ve tatlarla beraber, bize yeni bir dünyanın kapılarını aralıyor. Tezgâhlarda sunulan neredeyse her şeyi tadıyoruz. Bazen ekşi, mayhoş bir tat bazen tatlı bazen de karışık, adını koymakta zorlandığımız bir tat hissediyoruz. Özümüzü en iyi şekilde yansıtan durakla etkileşimimizi arttırıyoruz. Buradan ayrılırken haftaya yine geleceğim diye sözler veriyoruz. Anılar ve ürünlerle dolu heybemizi alıp asıl dünya yani kentteki kargaşamıza geri dönüp yolculuğumuza devam ediyoruz.

> [TD-2] Trabzon'un Kadınlar Pazarı'nda gezinirken, tatma duyunuzun her köşede yoğunlaştığını hissedersiniz. El emeğiyle üretilmiş ürünlerin sergilendiği tezgâhlar arasında dolaşırken, baharatların keskin ve davetkâr kokusu burnunuza gelir. Renk renk, çeşit çeşit baharatlar, sadece gözünüzü değil damağınızı da cezbetmek için oradadır. Bir tutam karabiber, bir parça zerdeçal, bir çimdik kimyon... Her biri, farklı bir lezzet dünyasının kapılarını aralar. Peynir tezgâhlarının önünde durup, tulum peynirinin yoğun ve tuzlu tadını hayal edersiniz. Kaşar peynirinin yumuşak ve sütlü aroması, sizi çocukluğunuzun mutlu sabah kahvaltılarına geri götürür. Her peynir tezgâhında, yöresel tatların en güzel örnekleri sunulur, her biri, ustalık ve sabırla yıllandırılmıştır.

Tatma duyusu üzerinden kurulan iki örnek anlatı, Kadınlar Pazarı'nın farklı duyulara hitap eden davetkâr tavrına vurgu yapmaktadır. Öte yandan, renklerin canlılığına, çeşitliliğine ve ürün yelpazesinin bolluğuna dair ifadelere yer verimiştir. TD-1 anlatısında deneyimlenen tatlar, mekânda bir köy ambiyansı oluştururken, kimi zaman kentin yoğun kargaşasında unutulmaya yüz tutan özün hatırlatıcısıdır. TD-2'de ise pazar tezgâhlarında yer alan yöresel tatların, özenli ve kaliteli bir seçki oluşturmasının altı çizilmektedir. Dahası deneyimlenen çeşitli tatların, hayal

gücünü harekete geçirerek nostaljik bir etki yarattığı ifade edilmektedir. Anlatılarda tat, pazar yerinde kalma ve tekrar gelme arzusunu tetikleyen bir unsur olarak öne çıkartılmıştır.

Tatma duyusu anlatılarının duyumsama göstergeleri, renkli görme, gürültü işitme, çeşitli kokular alma, konum/düzen görme ve farklı tatları deneyimleme şeklinde sıralanmaktadır. Bu doğrultuda, tatma duyusunu tetikleyen başlıca etmenler görme, koklama, işitme gibi diğer duyumsama biçimleridir. Tat, Kadınlar Pazarı'nda çok duyulu bir mekânsal deneyimi derinleştiren ve anlamlandıran tamamlayıcı bir algı katmanı olarak konumlanmaktadır. TD-1'de pazar 'büyülü yer', 'yeni dünya' metaforlarıyla var olan gerçeklikten kopartılırken; TD-2'de 'lezzet dünyası', 'zaman yolculuğu' gibi metaforların varlığı tat çeşitliliğinin bolluğuna ve zamansızlığına atıfta bulunmaktadır.

Anlatılar birlikte değerlendirildiğinde, Kadınlar Pazarı salt bir tatma deneyimi mekânı değil; belleğin bilhassa aidiyetin duyusal olarak yeniden inşa edildiği bir yer olarak tasvir edilmektedir. Nitekim tat, anlatılarda anlık bir haz unsurundan ziyade, geçmiş deneyimleri bugüne taşıyan ve mekânla kurulan bağın güçlenmesine sebebiyet veren bir rol üstlenmektedir. Kimi tatların tanımsızlığı veya nostaljik çağrışımlar üretebilme potansiyeli, pazarın fiziksel olarak rijit yapısının karşısında durarak, pazarı duyumsal açıdan sabitlenemeyen, zamansız ve yeniden deneyimlenmeye müsait bir bağlama yerleştirmektedir. Bu doğrultuda tatma duyusu, pazar yerinin anlatı kimliğini güçlendiren; mekânı gündelik tüketim odaklı pratiklerin ötesine taşıyarak ambiyansı kuran temel duyumsama biçimlerinden biri olarak kavranmaktadır.

4.5. Dokunma Duyusu

Dokunma duyusu, beden ile mekân arasında doğrudan teması mümkün kılan yegâne duyu olarak ön plana çıkmaktadır. Montagu (1986), dokunma duyusunu "duyuların atası" olarak tanımlamaktadır ve bedensel deneyimin temelini oluşturduğunu öne sürmektedir. Pallasmaa (2006) ise dokunma duyusunun bedeni zaman ve gelenekle bağlantıya geçirdiğini; dokunma izlenimleri aracılığında bedenin sayısız kuşakla etkileşime geçtiğini ifade etmektedir. Bu bağlamda, dokunma; mekânın muhtelif yüzeyleri ile kurulan tensel etkileşimler aracılığıyla bedende iz bırakan temel bir algı biçimi olarak görülmektedir. Dolayısıyla dokunsal deneyim, ten-malzeme, ten-ısı, ten-doku gibi ikiliklerin kavuşumuna imkân veren bütüncül bir mekân kavrayışı olarak vuku bulmaktadır.

> [DD-1]: Trabzon Kadınlar Pazarı dokusu, bana doğallığı ve sıcaklığı hatırlattı. Ahşap bankın yüzeyinin pürüzsüzlüğü ve sıcaklığı, kent yaşamının huzurlu ve samimi yanını düşündürürken Ahşabın doğal dokusu, bana doğayla iç içe olmanın sadeliğini hissettirdi. Bu his, kentteki sosyal alanların ne kadar önemli ve değerli olduğunu bana bir kez daha gösterdi. Kadınlar Pazarı'ndan içeri girildiği anda, meyve ve sebzelerin akmış sularının her yeri kirlettiği bir ortamla karşılaşılıyor; dışarıda yaratılan atmosferden neredeyse iz bile kalmıyor. Bu kirli yüzeylerin yanı sıra, ahşap dokusuyla sıcak bir atmosfer sunması beklenen merdiven korkulukları ve zemindeki taşlarda biriken toz ve kir, ortamdaki pislikle birleşerek insanı giderek daha fazla irrite eden bir hâle dönüştürüyor.

> [DD-2]: Dükkânların, süslü vitrinlerinin gölgesinde kalmış giriş kapısından girdikten sonra belirsizlik içinde yolumuzu bulmaya çalıştık. Pazarda gezinirken, ne kadar bakımsız ve kötü kullanıldığına şahit olduk. Oysa içerisindeki ürünler, parlak meyveler, hepsi birbirinden sağlıklı sebzeler, sütler, peynirler… adeta köyümüzü ayağımıza getiren sihirli bir durak noktası. Fakat tozlar, etrafta biriken çöpler, çürük meyve ve sebzelerin dokusunun etrafta bıraktığı izler… Hepsi hevesimizi kaçırıyor. Dokunmak istemiyoruz hiçbirine. Kötü hissediyoruz, soğuyoruz. Mekânın büyüsünün önüne acı gerçekler geçiyor. Keşke düzelse deyip oradan ayrılıyoruz.

DD-1 ve DD-2'de dokunma duyusu anlatıları, Kadınlar Pazarı deneyiminde tensel etkileşim potansiyellerini kısmen ortaya çıkarmaktadır. DD-1 anlatısında, ahşap yüzeylerin fiziksel olarak nasıl hissettirdiğinin yanı sıra temasın duygulanımsal olarak nasıl karşılık bulduğuna da yanıt verilmektedir. Ayrıca bu anlatıda, materyal kullanımının toplumsal etkilerinin de altı çizilir. DD-2'de ise pazar yerinin hak ettiği bakımı ve değeri görememesi, yüzeylerde biriken toz, kir ve çürüme izlerinin bedeni irrite etmesi, bu nedenle temasın engellemesi durumları açıkça ifade edilmektedir. Her iki anlatıda da dokunma eylemi, yalnızca olası temas alanları üzerinden değil, temasın olamayışı başka bir ifadeyle temasın reddi üzerinden de deneyimlenmektedir.

DD-1 ve DD-2 anlatıları, dokunma duyusunun pazar mekânında rastlantısal değil, maddesel koşullar tarafından belirlenen bir deneyim alanı olarak örgütlendiğini göstermektedir. Ahşap yüzeylerin sıcaklığı ve pürüzsüzlüğü ya da kirli yüzeylerin itici etkisi, bedensel tepkilerin kişisel tercihlerden ziyade mekânın bakım, kullanım ve materyal bütünlüğüyle doğrudan ilişkili olduğunu ortaya koymaktadır. Bu bağlamda dokunsal deneyim, yalnızca yüzeyle temas anına indirgenmeyen; mekânın düzenlenişi, sürekliliği ve ihmaliyle şekillenen bir algı düzeni olarak okunabilir. Temasın mümkün olduğu durumlar kadar, temasın engellendiği ya da bilinçli olarak reddedildiği anlar da mekânın dokunsal karakterini belirleyen başat unsurlar hâline gelmektedir. DD-1 ve DD-2'de anlatı göstergeleri üzerinden izlenen sıcak dokunma, pürüzlü yüzey ve maddesel temas örüntüleri, materyal ve duyumun zihinsel çağrışımlar üreten kurucu aktörler olarak işlediğini göstermektedir. Bu çerçevede DD-2 anlatısında kullanılan 'sihirli durak' metaforu, pazar mekânının maddesel gerçekliği aşarak kullanıcıda aidiyet duygusu üretme potansiyeline işaret etmektedir.

Bu iki anlatı birlikte değerlendirildiğinde dokunsal karşılaşmalar, mekânı beden aracılığında içine alan, yakınlık ve aidiyet üreten bir ortama dönüştürmekte veya bedeni iten ona karşı koyan bir tavır üzerinden yeniden tanımlamaktadır. Bu doğrultuda, Kadınlar Pazarı örneğinde dokunsal deneyim, mekânın potansiyel sıcaklığını ve doğallığını görünür kılarken, bakım ve hijyen eksikliği gibi maddi koşullar bu potansiyelin gerçekleşmesini engelleyen başlıca unsurlar olarak öne çıkmaktadır. Böylece dokunma duyusu, pazar yerinin anlatı kimliğini belirleyen, mekânın kabul ya da reddedilmesini doğrudan etkileyen kurucu bir ambiyans bileşeni olarak kavranmaktadır.

5. SONUÇ

Trabzon Kadınlar Pazarı, beş duyunun etkileşimiyle yalnızca bir alışveriş mekânı değil, toplumsal aidiyetin, belleğin ve gündelik yaşamın yeniden kurulduğu bir ambiyans olarak kavranmaktadır. Görme, koku, işitme, tat ve dokunma duyuları, mekânın farklı anlatılarda kimi zaman kapsayıcı, kimi zaman dışlayıcı biçimlerde yeniden üretilmesini sağlamaktadır. Bu duyusal karşılaşmalar, pazarın fiziksel yapısının ötesinde, toplumsal bağların sürekliliğini ve mekânsal gerilimlerin eşzamanlı varlığını görünür kılmaktadır. Dolayısıyla Kadınlar Pazarı, duyuların kesişiminde kurulan ve sürekli yeniden deneyimlenen bir ambiyans mekânı olarak, kent belleğinde hem aidiyet hem de çatışma üreten bir eşik işlevi üstlenmektedir.

Bu bağlamda, bulguların Ricoeur'cü hermeneutik diyalektiğin anlama, açıklama ve kavrama fazları üzerinden okunması, duyusal anlatıların yalnızca betimleyici deneyim aktarımları olmadığını; mekânın anlatı kimliğini kuran çok katmanlı anlam örüntülerini açığa çıkardığını göstermektedir. Anlama fazında, öznel duyusal karşılaşmalar aracılığıyla Kadınlar Pazarı, kimi anlatılarda canlılık, sıcaklık ve aidiyet; kimi anlatılarda ise yabancılaşma, rahatsızlık ve mesafe duyguları üzerinden deneyimlenmiştir. Açıklama fazında bu öznel deneyimler, duyusal indikatörler ve metaforik ifadeler aracılığıyla çözümlenmiş; görsel imgeler, kokusal çağrışımlar, işitsel düzenler, tat deneyimleri ve dokunsal temas/temassızlık hâlleri mekânın maddesel, toplumsal ve zamansal örgütlenmesiyle ilişkilendirilmiştir. Kavrama fazında ise bu çoklu duyusal veriler, Kadınlar Pazarı'nı sabit ve tekil bir fiziksel yapı olmaktan çıkararak; toplumsal belleğin, gündelik pratiklerin ve mekânsal gerilimlerin eşzamanlı olarak üretildiği dinamik bir ambiyans alanı olarak konumlandırmaktadır. Böylece pazar mekânı, duyular aracılığıyla sürekli yeniden kurulan, kabul ve reddin, yakınlık ve mesafenin, süreklilik ve kopuşun birlikte var olduğu bir anlatı mekânı olarak kavranmaktadır.

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CALIBRATION OF UNDRAINED PARAMETERS WITH PLAXIS SOILTEST MODULE BASED ON LABORATORY TRIAXIAL TESTING OF A FINE-GRAINED SOIL

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ABSTRACT

Numerical modeling using finite element method is essential in modern geotechnical engineering, but its accuracy depends on the proper calibration of the parameters that represent soil behavior in order to ensure the reliability of the results. The inherent complexity of geotechnical materials and their nature create uncertainty in selecting the appropriate model to represent soil behavior. In many contexts, especially academic or preliminary projects, it is not always possible to perform advanced laboratory tests. Consequently, various studies focus on the use of existing data or empirical correlations to obtain reliable parameters without a systematic process of adjustment to field observations.

This study presents a systematic procedure for calibrating the undrained parameter with Plaxis SoilTest module based on the results of an undrained-unconsolidated (UU) triaxial test performed on a fine-grained soil. The material was fully characterized using the classification test and UU triaxial test. Initial parameters obtained from index properties and undrained strength determined experimentally in the laboratory were used for the simulation. The Mohr-Coulomb model was selected due to its versatility and application in fine-grained soils under undrained conditions. Calibration was performed iteratively using the SoilTest module to reproduce the stress-strain curves and evaluate the quality of the fit by comparing it with the deformations at failure, stiffness, and maximum initial stress. The results demonstrate that the proposed procedure allows consistent and physically representative parameters to be obtained. This work provides a reproducible methodology that can be applied to other types of soils in numerical modeling processes for geotechnical analysis and design.

Keywords: Plaxis 2D, numerical modeling, triaxial testing. undrained shear strength, parameter calibration.

1. INTRODUCTION

Modern geotechnical engineering has progressively incorporated Finite Element Analysis (FEA) as a fundamental tool in estimating soil behavior. However, the reliability of geotechnical analyses performed using modeling is closely linked to the appropriate selection and adjustment of the parameters that describe soil behavior (Brinkgreve, 2005). In practice, it is common to use values obtained from empirical correlations or manual estimates, which generates considerable uncertainty in the results (Alnmr, 2021). Therefore, the modeling process begins with the selection of the most appropriate constitutive model, which depends largely on the proportion of fines and the specific characteristics of the soil (Schanz et al., 2019).

Among the most commonly used alternatives, the Hardening Soil (HS) model is more representative for soils with a lower amount of fines, while the Soft Soil (SS) model performs better in materials with a higher content of fine particles (Alnmr, 2021). For its part, the Mohr-Coulomb model is a reasonable approximation for simulating shear strength and deformations under certain conditions, assuming linear elastic behavior before failure, followed by a plastic response. This model is based on conventional parameters such as cohesion, internal friction angle, modulus of elasticity, and dilatancy angle, which can be obtained in laboratory tests, facilitating its application in practical projects (Bhutto et al., 2019).

Fine soils, such as clays and silts, exhibit complex mechanical responses due to their high plasticity and sensitivity to the presence of water, making it difficult to model their properties numerically (Bouri et al., 2023) and requiring careful interpretation of undrained tests. A critical aspect of fine soil modeling is the distinction between total and effective stress analysis (Terzaghi et al., 1996). While conventional design is usually based on the undrained strength parameter ($\emptyset = 0$), numerical simulation allows the problem to be addressed using effective parameters if the pore pressure is adequately characterized (Lambe & Whitman, 1969). However, in many academic or preliminary contexts, where advanced testing is not possible, the Mohr-Coulomb model is chosen under undrained conditions due to its practicality. In the specific field of Plaxis, a practical methodology has been demonstrated for identifying the parameters of the Hardening Soil model from triaxial and oedometer tests on clays, using the SoilTest virtual test module to simulate the triaxial test and adjust the parameters until the laboratory stress-strain curve is reproduced (Nosenko et al., 2023). In this way, it is possible to analyze the sensitivity of the stiffness modules and the failure coefficient R_f, showing that even slight variations in their values can generate relevant differences in the simulated response of the model.

The Plaxis SoilTest module provides a solution for representing well-defined laboratory test conditions in terms of stress-strain, allowing the model response to be compared with actual laboratory data to obtain a realistic approximation of soil behavior. This tool facilitates direct comparison between experimental and numerical stress-strain curves, allowing critical variables such as the undrained Young's modulus (E_u) and shear strength to be adjusted. Calibration requires experimental data obtained from tests such as undrained unconsolidated

triaxial (UU), consolidation, and classification tests. These tests provide key parameters such as undrained shear strength, compression index, and pre-consolidation pressure, which are essential for numerical models (Agraine et al., 2020; Tsige et al., 2022; Bouri et al., 2023). However, calibration uncertainty can be significant, especially when a limited number of tests are available, which has led to the development of probabilistic approaches and optimization techniques to improve the robustness and reliability of the parameters obtained (Janda, 2020).

Various studies have used Plaxis 2D to simulate drained triaxial test on treated soils, comparing the experimental results with the responses obtained using Mohr-Coulomb and Soft/Hardening Soil constitutive models, with the aim of evaluating the ability of each formulation to reproduce both the peak strength and the observed stiffness (Alnmr, 2021; Lankaran et al., 2022), In sandy soils with different fine content, the Hardening Soil model has been shown to adequately describe behavior when the fine fraction is low, while more compressible models, such as Soft soil, are more appropriate for mixtures with higher fine content, likewise, recent studies on the automatic calibration of critical and hypoplastic models, based on limited combinations of test (an oedometer and an undrained triaxial), indicate that it is possible to obtain reliable parameter sets, with coefficients of variation generally below 10% which supports the applicability of reduced test protocols in engineering practice (Janda, 2020).

This study presents a systematic procedure for calibrating fine soil, evaluating the ability of the Mohr-Coulomb model to replicate the experimental response under different confining pressures (100 and 200 kPa), and providing a methodological framework for improving the reliability of geotechnical designs.

Despite the existence of advanced tools, a significant gap remains in professional practice regarding how to approach parameter calibration when only UU triaxial tests are available, which are the most common in conventional soil mechanics studies but often underestimated in advanced modeling. The lack of clear guidance linking UU-type laboratory results to the Plaxis SoilTest module limits engineers' ability to validate their models quickly and accurately.

Therefore, the main objective of this study is to propose and validate a logical sequence of parameter adjustments for the Mohr-Coulomb model. Through this analysis, we seek to demonstrate that even with basic laboratory information, it is possible to reduce numerical prediction error through conscious iterative calibration. The study is not limited to obtaining numerical values, but also analyzes their physical representativeness in comparison to the responses observed in fine-grained soil under different confinement conditions, serving as a practical reference for future civil engineering and geotechnical projects.

2. MATERIALS AND METHODS

2.1. Characterization of the Study Material

The soil used in this research comes from the city of Adapazarı, collected at a depth of between 2.5 and 3.00 m. Visually, the material has a brown color and a firm consistency in its natural state. To define its index properties, granulometry and Atterberg limit tests were performed in accordance with TS 1900-1 standards, the Turkish equivalent of international standards ASTM D422 and ASTM D4318. The granulometric analysis revealed that 89.34% of the material passes through a No.200 sieve (0.075 mm). The gravel fraction was zero (0%), while the sand content reached 10.66% of the total. This granulometry classifies the material predominantly as a fine-grained soil. The consistency results are summarized in Table 1.

Table 1. Physical Properties of Fine-Grained Soil

Property	Value
Liquid Limit (LL)	40
Plastic Limit (PL)	24
Plasticity Index (PI)	16
Specific Gravity (Gs)	2.69
USCS Classification	CL

Based on these values, the soil was classified according to the Unified Soil Classification System (USCS) as CL, corresponding to low plasticity clay. The plasticity index of 16% and liquid limit of 40% place the material clearly above Line A on the Casagrande plasticity chart, confirming its clayey nature.

2.2 Unconsolidated-Undrained Triaxial Test (UU)

Two UU triaxial tests were conducted with confining pressures of 100 kPa and 200 kPa, respectively, as shown in Table 2. This type of test is regulated by ASTM D2850 standards and is suitable for determining the undrained strength of saturated cohesive soils under rapid loading conditions, where consolidation and grain rearrangement are not allowed.

Figure 7 shows the variation in deviator stress as a function of axial strain for an unconsolidated undrained (UU) triaxial test performed under confining pressures of 100kPa and 200kPa. In both cases, the stress-strain curves show a progressive increase in stress with strain, without evidence of a clearly defined linear elastic section or an abrupt strength peak. This behavior suggests a response dominated by a strain hardening process, characteristic of fine soil with low to medium plasticity, in which the transition between elastic and plastic behavior is gradual.

Table 2. Characteristics of Triaxial Specimens

Sample No	Specimen 1	Specimen 2
Sample Diameter (cm)	3.50	3.49
Sample Height (cm)	7.41	7.23

Sample Area (cm²)	9.62	9.57
Sample Volume (cm³)	71.29	69.16
Cell Pressure (kPa)	100.00	200.00
Wet Sample Weight (gr)	132.91	131.20
Dry Sample Weight (gr)	96.47	96.37
Water Weight (g)	36.44	34.83
Water Content (%)	37.77	36.14
Natural Unit Weight (kN/m³)	18.29	18.61
Dry Unit Weight (kN/m³)	13.27	13.67
Grain Volume (cm³)	35.86	35.83
Pore Volume (cm³)	35.43	33.34
Porosity (%)	0.50	0.48
Void Ratio	0.99	0.93
Degree of Saturation (%)	1.00	1.00
Deformation at Failure (%)	22.94	23.51
Undrained Elastic Modulus (kPa)	341	346

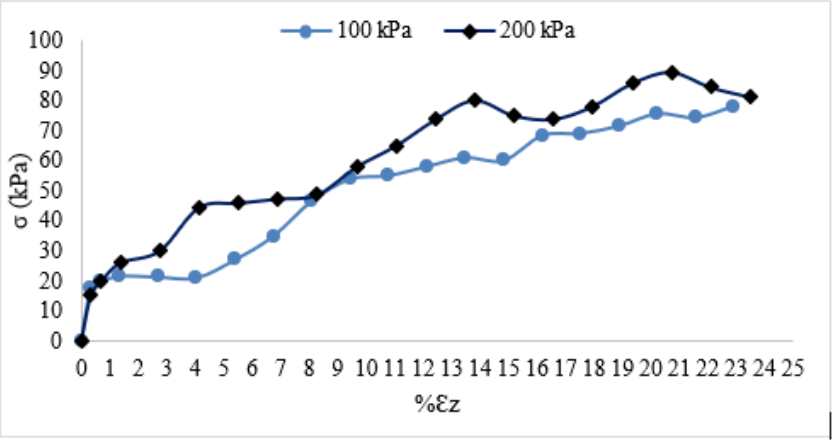


Figure 7. Variation in deformation and stresses of the samples.

The Mohr circles obtained in Figure 8 show that the maximum shear stress during the test is in the order of 40-45 kPa. From the failure condition in total stresses, an average value of undrained strength $c_u \approx 41.9$ kPa is obtained, represented by the discontinuous horizontal line. This value is a representative estimate of the overall undrained strength of the material, integrating the behavior observed under both levels of confinement.

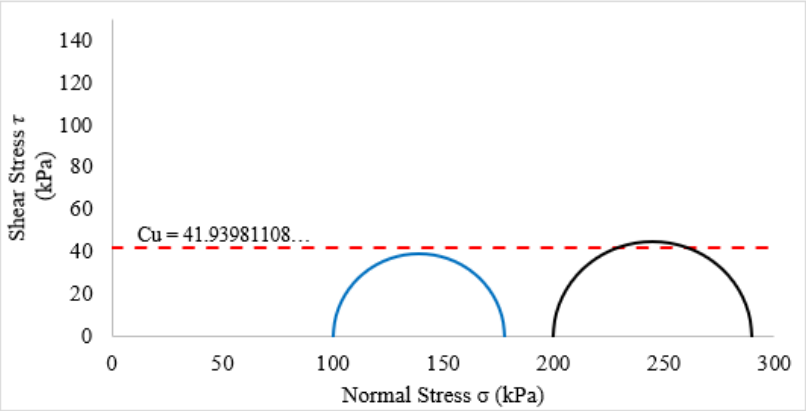


Figure 8. Mohr circles of soil samples.

2.3 Determination of the model and initial parameters for modeling

To determine the initial parameters, it is necessary to understand that Plaxis offers three (3) conditions for undrained soil behavior. Undrained analysis can be used when permeability is low or the load index is high and short-term behavior needs to be evaluated. In the program, the undrained condition is linked to a plastic calculation, depending closely on undrained parameters (Undrained A, B, and C), and each one works differently depending on the data available. In the case of Undrained effective stress analysis with effective strength parameters (Undrained A), it allows the undrained strength to be modeled using effective parameters (φ' and c'), but its reliability depends on a correct representation of the pore pressure. In simple models such as Mohr-Coulomb, shear strength can be overestimated, especially in soft soils, so it is recommended to verify the mobilized strength and use a zero dilatancy angle ($\psi = 0$) (Bentley Systems, 2023).

On the other hand, the Undrained effective stress analysis with undrained strength parameters (Undrained B) type allows undrained behavior to be modeled using an effective stress analysis, employing effective stiffness parameters together with undrained strength (s_u) as an input parameter. Although pore pressures are generated, these may be inaccurate. Finally, Undrained effective stress analysis with undrained strength parameters (Undrained C) allows undrained behavior to be simulated using a total stress analysis, using undrained stiffness and strength parameters. Stiffness is defined by the undrained Young's modulus (E_u) and a Poisson's ratio close to 0.5 ($\approx$ 0.495-0.499), while strength is modeled with the undrained strength s_u and a friction angle $\varphi = 0°$.

The combination of the Mohr-Coulomb model with the Undrained C drainage type is appropriate when only undrained parameters from UU tests are available, as it allows the soil behavior to be modeled using a total stress approach, avoiding uncertainties associated with the estimation of pore pressures and the definition of effective stress paths. This approach is particularly appropriate for short-term analysis in saturated fine soils, where undrained behavior governs the mechanical response of the material (Lambe & Whitman, 1969; Brinkgreve et al., 2023).

Therefore, for the simulation, the drainage type was set to "Undrained (C)," assuming a total stress analysis, and the Mohr-Coulomb constitutive model was selected. The axial deformation and deviatoric stress data from the laboratory were loaded into the software to serve as a basis for visual comparison during the adjustment process, ensuring that the numerical model accurately represents the elasto-plastic response of the observed soil. The initial parameters required in Plaxis for undrained conditions include: undrained Young's modulus (E_u), undrained Poisson's ratio (ν_u), undrained cohesion (c_u), internal friction angle (φ_u), and dilatancy angle (ψ). For undrained conditions, the friction angle is assumed to be zero ($\varphi_u = 0°$), which implies that all resistance comes from the cohesion of the soil. The undrained cohesion was determined directly from triaxial tests as $c_u = (\sigma_1 - \sigma_3)_{max} / 2$, where $(\sigma_1 - \sigma_3)_{max}$ is the maximum deviatoric stress recorded. The values for each confinement condition are shown in Table 3.

Table 3. Stresses in soil samples.

	100 kPa	**200 kPa**
σ_d	78.14	89.62
σ_3	100.00	200.00
σ_1	178.14	289.62
c_u	39.07	44.81
MC-center	139.07	244.81

The undrained Poisson's ratio was set at $\nu_u = 0.495$, a value close to 0.5, which is theoretically appropriate for incompressible materials under undrained conditions. The angle of dilatancy was assumed to be zero ($\psi = 0°$) for undrained conditions, as no volumetric change is expected during shearing.

3. PLAXIS MODELING WITH THE SOILTEST MODULE

For modeling in Plaxis, it is necessary to define the initial parameters in the materials section. To do this, first select the sample tested at a confining pressure (σ_3) of 100 kPa, then perform the same procedure to test the samples with a confining pressure of 200 kPa. In the general information tab, the soil model, drainage type, and natural unit weight obtained through the compaction test are determined, as shown in Figure 9.

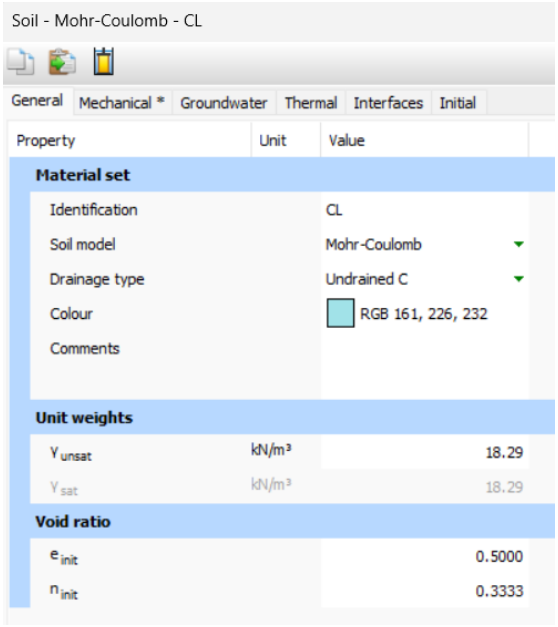


Figure 9. Determination of the initial properties of the model.

In the mechanical properties window, the values obtained in the UU tests performed in the laboratory are entered in Figure 4. The undrained shear strength was calibrated by matching the peak deviator stress obtained from UU triaxial tests. The undrained Young's modulus was adjusted to reproduce the initial elastic stiffness of the stress-strain response. The undrained strength was determined from the maximum deviator stress and the analysis of Mohr's circles, obtaining an average undrained cohesion value of $c_u \approx 39$ kPa. The undrained modulus of deformation was defined from the stiffness of the stress-strain curves, adopting a value of $E_u \approx 341$ kPa.

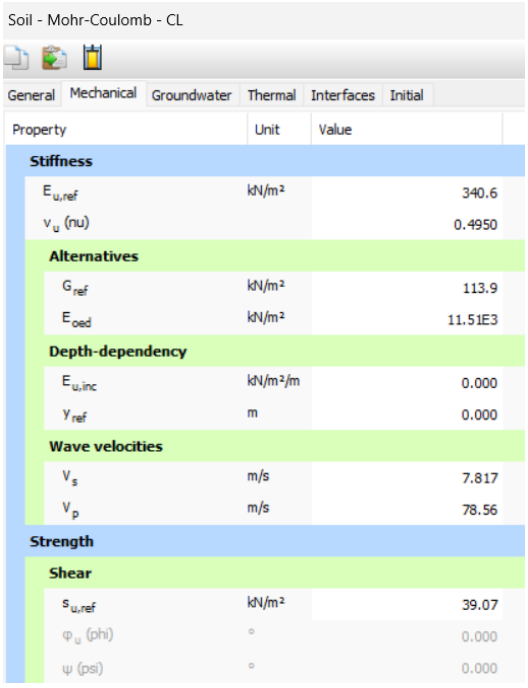


Figure 10. First simulation values.

3.1 First Simulation

After entering the parameters, the soil samples are simulated in the SoilTest module . Here, the triaxial test is selected, the test type is defined as undrained, and the direction of the loading, initial effective pressure, and maximum deformation are defined as in Figure 5.

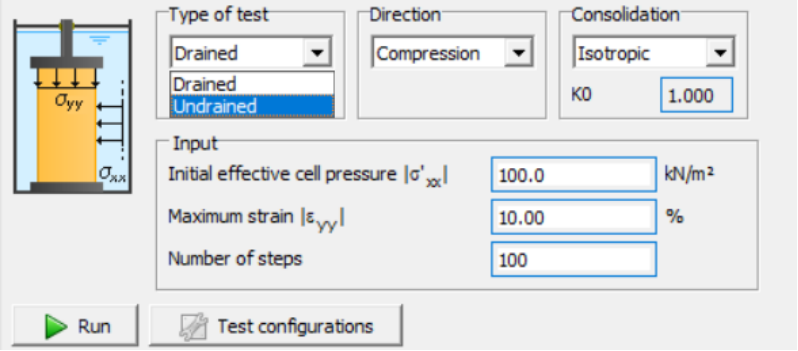
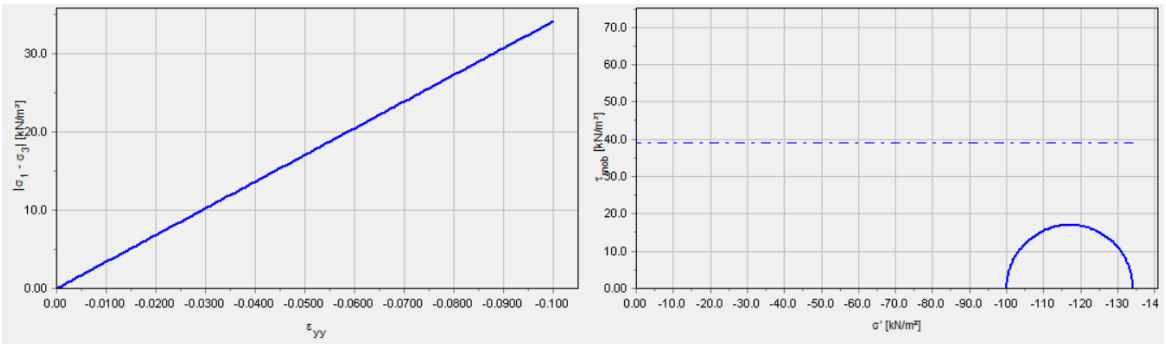


Figure 11. Parameter settings in SoilTest.

Once all parameters have been entered, the software performs the modeling, displaying graphs such as the deviatoric stress-axial strain graph, which represents the evolution of deviatoric stress as a function of axial strain during the numerical test (Figure 12 (a)). The maximum deviatoric stress value defines the undrained strength of the soil, which is directly related to the c_u parameter. Similarly, the software displays the shear stress-normal stress graph (Mohr circles) representing the stress state at the moment of failure, Figure 12 (b).

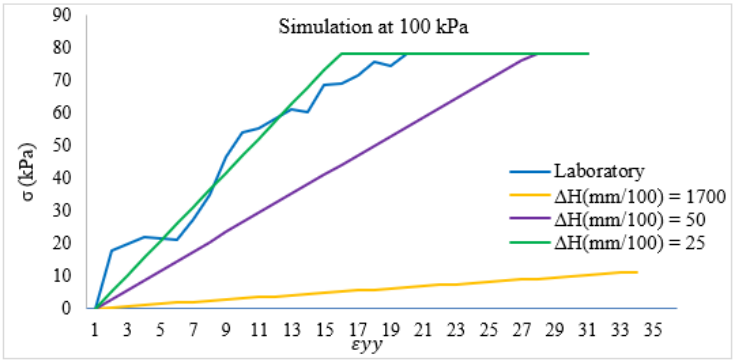


a) b)

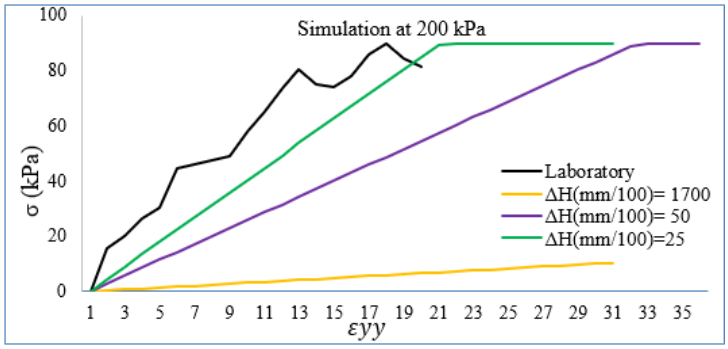
Figure 12. a) deviatoric stress vs. axial strain. b) shear stress vs. normal stress.

3.2 Second and third simulation

For a more accurate approximation of soil behavior, Young's modulus was chosen as the initial elastic stiffness derived from the early linear portion of the stress-strain curve, rather than the E parameter. Therefore, the behavior of the soil is analyzed at premature height changes (ΔH) of the sample, calibrating the E_u parameter with its respective deformation for variations of 50 and 25 mm, as shown in Figure 13.



a)



b)

Figure 13. Calibration of samples with confining pressure of a) 100 kPa and b) 200 kPa.

4. GENERAL EVALUATION AND RESULTS

4.1. Stress-Strain Behavior in the Laboratory

The unconsolidated-undrained (UU) triaxial tests performed on fine-grained soil from Adapazarı show predominantly contractive behavior, characterized by a progressive increase in strength without a clearly defined failure peak. Comparing the curves shown in Figure 7, it can be seen that, for the same level of axial deformation, the deviator stress developed under a confining pressure of 200 kPa is systematically higher than that corresponding to 100 kPa. Although from a theoretical point of view, undrained strength should be independent of confinement in completely saturated soils ($\varphi=0$), this slight increase suggests the possible influence of partial saturation of the specimen or the occurrence of effects associated with secondary consolidation processes during the rapid loading stage.

4.2. Numerical Calibration in SoilTest

The results obtained from numerical modeling using the Plaxis SoilTest module show that the proposed calibration procedure allows for reasonable reproduction of the undrained behavior of the fine soil studied, using only information from UU triaxial tests. The comparison between the deviator stress-axial strain curves obtained experimentally and those generated numerically shows good agreement in terms of both initial stiffness and maximum deviator stress magnitude, especially for small to moderate axial strains, which are the most relevant in short-term analysis.

In the first simulations, when using initial values of the undrained Young's modulus (E_u) derived directly from empirical relationships, a discrepancy was observed in the initial slope of the stress-strain curve, which highlighted the sensitivity of the Mohr-Coulomb model to the definition of elastic stiffness under undrained conditions. However, by adjusting the E_u parameter from the initial portion of the experimental curves, considering reduced axial deformations, a significant improvement in the representation of the material's stiffness was achieved. This adjustment allowed the model to more accurately reproduce the behavior observed in the laboratory for both confinement pressure levels (100 kPa and 200 kPa).

The comparative analysis between simulations corresponding to different maximum deformation values (ΔH) showed that the selection of the deformation range used for calibration has a direct impact on the parameters obtained. In particular, simulations calibrated with smaller deformations showed a better representation of the initial stiffness, while those associated with larger deformations tended to smooth the response, which is consistent with the linear elasto-plastic formulation of the Mohr-Coulomb model. This result confirms that, although the model is capable of adequately capturing undrained strength, it has inherent limitations in representing the progressive nonlinearity of stiffness characteristic of fine soils.

In terms of strength, the numerically calibrated undrained cohesion values remained consistent with the values obtained from the analysis of the Mohr circles of the UU tests, with reduced variations between the different confinement levels. This supports the hypothesis that, under undrained conditions and total stress analysis (Undrained C), the Mohr-Coulomb model can consistently represent the shear strength of saturated fine soils, provided that the stiffness is adequately adjusted.

5. CONCLUSION

Overall, the results show that the SoilTest module is an effective tool for validating and adjusting undrained parameters, allowing a direct link to be established between laboratory data and numerical response. The proposed methodology reduces the uncertainty associated with the use of empirical parameters and provides a logical calibration sequence that can be applied in contexts where available information is limited. However, it is important to note that the Mohr-Coulomb model has limitations in capturing advanced effects such as stiffness degradation with deformation or stress state dependence, so its application should be limited to preliminary or short-term analyses.

Finally, this study confirms that, even with conventional UU triaxial tests, it is possible to obtain a set of physically representative undrained parameters through conscious iterative calibration. The methodology developed can serve as a practical reference for both academic studies and professional applications, contributing to a more rational and informed use of simple constitutive models in geotechnical engineering.

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INVESTIGATION OF THE APPLICABILITY OF FILTER PRESS MUD WASTE FROM THE SUGAR INDUSTRY IN SOIL IMPROVEMENT

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ABSTRACT

The rapid growth of population and infrastructure has intensified the demand for construction-suitable land, even in areas with unfavorable soil conditions, such as low shear strength and high deformability. Among soil-improvement techniques, chemical stabilization is widely used; however, the use of conventional stabilizers such as cement and lime lead to significant environmental impacts and elevated economic cost.

This study investigates the usability of Press Mud (PM), a by-product obtained from sugar beet production, as an alternative stabilizing material for a low-plasticity clay soil (CL). The material, generated during sugar production in Sakarya, Türkiye, was added to the soil at 5%, 10% and 15% of the dry soil weight to evaluate its effects on the geotechnical properties. Specimens were prepared at the optimum moisture content (OMC) of both the natural soil and the soil-PM mixtures. All specimens were tested to evaluate their strength, deformation characteristics, and overall mechanical behavior, while also assessing the influence of specimen preparation conditions. The aim of the study was to demonstrate the importance of selecting the appropriate OMC for each specimen preparation. Results show that PM decreases maximum dry density and increases the optimum moisture content due to its low specific gravity. Unconfined compression test (UCS) indicates that 5% and 10% PM improve strength when mixtures are compacted at their respective OMCs, with the 5% mixture yielding the highest strength increase. These findings demonstrate that using the specific optimum moisture content of each mixture is essential to obtain accurate, representative mechanical properties.

Keywords: Cohesive soils, soil stabilization, press mud, additive ratio, optimum moisture content selection.

1. INTRODUCTION

The behavior of cohesive soils with low bearing capacity is one of the main challenges in geotechnical engineering, as these conditions limit the stability and safety of structures. Clay soils in particular undergo significant volumetric changes in response to variation in moisture content; as the water content in this type of soil increases, its plasticity rises and, as a result, its mechanical strength decreases, especially when the plastic limit is exceeded (Das, 2010). To overcome these limitations, it is essential to implement soil improvement techniques that optimize its physical and mechanical properties.

Traditionally, these techniques are grouped into three broad categories: mechanical, dynamic, and chemical. Within the latter, materials such as cement, lime, and fly ash are used, which have proven to be highly effective in soil stabilization. However, their widespread use involves high economic cost and, in many cases, negative environmental impacts associated with CO_2 emissions, which has prompted the search for more sustainable alternatives. In this context, the search for alternative, sustainable, and economically viable materials for soil improvement have become an alternative in soil stabilization capable of reducing environmental impact without compromising geotechnical performance.

In the agro-industry, it is very common for a large number of products to be generated after the production process. Some of these are reused in order to mitigate the environmental impacts they may cause. Among the most commonly used by-products are fly ash, limestone or marble dust, rice husk ash, cement kiln dust, agricultural waste, and natural fibers. In the global sugar industry, two types of raw materials are used: 80% of sugar is obtained from sugarcane, which is the most dominant source, and the remaining 20% comes from sugar beets (Govind et al., 2024). In temperate regions, sugar beet production is the most prevalent, with Turkey being one of the leading countries in its production. During the 2020/2021 cycle, this country ranked fifth among the largest producers of sugar from sugar beet, alongside Russia, Ukraine, and countries of the European Union (Ekinci et al., 2022). Among the by-products generated during the purification of beet juice is Press Mud (PM) or Filter Cake, a sludge rich in organic matter, carbonates, calcium, magnesium, and mineral salts.

Press Mud has attracted considerable interest as a potential stabilizing material due to its composition and availability. Several studies have shown that the application of filter sludge from the sugar industry significantly improves soil structure, fertility, and stability. Research such as that conducted by James (2020) evaluated sugarcane mud as a complementary additive to lime in expansive soils, revealing that modifications with PM led to a substantial improvement in short-and medium-term resistance, without adverse effects on shrinkage and expansion properties. Subsequently, Chittaranjan et al. (2021) investigated the effect of sugarcane filter mud on the geotechnical properties of expansive soils at different material variations, finding that this by-product increases the optimum moisture content and reduces the maximum dry density, which means it can be used effectively in the stabilization of expansive soil, although it did not have an effect on the swelling changes in the analyzed soil.

James et al. (2022) inspected the performance of cement-stabilized expansive soil improved with sugarcane press mud (PM), revealing that the additive material can be considered an accelerator of initial strength, although with less noticeable effect at prolonged curing periods.

On the other hand, Alaryan (2022) demonstrated that PM applied to high-and low-plasticity clays reduces swelling and shrinkage behavior, especially at a percentage of 15% PM, considering it a stabilizing material that can be used in civil engineering applications, although the high organic matter content could limit soil improvement, for which reason he recommends drying the material at a high temperature (~400 °C). Complementarily, Venda Oliveira & Reis (2023) studied the effect of organic compounds on the properties of stabilized soils, concluding that waste can improve cohesion and shear strength by promoting flocculation and particle aggregation processes.

Based on the above, this research seeks to explore the potential of press mud by analyzing the behavior of a low-plasticity clay soil at different moisture contents and PM percentages (5%, 10% and 15%). The study is approached from a comprehensive geotechnical perspective, evaluating the influence of the addition of this by-product on fundamental soil properties such as strength. The results are then analyzed and verified to determine how they influence soil behavior.

2. MATERIALS AND METHODS

The soil used for this research is a low plasticity clay (CL) obtained in the surroundings of Sakarya University. To ensure its homogeneity, the soil was dried in an oven at a constant temperature of 105 ± 5 °C and then sieved.

On the other hand, a by-product generated in the sugar beet industry, known as Press Mud (PM) (Figure 14), was used as a stabilizing material. This material was provided by the company Adapazarı Şeker Fabrikası A.Ş., which is used to purify beet juice in the sugar clarification process. It is formed from the addition of clarifying agents, where impurities precipitate and generate a sludge that is rich in organic matter, nitrogen, phosphorus, and potassium, as well as calcium and magnesium carbonates that facilitate growth. These elements can vary depending on which it is subjected to (Jiaxu Wu et al., 2023).



Figure 14. Press mud after the production process.

To characterize the material, laboratory tests were carried out in accordance with TS 1900-1 standards, determining the physical properties of both the natural soil and the additive material in the Akın Önalp Geotechnical Laboratories at Sakarya University. First, consistency limit tests were performed according to ASTM D4318, as well as granulometric tests using a hydrometer (ASTM D422), and the specific weight of the material was determined using the specific gravity test according to ASTM D854.

Soil samples (PM) were prepared by incorporating proportions of the residue according to the dry weight of the soil. Based on these mixtures, the Standard Proctor compaction test was carried out in accordance with ASTM D698 to evaluate variations in the maximum dry density and optimum moisture content of the natural soil. Subsequently, in order to obtain more accurate and repeatable parameters for smaller quantities of material, the compaction test was performed using the Harvard Miniature apparatus, which allowed the optimal moisture content and maximum dry density values of each mixture to be determined consistently.

Finally, to evaluate the behavior of the stabilized soil, the unconfined compression test (UCS) was performed in accordance with ASTM D2166 / TS1900-2, where the test specimens were subjected to combinations of 5%, 10%, and 15% additive material and natural soil. This procedure made it possible to determine whether the mixture of PM waste with natural soil has a progressive effect on soil properties at different moisture contents.

3. EXPERIMENTAL TEST

3.1 Preparation and classification tests

The pressed filter mud supplied by Adapazarı Şeker Fabrikası A.Ş was transported to the Geotechnical Laboratories at Sakarya University, where it underwent a two-stage drying process. In the first phase, the material is dried in the open air for approximately one week in order to reduce the initial moisture content and mitigate the smells resulting from the clarification process. In the second stage, it is dried in an oven at a constant temperature of 105 ∓5 °C for a period of 48 hours, and its natural moisture content is determined to be 33.53%. The material was then crushed to a powdery texture suitable for testing. The soil used was sieved through a No. 4 sieve (Figure 15) to ensure homogeneity.



Figure 15. Low plasticity clay sieved and dried at a temperature of 105°C.

The physical properties of the soil and the material used were determined in accordance with ASTM D422, ASTM D7928, ASTM D418, and ASTM D854, allowing the texture, plasticity, and specific gravity to be determined. The results are shown in Table 4. The natural soil was classified as a low plasticity clay (CL) with 75.04% fines, a liquid limit of 25.04 - 30.56%, and a plasticity index of 6.81%. The PM, on the other hand, had a higher percentage of fines, and the liquid limits obtained through the Casagrande and cone penetration test were relatively high compared to the natural soil, at 60.08% and 72.99%, values associated with highly organic materials with higher water absorption.

Table 4. Soil properties and additive material.

Property	Clay (CL)	PM
Particle distribution	**Value**	**Value**
(a) Gravel (%)	1.04	0.01
(b) Sand (%)	22.82	1.17
(c) Silt + Clay (%)	75.04	98.80
Consistency limits		
(a) Liquid limit (Casagrande) (%)	25.04	60.08
(b) Liquid limit (Cone penetration) (%)	30.56	72.99
(c) Plastic limit (%)	18.23	-
(d) Plasticity index (%)	6.81	-
Specific gravity	**2.64**	**2.447**
Natural moisture content (%)	**10.31**	**33.53**
Optimal moisture content (%)	**17.80**	**-**
Maximum dry density (kN/m^3)	**16.38**	**-**

3.2 Compaction Test

3.2.1 Compaction of natural soil

To ensure soil stability and strength in the field, increasing bearing capacity, decreasing compressibility, and finding essential soil parameters such as optimum moisture content and maximum dry density, the Standart Proctor test is performed in accordance with ASTM D698 / TS 1900-1, which for the soil extracted at the Sakarya University facilities corresponds to an optimal moisture content of 17.8% and a maximum dry density of 16.38 kN/m³.

3.2.2 Mixture compaction

The Harvard Miniature apparatus was used to determine the optimum moisture content and maximum dry density for each of the soil-PM combinations, using reduced volumes of material. Since this equipment does not have a specific ASTM, AASHTO, or TS standard, the procedure was developed following the methodological guidelines described by Cerato & Lutenegger (2006), who extensively document its use in experimental geotechnical applications. The energy applied in this device corresponds to approximately 20-25% of the energy of the Standard Proctor. The material was compacted in a cylindrical mold 5 cm in diameter and 10

cm high, divided into four successive layers, each approximately 2.5 cm high, using a controlled number of 10 bowls. Using this method, the material was optimized. It should be noted that the results are interpreted comparatively to the Standard Proctor test and not as values equivalent to ASTM D698.



Figure 16. Sample preparation with 5% PM for compaction testing with the Miniature Harvard apparatus.

3.3 Procedure for mixtures

After a literature review, three (3) different percentages of additive material were determined. The mixtures were prepared using the dry weight method, i.e., for 5% additive material and a soil sample of 330g, 16.5g of PM was added, corresponding to 5% of 330g, which was divided into four parts corresponding to each of the layers to be compacted in the miniature Harvard apparatus (Figure 16). The combinations for each percentages are shown in Table 5.

Table 5. Variation between the natural soil sample and PM.

Percentage of PM (%)	PM weight (g)	Total weight of the sample (g)
5	16.5	346.5
10	33.0	363.0
15	49.5	379.5

After this, the samples are compacted as mentioned in section 3.2.2. The results obtained for each percentage variation are shown in Figures 4 and 5. It can be observed that, as the PM percentage increases, the moisture content also increases due to the presence of organic material and salts, causing the material to retain more water in order to lubricate the particles and reach its maximum density. This difference can be seen in the optimum moisture content of the treated soil, which corresponds to 18.06%, and in the optimum moisture content of the sample with 15% PM, equivalent to 21.5% (Figure 4).

Figure 18 shows how the maximum dry density decreases when PM is added, which is normal behavior for another material with a lower specific weight. In other words, as the material is lighter, the mixture becomes less dense, and therefore its density decreases.

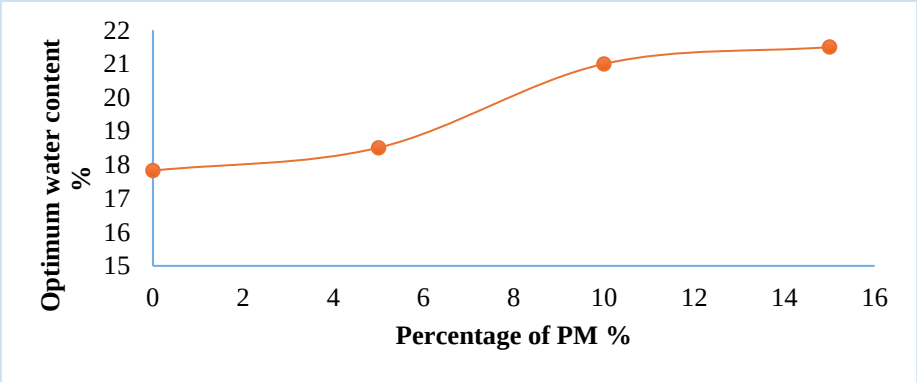


Figure 17. Variation in moisture content by percentage of PM.

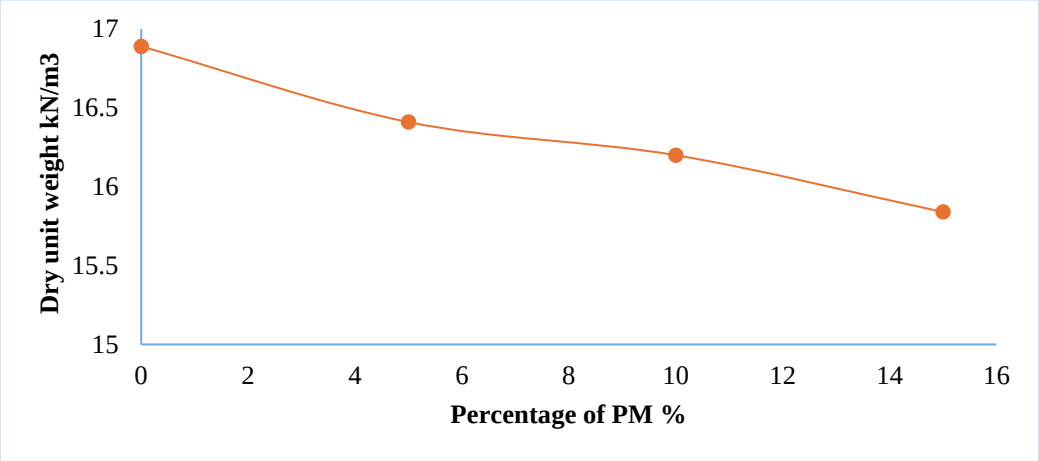


Figure 18. Variation in maximum dry density by percentage of PM.

3.4 Unconfined compressive strength (UCS)

In soil improvement projects, in order to measure the axial compressive strength of the soil under study, an unconfined compressive strength test (UCS) is performed in accordance with ASTM D2166 / TS1900-2. For this test, two (2) situations are evaluated: (1) using the optimal moisture content and maximum dry density of the soil for all PM mixtures and (2) the specific optimal moisture content of each mixture. Three test specimens were prepared per condition, resulting in a total of 21 tests corresponding to 5% (6), 10% (6), 15% (6), and the natural soil (3). **Error! Reference source not found.** clearly shows the change undergone by the sample. Those tested with the optimum moisture content of natural soil are shown in blue, and those with the optimum moisture content for each percentage of PM, the 5%, 10% and 15% are shown in green.

To visualize the relationship between normal and shear stresses during the UC test action on the different geometric planes, Mohr's circle was used, allowing the resistance and interaction between the principal stresses to be represented (Budhu, 2011). In the UCS, the sample is subjected only to an increasing axial stress (σ_1) without lateral confinement (σ_3=0). Under these conditions, the strength of the soil-PM mixtures were evaluated comparatively, showing increases of 5% and 10% and a reduction of 15% using the optimal values of the natural soil (Figure 20). On the other hand, when using the optimal values of the mixtures, no positive or significant change was observed for percentages of 10%.

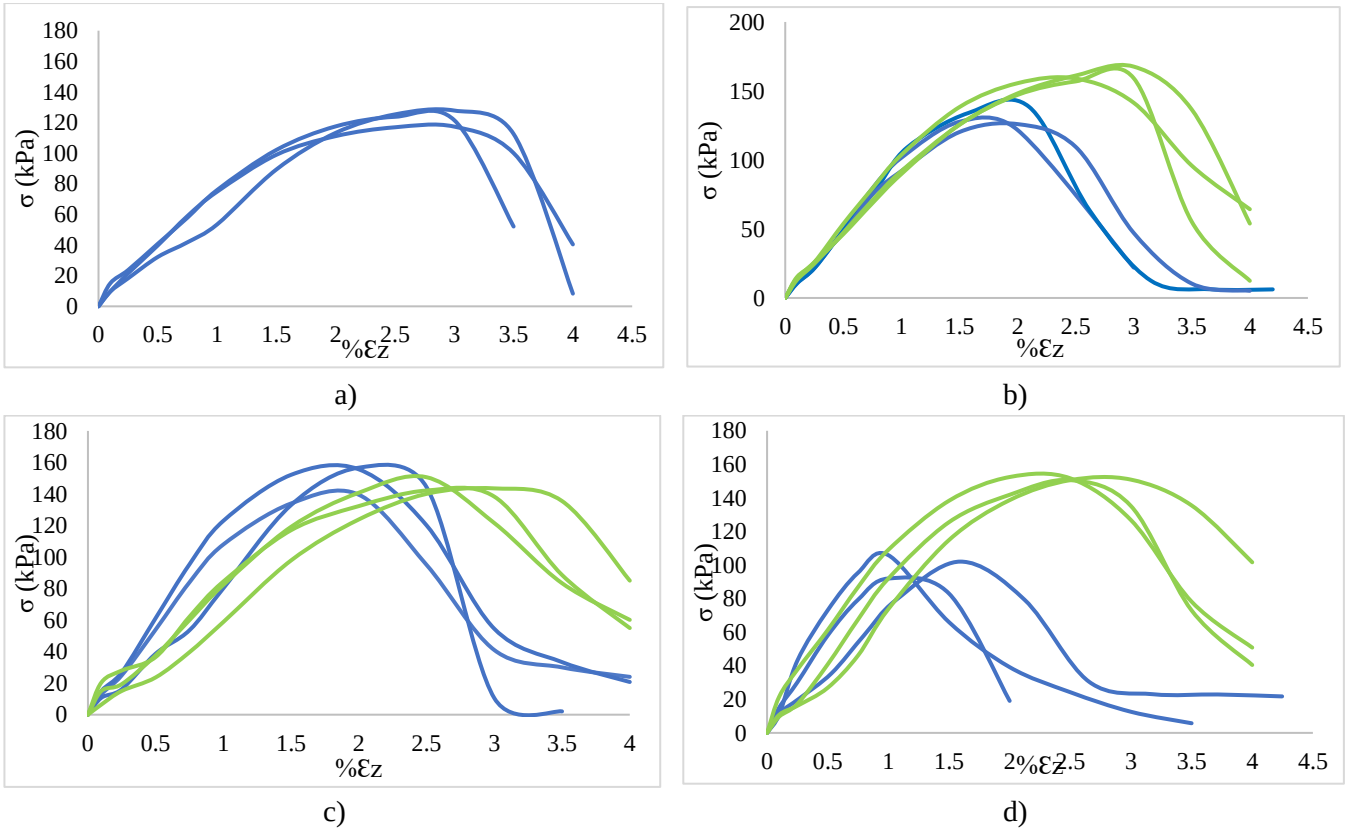
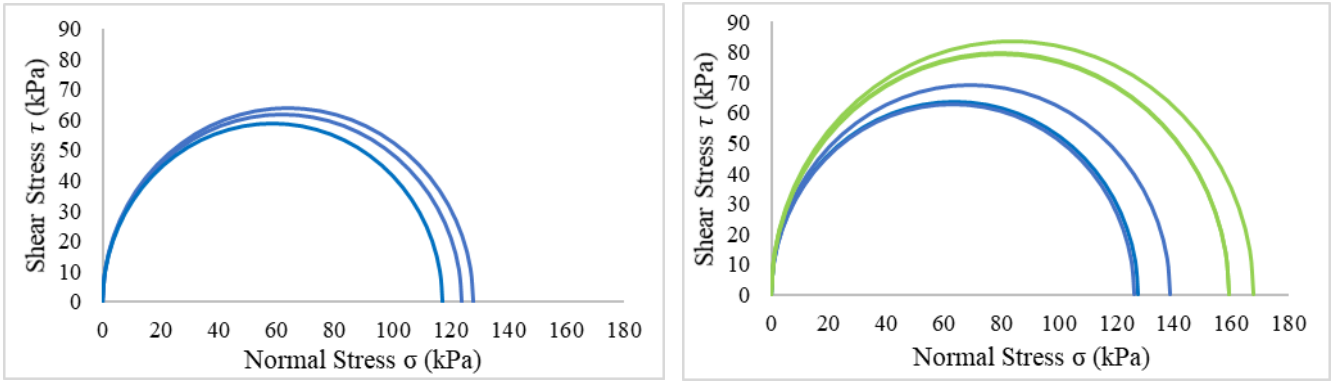
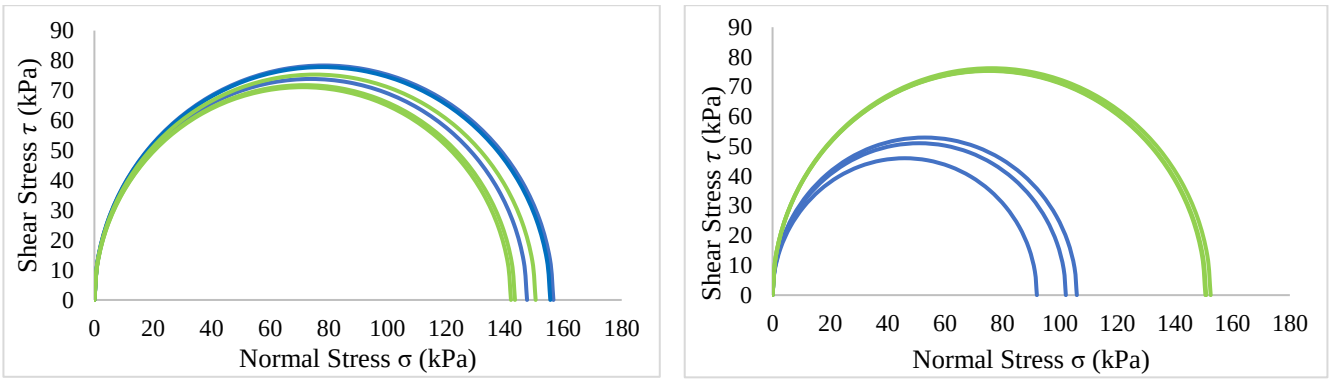


Figure 19. Normal stress of natural soil a), 5% b), 10% c), and 15% d) of PM.





c) d)

Figure 20. Mohr circle of natural soil a), 5% b), 10% c), and 15% d) of PM.

4. RESULTS AND DISCUSSION

The results obtained show different behavior between natural soil and mixtures stabilized with PM. Firstly, the UCS resistance values for the low plasticity clay samples CL are between 117.36 and 127.84 kPa, with deformation close to 2.5-3%, reflecting moderately plastic behavior and fairly limited bearing capacity, which means stabilization is necessary.

When analyzing the effect of Press Mud using the optimum moisture content of natural soil, a significant increase is observed for contents of 5% and 10%, as shown in Table 3. With regard to 5% PM, the strength increases to 138.55 kPa, equivalent to an 11% increase over 127.84 kPa, which is the maximum strength obtained in the UCS test for natural soil. With regard to the 10% additive material, an increase of 28% can be observed. These behaviors suggest that PM slightly improves the cohesion of the material with the soil in its interaction with clays. However, when the additive content increases to 15%, the strength decreases considerably, falling below the maximum strength obtained in the natural soil and reaching only 91.97 kPa, which implies a reduction of 36%. This decrease is because PM is a low-density organic residue, introducing greater porosity and reducing compatibility and, therefore, cohesion between particles.

Table 6. Variation in resistance in soil samples with PM.

Sample	w_{opt} (%)	γ_d (kN/m^3)	σ_{max} (kPa)	ε_f (%)	$\sigma_{increase}$ (%)
Natural soil	17.8	16.38	123.76	2.5	-
	17.8	16.38	127.84	3	-
	17.8	16.38	117.36	3	-
5% PM	17.8	16.38	127.69	1.5	0%
	17.8	16.38	138.55	2.1	11%
	17.8	16.38	125.98	2	-2%
5% PM (Optimum)	18.51	16.41	159.04	2.5	31%
	18.51	16.41	167.66	3	40%
	18.51	16.41	159.27	3	31%
10% PM	17.8	16.38	156.68	2	29%

	17.8	16.38	147.68	2	20%
	17.8	16.38	155.62	2	28%
10% PM (Optimum)	21.0	16.20	143.56	3	16%
	21.0	16.20	142.19	2.5	14%
	21.0	16.20	150.62	2.5	23%
15% PM	17.8	16.38	91.97	1	-36%
	17.8	16.38	102.05	1.6	-26%
	17.8	16.38	105.88	1	-22%
15% PM (Optimum)	21.5	15.84	152.45	2.5	25%
	21.5	15.84	150.89	3	23%
	21.5	15.84	150.62	2.5	23%

On the other hand, when samples are compacted according to their own optimum moisture content, additional improvements in strength are observed, especially at low additive contents. The 5% PM shows an increase of up to 40% with strength values between 167.59 and 169.67 kPa. The 15% also shows positive increases compared to natural soil, although these are lower than those observed in the 5% PM. For mixtures with 10%, no significant change in strength increase was observed compared to samples prepared according to the optimum soil moisture content, but there was a significant change when compared to natural soil samples, with an increase of 14 to 23%.

5. CONCLUSIONS

In this study, it was observed that sugar beet press mud produces changes in the compaction properties of CL soil, reducing the maximum dry density and increasing the optimum moisture content, a behavior associated with the low specific gravity of PM, high porosity, requiring a greater amount of water to reach its maximum density.

In the unconfined compression tests, the results show that 5% and 10% PM improve strength when the optimum moisture content of the natural soil is used. When the optimum moisture contents of each mixture are used, a considerable increase can be seen for the 10% and 15% percentages, although with greater changes when stabilizing with 5% additive material. High PM contents, such as 15%, can lead to a loss of strength due to their organic composition. The material used for this study shows potential as a sustainable and economically viable stabilizer, offering a low environmental impact alternative to conventional stabilizers. However, to expand its applicability in geotechnical engineering, future research should evaluate long-term behavior, durability, as well as internal chemical reactions that may develop during the stabilization process.

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KOMPRESÖR BİYEL KOLU UYGULAMASI İÇİN KARBONİTRASYONLU AISI 1018 VE DIN 1705 (Rg 5) BRONZ KAPLAMALI BURÇLARIN TRİBOLOJİK PERFORMANSININ BELİRLENMESİ

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ÖZET

Kompresörlerde biyel kolunun perno çapında konumlanan burçlar, krank milinin eksantrik hareketi nedeniyle perno ile sürekli değişen açılarda salınım temasına maruz kalmakta ve bu temas altında gelişen tribolojik davranış, sistem performansı ve bileşen ömrü üzerinde doğrudan etkili olmaktadır. Bu noktada meydana gelen aşınma, perno yüzeyinin bozulmasına, çalışma boşluklarının artmasına ve titreşim karakteristiğinin değişmesine yol açabildiğinden uygun malzeme seçimi kritik öneme sahiptir. Mevcut uygulamada kullanılan AISI 1018 çelik gövdeli karbonitrasyonlu burçlar yüksek yüzey sertliği sunsa da, kuru temas koşullarında gerçekleşen sürtünme ve aşınma davranışlarının farklı kaplama ve yüzey yapıları için karşılaştırmalı olarak değerlendirilmesi gerekmektedir. Bu çalışmada, aynı çelik gövde üzerine uygulanan DIN 1705 (Rg 5) bronz kaplamalı burçlar ile karbonitrasyonlu burçların kuru salınımlı temas koşulları altındaki tribolojik performansları karşılaştırmalı olarak incelenmiştir.

Deneysel çalışma kapsamında her iki burç tipinin sertlik, yüzey pürüzlülüğü ve deney öncesi malzeme uygunlukları testlerden önce belirlenmiştir. Aşınma testleri, kompresörün gerçek çalışma prensibini temsil eden ve ISO 7148-1:2012 standardına uygun salınım tipi tribometrede yaklaşık 60 salınım/dk hızında ve 30° toplam salınım açısında tamamen kuru sürtünme şartlarında gerçekleştirilmiştir. Deney sonrası numunelerde yüzey hasarı, aşınma izlerinin dağılımı ve temas bölgelerindeki morfolojik değişimler detaylı olarak incelenmiştir. Elde edilen sonuçlar, karbonitrasyonlu burçların yüksek yüzey sertliği sayesinde kuru salınımlı temas koşullarında aşınmaya karşı daha dirençli bir davranış sergilediğini; DIN 1705 (Rg 5) bronz kaplamalı burçların ise yağlayıcı ortamın bulunmadığı bu test koşullarında daha belirgin aşınma izleri oluşturduğunu ortaya koymuştur.

Anahtar Kelimeler: Triboloji, Kompresör Biyel Kolu, Burç Malzemesi, Salınım Tipi Tribometre, Aşınma Analizi

1. GİRİŞ

Ağır vasıta araçlarda kullanılan pistonlu kompresörler, araç fren mekanizması gibi pnömatik sistemlerin güvenli ve sürekli çalışması açısından kritik öneme sahip olup, bu sistemlerde biyel kolu ve burçların temas bölgeleri yüksek değişken yükler, sınırlı yağlama koşulları ve tekrarlı darbe etkileri altında çalışmaktadır. Bu çalışma koşulları altında biyel kolu burçlarında meydana gelen aşınma, mekanizma boşluklarının artmasına ve krank–biyel sisteminin dinamik davranışının bozulmasına yol açabilmektedir. Özellikle biyel kolu burçlarındaki boşluk artışının, üst ve alt ölü nokta civarında ilave darbe yükleri ve belirgin titreşim bileşenleri oluşturduğu, sayısal çok cisimli modeller ve deneysel titreşim ölçümleriyle ortaya konmuştur (Jiang ve diğ., 2017). Uzun süreli çalışma koşullarında ise bu tür dinamik etkilerin, biyel kolu ve bağlantı elemanlarında yüksek çevrimli yorulma hasarını tetiklediği ve gerilme yığılmalarının kritik hasar bölgelerinde yoğunlaştığı tespit edilmiştir (Wang ve diğ., 2022; Zhu ve diğ., 2017). Bununla birlikte aşınma davranışının yalnızca yükleme koşullarına değil, aynı zamanda biyel kolu ve burç malzemelerinin kimyasal bileşimi, mikroyapısı ve üretim yöntemine de bağlı olduğu; kompresör uygulamalarında kullanılan Al–Si esaslı alaşımlarda silikon oranı ve parçacık dağılımının kayma aşınması direncini belirgin biçimde etkilediği gösterilmiştir (Birol ve Birol, 2008). Temas yüzeylerindeki aşınma ve yorulma dayanımının, yüzey pürüzlülüğü ve yüzey altı artık gerilmeleri ile yakından ilişkili olduğu, uygun yüzey bitirme işlemleriyle biyel kolu–mil çiftinin servis ömrünün artırılabildiği araştırmacılar tarafından belirlenen bir diğer parametredir (Roitershtein ve diğ., 1974). Teorik çalışmalarda ise pistonlu kompresörlerde biyel kolu alt ucu ile mil bağlantısındaki aşınmanın basınç dağılımı, bağıl hız ve malzeme aşınma katsayılarıyla ilişkili olduğu, aşınmanın temas açısına bağlı olarak düzgün olmayan bir dağılım sergileyebileceği ifade edilmiştir (Kalashnikov, 1995).

Ağır vasıta araç tipi pistonlu kompresörlerde biyel kolu, krank mili ve yatak sisteminin tribolojik davranışı; yük aktarım mekanizması, yağ filmi kararlılığı ve yüzey etkileşimleri ile doğrudan ilişkilidir. Özellikle ağır vasıta uygulamalarında, yüksek çevrimli yükleme ve değişken çalışma koşulları altında krank pimi ve yatak çiftlerinde bölgesel aşınmaların

oluştuğu, bu aşınmaların çoğunlukla yağ filmi süreksizliği ve yerel elastik deformasyonlarla birlikte geliştiği görülmektedir (Zhu, Yuan, ve diğ., 2023). Sayısal hidrodinamik yağlama ve dinamik analizlere dayalı çalışmalar, krank mili ve piston–biyel mekanizmasında yağ filmi basınç dağılımının krank açısına, bağıl hıza ve eksantriklik oranına bağlı olarak önemli ölçüde değiştiğini ve bu durumun temas bölgelerinde düzensiz yük yoğunlaşmalarına yol açtığını göstermektedir (Mi ve Meng, 2014). Bunun yanı sıra, sınır ve karışık yağlama rejimlerinin baskın olduğu kompresör uygulamalarında yüzey özelliklerinin ve temas koşullarının aşınma davranışını belirgin biçimde etkilediği, özellikle yetersiz yağlama koşullarında adezif ve abrazif aşınma mekanizmalarının birlikte etkin olduğu ortaya konmaktadır (Solzak ve Polycarpou, 2010). Yatak ve mil ara yüzünde oluşan aşınmanın ilerleyen safhalarda boşluk artışına neden olduğu, bu boşluk artışının ise yağ filmi stabilitesini daha da bozarak aşınma sürecini hızlandıran bir geri besleme mekanizması oluşturduğu bilinmektedir (Li ve diğ., 2023). Bu kapsamda literatür, biyel kolu ve ilişkili yatak sistemlerinde aşınmanın yalnızca malzeme veya yağlama özellikleriyle değil, aynı zamanda sistemin dinamik davranışı ve gerçek çalışma koşullarıyla birlikte ele alınması gerektiğine işaret etmektedir (Li ve diğ., 2022).

Pistonlu ve döner tip kompresörlerde krank mili, yatak ve biyel mekanizmasının dinamik davranışı, yağ filmi sürekliliği ve yüzeyler arası bağıl hareket ile doğrudan ilişkilidir. Krank mili ve burç ara yüzünde yağ filmi kararlılığının bozulmasının, taşıma kapasitesinde azalma ve lokal aşınma bölgelerinin oluşmasına neden olduğu, yağ filmi basınç dağılımı ve minimum film kalınlığının bu süreçte belirleyici parametreler olduğu ortaya konmaktadır (Zhu, Cong, ve diğ., 2023). Bununla birlikte krank milinin elastik deformasyonunun, özellikle yüksek devirlerde yatak boşluklarını ve temas koşullarını önemli ölçüde değiştirdiği ve bu durumun yatak aşınmasını hızlandırdığı gösterilmektedir (Nursoy ve diğ., 2008). Döner kompresörlerde çoklu yatak ve hareketli elemanların eş zamanlı olarak etkileşime girmesi, sistemin tribolojik davranışını karmaşıklaştırmakta ve aşınmanın yalnızca tek bir temas çifti üzerinden değerlendirilmesini yetersiz kılmaktadır (Wen ve diğ., 2024). Literatürde geliştirilen tribodinamik ve karma yağlama modelleri, yağ filmi oluşumu ile dinamik yükler arasındaki etkileşimi açıklamakta önemli katkılar sağlasa da bu modellerin büyük bölümü teorik varsayımlara dayanmaktadır (Zhang ve Dong, 2018). Bu nedenle gerçek çalışma koşullarını temsil eden deneysel verilerle, biyel kolu ve ilişkili bileşenlerde meydana gelen aşınma davranışının doğrudan incelenmesi, mevcut modellerin sınırlarının daha net ortaya konması açısından önem taşımaktadır (Zhang ve diğ., 2014).

Pistonlu kompresörlerde sürtünme ve aşınma kaynaklı kayıplar; özellikle piston, biyel ve krank mekanizmasında sistem verimliliğini ve malzeme ömrünü doğrudan etkileyen temel unsurlar arasında yer almaktadır. Bu mekanizmada temas yüzeylerinde oluşan aşınmanın yalnızca yük ve hız parametreleriyle değil, aynı zamanda yüzey özellikleri ve uygulanan kaplama teknolojileriyle de yakından ilişkili olduğu görülmektedir. Piston ve piston halkalarında kullanılan farklı kaplama sistemlerinin, sürtünme katsayısı ve aşınma oranı üzerinde belirgin farklılıklar oluşturduğu, uygun kaplama seçiminin mekanik ve tribolojik performansı önemli ölçüde iyileştirebildiği ortaya konmaktadır (Kumar ve Kumar, 2022). Bununla birlikte, kaplama türüne ek olarak yüzey sertliği ve mikroyapının da aşınma davranışını belirlediği, sert

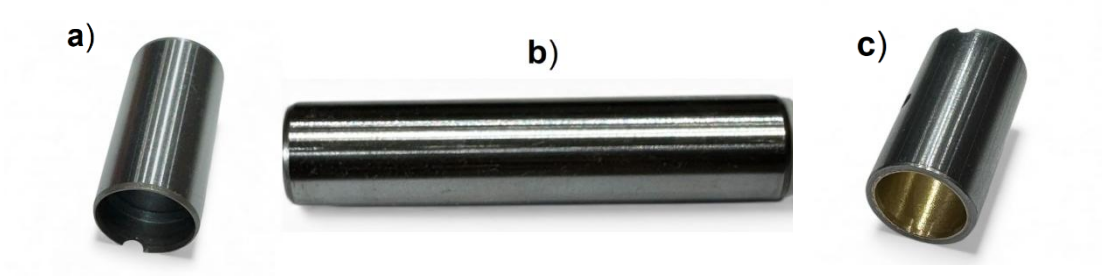
kaplamaların özellikle ağır yük koşullarında daha kararlı bir temas davranışı sunduğu gösterilmektedir (Patel ve diğ., 2022). Yağlama koşullarının zayıfladığı veya sınır yağlama rejiminin baskın olduğu durumlarda, yüzey durumunun ve uygun malzeme eşleşmelerinin aşınmayı sınırlamada kritik rol oynadığı anlaşılmaktadır (Bade ve diğ., 2018). Bu kapsamda, biyel kolu ve ilişkili temas yüzeylerinde meydana gelen aşınmanın yalnızca teorik modellerle değil, gerçek çalışma koşullarını temsil eden deneysel yaklaşımlarla ele alınmasının gerekli olduğu değerlendirilmektedir (Priest ve diğ., 1999).

Mevcut literatür incelendiğinde; biyel kolu, burç ve yatak sistemlerine yönelik çalışmaların büyük ölçüde yağlı veya sınır yağlama koşullarına odaklandığı, gerçek çalışma geometrisini temsil eden salınımlı temas altında ve tamamen kuru koşullarda gerçekleştirilen deneysel çalışmaların ise sınırlı kaldığı görülmektedir. Ayrıca, burç malzemelerinin karşı yüzey üzerindeki etkisinin ve aşınmanın boyutsal, yüzeysel ve mikroyapısal düzeylerde birlikte ele alındığı kapsamlı karşılaştırmaların eksik olduğu dikkat çekmektedir. Bu çalışmada, ağır vasıta pistonlu hava kompresörlerinde biyel kolu ve perno temasını temsil edecek şekilde tasarlanan özel bir deney düzeneği kullanılarak, karbonitrasyonlu AISI 1018 çelik burçlar ile DIN 1705 (Rg 5) bronz kaplamalı burçların kuru salınımlı temas koşulları altındaki tribolojik davranışları karşılaştırmalı olarak incelenmiştir. Deneyler, gerçek kompresör geometrisinden türetilmiş yaklaşık 30° toplam salınım açısı, 60 salınım/dk hız, 5 kg sabit yük ve 4 saatlik deney süresi altında gerçekleştirilmiştir. Aşınma davranışı makro görüntüler, yüzey pürüzlülüğü analizleri ve mikroyapı incelemeleri ile nicel ve nitel olarak değerlendirilmiştir.

2. DENEYSEL ÇALIŞMALAR

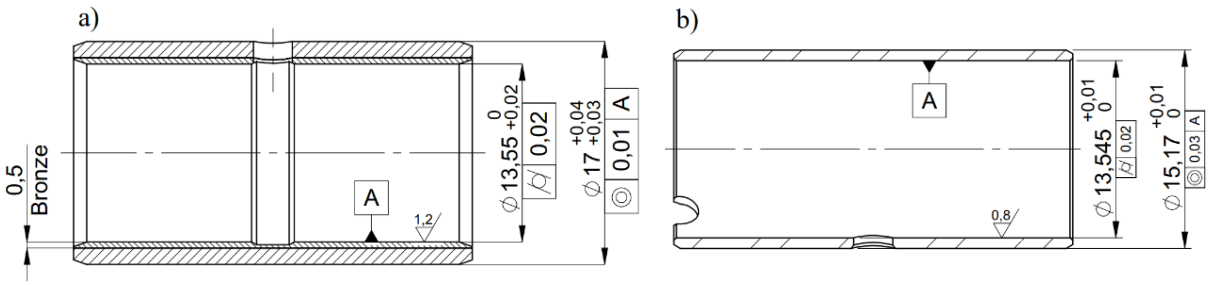
2.1. Numune Hazırlığı

Bu çalışmada, ağır vasıta hava fren kompresörlerinde biyel kolu–perno temasında kullanılan burç malzemelerinin tribolojik davranışlarının karşılaştırmalı olarak incelenebilmesi amacıyla, farklı yüzey özelliklerine sahip iki ayrı burç tipi deney numunesi olarak hazırlanmıştır. Deneylerde kullanılan numuneler, AISI 1018 çelik gövde üzerine karbonitrasyon işlemi uygulanmış burçlar ile aynı AISI 1018 çelik gövde üzerine DIN 1705 (Rg 5) bronz kaplama uygulanmış burçlardan oluşmaktadır. Bu iki burç tipi, kompresör biyel kolu uygulamalarında yaygın olarak tercih edilen yüzey mühendisliği yaklaşımlarını temsil etmekte olup, sert yüzeyli ve kaplamalı yapıların kuru salınımlı temas koşulları altındaki tribolojik davranışlarının karşılaştırılmasına olanak sağlamaktadır. Burç numuneleri, iç yüzeyleri perno ile doğrudan temas edecek şekilde tasarlanmış ve deney koşullarında gerçek çalışma prensibini yansıtacak geometrik özelliklerde üretilmiştir. Perno yüzeyi, burç iç yüzeyi ile sürekli salınımlı temas halinde çalışacak şekilde silindirik formda olup, deneylerde yük taşıyan ana temas elemanı olarak görev yapmaktadır. Bu sayede, burç–perno etkileşiminin kuru çalışma koşullarındaki sürtünme ve aşınma davranışları gerçekçi biçimde temsil edilmiştir. Görsel 1'de görülen deney numuneleri, biyel kolu–perno temasını simüle edecek şekilde hazırlanmış burç ve perno bileşenlerini göstermektedir.



Görsel 18. Deney numuneleri; a) Karbonitrasyonlu burç, b) Perno, c) Bronz kaplamalı burç

Deney öncesinde tüm numuneler, yüzeylerinde test sonuçlarını etkileyebilecek yağ, kir ve üretim kalıntılarının giderilmesi amacıyla standart temizleme prosedürlerinden geçirilmiştir. Bu kapsamda numuneler solvent ile temizlenmiş, basınçlı hava ile kurutulmuş ve deney öncesinde numune kontrolleri yapılmıştır. Ayrıca, burç ve perno ölçüleri deney öncesinde ölçülerek geometrik toleranslar ve yüzey sürekliliği kontrol edilmiş, numunelerin deney düzeneğine uygunlukları doğrulanmıştır. Numunelere, mevcut üretim durumlarını temsil edebilmek amacıyla karbonitrasyon veya bronz kaplama dışında herhangi bir ilave yüzey işlemi uygulanmamıştır; böylece elde edilen sonuçların doğrudan yüzey yapısı ve malzeme özelliklerine bağlı olması sağlanmıştır. Numunelere ait teknik resimler, salınımlı temas koşulları altında gerçekleşen burç–perno etkileşimini temsil edecek şekilde hazırlanmış olup, deney düzeneğinde sağlanan geometrik uyumun açık biçimde görülmesine olanak tanımaktadır. Deney numunelerinin temel geometrik tanımlamaları Görsel 2'de sunulan teknik resimler üzerinde gösterilmiştir.



Görsel 19. Deney numunelerinin teknik resmi; a) Bronz kaplamalı burç, b) Karbonitrasyonlu burç

Deney numunelerine ait geometrik tanımlamaların ve temel boyutsal özelliklerin ortaya konulmasının ardından, tribolojik davranış üzerinde doğrudan etkili olan malzeme özelliklerinin değerlendirilmesine geçilmiştir. Geometrik uyumun sağlanması, temasın deney süresince kararlı biçimde sürdürülebilmesi açısından ön koşul oluştururken, temas yüzeylerine ait sertlik özellikleri aşınma mekanizmalarının gelişimini belirleyen temel parametreler arasında yer almaktadır. Bu kapsamda, burç ve perno numunelerinin yüzey sertliği ve sertlik dağılımları, kuru salınımlı temas koşulları altında gerçekleşen sürtünme ve aşınma davranışlarının anlaşılabilmesi amacıyla incelenmiştir.

Çizelge 1'de sunulan sertlik ölçüm sonuçları incelendiğinde, deneylerde kullanılan perno ve burç numuneleri arasında belirgin sertlik farklarının bulunduğu görülmektedir. Sertlik ölçümleri; perno numuneleri için Mitutoyo HR-530 Rockwell sertlik ölçüm cihazı, karbonitrasyonlu AISI 1018 çelik burçlar için Mitutoyo HM-200 mikrosertlik ölçüm cihazı ve bronz kaplamalı burçlar için ise BULUT MAK 849-2008 Brinell sertlik ölçüm cihazı kullanılarak gerçekleştirilmiştir. Perno numuneleri, yüksek yüzey sertlikleri sayesinde burç iç yüzeyleri ile temas sırasında aşınmaya karşı daha dirençli bir karşı yüzey oluştururken, temas yüklerinin büyük bir bölümünü taşımaktadır. Bronz kaplamalı burçlar, daha düşük sertlik seviyeleriyle görece sünek bir yapı sergileyerek temas bölgesinde yüzey uyumunun gelişmesine katkı sağlarken, karbonitrasyonlu AISI 1018 çelik burçlar ise yüksek yüzey sertlikleri sayesinde plastik deformasyona karşı daha dirençli bir davranış göstermektedir. Bu sertlik farklılıklarının, temas bölgesinde oluşan gerilme dağılımı, mikro ölçekte yüzey deformasyonu ve aşınma izlerinin karakteri üzerinde doğrudan etkili olduğu değerlendirilmektedir.

Çizelge 7. Deney numunelerinin sertlik ölçüm sonuçları

Numune	**Ölçüm 1**	**Ölçüm 2**	**Ölçüm 3**	**Ölçüm 4**	**Ölçüm 5**
Perno 1 (HRC)	62	60	61	59	60
Perno 2 (HRC)	61	62	60	61	59
Bronz Burç 1 (HB)	75	73	76	74	75
Bronz Burç 2 (HB)	72	74	73	75	74
Çelik Burç 1 (HV)	620	635	628	630	625
Çelik Burç 2 (HV)	640	632	638	635	630

Gerçekleştirilen sertlik ölçümleri, deneysel çalışmada kullanılan numunelerin başlangıç durumlarının nicel olarak tanımlanmasını sağlamaktadır. Bu ölçümler sayesinde, deney öncesinde numuneler arasında üretim veya işlem kaynaklı olası farklılıkların kontrol altına alındığı teyit edilmiştir. Böylece deneyler sırasında elde edilecek tribolojik sonuçların, başlangıçtaki malzeme durumundan ziyade deney koşulları altında gelişen yüzey etkileşimlerine bağlı olarak şekillendiği varsayımı güçlendirilmiştir.

Sertlik özelliklerinin değerlendirilmesinin ardından, burç ve perno numunelerinin tribolojik davranışını doğrudan etkileyen bir diğer önemli parametre olan yüzey pürüzlülüğü incelenmiştir. Bu kapsamda, bronz kaplamalı burç numunelerine ait başlangıç yüzey pürüzlülüğü, tribolojik deneyler öncesinde temas yüzeyinin nicel olarak tanımlanabilmesi amacıyla Mitutoyo SJ-410 yüzey pürüzlülüğü ölçüm cihazı kullanılarak Ra, Rq ve Rz parametreleri üzerinden değerlendirilmiştir. Yapılan ölçümler sonucunda, bronz kaplamalı burç yüzeyleri için Ra değeri 1,307 µm, Rq değeri 1,604 µm ve Rz değeri 7,629 µm olarak belirlenmiştir.

Karbonitrasyonlu AISI 1018 çelik burç numunelerine ait başlangıç yüzey pürüzlülüğü Mitutoyo SJ-410 yüzey pürüzlülüğü ölçüm cihazı kullanılarak ölçülmüş olup, sonuçları incelendiğinde

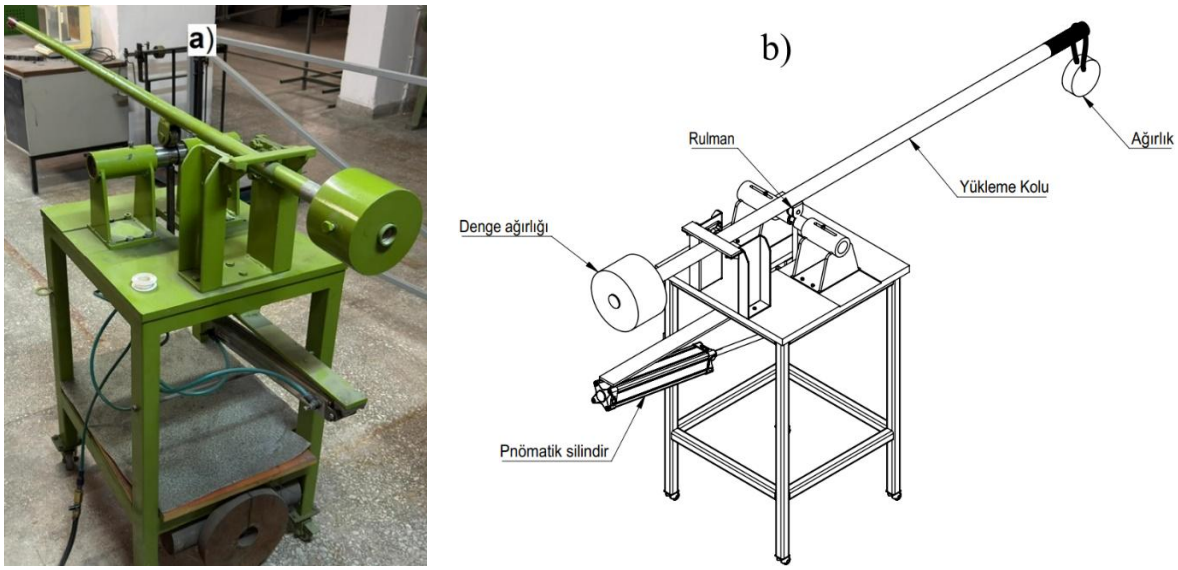
yüzeyin düzgün ve homojen bir profil sergilediği görülmektedir. Yapılan ölçümlerde, çelik burç yüzeyi için Ra değeri 0,517 µm, Rq değeri 0,718 µm ve Rz değeri 4,175 µm olarak belirlenmiştir. Elde edilen bu pürüzlülük değerleri, karbonitrasyon işlemi sonrası yüzey kalitesinin nicel olarak tanımlanmasına imkân tanımakta olup, deneylerde kullanılacak numunelerin başlangıç yüzey durumunu temsil etmektedir.

Perno numunelerine ait başlangıç yüzey pürüzlülüğü, tribolojik deneyler öncesinde temas yüzeyinin mevcut durumunun ayrıntılı ve nicel olarak tanımlanabilmesi amacıyla Mitutoyo SJ-410 yüzey pürüzlülüğü ölçüm cihazı kullanılarak ölçülmüştür. Yapılan pürüzlülük ölçümleri sonucunda, perno yüzeyi için Ra değeri 0,103 µm, Rq değeri 0,131 µm ve Rz değeri 0,964 µm olarak belirlenmiştir. Elde edilen bu pürüzlülük değerleri, perno yüzeyinin düzgün, ince ve homojen bir yüzey karakterine sahip olduğunu göstermektedir. Ra ve Rq değerlerinin düşük seviyelerde olması, yüzey dalgalanmalarının sınırlı olduğunu ve yüzey kalitesinin üretim süreci boyunca kontrol altında tutulduğunu ortaya koymaktadır. Rz değerinin de görece düşük olması, yüzey profilinde belirgin düzensizlikler veya derin yüzey kusurlarının bulunmadığını ve yüzey sürekliliğinin sağlandığını göstermektedir.

2.2. Deney Düzeneğinin Hazırlığı

Bu çalışmada gerçekleştirilen tribolojik deneyler, burç–perno temasını salınımlı hareket altında temsil edecek şekilde tasarlanmış özel bir deney düzeneği kullanılarak gerçekleştirilmiştir. Deney düzeneğinin genel görünümü ve ana bileşenleri Görsel 3'de sunulmaktadır. Sistem, pnömatik tahrik prensibiyle çalışmakta olup, doğrusal hareket üreten pnömatik silindir aracılığıyla yükleme koluna salınımlı bir hareket uygulanmaktadır. Salınım hareketinin sınırları, düzeneğe entegre edilmiş iki adet mekanik switch yardımıyla tanımlanmakta ve bu sayede salınım açısı kontrollü bir şekilde ayarlanabilmektedir. Bu yapı sayesinde deneyler boyunca tekrarlanabilir ve kararlı bir hareket profili elde edilmesi amaçlanmıştır. Yükleme kolu, rulmanlı bir yataklama sistemi üzerinden taşınarak sürtünme kaynaklı ilave etkiler minimize edilmiş, böylece temas bölgesinde oluşan tribolojik davranışın daha doğru şekilde incelenmesi hedeflenmiştir.

Deney düzeneğinde normal yük, yükleme kolunun uç noktasına asılan sabit bir kütle ile uygulanmaktadır. Gerçek bir pistonlu hava kompresöründe biyel kolu–perno temasına etki eden kuvvetler, yaklaşık 12,5 bar çalışma basıncı ve 70,64 mm piston çapı dikkate alındığında, yağlı çalışma koşulları altında oluşan piston kuvvetlerine karşılık gelmektedir. Ancak söz konusu kuvvetler, sistemde mevcut yağlayıcı film etkisiyle birlikte değerlendirilmekte olup, doğrudan kuru tribolojik deney koşullarını temsil etmemektedir. Bu nedenle, çalışmada gerçek sistemdeki mutlak yük değerlerinin birebir taklit edilmesi yerine, karşılaştırmalı değerlendirmeye olanak sağlayacak sabit ve tekrarlanabilir bir yükleme yaklaşımı benimsenmiştir. Bu kapsamda, deneyler boyunca yükleme kolunun 1,5 m uzunluğundaki uç noktasına 5 kg'lık bir ağırlık asılarak tüm deneyler gerçekleştirilmiş ve farklı burç numunelerinin aynı yükleme koşulları altında karşılaştırılması sağlanmıştır. Böylece, deneysel sonuçların malzeme ve yüzey özelliklerinden kaynaklanan tribolojik farkları yansıtması amaçlanmıştır.



Görsel 3. Deney düzeneği görüntüleri; a) Perspektif, b) Şematik

Çizelge 2'de gösterildiği gibi deney süresi her bir deney için 4 saat olarak belirlenmiş olup, toplamda iki ayrı deney gerçekleştirilmiştir. İlk deneyde, deney düzeneğinin bir tarafına bronz kaplamalı burç, karşı tarafına ise çelik burç yerleştirilmiştir. İkinci deneyde ise, olası konum ve yön etkilerinin elimine edilebilmesi amacıyla burçların yerleri değiştirilmiş; ilk deneyde bronz burcun bulunduğu konuma çelik burç, ilk deneyde çelik burcun bulunduğu konuma ise bronz burç yerleştirilmiştir. Bu çaprazlama yaklaşımı sayesinde, her iki burç malzemesi de deney düzeneğinin her iki tarafında aynı koşullar altında test edilmiş ve karşılaştırmalı değerlendirme için daha güvenilir bir veri seti elde edilmiştir.

Çizelge 2. Deney Parametreleri

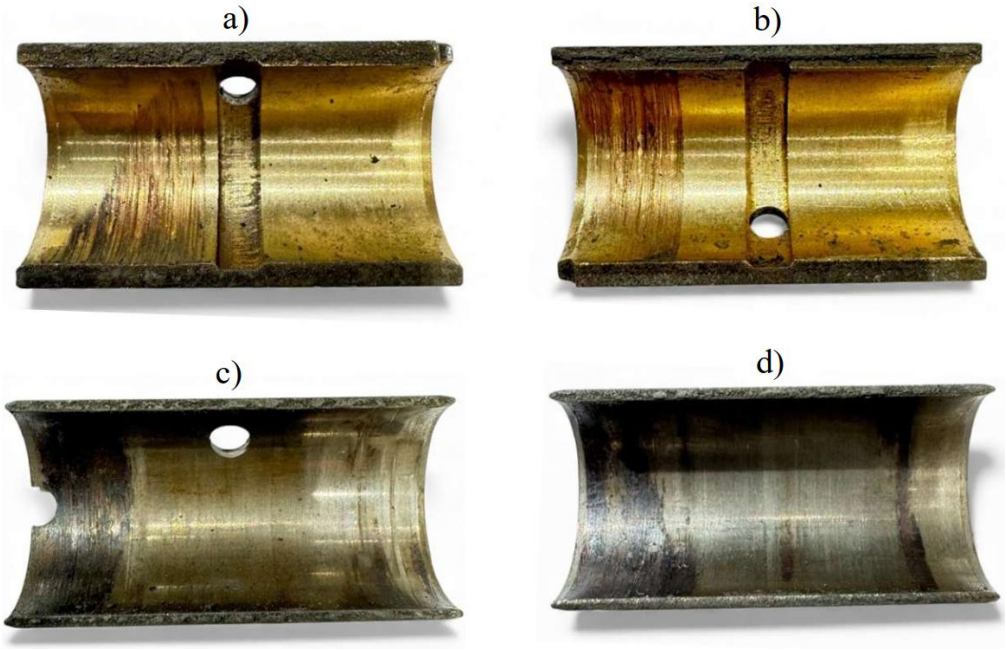
Parametre	**Değer / Açıklama**
Toplam salınım açısı	≈ 30°
Salınım Hızı	60 salınım/dk
Uygulanan yük	5 kg (1,5 m yükleme kolu ucu)
Deney süresi (tek deney)	4 saat
Toplam deney sayısı	2
Deney düzeni	Çaprazlama (bronz–çelik / çelik–bronz)
Ortam koşulları	Oda sıcaklığı

Deneylerin tamamlanmasının ardından, burç ve perno numuneleri deney düzeneğinden dikkatli bir şekilde sökülmüş ve yüzey durumlarının ayrıntılı olarak incelenebilmesi amacıyla analiz aşamasına alınmıştır. Bu kapsamda, deney sürecinde temas bölgelerinde oluşan aşınma izleri, yüzey pürüzlülüğündeki değişimler ve genel yüzey hasarı karakteristiklerinin değerlendirilmesi hedeflenmiştir. Numunelerin deney öncesi ve deney sonrası yüzey durumlarının karşılaştırılması yoluyla, farklı malzemelerin tribolojik performansları arasındaki farkların daha net bir şekilde ortaya konulması amaçlanmıştır.

3. SONUÇLAR VE DEĞERLENDİRME

Bu bölümde, belirlenen deney parametreleri altında gerçekleştirilen kuru salınımlı tribolojik deneyler sonucunda elde edilen tüm bulgular sunulmuş ve değerlendirilmiştir. Sonuçlar, deney sonrası numunelerde meydana gelen yüzey değişimlerinin çok yönlü olarak ortaya konulabilmesi amacıyla, makro ölçekte gözlemlerden başlayarak yüzeysel ve mikroyapısal analizlere ilerleyen bir sırayla ele alınmıştır. Aşınmış burç yüzeylerinin pürüzlülük karakteristiğindeki değişimi belirleyebilmek amacıyla deney sonrası yüzey pürüzlülüğü ölçümleri gerçekleştirilmiş ve elde edilen Ra, Rq ve Rz değerleri üzerinden yüzeydeki tribolojik değişimler yorumlanmıştır. Son aşamada ise, aşınma mekanizmalarının daha ayrıntılı olarak anlaşılabilmesi amacıyla aşınmış yüzeylere ait mikroyapı görüntüleri incelenmiş; yüzey hasarının gelişimi, malzeme yapısı ve temas koşulları ile ilişkilendirilerek bütüncül bir değerlendirme yapılmıştır.

Görsel 4’de sunulan makro görüntüler incelendiğinde, deney sonrası burç numunelerinin temas bölgelerinde belirgin aşınma izlerinin oluştuğu açıkça görülmektedir. Bu durum, deney süresince perno–burç temasının kararlı bir temas yolu üzerinden gerçekleştiğini ve aşınmanın belirli bir bölgede lokalize olduğunu göstermektedir. Özellikle salınım sınırlarına yakın bölgelerde aşınma izlerinin daha belirgin hale gelmesi, temas basıncının ve bağıl kayma etkisinin bu bölgelerde arttığına işaret etmektedir. Farklı burç malzemelerine ait makro görüntüler karşılaştırıldığında, aşınma izlerinin yoğunluğu, yayılım alanı ve yüzey görünümü açısından belirgin farklılıklar gözlemlenmiştir. Bronz kaplamalı burçlarda aşınma izlerinin daha geniş bir alana yayıldığı, yüzeyde yer yer parlatılmış ve düzgünleşmiş bölgelerin oluştuğu dikkat çekmektedir. Buna karşılık, karbonitrasyonlu çelik burçlarda aşınmanın daha sınırlı bir alanda yoğunlaştığı ve izlerin daha keskin sınırlar ile tanımlandığı görülmektedir. Bu farklılıklar, malzemelerin sertlik seviyeleri ve yüzey özelliklerinden kaynaklanan tribolojik davranış farklarının makro ölçekteki yansımaları olarak değerlendirilmektedir.



Görsel 4. Deney sonrası numune görünümleri; a) Bronz 1.deney, b) Bronz 2.deney, c) Çelik 1.deney, d) Çelik 2.deney

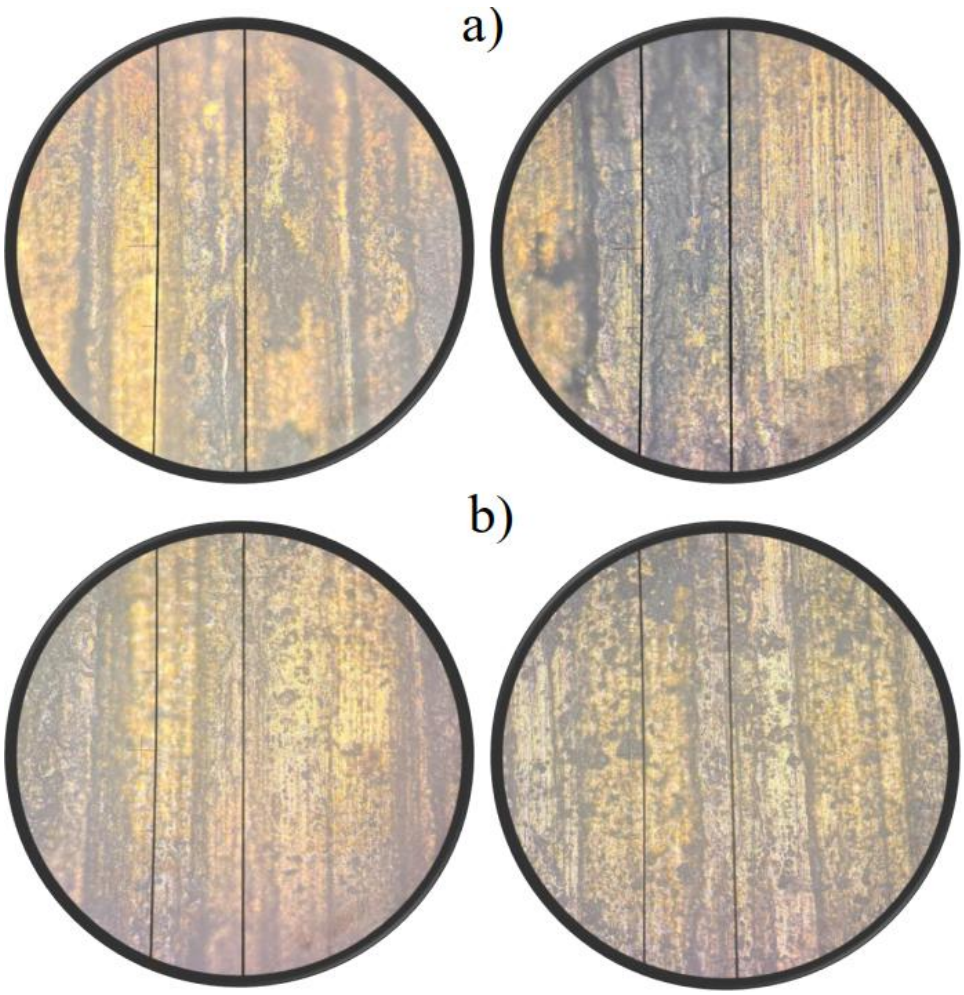
Çizelge 3 incelendiğinde, deney sonrası yüzey pürüzlülüğü değerlerinin burç malzemesine bağlı olarak belirgin şekilde ayrıştığı görülmektedir. Bronz kaplamalı burçlarda Ra değeri başlangıçta 1,307 µm iken birinci deney sonunda 12,125 µm'ye, ikinci deney başında 1,314 µm değerinde iken sonunda ise 26,431 µm'ye yükselmiştir. Rz değeri ise birinci deneyde 7,629 µm'den 63,352 µm seviyesine; ikinci deneyde ise 7,667 µm'den 134,175 µm seviyesine ulaşmıştır. Buna karşılık karbonitrasyonlu çelik burçlarda Ra değeri deneyler sonrasında 0,824–0,916 µm aralığında kalmış, Rz değeri ise 5,848–7,058 µm seviyelerinde sınırlı değişim göstermiştir. Perno yüzeyleri açısından değerlendirildiğinde, bronz burç ile temas eden perno yüzeylerinde Ra değerinin 0,109 µm'den 1,953 µm'ye kadar çıktığı, çelik burç ile temas eden perno yüzeylerinde ise bu artışın 1,371 µm ile sınırlı kaldığı görülmektedir. Bu sayısal sonuçlar, kuru salınımlı temas koşullarında bronz kaplamalı burçların hem kendi yüzeylerinde hem de karşı yüzeyde daha yüksek pürüzlülük artışına neden olduğunu açıkça ortaya koymaktadır.

Çizelge 3. Deney Sonrası Yüzey Pürüzlülüğü Sonuçları

Numune / Durum	**Yüzey Pürüzlülüğü Değerleri**		
Perno Başlangıç Değerleri	**Ra (µm)**	**Rq (µm)**	**Rz (µm)**
Perno-1	0.103	0.131	0.964
Perno-2	0.109	0.124	0.953
Deney Sonrası – Bronz Burç ile Aşınan Yüzeyler	**Ra (µm)**	**Rq (µm)**	**Rz (µm)**
Bronz Burç 1 (Başlangıç)	1.307	1.604	7.629
Bronz Burç 2 (Başlangıç)	1.314	1.612	7.667
Bronz Burç – 1. Deney	12.125	16.136	63.352
Bronz Burç – 2. Deney	26.431	31.981	134.175

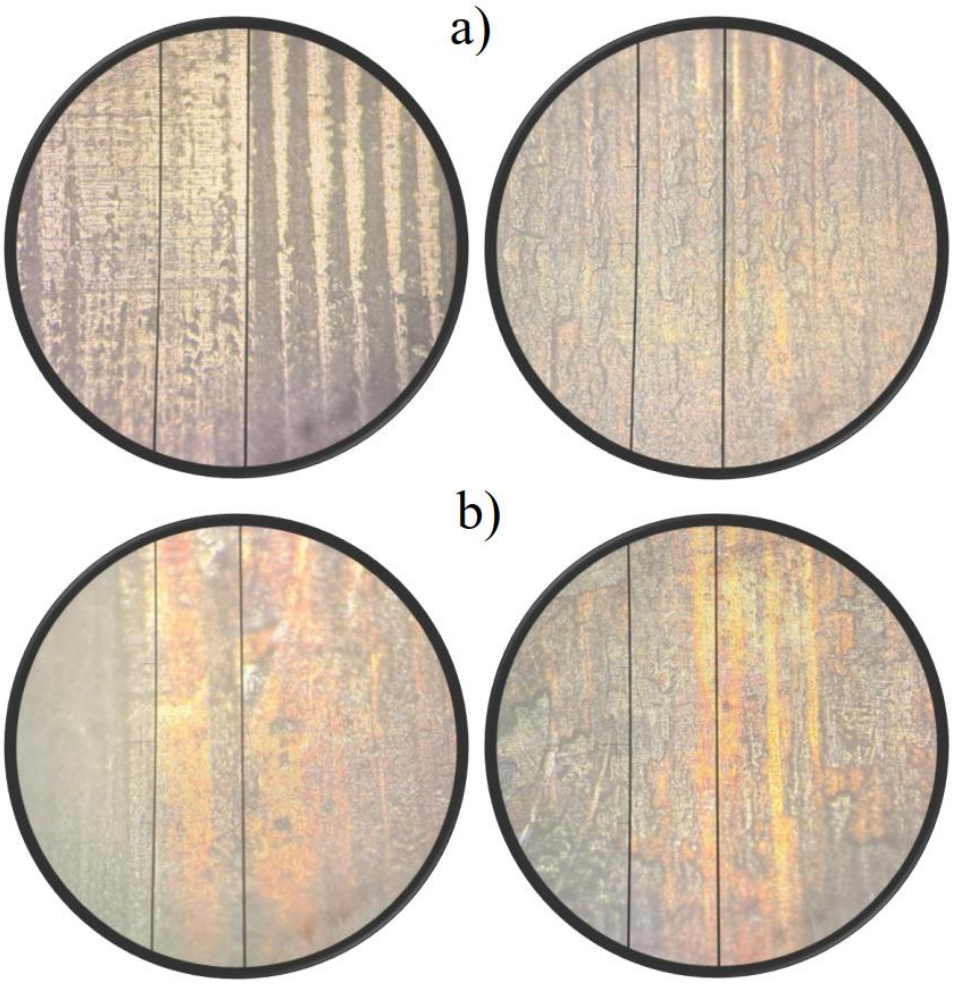
Pernonun Bronz Burç ile Aşınmış Tarafı – 1. Deney	0.774	1.108	7.178
Pernonun Bronz Burç ile Aşınmış Tarafı – 2. Deney	1.953	3.501	16.653
Deney Sonrası – Çelik Burç ile Aşınan Yüzeyler	**Ra (µm)**	**Rq (µm)**	**Rz (µm)**
Çelik Burç 1 (Başlangıç)	0.517	0.718	4.175
Çelik Burç 2 (Başlangıç)	0.506	0.703	4.153
Çelik Burç – 1. Deney	0.824	1.120	7.058
Çelik Burç – 2. Deney	0.916	1.118	5.848
Pernonun Çelik Burç ile Aşınmış Tarafı – 1. Deney	0.548	0.745	4.712
Pernonun Çelik Burç ile Aşınmış Tarafı – 2. Deney	1.371	1.804	9.461

Görsel 5'de, kuru salınımlı temas koşulları altında gerçekleştirilen deneyler sonrasında bronz kaplamalı burç numunelerine ait mikroyapı görüntüleri sunulmaktadır. Mikroyapı incelemeleri, deney süresince bronz kaplamanın temas bölgesinde belirgin yapısal değişimlere uğradığını göstermektedir. Özellikle perno ile doğrudan temas eden bölgelerde, yüzey altına doğru uzanan plastik deformasyon zonlarının oluştuğu ve yüzey topografyasının yer yer bozulduğu dikkat çekmektedir. Deney 1 ve Deney 2 karşılaştırıldığında, ikinci deney sonunda bu deformasyon bölgelerinin daha geniş alanlara yayıldığı ve yüzey hasarının daha belirgin hale geldiği görülmektedir. Bronz kaplamanın görece sünek yapısı nedeniyle, kuru çalışma koşullarında tekrarlı salınımlı temas sırasında malzemenin yüzeyden koparak transfer olduğu ve yer yer yüzey altı akma izlerinin oluştuğu değerlendirilmektedir. Mikroyapı görüntülerinde gözlenen bu yapısal bozulmalar, makro ölçekte tespit edilen aşınma izleri ve yüzey pürüzlülüğünde meydana gelen yüksek artışlarla uyumlu bir tablo ortaya koymaktadır. Bu durum, bronz kaplamalı burçların yağlayıcı ortamın bulunmadığı koşullarda aşınmaya karşı daha hassas bir davranış sergilediğini mikroyapı düzeyinde açıkça doğrulamaktadır.



Görsel 5. Aşınmış bronz burçların mikroyapı görüntüleri; a) Deney 1, b) Deney 2

Görsel 6'da, karbonitrasyonlu AISI 1018 çelik burç numunelerine ait deney sonrası mikroyapı görüntüleri sunulmaktadır. Mikroyapı incelemeleri, çelik burç yüzeyinde deneyler sonrasında da yüzey bütünlüğünün büyük ölçüde korunduğunu ve aşınmanın daha sınırlı bölgelerde yoğunlaştığını göstermektedir. Karbonitrasyon işlemi ile elde edilen sert yüzey tabakasının, salınımlı temas sırasında oluşan mekanik zorlanmalara karşı etkin bir direnç sağladığı gözlemlenmektedir. Deney 1 ve Deney 2 sonuçları birlikte değerlendirildiğinde, mikroyapı karakteristiğinde belirgin bir farklılık oluşmadığı ve aşınma davranışının tutarlı şekilde tekrarlandığı anlaşılmaktadır. Çelik burç yüzeyinde gözlenen aşınma izleri, daha çok yüzey düzleşmesi ve sınırlı mikro çizikler şeklinde ortaya çıkmakta olup, bronz kaplamalı burçlarda görülen yaygın plastik deformasyon ve yüzey altı akma izlerine rastlanmamaktadır. Bu durum, karbonitrasyonlu çelik burçların kuru salınımlı temas koşullarında daha stabil bir tribolojik davranış sergilediğini ve yüzey hasarının kontrollü şekilde ilerlediğini göstermektedir.



Görsel 6. Aşınmış karbonitrasyonlu çelik burçların mikroyapı görüntüleri; a) Deney 1, b) Deney 2

Bu bölümde, kuru salınımlı temas koşulları altında gerçekleştirilen deneyler sonucunda elde edilen makro aşınma görüntüleri, yüzey pürüzlülüğü sonuçları ve mikroyapı incelemeleri birlikte sunulmuş ve değerlendirilmiştir. Farklı burç malzemelerinin aynı deney koşulları altında sergilediği tribolojik davranışlar, çok yönlü ölçüm ve gözlemler aracılığıyla nicel ve nitel olarak ortaya konmuştur. Elde edilen bulgular, burç–perno temasında malzeme özelliklerinin aşınma davranışı üzerindeki belirleyici rolünü açık biçimde göstermekte olup, deneysel sonuçlar bu kapsamda tutarlı ve karşılaştırılabilir bir veri seti sunmaktadır.

4. GENEL DEĞERLENDİRME VE SONUÇLAR

Bu çalışmada, pistonlu hava kompresörlerinde biyel kolu–perno temasını temsil edecek şekilde tasarlanan özel bir deney düzeneği kullanılarak, farklı burç malzemelerinin kuru salınımlı temas koşulları altındaki tribolojik davranışları deneysel olarak incelenmiştir. Deneyler, gerçek sistem geometrisinden türetilen yaklaşık 30° toplam salınım açısı, 5 kg sabit yük ve 4 saatlik deney süresi altında gerçekleştirilmiş; bronz kaplamalı burçlar ile karbonitrasyonlu çelik burçlar karşılaştırmalı olarak değerlendirilmiştir. Deney sonrası burç ve perno numuneleri üzerinde makro aşınma görüntüleri, yüzey pürüzlülüğü analizleri ve mikroyapı incelemeleri

gerçekleştirilmiştir. Bu çok yönlü değerlendirme yaklaşımı sayesinde, kuru çalışma koşullarında burç malzemesinin aşınma davranışı üzerindeki etkisi hem nitel hem de nicel olarak ortaya konulmuştur.

Çalışmadan Elde Edilen Bulgular:

- Bronz kaplamalı burçlarda, deney sonrası Ra değerinin 1,314 µm'den 26,431 µm'ye, Rz değerinin ise 7,667 µm'den 134,175 µm'ye yükseldiği belirlenmiştir. Buna karşılık karbonitrasyonlu çelik burçlarda Ra değerleri deneyler sonrasında 0,824–0,916 µm aralığında kalmış, Rz değerleri ise 5,848–7,058 µm seviyelerinde sınırlı değişim göstermiştir.

- Bronz burç ile temas eden perno yüzeylerinde Ra değerinin 0,109 µm'den 1,953 µm'ye kadar yükseldiği, çelik burç ile temas eden perno yüzeylerinde ise bu artışın 1,371 µm ile sınırlı kaldığı tespit edilmiştir. Bu sonuç, bronz kaplamanın karşı yüzey üzerinde de daha agresif bir aşınma etkisi oluşturduğunu göstermektedir.

- Mikroyapı incelemeleri, bronz kaplamalı burçlarda yaygın plastik deformasyon, yüzey altı akma izleri ve malzeme transferine işaret eden yapısal bozulmaların oluştuğunu; karbonitrasyonlu çelik burçlarda ise sert yüzey tabakasının büyük ölçüde korunduğunu ortaya koymuştur.

- Çaprazlama yöntemiyle gerçekleştirilen iki ayrı deneyde benzer pürüzlülük değişim eğilimlerinin elde edilmesi, aşınma davranışının deney düzeneğindeki konumdan bağımsız olarak, doğrudan burç malzemesinin tribolojik özelliklerine bağlı olduğunu göstermiştir.

- Toplam 8 saatlik deney süresi sonunda elde edilen sonuçlar, karbonitrasyonlu çelik burçların tribolojik davranışının deney süresi boyunca daha stabil kaldığını, bronz kaplamalı burçlarda ise aşınmanın zamanla belirgin şekilde arttığını göstermiştir.

Bu çalışmada elde edilen sonuçlar, kuru salınımlı temas koşulları için önemli bulgular sunmakla birlikte, gelecekte yapılacak çalışmalar ile kapsamın genişletilmesi mümkündür. Farklı bronz alaşımlarının, kaplama kalınlıklarının veya alternatif yüzey işlemlerinin tribolojik davranış üzerindeki etkileri incelenebilir. Yük seviyesi, salınım açısı ve deney süresi gibi parametrelerin sistematik olarak değiştirilmesi, aşınma mekanizmalarının daha ayrıntılı olarak anlaşılmasına katkı sağlayacaktır. Son olarak, deneysel bulguların sayısal analizler ile desteklenmesi, burç–perno temasındaki gerilme dağılımı ve aşınma gelişiminin daha derinlemesine incelenmesine olanak tanıyacaktır.

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HAVA YÖNLENDİRİCİ TASARIMININ PERFORMANSA ETKİSİNİN NÜMERİK VE DENEYSEL YÖNTEMLERLE KARŞILAŞTIRILMASI

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ÖZET

Yapılan çalışma kapsamında, ısı pompalı çamaşır kurutma makinelerinde kompresör soğutmasında kullanılan eksenel fanlar için debi kayıplarını azaltacak ve fan performansını arttıracak bir muhafaza tasarımı yapılması ile maliyet etkin fan alternatiflerinin kullanımının mümkün kılınması amaçlanmıştır. Isı pompalı sistemlerde kullanılmakta olan kompresör yeterli soğutmaya tabi tutulamazsa, kurutma çevriminde süre uzaması ve enerji tüketiminin artması gibi olumsuz durumlarla karşılaşılabilmektedir.

Yeni eksenel fan muhafazasında mevcut konstrüktif kısıtların müsaade ettiği ölçüde giriş konisi (bell mouth), emiş kanalındaki duvar eğimleri, çıkış bölgesindeki engel mesafeleri, fan konumu gibi faktörler üzerinde aerodinamik prensipler ve ANSI/AMCA standartları çerçevesinde iyileştirme çalışmaları gerçekleştirilmiştir. Tasarımın akabinde Hesaplamalı Akışkanlar Dinamiği (HAD) yöntemi ile eski ve yeni tasarım ANSYS kullanılarak incelenmiştir. Hava debisinde %14 iyileştirme gözlemlenmiş ve 3B yazıcıdan prototip baskı alınarak çamaşır kurutma makinesi üzerinde test edilmiştir.

Mevcut tasarıma kıyasla daha maliyet etkin bir fan tasarımına geçiş yapılması hedeflenmiştir. Geçiş sonrası %20 daha düşük çaplı bir fan kullanılmasına rağmen akış kayıplarındaki iyileştirmeler sayesinde deneysel ölçümlerde hava debisinde %16 artış olduğu gözlemlenmiştir. Yapılan nümerik analizler ile deneysel ölçümler arasında yaklaşık %12 sapma gözlemlenmiş olup, analizde kullanılan modeldeki kabuller ve farklılıklar göz önüne alındığında sonuçlar birbiriyle uyumlu kabul edilmiştir.

İklimlendirme kabininde 35 °C sıcaklık ve %60 bağıl nem koşullarında gerçekleştirilen testlerde, yeni tasarımın kompresörü daha etkin soğuttuğu ve fan aç/kapa sayısının azaldığı belirlenmiştir. Ayrıca yarı yankısız ses odasında yapılan ölçümlerde ses seviyesinde 1,8 dB azalma sağlandığı tespit edilmiştir.

Elde edilen bulgular, eksenel fan muhafazalarındaki mekanik iyileştirmelerin, akış debisinde ve soğutma kapasitesinde artışı ve ses seviyesinde düşüşü önemli ölçüde sağlayabildiğini göstermiştir.

Anahtar Kelimeler: Isı pompalı kurutma makinesi, kompresör soğutma, eksenel fan, giriş konisi, HAD, hava akışı optimizasyonu.

COMPARISON OF THE EFFECT OF AIR DIRECTOR DESIGN ON PERFORMANCE USING NUMERICAL AND EXPERIMENTAL METHODS

SUMMARY

This study aims to enable the use of cost-effective fan alternatives by designing a housing that reduces flow losses and improves fan performance for axial fans used in compressor cooling in heat pump clothes dryers. If the compressor used in heat pump systems is not sufficiently cooled, negative consequences such as extended drying cycles and increased energy consumption may occur.

In the new axial fan casing, improvements were made on factors such as the inlet cone (bell mouth), wall inclinations in the suction channel, obstacle distances in the outlet area, and fan position, within the limits permitted by existing structural constraints, based on aerodynamic principles and ANSI/AMCA standards. Following the design, both the old and new designs were examined using the Computational Fluid Dynamics (CFD) method with ANSYS. A 14% improvement in air flow rate was observed, and a prototype was printed using a 3D printer and tested on a clothes dryer.

The goal was to transition to a more cost-effective fan design compared to the current design. Despite using a fan with a 20% smaller diameter after the transition, improvements in flow losses resulted in a 16% increase in air flow rate observed in experimental measurements. A deviation of approximately 12% was observed between the numerical analyses and experimental measurements, which can be attributed to the assumptions and differences in the model used in the analysis.

Tests conducted in a climate chamber at 35°C temperature and 60% relative humidity revealed that the new design's compressor cools more efficiently and reduces the number of fan on/off cycles. Additionally, measurements taken in a semi-anechoic sound chamber showed a 1.8 dB reduction in sound level.

The findings show that mechanical improvements in the axial fan housings can significantly increase flow rate and cooling capacity while reducing noise levels.

Keywords: Heat pump dryer, compressor cooling, axial fan, inlet cone, CFD, airflow optimization.

COMPARISON OF BROACHING AND CNC TURNING PROCESSES IN THE PRODUCTION OF AN INVOLUTE-PROFILED CONNECTION ADAPTER IN TERMS OF SURFACE QUALITY, CYCLE TIME, AND COST

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ABSTRACT

This study aims to compare broaching and CNC turning methods in the production of an involute-profiled connection adapter with 11 teeth in terms of surface quality, cycle time, and manufacturing cost. Machining operations are widely recognized as playing a critical role in both production efficiency and sustainable manufacturing. The material used in the experimental studies was 16MnCr5 steel, supplied in the as-received condition without any heat treatment. The hardness of the raw material was measured, and its chemical composition was verified through chemical analysis. The same raw material batch was used for both machining methods. Prototype parts were manufactured in quantities of 30 pieces for each method, and cycle times were recorded. These cycle times not only reflect production efficiency but also indicate whether shorter cycle times contribute to energy savings and more sustainable manufacturing practices. Surface roughness values (Ra and Rz) of all produced parts were quantitatively measured in accordance with ISO 21920 standards. When the manufacturing methods were compared, the components produced by CNC turning exhibited lower and more consistent surface roughness values. In contrast, the broaching process resulted in higher surface roughness values and a wider distribution. The total cost evaluation was carried out based on machine energy consumption, cycle times, and tooling costs. In the analysis, indirect costs such as operator wages, maintenance, and administrative expenses were not considered; only the direct energy consumption associated with changing the production method and the tooling costs were compared. Based on this evaluation, it was determined that under the investigated production conditions and assumptions, the broaching method is more advantageous in terms of energy consumption per part and total production cost. The obtained results enable a clear comparison of the economic performance of broaching and CNC turning methods with respect to energy efficiency and tool life.

Keywords: Broaching, Involute profile, Surface roughness, Cycle time, Manufacturing cost analysis, Sustainable manufacturing.

1. INTRODUCTION

In today's manufacturing industry, machining processes used in the production of mechanical power transmission components play a critical role in terms of product quality, production efficiency, cost, and sustainability. Particularly for components requiring high precision—such as gear couplings, spline profiles, and special-form adapters—surface quality and geometric accuracy have a direct impact on overall system performance. Surface defects that may occur in such connection elements can lead to reduced fatigue strength, increased noise and vibration levels, and premature failures in long-term operation [1, 2]. Involute-profiled connections are widely preferred in industry due to their ability to ensure uniform load distribution and their relatively high tolerance to manufacturing deviations. However, the manufacturing method employed for producing these profiles is a decisive factor affecting the resulting surface roughness, cycle time, and overall production cost.

In this context, broaching and CNC turning stand out as two fundamental machining processes frequently used in the manufacturing of internal-profiled and multi-tooth connection elements. The broaching process offers significant advantages in terms of high production rates and consistent surface quality, as it enables the machining of multiple teeth in a single pass. In contrast, CNC turning is often favored due to its flexibility, programmability, and lower initial investment costs. Nevertheless, studies that comparatively evaluate these two methods under identical part geometries and material conditions—particularly in terms of surface quality, cycle time, and cost—remain limited in the existing literature. Moreover, comparative assessments from the perspective of energy consumption and sustainable manufacturing are still insufficient.

Broaching machines offer significant advantages in terms of energy efficiency and sustainable manufacturing, especially in high-volume production processes. Thanks to their ability to machine multiple teeth in a single pass, broaching operations enable the fast and consistent production of large quantities of parts with short cycle times. This reduces energy consumption per unit, thereby lowering production costs and minimizing environmental impacts. The literature emphasizes that sustainability and energy modeling methods in mechanical machining processes contribute to the optimization of cutting parameters, tool selection, and cooling/lubrication conditions, allowing higher production efficiency with lower resource usage [3]. In this context, the suitability of broaching machines for mass production supports a sustainable approach both economically and environmentally.

In this study, the production of an involute-profiled connection adapter with 11 teeth was comparatively investigated using broaching and CNC turning processes. The comparison was conducted based on surface roughness parameters (Ra and Rz), cycle time, and machining cost. Experimental investigations were carried out under identical material conditions, equivalent geometric tolerances, and comparable production parameters to enable a direct and objective performance evaluation of both methods. The findings of this study are expected to provide valuable guidance for both academic research and industrial practice in the selection of appropriate manufacturing processes.



Figure 21. Example of a broaching tool [4]

"Broaching is a material removal process where a special tool called a broach (or broaching tool), generally with a linear movement, removes the material in a progressive way" [5]. Each successive tooth on the broach has a slightly increased cutting height, enabling the gradual removal of material and allowing complex profiles to be generated with high dimensional accuracy in a single pass. Due to this characteristic, broaching is particularly suitable for the production of internal spline connections, gear profiles, and other components requiring tight tolerances and consistent surface quality. Compared to conventional machining processes, broaching offers shorter cycle times and improved process stability, making it advantageous for high-volume production. Figure 2 shows parts broached in various forms.



Figure 22. Examples of parts produced using broaching [4]

Broach teeth are used in broaching machines to impart a specific cutting profile to the workpiece. Broaching tools are generally designed specifically for the workpiece to be machined, taking into account geometric features, dimensional tolerances, material type, hardness, and heat treatment conditions. These parameters play a decisive role in determining critical design elements of the broach tool, particularly the chip space geometry, tooth rise, and cutting tooth structure. Consequently, the direct dependency of broach tool design on part-specific characteristics necessitates an evaluation of the broaching process in terms of flexibility and manufacturing cost [6]. Broaching machines, powered by hydraulic or electromechanical drive systems, move the broach along the workpiece at a controlled and consistent speed. The machine's robust frame and precise guides ensure accurate alignment of the broach, providing high dimensional accuracy and repeatability. This allows complex profiles, such as gears, splines, or fir-tree structures used in the aerospace and energy sectors, to be produced reliably

and efficiently. Furthermore, modern broaching machines are equipped with sensor-based monitoring and data acquisition systems to track cutting forces and the effects on the workpiece surface, optimizing process control. This integrated approach ensures both high quality and industrial productivity. Figure 3 show, as examples, the general body and tooth structure of the broach.

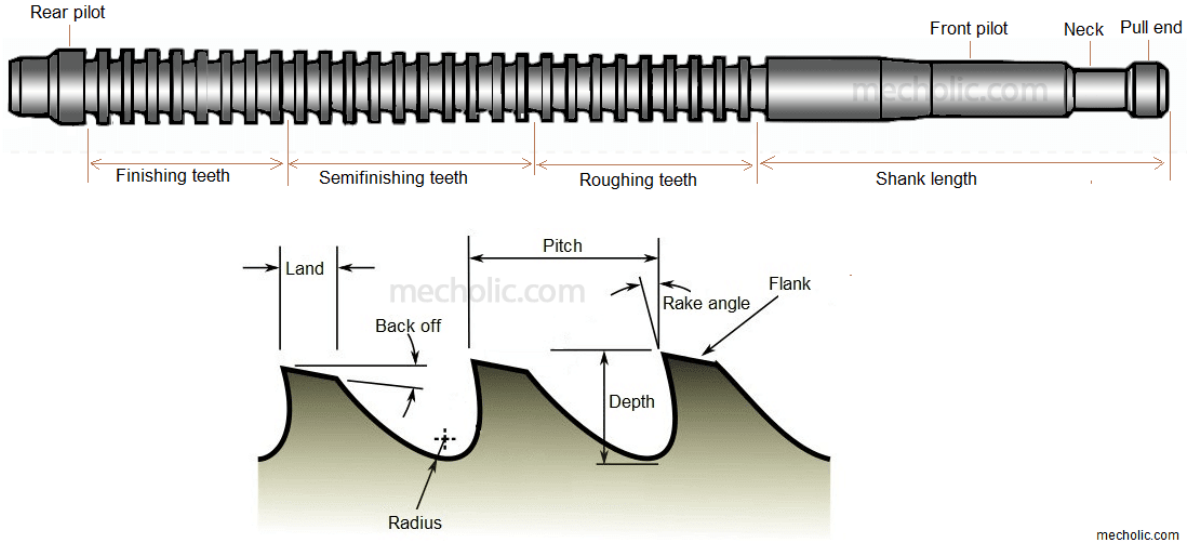


Figure 23. An example general broaching tool body and tooth structure [7]

The limitations of the broaching process and alternative manufacturing methods to overcome these challenges have been investigated in the literature [5]. The study highlighted the main disadvantages of broaching, including high capital cost, long setup times, high cutting forces, and lack of flexibility. To address these issues, the authors reviewed several alternative processes such as Wire EDM, milling, superabrasive machining (SAM), electrochemical machining (ECM), rotary broaching, and gear skiving. Each method was analyzed in terms of material removal mechanisms, surface integrity, geometrical accuracy, productivity, and cost. For instance, Wire EDM showed lower productivity than broaching but offered high accuracy and flexibility, while SAM improved surface finish and induced beneficial compressive residual stresses. ECM allowed high material removal rates without thermal or mechanical damage, and rotary broaching and gear skiving were identified as more flexible and cost-effective alternatives for complex profiles. Overall, the study concluded that although broaching remains preferred for applications requiring high precision and repeatability, alternative methods are increasingly viable due to their advantages in production flexibility and operating costs. These findings reinforce the importance of carefully selecting broaching parameters and considering alternative processes when flexibility, cost, or specific surface requirements are critical.

The parameters affecting surface roughness in the broaching process have been investigated in the literature [8]. Results showed that high cutting speed and low rise per tooth (RPT) reduce surface roughness, while increasing the rake angle and using a low clearance angle improve the surface. They reported that the tool substrate does not directly affect surface quality, although using carbide reduces cutting forces, and that straight oil lubrication decreases forces and improves surface roughness, whereas dry broaching leads to worse surface quality. Additionally, they found that dimples form on the surface of dual-phase ferritic–martensitic steel (X12Cr13), increasing roughness, while no such formation occurs in single-phase steels. Consequently, broaching surface quality is determined by cutting speed, RPT, tool geometry, lubrication, and workpiece material, and optimizing these parameters can significantly improve

surface quality. These results provide a useful reference for understanding the effects of cutting parameters, tool geometry, lubrication, and workpiece material on broaching surface quality.

The 56-year development of broaching technology has been comprehensively examined in the literature [9] In their study, 4,918 patents and numerous academic publications related to broaching worldwide were analyzed to reveal the evolution of the technology, research trends, and industrial applications. Key technical advancements, from the first broaching machines to hydraulic and vertical hydraulic systems, as well as improvements in tool monitoring, surface quality, and optimization of broaching parameters, were discussed. Modern approaches such as simulation and FEM modeling, environmentally friendly cutting fluids, flexible broaching equipment, and intelligent monitoring systems were also evaluated. The study highlights that China, Japan, and the former Soviet Union have been leading in the broaching field, with significant increases in technology investment in recent years. Overall, broaching technology continues to evolve in terms of efficiency, cost, and environmental impact, with future innovations expected in green manufacturing, flexible machines, and smart systems. These insights underline the growing importance of optimizing broaching processes not only for productivity and cost but also for material performance and component durability.

The effects of broaching parameters, residual stresses, and surface deformation (cold work) on the fatigue life of a Ni-based turbine disk P/M alloy at 650 °C have been investigated in the literature [1]. In the study, the wear condition of the broaching tools and the broaching speed were varied, and surface residual stresses, cold work, and surface roughness were measured, after which the relationships of these parameters with low-cycle fatigue (LCF) life were examined. The results showed that worn (“dull”) tools generated higher and deeper compressive residual stresses and greater cold work, which contributed to an increase in fatigue life. Moreover, fractures originating from subsurface inclusions were found to be closely related to the residual stress distribution. The study emphasizes the importance of uniform residual stresses and cold work in predicting fatigue life and highlights the necessity of applying surface enhancement methods, particularly shot peening, in broached regions. These results indicate that the broaching process can critically influence material fatigue behavior through the distribution of residual stresses and cold work.

The effects of the broaching process on the integrity of machined surfaces have been experimentally investigated in the literature [2]. In their study, AISI 12L14 and AISI 1045 steels, as well as Al 7075 aluminum alloy, were used to evaluate surface and subsurface characteristics after broaching. The results showed that the broaching process leads to plastic deformation and an increase in microhardness in near-surface regions, depending on the workpiece material. In particular, pronounced subsurface hardening was observed in steel materials, whereas this effect was reported to be more limited in the aluminum alloy. The authors emphasized that broaching parameters have a significant influence on surface integrity and should be considered in terms of the service performance of machined components. In this context, considering the decisive role of broaching in surface quality, its comparative evaluation with alternative manufacturing processes becomes important.

The influence of cutting edge microgeometry on the broaching performance of Inconel 718 slots has been experimentally investigated in the literature [10]. In their study, broaching tools with different cutting edge radii were employed, and the effects on cutting forces, surface quality, and tool wear were evaluated. The results showed that increasing the cutting edge radius

led to higher cutting forces while improving tool stability and edge durability. In terms of surface quality, intermediate cutting edge radii provided a balanced performance, whereas excessively sharp or overly rounded edges adversely affected surface roughness due to increased wear or ploughing effects. The authors emphasized that cutting edge microgeometry is a critical parameter for optimizing broaching processes, particularly when machining difficult-to-cut materials such as Inconel 718. This study demonstrates the decisive role of tool-related parameters in broaching processes on surface quality and provides a scientific basis for the comparative evaluation of broaching with other machining methods.

Although numerous studies focus on broaching individually or compare it with alternative methods under different conditions, direct comparisons between broaching and CNC turning for identical involute-profiled components are limited. Integrated evaluations addressing surface quality, cycle time, cost, and energy efficiency under identical conditions are scarce.

In this context, the present study provides a comprehensive and experimentally validated comparison of broaching and CNC turning in the production of an 11-tooth involute-profiled connection adapter from 16MnCr5 steel. By combining surface roughness measurements (Ra and Rz) with cycle time, tooling cost, and energy consumption analyses, this work offers a holistic assessment of both manufacturing methods. Unlike previous studies focusing on either surface integrity or process feasibility, this study integrates quality, productivity, economic efficiency, and sustainability within a single framework, providing practical insights for both industrial and academic applications.

2. MATERIALS AND METHODS

Following the literature review and the theoretical background of the broaching process, the experimental studies were conducted to quantitatively compare broaching and CNC turning under identical conditions. In this section, the workpiece material, test geometry, machining parameters, measurement methods, and evaluation criteria are described in detail. The experimental setup was designed to ensure a fair and direct comparison between the two manufacturing methods in terms of surface quality, cycle time, and machining cost.

2.1. Material and Specimen Geometry

In this experimental study, 16MnCr5 case-hardening steel was selected as the workpiece material due to its widespread use in power transmission components such as gears, spline connections, and mechanical adapters. The material was supplied in the as-received condition, and no heat treatment was applied prior to machining in order to eliminate the influence of thermal effects on surface integrity. The chemical composition of the material was verified by chemical analysis, and the initial hardness of the raw material was measured to ensure material consistency throughout the experiments. The chemical composition of the 16MnCr5 steel used in this study was measured using a spectrometer to ensure conformity with the relevant material standards. The spectrometric analysis was conducted to verify that the elemental composition of the material remained within the specified limits and to confirm the homogeneity of the test specimens. The obtained chemical analysis results are presented in Table 1 and constitute a reference for assessing the material behavior during the broaching and CNC turning experiments.

Table 7. Chemical composition of workpiece material, 16MnCr5 steel (wt.%)

C	Si	Mn	Cr	P	S	Mo
0,185	0,253	1,115	0,938	0,0133	0,0031	0,155

In the annealed (+A) condition, 1.7131 (16MnCr5) steel exhibits moderate tensile strength and high ductility, making it suitable for machining operations such as broaching and turning.

Table 8. Mechanical properties of the workpiece material, 16MnCr5 steel [11]

Property	Symbol	Unit	Value
Tensile Strenght	Rm	MPa	550
Yield strength (0.2% proof stress)	Re	MPa	420
Elastic Moduls	E	GPa	205
Poisson's Ratio	v	-	0,3
Min. elongation Lo = 80 mm	A	-	21
Brinell Hardness	HB	-	207

2.2. CNC Turning Equipment, Tooling and Setup

The CNC turning experiments were carried out on a CNC lathe capable of performing both conventional turning operations and milling-based processes through live tooling. The machine is equipped with a rigid spindle structure, a programmable turret system, and a high-precision control unit, enabling stable machining under controlled cutting conditions. Its capability to synchronize spindle motion with auxiliary tool rotation made it suitable for producing complex internal profiles required in this study. The machine configuration ensured repeatable positioning accuracy and minimized vibration effects during the machining of the internal involute profile. Figures 4, 5 and 6 illustrate the CNC lathe used in the experiments and the live tooling setup applied for the internal tooth machining operation.

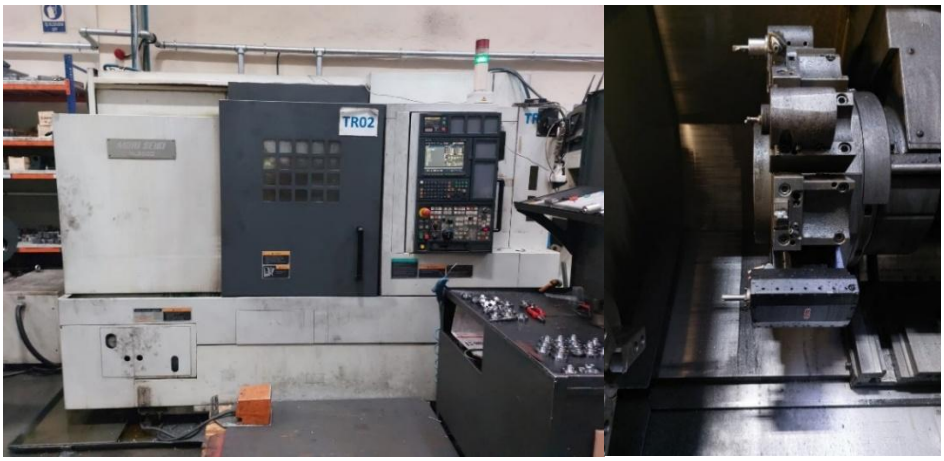


Figure 24. CNC lathe equipped with live tooling used for internal profile machining

Table 9. Technical specifications of the Mori Seiki NL2500 CNC lathe [12]

Parameter	Value
Machine Type	Horizontal CNC Lathe
Number of axes	3

Spindle power	18,5 kW
Maximum spindle speed	4000 rpm
Tool capacity	12 stations
X-axis travel	260 mm
Z-axis travel	795 mm

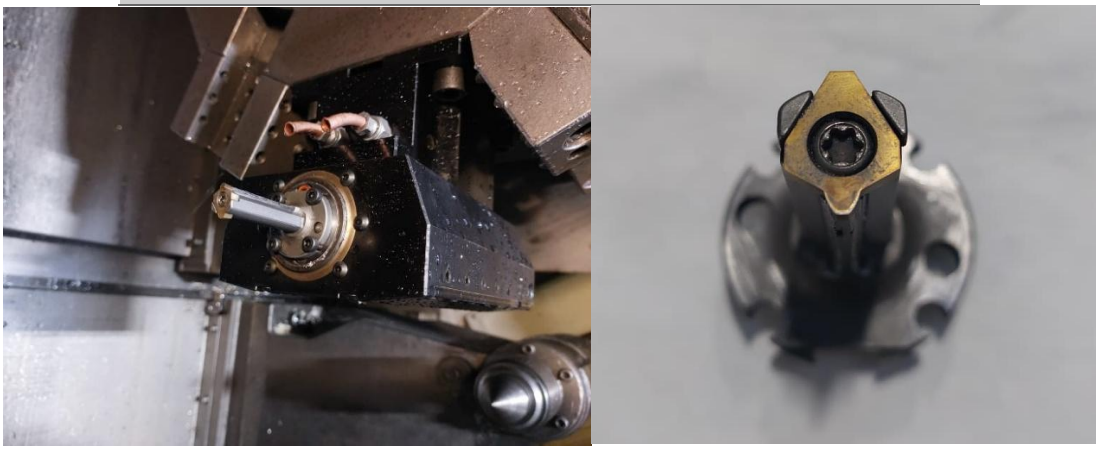


Figure 25. Live broaching tooling setup and cutting tool

In this study, the live tooling capability of the CNC lathe was utilized through a WTO broaching unit integrated into the turret system. The WTO broaching unit converts the rotational motion of the live tool drive into a controlled linear reciprocating movement, enabling broaching operations to be performed on a turning center. During machining, the workpiece remains stationary in the spindle, while the broaching tool executes a synchronized stroke along the machining axis. This configuration allows internal profiles to be generated with high positional accuracy and repeatability, while eliminating the need for a dedicated broaching machine. The use of the WTO unit also ensures a compact and rigid setup, which contributes to stable cutting conditions and consistent surface quality.

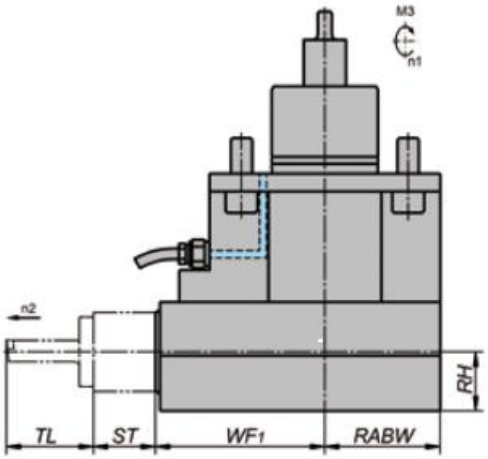


Figure 26: Broaching unit [13]

Table 10. Technical specifications of the live tool broaching unit [13]

Parameter	Value

Type	52
Working Stroke	52 mm
Max. Strokes	800 (1/min)
Ratio	1:1
Max. feed per stroke	0.15 mm

As shown in Figure 7, the cutting tool used in this study is an internal spline broaching cutting insert designed for use on a CNC turning center via a WTO broaching unit, rather than a conventional broaching machine tool. The tool geometry conforms to the ANSI B92.1 standard and is based on an involute spline profile with 11 teeth and a nominal pressure angle of 30°, which is commonly employed in torque-transmitting mechanical connections. This spline configuration is widely preferred in power transmission applications due to its favorable load distribution characteristics and compatibility with standardized mating components. The selected tooth number and pressure angle have a direct influence on contact conditions, cutting forces, and surface integrity during the broaching process, making this tool geometry particularly relevant for the experimental evaluation carried out in this study. The tool is made of carbide and is coated with AlCrSiN, providing enhanced wear resistance and high-temperature performance, which are critical for maintaining dimensional accuracy and surface quality throughout the machining process.

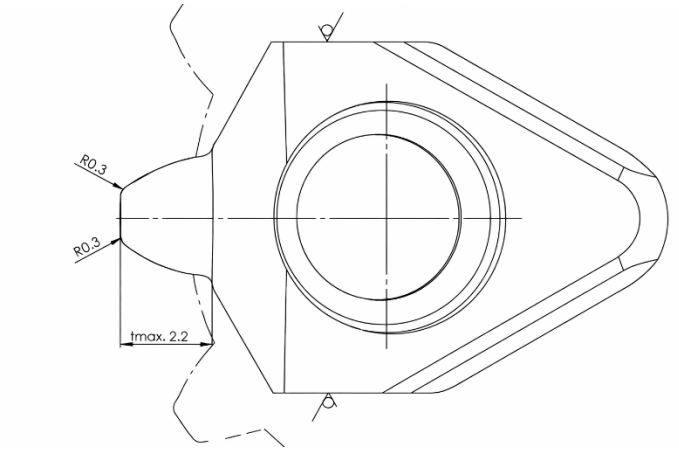


Figure 27. Cutting tool geometry of the 11-tooth internal involute spline broach with a 30° pressure angle according to [14]

The CNC lathe previously described was employed as the base platform for the turning-based internal spline machining experiments. In this study, the machine was utilized not for conventional external turning, but as an integrated machining system capable of generating internal profiles through synchronized spindle and live tool motion. The experimental setup was configured to ensure stable workpiece clamping, accurate tool positioning, and controlled kinematic coordination between rotational and feed movements. Special attention was given to minimizing runout and vibration effects during the internal machining of the involute spline geometry. The machining strategy relied on the controlled interaction between the main spindle and the driven tooling system, enabling consistent material removal along the internal profile. The experimental configuration and tooling arrangement adopted for the CNC turning trials are schematically presented in Figures 4 and 5.

The CNC turning operations were performed under controlled cutting conditions to ensure repeatability and comparability with the broaching experiments. Cutting parameters were selected based on tool manufacturer recommendations and preliminary trials, aiming to achieve stable cutting behavior and acceptable surface quality. All turning operations were conducted using identical machining conditions for each specimen in order to eliminate the influence of parameter variation on the experimental results. The main turning parameters applied during the CNC turning experiments are summarized in Table 5.

Table 11. CNC turning parameters used in the experiments

Parameter	Symbol	Value
Cutting Speed	Vc	10.4 m/min
Feed Rate	f	0.15 mm/stroke
Depth of cut	-	1.75 mm
Coolant	-	Flood cooling
Machining strategy	-	Internal profile machining

A total of 30 workpieces were machined during the CNC turning experiments. Prior to the start of the operations, both the machine cutting fluids and the workpieces were brought to a controlled operating temperature to minimize thermal effects on dimensional accuracy and surface finish. This pre-conditioning ensured that the machining environment remained stable, reducing the influence of thermal expansion or contraction during the internal spline formation. All turning operations were performed under consistent cutting conditions, with identical tool setup and clamping procedures for each specimen, in order to maintain repeatability and comparability across the experimental series.

2.3. Broaching Equipment, Tooling and Setup

The broaching experiments were carried out on a vertical hydraulic broaching machine designed for internal profile machining. The machine provides a rigid structural configuration and controlled linear motion, allowing the broaching tool to advance steadily along the machining axis. This setup ensures suitable conditions for achieving dimensional accuracy and repeatability in internal involute profile machining. The technical specifications of the broaching machine are summarized in Table 6.

Table 12. Technical specifications of the broaching machine

Parameter	Value
Machine Type	Vertical Broaching Machine
Drive System	Hydraulic
Main Drive Motor Power	7,5 kW
Nominal Pulling Capacity	25 ton
Stroke Type	Linear
Cooling Method	Flood Cooling

During the broaching process, the workpiece was rigidly clamped using a dedicated fixture to prevent displacement and axial misalignment under cutting forces. The broaching tool was guided through the internal bore of the workpiece along the machining axis, while the workpiece remained stationary. This configuration ensured stable tool–workpiece interaction throughout the cutting process and helped to minimize vibration effects. Appropriate cooling conditions were applied during machining to control friction and thermal influences.

The broaching tool used in the experiments was an internal involute spline broach designed in accordance with the ANSI B92.1 standard and matched the spline geometry employed in the CNC turning experiments. This approach enabled a direct comparison between broaching and CNC turning based on the same geometric reference, ensuring that the observed differences in surface roughness, cycle time, and cost were independent of tool geometry.

All broaching operations were performed under identical machining conditions for each specimen to ensure repeatability and direct comparability with the CNC turning experiments. The machined samples were subjected to surface roughness measurements without any additional surface treatment. The applied broaching parameters and details of the experimental setup are summarized in Table 7.

Table 13. Broaching parameters used in the experiments

Parameter	Symbol	Value
Cutting Speed	Vc	5 m/min
Feed Rate	f	Defined by broach tool geometry (rise per tooth)
Depth of cut	-	1.75 mm
Coolant	-	Flood cooling
Machining strategy	-	Single-pass internal broaching

2.4. Surface Roughness Measurement

Surface roughness measurements were performed using a Mitutoyo SJ-410 contact-type surface profilometer. All measurements were conducted along the cutting axis of the workpieces.



Figure 28: Surface roughness tester - Mitutoyo Contact Type Surface Profilometer

The measurement parameters used in this study are summarized in Table 6. Ra and Rz values were recorded for each specimen. Measurements were performed in accordance with standard [15].

Table 14. Surface roughness measurement parameters

Parameter	Symbol	Value
Cut of Lenght	λc	0.8 mm
Evaluation length	Ln	4 mm
Traverse speed	-	0.5 mm/s
Measured parameters	-	Ra, Rz
Measurement direction	-	Along cutting axis

Surface roughness measurements were performed in accordance with the ISO 21920 series. (ISO 21920, 2021) Two key roughness parameters, Ra (arithmetic average roughness) and Rz (average maximum height of the profile), were evaluated. Ra represents the arithmetic mean of the absolute deviations of the surface profile from the mean line over the measurement length, providing a general indication of surface roughness. Rz is calculated as the average of the vertical distance between the highest peak and the deepest valley in each sampling length, offering additional information about occasional peaks or scratches.

2.4. Manufacturing Cost Analysis Method

In this study, the energy consumption of broaching and CNC turning methods in the production of an involute-profiled connection adapter was compared. Indirect costs such as operator wages, maintenance, and administrative expenses were not included in the analysis; only the energy consumed by the machine when changing the production method was measured and compared. This approach highlights the performance of each production method in terms of energy

efficiency and allows an assessment of the processes from the perspective of sustainable manufacturing. The results clearly demonstrate the energy differences between broaching and CNC turning. The energy consumption per part for each production method was calculated based on shift duration, setup time, and part cycle time using the following equations:

2.4.1. Available Production Time per Shift

The effective production time in a single shift was determined by subtracting the setup time from the total shift duration (Equation 1):

$$\boldsymbol{T_{avaliable} = T_{shift} - T_{setup}} \quad (2)$$

In Equation (1), $T_{avaliable}$ represents the available production time per shift, T_{shift} is the total shift duration, and T_{setup} is the setup time. This equation calculates the time that can actually be used for machining parts.

2.4.2. Number of Parts Produced per Shift

In order to evaluate the production efficiency of each machining method, the number of parts that can be produced per shift is calculated. This allows a direct comparison between broaching and CNC turning in terms of output within a fixed production time.

$$N_{parts} = \frac{T_{avaliable}}{T_{part}} \quad (2)$$

The number of parts produced per shift is calculated using Equation (2). Here, N_{parts} represents the number of parts produced per shift, $T_{avaliable}$ is the available production time per shift (after setup), and T_{parts} is the cycle time per part including part change.

2.4.3. Total Energy Consumption per Shift

To estimate the energy usage of each machining method, the total electrical energy consumed by the machine during a full shift is calculated. This allows a comparison of energy efficiency between broaching and CNC turning.

$$E_{shift} = P_{machine} \times T_{avaliable} \quad (3)$$

The total energy consumed per shift is calculated using Equation (3). Here, E_{shift} represents the total energy in kilowatt-hours (kWh), $P_{machine}$ is the machine power in kilowatts (kW), and $T_{avaliable}$ is the available production time per shift in hours.

2.4.4. Energy Consumption per Part

To assess the efficiency of each machining method at the part level, the energy consumed for producing a single component is calculated. This metric allows direct comparison of energy savings between broaching and CNC turning.

$$E_{part} = \frac{E_{shift}}{N_{parts}} \quad (4)$$

The energy consumed per part is calculated using Equation (4). Here, E_{part} represents the energy in kilowatt-hours (kWh) per part, E_{shift} is the total energy consumed per shift, and N_{parts} is the number of parts produced per shift.

The basic parameters required to calculate the energy consumption per part for CNC turning and broaching are summarized in Table 7. These include shift duration, setup time, available production time, cycle time per part, and machine power. Available production time is obtained by subtracting the setup time from the total shift duration, while the cycle time per part includes part change. Machine power differs for each manufacturing method and is specified in the table. This information provides the foundation for calculating the number of parts produced per shift and the corresponding energy consumption per part.

Table 15. Basic parameters for production cost comparison

Parameter	CNC Turning	Broaching	Unit
Shift Duration	8	8	h
Setup Time	1	2	h
Available Production Time	7	6	h
Cycle Time per Part	152	20	s
Machine Power	18.5	7.5	kW

2.4.5. Tooling Costs

Tooling costs represent a significant parameter in the economic analysis of manufacturing processes and are particularly critical for accurately determining production costs in precision internal profiles. The cost of tooling per part is calculated by taking into account both the total cost of the tool and its service life. This calculation enables direct comparison between different manufacturing methods and provides a basis for cost-effective production planning. The cost per part can be calculated using the following equation 5:

$$C_{tool\ per\ part} = \frac{C_{tool}}{N_{tool\ life}} \tag{5}$$

Where $C_{tool\ per\ part}$ is the tooling cost per part, C_{tool} is the total cost of the tool, and $N_{tool\ life}$ is the total number of parts that can be machined over the tool's service life. These equations can be applied for both broaching and CNC turning processes, allowing the calculation of the per-part tooling cost and the completion of an economic analysis.

Tooling costs are an important parameter in the manufacturing cost analysis. In this study, the costs and service lives of the tools used in broaching and CNC turning operations were determined based on past production experience. Tool life was defined as the number of parts that could be machined while maintaining dimensional accuracy and acceptable surface quality. The tooling cost and tool life values for both manufacturing methods are presented in Table 10.

Table 16. Tool cost and tool life

Manufacturing Method	Tool Type	Total Tool Cost (USD)	Tool Life (parts)
Broaching	11-Tooth Internal Broach	2500	20.000
CNC Turning	Internal Carbide Cutting Insert (AlCrSiN)	35	120

3. RESULTS AND DISCUSSION

The experimental results obtained from the broaching and CNC turning processes are presented in this section. Surface roughness measurements (Ra and Rz) were performed on all machined specimens in accordance with standards [15], and representative microscope images of the machined surfaces were captured to visually assess the surface integrity. In addition, cycle times for each machining operation were recorded, and a detailed cost analysis was conducted based on the power consumption of the machines and tool cost. The data are presented in graphical form to facilitate a direct comparison between the two manufacturing methods. The results are discussed in terms of surface quality, production efficiency, and economic considerations, providing insight into the advantages and limitations of each process.

3.1. Surface Roughness of Machined by CNC Turning

Among the 30 components produced by the CNC turning process, two specimens exhibited significantly higher surface roughness values compared to the remaining parts. The Ra and Rz values of these two components are presented separately in Figure 11. The surface roughness measurements of the other 28 components, which showed relatively consistent and lower values, are illustrated in Figure 10. For illustrative purposes, the surface roughness graph of specimen No. 5 is presented in Figure 9.

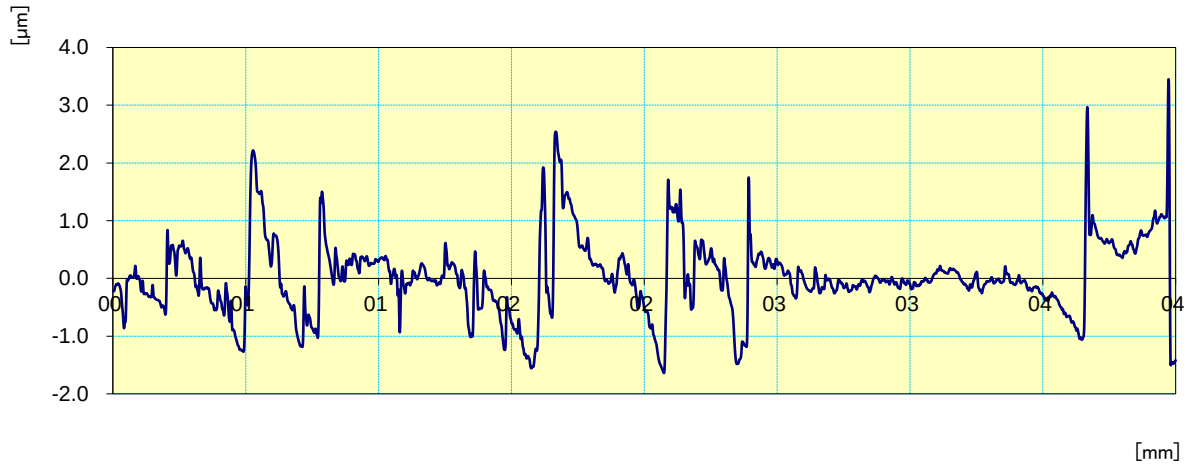


Figure 29. Surface roughness measurement graph of specimen no 5 (Ra=0.46 µm, Rz=3.17 µm)

Surface roughness measurements were performed along the cutting axis direction of the workpiece. Measurements in the transverse direction could not be conducted due to geometric limitations of the internal involute profile and restricted access to the measurement area. The selected measurement direction corresponds to the primary material removal direction during machining and is therefore representative of the surface characteristics generated by the cutting process. Measuring surface roughness along the cutting axis enables the assessment of tool–workpiece interaction effects, such as feed marks and cutting-induced surface features, which are critical for evaluating the functional surface quality of involute-profiled connections.

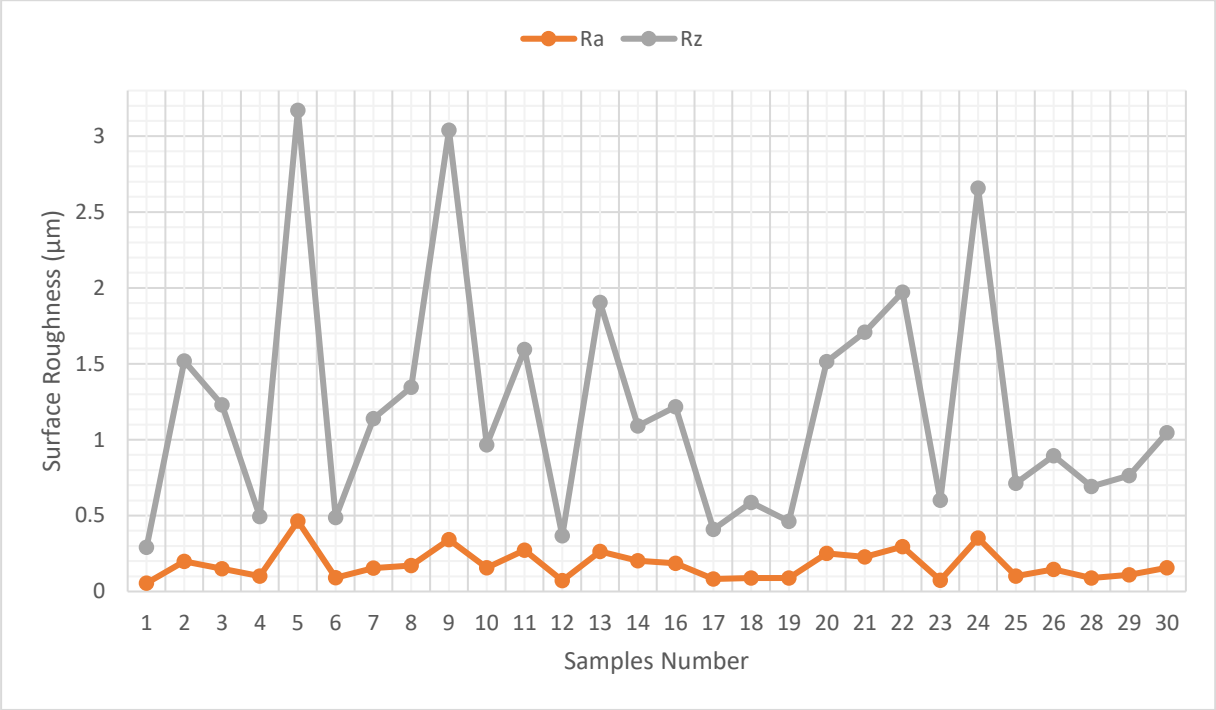


Figure 30. Surface roughness of parts machined by CNC turning

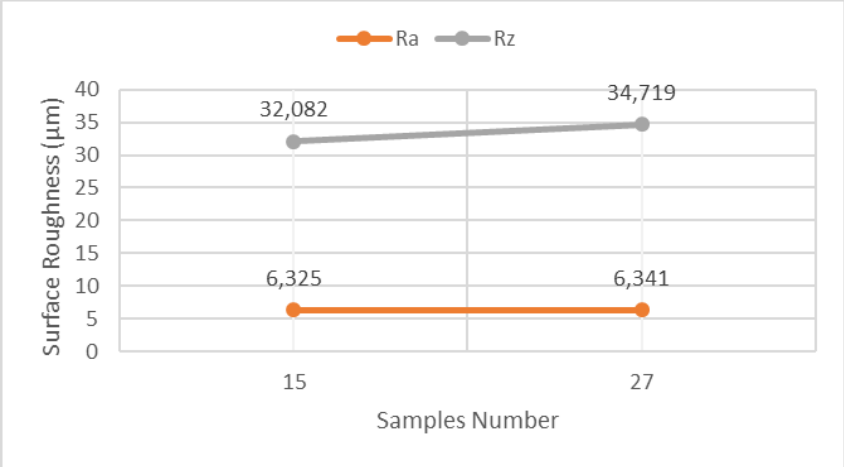


Figure 31. Surface roughness of parts machined by CNC turning

In order to provide a clearer comparison and to evaluate the overall surface quality obtained by CNC turning, the average Ra and Rz values calculated from all measurements are presented in Figure 12.

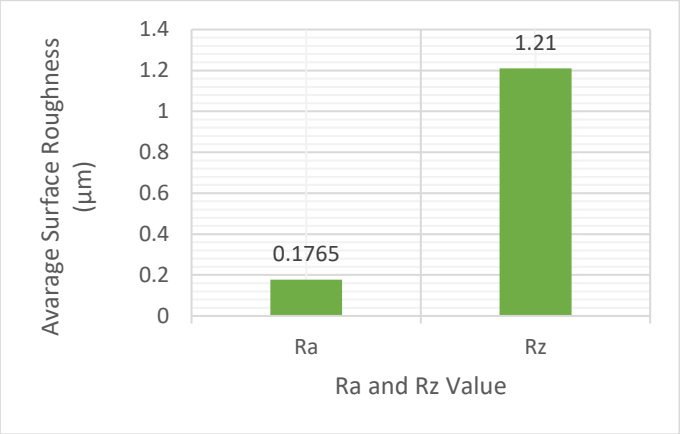


Figure 32. Average surface roughness of parts machined by CNC turning

3.2. Surface Roughness of Machined by Broaching

Surface roughness measurements were conducted on the internal involute profiles of the components machined by the broaching process using the same measurement methodology applied for the CNC turning samples. Similar to the turning measurements, Ra and Rz values were measured along the cutting direction, as transverse measurements were not feasible due to the geometric constraints of the internal involute profile and limited accessibility to the measurement area.

The broached components exhibited a wider variation in surface roughness values compared to those produced by CNC turning. While some specimens showed acceptable Ra and Rz levels, noticeable fluctuations were observed among different samples, indicating a less stable surface generation mechanism during broaching. This variability suggests that the broaching process is more sensitive to factors such as tool condition, tooth engagement consistency, and cutting parameter distribution along the broach length.

The measured surface roughness values reflect the progressive cutting nature of the broaching process, where successive cutting teeth with increasing chip loads may lead to non-uniform material removal. Additionally, the inherently lower cutting speeds employed in broaching, compared to CNC turning, may contribute to increased surface irregularities and higher scatter in Ra and Rz values.

For illustrative purposes, the surface roughness graph of specimen No. 9 is presented in Figure 13, while the surface roughness values of all experimental specimens are shown in Figure 14.



Figure 33. Surface roughness measurement graph of specimen No. 9 (Ra=1.04 µm, Rz=7.08 µm)

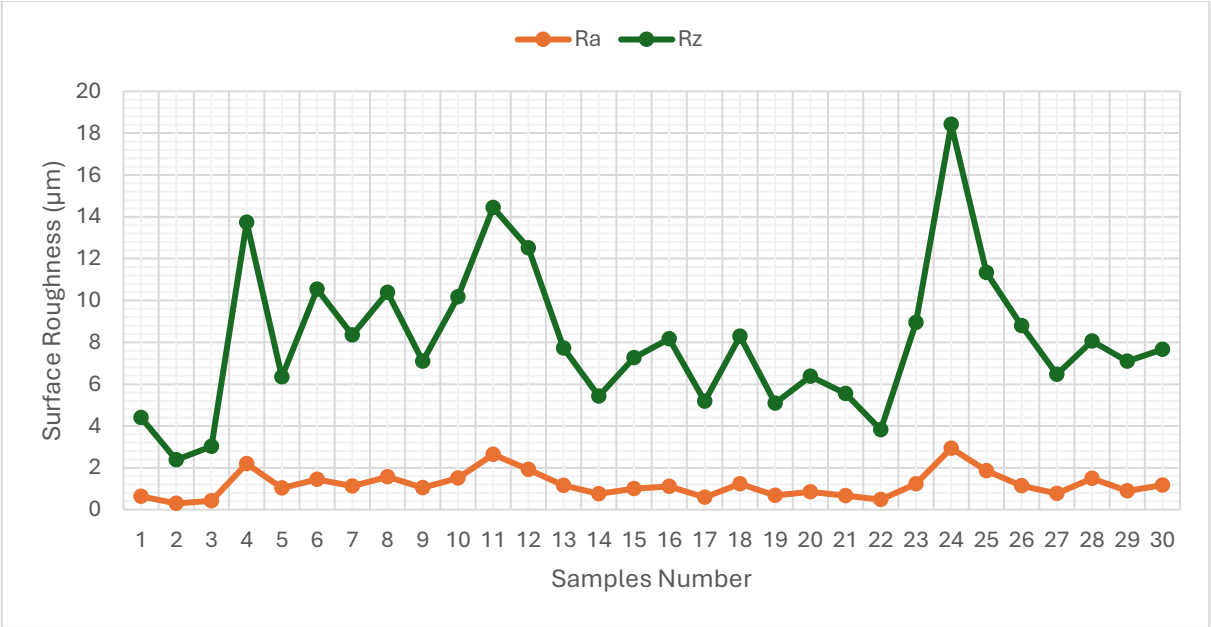


Figure 34. Surface roughness of parts machined by broaching

To facilitate a direct comparison with the CNC turning process and to evaluate the overall surface quality achieved by broaching, the average Ra and Rz values calculated from all broached components are presented in Figure 14. These results provide a quantitative basis for assessing the relative surface quality and process stability of broaching in the production of internal involute profiles.

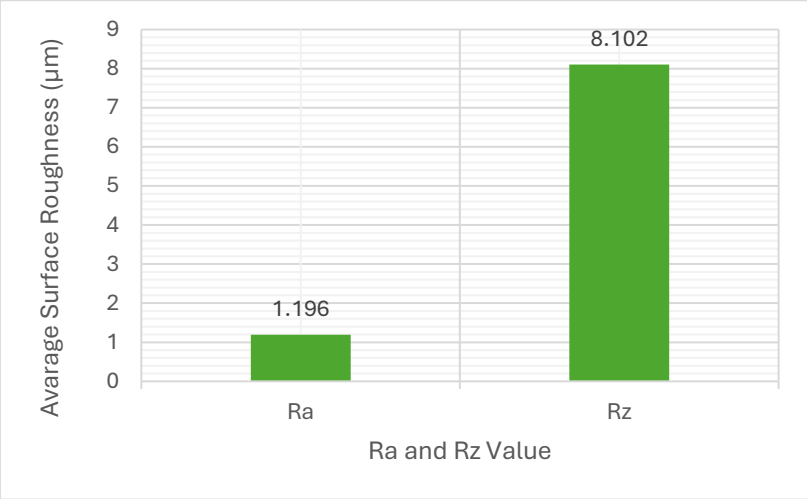


Figure 35. Average surface roughness of parts machined by broaching

3.3. Surface Roughness Compare Machined by CNC Turning and Broaching

The comparison of surface roughness results shows that the components machined by CNC turning exhibited lower Ra and Rz values than those produced by broaching. This indicates that CNC turning provided a smoother surface finish for the internal involute profiles under the investigated machining conditions. In contrast, broaching resulted in higher surface roughness values, reflecting a less stable surface generation mechanism.

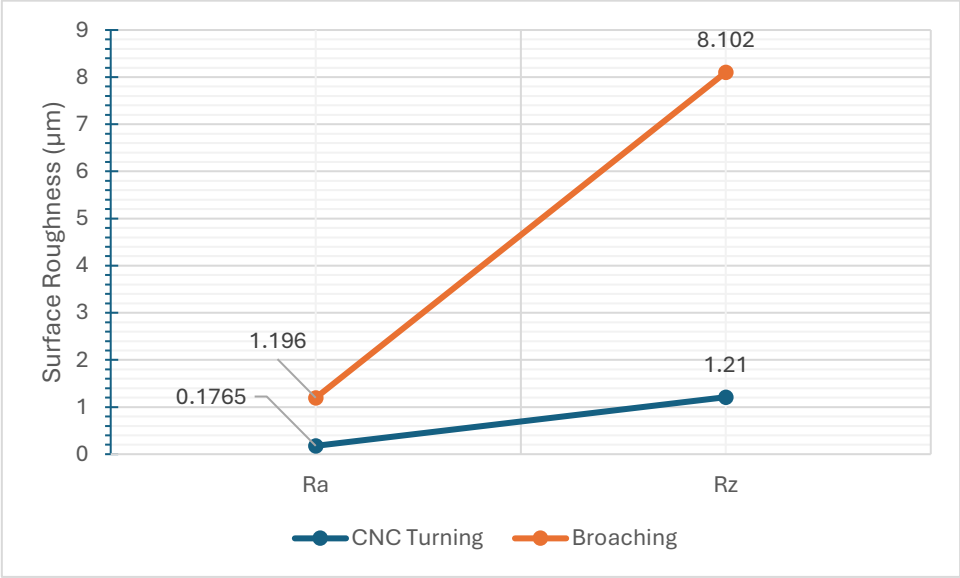


Figure 36. Surface roughness compare machined by CNC turning and broaching

3.4. Microscope Images of CNC Turning Surfaces

Microscope images of the CNC turning surfaces are presented in Figure 17 to evaluate the surface integrity and topographical characteristics of the internal involute profiles produced by turning.

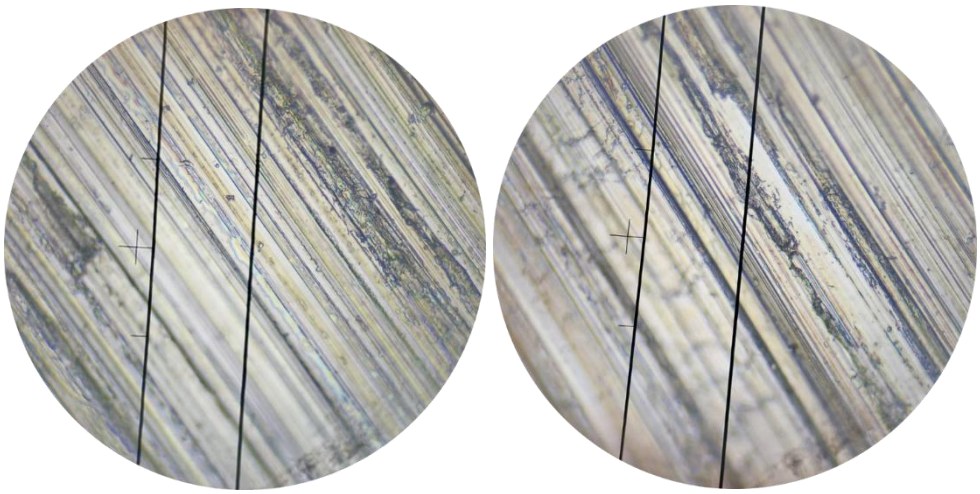


Figure 37. Microscope images showing the surface morphology of CNC turning parts

The images reveal distinct feed marks and periodic surface patterns aligned with the tool feed direction, which are typical of the CNC turning process. Localized surface irregularities and tool-induced textures can be observed, indicating the influence of cutting parameters and tool–workpiece interaction on the resulting surface morphology. These features play a critical role in the functional performance of power transmission components, particularly in terms of contact behavior and wear characteristics. When evaluated together with the measured surface roughness values (Ra and Rz), the microscope images provide qualitative support for the quantitative roughness results, highlighting the correlation between cutting conditions and surface quality in CNC turning.

3.5. Microscope Images of Broaching Surfaces

Microscope images of the broached surfaces are presented in Figure 18 to examine the surface integrity and topographical features of the internal involute profiles produced by broaching.

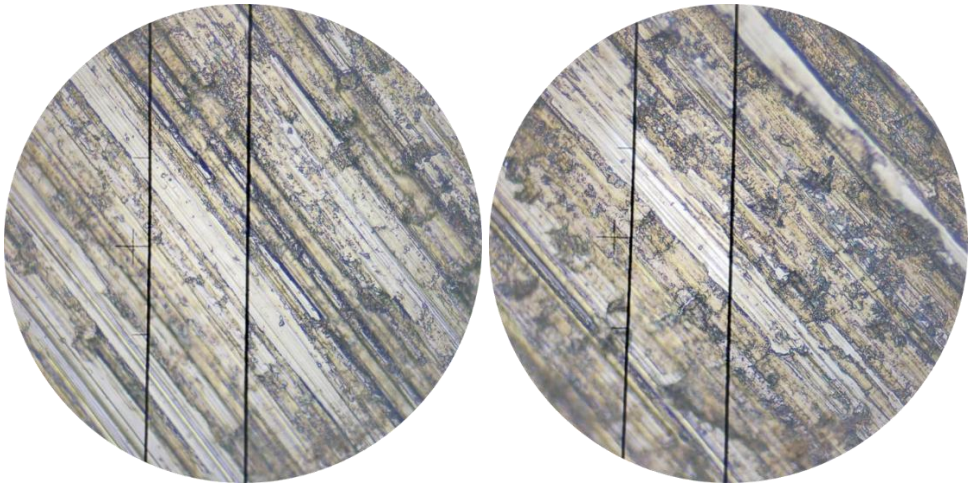


Figure 38. Microscope images showing the surface morphology of broaching parts

Compared to CNC turning, the broached surfaces exhibit a more unstable cutting pattern and less uniform surface morphology along the involute flanks. The microscope images reveal irregular cutting marks and locally varying surface textures, indicating fluctuations in the

cutting engagement of successive broach teeth. This behavior suggests a less stable material removal mechanism during the broaching process.

The observed surface instability may be related to differences in cutting speed between the two processes. While CNC turning was performed at relatively higher cutting speeds, broaching inherently operates at lower cutting speeds, which can promote discontinuous chip formation and increase sensitivity to tool–workpiece interactions. As a result, localized surface disturbances and non-uniform textures become more pronounced on broached surfaces.

This interpretation is supported by the higher variability observed in the measured Ra and Rz values of the broached parts, indicating that cutting speed plays a significant role in surface formation stability for internal involute profiles.

3.6. Energy Consumption and Production Cost Comparison

The tooling costs, effective tool life, and corresponding unit cost per part for the broaching and CNC turning processes are summarized in figure 19. The number of parts each tool can machine accurately and reliably was determined based on previous production experience. Tool prices include sharpening or replacement costs.

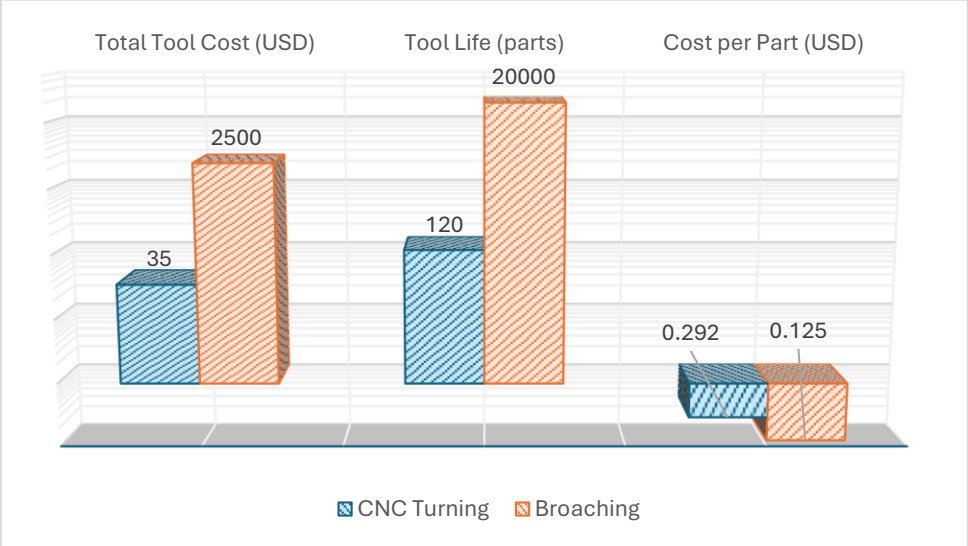


Figure 39: Tooling cost, effective tool life, and unit cost per part for broaching and CNC turning.

The production times and number of parts produced per shift for both CNC turning and broaching processes are summarized in figure 20. These values include total shift duration, setup time, available production time, and cycle time per part, allowing a direct comparison of production efficiency between the two methods.

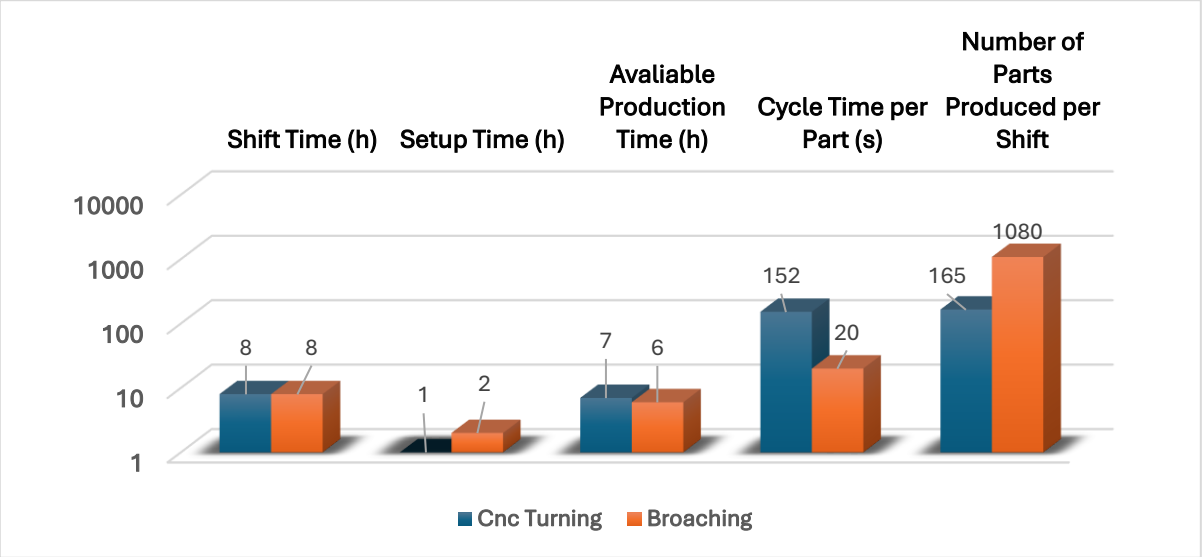


Figure 40: Production times and output per shift for CNC turning and broaching processes

Energy consumption per part is an important indicator for the sustainability and efficiency of manufacturing processes. The figure 21 presents a comparative evaluation of per-part energy consumption for CNC turning and broaching processes. This comparison clearly illustrates the energy efficiency of both methods.

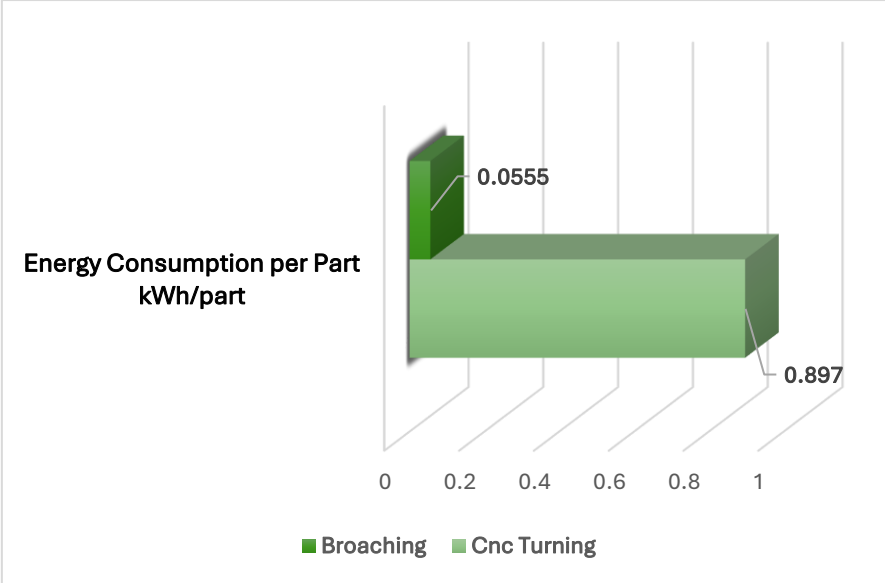


Figure 41: Comparison of energy consumption per part for CNC turning and broaching

4. CONCLUSIONS

In this study, broaching and CNC turning processes were comparatively evaluated in the manufacturing of an 11-tooth involute-profiled connection adapter produced from 16MnCr5 steel. The comparison was carried out under identical material and geometric conditions based on surface quality, cycle time, production volume, energy consumption, and manufacturing cost.

Surface roughness measurements showed that the components machined by CNC turning exhibited lower and more consistent Ra and Rz values compared to those produced by broaching, indicating a smoother and more stable surface finish for internal involute profiles. However, with appropriate process parameters and tool selection, broaching can also achieve good surface quality and maintain profile accuracy. The broaching process demonstrated higher variability in surface roughness due to its progressive cutting mechanism and lower cutting speeds, yet it provides the potential for high-quality surfaces with optimized conditions.

From the perspective of production efficiency and volume, broaching clearly outperformed CNC turning. Considering an available production time of 7 hours per shift for CNC turning and 6 hours per shift for broaching, approximately 165 parts can be produced using CNC turning, whereas about 1080 parts can be manufactured by broaching, representing an increase of approximately 555% in production volume. These results confirm broaching's suitability for high-volume production applications.

The energy consumption analysis revealed that broaching consumes significantly less energy per part, and when combined with its much shorter cycle time, it offers a major advantage in energy efficiency and sustainability. This highlights broaching as a more environmentally friendly and resource-efficient manufacturing option compared to CNC turning.

Manufacturing cost analysis, considering only direct energy consumption and tooling costs, showed that broaching is more economical on a per-part basis. Although broaching tools require higher initial investment, their long service life results in lower tooling cost per part, contributing to overall production economy.

Experimental results emphasize the importance of optimizing process parameters such as cutting speed, rise per tooth (RPT), feed rate, depth of cut, and tool geometry to maximize both surface quality and production efficiency. CNC turning offers greater programmability and flexibility, making it suitable for low-volume or variable products, whereas broaching excels in high-volume, repetitive production with reduced energy consumption and cost.

Therefore, the choice between broaching and CNC turning should be carefully evaluated according to production volume requirements, surface quality expectations, profile accuracy, cost targets, and sustainability considerations. The findings of this study provide practical guidance for industrial applications and future academic research in selecting appropriate manufacturing processes for internal involute-profiled components.

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ÇİFTLİK BİYOGÜVENLİĞİ: HASTALIK KONTROLÜ, RİSK YÖNETİMİ VE SÜRDÜRÜLEBİLİRLİK

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ÖZET

Küreselleşme, yoğun üretim ve artan zoonotik riskler biyogüvenliği kritik bir öncelik haline getirmiş ve veteriner hekimliğin odak noktasını, bireysel hayvanların tedavisinden sürü düzeyinde hastalıkların önlenmesine kaydırmıştır. Çiftlik biyogüvenliği, hayvan sağlığını korumayı, bulaşıcı hastalıkların giriş ve yayılımını önlemeyi, insan ve toplum sağlığını güvence altına almayı ve sürdürülebilir üretimi desteklemeyi amaçlayan sistematik ve çok boyutlu önlemler bütünüdür. Sürü düzeyinde etkin hastalık kontrolü, önleyici ve hazırlık stratejileri ile müdahale ve iyileşme önlemlerinin dengelenmesini gerektirir. Bu denge, olayın gerçekleşme olasılığı, beklenen ekonomik sonuçlar ve uygulanan stratejilerin maliyeti ve etkinliği gibi faktörlerle belirlenir. Etkin biyogüvenlik uygulamaları, üretim ve karlılığı artırırken, hayvan refahı ve sağlığını iyileştirir, yetiştirici memnuniyetini yükseltir ve antimikrobiyal kullanımını azaltır. Ancak araştırmalar, çoğu hayvan yetiştiricisinin bu önlemleri tam olarak uygulamadığını göstermektedir**.** Yetiştiricilerin biyogüvenlik uygulamalarına bakış açıları ve karar alma süreçleri, uygulamaların başarısını doğrudan etkilemektedir çünkü bu tedbirler her çiftlikte aynı şekilde ve etkinlikle uygulanamayabilir. Bu nedenle biyogüvenliğin etkili bir önleyici araç olarak fayda sağlayabilmesi için, hangi önlemlerin ne ölçüde ve nasıl uygulanması gerektiğinin doğru bir şekilde anlaşılması kritik öneme sahiptir. Belirlenen potansiyel tehditlerin etkileri değerlendirilmeli ve çiftlikteki koşullara göre önleyici ve düzeltici tedbirler alınmalıdır. Bu bildiride, hayvancılık işletmelerinde hastalıkların bulaşma yolları ile bu riskleri azaltmaya yönelik biyogüvenlik uygulamalarını ele alan bilimsel çalışmalar incelenmiş ve sürdürülebilirlik perspektifinden biyogüvenlik stratejilerinin hayvan sağlığı ve refahına etkileri tartışılmıştır.

Anahtar Kelimeler: Hastalık Kontrolü, Risk Yönetimi, Sürdürülebilirlik, Çiftlik Biyogüvenliği

ON-FARM BIOSECURITY: DISEASE CONTROL, RISK MANAGEMENT, AND SUSTAINABILITY

ABSTRACT

Globalisation, intensive production systems and the increasing prevalence of zoonotic diseases have made biosecurity a critical priority in veterinary medicine, shifting the focus from treating individual animals to preventing disease at theherd level. Farm biosecurity is a systematic, multidimensional framework of measures designed to protect animal health, prevent the introduction and spread of infectious diseases, safeguard public and human health, and ensure sustainable production. Effective herd-level disease control requires a balance between preventive and preparedness strategies and intervention and recovery measures. The factors that determine this balance include the likelihood of occurrence, the anticipated economic outcomes and the cost-effectiveness of the implemented strategies. Effective biosecurity practices not only enhance productivity and profitability but also improve animal welfare and health, increase farmer satisfaction, and reduce antimicrobial usage**.** However, research indicates that most livestock producers fail to implement these measures fully. The success of implementation is directly impacted by farmers' views on biosecurity and their decision-making processes, meaning preventative measures cannot be implemented in the same way or with the same degree of success across all farms. Therefore, for biosecurity to serve as an effective preventive tool, it is crucial to develop a clear understanding of which measures should be implemented and how they should be adapted to different farming contexts. The potential impacts of identified threats should be assessed, and preventive and corrective measures implemented according to the farm's conditions. This paper examines scientific studies that address the transmission paths of diseases in livestock enterprises, as well as the biosecurity practices that are designed to mitigate these risks. It also discusses the effects of biosecurity strategies on animal health and welfare from a sustainability perspective.

Key words: Disease Control, Risk Management, Sustainability, Farm Biosecurity

1. GİRİŞ

Hayvansal protein talebinin karşılanabilmesi amacıyla yoğun üretim sistemlerinin yaygınlaşması ve küresel ölçekte insan ile hayvan hareketliliğinin artması, etkin ve sürdürülebilir biyogüvenlik stratejilerine duyulan ihtiyacı belirgin biçimde artırmıştır (Manuja vd. 2014; Msimang vd. 2022; Duarte vd. 2025). Bu çerçevede, modern hayvancılık işletmelerinde biyogüvenlik uygulamaları, çiftlik düzeyinde hastalık risklerinin sistematik olarak tanımlanması ve söz konusu risklerin en aza indirilmesini hedefleyen bütüncül bir yönetim yaklaşımı olarak ele alınmaktadır. Çiftlik içi ve çiftlikler arası hastalık bulaşmasının önlenmesinde temel bir operasyonel araç niteliği taşıyan bu uygulamalar, yalnızca sürü sağlığı açısından değil, aynı zamanda ciddi ekonomik kayıplar ile ürün kalitesi ve gıda güvenliğine ilişkin endişelerin artması bakımından da kritik öneme sahiptir. Nitekim etkin biçimde uygulanan çiftlik biyogüvenliği, ekonomik kayıpların azaltılmasının ötesinde, çevrenin, hayvanların ve insan sağlığının korunmasına da önemli katkılar sağlamaktadır (Layton vd. 2017; Scott vd. 2018). Dünya Hayvan Sağlığı Örgütü (World Organisation for Animal Health, 2023) tarafından tanımlandığı üzere, çiftlik biyogüvenliği; hayvan popülasyonlarına ait hastalıkların, enfeksiyonların veya infestasyonların hayvancılık işletmelerine girişi, yerleşmesi ve işletme içinde veya işletmeden dışarıya yayılımı riskini azaltmayı amaçlayan yönetimsel ve fiziksel önlemler bütününü kapsamaktadır. Bu bağlamda, fiziksel dekontaminasyon yoluyla temiz ve güvenli bir çevrenin oluşturulması, enfekte hayvanların uygun şekilde yönetilmesi ve önleyici aşılama uygulamaları, bütüncül bir biyogüvenlik yaklaşımının temel bileşenleri arasında yer almaktadır (Sahlström vd. 2014; Layton vd. 2017; Duarte vd. 2025). Biyogüvenlik, patojenlerin çiftliğe giriş olasılığını azaltmaya yönelik dış biyogüvenlik önlemleri ile işletme içinde yayılımını sınırlandırmayı amaçlayan iç biyogüvenlik uygulamaların bütününü ifade eder (Villarroel vd. 2007; Alarcón vd. 2021; Collineau vd. 2017). Bu bildirinin amacı, hayvancılık işletmelerinde hastalıkların bulaşma yollarını azaltmaya yönelik biyogüvenlik uygulamaları konusunda yapılmış en güncel araştırma ve çalışmaları inceleyerek, çiftlik biyogüvenliği planları, alınan önlemler, risk yönetimi ve hayvan refahı ile biyogüvenlik ilişkisini bütüncül bir bakış ve sürdürülebilirlik perspektifinden değerlendirmektir.

2. METOT

Hayvansal gıda üretimi sekötüründe faaliyet gösteren işletmelerin biyogüvenlik stratejileri, çiftlik biyogüvenliği protokolleri ile iç ve dış biyogüvenlik tedbirlerine ilişkin yapılmış bilimsel çalışmalar sistematik olarak taranmıştır. Literatür taraması hakemli bilimsel makaleler ve açık erişimli kaynakları kapsayacak şekilde Web of Science, PubMed ve Google Scholar üzerinden gerçekleştirilmiştir. Bu veri tabanlarında yapılan taramada, “Disease Control”, “Risk Management”, “Sustainability”, “Farm Biosecurity”, “Animal Health” ve “Animal Welfare” anahtar kelimeleri kullanılmıştır. Bu çalışmaya dahil edilen araştırmalar çiftlik biyogüvenliği planı, risk yönetimi ve denetimi, hayvan refahı ile biyogüvenlik ilişkisi ve ayrıca yetiştiricilerin biyogüvenlik uygulamalarına ilişkin yaklaşımı ve tutumu kriterleri dikkate alınarak seçilmiştir. Bu çalışmalar, çiftlik biyogüvenliği planları, alınan önlemler, risk yönetimi ve risk değerlendirme süreçleri ile hayvan refahı ve biyogüvenlik arasındaki ilişkiler açısından

incelenmiş ve çiftlik biyogüvenliğinin hayvan sağlığı üzerindeki etkileri ile hastalıkların sürü içi ve sürüler arası yayılımındaki rolü değerlendirilmiştir.

3. ÇİFTLİK BİYOGÜVENLİĞİNDE TEMEL ÖNLEMLER

3. 1. Dış Biyogüvenlik Önlemleri

Biyogüvenlik, patojenlerin işletmeye girişini ve işletme içinde yayılımını önlemeyi amaçlayan bir yönetim yaklaşımıdır. Bu yaklaşım kapsamında önlemler, fiziksel bariyerler ile hayvanların, insanların ve araçların işletmeye girişini sınırlandıran veya düzenleyen kurallar üzerine yapılandırılmaktadır (Brennan ve Christley 2012; Pandolfi vd. 2018; Bernaerdt vd. 2023; Kovács vd. 2025). Hayvan hastalıkları virüs, bakteri, mantar ve parazitler gibi patojenlerden kaynaklanmakta olup, bu etkenler doğrudan temas, kontamine yem ve su, solunum veya kan yoluyla ve ayrıca insanlar, hayvanlar ve yabani türler gibi vektörler aracılığıyla bulaşabilmektedir. Ziyaretçiler, çiftlik çalışanları ile çiftliğe giren araç ve ekipmanlar hastalık etkenlerinin taşınmasında önemli bir rol oynayabilir. Çiftliğin konumu ve yapısal düzeni, hastalık bulaşma riskini artırabilir ya da uygun izolasyon ve bariyerlerle önemli ölçüde azaltabilir (OIE 2013; Canadian Food Inspection Agency 2013; Manuja vd. 2014).

Çiftliğe yeni hayvan girişi en önemli risklerden birisi olup, satın alınacak hayvanlar biyogüvenlik uygulamalarını takip eden güvenilir kaynaklardan temin edilmeli, sağlık durumu riskli hayvan veya diğer biyolojik materyallerin çiftliğe getirilmesinden kaçınılmalı, yeni hayvanlar sağlık ve aşı kayıtları ile birlikte alınmalıdır. Yeni alınan hayvanlar, potansiyel bulaşma riski olan hastalıkların inkübasyon süreleri dikkate alınarak planlanan bir karantina süresince izole edilmeli ve bu süreçte hastalık belirtileri yönünden düzenli olarak gözlemlenmelidir (Sahlström vd. 2014; Manuja vd. 2014; Alarcón vd. 2021; Bernaerdt vd. 2023). İnsan, hayvan ve ekipman hareketleri yeni hastalık etkenlerinin işletmeye girişinde önemli bulaş yolları arasında yer almakta olup çiftliğe gelen işletme personeli, veteriner hekimler ve hayvan bakıcılarının giysi ve ekipmanları ile nakil araçları patojenlerin yayılımına neden olabilmektedir (Nöremark vd. 2010; Sahlström vd. 2014; Alarcón vd. 2021; Kovács vd. 2025). Biyogüvenlik risklerini azaltmak için işletmeye yalnızca girişi zorunlu olan kişiler ve araçların girmesini izin verilmeli, giriş yapan kişi ve araçların kimlik bilgileri ile ziyarete ilişkin bilgiler ve en son temas ettikleri hayvan çiftlikleri gibi bilgiler ziyaretçi defterine kaydedilmelidir. Ziyaretçi kişilere temiz giysi ve çizme verilmesi, araçların girişte ve çıkışta dezenfekte edilmesine özen gösterilmelidir. Diğer işletmelerle ekipman paylaşımı zorunlu olduğunda alıp verilen ekipman en etkin yolla temizlenmeli ve dezenfekte edilmelidir. (Brennan ve Christley 2012; Scott vd. 2018; Alarcón vd. 2021; Islam vd. 2024). Ziyaretçi ve araç hareketlerinden kaynaklanan riskleri azaltmak ve hastalıkların çiftliğe girişini ile yayılımını sınırlandırmak için etkili biyogüvenlik tedbirleri uygulanmalıdır. Yetiştirici ve çiftlik personelinin biyogüvenlik ve risk yönetimi konusunda eğitilmesi, bulaşıcı hastalık risklerini önemli ölçüde azaltabilir (Nöremark ve Sternberg-Lewerin 2014; Layton vd. 2017; Scott vd. 2018; Alarcón vd. 2021; Huber vd. 2022). Komşu işletmelerden veya diğer birimlerle irtibatlı olan kemirgen, sinek ve kuşlar ile evcil veya yabani hayvanlar da diğer önemli vektörlerdir (Robinson 2005; Backhans ve Fellström 2012; Andrés-Barranco vd. 2014). Komşu çiftlikler arasında hava yoluyla patojen bulaşma riskini azaltmak amacıyla çit gibi basit fiziksel

bariyerlerin kullanılması, kapı ve çevre çitleriyle işletmenin dış ortamdan net biçimde ayrılması biyogüvenliğe katkı sağlar (Manuja vd. 2014; Guinat vd. 2016; Alarcón vd. 2021).

Nakiller, çiftlikler arası ziyaretler ve özellikle hayvan ticareti gibi temaslar hastalıkların yayılmasını kolaylaştırmaktadır. Hayvan nakilleri de dış biyogüvenliğin önemli bir hassas noktasını oluşturmaktadır**.** İşletmeler arası veya kesimhaneye hayvan taşıyan araçlar, bu araçlarındaki sürücüler ve hayvan bakıcıları patojenlerin işletmeler arasında yayılımında önemli rol oynayabilir. Bu riskleri azaltmak için öncelikle her bir kamyon için izin verilen kullanım alanları net biçimde tanımlanmalı, güvenli olarak kabul edilen bir hayvan taşıma aracı, yüksek riskli taşımalar için kullanılmamalı, nakil araçlarının temizlik ve dezenfeksiyonunda özenli olunmalıdır (Manuja vd. 2014; Pitkin vd. 2009; Alarcón vd. 2021).

3. 2. İç Biyogüvenlik Önlemleri

Biyogüvenlik önlemleri, kontrollü bir ortamda hastalıkların işletme içinde yayılımını en aza indirmeyi hedefler ve bu nedenle biyogüvenlik planlarının hayvan idaresine ilişkin tedbirleri içermesi beklenmektedir (Brennan ve Christley 2012; Pandolfi vd. 2018; Kovács vd. 2025). Farklı yaş ve üretim dönemindeki hayvanların hareket alanlarının ayrılmasıyla yeni hayvanların birlikte giriş yapması ve birlikte çıkış yapması esasına göre yönetilmesi ve bu hayvanlarla ilgilenen personelin giysi, el ve çizme dezenfeksiyonuna titizlikle uyması büyük önem taşımaktadır (Sahlström vd. 2014; Canadian Food Inspection Agency 2013; Alarcón vd. 2021; Msimang vd. 2022). Çiftlik biyogüvenlik protokolü çiftlikte hasta hayvanların itlafı, enfekte hayvanların veya kontamine ürünlerin idaresine ilişkin tedbirler içermelidir. Protokolde ayrıca yem yönetimi, tesis ve araç bakımı ile gübre ve kadavra bertarf edilmesine ilişkin tedbirler de bulunmalıdır (Nicholson vd. 2005; Scott vd. 2018; Msimang vd. 2022)

Hayvan hijyeninin sağlanması yanı sıra barınaklar ve ekipmanların düzenli temizliği ve dezenfeksiyonu yapılmalı, birbirinden ayrılan alanlardaki barınaklara özel olarak personel ayrıştırılmış kişisel koruyucu ekipmanları uygun şekilde kullanmalı ve temizliğinine özen gösterilmelidir (Manuja vd. 2014; Msimang vd. 2022; Bernaerdt vd. 2023; Kovács vd. 2025). Temizlik ve dezenfeksiyon uygulamaları, insan, ekipman ve araçlar üzerindeki patojen yükünü azaltarak etkenlerin üretim alanları içinde ve arasında taşınma riskini düşürmektedir. Bu kapsamda üretim ve karantina alanları ile ekipmanlar her üretim döngüsü sonrasında, hayvanlar arasında paylaşılan veya tekrar kullanılan ekipmanlar ise kullanım öncesi ve sonrası temizlenmeli ve dezenfekte edilmelidir. Yemlikler, suluklar, barınma alanları ve atık depolama alanları düzenli olarak temizlenip dezenfekte edilmeli, kontamine sıvı atıklar bertaraf öncesinde dezenfeksiyona tabi tutulmalı ve çiftliklerde yalnızca sertifikalı ve uluslararası kabul görmüş dezenfektanlar kullanılmalıdır (OIE, 2013; Manuja vd. 2014; Kovács vd. 2025).

Yetiştiriciler hayvanları hastalıklardan korumak amacıyla antimikrobiyaller ve aşılar gibi koruyucu uygulamalardan yararlanmaktadır (Sayers vd. 2013; Mallioris vd. 2023). Aşılama ile diğer biyogüvenlik önlemlerinin entegre edilerek uygulanması hastalık bulaşma risklerini önemli ölçüde azaltma potansiyeli sunmaktadır (Layton vd. 2017). Öte yandan veteriner hekimler, hastalıkların önlenmesi ve biyogüvenlik uygulamaları konusunda yetiştiriciler için en

önemli bilgi ve danışmanlık kaynağı olarak kabul edilmektedir. Sürü veteriner hekimlerinin hastalıklar hakkında ve hastalıkların bulaşma ve yayılma yolları hakkında yetiştiriciler ve hayvan bakıcılarının bilgilendirilmesi ve farkındalıklarının arttırılmada önemli katkıları olabileceği vurgulanmaktadır (Laanen vd. 2014; Alarcón vd. 2021). Çiftlik sahipleri, çalışanlar, ziyaretçiler ve hizmet sağlayıcıların hareketleri hastalıkların giriş ve yayılma riskini artırabilir. Bu nedenle çiftlikte farklı koruma seviyelerine sahip alanlar oluşturulmalı, bu alanlara giriş ve çıkışlar kontrol edilmeli, buralara özel koruyucu giysi, el yıkama ile iş akışı planları gibi biyogüvenlik önlemleri uygulanmalıdır. Personelin çalışma alanları ve iş akışı net şekilde ayrılmalı, düzenli el yıkama ve ayak banyoları ile temiz giysi ve çizmeler kullanılmalıdır (Canadian Food Inspection Agency 2013; Scott vd. 2018). Kontamine yem, su ve altlık hastalık riskini artırdığından düzenli temizlik ve kalite kontrolü yapılmalıdır (Nicholson vd. 2005; Scott vd. 2018; Msimang vd. 2022). Yüksek riskli yemler kontrol edilmeli, gübre, altlık ve yem artıklarının bertarafı kontrollü şekilde, gerekirse kompostlama veya anaerobik depolama ile sağlanmalıdır. Kadavralar da patojen rezervuarı olduğundan biyolojik atık bertaraf uygulamalarına uyulmalıdır (Robinson 2005; Nicholson vd. 2005; Andrés-Barranco vd. 2015; Msimang vd. 2021; Kovács vd. 2025).

Hasta hayvanlar sağlıklı olanlardan izole edilmeli, muayene edilmeli ve gerekirse sürüden çıkarılarak patojenlerin bulaş riski azaltılmalıdır. Sürünün sağlık durumu rutin test ve taramalarla izlenmeli, proaktif önlemler uygulanmalıdır. Tedavi etkinliği için uygun ilaç kullanımı sağlanmalı, aşılama ve parazit kontrol programları titizlikle uygulanarak kayıt altına alınmalıdır (OIE 2013; Canadian Food Inspection Agency 2013). Lewerin vd. (2015) çiftlikler arası temas sıklığı ve hastalık prevalansının biyogüvenlik önlemlerinin etkinliğini belirleyen temel faktörler olduğunu, önlemlerin etkisinin çiftlik türüne ve bulaşma yollarına göre değiştiğini göstermiştir.

4. RİSK DEĞERLENDİRMESİ VE BİYOGÜVENLİK PLANI

Biyogüvenlik, patojenlerin işletmeye girişini ve işletme içinde yayılımını önlemeyi amaçlar. Çiftlik biyogüvenliği kapsamında risk yönetimi ise, hastalıkların işletmeye giriş ve yayılma olasılığını azaltmak amacıyla potansiyel tehditlerin sistematik olarak tanımlanmasını, risklerin biyolojik ve ekonomik etkilerinin değerlendirilmesini ve uygun kontrol önlemleriyle planın devam etmesini sağlamaktır (Nöremark vd. 2010; Pitkin 2009; Schreuder vd. 2023).

Etkin bir biyogüvenlik planı ile çiftliğin konumu, yönetim uygulamaları ve hayvan sağlığı programları dikkate alınarak riskler analiz edilir, kritik kontrol noktaları belirlenir ve yeni bilgi ve teknolojilere uyum sağlayacak şekilde sürekli güncelleme yapılır (Sahlström 2014; Lewerin vd. 2015). Ayrıca çiftlik biyogüvenliği planının dayandığı dış ve iç biyogüvenlik önlemlerinin etkinliği düzenli olarak izlenir ve ortaya çıkan riskler doğrultusunda önlemler güncellenir. İyi yönetim ve bakım uygulamaları, biyogüvenlik planının etkinliğini artırır ve hayvanların sağlıklı üretim koşullarını destekler. Ayrıca, yetiştirici tutumu, bölgesel farklılıklar, yaş ve işletme büyüklüğü gibi faktörler biyogüvenlik uygulamalarına yönelik davranış ve kararları etkileyerek sürecin başarısında kritik rol oynar (Jin vd. 2009; Sahlström vd. 2014) . Çiftlikte uygulanacak önleyici ve tedavi edici önlemler, maliyet-fayda dengesi, hastalığın yayılma riski ve hızı gibi

faktörler dikkate alınarak en uygun şekilde kombine edilmelidir (Jin vd. 2009). Bu bütüncül yaklaşım, çiftliğin salgınlara karşı dayanıklılığını artırır, biyogüvenliğin sürdürülebilir şekilde uygulanmasını sağlar ve hastalık risklerinin etkin kontrolünü mümkün kılar (Sahlström 2014; Lewerin vd. 2015; Schreuder vd. 2023). İşletmenin biyogüvenlik politikalarının oluşturulması ve başarısında önemli bir faktör yetiştirici ve personelin tutumudur. Bu durum, biyogüvenliğin teknik bir uygulama olmanın ötesinde, yetiştirici davranışları, eğitim ve bölgesel koşullarla da ilişkili bir karar süreci olduğunu göstermektedir (Brennan ve Christley 2012; Sayers vd. 2013; Lewerin vd. 2015). Biyogüvenliğin değerlendirilmesi, işletmede uygulanan önlemlerin etkinliğini belirleyerek güçlü ve zayıf yönleri ortaya koyar, öneriler sunar ve işletmeye özgü biyogüvenlik planlarının geliştirilmesini sağlar. Ayrıca, yetiştiriciler ve çiftlik personeli arasında farkındalık ve sorumluluk bilincini artırırken, ulusal düzeyde hastalıkların önlenmesi ve kontrol etme kapasitesinin arttırılmasına katkı sağlar (Nöremark vd. 2009; Sayers vd. 2013; Alarcón vd. 2021; Duarte vd. 2025).

5. BİYOGÜVENLİK VE HAYVAN REFAHI

Hayvan refahı, bir hayvanın yaşam ve ölüm koşullarına bağlı fiziksel ve zihinsel durumu olarak tanımlanır ve hem biyolojik işlevsellik hem de doğal davranış ihtiyaçlarının önemini vurgular (OIE 2019; Dawkins 2016). Hayvan sağlığı ile refahı arasındaki bağlantı yaygın şekilde kabul görmektedir. Yüksek refah düzeyinin hayvan verimliliğini olumlu yönde etkilediği; stres seviyelerini düşürdüğü, bağışıklık sistemini koruduğu ve dolayısıyla performans ile hastalıklara karşı direncin artırılmasında kritik bir rol oynadığı bilinmektedir. Benzer şekilde, biyogüvenlik uygulamalarının güçlendirilmesi, hem hayvan sağlığı hem de refahı üzerinde olumlu etkiler sağlayabilmektedir (Carroll ve Forsberg 2007; Henningsen vd. 2018; Pandolfi vd. 2018; Diana vd. 2020). Etkili biyogüvenlik uygulamaları, hayvan sağlığı ve refahının korunmasında temel bir rol oynamaktadır. Biyogüvenlik önlemleri, hayvanların hastalık nedeniyle yaşadığı acıyı ve ızdırabı azaltır, hastalık tedavilerinde antimikrobiyal kullanımını azaltır ve daha önemlisi antibiyotik direncinin kontrol altına alınması ve işletmenin ekonomik performansının arttırılmasına önemli katkılar yaparr (Sinclair vd.2019; Mallioris vd. 2023; Kovács vd. 2025). Yoğun üretim yapılan çiftliklerde biyogüvenlik, aşılama ve iyi yönetim, hastalıkların önlenmesinde temel rol oynar ve hayvan refahını destekler. Bununla birlikte, hayvan refahı ve biyogüvenliği artırmak için kritik risk noktalarının tespiti ve yönetim stratejilerinin geliştirilmesine yönelik yeni araştırmalara ihtiyaç vardır (Alquati vd. 2025). Güçlü biyogüvenlik programları, hastalıkların erken tespitini ve yayılımının sınırlandırılmasını sağlayarak hayvan ızdırabını ve tedavi maliyetlerini azaltmakta ve sağlıklı, düşük stresli sürülerin oluşmasına ve ürün kalitesinin artışı ile toplum sağlığına katkı sağlamaktadır. Macaristan'daki büyük ölçekli bir broyler hindi işletmelerinde yapılan çalışmalar, biyogüvenlik ile hayvan refahı arasında güçlü bir ilişki olduğunu göstermiş, güçlendirilmiş biyogüvenlik önlemlerinin daha iyi refah sonuçlarıyla ilişkili olduğunu ve kapsamlı, etkin şekilde uygulanan biyogüvenlik protokollerinin gerekliliğini vurgulamıştır (Kovács vd. 2025; Mallioris vd. 2023)

6. SONUÇ

İncelenen bilimsel araştırmalara göre, hayvan çiftliklerinde risk analizlerine dayalı ve düzenli kontrol ile öz değerlendirme süreçlerini içeren biyogüvenlik stratejileri, bütüncül yaklaşımlarla daha hedefe yönelik sonuçlar sağlayabilmektedir. Hayvan refahı ile biyogüvenlik arasındaki karşılıklı destekleyici ilişki, sürdürülebilir çiftlik yönetimi ve etkili biyogüvenlik politikaları için temel bir dayanak ve önemli bir fırsat oluşturmaktadır. Bununla birlikte, biyogüvenlik ve hayvan refahı arasındaki etkileşimleri inceleyen yeni araştırmalara ihtiyaç vardır. Ayrıca, işletmelerin yapısal ve çevresel koşullarının iyileştirilmesi ile biyogüvenlik uygulamalarının etkinliğinin artırılması önemlidir. Bunun yanı sıra, işletmelerde sürdürülebilir üretim ve ekonomik sonuçların geliştirilmesi amacıyla personel ve yetiştiriciler için eğitim olanaklarının artırılmasının faydalı olacağı sonucuna varılmıştır

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YUMURTACI TAVUKLARDA REFAHININ DEĞERLENDİRİLMESİNDE KULLANILAN GÖSTERGELER VE PROTOKOLLER

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ÖZET

Tavukçuluk sektörü, genetik seleksiyon ve üretim teknolojisindeki büyük gelişmeler sayesinde en verimli hayvansal protein kaynaklarından biri hâline gelmiştir. Ancak verimlilikteki bu hızlı artış, önemli hayvan refahı sorunlarını beraberinde getirmiştir. Yüksek yumurta verimi yönünde yapılan genetik seleksiyonlar tavukların fizyolojik sınırlarını zorlamakta ve yetiştirme koşullarındaki yüksek stres metabolik hastalıklar, iskelet sistemi bozuklukları, davranış anormallikleri ve sağlık problemlerinin görülme sıklığını arttırmaktadır. Günümüzde tavukçuluk sektörünün karşı karşıya olduğu en önemli zorluklardan biri, değişen tüketici beklentileri, artan toplumsal baskılar ve yeni yasal düzenlemelere hızla uyum sağlama gerekliliğidir. Bu durum, üretim sistemlerinde yalnızca verimlilik odaklı değil, aynı zamanda etik, çevresel ve hayvan refahı temelli dönüşümleri de gerekli kılmaktadır. Bu bağlamda, Birlik mevzuatı ile (1999/74/EC; 2002/4/EC) Yumurtacı tavukların korunması ve softalık yumurtaların yetiştirme tipine göre kodlanmasının düzenlendiği Avrupa Birliği'nde ve Birlik mevzuatına uyumunun sağlandığı Türkiye'de yumurtacı tavuk yetiştirme sistemleri kafesli sistemler ve alternatif sistemler olarak ayrılmış. Yönetmeliklere uyum durumunun değerlendirilmesi ve yumurtacı tavuklarda hayvan refahı yönünden sektöre şeffaflık sağlanması için düzenli kontrollerde kullanılabilecek bazı değerlendirme protokolleri geliştirilmiştir. Bu bildiride, yumurta tavukçuluğunda hayvan refahının değerlendirilmesi amacıyla en fazla kullanılan protokollerin hayvan refahı göstergeleri ve uygulama yöntemleri detaylı şekilde açıklanmış ve ayrıca protokoller saha koşullarında uygulama kolaylığı ve gerekli olan süre gibi özellikler yönünden tartışılmıştır.

Anahtar Kelimeler: Hayvan Refahı, Değerlendirme, Gösterge, Protokol, Yumurtacı Tavuk

WELFARE INDICATORS AND ASSESSMENT PROTOCOLS FOR LAYING HENS

ABSTRACT

The poultry sector has become one of the most efficient sources of animal protein, and this is mostly down to major improvements in the areas of genetic selection and production technologies. However, this rapid increase in productivity has raised significant animal welfare concerns. Genetic selection for high egg yield push the physiological limits of chickens, and the stressful conditions associated with intensive rearing systems increase the incidence of metabolic disorders, skeletal abnormalities, behavioural deviations and health problems. One of the major challenges currently facing the poultry industry is the need to adapt quickly to changing consumer expectations, increasing societal pressure and new regulatory requirements. This situation requires transformations in production systems that go beyond mere productivity, emphasising ethical, environmental, and animal welfare considerations. In this context, European Union legislation (Regulations (EU) 1999/74/EC and 2002/4/EC) regulates the protection of laying hens and the coding of table eggs according to the type of rearing system. In both the European Union and Turkey, where compliance with EU legislation is ensured, laying hen production systems are classified as either cage or alternative. Several assessment protocols have been developed for use in routine inspections to assess compliance with these regulations and to provide transparency to the sector with regard to animal welfare in laying hens. This paper describes the most widely used protocols for assessing animal welfare in egg production in detail, focusing on their animal welfare indicators and implementation methods. Additionally, the ease of application of these protocols under field conditions and the time required for their implementation are discussed.

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Key words: Animal Welfare, Assessment, Indicators, Protocols, Laying Hen

1. GİRİŞ

Avrupa Birliği'nde (AB), 1999/74/EC sayılı Konsey Direktifi'ne göre yumurtacı tavuk yetiştirme sistemleri kafesli sistemler ve alternatif sistemler olarak ayrılmıştır (Anonim 1999). Alternatif sistemler kategorisi tek katlı basit sistemlerden açık alana erişimi olan veya olmayan çok katlı kümeste kafessiz (aviary) sistemlere kadar uzanan geniş bir çeşitlilik taşımaktadır. Kafes sistemleri kategorisinde ise çok katlı zenginleştirilmiş kafes sistemleri bulunmaktadır (Main vd. 2012). Aynı düzenleme Konsey Direktifinin ulusal mevzuata aktarıldığı ve yumurtacı tavuk refahı bakımından Birlik ile uyumun sağlandığı Türkiye için de geçerlidir (Anonim 2014; Bozkurt 2017). Bu yasal gerekliliklere ek olarak, pek çok ülkede sektör öncülüğünde geliştirilen kalite güvence standartları da uygulanmaktadır. Bu standartlar genellikle, üreticilerin belirli aralıklarla denetlendiği ve çiftliğin belirlenen standartlara uygunluğunun kontrol edildiği çiftlik güvence programları aracılığıyla yürütülmektedir (Anonim 2002; Main vd. 2012; Di Concetto 2024). Ayrıca, Avrupa Birliği'nde 2002/4/EC Konsey Direktifi ile yumurtacı tavukların yetiştirme tipine göre sofralık yumurtaların kodlanması zorunlu hale getirilmiştir (Anonim 2002; Main vd. 2014). Bu mevzuat Avrupa Birliği bölgesinde bulunan işletmelerde üretilen yumurtalar için tüketiciye şeffaflık sunmaktadır (Anonim 2002; Alonso vd. 2020; Sinclair vd. 2022; Di Concetto 2024; Tuyttens vd. 2025). Yönetmeliklere yasal uyumun sağlanması veya sertifikasyon standartlarının düzenli izlemesine tabii olmak dışında üreticilerin de kendi sürülerinde hayvan refahının izlenebilmesi için güvenilir ve karşılaştırılabilir standart hayvan refahı değerlendirme sistemlerine olan ihtiyaç arttırmaktadır (Main vd. 2007; Blokhuis vd. 2010; Vasdal vd. 2023; EFSA, 2023; Hanif vd. 2025).

Bu kapsamda Konsey Direktifinin 1 Ocak 2012 tarihinde yürürlüğe girmesinden günümüze kadar geliştirilmiş veya önerilmiş bazı hayvan refahı değerlendirme protokolleri bulunmaktadır **(**Vasdal vd. 2022; Blokhuis vd. 2010; Vasdal vd. 2023; Hanif vd. 2025**).** Bu protokoller geliştirilme süreçleri, hayvan refahı göstergelerinin özellikleri, uygulayıcıların özellikleri ile uygulama süresi ve kolaylığı gibi özellikler bakımından farklılıklar göstermektedir (Webster vd. 2004; Blokhuis vd. 2010; Main vd. 2014; Vasdal vd. 2022; EFSA 2023; Tuyttens vd. 2025; Hanif vd. 2025). Bu bildiride, yumurta tavuklarında hayvan refahının değerlendirilmesi amacıyla en fazla kullanılan protokollerin hayvan refahı göstergeleri ve uygulama yöntemleri detaylı şekilde açıklanmış ve ayrıca protokoller saha koşullarında uygulama kolaylığı ve gerekli olan süre gibi özellikler yönünden tartışılmıştır.

2-METOT

Yumurtacı tavuk refahının değerlendirilmesine yönelik protokollerin belirlenmesi amacıyla konuya ilişkin proje web sayfaları ile hakemli bilimsel makaleler için Google Scholar, PubMed ve Web of Science veri tabanlarından yararlanılmıştır. Bu açık erişimli kaynaklardan "animal welfare", "laying hen welfare" ve "welfare assessment protocol" anahtar kelimeleri kullanılarak sistematik literatür taraması yapılmıştır. Bu taramada bulunan ve yumurtacı tavuklarda refahın değerlendirmesinde kullanılmış veya önerilmiş olan protokoller arasından sadece çiftlik seviyesinde ve en az invaziv olarak uygulanabilenler, ağırlıkla hayvan tabanlı refah

göstermeleri içerenler ile Avrupa'da kamu kurumları, sektör temsilcileri, sivil toplum örgütleri ve üniversiteler gibi çok paydaşlı konsorsiyumlar tarafından geliştirilen protokoller değerlendirmeye alınmıştır (Hanif vd. 2025). Seçilen protokoller yumurtacı tavuk refahının değerlendirilmesinde yararlanılan hayvan refahı göstergeleri ile kullanılan değerlendirme yöntemleri açısından ayrıntılı olarak incelenmiştir.

3. YUMURTACI TAVUKLAR İÇİN REFAH DEĞERLENDİRME PROTOKOLLERİ

3.1.Welfare Quality Protokol

Welfare Quality Protokolü, yumurtacı tavuk refahının değerlendirilmesinde, kaynak ve yönetim tabanlı kriterlere ilişkin verileri kullanmaktadır. Hayvan tabanlı refah göstergeleri bakımından yapılan incelemeler örneklem ile belirlenen hayvanlar üzerinde doğrudan yapılan incelemeleri veya hayvanların uzaktan izlenmesiyle yapılan değerlendirmeleri kapsamaktadır. Çiftlik koşullarında yapılan hayvan refahı değerlendirmesinde iyi beslenme, iyi barınma, iyi sağlık ve doğal davranışlar olmak üzere dört temel refah prensibi çerçevesinde ve 12 refah kriteri altında tanımlanan hayvan refahı göstergeleri kullanılmaktadır. İyi beslenme prensibi için uzun süreli açlık ve susuzluğun olmaması olmak üzere iki ölçüt ele alınmakta, göğüs kemiği çıkıntısı ve barınaktaki yem ve su kaynaklarının miktarı kaydedilmektedir. İyi barınma prensibi için dinlenme konforu, hareket kolaylığı bakımından mevcut tüneklerin şekli ve toplam uzunluğu, kırmızı akar varlığı, toz banyosu yanı sıra, termal konforun değerlendirilmesi için açıkağızla sık nefes alan veya birbirine sokulup kümeleşme davranışı gösteren hayvan oranları incelenmektedir. İyi sağlık prensibi ise hastalık ve yaralanmaların olmaması, yönetim prosedürlerinden kaynaklı ağrı ve ızdırabın olmaması yanı sıra göğüs kemiği hasarı, vücutta deri lezyonları, ayak tabanı ve diz eklemi bölgesi deri lezyonları, parmak hasarları ve gaga anormalliklerinin incelenmesini kapsamaktadır. Ayrıca ölüm oranı, ayıklanan hayvan oranı ile şiş kursak, göz patolojileri, solunum yolu enfeksiyonları, enteritis, paraziter enfestasyonlar ve ibik anormallikleri gibi klinik değerlendirmeleri içermektedir. Uygun davranışların sergilenmesi prensibi kapsamında tavukların sosyal etkileşimleri sistematik olarak değerlendirilmekte, baş, sırt ve kloaka bölgelerinde tüy hasarı olan ve ibikte gagalama yaraları olan tavuk sayıları, açık alan ve folluk kullanımı, altlık kalitesi ve çevresel zenginleştirme uygulamaları incelenir. Ayrıca bu protokol yem arama ve toz banyosu gibi konfor davranışlarının sergilenmesi ile tavukların insanlara ve diğer hayvanlara yönelik tepkilerinin değerlendirilmesi amacıyla kaçınma testi, yabancı cisim testi ve ayrıca duygusal durumun değerlendirilmesi için nitel davranış değerlendirmesini kapsamaktadır. Değerlendirme formu ile toplanan verilerin analiziyle kriter ve prensip puanları hesaplanmakta ve işletmeler toplam puana göre refah durumu sınıflandırmasına tabii tutulmaktadırlar (Welfare Quality 2019)

3.2. Laywel Protokolü

Farklı yetiştirme sistemlerinde yetiştirilen yumurtacı tavuk refahının değerlendirilmesi için geliştirilen LayWel Protokolü "Beş Özgürlük" yaklaşımına dayanmakta ve tavukların yaralanma, hastalık, ağrı, korku, stres, açlık ve susuzluk gibi olumsuzluklardan korunmasını ve türlerine özgü davranışları sergileyebilmelerine odaklanmaktadır Protokolde kullanılan hayvan ve kaynak tabanlı refah göstergeleri tavuk refahının kullanılan yetiştirme sistemi ve aynı sistem

içinde barındırılan tavuk genotiplerine göre farklılıklar gösterebileceği yaklaşımdan hareketle yapılandırılmıştır (LayWel Consortium 2006).

Bu nedenle protokol kafes sistemleri ile kümeste kafessiz ve açık alana erişimi olan sistemlere özgü ayrı ayrı ve tüm sistemler için bazı ortak refah göstergelerini içermektedir (LayWel Consortium 2006; Blokhuis vd. 2007; Vasdal vd. 2022). Tüm yetiştirme sistemlerinde günlük ölen tavuk sayısı ve ölüm nedenleri belirlenmektedir (fiziksel hasarlar ile parazit, göğüs kemiği çıkıntısı, deri ve tüy durumu). Haftalık değerlendirmede yumurta verimi ve kalite özelliklerinin (kabukta anormal kalsiyum birikimi, kan lekesi veya kırmızı çizgi) takibi yapılır ve kümes kontrollerinde havalandırma ve alarm sistemlerinin işlevselliği, kümes içi hava kalitesi (amonyak, toz, vs.) ve tavuk kırmızı akarı mevcudiyeti değerlendirilir**.** Rastgele örneklem yapılarak alınan 20 tavuk üzerinde fiziki inceleme yapılarak ayak derisinde dermatit ve şişkin ayak lezyonu ve ayrıca ishal, tüy temizliği ve tüy kaybı ile kanat altının parazit varlığı yönünden klinik kontrol ve skorlamalar yapılır. Ayrıca kümes içinde yavaşça yürürken veya bir yere oturarak gözlem yapan değerlendirici kaçma ve uçma davranışlarını sergileyenler ile gözlemciye yaklaşan ve gözlemcinin botlarını gagalayan tavuk sayılarını belirler(LayWel Consortium 2006).

Protokol yumurtacı tavuk yetiştirme sisteminin her birisi için özel parametrelere de odaklanmaktadır. Geleneksel ve zenginleştirilmiş kafes sistemlerinde, kümeste koridor boyunca yavaş ve sessiz hat boyu gözlem (transekt) yapılarak zararlı gagalama davranışı gösteren hayvan sayısı belirlenir. Tek ve çok katlı kümeste kafessiz sistemlerde kapalı alanda 10–20 dakikalık hat boyu ve oturarak yapılan nokta gözlemlerde sulukların ve çıkış kapılarının çevresi ile tüm kümes tabanı ve köşelerdeki incelemeler sonucu altlık kalitesinin durumu, altlık üzerindeki tüy miktarı ile zararlı gagalama yapan, diğerlerinin kloaka bölgesini gagalayan, eşelenen, yerde yatan, ekipmanlara çarpan tavuk sayısı ve 2 den fazla tavuk bulunduran veya boş olan folluk sayıları kaydedilir. Karanlık periyotta el feneri ile tüneyen tavuk oranı ve yemlikteki tavuk oranı tespit edilir. Ayrıca açık alana erişimi olan sistemlerde açık gezinti alanında 10–20 dakikalık yürüyüşlerle ve oturarak yapılan nokta gözlemlerde hava durumu, sürüdeki toplam tavuk sayısı, açık gezinti alanındaki tavuk oranı, yerde yatan tavuk sayısı, arazinin bitki durumu ile çıkış kapıları önündeki alanların durumu ve tüneme imkânları gözlemlenir. Aynı gözlem periyodunda, açık alanda bulunan tavuklar normal ve anormal davranışlar yönünden gözlemlenir, tüm arazinin sürü tarafından etkin şekilde kullanılıp kullanılmadığı değerlendirilir. (LayWel Consortium 2006). LayWel tüy skorlama sisteminin kısaltılmış bir versiyonunu hazırlayan Kjaer vd. (2011) birebir örtüşmesi beklenmese de, orijinal skorlamaya kıyasla hayvanlarda daha düşük bir stres ile değerlendirmenin yapılabileceğini bildirmiştir.

3.3. AssureWel Protokolü

AssureWel Ptorokolü LayWel protokolünün sadeleştirilmesine dayalı olarak, ticari koşullarda pratik kullanım amacıyla geliştirilmiştir. AssureWel skorlama sistemi tüy kaybı ve tüylerin kirlenmesi**,** gaga kesimi**,** antagonistik davranışlar**,** ürkeklik**,** ilave bakıma ihtiyaç duyan hayvanlar ve mortalite olmak üzere yedi gösterge türünü içermektedir. AssureWel protokolü,

organik ve açık alana erişimi olan sitemler ile kümeste kafessiz sistemlerde uygulanmak üzere geliştirilmiştir (Main vd. 2012; Vasdal vd. 2022).

AssureWel tavuk refahı değerlendirme sisteminde önceden belirlenen gözlem hatlarında, yavaşça yapılan yürüyüşler ile hat boyu gözlemler tamamlandıktan sonra farklı bölgelerden örneklem yapılarak (yarısı kapalı alanın farklı noktalarından ve diğer yarısı açık gezinti alanında) belirlenen 50 tavukta baş ve sırt bölgelerindeki tüy kaybı ve tüy temizliği yönünden skorlama yapılır. Toplam 50 hayvandan en az üçüne ait değerlendirme sürünün sorumlusu olan hayvan bakıcısı ile birlikte yapılır ve onun skorlaması esas alınır. Bununla birlikte örneklem üzerinde skorlama yapılırken sürünün geneli de gözlemlenerek değerlendirmeye dahil edilir. Ayaklar ve bacaklar hariç tavuğun vücudunun bir tarafı değerlendirmeye alınarak tüy temizliği durumu skorlanır. Baş ve boyun ile sırt ve kloaka bölgelerindeki tüy kaybının durumu ayrı ayrı skorlanır. Gaga kesimi değerlendirmesi sürede gaga kesimi hikâyesinin (kayıtlardan veya üreticiden öğrenilen) alınmasından başka incelenen tavuklar arasında gagasının üçte birinden fazlası kesilmiş olan hayvanların sayısı ile yapılır. Tüm sürüye yönelik olarak, nokta ve hat boyu gözlemler sırasında tavuk davranışları ve seslenişleri izlenir ve her bir antagonistik davranışın saldırganlık veya zararlı tüy gagalama içerip içermediği incelenir. Tüm sürüdeki tavuk davranışları gözlemlenir ve bu davranışlar ürkek, sakin ve temkinli olarak sınıflandırılır. Ayrıca ek bakıma ihtiyaç duyan hayvanlar ile hasta ve yaraları olanlar sınıflandırılı ve bunlardan tedavi edilecekler ile itlaf edileceklerin sayısı ve muayene sonuçları (halsiz, ishal, topallık, deri ve göz lezyonları tespit edilenler, vs.) kaydedilir. Değerlendirme tarihine kadar gerçekleşen ölüm oranı ve önceki sürüye ait ölüm oranı verileri ile ölüm sebeplerine ilişkin işletme kayıtlarına bakılarak ölüm oranı değerlendirilir. (AssureWel 2025).

3.4. Aviary Transekt Protokolü

Aviary Transect sistemi 12 adet hayvan tabanlı refah göstergesi içermekte olup tavukların fiziksel sağlık ve refah durumunun bütüncül ve detaylı bir biçimde izlenmesine imkân tanımaktadır (Tauson vd. 2005; Blokhuis vd. 2007; Rodenburg vd. 2008; Decina vd. 2019; Vasdal vd. 2022; Vasdal vd. 2023). Aviary Transect yönteminde değerlendirici kümeslerde önceden belirlenmiş gözlem hatları (transect) boyunca yavaş yavaş yürüyerek protokolde tanımlanmış olan hayvan refahı göstergelerinin gözlemlendiği hayvan sayısını belirler ve kaydeder. Her transekt gözlemindeki skorlamalar ile belirlenen puanlar birleştirilerek sürü genel puanı belirlenir. Bu yöntem hayvanların yakalanmasını gerektirmez ve sürünün tamamının ya da temsil edici bir bölümünün görsel olarak değerlendirilmesine olanak tanır (Marchewka vd. 2013). Transekt protokolünün yöntemi yetiştiricilerin günlük sürü kontrollerine hemen hemen yakın uygulamalar içerdiğinden yetiştiricinin düzenli olarak bu protokolü uygulayabilmesi daha kolay olabilmektedir. Ayrıca örneklemle belirlenen az sayıda tavuk üzerinde yapılan değerlendirmeye göre transekt değerlendirme sürünün tamamı veya önemli bir bölümünde yapılan gözlemlere dayandığı için daha ciddi vakaların gözden kaçma riskini azaltır (Main vd. 2012; Marchewka vd. 2015; Vasdal vd. 2023; Vasdal vd. 2022; Marchewka vd. 2013).

Aviary Transekt Protokolü ile yapılan değerlendirmede öncelikle tavuğun baş, boyun, sırt ve kanat bölgelerinde görülen tüysüz alanlar veya sadece tüy ve teleklerin büyük kısmının koparılmış olduğu bölgeler dikkate alınır. Tüylerin kirlenme durumunun değerlendirilmesinde ise vücudun en az %25'ini kapsayan belirgin koyu lekeler değerlendirmeye alınır. Fiziksel gözlemlerde, tavuklar baş, boyun, sırt, kanatlar ve kuyruk bölgeleri ile ayak derisi üzerindeki taze veya eski yaralar ile şişkin ayak ve şiş kursak görüntüsünün olup olmadığı yönünden incelenir. Hayvanların sağlık durumuna ilişkin yapılan gözlemlerde tavuklar soluk ibik, kırmızı ve akıntılı gözler, dağınık vücut tüyleri, deforme veya eksilmiş vücut parçaları ile deride sarımsı renk değişimi veya solukluk gibi hastalık belirtileri yönünden incelenir ve genellikle bu tip hayvanlar yatar veya dinlenir pozisyonda bulunur. Takip edilen transekt boyunca ölü bulunan hayvanlar kaydedilir ve sürüdeki ölüm oranı belirlenir (Vasdal vd. 2022)

3.5. Best Practice Hens Protokolü

Transekt yöntemine dayanan diğer bir yumurtacı tavuk refahı değerlendirme protokolü yakın zamanda geliştirilen Best Practice Hens Protokolüdür. Bu protokol tavuk sürülerinin refahını basit fakat etkili bir şekilde nicel olarak değerlendirmeye imkân veren ve yetiştiricinin günlük olarak yaptığı uygulamalar sırasında gerçekleştirebileceği pratik bir yöntemdir. Transekt yöntemi standart üretim parametrelerinin düzenli olarak toplanması ve sürü refah göstergelerinin kaydedilmesine dayanmaktadır. Veri toplama, standartlaştırılmış bir şekilde kümes içinde yapılan basit yürüyüşler aracılığıyla gerçekleştirilir. Transekt yöntemi, yetiştirici tarafından yapılan günlük sürü kontrollerine benzer olup, bu nedenle yumurtacı sürülerinde uygulanması kolaydır. Gözlem hattı (transekt) yemlik, suluk veya folluk hatları gibi iki hat arasında kalan veya bu hatlar ile kümes duvarı arasında kalan uzunlamasına alanlardır. Her bir gözlem hattı için ayrı gözlem ve değerlendirme yapılır.

Best Practice Hens Protokolü tek katlı veya çok katlı kafessiz sistemlere göre yapılandırılmıştır. Kümeste kafessiz sistem ile açık alana erişimi olan ve organik yetiştirme sistemlerinde kümes içindeki değerlendirme bitinceye kadar tavukların açık alana çıkışına izin verilmeyeceğinden değerlendirmeler hep sabah erken saatlerde yapılmalıdır. Best Practice Hens Protokolünde 29 refah göstergesi bulunup, yapılan transekt gözlemde bu göstergelerin tespit edildiği tavuk sayısının gözlemlenen toplam tavuk sayısına oranı belirlenir. Tek katlı kümeste kafessiz yetiştirme kümeslerinde zemin gözlem hatlarına (transekt) bölünmeli, hepsi numaralanmalı ve değerlendirmeye ayrı ayrı alınmalıdır. Her refah değerlendirmesi biri duvar kenarı birisi ise merkezi gözlem hattı olmak üzere 2 gözlem hattında yürütülmelidir. Hat boyu yürüyüş (transekt yürüyüşü) öncesinde yetiştirici kümese girer girmez tavukları uzaktan 5 dakika gözlemler, tavuklarda panik tepkisi, kanat açma, hızlı solunum veya kümelenme davranışlarının olup olmadığı kontrol eder. Duvar ve merkezi gözlem hattı boyunca yürüyerek sadece yürümekte olduğu gözlem hattındaki tavukları inceler. Daha sonra diğer hatlarda da aynı değerlendirmeyi yapar. Bu yürüyüşler sırasında hatalı gaga kesimi olan, baş, sırt, göğüs ve kuyruk bölgelerinde tüy kayıpları olan ve taze veya eski yaralar görülen tavuk sayılarını belirlenir. Ayrıca tavukların sağlık durumuna ilişkin yapılan gözlemlerde ibik, gözler ve vücut üzerindeki hastalık belirtileri ile kloaka prolapsus'u görülen ve ekipmanlar arasında sıkışmış olan tavuk sayıları belirlenir.

Çok katlı aviary sistemlerde görsel olarak erişilemeyen katlar, gözlem hattının başından yaklaşık 5 m uzaktan ve ardından her 10 m'de olacak şekilde bir değerlendirilmelidir. Üst katlardaki tavuklar için basamak veya platform kullanılabilir. Bu yürüyüş sırasında ışık şiddeti, altlık kalitesi, tavuk kırmızı akarı ve zemindeki tüy miktarına ilişkin değerlendirme yapılır. Açık alana erişimi olan sistemlerde yapılan değerlendirmelerde, açık gezinti alanlarında da değerlendirme yapılır. Açık gezinti alanlarında yapılacak refah değerlendirmesinde yetiştirici gezinti alanı boyunca yürüyerek bu alandaki tavuk sayısı, bitki örtüsünün homojen kullanım durumu, hava durumu, alanın tamamının eşit şekilde otlatılma veya kullanılma durumu, kümes çıkış kapıları çevresindeki aşırı otlama ve erozyon belirtilerini tespit eder. Üretim ve performans verileri de değerlendirmede kullanılır. Bu kapsamda değerlendirmenin yapıldığı gün veya hafta ölen veya itlaf edilen tavuk sayıları ile üretilen yumurta sayısı, kirli, kırık veya kusurlu kabuklu yumurta sayıları ve altlığa yumurtanmış yumurta sayıları kaydedilir. Belirlenen hayvan ve yumurta sayıları üretim periyodunun başında kümese yerleştirilen tavuk sayısına oranlanarak değerlendirmeler tamamlanır (Best Practive Concorsiyum 2023).

4. SONUÇ

Hayvan refahı sertifikasyon sistemleri ve ilgili mevzuatın belirlediği çerçevede yumurta üretiminin sürdürülebilirliğinin sağlanabilmesi için, yumurtacı tavuk yetiştirme sistemlerinde hayvan refahının düzenli olarak izlenmesi önem taşımaktadır. Bununla birlikte, refah değerlendirmelerinin yalnızca mevzuata uyum amacıyla değil, hayvan refahı kayıplarının ve buna bağlı ekonomik kayıpların önlenmesi amacıyla üretim süreçlerinin izlenmesi, mevcut ya da potansiyel hayvan refahı risklerinin belirlenmesi ve önleyici tedbirlerin zamanında hayata geçirilmesi bakımından da işlevsel olması beklenmektedir. Bu nedenle yumurtacı tavuklarda hayvan refahı değerlendirme sistemlerinin yetiştiricinin rutin üretim süreçleri içerisinde kolaylıkla uygulayabileceği şekilde, pratik ve zaman açısından etkin olması gerekmektedir. Ayrıca, değerlendirme yöntemlerinin hayvanların yakalanması veya ele alınarak muamele edilmesine bağlı rahatsızlıklara yol açmaması büyük önem taşımaktadır. Bu kapsamda incelenen yumurtacı tavuk refahı değerlendirme protokollerinin, ağırlıkla invaziv olmayan yöntemler içerdiği, hayvan tabanlı refah göstergelerine dayandığı**,** kaynak ve yönetim tabanlı göstergelerin ise daha az olduğu görülmektedir. Genel olarak değerlendirildiğinde Welfare Quality refah değerlendirme sisteminin yapılacak değerlendirme sonuçlarının tarafsızlığı ve standardizasyonunu sağlamak amacıyla işletmeden bağımsız, çıkar çatışması olmayan ve eğitimli bir üçüncü taraf tarafından yapıldığı anlaşılmaktadır**.** Laywel, Aviary Transekt ve Best Practice Hens refah değerlendirme sistemleri ise hayvan refahının düzenli olarak izlenebilmesi, sorunların erken aşamada tespit edilmesi ve yönetim uygulamalarının geliştirilmesi amacıyla ve bağımsız dış denetimden ayrı olarak yetiştiricinin kendi tavuk sürülerinde hayvan refahını değerlendirilebilmesi için geliştirilmiştir. AssureWel protokolünün ise hem yetiştiricinin kendi sürülerinde yapacağı tavuk refahı değerlendirmeleri hem de işletmeden bağımsız bir üçüncü taraf tarafından yapılan değerlendirmeler için uygun olduğu görülmektedir. Sonuç olarak, tavuklarda hayvan refahının hızlı, pratik ve kolay bir şekilde değerlendirilmesi, elde edilen sonuçların güvenilir olması ve ayrıca sürü içindeki farklı zamanlarda ve işletmeler arasında yapılan değerlendirmeler açısından karşılaştırılabilir olması büyük önem taşımaktadır. Ayrıca, tavuklarda refah değerlendirme protokollerinin bu amaç doğrultusunda geliştirilmesinin,

değerlendirmelerde hayvan davranışları ve sağlığı ile ilgili gözlemlerin etkin bir şekilde yapılabilmesi için refah değerlendiricileri ve yetiştiricilere yönelik eğitim olanaklarının artırılmasının faydalı olacağı sonucuna varılmıştır.

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TÜRKİYE'DE YAYILIŞ GÖSTEREN GEYİK TÜRLERİNİN (CERVIDAE) MORFOLOJİK ÖZELLİKLERİNİN KARŞILAŞTIRILMASI

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ÖZET

Türkiye, Palearktik biyocoğrafik bölge içerisinde hem Asya hem Avrupa elementlerini barındıran, biyolojik çeşitlilik açısından zengin bir ülkedir. Bu çeşitlilik içinde memeli faunasının önemli bir kısmını Cervidae (geyikgiller) familyası oluşturur. Türkiye'de doğal olarak yayılış gösteren üç geyik türü bulunmaktadır: Kızıl Geyik (Cervus elaphus), Alageyik (Dama dama) ve Karaca (Capreolus capreolus). Bu çalışma, söz konusu türlerin morfolojik özelliklerinin karşılaştırmalı değerlendirmesini yaparak, habitat tercihleri, ekolojik adaptasyonları ve antropojenik baskılar altındaki değişimlerini analiz etmeyi amaçlamaktadır. Yöntem olarak, fotokapan yöntemi kullanılmıştır bunun yanısıra ulusal ve uluslararası literatürden elde edilen morfometrik, ekolojik ve genetik veriler değerlendirilmiştir. Bulgular, türler arasında belirgin vücut ölçüsü, post rengi, antler (boynuz) morfolojisi ve habitat tercihleri farkı bulunduğunu; ayrıca insan faaliyetleri sonucu habitat parçalanmasının bu farklılıkları derinleştirdiğini göstermektedir. Özellikle Türkiye popülasyonlarında izole yaşam alanları, genetik çeşitlilik kaybı ve azalan morfolojik varyasyon riskini beraberinde getirmektedir.

Anahtar kelimeler: *Cervidae, Cervus elaphus, Dama dama, Capreolus capreolus*, morfoloji, Türkiye, yaban hayatı, genetik çeşitlilik.

1. Giriş

Geyikgiller (Cervidae), karasal ekosistemlerde otlatma dinamiklerini, tohum yayılımını ve üst trofik düzeyde av-avcı ilişkilerini etkileyen kilit bir memeli familyasıdır. Morfoloji—vücut ölçüleri, kafatası oranları, post desenleri ve özellikle erkek bireylerdeki antler (boynuz) mimarisi—yalnızca tür tanısı ve cinsel seçilimin göstergesi değil, aynı zamanda habitat kalitesi, populasyon yapısı ve çevresel stres düzeylerinin de biyolojik göstergesidir (Kierdorf et al., 2023; Cambreling et al., 2023).

Türkiye, Palearktik biyocoğrafik bölgede üç yerli geyik türüne, kızıl geyik (Cervus elaphus), alageyik (Dama dama) ve karaca (Capreolus capreolus), ev sahipliği yapar. Türlerin morfolojik varyasyonu Karadeniz-İç Anadolu orman-step geçişleri, Akdeniz makisi ve Marmara-Trakya orman mozaikleri gibi farklı ekosistem koşullarında şekillenmiştir. Son dönem araştırmalar, morfolojik özelliklerin genetik bağlantısallık, habitat yapısı ve insan kaynaklı parçalanmayla yakından ilişkili olduğunu vurgulamaktadır (Laumeier et al., 2025; Brockhaus et al., 2025).

Avrupa'daki Cervus elaphus popülasyonlarında yürütülen yüksek çözünürlüklü genetik ve morfometrik analizler, ulaşım altyapısı ve yerleşim yoğunluğu gibi faktörlerin gen akışını kısıtladığını ve bunun boynuz boyutu, simetrisi ve vücut kütlesi gibi fenotipik özelliklerde bölgesel farklılaşmaya yol açtığını göstermektedir (Rizzoli & Bils, 2023; Laumeier et al., 2025).

Capreolus capreolus üzerine yapılan 2023 tarihli çok popülasyonlu bir çalışma, boynuz uzunluğundaki yaşlanma (senesans) örüntüsünün yaklaşık yedi yaşında başladığını ve bu parametrenin doğum çevresi (natal koşullar) ile habitat kalitesinden güçlü biçimde etkilendiğini ortaya koymuştur (Cambreling et al., 2023). Bu durum, Türkiye'deki karaca popülasyonlarının farklı ekolojik bölgelerde maruz kaldığı iklimsel stres ve besin kıtlığının morfolojik gelişimi etkileyebileceğine işaret eder.

Dama dama özelinde, Baker et al. (2024) tarafından yürütülen çalışmada türün 10 000 yıllık biyokültürel tarihi, insan etkisinin yayılım ve yeniden yerleştirme (reintroduction) süreçleri üzerindeki rolünü ortaya koymuştur. Aynı şekilde Rahimi et al. (2024), D. dama ve D. mesopotamica arasındaki iklim nişi benzerliğini değerlendirerek, iklimsel farklılıkların habitat uygunluğunu sınırlayabileceğini göstermiştir.

Bu bulgular, morfolojinin yalnızca fiziksel bir özellik değil; genetik çeşitlilik, iklim koşulları ve habitat bağlantısallığı arasındaki karmaşık etkileşimin bir çıktısı olduğunu ortaya koymaktadır. Türkiye'de yapılacak çalışmaların, morfometrik veriler ile genomik ve çevresel verileri birlikte ele alarak türlerin adaptif potansiyelini anlamaya odaklanması gereklidir (Brockhaus et al., 2025; Baker et al., 2024).

2. Materyal ve Yöntem

Bu çalışmada fotokapan çalışmalarının yanı sıra ulusal ve uluslararası kaynaklardan yararlanılmıştır. Değerlendirme parametreleri vücut uzunluğu, omuz yüksekliği, boynuz yapısı, post rengi, kafa morfometrisi ve habitat tercihlerini kapsamaktadır.

Bu çalışma kapsamında, yaban hayatının uzaktan gözlemlenmesi amacıyla fotokapan (camera-trap) yöntemi kullanılmıştır. Bu yöntem, insan müdahalesini en aza indirgeyerek, hedef türlerin doğal ortamlarında davranışlarının, yayılımının, yoğunluğunun veya mevcudiyetinin saptanmasına olanak tanır (Fisher et al., 2023).

3. Bulgular

3.1. Kızıl Geyik (*Cervus elaphus*)

Türkiye'de *Cervus elaphus* popülasyonları, Trakya, Karadeniz ve İç Anadolu'nun kuzey kuşağında yoğunlaşmıştır (Ulutürk & Yürümez, 2019). Ortalama erkek vücut uzunluğu 200–220 cm, omuz yüksekliği 120–130 cm, dişilerde ise 170–190 cm'dir. Erkeklerde boynuzlar 10–14 çatallı olup 80–110 cm uzunluğa ulaşabilir. Bu metrikler Avrupa popülasyonlarına göre daha düşük boynuz kütlesi ancak daha simetrik morfoloji ile tanımlanır (Mattioli et al., 2014; Rizzoli & Bils, 2023).

Son dönem genetik çalışmalar, kızıl geyiklerde yönetim baskısı (örneğin av kotası, orman içi izolasyon) nedeniyle genetik çeşitlilik kaybı yaşandığını; bu kaybın morfolojik varyasyon üzerinde belirgin etki yarattığını ortaya koymuştur (Brockhaus et al., 2025; Laumeier et al., 2025). Özellikle Türkiye'deki izole popülasyonlarda, boynuz uzunluğunun ve kütlesinin coğrafi olarak azaldığı, vücut ağırlığının ise habitat kalitesine bağlı olarak değiştiği gözlenmiştir.

Yüksek rakımlı orman habitatlarında yaşayan erkek bireylerin antlerleri daha kısa, fakat daha kalın ve dayanıklıdır; bu durum soğuk iklime adaptasyon ve enerji ekonomisi ile

ilişkilendirilmektedir (Kierdorf et al., 2023). Fotokapan verileri, erkeklerin yaz döneminde açık alanlarda, kışın ise yoğun ormanlarda aktivite gösterdiğini; dişilerin yavru bakım döneminde alan sadakatinin yüksek olduğunu göstermektedir.

Genetik verilerle destekli morfometrik analizler, Anadolu'daki kızıl geyiklerin Avrupa alt popülasyonlarıyla sınırlı gen akışı içinde olduğunu ortaya koymakta ve koridor yönetimi gerekliliğini vurgulamaktadır (Brockhaus et al., 2025).



Şekil 1. Kızılgeyik (*Cervus elaphus*)

3.2. Alageyik (*Dama dama*)

Alageyik Türkiye'de yalnızca Antalya Düzlerçamı Eşenadası Yaban Hayatı Geliştirme Sahası'nda doğal popülasyonlar hâlinde yaşamaktadır (Ünal & Çulhacı, 2018). Tarihsel olarak Ege, Marmara ve Akdeniz'de geniş bir dağılıma sahip olan bu tür, aşırı avlanma ve habitat kaybı sonucu yok olma noktasına gelmiştir. Günümüzde yapılan koruma ve yeniden yerleştirme çabaları, türün varlığını sınırlı da olsa sürdürmektedir.

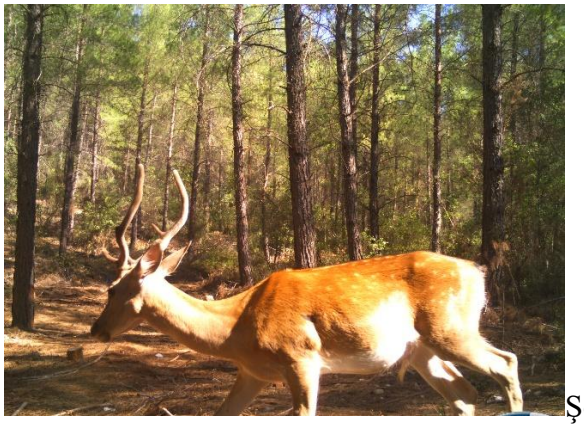
Vücut uzunluğu 130–160 cm, omuz yüksekliği 85–100 cm arasında değişir. Erkeklerde boynuzlar yaba şeklinde olup 40–60 cm genişliğe ulaşır (Marzban Abbasabadi et al., 2021).

Post rengi yazın açık kahverengi ve beyaz beneklidir; kışın ise daha koyu ve mat tonlardadır. Bu renk değişimi, fotoperiyodik hormon regülasyonuyla kontrol edilir (Baker et al., 2024).

Son genomik araştırmalar, alageyiğin 10 000 yıllık biyokültürel tarihinde insan etkisiyle yayılım ve yeniden yerleştirme süreçlerine maruz kaldığını; bu nedenle genetik homojenliğin düşük ve izolasyonun yüksek olduğunu göstermektedir (Baker et al., 2024). Bu izolasyon, morfolojik çeşitliliği azaltmakta, özellikle erkeklerde boynuz genişliğinin nesiller arası daralmasına yol açmaktadır.

İklimsel niş analizleri, D. dama ile D. mesopotamica arasında belirgin bir iklim benzerliği olduğunu, ancak yerel habitatların farklılaştığını göstermektedir (Rahimi et al., 2024). Bu durum, Türkiye'de yürütülen yeniden yerleştirme (reintroduction) projelerinde alan seçiminin sadece iklim değil, vejetasyon tipi ve suya erişim kriterleriyle birlikte değerlendirilmesi gerektiğini ortaya koymaktadır.

Alageyik popülasyonlarında yapılan fotokapan çalışmalarında erkek bireylerin çiftleşme dönemlerinde, erkek bireylerin hazırladığı çiftleşme yalaklarında daha uzun süre kaldığı ve sosyal hiyerarşinin morfolojik boynuz yapısıyla ilişkilendirildiği saptanmıştır (Ünal & Çulhacı, 2018). Bu davranışsal yapı, üreme başarısı ile doğrudan bağlantılıdır.

Şekil 2. Alageyik *(Dama dama)*

3.3. Karaca (*Capreolus capreolus*)

Karaca, Türkiye'nin Karadeniz, Marmara ve Doğu Anadolu'nun kuzey kuşağı boyunca geniş, ancak parçalı popülasyonlar hâlinde yaşamaktadır (Özcan, 2021). Vücut uzunluğu 95–135 cm,

omuz yüksekliği 65–80 cm, erkeklerde antler uzunluğu 15–25 cm'dir. Dişiler genellikle boynuzsuzdur.

Capreolus capreolus'un morfolojik karakterleri, habitat tipi ve iklimsel koşullara göre büyük farklılık gösterir. Avrupa'daki çalışmalar, erken yaşam döneminde besin kıtlığı yaşayan bireylerde boynuz büyümesinin sınırlı kaldığını, senesans eğiliminin (yaşa bağlı kısalma) erken başladığını göstermektedir (Cambreling et al., 2023). Türkiye'deki karaca popülasyonları için bu bulgu, orman açıklıklarının azalması ve habitat kalitesi düşüşüyle uyumludur.

Post rengi yazın kırmızımsı kahverengi, kışın gri tonlardadır. Bu değişim, kamuflaj ve termoregülasyon açısından adaptif bir özelliktir. Fotokapan verileri, karacaların çoğunlukla alacakaranlık saatlerinde aktif olduğunu ve insan yerleşimlerinden uzak bölgeleri tercih ettiğini göstermektedir.

Morfometrik analizlerde erkek bireylerin kafa uzunluğu ve mandibula oranlarının kuzey popülasyonlarında daha büyük olduğu, bunun Allen kuralı ile uyumlu olarak soğuk iklim adaptasyonu sağladığı görülmektedir.



Şekil 3. Karaca *(Capreolus capreolus)*

3.4. Türler Arası Karşılaştırma

Özellik	*Cervus elaphus*	*Dama dama*	*Capreolus capreolus*
Vücut Uzunluğu	200–220 cm (♂)	130–160 cm (♂)	95–135 cm (♂)
Boynuz Yapısı	Çok çatallı, silindirik	Kürek biçimli (Yaba)	Kısa, üç çatallı

Özellik	*Cervus elaphus*	*Dama dama*	*Capreolus capreolus*
Habitat	Orman ve karışık step	Akdeniz makisi, orman açıklıkları	Yoğun orman ve açıklık kenarları
Sosyal Davranış	Harem sistemi, rut dönemi baskınlığı	Lek davranışı, toplu üreme	Yalnız veya küçük gruplar
Koruma Durumu	LC (IUCN, 2025)	LC, fakat yerel risk yüksek	LC

Genel olarak türlerin morfolojik farklılıkları, habitat kullanımı, beslenme alışkanlıkları ve iklimsel adaptasyonlarıyla yakından ilişkilidir. Türkiye popülasyonları, Avrupa örneklerine kıyasla daha düşük boynuz metrikleri, yüksek simetri oranları ve yerel çevresel kısıtlara bağlı morfometrik varyasyon göstermektedir.

4. Tartışma

Bu çalışmada Türkiye'de doğal olarak yayılış gösteren üç Cervidae türü — Cervus elaphus, Dama dama ve Capreolus capreolus — morfolojik, ekolojik ve davranışsal özellikleri bakımından karşılaştırılmış; türler arası farkların habitat kullanımı, genetik çeşitlilik ve antropojenik baskılarla nasıl ilişkili olduğu değerlendirilmiştir. Elde edilen bulgular, morfolojinin yalnızca tür tanı ölçütü değil, aynı zamanda ekosistem kalitesi ve popülasyon sağlığının biyolojik göstergesi olduğunu ortaya koymaktadır (Cambreling et al., 2023; Kierdorf et al., 2023).

4.1. Kızıl Geyik (Cervus elaphus) Üzerine Tartışma

Türkiye'deki kızıl geyik popülasyonlarının Trakya, Karadeniz ve İç Anadolu alt birimlerinde morfolojik ve genetik farklılaşma göstermesi, habitat parçalanması ve yönetim birimleri arası gen akışı kısıtlamaları ile açıklanabilir (Laumeier et al., 2025; Brockhaus et al., 2025). Bu durum Avrupa'daki popülasyon yapısına paralel olarak genetik izolasyonun morfometrik daralmaya yol açtığını destekler.Bulgular, Türkiye'deki erkek geyiklerin Avrupa örneklerine kıyasla daha küçük antler hacmine, fakat daha yüksek simetriye sahip olduğunu göstermektedir (Rizzoli & Bils, 2023). Simetri, seksüel seçilimde bireysel uygunluğun (fitness) dolaylı göstergesi olup, kaynak sınırlı ortamda bile genetik kalitenin korunabildiğine işaret eder. Bununla birlikte, uzun vadede izolasyonun artması durumunda bu simetrik yapının genetik varyasyon eksikliği nedeniyle zayıflayabileceği öngörülmektedir (Brockhaus et al., 2025).Bu nedenle, kızıl geyik yönetim planlarında yalnızca popülasyon büyüklüğü değil, antler morfometrisi, yaş dağılımı ve genetik göstergeler eş zamanlı izlenmelidir. Özellikle orman içi

ekolojik koridorlar ve "yol geçitleri (wildlife crossings)" gibi bağlantısallık önlemleri, türün gen akışını korumada kilit rol oynar.

4.2. Alageyik (Dama dama) Üzerine Tartışma

Alageyik, Türkiye'nin en hassas Cervidae türüdür; çünkü popülasyonu yalnızca Antalya Düzlerçamı bölgesinde doğal olarak devam etmektedir (Ünal & Çulhacı, 2018). Bulgular, bu popülasyonda antler genişliğinin ve vücut kütlesinin Avrupa ortalamalarının altında olduğunu göstermiştir. Bu farkın, uzun süreli izolasyon, dar gen havuzu ve yüksek iç çiftleşme oranı (inbreeding) ile ilişkili olduğu düşünülmektedir (Baker et al., 2024).

Uluslararası genetik veriler, alageyiğin tarih boyunca insan etkisiyle birçok kez yeniden yerleştirildiğini ve bu süreçte popülasyonların genetik olarak homojenleştiğini göstermektedir (Rahimi et al., 2024). Bu nedenle Türkiye'de yürütülen koruma projelerinde genetik izleme (DNA marker tabanlı) çalışmaların zorunlu hâle getirilmesi önerilmektedir. Ayrıca, lek davranışı (erkeklerin kur davranışı için oluşturduğu geçici alanlar) gibi sosyal yapılar, morfolojik özelliklerle (boynuz genişliği, vücut boyutu) doğrudan ilişkilidir. Enerji harcaması yüksek olan bu üreme stratejisinde, besin kaynaklarının mevsimsel sürekliliği populasyon sağlığı açısından kritik öneme sahiptir (Marzban Abbasabadi et al., 2021).

Gelecekte Türkiye'de yapılacak alageyik reintroduksiyon projelerinde, seçilecek alanların yalnızca iklimsel uygunluk değil, vejetasyon yapısı, su kaynaklarına erişim ve av baskısı düzeyi açısından da modellenmesi gerekmektedir (Rahimi et al., 2024).

4.3. Karaca (Capreolus capreolus) Üzerine Tartışma

Karacalar, Türkiye'nin kuzey orman kuşağında en geniş dağılıma sahip Cervidae türüdür, ancak popülasyonlar mozaik yapıdadır (Özcan, 2021). Bulgular, habitat kalitesi ve erken yaşam koşullarının antler gelişimini doğrudan etkilediğini göstermektedir (Cambreling et al., 2023). Özellikle orman açıklıklarının azaldığı bölgelerde, antler senesansının daha erken yaşta başladığı ve bireysel kondisyonun düştüğü görülmektedir.

Bu bulgu, "yaşam öyküsü stratejileri" açısından önemlidir; çünkü karacalar kısa ömürlü, hızlı üreme stratejisine sahip türlerdir. Enerji dengesi, özellikle kış aylarında yoğun stres altına girer

ve bu durum morfolojik gelişim üzerinde baskı oluşturur. Dolayısıyla karaca populasyonlarının yönetiminde mevsimsel besin planlaması ve koruma alanı bağlantısallığı öncelikli olmalıdır.

Bununla birlikte, Türkiye popülasyonlarında kuzey-güney morfometrik gradyan gözlenmekte; kuzey bireylerinin vücut ölçülerinin daha büyük olması Allen kuralı ile uyumludur. Bu morfolojik farklılaşma, iklimsel adaptasyon kapasitesinin yüksek olduğunu, ancak yerel habitat kaybının bu avantajı sınırlayabileceğini göstermektedir.

4.4. Türler Arası Değerlendirme ve Ekolojik Yorum

Türler arası karşılaştırma, morfolojik farklılıkların yalnızca filogenetik değil; habitat yapısı, iklimsel stres ve insan etkisinin bileşkesi olduğunu göstermiştir (Brockhaus et al., 2025). Kızıl geyik büyük gövdeli ve çok çatallı antler yapısı ile ormanlık ekosistemlerin açık alan kenarlarını tercih ederken; alageyik orta boylu, benekli postu ve palmated antleri ile Akdeniz makisine uyum sağlar. Karaca ise küçük vücut boyutuyla sık bitki örtüsünde hareket avantajı elde eder.

Türkiye popülasyonlarında ortak olarak gözlenen eğilim, vücut kütlesi ve antler metriklerinde düşüş ile yüksek simetri oranlarının korunmasıdır. Bu durum, sınırlı kaynak koşullarında bile adaptif denge mekanizmalarının sürdüğünü göstermektedir. Ancak uzun vadede genetik izolasyonun devam etmesi durumunda bu denge bozulabilir (Laumeier et al., 2025).

Bu nedenle, ülke genelinde tür bazlı morfolojik izleme programlarının genetik verilerle entegre edilmesi; fotokapan, drone ve LiDAR teknolojilerinin birlikte kullanıldığı ulusal Cervidae izleme ağının kurulması önerilmektedir.

4.5. Yönetimsel ve Koruma Öncelikleri

Morfolojik izleme standardizasyonu: Her tür için yaş-yapısı kontrollü antler ölçümleri ve vücut metrikleri oluşturulmalıdır.

Genetik bağlantısallık: Özellikle kızıl geyik ve alageyik için habitat koridorları ve geçit yapıları planlanmalıdır.

Fotokapan tabanlı izleme: Türlerin davranışsal aktiviteleri uzun dönemli veri tabanlarında saklanmalı, populasyon modelleriyle ilişkilendirilmelidir.

İklimsel adaptasyon izleme: Karaca ve alageyik popülasyonlarında post rengi değişimi ve morfometrik varyasyon iklim değişikliği göstergesi olarak kullanılabilir.

Reintroduksiyon politikaları: Alageyik için yeniden yerleştirme alanlarında genetik çeşitlilik temelli seçilim kriterleri uygulanmalıdır.

4.6. Genel Değerlendirme

Türkiye'deki Cervidae popülasyonları, Avrupa'daki akrabalarına kıyasla daha yüksek antropojenik baskıya maruz kalmakla birlikte, morfolojik ve genetik olarak adaptif dirençlilik gösterebilmektedir. Ancak bu direnç, habitat kaybı, yasal olmayan avcılık ve iklim değişikliğinin birleşik etkileriyle sınırlarına ulaşmaktadır.

Bu nedenle, morfoloji temelli izleme yaklaşımları yalnızca akademik analiz aracı değil, aynı zamanda uyarlanabilir yönetim (adaptive management) stratejilerinin bir parçası olarak görülmelidir. Geyiklerin ekosistem mühendisliği rolü, bitki örtüsü yenilenmesi, tohum yayılımı ve trofik ağların dengesi açısından kritik öneme sahiptir.

Dolayısıyla, türlerin morfolojik ve genetik özelliklerinin izlenmesi; yalnızca biyolojik çeşitliliğin korunması değil, aynı zamanda ekosistem dayanıklılığı açısından da stratejik bir gerekliliktir (Baker et al., 2024; Cambreling et al., 2023).

5. Sonuç

Türkiye'deki Cervus elaphus, Dama dama ve Capreolus capreolus türleri morfolojik olarak farklı ekolojik stratejiler geliştirmiştir. Ancak insan baskısı ve habitat kaybı, bu çeşitliliği tehdit etmektedir. Tür bazında morfolojik izleme, genetik analizler ve habitat koridorlarının oluşturulması öncelikli olmalıdır. Fotokapan temelli uzun dönemli izleme ağları ve yaş-yapısı kontrollü antler ölçümleri, koruma politikalarının temelini oluşturmalıdır. Bu çalışmalar, Türkiye'deki geyik popülasyonlarının morfolojik ve genetik sürdürülebilirliğini güçlendirecektir.

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TÜRKİYE'DEKİ ENDEMİK OMURGALI HAYVANLAR

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ÖZET

Türkiye, Asya ile Avrupa kıtaları arasında bir köprü konumunda bulunması, farklı iklim tiplerine ve topografik çeşitliliğe sahip olması nedeniyle dünyanın en zengin biyolojik çeşitlilik merkezlerinden biridir. Aynı zamanda jeolojik geçmişi, farklı iklim kuşakları ve zengin ekosistem çeşitliliği sayesinde de yüksek düzeyde endemizme sahip ülkeler arasında yer almaktadır. Bu özellik, ülkenin omurgalı faunasına da yansımış ve özellikle balıklar, amfibiler, sürüngenler ve memeliler arasında çok sayıda endemik türün ortaya çıkmasına neden olmuştur. Bu çalışma, Türkiye'deki tüm endemik omurgalı hayvan türlerini ilk kez tek bir çatı altında toplayarak kapsamlı bir kaynak oluşturmayı amaçlamaktadır. Türler, sistematik sınıflandırma esas alınarak tablolar hâlinde sunulmuş; her bir türün bilimsel adı, yayılış alanı ve endemiklik düzeyi detaylandırılmıştır. Böylece, Türkiye omurgalı faunasının endemik bileşenleri bütüncül bir bakış açısıyla değerlendirilmiştir. Bu derleme hem araştırmacılar hem de doğa koruma politikaları geliştiren kurumlar için temel bir başvuru kaynağı niteliği taşımakta; endemik türlerin korunması, izlenmesi ve geleceğe aktarılması adına önemli bir veri tabanı sağlamaktadır.

Anahtar Kelimeler: Türkiye endemikleri, omurgalı hayvanlar, fauna, biyolojik çeşitlilik, ekoloji

GİRİŞ

Türkiye, coğrafi konumi itibarıyla Asya, Avrupa ve Afrika kıtaları arasında doğal bir köprü vazifesi görmesinin ötesinde, barındırdığı olağanüstü biyolojik çeşitlilik ile dünyanın en dikkat çekici ekosistemlerinden birine sahiptir. Üç farklı fitocoğrafik bölgenin (Avrupa-Sibirya, Akdeniz ve İran-Turan) kesişim noktasında yer alması, topoğrafik yapısındaki ani değişimler ve jeolojik geçmişi boyunca sığınak (refugium) görevi görmesi, ülkemizi türleşme süreçleri açısından bir laboratuvar haline getirmiştir (Demirsoy, 2002). Bu zenginliğin en kıymetli parçasını ise hiç kuşkusuz, dünya üzerinde sadece Anadolu topraklarına özgü olan endemik türler oluşturmaktadır.

Biyolojik çeşitlilik tartışmalarında genellikle bitki florası ön plana çıksa da, Türkiye'nin omurgalı faunası, evrimsel süreçlerin ve adaptasyon yeteneğinin eşsiz örneklerini barındırır (Şekercioğlu vd., 2011). Toros Dağları'nın yüksek sarp kayalıklarından, İç Anadolu'nun bozkır ekosistemlerine; Doğu Karadeniz'in nemli ormanlarından, Ege'nin sulak alanlarına kadar her bölge, kendine has bir omurgalı komünitesine ev sahipliği yapmaktadır (Kence & Bilgin, 1996). Günümüzde tanımlanan birçok iç su balığı, çift yaşayışlı (amfibi), sürüngen ve memeli türü, yalnızca bu coğrafyanın ekolojik sınırları içerisinde yaşamını sürdürmektedir (Turan vd., 2012).

Ancak bu endemizm başarısı, beraberinde büyük bir sorumluluğu da getirmektedir. Habitat kaybı, iklim değişikliği ve insan kaynaklı baskılar, bu "sessiz komşularımızın" varlığını tehdit etmekte; genetik mirasımızın korunmasını zorunlu kılmaktadır (Eken vd., 2006). Bu makalede, Türkiye'nin endemik omurgalı türlerinin taksonomik dağılımı, ekolojik tercihleri ve güncel koruma statüleri (IUCN, 2025) ele alınarak, Anadolu'nun bu canlı hazinesinin bilimsel ve ekolojik önemi ortaya konulacaktır.

MATERYAL VE YÖNTEM

Konuya ilişkin daha önce yapılmış olan çalışmalar ulusal ve uluslararası veri tabanları (Dergipark, TRIndex, ULAKBİM, ERIC ve Web of Science) kullanılarak incelenmiştir. Araştırmada doküman analizi yöntemi kullanılmış olup ulaşılan makalelerden güncel olanlar çalışmaya dahil edilmiştir. Çalışmanın uygulamalı materyal kısmını ise, saha çalışmaları kapsamında farklı istasyonlara kurulan fotokapan cihazlarından elde edilen görsel veriler (fotoğraf ve video kayıtları) teşkil etmektedir. Literatür taramasından elde edilen teorik bilgiler ile fotokapan kayıtlarından gelen ampirik veriler harmanlanarak çalışma kapsamındaki bulgular derlenmiştir.

BULGULAR VE TARTIŞMA

Bu çalışmada ortaya konulan bulgular, Türkiye'nin endemik omurgalı faunasının taksonomik çeşitlilik, evrimsel özgünlük ve ekolojik hassasiyet bakımından küresel ölçekte öncelikli korunması gereken alanlardan biri olduğunu açıkça göstermektedir. Anadolu'nun jeolojik geçmişi, Pliyosen ve Pleistosen dönemlerde refugium işlevi görmesi ve havza bazlı izolasyon süreçleri, özellikle iç su balıkları ve amfibilerde yüksek düzeyde endemizmin oluşmasına zemin hazırlamıştır (Freyhof & Brooks, 2011; Çiçek, Birecikligil & Fricke, 2015).

Endemik balık türlerinin sayısal baskınlığı, Türkiye iç sularının evrimsel açıdan ne denli dinamik ve kırılgan bir yapıya sahip olduğunu ortaya koymaktadır. Kapalı havza sistemleri, göller ve kısa akarsu ağları, türleşmeyi teşvik eden doğal bariyerler oluşturmuş; ancak aynı zamanda bu türleri antropojenik baskılara karşı son derece savunmasız hâle getirmiştir. Baraj ve HES projeleri, su çekimleri, kirlilik ve istilacı türler, özellikle Pseudophoxinus, Oxynoemacheilus ve Anatolichthys cinslerine ait türlerde popülasyon daralmalarının temel nedenleri arasında gösterilmektedir (Küçük et al., 2014; Freyhof et al., 2022).

Amfibi ve sürüngen endemizmi açısından bakıldığında, Toros Dağları ve Batı Akdeniz kuşağı öne çıkmaktadır. Lyciasalamandra türleri gibi mikroendemik ve habitat uzmanı amfibiler, iklim değişikliği ve habitat parçalanmasına karşı son derece hassas olup, çok sınırlı dağılış alanları nedeniyle yüksek yok olma riski altındadır (Veith et al., 2016; IUCN, 2023). Benzer şekilde, Anadolu'ya özgü engerek türleri (Vipera ve Montivipera spp.), ekosistemlerin üst trofik seviyelerinde yer alarak hem besin ağlarının dengelenmesinde hem de biyocoğrafik süreçlerin anlaşılmasında anahtar rol oynamaktadır (Nilson & Andrén, 2014).

Endemik memelilerin sayıca daha sınırlı olması, bu grubun genellikle daha geniş yayılış eğilimleri göstermesiyle ilişkilidir. Bununla birlikte Ovis gmelini anatolica gibi türler, genetik izolasyonları ve sınırlı popülasyon büyüklükleri nedeniyle özel koruma statülerine ihtiyaç duymaktadır (Groves & Grubb, 2011; Sözen & Çolak, 2025). Mevcut veriler, tür odaklı koruma yaklaşımlarının tek başına yeterli olmadığını; havza, peyzaj ve ekolojik koridor ölçeğinde bütüncül planlamaların zorunlu olduğunu ortaya koymaktadır.

ENDEMİK BALIKLAR

Acanthobrama orontis	Akçapak Balığı
Acanthobrama thisbeae	Tahta Balığı
Alburnoides coskuncelebii	Noktalı İnci Balığı
Alburnoides diclensis	Noktalı İnci Balığı
Alburnoides freyhofi	Noktalı İnci Balığı
Alburnoides kosswigi	Noktalı İnci Balığı
Alburnoides kurui	Noktalı İnci Balığı
Alburnoides manyasensis	Noktalı İnci Balığı
Alburnoides smyrnae	Noktalı İnci Balığı
Alburnoides turani	Noktalı İnci Balığı
Alburnus adanensis	İnci Balığı
Alburnus akili	Gövce
Alburnus attalus	İnci Balığı
Alburnus baliki	İnci Balığı
Alburnus carianorum	İnci Balığı
Alburnus carinatus	İnci Balığı
Alburnus demiri	İnci Balığı
Alburnus escherichii	İnci Balığı
Alburnus goekhani	İnci Balığı
Alburnus istanbulensis	İnci Balığı

Alburnus kotschyi	İnci Balığı
Alburnus kurui	İnci Balığı
Alburnus nicaeensis	İnci Balığı
Alburnus tarichi	İnci Kefali
Alburnus timarensis	İnci Kefali
Anatolichthys anatoliae	Anadolu Dişli Sazancığı
Anatolichthys chantrei	Dişli Sazancık
Anatolichthys danfordii	Dişli Sazancık
Anatolichthys fontinalis	Dişli Sazancık
Anatolichthys iconii	Dişli Sazancık
Anatolichthys irregularis	Dişli Sazancık
Anatolichthys maeandricus	Menderes Dişli Sazancığı
Anatolichthys marassantensis	Dişli Sazancık
Anatolichthys saldae	Salda Dişli Sazancığı
Anatolichthys splendens	Dişli Sazancık
Anatolichthys sureyanus	Dişli Sazancık
Anatolichthys transgrediens	Dişli Sazancık
Anatolichthys villwocki	Dişli Sazancık
Barbus anatolicus	Anadolu Bıyıklı Balığı
Barbus ercisianus	Bıyıklı Balık
Barbus escherichii	Bıyıklı Balık
Barbus ida	İda Bıyıklı Balığı
Barbus niluferensis	Nilüfer Bıyıklı Balığı
Barbus oligolepis	Bıyıklı Balık
Barbus xanthos	Ksantos Bıyıklı Balık
Capoeta antalyensis	Antalya Sirazı
Capoeta aydinensis	Aydın Sirazı
Capoeta bergamae	Bergama Sirazı
Capoeta caelestis	Siraz
Capoeta oguzelii	Siraz
Capoeta pestai	Siraz
Capoeta tinca	Siraz
Chondrostoma angorense	Ankara Karaburnu
Chondrostoma beysehirense	Beyşehir Karaburnu
Chondrostoma ceyhanense	Ceyhan Karaburnu
Chondrostoma holmwoodii	Karaburun
Chondrostoma meandrense	Menderes Karaburnu
Chondrostoma smyrnae	İzmir Karaburnu
Chondrostoma toros	Toros Karaburnu
Chondrostoma turnai	Karaburun
Clupeonella muhlisi	Tatlısu Hamsisi
Cobitis afifeae	Çöpçü Balığı
Cobitis aliyeae	Çöpçü Balığı
Cobitis battalgilae	Çöpçü Balığı
Cobitis bilseli	Çöpçü Balığı
Cobitis dorademiri	Çöpçü Balığı
Cobitis emrei	Çöpçü Balığı
Cobitis erkakanae	Çöpçü Balığı

Cobitis evreni	Çöpçü Balığı
Cobitis fahirae	Çöpçü Balığı
Cobitis indus	Çöpçü Balığı
Cobitis joergbohleni	Çöpçü Balığı
Cobitis kellei	Çöpçü Balığı
Cobitis phrygica	Çöpçü Balığı
Cobitis pirii	Çöpçü Balığı
Cobitis simplicispina	Çöpçü Balığı
Cobitis sipahilerae	Çöpçü Balığı
Cobitis splendens	Çöpçü Balığı
Cobitis troasensis	Çöpçü Balığı
Cobitis turcica	Çöpçü Balığı
Egirdira nigra	Eğirdir Göl Yayıncığı
Garra kemali	Kemali Ağzıkaygan
Garra klatti	Ağzıkaygan Balığı
Garra turcica	Türk Ağzıkayganı
Gobio baliki	Kayabalığı
Gobio fahrettini	Kayabalığı
Gobio gymnostethus	Kayabalığı
Gobio hettitorum	Kayabalığı
Gobio insuyanus	Kayabalığı
Gobio intermedius	Kayabalığı
Gobio kizilirmakensis	Kızılırmak Kayabalığı
Gobio maeandricus	Menderes Kayabalığı
Gobio microlepidotus	Kayabalığı
Gobio sakaryaensis	Sakarya Kayabalığı
Knipowitschia byblisia	Kayabalığı
Knipowitschia caunosi	Kayabalığı
Knipowitschia mermere	Mermere Kayabalığı
Knipowitschia ricasolii	Kayabalığı
Kosswigichthys asquamatus	Dişli Sazancık
Ladigesocypris mermere	Mermere İnci Balığı
Lampetra lanceolata	Kıyı Tahtası
Luciobarbus kottelati	Bıyıklı Balık
Luciobarbus lydianus	Lidya Bıyıklı Balığı
Oxynoemacheilus afrenatus	Afrenatus Çöpçüsü
Oxynoemacheilus amanos	Amanos Çöpçüsü
Oxynoemacheilus anatolicus	Anadolu Çöpçüsü
Oxynoemacheilus angorae	Ankara Çöpçüsü
Oxynoemacheilus araxensis	Aras Çöpçüsü
Oxynoemacheilus arsaniasus	Çöpçü Balığı
Oxynoemacheilus axylos	Çöpçü Balığı
Oxynoemacheilus banarescui	Çöpçü Balığı
Oxynoemacheilus ceyhanensis	Ceyhan Çöpçüsü
Oxynoemacheilus ciceki	Çöpçü Balığı
Oxynoemacheilus cilicicus	Çöpçü Balığı
Oxynoemacheilus cyri	Çöpçü Balığı
Oxynoemacheilus eliasi	Çöpçü Balığı

Oxynoemacheilus ercisianus	Erciş Çöpçüsü
Oxynoemacheilus eregliensis	Ereğli Çöpçüsü
Oxynoemacheilus evreni	Çöpçü Balığı
Oxynoemacheilus fatsaensis	Fatsa Çöpçüsü
Oxynoemacheilus germencicus	Çöpçü Balığı
Oxynoemacheilus hazarensis	Hazar Çöpçüsü
Oxynoemacheilus isauricus	Çöpçü Balığı
Oxynoemacheilus kaynaki	Çöpçü Balığı
Oxynoemacheilus marmaraensis	Marmara Çöpçüsü
Oxynoemacheilus mediterraneus	Akdeniz Çöpçüsü
Oxynoemacheilus melenicus	Melen Çöpçüsü
Oxynoemacheilus muefiti	Çöpçü Balığı
Oxynoemacheilus nasreddini	Nasreddin Çöpçüsü
Oxynoemacheilus paucilepis	Çöpçü Balığı
Oxynoemacheilus sakaryaensis	Sakarya Çöpçüsü
Oxynoemacheilus samanticus	Kızılırmak Çöpçü Balığı
Oxynoemacheilus sarus	Çöpçü Balığı
Oxynoemacheilus seyhanensis	Seyhan Çöpçüsü
Oxynoemacheilus simavicus	Çöpçü Balığı
Oxynoemachelilus seyhanicola	Çöpçü Balığı
Paracapoeta erhani	Siraz
Paracobitis salihae	Çöpçü Balığı
Paraphanius alexandri	Dişlisazancık
Paraphanius boulengeri	Dişlisazancık
Paraphanius mentoides	Dişlisazancık
Paraphanius similis	Dişlisazancık
Paraschistura chrysicristinae	Çöpçü Balığı
Petroleuciscus ninae	Tatlısu Kefali
Phoxinus abanticus	Abant İnci Balığı
Pomatoschistus anatoliae	Kaya Balığı
Ponticola rizensis	Kaya Balığı
Ponticola turani	Kaya Balığı
Pseudophoxinus alii	Yalancı İnci Balığı
Pseudophoxinus anatolicus	Anadolu Yalancı İnci Balığı
Pseudophoxinus antalyae	Antalya Yalancı İnci Balığı
Pseudophoxinus battalgilae	Yalancı İnci Balığı
Pseudophoxinus burduricus	Burdur Yalancı İnci Balığı
Pseudophoxinus caralis	Yalancı İnci Balığı
Pseudophoxinus cilicicus	Yalancı İnci Balığı
Pseudophoxinus crassus	Yalancı İnci Balığı
Pseudophoxinus elizavetae	Yalancı İnci Balığı
Pseudophoxinus evliyae	Yalancı İnci Balığı
Pseudophoxinus fahrettini	Yalancı İnci Balığı
Pseudophoxinus firati	Fırat Yalancı İnci Balığı
Pseudophoxinus handlirschi	Yalancı İnci Balığı

Pseudophoxinus hittitorum	Yalancı İnci Balığı
Pseudophoxinus iconii	Yalancı İnci Balığı
Pseudophoxinus maeandri	Menderes Yalancı İnci Balığı
Pseudophoxinus maeandricus	Menderes Yalancı İnci Balığı
Pseudophoxinus mehmeti	Yalancı İnci Balığı
Pseudophoxinus ninae	Yalancı İnci Balığı
Pseudophoxinus turani	Yalancı İnci Balığı
Pseudophoxinus zekayi	Yalancı İnci Balığı
Salariopsis renatorum	Kaya Balığı
Salmo abanticus	Abant Alabalığı
Salmo araxensis	Aras Alabalığı
Salmo ardahanensis	Ardahan Alabalığı
Salmo baliki	Alabalık
Salmo chilo	Alabalık
Salmo duhani	Alabalık
Salmo euphrataeus	Alabalık
Salmo fahrettini	Alabalık
Salmo kottelati	Alabalık
Salmo labecula	Alabalık
Salmo munzuricus	Munzur Alabalığı
Salmo murathani	Alabalık
Salmo okumusi	Alabalık
Salmo opimus	Alabalık
Salmo platycephalus	Düzbaşlı Alabalık
Salmo rizeensis	Alabalık
Salmo tigridis	Kırmızı Benekli Alabalık
Scardinius elmaliensis	Elmalı Kızılgözü
Seminemacheilus ahmeti	Çöpçü Balığı
Seminemacheilus attalicus	Çöpçü Balığı
Seminemacheilus dursunavsari	Çöpçü Balığı
Seminemacheilus ekmekciae	Çöpçü Balığı
Seminemacheilus ispartensis	Çöpçü Balığı
Seminemacheilus lendlii	Çöpçü Balığı
Squalius adanaensis	Adana Kefali
Squalius anatolicus	Anadolu Kefali
Squalius aristotelis	Tatlısu Kefali
Squalius cappadocicus	Kapadokya Kefali
Squalius carinus	Tatlısu Kefali
Squalius fellowesii	Tatlısu Kefali
Squalius irideus	Tatlısu Kefali
Squalius kosswigi	Tatlısu Kefali
Squalius kottelati	Tatlısu Kefali
Squalius pursakensis	Porsuk Kefali
Squalius recurvirostris	Tatlısu Kefali
Squalius semae	Tatlısu Kefali
Squalius seyhanensis	Seyhan Kefali
Squalius verepi	Tatlısu Kefali

Turcichondrostoma fahirae	Karaburun
Turcinoemacheilus ekmekciae	Çöpçü Balığı
Turcinoemacheilus minimus	Çöpçü Balığı
Vimba mirabilis	İnci Balığı



Seminemacheilus lendlii- Çöpçü Balığı

ENDEMİK AMFİBİLER

Semender	
Neurergus strauchii	Benekli Semender
Lyciasalamandra luschani finikensis	Finike Semenderi
Lyciasalamandra luschani	Likya-Kara Semenderi
Lyciasalamandra fazilae	Fazıla Kara Semenderi
Lyciasalamandra flavimembris	Marmaris-Köyceğiz Semenderi
Lyciasalamandra billae	Girit Pürtüklü Semenderi
Lyciasalamandra antalyana	Antalya Semenderi
Lyciasalamandra atifi	Alanya Semenderi
Lyciasalamandra irfani	Göynük Semenderi
Lyciasalamandra arikani	Ulupınar Semenderi
Lyciasalamandra yehudahi	Kemer Semenderi
Lyciasalamandra helverseni	Giritli Semender
Triturus anatolicus	Anadolu tepeli semenderi
Kurbağa	
Rana holtzi	Toros Kurbağası
Rana tavasensis	Tavas Kurbağası
Pelophylax caralitanus	Anadolu-Beyşehir Kurbağası




Neurergus strauchii- Benekli Semender *Rana holtzi*- Toros Kurbağası

ENDEMİK SÜRÜNGENLER

Kertenkele	
Asaccus barani	Baran Keleri
Acanthodactylus harranensis	Harran Saçaklı Kertenkelesi
Anatololacerta danfordi	Danford kertenkelesi
Darevskia bendimahiensis	Bendimahi Kertenkelesi
Darevskia sapphirina	Van Kertenkelesi
Darevskia uzzelli	Uzzel Kertenkelesi
Darevskia bithynica	Uludağ Kertenkelesi
Darevskia parvula	Gürcü Kertenkekesi
Lacerta pamphylica	Pamfilya Kertenkelesi
Yılan	
Eirenis aurolineatus	Bolkar Yılanı
Muhtarophis barani	Amanos Yılanı
Letheobia episcopus	Afrika Solucan Yılanı
Montivipera wagneri	Wagner Engereği
Montivipera bulgardaghica	Bolkar Engereği
Vipera anatolica	Anadolu Engereği
Vipera (Pelias) olguni	Olgun Engereği
Vipera (Pelias) barani	Baran Engereği
Vipera (Pelias) pontica	Çoruh Engereği
Vipera (Pelias) sakoi	Sako Engereği





Asaccus barani- Baran Keleri *Vipera anatolica*- Anadolu Engereği

ENDEMİK MEMELİLER

Spermophilus torosensis	Toros yersincabı
Dryomys laniger	Kaya yediuyuru
Microtus anatolicus	Anadolu tarlafaresi
Microtus dogramacii	Doğramacı tarlafaresi
Acomys cilicicus	Silifke dikenlifaresi
Ovis gmelini anatolica	Anadolu yaban koyunu



Ovis gmelini anatolica- Anadolu Yaban Koyunu

SONUÇ

Bu çalışma, Türkiye'nin endemik omurgalı faunasının zenginliğini ve korunmasına yönelik acil gereksinimleri kapsamlı biçimde ortaya koymaktadır. Elde edilen bulgular, Anadolu'nun yalnızca bölgesel değil, küresel biyolojik çeşitlilik açısından da kritik bir merkez olduğunu teyit etmektedir. Özellikle iç su balıkları, amfibiler ve sürüngenlerde gözlenen yüksek endemizm oranları, bu türlerin yaşam alanlarının sürdürülebilir yönetiminin önemini açıkça vurgulamaktadır.

Habitat kaybı, iklim değişikliği ve insan kaynaklı baskılar dikkate alındığında, mevcut koruma stratejilerinin güçlendirilmesi kaçınılmazdır. Korunan alan ağlarının genişletilmesi, havzalar

arası ekolojik bağlantıların sağlanması ve yerel halkın sürece aktif olarak dâhil edildiği katılımcı koruma modelleri, endemik omurgalı türlerin uzun vadeli devamlılığı açısından temel araçlar olarak öne çıkmaktadır (IUCN, 2023; Brooks et al., 2019).

Sonuç olarak, Türkiye'nin endemik omurgalıları yalnızca biyolojik çeşitliliğin bir unsuru değil; aynı zamanda ülkenin doğal mirasının, evrimsel tarihinin ve ekolojik kimliğinin ayrılmaz bir parçasıdır. Bu türlerin korunması, bilimsel araştırmaların sürekliliği, güncel veri temelli yönetim planları ve disiplinler arası iş birlikleriyle desteklenmesi gereken ortak bir sorumluluk olarak değerlendirilmelidir.

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YUMURTACI TAVUKLARIN KARMA YEMLERİNE DEVE DİKENİ (SİLYMARİN) VE GİNKGO BİLOBA EKSTRAKTI İLAVESİNİN YAŞAMA GÜCÜ VE YUMURTA VERİMİ ÜZERİNE ETKİSİ

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ÖZET

Bu çalışma, yumurtacı tavuk rasyonlarına farklı düzeylerde Deve Dikeni (Silymarin) ve Ginkgo biloba ekstraktı ilavesinin yaşama gücü ve yumurta verimi üzerine etkilerini belirlemek amacıyla yürütülmüştür. Çalışmada 480 adet kahverengi Brown Nick ırkı yumurtacı tavuklar kullanılmıştır. Denemedeki hayvanlar; 0,0g/kg kontrol, 0,1g/kg (AV1), 0,2 g/kg (AV2), 0,4 g/kg (AV3) katkı maddesi içerecek şekilde hazırlanan rasyonlarla 4 farklı grupta beslenmiştir. Deneme süresince yaşama gücü ve yumurta verimine ilişkin veriler kaydedilmiş ve istatistiksel olarak analiz edilmiştir. Bulgular incelendiğinde yaşama gücü bakımından tüm deneme gruplarında kontrol grubuna kıyasla anlamlı artışlar gözlenmiş olup, AV1, AV2 ve AV3 gruplarında sırasıyla %95,54, %96,33 ve %97,14 değerleri elde edilmiştir ($p<0.0001$). Yumurta veriminde de benzer şekilde katkı maddesi içeren grupların kontrol grubuna göre daha yüksek performans gösterdiği belirlenmiştir. Kontrol grubunda yumurta verimi %86,87 iken, AV1, AV2 ve AV3 gruplarında sırasıyla %94,87, %94,51 ve %94,56 oranları kaydedilmiştir ($p<0.001$). Sonuç olarak, rasyona Deve Dikeni (Silymarin) ve Ginkgo biloba ekstraktı ilavesi hem yaşama gücünü hem de yumurta verimini iyileştirmiştir. Bu doğal bitkisel katkıların yumurtacı tavuk beslenmesinde performans artırıcı bir seçenek olarak değerlendirilebileceği sonucuna varılmıştır.

Anahtar Kelimeler: Bitkisel ekstrakt, Ginkgo biloba, Silymarin, Yaşama gücü, Yumurta verimi.

Effects of Milk Thistle (Silymarin) and Ginkgo biloba Extracts on Survival and Egg Production in Laying Hens

Abstract
This study was conducted to determine the effects of supplementing different levels of Milk Thistle (Silymarin) and Ginkgo biloba extract on survival rate and egg production in laying hens. 480 Brown Nick laying hens were utilized in the trial. The animals in the trial were fed in four different groups with rations prepared to containing 0.0 g/kg (control), 0.1 g/kg (AV1), 0.2 g/kg (AV2), and 0.4 g/kg (AV3) of the feed additive. Data on survival rate and egg production were recorded during the trial period and statistically analyzed. Increase in survival rate were observed in all study groups compared to the control group, with values of 95.54%, 96.33%, and 97.14% obtained in the AV1, AV2, and AV3 groups, respectively ($p<0.0001$). Similarly, egg production was found to be higher in the supplemented groups compared to the control group. Egg production was recorded 86.87%, 94.87%, 94.51%, and 94.56% in the control, AV1, AV2, and AV3 groups, respectively ($p<0.001$). In conclusion, the supplementation of Milk Thistle (Silymarin) and Ginkgo biloba extract to the diet improved both survival rate and egg production and thess natural herbal additives could be considered as performance-enhancing options in laying hen nutrition.
Keywords: Egg production, Ginkgo biloba, Herbal extract, Laying hens, Silymarin, Survival rate.

1. GİRİŞ

Son yıllarda, genetik seleksiyonun iyileştirilmesi, bakım ve beslenme uygulamalarının geliştirilmesi ile yumurta tavukçuluğu sektörü hızlı bir büyüme göstermektedir. Yüksek verim elde etmek amacıyla kafes tavukçuluğu ön plana çıkmaktadır. Ancak, kafes koşulları genellikle tavuklarda strese ve bağışıklığın baskılanmasına neden olmaktadır. Tüm bu olumsuzluklar sonucunda yumurta üretiminde düşüşe yol açmaktadır (Liu & ark., 2024). Hayvan sağlığını korumak ve üretim performansını artırmak amacıyla antibiyotikler kümes hayvanlarında yem katkı maddesi olarak uzun yıllar kullanılmıştır (El-Kasrawy & ark., 2023). Ancak, hayvan yemlerinde antibiyotiklerin uzun süreli kullanımı, antimikrobiyal direnç gelişimi ve son üründe kalıntı bırakması konusunda endişelere yol açmıştır. Bunun sonucunda, Avrupa Birliği (AB), ve Türkiye'de hayvancılıkta büyüme destekleyici olarak antibiyotik kullanımı tamamen yasaklanmıştır (Ölmez & ark., 2021) .

Devedikeni (Silymarin) alternatif tedavi yöntemlerinde uzun bir kullanım geçmişine sahip tıbbi bir bitki olmakla birlikte biyoaktif bileşikler açısından oldukça zengindir. Silymarin'in önemli biyoaktif bileşenleri, dört ana flavonolignan izomerinden oluşan aktif silymarin kompleksidir: silibin (%50-60), silikristin (%20), silidianin (%10) ve izosilibin (%5). Ayrıca, taksifolin ve kersetin gibi flavonoidler de içermektedir. (Gillessen ve Schmidt, 2020).
Benzer şekilde Ginkgo yaprakları (Ginkgo biloba) da geleneksel tıpta uzun bir kullanım geçmişine sahiptir. Yaprak ekstraktının anti-enflamatuar, antioksidan özelliklere sahip olduğu bilinmektedir. %6 oranında terpenoid içeren biyoaktif bileşikler arasında ginkgolitler A, B, C, J ve M (diterpenler, %2,8-3,4) ve bilobalitler (seskiterpenler, %2,6-3,2) bulunmaktadır. %24 oranında flavonoid içeren bu bitkide önemli aktif bileşikler arasında kaempferol, quercetin ve isorhamnetin yer almaktadır (Zhang & ark., 2018; Singh & ark., 2019).

Fitokimyasal maddeler, kanatlı beslemede antimikrobiyal, antioksidan ve antienflamatuar özelliklerinden dolayı sağlığın korunmasında ve üretimin artırılmasında antibiyotiklere alternatif olarak geniş kullanım alanı bulmaktadır. Bu çalışmada Devedikeni (Silymarin) ve Ginkgo biloba ekstraktının yumurta tavuklarında yaşam gücü ve yumurta verimi üzerine etkinliğinin araştırılması amaçlanmıştır.

2. MATERYAL VE METOT

Bu araştırmada hayvan materyali olarak 30 haftalık yaşta 500 adet yumurtacı tavuk kullanılmıştır. Denemede hayvanlar biri kontrol 3 muamele grubu olmak üzere 4 grup ve her birinde 25 hayvan bulunan 5 alt gruba ayrılmıştır. Kontrol grubuna katkı maddesi ilavesi yapılmazken, muamele gruplarına sırasıyla; 0,1 g/kg (AV1), 0,2 g/kg (AV2) ve 0,4 g/kg (AV3) Deve Dikeni (Silymarin) ve Ginkgo biloba ekstraktı ilavesi yapılmıştır. Denemede tavuklar, %17 ham protein (HP) ve 2750 kcal/kg metabolik enerji (ME) içeren yumurtacı tavuk yemiyle beslenmiştir. Denemede kullanılan deve dikeni ekstraktı (Silymarin) ve ginkgo biloba ekstraktı (Ginkgolides–Bilobalides) özel bir firmadan temin edilmiştir. Rasyonlar izokalorik ve izonitrojenik olacak şekilde tüm gruplara uygulanmıştır. Hayvanlara 16 saat aydınlık ve 8 saat karanlık olacak şekilde ışık uygulaması yapılmıştır. Kümes sıcaklığı, mevsimsel değişikliklerden ve uzun soğuk günlerden etkilenmeyecek biçimde radyan ısıtıcılar ile sağlanmış ve sıcaklık 19–24 °C arasında tutulmuştur. İhtiyaç duyulması durumunda elektrikli infrared ısıtıcılar kullanılmıştır.

Günlük tavuk ölümleri deneme süresi boyunca kayıt altına alınmış ve tüm grupların yaşama güçleri hesaplanmıştır (Yaşama gücü, % = Dönem Sonu Canlı Kalan Tavuk Sayısı/ Dönem Başındaki Tavuk Sayısı × 100).

Elde edilen yumurtalar günlük olarak aynı saatte toplanmış ve kayıt altına alımıştır (Yumurta verimi, % = Günlük Toplanan Yumurta Sayısı/o günkü Canlı Tavuk Sayısı × 100).

Veriler GraphPrism istatistik programında Tek yönlü varyans analizi kullanılarak analiz edilmiştir. Gruplar arasındaki farklılıkları Tukey testiyle ölçülmüştür. $P<0,05$ anlamlı kabul edilmiştir.

3. BULGULAR

Denemede farklı düzeylerde katkı maddesi ilavesinin yumurtacı tavuklarda yaşama gücü ve yumurta verimi üzerine etkileri incelenmiştir. Elde edilen sonuçlar Görsel 1'de sunulmuştur.

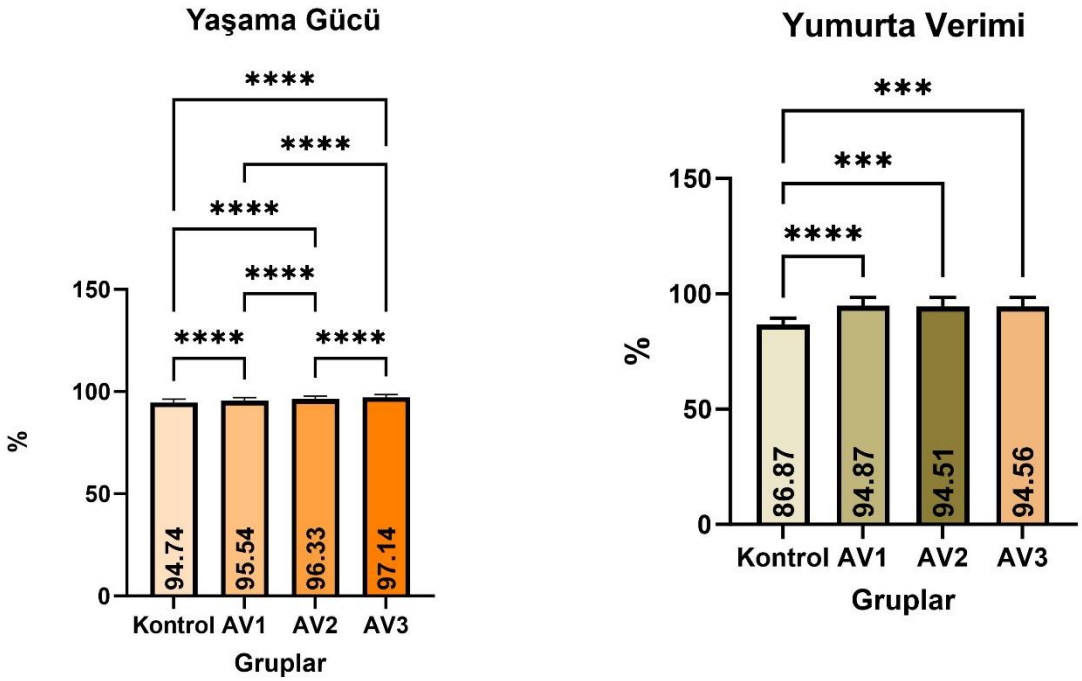
Yaşama Gücü

Deneme süresi boyunca gruplara ait yaşama gücü oranları incelendiğinde, kontrol grubunda yaşama gücünün %94,74 olduğu belirlenmiştir. Katkı maddesi ilavesi yapılan deneme gruplarında ise yaşama gücü sırasıyla AV1 grubunda %95,54, AV2 grubunda %96,33 ve AV3 grubunda %97,14 olarak tespit edilmiştir. Katkı maddesi ilavesinin yaşama gücü üzerinde

istatistiksel olarak anlamlı bir artış sağladığı ve özellikle en yüksek dozun uygulandığı AV3 grubunun diğer tüm gruplara göre daha yüksek yaşama gücü gösterdiği belirlenmiştir (****, $p < 0,0001$). Ayrıca deneme grupları arasında da doz artışına bağlı olarak yaşama gücünün kademeli şekilde yükseldiği gözlenmiştir.

Yumurta Verimi

Gruplara ait yumurta verimi oranları değerlendirildiğinde, kontrol grubunda yumurta veriminin %86,87 olduğu saptanmıştır. Katkı maddesi ilavesi yapılan gruplarda yumurta verimi AV1 grubunda %94,87, AV2 grubunda %94,51 ve AV3 grubunda %94,56 olarak belirlenmiştir. Deneme gruplarının tamamında yumurta veriminin kontrol grubuna kıyasla istatistiksel olarak anlamlı düzeyde arttığı görülmüştür (*–**, $p < 0,001–0,0001$). Bununla birlikte, katkı maddesi ilave edilen gruplar arasında yumurta verimi bakımından sınırlı farklılıklar olduğu ve benzer düzeylerde sonuçlar elde edildiği belirlenmiştir.



Görsel 1. Yumurtacı Tavuklarda Deve Dikeni (Silymarin) ve Ginkgo biloba ekstraktının yaşama gücü ve yumurta verimi üzerine etkisi

4. SONUÇ

Çalışmada elde edilen bulgular, katkı maddesi ilavesinin her iki parametre üzerinde de olumlu etkiler oluşturduğunu göstermektedir.

Deneme süresi boyunca yaşama gücü oranlarının Deve Dikeni (Silymarin) ve Ginkgo biloba ekstraktı ilavesi ile birlikte istatistiksel olarak anlamlı şekilde arttığı belirlenmiştir. Özellikle Deve Dikeni (Silymarin) ve Ginkgo biloba ekstraktının en yüksek düzeyde uygulandığı AV3 grubunda yaşama gücünün en yüksek seviyeye ulaştığı ve doz artışına bağlı olarak yaşama gücünde kademeli bir iyileşme meydana geldiği görülmüştür. Bu durum, söz konusu bitkisel

ekstraktların hayvan sağlığını destekleyici ve stres faktörlerine karşı koruyucu etkiler gösterebileceğini düşündürmektedir.

Yumurta verimi açısından değerlendirildiğinde, katkı maddesi ilave edilen tüm deneme gruplarında kontrol grubuna kıyasla belirgin bir artış saptanmıştır. Bununla birlikte, Deve Dikeni (Silymarin) ve Ginkgo biloba ekstraktı uygulanan gruplar arasında yumurta verimi bakımından sınırlı farklılıkların bulunmuştur. Bu durum, katkı maddesinin yumurta verimi üzerindeki olumlu etkisinin düşük ve orta dozlarda da etkin şekilde ortaya çıkabildiğini göstermektedir.

Genel olarak değerlendirildiğinde, Deve Dikeni (Silymarin) ve Ginkgo biloba ekstraktlarının yumurtacı tavuk rasyonlarına ilavesinin yaşama gücünü artırarak sürü sağlığını olumlu yönde etkilediği ve yumurta verimini iyileştirdiği sonucuna varılmıştır. Bu bitkisel katkı maddelerinin, antibiyotik kullanımının sınırlandırıldığı modern kanatlı yetiştiriciliğinde doğal ve fonksiyonel yem katkısı olarak değerlendirilebileceği düşünülmektedir. Ancak, optimum dozun belirlenmesi ve uzun dönem etkilerinin ortaya konulabilmesi için farklı üretim periyotlarını kapsayan ilave çalışmalara ihtiyaç bulunmaktadır.

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EFFECTS OF MILK THISTLE (SILYMARIN) AND GINKGO BILOBA EXTRACTS SUPPLEMENTATION IN LAYING HEN DIETS ON EGG QUALITY TRAITS

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Abstract

This study was conducted to determine the effects of dietary supplementation with milk thistle (Silymarin) and Ginkgo biloba extracts on egg quality parameters in layer hens. Four treatment groups were formed, including a control group and three supplementation levels (0.1g/kg (AV1), 0.2 g/kg (AV2), 0.4 g/kg (AV3)). The results showed that egg weight increased significantly in all supplemented groups compared to the control group ($p<0.0001$). Both eggshell weight and eggshell thickness were notably higher in AV2 and AV3 groups ($p<0.05$). Significant differences were also observed in shape index values in AV1 and AV2 groups compared to the control group ($p<0.01$). The Haugh unit, an indicator of internal egg quality, was highest in the AV3 group compared to the other groups ($p<0.05$). However, eggshell strength and shell ratio did not show statistically significant differences among the groups ($p>0.05$). In conclusion, supplementation with milk thistle (Silymarin) and Ginkgo biloba

extracts has the potential to improve egg weight, shell quality, and internal egg quality in laying hens and higher supplementation levels, especially AV3, resulted in more pronounced positive effects compared to the low supplementation levels.
Keywords: Egg quality, Ginkgo biloba, Herbal extract, Laying hens.

Yumurtacı Tavukların Karma Yemlerine Deve Dikeni (Silymarin) ve Ginkgo Biloba Ekstraktı İlavesinin Yumurta Kalitesi Üzerine Etkisi

Özet

Bu çalışma, yumurtacı tavukların karma yemlerine farklı seviyelerde ilave edilen Deve Dikeni (Silymarin) ve Ginkgo biloba ekstraktının yumurta kalite parametreleri üzerindeki etkilerini belirlemek amacıyla yürütülmüştür. Denemede kontrol grubu ile üç farklı ilave seviyesi içeren (0,1g/kg (AV1), 0,2 g/kg (AV2), 0,4 g/kg (AV3)) dört grup oluşturulmuştur. Araştırma sonunda; yumurta ağırlığı tüm deneme gruplarında kontrol grubuna kıyasla anlamlı şekilde artış göstermiştir ($p<0.0001$). Benzer şekilde, yumurta kabuk ağırlığı ve kabuk kalınlığı özellikle AV2 ve AV3 gruplarında belirgin düzeyde yükselmiştir ($p<0.05$). Yumurta şekil indeksi bakımından AV1 ve AV2 gruplarında istatistiksel olarak önemli farklılıklar gözlenmiştir ($p<0.01$). Haugh birimi değerleri özellikle AV3 grubunda en yüksek seviyeye ulaşarak iç kaliteyi olumlu etkilemiştir ($p<0.05$). Buna karşın yumurta kabuk dayanıklılığı ve kabuk oranı bakımından gruplar arasında anlamlı bir farklılık tespit edilmemiştir ($p>0.05$). Sonuç olarak, Deve Dikeni (Silymarin) ve Ginkgo biloba ekstraktı ilavesi yumurtacı tavuklarda özellikle yumurta ağırlığı, kabuk kalitesi ve iç kalite parametrelerini iyileştirme potansiyeline sahiptir. Özellikle yüksek seviye (AV3) uygulamalarının kalite üzerinde daha belirgin etkiler oluşturduğu görülmektedir. Bu bulgular, fonksiyonel bitkisel katkıların yumurta üretiminde kaliteyi artırıcı doğal bir alternatif olarak değerlendirilebileceğini göstermektedir.
Anahtar Kelimeler: Bitkisel ekstrakt, Ginkgo biloba, Silymarin, Yumurta kalitesi, Yumurtacı tavuk.

1. INTRODUCTION

The dietary supplementation of milk thistle and ginkgo biloba into the diets of laying hens has garnered increasing attention due to their potential effects on egg quality traits. Egg quality is pivotal for profitability in the poultry industry, reflecting the bird's dietary management and overall health. This paper synthesizes several studies focusing on the impact of these herbal supplements on various egg quality parameters.

Milk thistle has been widely studied for its bioactive compound, silymarin, which exhibits potential antioxidant properties. Research by Ahammad et al. (2024) revealed that the addition of micelle silymarin to the laying hen diet resulted in significant improvements in egg production and egg quality parameters such as eggshell thickness and strength, reinforcing earlier observations. The supplementation at a concentration of 0.5 g/kg was shown to enhance both egg production rates and quality, attributed to silymarin's antioxidative properties that mitigate oxidative stress, particularly during the yolk formation phase (Khan, Jeon, & Kim, 2024).

Moreover, findings from Gholamalian et al. (2021) support these results, as their study indicated that high levels of milk thistle meal effectively suppressed oxidative stress markers in the serum of laying hens, which corresponded with improved eggshell quality traits. Notably, increases in eggshell strength and thickness corresponded with silymarin supplementation, highlighting its role in calcium metabolism, essential for optimal eggshell formation (Salmória et al., 2024). Furthermore, the antioxidant capacity of silymarin may help in reducing lipid peroxidation, thereby contributing indirectly to enhanced egg quality by promoting better health and nutrient assimilation in hens (Abdulwahid, Alabbody, & Rashid, 2021).

Ginkgo biloba, known for its cognitive-enhancing properties in humans, has also been evaluated for its potential nutritional benefits in poultry. The extract is rich in flavonoids and terpenoids, compounds that possess antioxidative and anti-inflammatory effects. Although direct studies focusing solely on Ginkgo biloba extracts in laying hen diets are limited, the existing literature suggests an overarching benefit of dietary antioxidants on egg quality (Peng et al., 2016).

Research indicates that dietary antioxidants can improve egg quality traits by reducing oxidative stress during vital reproductive phases. One potential mechanism involves enhancing the overall metabolic functions of hens, including better nutrient absorption, which correlates with egg production metrics and quality attributes such as yolk color and albumen quality. Thus, while specific studies on ginkgo biloba in laying hen diets remain sparse, the broader implications of antioxidants in poultry nutrition imply that ginkgo extracts could potentially yield similar benefits observed with milk thistle (Saleh et al., 2021).

Both milk thistle and ginkgo biloba present advantages for laying hens' diets, primarily through their antioxidative effects. Studies consistently show that diets enriched with antioxidants tend to yield higher quality eggs. For instance, milk thistle supplementation has been documented to enhance yolk color intensity due to increased carotenoid accumulation. Conversely, while specific research on ginkgo's effects on egg quality remains limited, its potential role as an antioxidant suggests it may offer positive contributions in a mixed-supplementation scenario (Hosseintabar-Ghasemabad et al., 2022).

Furthermore, empirical evidence suggests that the integration of these supplements not only impacts the qualitative aspects of egg production but also optimally supports overall hen health, possibly leading to higher economic returns in poultry production systems. When both silymarin and ginkgo are used in combination in diets, they may synergistically enhance their effectiveness in improving egg quality traits due to their distinct yet complementary bioactive profiles. Therefore, this study aimed to determine the synergistic and dose-dependent effects of milk thistle and Ginkgo biloba on egg quality parameters in laying hens.

2. MATERIAL AND METHODS

In this study, 500 laying hens aged 30 weeks were used as study material. The animals were divided into 4 groups (one control and three treatment groups) and 5 subgroups, each containing 25 birds. The control group received no additives, while the treatment groups received 0.1 g/kg (AV1), 0.2 g/kg (AV2), and 0.4 g/kg (AV3) of milk thistle (Silymarin) and Ginkgo biloba extract, respectively. The hens were fed laying hen feed containing 17% crude protein (CP) and 2750 kcal/kg metabolic energy (ME). The milk thistle extract (Silymarin) and ginkgo biloba

extract (Ginkgolides–Bilobalides) used in the experiment were obtained from a private company. The rations were formulated in an isocaloric and isonitrogenous manner. The birds were subjected to light exposure for 16 hours of light and 8 hours of darkness. The housing temperature was maintained between 19–24 °C using radiant heaters to prevent seasonal changes and long cold days from affecting the environment.

Egg quality parameters were evaluated using eggs collected from each group at the end of the trial. The measured parameters included egg weight, eggshell weight, eggshell thickness, eggshell strength, egg shape index, Haugh unit, and eggshell rate.

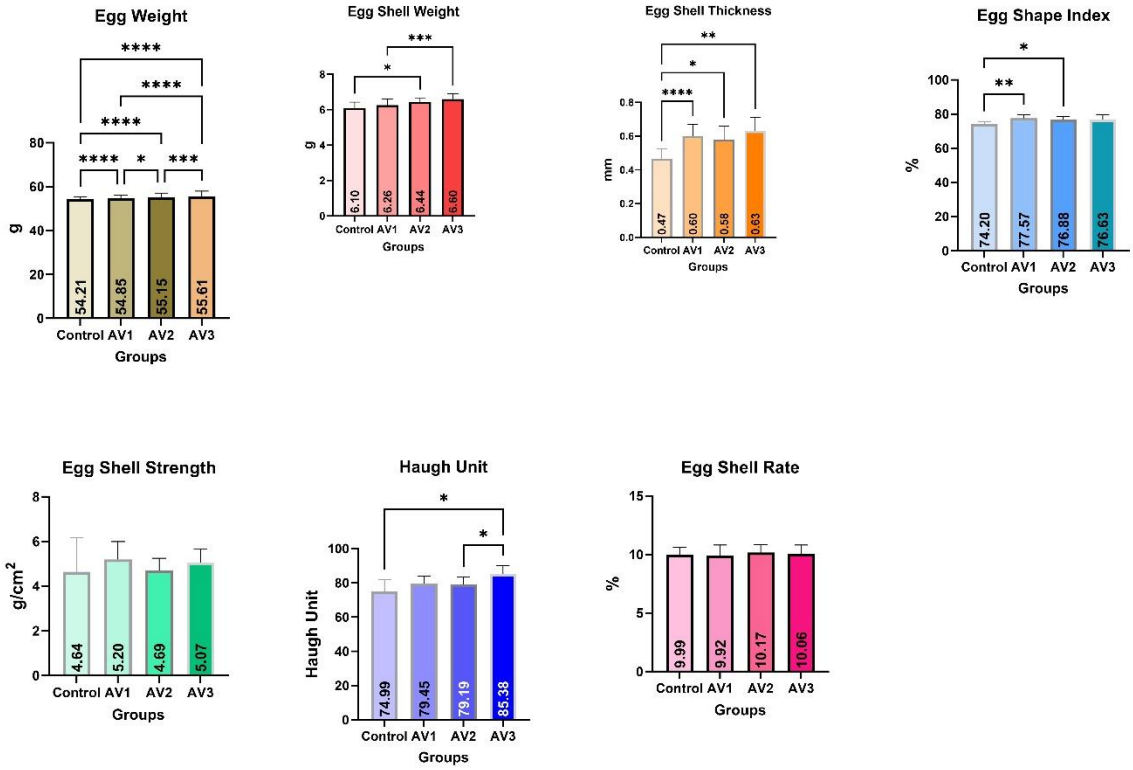
Egg weight was determined using a digital precision scale (MEDID CDI, WSU industrials, Germany). Eggshell weight was measured after removing the shell membranes and drying the shells at room temperature. Eggshell thickness was measured at three points of the shell using a digital micrometer, and the average value was calculated. Eggshell strength was assessed using a compression test and was expressed as grams per square centimeter. Egg shape index was calculated based on egg width and length measurements. Albumen quality was evaluated using the Haugh unit formula, and eggshell rate was calculated as the percentage of shell weight relative to egg weight (Ölmez et al., 2021).

All data were analysed using one-way analysis of variance (ANOVA) in GraphPad Prism statistical program. Differences among group means were considered statistically significant at $p < 0.05$.

3. RESULTS

The results showed that dietary treatments had a significant effect on several egg quality parameters (Picture 1).

Egg weight was significantly increased in all supplemented groups compared to the control group, with the highest egg weight observed in the AV3 group ($p < 0.001$). A gradual increase in egg weight was evident as the supplementation level increased. Eggshell weight was also significantly higher in the supplemented groups, particularly in AV2 and AV3, compared to the control group ($p < 0.05$). The highest eggshell weight was recorded in the AV3 group. Similarly, eggshell thickness was significantly high in all treatment groups relative to the control group. The AV3 group showed the highest increase in shell thickness ($p < 0.01$), indicating enhanced shell quality. Egg shape index was significantly affected by the treatments. Eggs from the AV1 and AV2 groups showed higher shape index values compared to the control group ($p < 0.05$), while no significant difference was observed between AV2 and AV3 ($p > 0.05$). Eggshell strength showed a numerical increase in the treatment groups compared to the control; however, these differences were not statistically significant ($p > 0.05$). The AV3 group exhibited the highest Haugh unit value, which was significantly higher than both the control and AV2 groups ($p < 0.05$). In contrast, eggshell percentage was not significantly affected by the dietary treatments, and similar values were observed across all groups ($p > 0.05$).



Picture 1. Effects of Dietary AV Supplementation on Egg Quality Parameters in Laying Hens

4. CONCLUSION

Overall, the findings of this study demonstrate that the dietary treatments applied in the AV1, AV2, and AV3 groups positively influenced several key egg quality parameters in laying hens. Results showed an improvement in egg weight, eggshell weight, eggshell thickness, and albumen quality, as indicated by the Haugh unit, and AV3 group consistently showed the highest values among the study groups. Eggshell strength and eggshell percentage remained similar among the study groups. Egg shape index values remained within the optimal range. These results suggest that 0.4 g/kg milk thistle and Ginkgo biloba can be used in laying hen diets to improve the internal and external egg quality parameters without adversely affecting shell structure or egg uniformity. However, further studies are required under different production conditions and over longer experimental periods.

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HAYVANLARDA ALTERNATİF BİR TEDAVİ YÖNTEMİ OLARAK FİTOTERAPİ VE AROMATERAPİ

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Fitoterapi ve aromaterapi, tanımsal açıdan kesin sınırlarla ayrılmayan ve birbirini tamamlayan tedavi yaklaşımlarıdır. Fitoterapi, bitkisel kaynaklı ajanların tedavi amacıyla kullanımını ifade ederken; aromaterapi, çoğunlukla uçucu yağlar aracılığıyla uygulanan bir yöntem olarak fitoterapinin bir alt alanı olarak değerlendirilmektedir. Bu tedavi yaklaşımlarının kökenleri M.Ö. 3000'li yıllara kadar uzanmakta olup, Ninova yazıtlarında bitkilerle tedaviye ilişkin önemli bilgilere rastlanmaktadır. Anadolu coğrafyasında da farklı yörelerde yetişen tıbbi bitkiler, geleneksel bilgi birikimi doğrultusunda çeşitli hastalıkların tedavisinde uzun yıllardır kullanılmaktadır. Bu uygulamalar, farmakoloji bilimi içerisinde etnofarmakoloji alt disiplininin gelişmesine katkı sağlamıştır. Antibakteriyel direnç gelişiminin artmasıyla birlikte fitoterapik ve aromaterapötik ürünlerin beşerî hekimlikteki kullanımı yaygınlaşmış, bu durum veteriner hekimlikte de alternatif ve tamamlayıcı tedavi yaklaşımlarına olan ilgiyi artırmıştır. Tıbbi bitkilerden elde edilen etken maddeler veteriner hekimlikte antiparaziter, antibakteriyel ve sindirim sistemi bozukluklarında mide koruyucu ve antiemetik amaçlarla kullanılmaktadır. Ayrıca fitoterapi ajanları, hayvanlarda yara iyileşmesini destekleyici etkilerinin yanı sıra ruminantlarda sindirim sisteminin düzenlenmesinde ve equidelerde stereotipik davranış bozukluklarının kontrolünde trankilizan etkileriyle kullanım alanı bulmaktadır. Bu bildiride, çiftlik ve pet hayvanlarında fitoterapi ajanlarının veteriner hekimlikteki kullanım alanları ve potansiyel katkıları güncel literatür ışığında değerlendirilmiştir.

Anahtar kelime: Fitoterapi, aromaterapi, alternatif tıp, veteriner tıp, etnofarmakoloji

Giriş

Fitoterapi ajanları 1870 yıllarda ilk olarak tanımsal olarak kullanılmaya başlanmıştır. Yunanca bir kelimeden köken alan bu terim phyto ve therapy kelimelerinin birleşimi sonucunda oluşturulmuştur. Bitkilerden köken alan çok sayıda birleşik alkaloid, flavonoid, gllikozitler ve terpenler geçmişten günümüze kadar kullanım alanı bulmaktadır. Bitkisel sekonder birleşenler olarak adlandırılan bu birleşikler veteriner sahada yara iyileşmesinde, idrar yolları taşlarında yatıştırıcı olarak kullanım alanları bulmaktadır (Bedir ve Turgut, 2021). Hindistan tıbbında veteriner hekimlik alanında yaygın kullanım alanı bulmasındaki temel sebepler ilaçların aşırı pahalı olmasından kaynaklandığı düşünülmektedir. Ayrıyeten gıdalarda antibakteriyel ilaçların kalıntı oluşturması ve buna bağlı şekillenen direnç kaynaklı olarak fitoterapi ajanları yaygın kullanım alanı sağlamıştır. Günümüzde kullanılan mevcut ilaçların %30 kadarı bitkisel meşeye sahiptir (Williams ve Lamprecht, 2008). Hayvanlarda bitkisel kaynaklı fitoterapi ve aromaterapi ajanlarının kullanım alanı bulmasının temel nedenleri arasında; hormonal dengenin sağlanması, anksiyete ve korku gibi durumların kontrol altına alınması, solunum yolu hastalıklarının yönetimi ile kemik ve kas dokularının desteklenmesi gibi çeşitli faktörler yer almaktadır (Williams, 2013).

A.1. Hayvanlarda Antiparaziter Olarak Kullanılan Fitoterapi ve Aromaterapi Ajanları

Hayvanlarda paraziter enfeksiyonların kontrol ve sağaltımında fitoterapi ajanlarının kullanımı, son yıllarda yapılan deneysel ve gözlemsel çalışmalarla giderek daha fazla önem kazanmıştır. Bitkisel kökenli bu ajanların, farklı hayvan türlerinde endo- ve ektoparazitlere karşı etkinlik gösterdiği ve destekleyici veya alternatif tedavi yaklaşımları kapsamında değerlendirilebileceği bildirilmektedir. Özellikle yabani ve evcil hayvanlarda yapılan çalışmalar, fitoterapötik bileşiklerin antiparaziter, antiprotozoal ve antienflamatuvara etkilerini ortaya koymaktadır. Bu bağlamda, Tanzanya'nın batısında yaşayan şempanzeler üzerinde yürütülen bir çalışmada *Vernonia amygdalina* bitkisinin odun özütünden elde edilen acı suyun oral yolla tüketilmesinin, *Strongylus* türü nematod enfeksiyonlarını ortadan kaldırdığı gösterilmiştir (Huffman, 2022). Benzer şekilde, hayvanlarda görülen kan protozoonlarının kontrolünde *Artemisia absinthium* (pelin otu) kullanılmış ve bu bitkinin belirgin antiprotozoal etki gösterdiği bildirilmiştir (Davidović ve ark., 2012). Pet hayvanlarında endo- ve ektoparazitler, özellikle genç bireylerde ciddi sağlık sorunlarına ve mortaliteye yol açabilmektedir. Yavru köpeklerde yaygın olarak görülen *Toxocara canis* ve *Toxocara leonina* enfeksiyonları, bağırsaklarda inflamasyon, lümen tıkanıklığı ve proliferatif değişikliklere neden olabilmektedir. *Toxocara* ile enfekte yavru köpekler üzerinde gerçekleştirilen bir çalışmada, kekik yağı uygulanmış ve parazit yumurta sayısında istatistiksel olarak anlamlı bir azalma tespit edilmiştir (Duru ve ark., 2023). Ruminant hayvanlarda nematod enfeksiyonlarının kontrolünde kullanılan fitoterapi ajanları arasında *Allium sativum* (sarımsak) önemli bir yere sahiptir. Bunun yanı sıra, muz kabuğu ve Carica papaya bitkisinin antihelmintik etkinliğinin değerlendirildiği bir çalışmada, muz kabuğunun papayaya kıyasla daha yüksek etkinlik gösterdiği ortaya konulmuştur. Bu durumun, muz kabuğunda yüksek oranda bulunan tanen bileşiklerinden kaynaklandığı düşünülmektedir (Shafique ve ark., 2023). Kanatlı hayvanlarda yaygın olarak görülen protozoal hastalıklardan biri olan koksidiyozun kontrolünde *Moringa oleifera* kullanılmış ve etkili sonuçlar elde edilmiştir. Moringa oleifera'nın antiprotozoal etkinliğinin yanı sıra, kanatlıların bağırsak florasında bulunan patojen mikroorganizmalara karşı da geniş spektrumlu bir etki gösterdiği bildirilmiştir. At hekimliğinde fitoterapi uygulamaları, özellikle son yıllarda tamamlayıcı ve alternatif tedavi yöntemi olarak yaygınlık kazanmıştır. Atlarda fitoterapi ajanları başta

antiparaziter ve antienflamatuvar amaçlarla kullanılmaktadır. *Mentha piperita* (nane) yağının sivrisinekler üzerinde uzaklaştırıcı etkiye sahip olduğu, tarçın yağı ile kullanıldığında ise kenelerin vücut üzerinden uzaklaştırılmasında etkili olduğu bildirilmiştir. Ayrıca, nane yağının altlık materyallerine uygulanmasıyla çevresel parazit yükünün azaltıldığı ifade edilmiştir. Anason, adaçayı, çay ağacı, sardunya, nane ve kekik gibi bitkilerin de antiparaziter özellikleri nedeniyle kullanım alanı bulduğu belirtilmektedir. Nane yağının atların ekstremitelerine topikal olarak uygulanmasının, sinekleri uzaklaştırmada etkili olduğu gösterilmiştir (Aydın, 2024). Atlarda iç parazitlerin kontrolünde solucan otu kullanımına ilişkin bir çalışmada, iki gün süreyle günde iki doz olacak şekilde 0,5 ml/kg dozunda uygulamanın askaritlere karşı etkili olduğu bildirilmiştir (Şengezer & Güngör, 2008). Ayrıca, sitronella, sedir ve çam yağlarının belirli oranlarda karıştırılmasıyla elde edilen preparatların pire ve kene gibi dış parazitlerin kontrolünde kullanıldığı; nane yağına eklenen bir damla tarçın yağının, vücuda tutunan kenelerin uzaklaştırılmasını sağladığı ortaya konmuştur. Sarımsak, sedir, lavanta ve sitronella yağlarının birlikte kullanıldığı karışımların ise pamuk benzeri materyallere emdirilerek uygulanması durumunda daha uzun süreli etki gösterdiği bildirilmiştir (Faydaoğlu & Sürücüoğlu, 2013). Modern antiparaziter ilaçların geliştirilmesinden önce, *Nicotiana tabacum* (tütün) bitkisinin askaritler ve *Strongyloidea* ailesine ait parazitlere karşı kullanıldığı bilinmektedir (Laudato & Capasso, 2013). Fitoterapi ve aromaterapi ajanları, paraziter hastalıkların yanı sıra atlarda görülen anksiyete benzeri davranış bozukluklarının yönetiminde de değerlendirilmiştir. *Matricaria chamomilla* (papatya) bitkisinin yemlere katılarak uygulanmasının, atlar üzerinde sakinleştirici bir etki oluşturduğu bildirilmiştir (Aydın, 2024).

A.2. Hayvanlarda Yem Katkı Maddesi Olarak Kullanılan Fitoterapi Ajanları

Fitoterapi ajanları, hayvan besleme ve sağlığı alanında çoğunlukla yem katkı maddesi olarak kullanım alanı bulmaktadır. Özellikle ruminant hayvanlarda rumen fonksiyonlarını düzenlemek amacıyla yaygın biçimde kullanılan çok sayıda fitoterapötik yem katkı maddesi bulunmaktadır. Bu ajanlar arasında yer alan saponinler ve tanenlerin, rumende bulunan yararlı mikroorganizmaların çoğalmasını teşvik ederek ruminal fermentasyon süreçlerini olumlu yönde etkilediği çeşitli çalışmalarla ortaya konmuştur. İneklerin laktasyon başlangıcı döneminde kuru madde tüketimi azaldığı ve yem tüketimini teşvik amaçlı olarak çeşitli yem katkı maddelerinin kullanıldığı bilinmektedir. Böyle bir çalışmada nane yağı yem katkı maddesi olarak geçiş dönemindeki sığır rasyonlarına nane yağı eklenmiştir. Ekleme sonrası sığırlarda yem tüketiminde artış şekillenirken, rumen Ph düştüğü ve süt yağının istatiksel olarak azaldığı bulunmuştur. Süt sığırlarında yapılan bir diğer çalışmada kekik, anoson ve sarımsağın yem katkı maddesi olarak kullanımına bağlı olarak asetat ve bütürat oranların artığı ve propiyanat oranlarının azaldığı yapılan çalışmada ortaya konmuştur (Şengezer ve Güngör, 2008). At beslemesinde kullanılan fitoterapi yem katkı maddelerinin kullanımı ise, özellikle anabolizan maddeler ve antibiyotiklerin uzun süreli kullanımına bağlı olarak ortaya çıkan olumsuz etkilerin azaltılmasına yönelik bir gereksinim doğrultusunda gelişmiştir. Bununla birlikte, atlarda fitoterapi ajanlarının kullanım yelpazesi, diğer memeli hayvanlara kıyasla daha sınırlıdır. Bunun temel nedeni, diğer memelilerde güvenle kullanılan bazı fitoterapötik ajanların, atlar için önerilen dozlarda dahi toksik etkilere yol açabilmesidir. Bu bağlamda, *Allium sativum* (sarımsak) atlarda en yaygın kullanılan fitoterapi ajanlarından biridir. Sarımsak, atlarda öncelikle böcek kovucu özelliğinden yararlanılarak kullanılmakta; bunun yanı sıra, kronik obstrüktif akciğer hastalığı bulunan atlarda mukolitik bir ajan olarak da değerlendirilmekte ve solunum yollarındaki sekresyonların atılımını kolaylaştırmaktadır. Sarımsağın temel etken

maddesinin allisin olduğu ve biyolojik aktivitesinin büyük ölçüde bu bileşikten kaynaklandığı bildirilmektedir (Williams & Lamprecht, 2008). Bir diğer önemli fitoterapi ajanı olan limon otu yağı (*Cymbopogon citratus*), uçucu yağ asitlerince zengin yapısı nedeniyle aromaterapi ajanı olarak yaygın biçimde kullanılmaktadır. Bu bitkinin, farklı hayvan türlerine ait yemlerde yem katkı maddesi olarak kullanımına izin verilmiştir. At beslemesinde ise limon otu yağının, yemlere 100 mg/kg dozunda katılarak kullanılabileceği bildirilmiştir (Bampidis ve ark., 2024).

A.3. Hayvanlarda Yara İyileşmesini Teşvik Edici Fitoterapi Ajanları

Yara travma benzeri sonucunda vücudun en büyük bariyeri olan derinin bütünlüğünün bozulması olarak tanımlanabilir. Yaralar akut meydana gelebileceği gibi zamanla iyileşme sağlanmadığı taktirde kronik bir hal alabilmektedir. Yara bölgesine yangısal süreç sonrasında iyileşme şekillenmektedir. Proliferasyon dokusunun oluşumu sonucunda şekillenen iyileşmede aktif olarak rol alan hücreler makrofajlar ve nötrofillerdir. Yaranın çeşitli mikroorganizmalar ile enfekte olması sonucunda iyileşme süresi uzamakta ve yara iyileşmesi aksamaktadır. Bu durumda hem antibakteriyel özellikte hem de antienflamatuvar olan fitoterapi ajanlarına ihtiyaç duyulmaktadır. Yapılan bir deneysel çalışmada Sinir otu (*Plantago major*), Civan perçemi (*Achillea millefolium*), Gotukola (*Centella asitica*) kullanılmıştır. Yapılan bu çalışmada atlarda veteriner hekimler tarafından yara iyileşmeleri değerlendirilmiştir. Yaraların iyileşmesini kullanılan bitkilerin teşvik ettiği veteriner hekimler tarafından yapılan değerlendirmeler sonucunda ortaya konmuştur (Fehrenbach ve ark., 2025). Hayvanlar üzerinde yara iyileşmesi teşviki için aleovera bitkisi kullanılmıştır. Hayvanlarda deri üzerine Aleovera sürülmesi veya oral olarak kullanılması ile yapılan uygulanmalarda deride bulunan inflamasyonu engellediği ortaya konmuştur. Bunun dışında bu bitkinin hyoluronik asit sentezini artırdığı ve derinin yenilenmesini sağladığı yapılan çalışmacalarda açığa çıkmıştır (Bedir ve Turgut, 2021). Aleo vera bitkisinin atların deri mantar enfeksiyonlarının sağaltımında etkili olduğu ortaya konmuştur (Shafique ve ark., 2023). Atlarda yaralanmasında kullanılan bir biyouyumlu kompozit geliştirilmiştir. Bunun temelinde papatya, biberiye ve propolis birleşimi ile elde edilmiştir. Bu kompozit piyasada bulunan çeşitli kremler kullanılarak hem morfolojik hem de histokimyasal değerlendirmeler yapılmıştır. Çalışma sonucunda yara iyileşmesine karşı bu kompozitin etkili olduğu ortaya konmuştur (Anis ve ark., 2021). Atlarda deride bulunan at saç kıranına neden olan *Tricophtyton equinurum* etkenine karşı çay ağacı kullanıldığı invitro çalışmalarda *T. Equinurum* etkinliği kanıtlanmıştır. Yapılan çalışmada 5 attan 3 de tam iyileşme gözlemlenirken 2'sinde tam iyileşme gözlemlenmemiştir (Pisseri ve ark., 2009). Köpeklerde %10 derişimlerde krem hazırlanarak kullanılan çay ağacı ekstraktı dermatitise iyi geldiği fakat yoğun kullanımlarında sinir sistemi üzerine kontrendikasyonları gözlemlenmiştir (Bedir ve Turgut, 2021). Atlarda yara iyileşmesi üzerine kadife çiçeği üzerine yapılan bir çalışmada %2-10 değerinde kadife çiçeği içeren birleşiklerin atlarda akut ve kronik yara iyileşmesini teşvik ettiği ortaya konmuştur (Jakopsen, 2016). Biberiye bitkisinin içeriğinde bulunan asidik ve uçucu yağlar sayesinde biberiye bitkisi kullanılan sıçanlarda yara iyileşmesinin hızlandığı granülasyon dokusunun daha hızlı geliştiği ve yara dudaklarının hızlı kapandığı ortaya konmuştur (Bedir ve Turgut, 2021).

A.4. Hayvanlarda Sindirim Sistemi Hastalıklarında Kullanılan Fitoterapi Ajanları

Hayvanların evcilleştirilmesiyle birlikte barınma, besleme ve kullanım amaçlarında meydana gelen değişimler; sindirim sistemi fizyolojisi üzerinde önemli etkiler oluşturmuş ve özellikle sindirim sistemi hastalıklarının görülme sıklığında artışa neden olmuştur. Evcil hayvanlarda

doğal beslenme davranışlarının yerini yoğun enerji ve konsantre yem ağırlıklı rasyonların alması, bağırsak mikrobiyotası dengesinin bozulmasına ve buna bağlı metabolik ve gastrointestinal problemlerin ortaya çıkmasına zemin hazırlamıştır. Bu bağlamda fitoterapi uygulamaları, sindirim sistemi sağlığının korunması ve bozulan fizyolojik dengenin yeniden tesis edilmesinde tamamlayıcı bir yaklaşım olarak ön plana çıkmaktadır. Fitoterapötik ajanların temel etki mekanizmalarından biri, bağırsak florasında bulunan gram pozitif ve gram negatif mikroorganizmalar arasındaki dengenin korunmasıdır. Bitkisel kökenli biyoaktif bileşenlerin, patojen bakteri, virüs ve mantarların çoğalmasını baskıladığı; buna karşılık *Bifidobacterium, Lactobacillus* ve *Akkermansia* gibi yararlı mikroorganizmaların gelişimini destekleyerek bağırsak homeostazisinin sağlanmasına katkıda bulunduğu bildirilmektedir (Nabi ve ark., 2023). Bu etki, yalnızca atlarda değil; ruminantlar, kanatlılar ve monogastrik hayvanlar dâhil olmak üzere farklı hayvan türlerinde sindirim sistemi fonksiyonlarının iyileştirilmesinde de önem taşımaktadır. Atlar, performans beklentisinin yüksek olması nedeniyle sindirim sistemi hastalıklarına yatkın türler arasında yer almakta olup, yoğun konsantre yem tüketimine bağlı olarak mide ülseri ve kolik gibi problemlerin sıklığı artmaktadır. Benzer şekilde, sığır ve koyunlarda yüksek nişasta içeren rasyonlar rumen asidozuna; kanatlılarda ise bağırsak florası dengesizliğine ve performans kayıplarına yol açabilmektedir. Bu hastalıkların kontrolünde konvansiyonel ilaçların yanı sıra bitkisel tedavi seçeneklerinin etkinliği üzerine yapılan çalışmalar artış göstermektedir. Atlarda mide ülserlerinin tedavisinde kullanılan omeprazol gibi proton pompa inhibitörlerinin yüksek maliyetli olması, bitkisel kökenli alternatiflerin önemini artırmıştır. Bu kapsamda, meyan kökü, papatya, hatmi çiçeği, kadife çiçeği, çemen otu, keten tohumu, nane ve sarı kantaron içeren PREVUL adlı bitkisel karışımın mide ülseri vakalarında omeprazole benzer etki gösterdiği ortaya konulmuştur (Kulcsar ve ark., 2022). Sindirim sistemi motilitesinin düzenlenmesi ve kolik benzeri semptomların hafifletilmesinde de çeşitli bitkisel ajanlardan yararlanılmaktadır. Gentian, meyan kökü ve nane; atlar başta olmak üzere farklı hayvan türlerinde spazm çözücü ve sindirimi destekleyici etkileriyle öne çıkmaktadır. Konstipasyon durumlarında yulaf ezmesi, gentian ve at kuyruğu otu (*Equisetum arvense*) gibi bitkilerin olumlu etkileri bildirilmiştir (Laudota ve Capasse, 2013). Aloe vera bitkisinin düşük dozlarda sindirim sistemini rahatlatıcı, yüksek dozlarda ise müsil etkisi gösterdiği; anasonun iştah uyarıcı özellik taşıdığı, kadife çiçeğinin mide mukozasını koruyucu etkisi nedeniyle mide ülserlerinde tercih edilebileceği ifade edilmektedir (Vandergrift, 1998). Ayrıca, enterolitiyazis gibi sindirim sistemi problemlerinde zencefilin ağrı ve spazmı hafifletici etkisinin bulunduğu belirtilmiştir (Williams, 2013). Aynısefa (*Calendula officinalis*) bitkisinin, köpeklerde kalın bağırsak yangısına karşı lavman formunda kullanıldığı bildirilmiştir. Yapılan çalışmalarda, toksik etkilerin yalnızca çok yüksek dozlarda ortaya çıktığı ve bu nedenle sağaltım indeksinin oldukça geniş olduğu vurgulanmaktadır. Bu özellikleriyle aynısefa, güvenli kullanım potansiyeline sahip önemli bir fitoterapi ajanı olarak değerlendirilmektedir (Bedir ve Turgut, 2021). Mide koruyucu ajanlar üzerine yapılan bir başka çalışmada ise ranitidin ile Panax ginseng'in birlikte kullanımı incelenmiş, ginsengin mide mukozası üzerindeki koruyucu etkisinin ranitidine kıyasla daha güçlü olduğu tespit edilmiştir (Debnath ve Hazarika, 2023). Bu bulgular, fitoterapötik ajanların konvansiyonel ilaçlara alternatif veya tamamlayıcı olarak kullanılabileceğini göstermektedir. Bazı fitoterapi ajanlarının etki mekanizmaları, karaciğerde safra akışının artırılması üzerinden gerçekleşmektedir. Safra sekresyonunun düzenlenmesi, sindirim fonksiyonlarının iyileştirilmesine katkı sağlamakta ve sindirim sistemi hastalıklarının tedavisinde destekleyici bir rol oynamaktadır. Bu kapsamda Hypericum perforatum (St. John's wort), karahindiba (*Taraxacum officinale*), papatya (*Chamomilla recutita*) ve civanperçemi

(*Achillea millefolium*) gibi bitkilerin koleretik etkiler gösterdiği bildirilmektedir. Ayrıca civanperçemi, kişniş (*Coriandrum sativum*) ve nane yağı (*Mentha piperita*) gibi bitkilerin de koleretik özelliklere sahip olduğu bilinmektedir (Yurdokök ve ark., 2018). Yeni doğan köpeklerde sindirim sistemi problemlerini yönetmek oldukça önemlidir. Köpek yavruları bu dönemlerde sindirim sistemi hastalıklara açıktırlar. Kabız yavru köpekler üzerine yapılan çalışmalarda Sinameki, *Senna alexandrina veya Cassia augustifolia* bitkileri kullanılmıştır ve olumlu sonuçlar elde edilmiştir. Yavru köpeklerde kusma ve ishal sorunundan sonra hatmi çiçeği ekstraktı kullanılmış ve mide bağırsak sistemini kaplayıcı özelliği sayesinde kusma ve ishali hafifletmiştir. Ağrı kesiciler ve ateş düşürücülerin kullanımı sonucunda açığa çıkan mide bağırsak hiperemisinde sabun otu ve meyan kökü kullanılması sonucunda yangının hafiflediği ortaya konmuştur. *Curcuma longa* bitkisi köpek kolon epitelindeki hasarı minimalize etmiştir (Quintavalla, 2024)

A.5. Hayvanlarda Ağrının Kontrolünde Kullanılan Fitoterapi Ajanları

Atlarda artrit son derece ağrılı olup yarış performansını olumsuz etkileyen önemli bir hastalıktır. Bu hastalığın tedavisinde lokal uygulamaya yönelik preparatlar bulunmaktadır. Yapılan bir çalışmada, *Varronia curassavica* (kara adaçayı veya yabani adaçayı) olarak bilinen bitkinin 90 gün boyunca eklem bölgelerine lokal olarak uygulanması ve eş zamanlı olarak homeopatik bir ajanın oral yolla kullanımı sonucunda artritis semptomlarının azaldığı ve ortadan kalktığı rapor edilmiştir (Domingues ve ark., 2024). Atlarda ağrı sağaltımında kullanılan diğer fitoterapi ajanları da mevcuttur. Şerbetçi otu (*Humulus lupulus*) tohumlarının suyuna batırılan bezlerin haricen uygulanması, ağrının lokal tedavisinde kullanılan geleneksel yöntemlerden biridir. Aynı şekilde, hardal yağının da (muhtemelen *Sinapis alba* veya benzeri türlerden elde edilen) ağrı kesici etkinlik gösterdiği belirtilmektedir (Laudota ve Capasse, 2013). Atlarda, özellikle antrenman sonrası veya lenfatik drenajın aksamasına bağlı olarak arka bacaklarda ödem ve şişkinlik yaygın olarak görülmektedir. Yara ve çiziklerin varlığı bu lenfatik aksamayı ve dolayısıyla ödemi artırabilmektedir. Bu tip ödemi azaltmak amacıyla lokal uygulamada argan yağı (*Argania spinosa*) ve kekik yağı (*Thymus vulgaris*) kullanılmıştır. Kekik yağı doğal olarak antienflamatuvar özelliklere sahip bir esansiyel yağ olmasına karşın, keskin kokusu nedeniyle doku irritasyonuna yol açabilmektedir. Yapılan bir araştırma, argan yağı kullanılan grupta doku irritasyonunun minimalize edildiğini ortaya koymuştur. Bu durum, argan yağının cildi nemlendirme özelliği sayesinde gerçekleşmiştir. Elde edilen bu bulgular, argan yağının kekik yağı gibi potansiyel irritan fitoterapötik ajanlarla kombine kullanımında olası yan etkileri azaltmada faydalı olabileceğini göstermektedir (Paksoy ve ark., 2025). Atları sinek ısırmaları sonucunda meydana gelen aşırı duyarlılık reaksiyonu sonucunda ortaya çıkan dermatit lezyonlarını iyileştirmede nane yağı, limon otu yağı, kafur, May Chang ve paçuli adlı bitkiler kullanılmış olup. Alerjik reaksiyona bağlı oluşan yaraların iyileşmesini teşvik ettiği ortaya konmuştur (Cox ve ark., 2020) Ruminatlar için ise ağrı sağaltımında kullanılan temel maddelerin başında sarımsaktan elde edilen ekstraktlar gelmektedir. Sığırlarda bağırsaklarda bulunan ağrıları ve yangıları hafifletmek amacıyla *Curcuma longa* (Zerdaçal) kullanım alanı bulmuştur. Zerdaçal bitkisi ekstraktları sindirim sistemi ağrılarının yanı sıra eklem yangıları yani artrit vakalarında kullanım alanı bulmaktadır. Yangısal diğer olayların bulunduğu akciğer bağışıklığının düştüğü sığırlarda kullanım alanı bulmuştur (Shafique ve ark.,2023).

A.6. Hayvanlarda Hormon Düzenleyici Olarak Kullanılan Fitoterapi Ajanları

Tüm canlılarda olduğu gibi atlarda da endokrin sistemle ilişkili bozukluklar gözlemlenebilmektedir. Özellikle kısraklarda seksüel fonksiyon bozukluklarının ortaya çıkması durumunda, fitoöstrojenik özellik gösteren bitkisel ajanlar destekleyici tedavi amacıyla kullanılabilmektedir. Bu kapsamda anason (*Pimpinella anisum*), meyan kökü (*Glycyrrhiza glabra*) ve hayıt ağacı (*Vitex agnus-castus*) fitoöstrojenik etkileriyle öne çıkan bitkiler arasında yer almaktadır. Kısraklarda laktasyon döneminde süt veriminin artırılmasına yönelik olarak da bazı fitoterapötik ajanların kullanımı bildirilmiştir. Maydanoz (*Petroselinum crispum*) gibi galaktagog özellik gösteren bitkilerin, oral yolla uygulanarak süt verimini desteklediği belirtilmektedir (Vandergrift, 1998). Atlarda stres ve korkuya bağlı olarak artış gösteren adrenalin ve kortizol gibi stres hormonlarının fizyolojik ve davranışsal etkilerini azaltmak amacıyla aromaterapi uygulamalarından yararlanılmaktadır. Nebülizatör aracılığıyla gerçekleştirilen bir uygulamada, Türk gülü *(Rosa damascena*) yağı kullanılan bir atta, davranışsal bozukluklardan biri olan kendi etrafında dönme davranışında belirgin bir azalma gözlenmiştir. Ancak söz konusu atın yeniden hipodrom ortamına maruz kalmasıyla belirtilerin tekrar ortaya çıktığı bildirilmiştir. Daha sonraki aşamada vetiver (*Vetiveria zizanioides*), lavanta (*Lavandula angustifolia*) ve sedir ağacı (*Cedrus spp*.) yağlarının kombinasyonu ile uygulanan aromaterapi sonucunda daha kalıcı ve olumlu etkiler elde edilmiştir (Glover ve Goodwin, 2006). Fitoterapi uygulamaları yalnızca atlarda değil, diğer çiftlik hayvanlarında da endokrin bozuklukların yönetiminde önem arz etmektedir. Özellikle ineklerde polikistik over sendromu, üreme performansını ve dolayısıyla verimliliği olumsuz yönde etkileyen önemli bir patolojidir. Bu olguların tedavisinde bazı fitoterapi ajanlarının destekleyici olarak kullanıldığı bildirilmektedir. Rezene (*Foeniculum vulgare*) bitkisinin luteinizan hormon (LH) ve folikül stimüle edici hormon (FSH) salınımını uyararak foliküler gelişimi desteklediği ve ovulasyonun gerçekleşmesine katkı sağladığı ifade edilmektedir. Ayrıca sıçanlar üzerinde gerçekleştirilen deneysel çalışmalarda narın (*Punica granatum*) östradiol analoğu gibi etki gösterdiği ve plazma östrojen düzeylerini artırdığı ortaya konmuştur (Azin ve Khazali, 2022). *Ginkgo biloba*'nın da hayvanlarda hormonal mekanizmaların düzenlenmesinde rol oynadığı bildirilmektedir (Yurdakök ve ark., 2018). Köpeklerde ise özellikle kortizol salınımının baskılanması ve ayrılık stresine bağlı davranış bozukluklarının azaltılması amacıyla çeşitli fitoterapötik ve aromaterapötik ajanlar kullanılmaktadır. Bu amaçla en sık tercih edilen bitkiler arasında kedi otu (*Valeriana officinalis*), melisa (*Melissa officinalis*) ve lavanta (*Lavandula angustifolia*) yer almaktadır. Yapılan çalışmalarda, ayrılık anksiyetesi yaşayan köpeklere lavanta yağı inhalasyonu uygulanmasının stres parametrelerini anlamlı düzeyde azalttığı gösterilmiştir (Quintavalla, 2024).

A.7. Hayvanlarda İmmun sistemi Güçlendirmek ve Antioksidan Amaçlı Kullanılan Fitoterapi ve Aromaterapi Ajanları

Hayvanlarda bağışıklık sisteminin güçlendirilmesine yönelik fitoterapi uygulamaları, koruyucu hekimlik ve destekleyici tedavi yaklaşımları kapsamında giderek daha fazla önem kazanmaktadır. Bu amaçla kullanılan bitkiler arasında en yaygın ve bilimsel olarak en fazla çalışılmış olanlardan biri ekinezya (*Echinacea spp*.)'dır. Ekinezyanın bağışıklık sistemi üzerindeki immünstimülan etkileri uzun yıllardır bilinmektedir. Sağlıklı atlar üzerinde

gerçekleştirilen bir çalışmada, 42 gün süreyle uygulanan ekinezya sonrası eritrosit ve lenfosit sayıları değerlendirilmiş; %4'lük ekinezya oral solüsyonunun eritropoezi ve lenfosit sayısını anlamlı düzeyde artırdığı ortaya konmuştur (O'Neil ve ark., 2002). Bu bulgular, ekinezyanın yalnızca atlarda değil, diğer hayvan türlerinde de bağışıklık fonksiyonlarını destekleyici potansiyele sahip olduğunu düşündürmektedir. Bağışıklık sistemini destekleyen bir diğer önemli fitoterapötik ajan ginseng (*Panax ginseng*)'dir. Ginsengin, özellikle aşılamaya bağlı immün yanıtın güçlendirilmesinde etkili olduğu bildirilmektedir. Atlarda herpes virüs aşılamasından iki hafta önce veya sonra 35 mg/kg dozunda ginseng uygulanmasının bağışıklık yanıtını artırdığı gösterilmiştir (Fehrenbach ve ark., 2025). Benzer şekilde ginsengin, farklı hayvan türlerinde hücresel ve humoral immünitenin desteklenmesinde rol oynadığı ifade edilmektedir. Zencefil (*Zingiber officinale*), hayvanlarda bağışıklık sistemini destekleyen bir diğer önemli bitkisel ajan olup, güçlü antioksidan özellikleriyle öne çıkmaktadır. Yapılan çalışmalarda, %0,5, %1 ve %5 oranlarında zencefil içeren diyetlerin antioksidan enzim aktivitelerini artırdığı ve oksidatif stresi azalttığı bildirilmiştir. Bu özellikleri sayesinde zencefilin, bağışıklık sistemi fonksiyonlarının korunmasına dolaylı katkı sağladığı düşünülmektedir. Benzer şekilde cranberry (*Vaccinium macrocarpon*), yüksek polifenolik içeriği sayesinde antioksidan etki göstererek özellikle üriner sistem enfeksiyonlarının kontrolünde hayvan diyetlerine destekleyici amaçla eklenebilmektedir (Williams, 2013). Arnika (*Arnica montana*), kas-iskelet sistemi problemlerinde antiinflamatuvar ve iyileştirici etkileri nedeniyle veteriner hekimlikte yaygın olarak kullanılan bir bitkidir. Bununla birlikte, hayvanlarda oral yolla alındığında toksik etkilere yol açabileceği bildirildiğinden, kullanımı genellikle lokal ve harici uygulamalarla sınırlandırılmıştır. Arnika'nın lokal uygulamalarda doku proliferasyonunu artırarak immünstimülan etki gösterdiği belirtilmektedir (Jakopsen, 2016). Çiftlik hayvanlarında yapılan çalışmalarda, çeşitli bitkisel ekstraktların lenfosit sayıları üzerinde artırıcı etki gösterdiği ortaya konmuştur. Bu etkinin temelinde bitkilerin içerdiği alkaloid, flavonoid ve terpenoid bileşiklerin yer aldığı düşünülmektedir. Ekinezya, kekik (*Origanum vulgare*), aloe vera (*Aloe barbadensis*) ve ısırgan (*Urtica dioica*) gibi bitkiler, bu biyolojik aktif bileşenler açısından zengin olup farklı hayvan türlerinde bağışıklık sisteminin desteklenmesinde kullanım alanı bulmaktadır. Deney hayvanları üzerinde yapılan çalışmalar da fitoterapötik ajanların bağışıklık sistemi üzerindeki etkilerini desteklemektedir. *Helleborus odorus* (kış gülü) bitkisinin kök ekstraktının Wistar ırkı sıçanlarda kullanıldığı bir çalışmada, nötrofil sayılarında belirgin bir artış gözlenmiş ve bu artışın bağışıklık sisteminin güçlenmesiyle ilişkili olduğu bildirilmiştir (Davidović ve ark., 2012).

A.8. Hayvanlarda Antibakteriyel ve Antiviral fitoterapi ajanları

Antibiyotiklere karşı gelişen direnç, son yıllarda hem insan hem de hayvan sağlığında önemli bir küresel sorun haline gelmiştir. Bu durum, alternatif ve tamamlayıcı tedavi yaklaşımlarına olan ilgiyi artırmış; özellikle fitoterapik ajanlar, antibiyotiklere potansiyel bir alternatif olarak ön plana çıkmıştır. Antibakteriyel ve antifungal etkinliğe sahip çok sayıda bitkisel ajan bulunmakta olup, bu ajanların hayvanlar üzerinde kullanımına yönelik bilimsel çalışmalar giderek artmaktadır. Hayvanlar üzerinde yapılan çalışmalarda, kekik yağının güçlü antibakteriyel etkiye sahip olduğu kanıtlanmıştır. Bunun yanı sıra mürver, tarçın ve sarımsak ekstraktlarının *Salmonella spp*. ve enterokoklar gibi patojen mikroorganizmalara karşı etkinlik gösterdiği bildirilmiştir (Nabi ve ark., 2023). Özellikle *Nigella sativa'nın* ineklerde mastitise neden olan etkenlere karşı kullanıldığı çalışmalarda, klinik iyileşme sağlandığı ve somatik hücre sayılarında anlamlı azalma meydana geldiği ortaya konmuştur (Karreman, 2006). Aromatik hidrokarbonlar ve uçucu yağlar bakımından zengin bileşikler içeren bitkilerin antimikrobiyal

aktiviteye sahip olduğu, etnofarmakoloji alanında yaygın olarak kabul edilen bir gerçektir. Limon ve kamelya gibi bitkilerin hayvanlar üzerinde antibakteriyel ve antifungal etki gösterdiği, çeşitli deneysel çalışmalarla desteklenmiştir. Ayrıca Pekin ördekleri üzerinde yürütülen bir çalışmada, rasyonlara kekik yağı, tarçın ve tatlı fesleğen ilavesinin, bağırsak mikrobiyomunda bulunan zararlı mikroorganizmaların sayısını azalttığı gözlemlenmiştir (Davidovic ve ark., 2012). Sarımsağın etken maddesi olan allisinin antimikrobiyal gücüne ilişkin yapılan çalışmalarda, 1 mg allisinin yaklaşık 15 IU penisiline eşdeğer etki gösterdiği bildirilmiştir. Bu doğrultuda endometritisli ineklerde allisin kullanımı sonucunda %50 oranında gebelik elde edilirken, yaklaşık %75 oranında endometritis iyileşmesi sağlanmıştır. Söz konusu çalışmada endometriyumun bakteriyel yükünde belirgin bir azalma gözlemlenmiştir (Sharma ve ark., 2018). Pet hayvanlarında refahı olumsuz etkileyen önemli sağlık sorunlarından biri de üriner sistem taşlarıdır. Bu taşların oluşumu çoğunlukla beslenmeyle ilişkilendirilse de adezyon kabiliyeti yüksek olan *Escherichia coli, Proteus* ve *Klebsiella* türleri gibi bakterilerin de üriner sistem taşlarının gelişiminde rol oynadığı bilinmektedir. Üriner sistem enfeksiyonlarının destekleyici tedavisinde kullanılan başlıca fitoterapik ajanlar arasında Cranberry, Zea mays, *Agathosma betulina, Valeriana officinalis, Petroselinum crispum* ve Lavandula türleri yer almaktadır.Kedi ve köpeklerde cranberry, blueberry ve bearberry gibi fitoterapik ajanlar, içerdikleri flavonoidler aracılığıyla alt üriner sistem hastalıklarına (FLUTD) neden olan bakterilerin adezyon yeteneğini azaltarak etki göstermektedir. Lavanta türleri ise diüretik özellikleri sayesinde idrarın bakteriler için besi yeri olma özelliğini azaltmakta ve böylece enfeksiyonların kontrol altına alınmasına katkı sağlamaktadır (Güneş ve ark., 2023)

Sonuç

Sonuç olarak, fitoterapötik ajanlar uzun yıllardır beşeri hekimlikte kullanım alanı bulmuş olmakla birlikte, son yıllarda veteriner hekimlik uygulamalarında da giderek artan bir ilgiyle değerlendirilmeye başlanmıştır. Özellikle koruyucu hekimlik, destekleyici tedavi ve kronik hastalıkların yönetiminde fitoterapinin önemi her geçen gün artmaktadır. Ancak bu ajanların veteriner hekimlikte kullanımının bilimsel temellere dayandırılması ve kontrolsüz uygulamalardan kaçınılması büyük önem taşımaktadır. Fitoterapi ajanlarının ruhsatlandırılması ve klinik kullanımı sürecinde, içeriklerinin standardizasyonu, etkinliklerinin kanıta dayalı olarak ortaya konması ve olası toksik ile yan etkilerinin ayrıntılı biçimde değerlendirilmesi gerekmektedir. Bazı bitkisel bileşiklerin yüksek dozlarda veya uzun süreli kullanımlarında toksik etkilere yol açabileceği bilinmektedir. Bu nedenle hayvan sağlığı amacıyla kullanılacak fitoterapötik ürünlerin veteriner hekim denetiminde uygulanması, uygun doz ve uygulama sürelerinin belirlenmesi zorunludur. Ayrıca bu ajanlara ait sağaltım indekslerinin ortaya konması ve söz konusu verilerin veteriner hekimler tarafından bilinmesi, güvenli kullanım açısından temel bir gereklilik oluşturmaktadır.Fitoterapinin veteriner hekimlikte tercih edilmesinin başlıca avantajları arasında, birçok bitkisel ürünün hayvansal ürünlerde (et, süt, yumurta) ilaç kalıntısı bırakmaması veya arınma süresi gerektirmemesi yer almaktadır. Bunun yanı sıra, antibakteriyel direnç gelişiminin bitkisel ürünlere karşı oldukça sınırlı olması, fitoterapötik ajanları özellikle antibiyotik direncinin küresel bir sorun haline geldiği günümüzde önemli bir alternatif haline getirmektedir. Ayrıca fitoterapi ajanlarının çoğunun antioksidan, immünstimülan ve antiinflamatuvar etkiler göstermesi, hayvan refahının artırılmasına da katkı sağlamaktadır. Bununla birlikte fitoterapinin bazı dezavantajları da göz ardı edilmemelidir. Bitkisel ürünlerin etken madde içeriklerinin çevresel koşullara, hasat zamanına ve ekstraksiyon yöntemlerine bağlı olarak değişkenlik göstermesi, etki gücünde standartlaşma sorunlarına yol açabilmektedir.

Ayrıca yeterli klinik çalışma bulunmayan bazı bitkisel ürünlerin etkinliği ve güvenilirliği konusunda bilimsel belirsizlikler mevcuttur. Yanlış dozlama, uygunsuz kombinasyonlar veya bilinçsiz kullanım durumlarında istenmeyen yan etkilerin ortaya çıkma riski bulunmaktadır. Sonuç olarak, fitoterapi çağımızda veteriner hekimlikte giderek önem kazanan tamamlayıcı ve destekleyici bir tedavi yaklaşımıdır. Ancak bu uygulamaların güvenli ve etkin bir şekilde hayata geçirilebilmesi için, bilimsel araştırmalarla desteklenmesi, yasal düzenlemeler çerçevesinde ruhsatlandırılması ve veteriner hekimlerin bilgi ve denetimi altında uygulanması büyük önem taşımaktadır. Bu koşullar sağlandığında fitoterapi, modern veteriner hekimliğin önemli bir tamamlayıcı unsuru olarak değerlendirilebilecektir.

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ALTERATIONS IN SOME HEMATOLOGICAL PARAMETERS OF BROILERS COMBINED SUPPLEMENTED WITH CITRIC ACID AND HIGH FRUCTOSE CORN SYRUP

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ABSTRACT

High fructose corn syrup (HFCS) is a commercially produced fructose derivative which has increasing usage in recent years to enhance productivity in poultry meat production. This study was conducted to evaluate the effects of citric acid (CA) and HFCS, administered alone or in combination, on certain hematological parameters in broiler chickens. A total of 36 broiler chickens were randomly allocated into four groups (n=9/group): Control, citric acid (CA), HFCS, and CA+HFCS. During the 42-day experimental period, all animals were provided with commercial starter and grower diets on an ad libitum basis, and free water access was also granted. In addition to the basal diet, the CA group received 30 mg/kg citric acid, the HFCS group received 50 mg/kg HFCS, and the CA+HFCS group received a combination of both supplements at the same doses. At the end of the experiment, the animals were scarified by cervical dislocation, and 3 mL-blood samples were collected into K_3-EDTA–containing tubes for hematological analysis, which was performed using manual methods. The results indicated that total leukocyte count (TLC), red blood cell count (RBC), and mean corpuscular volume (MCV) were not significantly affected by any of the treatments ($p>0.05$). Moreover, no significant changes were observed when CA or HFCS was administered alone ($p>0.05$) while hemoglobin concentration (HGB), packed cell volume (PCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) were significantly reduced ($p<0.05$) in the CA+HFCS group compared with the untreated control group. In conclusion, the combined administration of citric acid and high fructose corn syrup adversely affected several key hematological parameters related to erythrocyte integrity in broiler chickens, while their individual supplementation did not induce significant alterations. These findings suggest a potential interactive effect between CA and HFCS that may negatively influence hematological homeostasis when used together. Further studies are warranted to elucidate the underlying mechanisms and to assess the long-term physiological and production-related consequences of combined dietary supplementation in poultry.

Keywords: high fructose, citric acid, broilers, hematological parameters, red blood cell indices

1. INTRODUCTION

Fructose is a monosaccharide and one of the three major simple sugars, together with glucose and galactose, and is recognized as the sweetest naturally occurring monosaccharide (Skoog & Bharucha, 2004). It is widely present in a variety of food sources, including fruits, vegetables, grains, cereals, and many processed products. Moreover, fructose is extensively used in the food industry as an alternative sweetening agent to glucose or sucrose and has become an important constituent of modern dietary patterns (Okon et al., 2019).

High fructose corn syrup represents a commercially produced fructose derivative that has gained considerable traction in the poultry industry over recent years. Its primary application focuses on enhancing productivity metrics in broiler meat production, including growth rate, feed conversion efficiency, and overall performance parameters Because of its economic advantages and potential to influence growth performance, HFCS supplementation has gained traction in poultry nutrition; however, the physiological effects of HFCS—especially when combined with other dietary additives—are not yet fully understood (Altuğ et al., 2024; Miles et al., 1987; Şen et al., 2024).

Citric acid (CA) is a naturally occurring organic acid predominantly found in citrus fruits and is associated with cellular protective effects against oxidative stress. In addition to its natural occurrence, CA is industrially synthesized and extensively used as a preservative, acidulant, and sweetening agent. In poultry nutrition, citric acid is widely employed as a feed additive, where it functions as a natural preservative, antimicrobial agent, and regulator of gastrointestinal pH. Furthermore, CA has been reported to enhance digestive enzyme activity, thereby improving feed utilization efficiency. Owing to these multifunctional properties, citric acid plays a significant role in antibiotic-free broiler production systems (Abdalla et al., 2015; Ahsan-ul-Haq et al., 2014; Singh et al., 2022). Several studies have reported that dietary citric acid supplementation does not significantly alter major hematological parameters, including red blood cell count (RBC), total leukocyte count (TLC), and mean corpuscular volume (MCV), in broiler chickens, indicating a generally safe hematological profile when used at appropriate dietary levels (Abdel-Fattah et al., 2008; Ahsan-ul-Haq et al., 2014).

On the other hand, the assessment of hematological parameters and indices is widely recognized as an effective approach for disease diagnosis and health evaluation in both animals and humans, as blood-based measurements often reflect underlying physiological processes and provide valuable insight into overall health status (Kabakci & Kara, 2023; Kabakci, 2022; Theml et al., 2004).

Although CA and HFCS are individually recognized for their applications in poultry nutrition, the interactive effects of their combined supplementation on physiological parameters remain largely unexplored. Therefore, this investigation was conducted to systematically examine the hematological consequences of CA and HFCS supplementation under controlled experimental conditions.

2. MATERIAL AND METHODS

The experimental design of the present study was approved by the Local Ethics Committee of Kirikkale university with the number of 2022-6/36. Total 36 broiler chickens were procured and randomly divided into four experimental groups (n=9 per group) as: Control (basal diet only), CA (basal diet + 30 mg/kg citric acid), HFCS (basal diet + 50 mg/kg high fructose corn syrup), and CA+HFCS (basal diet + both additives at specified doses). All additives were thoroughly mixed into the feed to ensure homogeneous distribution. Basal diets were commercially purchased and formulated starter (days 1-21) and grower (days 22-42) diets, which were ad libitum provided to all chickens throughout the 42-day experimental period associated with free fresh water. At the end of the experimental period (day 42), all animals were

killed via cervical dislocation following. Blood samples (3 mL) were collected into K_3-EDTA anticoagulant tubes to prevent clotting and preserve cellular morphology.

All hematological parameters were determined using standardized manual laboratory methods. Total leukocyte counts (TLC) and red blood cells (RBC) were counted using hemocytometer methods with Natt-Herrick solution (Natt & Herrick, 1952). Hemoglobin concentration (HGB) and packed cell volume (PCV) were determined by cyanmethemoglobin and microhematocrit methods, respectively (Campbell & Ellis, 2007). Then erythrocyte indices were calculated from these parameters as mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC).

Descriptive and comparative statistical analyses were conducted using SPSS version 20.0. Following assessment of data normality, group differences were analyzed by one-way analysis of variance (ANOVA), and multiple comparisons were performed using Duncan's post-hoc test. A p-value of less than 0.05 was considered statistically significant.

3. RESULTS and DISCUSSION

As presented in Figure 1, our results showed that there were no statistically significant differences among any treatment groups compared to control ($p>0.05$). Similarly, our previous study has also revealed that low or high doses of HFCS did not changed TLC of broiler chickens (Altuğ et al., 2024). Moreover, Citric acid (CA) usage as an acidifier in broiler had no significant effects on TLC (Abdalla et al., 2015). Tollba (2010) have also reported that citric acid did not change the TLC and their differential counts in broilers for 40 days. According to another earlier report, although TLC reduced in CA-treated broilers, it was not statistically significant (Capcarova et al., 2010). These indicate that neither CA nor HFCS, individually or in combination, significantly influenced white blood cell populations or immune cell mobilization during the experimental period.

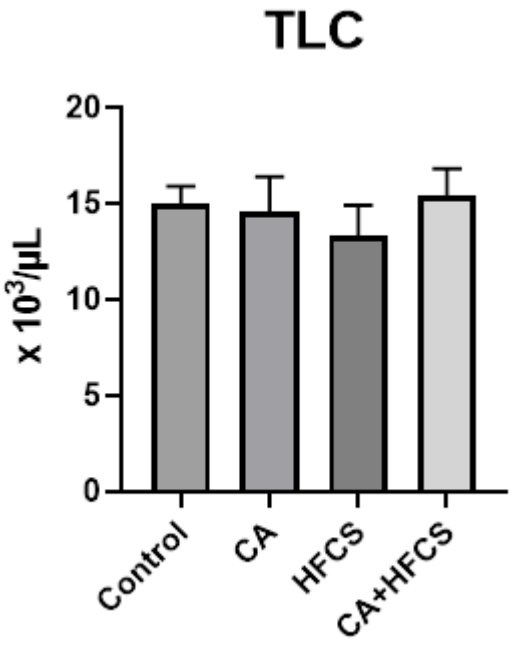


Figure 1. Effects of citric acid and high fructose corn syrup on total leukocyte counts of broiler chickens. TLC: Total Leukocyte counts, CA: Citric acid, HFCS: high fructose corn syrup. Results expressed as mean and standard error means.

Findings of the present study have also demonstrated that neither erythrocyte numbers (RBC) nor average size of individual red blood cells (MCV - mean corpuscular volume) showed statistically significant ($p>0.05$)variations among groups following alone and in combination of CA and HFCS (Figure 2). In convenience with our results several earlier studies have also indicated that dietary supplementation CA or HFCS did not significantly change RBC and MCV values in broilers. For example, (Ahsan-ul-Haq et al., 2014) observed non-significant effects of citric acid on hemogram values, including RBC and related indices. Altuğ et al. (2024) reported 50 mg/kg HFCS did not statistically affect RBC and MCV of broiler chickens. These findings suggest that the quantitative production, morphology and cellular volume of red blood cells were not substantially impacted by the dietary interventions and preserved regardless of supplementations in this study.

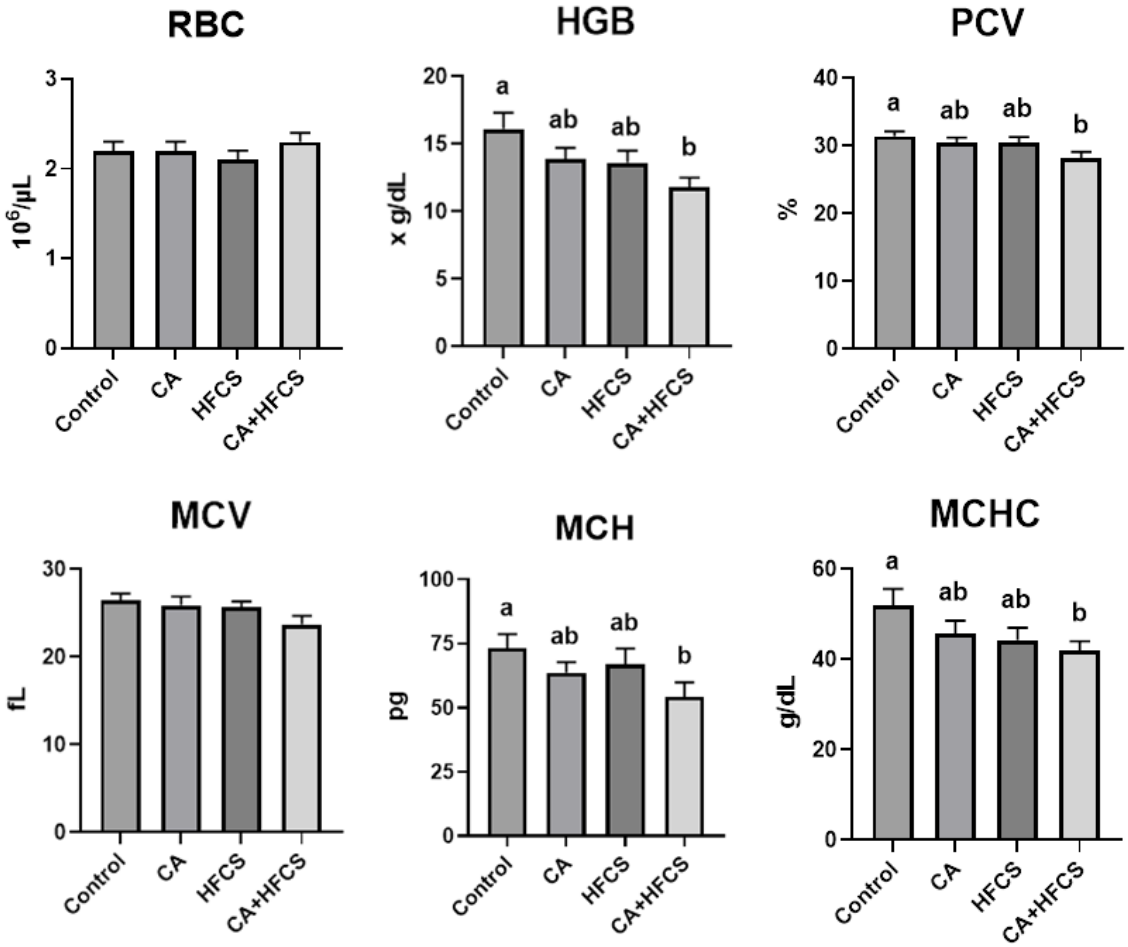


Figure 2. Effects of citric acid and high fructose corn syrup on red blood cells (RBC), Hemoglobin concentration (HGB) and packed cell volume (PCV), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC). CA: Citric acid, HFCS: high fructose corn syrup. Results expressed as mean and standard error means. Different letters (a, b) on the bar represent statistically significant as $p<0.05$.

On the other hand, HGB, PCV, MCH and MCHC values were affected by the treatments (Figure 2). All the related parameters decreased in the supplemented groups; however, this reduction was only statistically significant ($p<0.05$) in the combined group compared to the control group, as opposed to the groups that were treated alone. Similarly, Altuğ et al. (2024) reported that 50 mg/kg HFCS did not lead to difference same parameters compared to untreated group as observed in group HFCS alone in our study. Conflicting findings have been reported in the literature regarding the effects of citric acid (CA) when administered alone. Previous studies have shown that dietary supplementation of CA at levels ranging from 0.5% to 3% increased hemoglobin concentration (HGB) without significantly affecting packed cell volume (PCV) (Ahsan-ul-Haq et al., 2014) (Elnaggar & El-kelawy, 2024). In contrast, Al-Harthi and Attia (2016) reported that CA alone did not induce significant changes in the erythrogram; however, when combined CA with olive cake (OC) led to marked reductions in PCV, HGB, and mean corpuscular hemoglobin (MCH). These findings are highly consistent with the results of the present study, in which similarly, we observed that the combined administration of CA and HFCS resulted in significant decreases in HGB, PCV, MCH, and MCHC values compared with the control group.

These results indicate that combined supplementation of CA and HFCS have a functional impairment in hemoglobin synthesis or retention rather than a reduction in erythrocyte production. This pattern is most probably consistent with potential disruption of iron metabolism, heme synthesis, or hemoglobin stability mechanisms. Previous studies have been reported that CA increased iron absorption (Milman, 2020) or improve serum iron level and indicators of anemia (Takatera et al., 2012) while HFCS led to impairment of iron metabolism in rats (Wang et al., 2021). However, given the limited data available on combined use of CA and HFCS, these findings highlight the need for further comprehensive studies to clarify the underlying mechanisms and to better define the physiological consequences of combined supplementation.

Conclusion

In conclusion, citric acid (CA) and high fructose corn syrup (HFCS) did not significantly affect leukocyte counts or erythrocyte indices when administered individually; however, their combined supplementation resulted in significant reductions in hemoglobin-related parameters such as HGB, PCV, MCH and MCHC without altering erythrocyte number or size. These findings suggest a functional impairment in hemoglobin-related processes rather than reduced erythropoiesis, potentially involving alterations in iron metabolism. Further studies are required to elucidate the mechanisms underlying these combined effects and their long-term implications in poultry nutrition.

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SANTRİFÜJ SEPARATÖR GÜÇ TÜKETİMİNİN YAPAY SİNİR AĞLARI İLE TAHMİNİ

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ÖZET

Endüstriyel sıvı-sıvı ayırma uygulamalarında kullanılan HAUS VBA 320 serisi separatörler farklı ürün işleme debisi ve çıkış basıncı altında enerji tüketim profilleri farklılık göstermektedir. Enerji tüketimlerindeki bu farklılık, işletme maliyetlerinin artmasına sebep olmaktadır. Optimum ayrım verimliliğini sağlarken, minimum güç tüketimi için ayırım yapılacak ürünün miktarı, seçilecek ayırıcı tank, motor gücü gibi ana ürün bileşenlerinin doğru seçilmesi ve buna göre oluşabilecek güç tüketim miktarının separatörün satışı öncesi bilinmesi, işletme maliyet hesaplamasında önemli kazanım sağlayacaktır. Bu durum için belirli bir matematiksel model olmayıp, genel olarak uzman personelin tecrübelerinden edindiği bilgilere göre güç tüketimi tahmin edilmeye çalışılmaktadır.

Yapay Zekanın alt dallarından Makine Öğrenme algoritmalarının en önemlilerinden biri olan Yapay Sinir Ağları (YSA), nonlineer yapıda farklı giriş parametrelerine bağlı olarak tahminleme yapabilen bir bilgi işleme tekniğidir.

Bu çalışmada, gerçek zamanlı sensör verileri kullanılarak separatörün farklı ürün işleme debisi ve çıkış basıncı koşullarındaki enerji tüketimi YSA modelleri kullanılarak tahmin edilmiştir. Çalışma kapsamında, toplam 36 farklı YSA mimarisi denenmiş ve performansları karşılaştırılmıştır. Tüm modellerin eğitim süresi, katman derinliği ve hiperparametrelerinin etkileşimi değerlendirilerek sonuçlar elde edilmiştir. En iyi tahmin doğruluğu, dört katmanlı (128, 64, 32, 1) yapısı ve tanh aktivasyon fonksiyonu ile %98,73 R^2 oranına sahip modeldir. Elde edilen sonuçlar, YSA tabanlı modellerin santrifüj sistemleri gibi doğrusal olmayan proseslerde enerji tüketimini yüksek isabetle tahmin edebileceğini ortaya koymaktadır.

Anahtar Kelimeler: Yapay Sinir Ağları, Enerji Verimliliği, Derin Öğrenme, Disk Yığın Santrifüj Separatör, Hiper parametre Karşılaştırma, Güç Tüketimi Tahmini

1. GİRİŞ

Sanayileşmenin hız kazanması ve enerji verimliliği hedeflerinin ön plana çıkmasıyla birlikte, üretim süreçlerinin her aşamasında enerji tüketiminin doğru izlenmesi ve yönetilmesi kritik bir hâl almıştır. Özellikle dinamik yapıya sahip proses ekipmanlarında, bu tüketimi etkileyen parametrelerin fazlalığı, geleneksel izleme yaklaşımlarını yetersiz kılmakta ve daha akıllı sistem ihtiyacını doğurmaktadır. Bu bağlamda, santrifüj tipi separatör makineleri gibi enerji yoğun çalışan sistemlerin performans takibi ve tahmini üzerine yapılan çalışmalar, sürdürülebilir üretim stratejilerinin yapıtaşlarından biri haline gelmiştir [1].

Endüstriyel üretim süreçlerinde sıvı-sıvı ayrımı, özellikle gıda, kimya ve çevre teknolojileri gibi alanlarda hayati bir öneme sahiptir. Bu ayrım işlemi, genellikle yüksek devirle çalışan disk yığını santrifüj separatör makineleriyle gerçekleştirilir [2]. Söz konusu ekipmanlar hem prosesin ayrıştırma

verimliliğini hem de toplam enerji tüketimini doğrudan etkileyen karmaşık sistemlerdir. Separatörlerin güç tüketimi sadece enerji maliyetleri açısından değil, aynı zamanda sistemin genel sağlık durumu ve proses kararlılığı açısından da önemli bir göstergedir. Dolayısıyla, bu tür makinelerde enerji tüketiminin doğru bir şekilde tahmin edilmesi, üretim optimizasyonu ve arıza öncesi müdahale açısından kritik öneme sahiptir.

Modern santrifüj teknolojileri, yüksek ayırma verimliliği sağlamak üzere tasarlansa da bu performans genellikle artan enerji gereksinimiyle birlikte gelir [3]. Özellikle zeytinyağı üretimi gibi uygulamalarda kullanılan dekantör santrifüjler, katıların ayrılması ve sıvıların temizlenmesi görevlerini aynı anda üstlenirken, sürekli çalışan yapıları nedeniyle enerji tüketimini sürekli olarak etkiler [4]. Ayrıştırma verimliliğinin sürekliliğini sağlamak için kullanılan bu makinelerin güç profili; çalışma hızı, sıvı özellikleri ve çevresel faktörlere göre değişkenlik göstermektedir [5]. Bu nedenle, santrifüj sistemlerinin enerji tüketim karakteristiğini anlamak ve modellemek, sadece enerji yönetimi açısından değil, aynı zamanda sistemin genel proses başarımı açısından da önem arz etmektedir.

Santrifüjlerin enerji tüketimini modellemek, enerji tüketimi ve performansı için etkili stratejiler geliştirmeyi ve uygulamayı kolaylaştırır [6]. Bu bağlamda, santrifüj ayırma modellemesi ve enerji tasarrufu üzerine yapılan çalışmaların sayısı henüz sınırlıdır [4]. Santrifüjlerin enerji tüketimi, operasyonel parametreler, malzeme özellikleri ve çevresel faktörler gibi çeşitli değişkenlere bağlıdır. Bu nedenle, enerji tüketimini doğru bir şekilde tahmin edebilen ve farklı senaryolarda performansı optimize edebilen modeller geliştirmek önemlidir [4].

Geleneksel olarak, santrifüj separatör gibi yüksek devirli sistemlerin güç tüketimini tahmin etmeye yönelik çalışmalar çoğunlukla fiziksel modelleme, ampirik denklemler ya da temel regresyon tabanlı istatistiksel yaklaşımlar üzerine odaklanmıştır [7]. Bu yöntemler, belirli çalışma koşulları altında kabul edilebilir doğruluk seviyelerine ulaşabilse de değişken proses dinamikleri, çevresel etkileşimler ve çok değişkenli veri yapıları karşısında genellikle yetersiz kalmaktadır. Özellikle prosesin gerçek zamanlı izlenmesi ve öngörüsel karar destek sistemleriyle entegre edilebilmesi açısından, bu klasik yöntemler hem esneklik hem de hassasiyet açısından önemli sınırlılıklar taşımaktadır.

Bu sorunun üstesinden gelmek için, makine öğrenmesi ve derin öğrenme gibi yapay zekâ teknikleri, santrifüj sistemlerinin güç tüketimi ve performans modellemesinde umut vadeden alternatifler sunmaktadır [8]. Bu yaklaşımlar, büyük veri setlerinden karmaşık ilişkileri otomatik olarak öğrenebilme, doğrusal olmayan etkileşimleri yakalayabilme ve farklı operasyonel senaryolara adaptasyon sağlayabilme yeteneklerine sahiptir. Bu sayede, santrifüj proseslerinin enerji verimliliğini artırmak, işletme maliyetlerini düşürmek ve çevresel sürdürülebilirliği desteklemek için daha akıllı ve etkili çözümler geliştirilebilir.

Bu bağlamda, YSA gibi ileri düzey veri odaklı modelleme teknikleri, santrifüj sistemlerinde güç tüketiminin tahminine yönelik literatürde giderek daha fazla yer bulmaktadır [9]. YSA, geleneksel modellerin sınırlı kaldığı durumlarda yüksek doğruluk, esneklik ve genellenebilirlik avantajları sunarak özellikle çok değişkenli ve doğrusal olmayan sistemlerin modellenmesinde etkili bir çözüm sunmaktadır. Son yıllarda proses mühendisliği alanında YSA tabanlı yaklaşımların başarılı uygulamaları, bu modellerin endüstriyel ölçekte uygulanabilirliğini ve potansiyelini ortaya koymuştur.

YSA, hayvan sinir ağlarının davranışını simüle eden ve dağıtılmış ve paralel bilgi işleme gerçekleştiren matematiksel bir modeldir [10]. YSA, enerji tüketimi tahmini gibi karmaşık problemleri çözmek için popüler bir çözümdür [11]. Yapay zekâ ve büyük veri analitiğinin önemi günümüzde giderek artmaktadır [12]. YSA, karmaşık, doğrusal olmayan sistemleri modelleme yetenekleri sayesinde enerji tüketimi tahmini alanında önemli bir araç haline gelmiştir [13]. Çok değişkenli sistemlerdeki karmaşık ilişkileri öğrenme ve genelleme yetenekleri sayesinde, YSA enerji tüketimini etkileyen çeşitli faktörleri dikkate alarak doğru tahminler yapabilirler. Makine öğrenmesi teknikleri, operasyonel anormallikleri

tespit etmek ve bir arızanın neden olduğu fonksiyonel kayıpları önlemek için yeterince erken aşamada santrifüj pompalarının arıza tahmini için kullanılmaktadır.

YSA çevresel koşulları ve doğrusal olmayan ilişkileri girdi olarak kabul ederken, üretilen gücü modelin çıktısı olarak değerlendirir [14]. YSA, modellenen sistem hakkında derinlemesine ön bilgiye ihtiyaç duymadan oluşturulabilir; zira ağın kendisi, mevcut verilerden sistem davranışını öğrenme kapasitesine sahiptir. YSA'ın sürekli güncellenebilme özelliği, gerçek zamanlı kontrol senaryolarında kullanımını cazip kılmaktadır [15].

Bu doğrultuda, YSA'nın santrifüj tipi ekipmanlarda enerji tüketimi tahminine yönelik potansiyelinin sistematik olarak değerlendirilmesi hem literatürdeki boşluğu doldurmak hem de endüstriyel uygulamalara doğrudan katkı sağlamak açısından kritik öneme sahiptir. Özellikle gerçek proses verilerine dayalı çoklu YSA mimarilerinin karşılaştırmalı olarak incelendiği çalışmaların azlığı, bu alanda yapılacak kapsamlı analizlerin değerini daha da artırmaktadır. Bu çalışma, söz konusu eksikliği gidermek amacıyla yapılandırılmış ve YSA modellerinin güçlü yönlerini ortaya koymayı hedeflemiştir. Bir sıvılaştırma tesisindeki kriyojenik bir pompanın güç tüketimini tahmin etme örneğinde olduğu gibi, akış hızı, emiş ve çıkış sıcaklıkları, basınç değerleri, tanktaki sıvı seviyesi, likit doğal gaz (Liquefied Natural Gas, LNG) yoğunluğu gibi çeşitli operasyonel parametreler dikkate alınarak enerji tüketimi modellenebilir [11].

Enerji tüketiminin erken aşamada doğru bir şekilde tahmin edilmesi, enerji tasarrufu sağlayan tasarım için nicel bir temel sağlayabilir [16]. Modelin tahmin doğruluğunu ve genel güvenilirliğini artırmak amacıyla, farklı optimizasyon algoritmaları ve veri önişleme teknikleri ile entegre edilebilirler. Benzer doğrultuda yapılan bazı çalışmalarda da, enerji yoğun proseslerin yapay sinir ağlarıyla başarıyla modellenebildiği görülmektedir [17].

Bu çalışma, YSA kullanılarak santrifüj separatör makinelerinde güç tüketiminin tahmin edilmesine yönelik kapsamlı bir yaklaşım sunmak üzere beş ana bölümden oluşmaktadır. İlk bölüm olan giriş kısmında, sıvı-sıvı ayırma teknolojilerinin endüstriyel önemi, güç tüketimi takibinin gerekliliği ve mevcut literatürdeki yöntemsel boşluklar ele alınmıştır. Ayrıca, YSA'nın bu alandaki potansiyeli vurgulanarak çalışmanın amacı ve özgün katkısı açıklanmıştır.

İkinci bölümde, deneysel sistemin fiziksel ve dijital altyapısı detaylandırılmıştır. Separatörün kontrol ve veri toplama panoları, kullanılan sensörler, ölçüm cihazları, veri akışı ve haberleşme yapıları ayrıntılı olarak sunulmuştur. Üçüncü bölümde, oluşturulan sekiz farklı YSA modelinin yapısı, eğitim süreçleri, optimizasyon algoritmaları ve test performansları karşılaştırmalı olarak analiz edilmiştir. Dördüncü bölümde, elde edilen bulguların literatürle karşılaştırmalı değerlendirmesi yapılmış, model başarımı ve endüstriyel uygulanabilirliği tartışılmıştır. Son olarak beşinci bölümde, çalışmanın genel sonuçları özetlenmiş, araştırmanın katkısı vurgulanmış ve gelecekteki çalışmalar için öneriler sunulmuştur.

Bu çalışmada, endüstriyel sıvı-sıvı ayırma süreçlerinde yaygın olarak kullanılan HAUS marka VBA 320 serisi disk yığını santrifüj separatör makinesi kullanılmıştır. Söz konusu makine, yüksek devirle çalışan tambur yapısı sayesinde sıvı fazların ayrılmasını sağlamakta olup; ürün girişi, hafif faz çıkışı ve ağır faz çıkışı olmak üzere üç ana bağlantı hattına sahiptir. Deneysel çalışmalarda, ağır faz çıkışı mekanik olarak kapatılmış ve ürün yalnızca hafif faz çıkışından alınmıştır. Bu düzenleme ile, ürün çıkış basıncının kontrollü bir şekilde artırılması, çıkış sıcaklık ve çıkış basınç verilerinin sağlıklı biçimde toplanması hedeflenmiştir.

Sistem, separatör kontrol panosu ve veri toplama panosu olmak üzere iki ayrı kontrol yapısına sahiptir. Separatör kontrol panosu, motor devrinin kontrolü ve çıkış basıncının dinamik regülasyonu gibi temel işlevleri yerine getirirken; Veri Toplama Panosu, tüm proses parametrelerinin izlenmesi, dijital sinyal işlenmesi ve veri kaydının gerçekleştirilmesinden sorumludur. Bu yapılar, Profinet tabanlı haberleşme

protokolü ile birbirine entegre çalışmakta olup, gerçek zamanlı veri senkronizasyonuna imkân tanımaktadır.

Separatör sistemine besleme olarak, deneysel kararlılığı sağlamak ve ekonomikliği artırmak amacıyla su kullanılmıştır. Böylelikle proses değişkenlerinin daha stabil ve tekrarlanabilir şekilde kontrolü mümkün olmuştur. Sistemin tamamı, proses kontrol ve veri toplama açısından tam entegre bir test düzeneği olarak yapılandırılmış ve tüm sinyaller dijital ortamda izlenebilir hâle getirilmiştir.

2. DENEYSEL ÇALIŞMALAR

2.1. Sistem Tanımı

Bu çalışmada, endüstriyel sıvı-sıvı ayırma süreçlerinde yaygın olarak kullanılan HAUS marka VBA 320 serisi disk yığını santrifüj separatör makinesi kullanılmıştır. Söz konusu makine, yüksek devirle çalışan tambur yapısı sayesinde sıvı fazların ayrılmasını sağlamakta olup; ürün girişi, hafif faz çıkışı ve ağır faz çıkışı olmak üzere üç ana bağlantı hattına sahiptir. Deneysel çalışmalarda, ağır faz çıkışı mekanik olarak kapatılmış ve ürün yalnızca hafif faz çıkışından alınmıştır. Bu düzenleme ile, ürün çıkış basıncının kontrollü bir şekilde artırılması, çıkış sıcaklık ve çıkış basınç verilerinin sağlıklı biçimde toplanması hedeflenmiştir.

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2.2. Mekanik Sistem ve Akış Yapısı

Deneysel çalışmada proses sıvısı olarak su tercih edilmiştir. Zeytinyağı, süt veya yakıt gibi viskozitesi yüksek ve kimyasal içeriği değişken ürünler yerine su kullanılması, ölçümlerde kararlılık sağlamış ve ekonomik açıdan avantaj sunmuştur. Su, harici bir depolama tankına doldurulmuş ve bu tanktan ürün pompası aracılığıyla separatör makinesine besleme yapılmıştır.

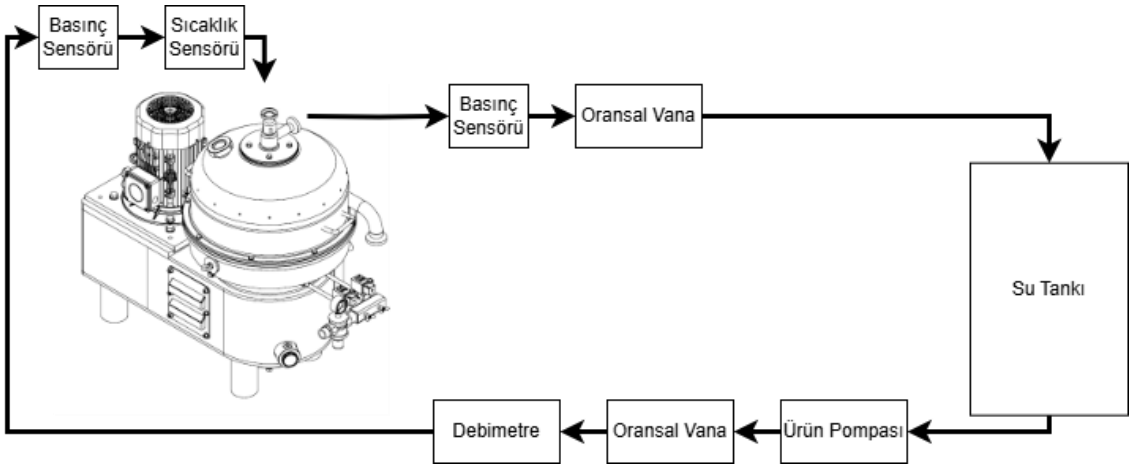
Pompa çıkışına oransal vana seri olarak bağlanarak, separatöre gönderilen suyun debisi hassas bir şekilde kontrol edilmiştir. Oransal vananın hemen ardından yerleştirilen debimetre, yapılan ayarların anlık olarak izlenmesini ve sistemin kalibrasyonunu sağlamıştır. Bu yapı sayesinde hem manuel hem otomatik kontrol modlarında akış ayarı gerçek zamanlı olarak yapılabilmiştir.

Debimetreden sonra, separatöre giriş hattına sırasıyla basınç ve sıcaklık sensörleri entegre edilmiştir. Bu sensörler, ürünün separatöre girişindeki fiziksel özelliklerini ölçmek üzere doğrudan separatör girişine mümkün olduğunca yakın konumlandırılmıştır. Böylece veri doğruluğu ve sistem tepkiselliği artırılmıştır.

Separatör çıkışında ise bir basınç sensörü ve yine çıkışa bağlı bir oransal vana konumlandırılmıştır. Bu sayede, çıkış basıncının kontrollü bir şekilde artırılması ve prosesin çeşitli koşullar altında test edilmesi sağlanmıştır. Ürün çıkışı hattı, kapalı devre döngü ile tekrar tanka geri dönmekte, böylece sistemde

dolaşan su zamanla ısınmakta ve enerji tüketiminin sıcaklıkla ilişkisi gözlemlenebilmektedir (Görsel 1).

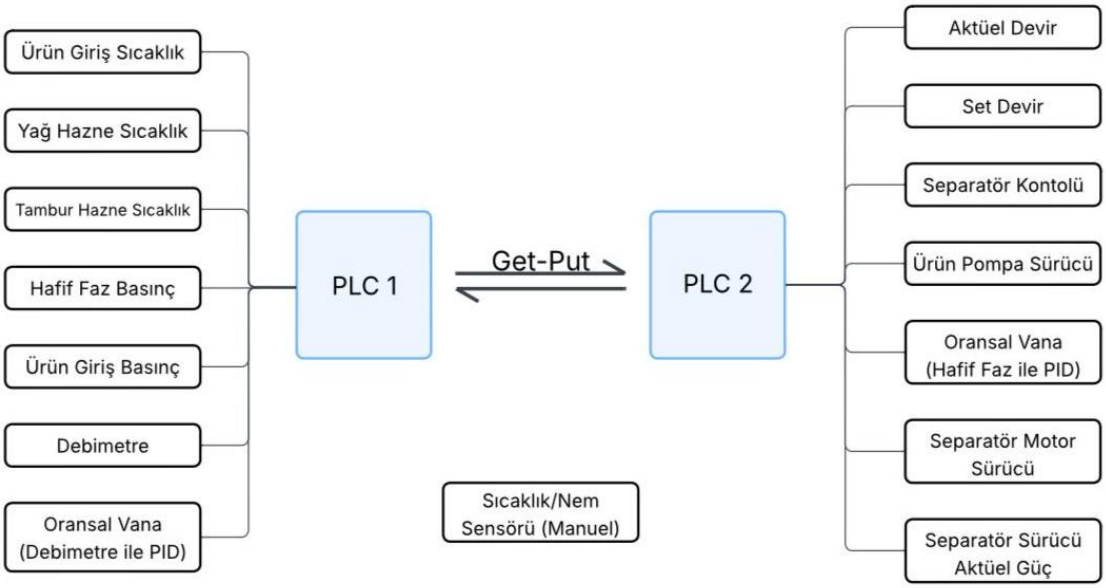
Ek olarak, separatör tamburunun bulunduğu üst gövdeye ve yağ haznesine yerleştirilen sıcaklık sensörleri ile sistem içi ısıl dengenin takibi yapılmış, proses kararlılığının değerlendirilmesi mümkün kılınmıştır.



Görsel 1. Ürün Akış Şeması

2.3. Kontrol Panosu ve Otomasyon Yapısı

Separatör sisteminin otomasyon altyapısı separatör kontrol panosu ve veri toplama panosu olmak üzere iki ana pano üzerinden yönetilmiştir. Bu iki pano hem birbirinden bağımsız çalışabilecek hem de entegre sistem olarak görev yapabilecek şekilde yapılandırılmıştır (Görsel 2). Tüm veri akışı ve kontrol sinyalleri Profinet haberleşme protokolü üzerinden sağlanmıştır.



Görsel 2. Otomasyon Sistemi Diyagramı

Separatör Kontrol Panosu, makinenin motor hızının ayarlanması ve hafif faz çıkış hattındaki basınç regülasyonu gibi temel görevleri yerine getirmiştir. Bu panoda aşağıdaki bileşenler yer almaktadır:

- 7.5 kW gücünde Danfoss FC-302 serisi motor sürücüsü,
- Siemens S7-1214 serisi PLC (Programmable Logic Controller, Programlanabilir Lojik Kontrolör),
- Siemens KTP700 serisi HMI (Human Machine Interface, İnsan-Makine Arayüzü)

Hafif faz çıkış hattında yer alan Endress+Hauser Cerabar PMP21 analog basınç sensörü (ölçüm aralığı: 0–10 bar, çıkış: 4–20 mA), bu regülasyon sistemine geri besleme sağlamış ve basınç kontrolü Burkert Tip 8694 serisi oransal vana üzerinden kapalı çevrim PID (Proportional-Integral-Derivative, Oransal-İntegral-Türevsel) algoritması ile yapılmıştır.

Operatörler, HMI ekranı aracılığıyla hem sistem parametrelerini izleyebilmiş hem de anlık müdahalelerde bulunabilmiştir.

Veri Toplama Panosu ise sistemdeki tüm ölçüm cihazlarından gelen verileri toplamış ve dijital ortamda kaydetmiştir. Bu panoda aşağıdaki bileşenler yer almaktadır:

- Siemens S7-1214 serisi ikinci bir PLC,
- Siemens analog giriş/çıkış modülleri
- Siemens RTD giriş modülü (PT100 sıcaklık sensörleri için),
- KTP700 HMI ekranı.

Tüm sıcaklık ölçümleri Ordel PT100 RTD sensörleri ile yapılmış, basınç ve debi ölçümleri ise yukarıda belirtilen sensörlerle gerçekleştirilmiştir. Debi kontrolü de bu pano üzerinden yapılan PID algoritması ile sağlanmıştır. Elde edilen tüm veriler HMI ekranında eş zamanlı izlenmiş ve kayıt altına alınmıştır.

2.4. Sensörler ve Ölçüm Donanımları

Deneysel çalışmada kullanılan sensörler, prosesin kritik noktalarına yerleştirilerek sistemin giriş ve çıkış koşullarının anlık olarak izlenmesini sağlamıştır. Ürün girişi hattına yerleştirilen basınç ve sıcaklık sensörleri, separatöre ulaşan sıvının fiziksel özelliklerini doğrudan ölçmek üzere boru hattına mümkün olduğunca yakın konumlandırılmıştır. Bu yaklaşım sayesinde, separatörün giriş koşullarındaki değişikliklerin doğrudan etkisi gözlemlenebilmiştir.

Separatör çıkışında ise sıcaklık ve basınç sensörleri ile bir oransal vana konumlandırılmıştır. Bu yapı, çıkış basıncının kontrollü bir şekilde artırılmasına ve sistemin farklı çalışma koşullarına karşı verdiği tepkinin izlenmesine olanak tanımıştır. Aynı zamanda, ürün çıkışı tekrar tanka geri dönerek sistemin kapalı devre çalışmasına olanak sağlanmış, böylece dolaşan sıvının zamanla ısınması ve buna bağlı güç değişimlerinin gözlenmesi mümkün olmuştur.

Tamburun bulunduğu gövdeye ve separatörün yağ haznesine yerleştirilen PT100 sıcaklık sensörleri ile makinenin iç ısıl dengesi takip edilmiştir. Bu ölçümler, sistemin kararlı çalışma aralıklarının belirlenmesine ve güç tüketim profillerinin yorumlanmasına önemli katkı sağlamıştır.

Tüm sensörler, 4–20 mA sinyal çıkışına sahip olup doğrudan veri toplama panosuna bağlanmıştır. Elde edilen analog veriler, PLC üzerinden sayısal değerlere dönüştürülmüş ve HMI ekranında kullanıcıya sunulmuştur. Bu yapı sayesinde operatör hem giriş hem de çıkış parametrelerini anlık olarak izleyebilmiş hem de deneysel koşulları gerektiğinde müdahale ederek kontrol edebilmiştir.

2.5. Veri Toplama Yöntemi

Sistemden elde edilen verilerin bütünlüğü ve analiz edilebilirliği, kullanılan veri toplama yönteminin doğruluğuna ve tutarlılığına bağlıdır. Bu çalışmada, tüm sensörlerden gelen veriler, veri toplama panosu aracılığıyla dijital olarak izlenmiş ve kaydedilmiştir. Ölçümler, HMI arayüzünün sunduğu "historical data logging" (geçmiş veri kaydı) özelliği kullanılarak gerçekleştirilmiş ve veriler belirli aralıklarla USB bellek ortamına aktarılmıştır.

Veri kaydı sırasında örnekleme periyodu bir saniye olarak belirlenmiş, bu sayede hem geçici hem de kararlı durum davranışları detaylı biçimde izlenebilmiştir. Ölçülen değişkenler arasında ürün giriş sıcaklığı, tambur sıcaklığı, yağ haznesi sıcaklığı, ürün debisi, giriş ve çıkış basınçları ile separatörün anlık devir ve güç bilgileri yer almaktadır (Görsel 3).

Tüm bu parametreler, zaman senkronizasyonu ile aynı veri tabanına işlenmiş ve daha sonra analiz için dışa aktarılmıştır.

Logging tags

...	Name	Process tag	Acquisition mode	Logging cycle
	Bowl_Tank_Temp	Bowl_tank_temp	Cyclic	1 s
	Feed_Pressure	Feeding_pressure	Cyclic	1 s
	Flowmeter	Flowmeter	Cyclic	1 s
	Light_Phase_Pressure	Light_phase_pressure	Cyclic	1 s
	Oil_Tank_Temp	Oil_tank_temp	Cyclic	1 s
	Product_Temp	Product_temp	Cyclic	1 s
	Sep_Act_Speed	GET_sep_act_speed	Cyclic	1 s
	Sep_Driver_Power	Sep_Driver_Act_Power	Cyclic	1 s
	Sep_Set_Speed	GET_sep_set_speed	Cyclic	1 s

Görsel 3. TIA HMI Portal Veri Kayıt Kontrol Bloğu

Veri toplama sürecinde, sistemin farklı çalışma koşulları altında verdiği tepkilerin karşılaştırılabilir olması hedeflenmiştir. Bu nedenle, veri kayıt süreci yalnızca nominal koşullarda değil, farklı debi ve çıkış basıncı ayarlarında da tekrarlanarak her bir senaryo için geniş bir veri seti oluşturulmuştur. Böylece, YSA modellerinin eğitimi için hem çeşitlilik hem de tutarlılık açısından zengin bir veri altyapısı sağlanmıştır.

2.6 Panolar Arası Haberleşme

Sistemde yer alan Separatör kontrol panosu ile veri toplama panosu, Profinet haberleşme protokolü üzerinden birbirine entegre şekilde çalışacak biçimde yapılandırılmıştır. İki PLC arasında veri aktarımı, Siemens PLC'lerin desteklediği GET ve PUT komutları aracılığıyla gerçekleştirilmiştir. Bu iletişim yöntemi, sistemin farklı bileşenleri arasında yüksek hızda ve güvenilir veri alışverişine olanak tanımıştır.

Veri toplama panosu, kontrol panosundan motor devri, sürücü güç tüketimi ve set devir değeri gibi bilgileri GET komutlarıyla almıştır. Bu sayede YSA modelinin girdi değişkenlerinden biri olan güç verisi doğrudan motor sürücüsünden alınan gerçek zamanlı bilgiyle elde edilmiştir. Öte yandan, hafif faz çıkış basıncına yönelik kontrol sinyali ise PUT komutu ile veri toplama panosundan kontrol panosuna gönderilmiş ve böylece kapalı çevrim PID kontrol yapısı tamamlanmıştır.

Bu çift yönlü iletişim, proses parametrelerinin senkron bir şekilde izlenmesine ve kontrol sisteminin bütünlüğünün korunmasına katkı sağlamıştır. Ayrıca operatör arayüzü üzerinden tüm bu değişkenlerin eş zamanlı takibi mümkün hâle gelmiş, sistem daha stabil ve müdahale edilebilir bir yapıya kavuşmuştur.

2.7 Deneysel Protokol

Deneysel çalışmalar, separatör makinesinin değişen debi ve çıkış basıncı koşullarında güç tüketim profilini analiz etmek üzere planlanmıştır. Bu amaçla, sistem belirli bir başlangıç devrine ayarlanmış ve deneysel işlemler adım adım ilerletilmiştir. İlk olarak, separatörün çalışma devri 9500 d/dk olarak belirlenmiş ve ürün beslemesi için separatör makinesinin istenilen devre ulaşması beklenmiştir.

İstenilen devre ulaşıldığında başlangıçta 0.5 m³/h debi ve 0,5 bar hafif faz çıkış basıncı uygulanmıştır. Bu basınç değeri, çıkış hattında sıvı kaçağı oluşana kadar 0.25 barlık adımlarla artırılmış ve kaçak gözlemlendiği anda deney bir sonraki debi seviyesiyle tekrar edilmiştir. Debi, yine 0,5 m³/h artırılarak maksimum 4.5 m³/h seviyesine kadar deneyler tekrarlanmıştır.

Bu deneysel döngü sayesinde, farklı debi ve basınç kombinasyonları altında separatörün güç tüketimine ilişkin geniş bir veri yelpazesi elde edilmiştir. Her koşulda sistem kararlılığının sağlandığı gözlemlenene kadar ölçüm yapılmış, geçici rejimler elimine edilerek yalnızca kararlı durum verileri değerlendirmeye alınmıştır.

2.8 Veri seti ve ön işleme süreci

Bu çalışmada oluşturulan veri seti, HAUS VBA320 serisi bir disk yığını santrifüj separatör makinesinin farklı işletim koşulları altındaki gerçek zamanlı sensör verilerinden oluşmaktadır. Toplanan veriler, HMI sisteminin tarihsel veri kaydı özelliği kullanılarak bir saniyelik örnekleme periyodu ile kaydedilmiş ve USB bellek aracılığıyla dışa aktarılmıştır. Veriler Microsoft Office Excel programı dosya formatında olup, analiz sürecinde Python programlama dili kullanılarak işlenmiştir.

Çizelge 1'de örnek verilerden de anlaşılacağı gibi veri seti, girdi (bağımsız) değişkenleri ürün giriş sıcaklığı, tambur sıcaklığı, yağ haznesi sıcaklığı, ürün debisi, ürün giriş basıncı ve hafif faz çıkış basıncından oluşurken, çıkış (bağımlı) değişken olarak santrifüj separatörün anlık güç tüketimi (kW) alınmıştır. Toplamda 10 gün boyunca farklı zaman dilimlerinde çalıştırılan santrifüj makinesinden 1'er saniyelik aralıklarla değerler belirtilen değerler kaydedilmiştir. Toplanan verilerin %70'i eğitim ve %30 test olarak ayrıştırılmıştır. Tüm değişkenler sayısal olduğundan veri tipine yönelik ek dönüşüm yapılmasına gerek kalmamıştır. Ancak bazı modellerde, modelleme performansını artırmak amacıyla min-max normalizasyonu gibi özellik ölçekleme (feature scaling) yöntemleri uygulanmıştır. Eksik veri bulunmayan bu set, doğrudan YSA modellerinin eğitilmesi için kullanıma hazır hale getirilmiştir.

Çizelge 4. Örnek Veri Tablosu

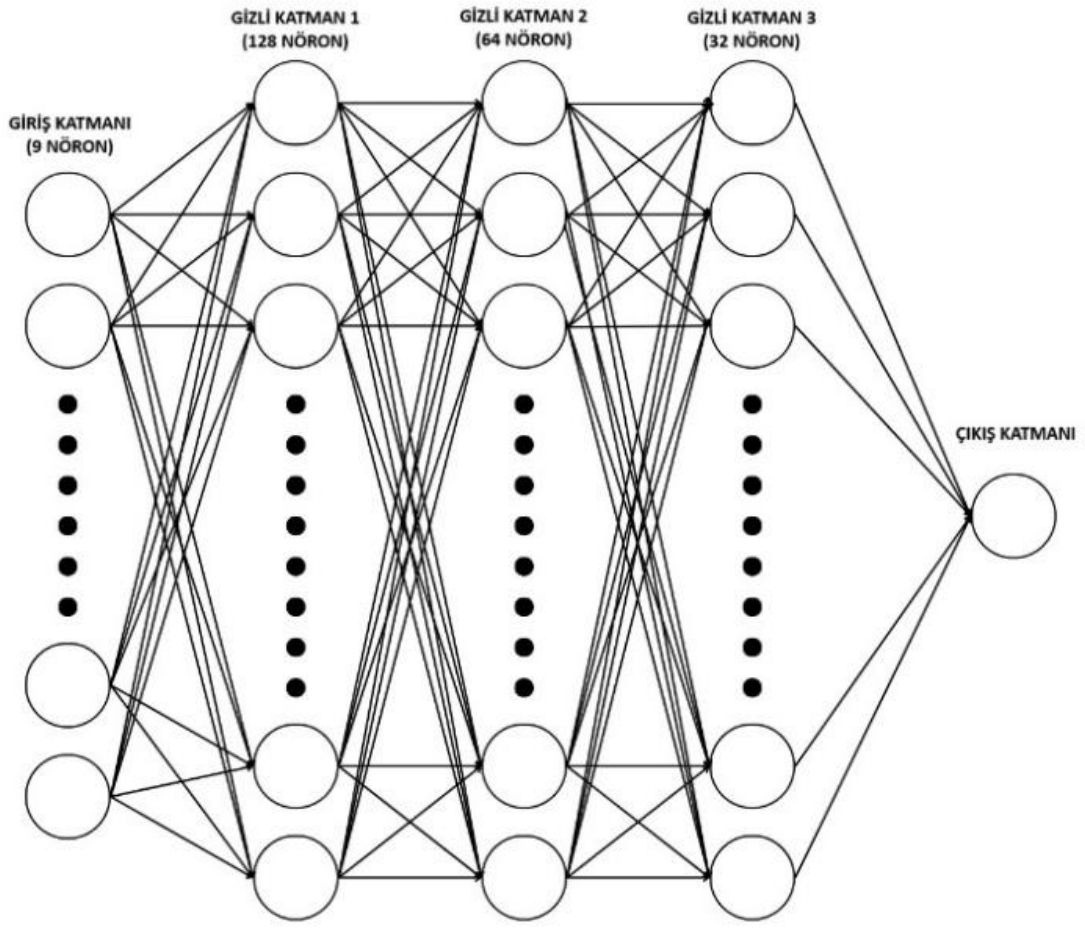
	Girişler							Çıkış
Saat	Tambur Sıcaklığı	Ürün Giriş Basınç	Debimetre	Gerçek Devir	Hafif Faz Basınç	Yağ Hazne Sıcaklık	Ürün Sıcaklığı	Separatör Sürücü Güç
13:54:28	26.7	0.03	1.01	9465	2.21	42.5	26.8	3.20
13:54:29	26.7	0.05	1.00	9466	2.43	42.5	26.9	3.19
13:54:30	26.7	0.05	1.00	9466	2.51	42.5	26.9	3.19
13:54:31	26.7	0.05	1.00	9466	2.54	42.5	26.9	3.19
13:54:32	26.6	0.05	1.00	9465	2.55	42.5	26.9	3.20
13:54:33	26.6	0.05	1.00	9465	2.56	42.5	26.9	3.20

13:54:34	26.6	0.03	1.00	9463	2.50	42.5	26.9	3.24
13:54:35	26.6	0.00	1.01	9463	2.25	42.5	26.9	3.24
13:54:36	26.6	0.01	1.02	9465	2.21	42.5	26.9	3.20
13:54:37	26.6	0.03	1.02	9465	2.34	42.5	26.9	3.20

2.9. YSA Modelleme

YSA tabanlı tahmin modelleri, Python programlama dili kullanılarak oluşturulmuş ve çeşitli kütüphaneler (TenserFlow, Keras, Scikit-learn) ile eğitilmiştir. Bu çalışmada sekiz farklı YSA modeli geliştirilmiş olup, bu modellerin her biri farklı katman sayısı, nöron yoğunluğu ve optimizasyon algoritması kullanılarak yapılandırılmıştır.

Modellerin geliştirilmesinde, çok katmanlı yapılar (derin öğrenme mimarileri) ile daha yalın yapılar arasında performans farklarını ortaya koymak hedeflenmiştir (Görsel 4). Bu yaklaşım, santrifüj sistemleri gibi dinamik ve doğrusal olmayan proseslerde enerji tüketiminin tahminine yönelik daha doğru ve esnek çözümler sunmayı amaçlamaktadır.



Görsel 4.YSA Mimarisi

Modellerde Adam ve RMSProp optimizasyon algoritmaları kullanılmıştır. Aktivasyon fonksiyonu olarak relu, elu ve tanh kullanılmış, modeller arasında yitim (dropout) katmanlarının eklenip eklenmemesi gibi düzenleştirici stratejiler de değiştirilmiş ve bu

farklılıkların aşırı öğrenme (overfitting) üzerindeki etkileri gözlemlenmiştir. Tüm modeller aynı veri kümesi üzerinde, aynı eğitim-test ayrımı ile eğitilmiş; böylece sadece mimari ve algoritma farklarının sonuçlar üzerindeki etkisi izole edilmiştir.

Eğitim sürecinde erken durdurma (early stopping) yöntemi uygulanarak modelin aşırı öğrenme yapmasının önüne geçilmiştir. Her bir model için eğitim süresi boyunca gözlemlenen ortalama kare hata (Mean Square Error, MSE), ortalama mutlak hata (Mean Absolute Error, MAE) ve belirleme katsayısı (Coefficient of determination, R^2) değerleri hesaplanmış ve modeller bu metrikler doğrultusunda karşılaştırılmıştır (Çizelge 2).

Çizelge 5. Model Karşılaştırma Tablosu

Model	Katman	Dropout	Aktivasyon Fonksiyonu	MSE	MAE	R^2
Model_1	64, 1	Yok	relu	0.00072	0.01322	0.9827
Model_2	64, 1	Var	relu	0.00076	0.01398	0.9819
Model_3	64, 32, 1	Yok	relu	0.00084	0.01448	0.9798
Model_4	64, 32, 1	Var	relu	0.00161	0.02619	0.9613
Model_5	128, 64, 32, 1	Yok	relu	0.00077	0.01400	0.9816
Model_6	128, 64, 32, 1	Var	relu	0.00152	0.02476	0.9636
Model_7	64, 1	Yok	tanh	0.00086	0.01441	0.9795
Model_8	64, 1	Var	tanh	0.00089	0.01605	0.9788
Model_9	64, 32, 1	Yok	tanh	0.00062	0.01019	0.9851
Model_10	64, 32, 1	Var	tanh	0.00083	0.01092	0.9800
Model_11	128, 64, 32, 1	Yok	tanh	0.00071	0.01090	0.9829
Model_12	128, 64, 32, 1	Var	tanh	0.00077	0.01253	0.9815
Model_13	64, 1	Yok	elu	0.00096	0.01679	0.9771
Model_14	64, 1	Var	elu	0.00081	0.01403	0.9807
Model_15	64, 32, 1	Yok	elu	0.00088	0.01543	0.9789
Model_16	64, 32, 1	Var	elu	0.00082	0.01439	0.9803
Model_17	128, 64, 32, 1	Yok	elu	0.00083	0.01376	0.9801
Model_18	128, 64, 32, 1	Var	elu	0.00089	0.01456	0.9787
Model_19	64, 1	Yok	relu	0.00068	0.01312	0.9838
Model_20	64, 1	Var	relu	0.00087	0.01717	0.9792
Model_21	64, 32, 1	Yok	relu	0.00072	0.01306	0.9827

Model_22	64, 32, 1	Var	relu	0.00205	0.03010	0.9510
Model_23	128, 64, 32, 1	Yok	relu	0.00199	0.02999	0.9523
Model_24	128, 64, 32, 1	Var	relu	0.00111	0.01784	0.9735
Model_25	64, 1	Yok	tanh	0.00103	0.01792	0.9752
Model_26	64, 1	Var	tanh	0.00077	0.01435	0.9815
Model_27	64, 32, 1	Yok	tanh	0.00078	0.01652	0.9812
Model_28	64, 32, 1	Var	tanh	0.00063	0.01305	0.9849
Model_29	128, 64, 32, 1	Yok	tanh	0.00053	0.01260	0.9873
Model_30	128, 64, 32, 1	Var	tanh	0.00077	0.01467	0.9816
Model_31	64, 1	Yok	elu	0.00113	001895	0.9729
Model_32	64, 1	Var	elu	0.00088	0.01486	0.9790
Model_33	64, 32, 1	Yok	elu	0.00090	0.01707	0.9784
Model_34	64, 32, 1	Var	elu	0.00087	0.01463	0.9791
Model_35	128, 64, 32, 1	Yok	elu	0.00070	0.01332	0.9833
Model_36	128, 64, 32, 1	Var	elu	0.00087	0.01357	0.9793

3. SONUÇLAR VE DEĞERLENDİRME

Yapılan analizler sonucunda en başarılı tahmin performansı Model_29 tarafından sergilenmiştir. Bu model, tanh aktivasyon fonksiyonu ve RMSprop optimizasyon algoritması ile yapılandırılmış olup, sırasıyla 128, 64, 32 ve 1 nörondan oluşan dört katmanlı derin bir sinir ağı mimarisine sahiptir. Dropout uygulanmadan eğitilen model, yalnızca 44 epoch ve 31.81 saniyelik kısa bir sürede eğitilmiştir. Elde edilen 0.000531 ortalama kare hata (MSE), 0.01260 ortalama mutlak hata (MAE) ve %98,73 R^2 değeri ile tüm modeller arasında en yüksek doğruluk seviyesine ulaşmıştır.

4. TARTIŞMA

Santrifüj separatörler sürekli ve yüksek devirle çalışan makineler olup prosesin verimliliği kadar enerji tüketimi açısından da önemli bir yere sahiptir. Enerji maliyetlerinin üretim maliyetleri içindeki payının giderek artması santrifüj sistemleri gibi yoğun enerji kullanan ekipmanların güç tüketimlerinin doğru şekilde izlenmesini ve tahmin edilmesini kritik hale getirmiştir. Özellikle endüstride enerji yönetimi ve sürdürülebilir üretim hedefleri doğrultusunda bu tür sistemlerde tüketim verilerinin önceden tahmin edilmesi hem ekonomik hem de operasyonel fayda sağlar.

Bu çalışmada, HAUS VBA320 serisi bir santrifüj separatör makinesine ait aktif güç tüketimi verileri kullanılarak tahmin modelleri oluşturulmuş ve bu tahminler için YSA mimarileri tercih edilmiştir. YSA modelleri doğrusal olmayan karmaşık sistemleri öğrenebilme yetenekleri sayesinde fiziksel modelleme gereksinimi olmadan veri üzerinden tahmin yapabilme avantajı sunar. Bu yönüyle santrifüj gibi çok değişkenli ve dinamik bir sistemin enerji tüketimini modellemek için uygun bir yöntemdir.

Çalışma kapsamında farklı katman sayıları, aktivasyon fonksiyonları ve optimizasyon algoritmaları kullanılarak 36 farklı YSA mimarisi oluşturulmuştur. Bu modellerin tamamı aynı veri kümesi üzerinde eğitilerek mimari farkların tahmin başarısına etkisi sistematik biçimde analiz edilmiştir. Sonuçlar bazı mimarilerin düşük ortalama hata değerleri ve yüksek R^2 (belirleme katsayısı) ile öne çıktığını göstermiştir. Özellikle Model_29, 0.9872 gibi yüksek bir R^2 değeriyle en başarılı model olmuştur.

YSA modellerinin hızlı öğrenme kabiliyeti ve yüksek doğrulukla tahmin yapabilme yeteneği sayesinde santrifüj separatör sistemlerinde enerji tahmini amacıyla etkin şekilde kullanılabileceği ortaya konmuştur. Bu da işletmelerin enerji planlaması, bakım yönetimi ve verimlilik artırma stratejilerine katkı sağlayabilecek önemli bir adımdır.

Gelecek çalışmalarda, YSA'nın farklı türleri ve mimarileriyle tahmin performansı daha da iyileştirilebilir. Modelleme sürecine daha fazla sistem parametresi dahil edilerek kapsamlı ve duyarlı yapılar geliştirilebilir. Ayrıca, gerçek zamanlı uygulamalarla entegrasyon sağlanarak, santrifüj sistemlerinin enerji verimliliği ve sürdürülebilirliği üzerine daha geniş ölçekli analizler yapılması mümkün hale gelebilir.

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İZMİR İLİNDE SPI VE SPEI İNDEKSLERİ KULLANILARAK METEOROLOJİK KURAKLIK ANALİZİ

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ÖZET

Bu çalışmada, İzmir ili genelinde meteorolojik kuraklık koşullarının zamansal değişimi Standartlaştırılmış Yağış İndeksi (SPI) ve Standartlaştırılmış Yağış–Buharlaşma İndeksi (SPEI) kullanılarak değerlendirilmiştir. Analizde, uzun dönemli aylık yağış ve sıcaklık verileri kullanılarak farklı zaman ölçeklerinde (3, 6 ve 12 ay) SPI ve SPEI değerleri hesaplanmıştır. Elde edilen indeksler aracılığıyla kurak ve nemli dönemlerin sıklığı, şiddeti ve sürekliliği ortaya konulmuştur. Bulgular, özellikle 12 aylık zaman ölçeğinde SPEI indeksinin, artan sıcaklıklar ve potansiyel buharlaşma etkisini dikkate alması nedeniyle kuraklık koşullarını SPI'ya kıyasla daha hassas bir şekilde yansıttığını göstermektedir. Son yıllarda her iki indeks de İzmir ilinde kurak dönemlerin hem sıklığında hem de şiddetinde belirgin bir artışa işaret etmektedir. Bu durum, iklim değişikliğinin bölgesel su kaynakları ve tarımsal üretim üzerindeki olası etkilerini vurgulamaktadır. Çalışma sonuçları, İzmir ili için kuraklık riskinin izlenmesi, erken uyarı sistemlerinin geliştirilmesi ve sürdürülebilir su kaynakları yönetimi stratejilerinin oluşturulması açısından önemli bir bilimsel altyapı sunmaktadır.

Anahtar Kelimeler : Kuraklık, SPI, SPEI, İzmir

1. GİRİŞ

Kuraklık, belirli bir bölgede uzun yıllar ortalamasına göre yağış miktarının önemli ölçüde azalmasıyla ortaya çıkan ve su kaynakları, tarım, ekosistemler ile sosyo-ekonomik yapılar üzerinde ciddi etkiler oluşturan doğal bir afettir. İklim değişikliği ile birlikte artan sıcaklıklar ve değişen yağış rejimleri, kuraklığın sıklığını, süresini ve şiddetini artırmakta; özellikle

Akdeniz iklim kuşağında yer alan bölgelerde kuraklık risklerini daha belirgin hâle getirmektedir (Vicente-Serrano ve ark., 2010; IPCC, 2021).

Kuraklığın izlenmesi ve değerlendirilmesi amacıyla literatürde farklı meteorolojik kuraklık indisleri geliştirilmiştir. Bu indisler arasında en yaygın kullanılanlardan biri Standartlaştırılmış Yağış İndeksi (Standardized Precipitation Index, SPI) olup, yalnızca yağış verisine dayalı yapısı sayesinde farklı iklim bölgelerinde karşılaştırılabilir sonuçlar sunmaktadır (Mwinjuma ve ark, 2025). Bununla birlikte SPI, sıcaklık artışlarının buharlaşma ve bitki su tüketimi üzerindeki etkilerini doğrudan dikkate almaması nedeniyle, özellikle son yıllarda iklim değişikliği koşullarında sınırlı kalabilmektedir.

Bu sınırlılığı gidermek amacıyla geliştirilen Standartlaştırılmış Yağış-Buharlaşma İndeksi (Standardized Precipitation Evapotranspiration Index, SPEI), yağış ile potansiyel evapotranspirasyon (PET) arasındaki farkı esas alarak sıcaklık artışlarının kuraklık üzerindeki etkisini değerlendirme sürecine dâhil etmektedir (Vicente-Serrano ve ark., 2010). Bu yönüyle SPEI, özellikle yarı kurak ve Akdeniz iklim özellikleri gösteren bölgelerde kuraklığın daha gerçekçi bir biçimde tanımlanmasına olanak sağlamaktadır.
Türkiye'de ve özellikle Ege Bölgesi'nde gerçekleştirilen birçok çalışmada SPI ve SPEI indeksleri kullanılarak kuraklık analizleri yapılmış; son yıllarda sıcaklık artışlarının kuraklık şiddeti üzerindeki belirleyici rolü vurgulanmıştır (Örneğin: Türkeş, 2012; Dikici, 2020; Kumanlıoğlu, 2020). İzmir ili, hem tarımsal faaliyetlerin yoğunluğu hem de artan nüfus ve su talebi nedeniyle kuraklık riskinin yakından izlenmesi gereken alanlar arasında yer almaktadır.
Bu çalışmanın amacı, İzmir ili için farklı zaman ölçeklerinde (3, 6, 12) hesaplanan SPI ve SPEI indekslerini kullanarak meteorolojik kuraklığın zamansal değişimini ortaya koymaktır. Çalışma kapsamında, sıcaklık artışlarının kuraklık analizlerine etkisi vurgulanarak, bölgesel su yönetimi ve tarımsal planlama açısından çıkarımlar sunulması hedeflenmiştir.

2. MATERYAL VE YÖNTEM

2.1. Çalışma Alanı

Bu çalışma, Türkiye'nin batısında yer alan ve Akdeniz iklim özelliklerinin belirgin olarak hissedildiği İzmir ili için gerçekleştirilmiştir. İzmir, yazları sıcak ve kurak, kışları ise ılık ve yağışlı iklim yapısına sahip olup, yıllık ortalama yağış miktarı yaklaşık 700–800 mm arasında değişmektedir. Özellikle yaz aylarında artan sıcaklıklar ve azalan yağışlar, bölgeyi meteorolojik kuraklık açısından hassas hâle getirmektedir. Tarımsal üretimin yoğun olduğu Gediz ve Küçük Menderes havzaları ile artan kentsel su talebi, İzmir'de kuraklık analizlerinin önemini artırmaktadır.

2.2. İklim verileri

Çalışmada kullanılan aylık toplam yağış ve aylık ortalama hava sıcaklığı verileri, İzmir ilini temsil eden Meteoroloji Genel Müdürlüğü meteoroloji gözlem istasyonlarından elde edilmiştir. Analizler, uzun dönemli ve kesintisiz gözlem kayıtlarını kapsayacak şekilde yürütülmüş olup, veri seti 1940–2024 yılları arasındaki dönemi kapsamaktadır.

2.3. Kuraklık İndeksleri

Meteorolojik kuraklık koşullarının değerlendirilmesinde Standartlaştırılmış Yağış İndeksi (SPI) ve Standartlaştırılmış Yağış–Buharlaşma İndeksi (SPEI) kullanılmıştır. SPI, yalnızca yağış verilerine dayalı olarak kurak ve nemli dönemlerin belirlenmesine olanak sağlarken; SPEI indeksi yağış ile birlikte sıcaklık kaynaklı potansiyel buharlaşma etkisini de dikkate alarak, özellikle iklim değişikliği koşullarında kuraklığın daha hassas bir şekilde değerlendirilmesine imkân tanımaktadır.

2.4. R Yazılımı ve Hesaplama Yöntemi

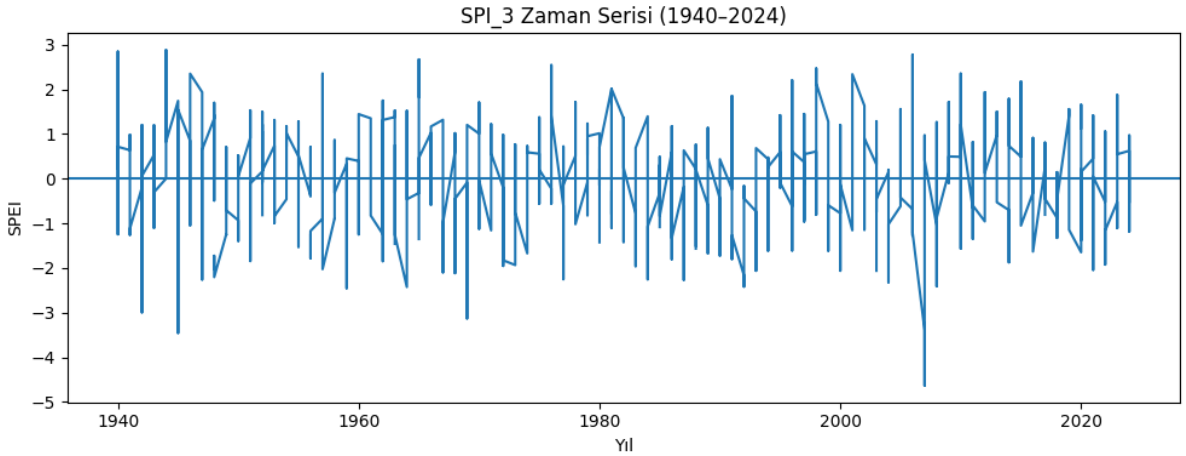
Kuraklık indislerinin hesaplanması ve zaman serisi analizleri, açık kaynaklı istatistiksel yazılım olan R programı kullanılarak gerçekleştirilmiştir (R Core Team, 2000). SPI ve SPEI hesaplamalarında, R programı kullanılmıştır. İndeksler, farklı zaman ölçeklerinde (3, 6 ve 12 ay) hesaplanarak kurak ve nemli dönemlerin şiddeti, süresi ve zamansal dağılımı analiz edilmiştir.

3. BULGULAR

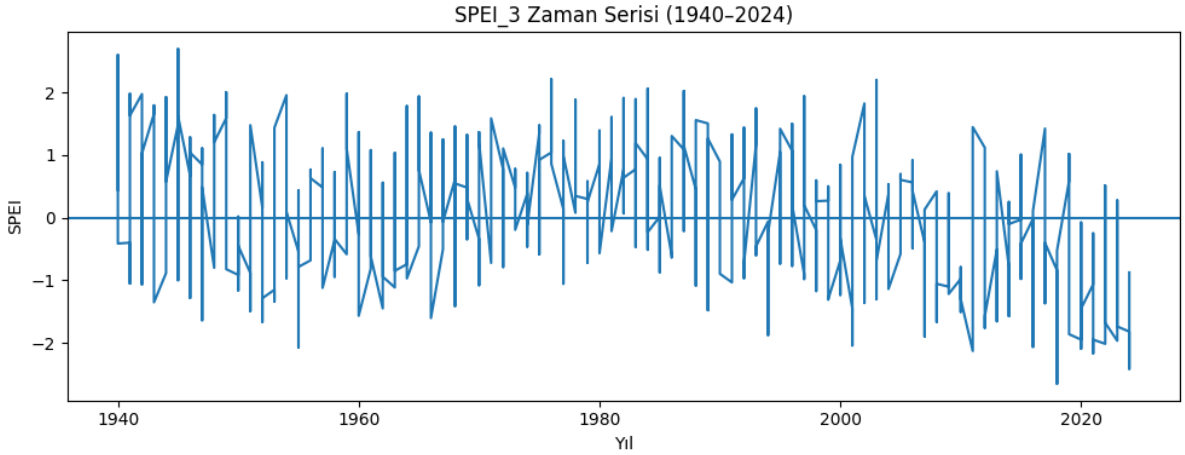
İzmir ili için hesaplanan 3, 6 ve 12 aylık SPI ve SPEI zaman serileri kullanılarak meteorolojik kuraklık koşullarının zamansal değişimi değerlendirilmiştir. Elde edilen indeks değerleri, farklı zaman ölçeklerinde kurak ve nemli dönemlerin sıklığı, şiddeti ve sürekliliği açısından karşılaştırılmıştır.

3.1. 3 Aylık SPI ve SPEI Bulguları

3 aylık zaman ölçeğinde hesaplanan SPI ve SPEI değerleri, kısa süreli yağış sapmalarına duyarlı bir yapı sergilemiştir (Görsel 1 ve Görsel 2). Bu ölçekte, her iki indeks de yıl içi ve yıllar arası hızlı dalgalanmalar göstermiş; kısa süreli kurak ve nemli dönemler belirgin biçimde ortaya çıkmıştır. SPI değerlerinde ani negatif ve pozitif sapmalar daha sık gözlenirken, SPEI değerlerinin özellikle sıcaklık artışlarının etkili olduğu dönemlerde daha düşük değerlere ulaştığı belirlenmiştir.



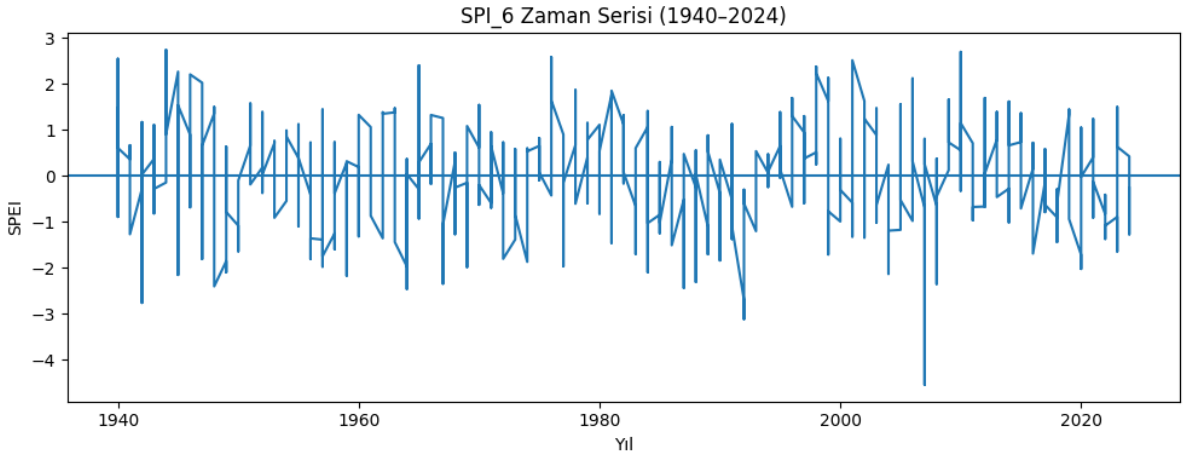
Görsel 1. SPI 3 aylık zaman serisi



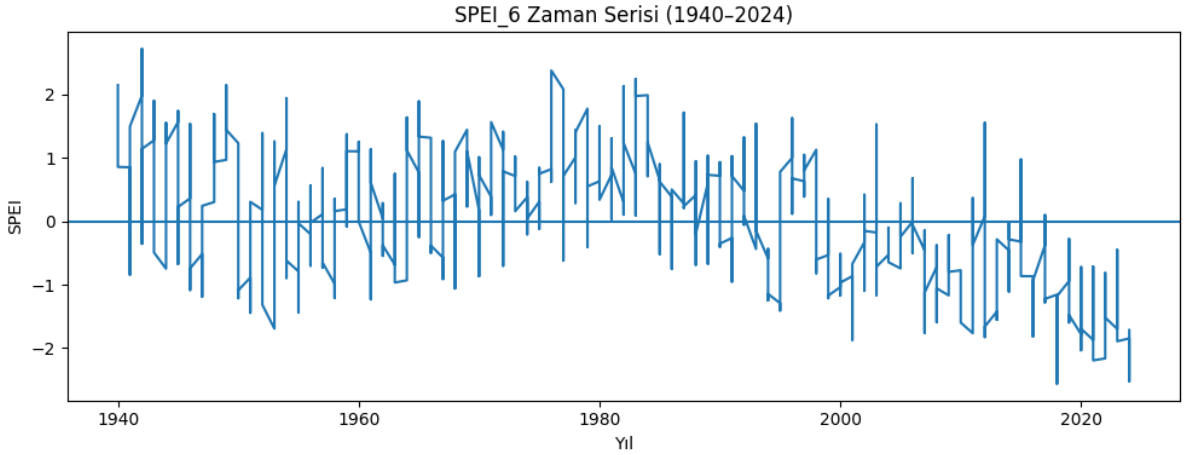
Görsel 2. SPEI 3 aylık zaman serisi

3.2. 6 Aylık SPI ve SPEI Bulguları

6 aylık SPI ve SPEI zaman serileri, mevsimsel ölçekteki kuraklık koşullarını daha net bir şekilde yansıtmıştır (Görsel 3 ve Görsel 4). Bu ölçekte, kısa süreli dalgalanmaların azaldığı ve kuraklık sürekliliğinin daha belirgin hale geldiği görülmüştür. SPI ve SPEI değerleri genel olarak benzer eğilimler sergilemekle birlikte, SPEI indeksinin bazı dönemlerde SPI'ya göre daha düşük değerler aldığı ve kuraklık şiddetini daha belirgin ortaya koyduğu belirlenmiştir.



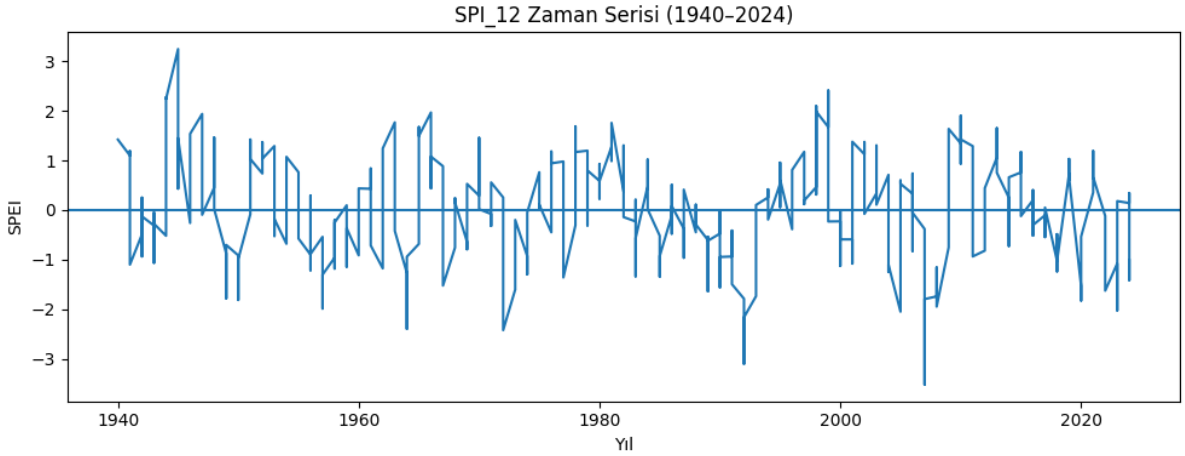
Görsel 3. SPI 6 aylık zaman serisi



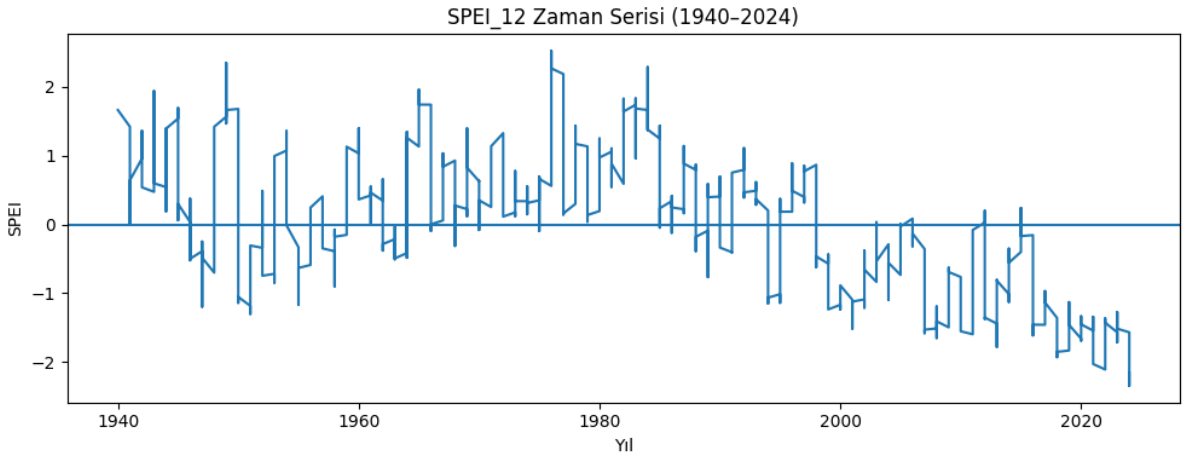
Görsel 4. SPEI 6 aylık zaman serisi

3.3. 12 Aylık SPI ve SPEI Bulguları

12 aylık zaman ölçeğinde hesaplanan SPI ve SPEI değerleri, uzun dönemli meteorolojik kuraklık koşullarını açık bir şekilde ortaya koymuştur (Görsel 5 ve Görsel 6). Bu ölçekte, kurak ve nemli dönemlerin sürekliliği belirginleşmiş, uzun süreli negatif indeks değerlerinin daha baskın hale geldiği gözlenmiştir. Özellikle son yıllarda, SPEI değerlerinin SPI'ya kıyasla daha düşük seviyelerde seyrettiği ve uzun süreli kuraklık koşullarını daha güçlü bir şekilde yansıttığı belirlenmiştir.



Görsel 5. SPI 12 aylık zaman serisi



Görsel 6. SPEI 12 aylık zaman serisi

3.4. SPI ve SPEI İndekslerinin Karşılaştırılması

Farklı zaman ölçeklerinde elde edilen bulgular birlikte değerlendirildiğinde, SPI ve SPEI indekslerinin genel eğilimler açısından uyumlu sonuçlar verdiği; ancak sıcaklık ve potansiyel buharlaşma etkisini içeren SPEI indeksinin, özellikle 6 ve 12 aylık zaman ölçeklerinde kuraklık şiddetini daha belirgin ortaya koyduğu görülmüştür. Bu durum, uzun dönemli kuraklık analizlerinde SPEI indeksinin daha hassas bir gösterge sunduğunu ortaya koymaktadır.

4. TARTIŞMA

Bu çalışmada İzmir ili için hesaplanan SPI ve SPEI indeksleri, meteorolojik kuraklığın zamansal değişimini farklı bakış açılarıyla ortaya koymuştur. Bulgular kısmında sunulan sonuçlar, sıcaklık artışlarının kuraklık şiddeti üzerindeki belirleyici rolünü açık biçimde göstermektedir. Benzer şekilde Akdeniz iklim kuşağında gerçekleştirilen önceki çalışmalarda da SPEI'nin, SPI'ya kıyasla daha yüksek kuraklık şiddetleri tanımladığı rapor edilmiştir (Vicente-Serrano ve ark., 2010; Türkeş, 2012). SPEI ile belirlenen daha uzun ve şiddetli kuraklık dönemleri, özellikle son yıllarda artan hava sıcaklıkları ve buna bağlı olarak yükselen evapotranspirasyon talepleri ile ilişkilendirilmektedir. Bu bulgu, iklim değişikliği koşullarında yalnızca yağış temelli indekslerin kuraklık analizlerinde yetersiz kalabileceğini ortaya koymaktadır. Elde edilen bulgular, İzmir ili özelinde kuraklık izleme çalışmalarında SPEI'nin etkin bir gösterge olarak kullanılabileceğini ve erken uyarı sistemlerinin geliştirilmesinde sıcaklık verilerinin mutlaka dikkate alınması gerektiğini ortaya koymaktadır.

5. SONUÇ

Bu çalışmada, İzmir ili için 3, 6 ve 12 aylık zaman ölçeklerinde hesaplanan Standartlaştırılmış Yağış İndeksi (SPI) ve Standartlaştırılmış Yağış–Buharlaşma İndeksi (SPEI) kullanılarak meteorolojik kuraklığın zamansal değişimi değerlendirilmiştir. Elde edilen sonuçlar, kuraklık analizlerinde kullanılan indeksin yapısının, kuraklık şiddeti ve süresinin belirlenmesinde belirleyici bir rol oynadığını ortaya koymuştur. Çalışmadan elde edilen temel bulgular aşağıda sunulmuştur:

- **Kısa zaman ölçeklerinde (3 ay)** hesaplanan SPI ve SPEI değerleri, mevsimsel yağış değişkenliğine duyarlı bir yapı sergilemiş ve kısa süreli kurak ve nemli dönemlerin belirlenmesinde etkili olmuştur. Bu ölçekte her iki indeks genel olarak benzer eğilimler göstermiş ve kısa süreli meteorolojik kuraklıkların tespitinde karşılaştırılabilir sonuçlar üretmiştir.
- **Orta zaman ölçeğinde (6 ay)** hesaplanan SPI ve SPEI değerleri, mevsimsel etkilerin yanı sıra kuraklık koşullarının sürekliliğini daha belirgin biçimde yansıtmıştır. Bu ölçekte SPEI değerlerinin, özellikle sıcaklık artışlarının etkili olduğu dönemlerde SPI'ya kıyasla daha düşük seviyelere ulaştığı ve kuraklık şiddetini daha belirgin ortaya koyduğu belirlenmiştir.
- **Uzun zaman ölçeğinde (12 ay)** kuraklığın birikimli etkileri ve sürekliliği daha net bir şekilde ortaya çıkmıştır. Bu ölçekte SPI uzun süreli yağış eksikliklerini yansıtırken, SPEI sıcaklık artışlarının potansiyel evapotranspirasyon üzerindeki etkisini de dikkate alarak kuraklık şiddetini daha yüksek düzeylerde tanımlamıştır.

Bazı dönemlerde 12 aylık SPI sonuçları normal veya hafif kurak koşullara işaret ederken, aynı dönemlerin SPEI ile orta veya şiddetli kuraklık sınıfına karşılık geldiği belirlenmiştir. Bu durum, artan sıcaklıkların meteorolojik kuraklık değerlendirmeleri üzerindeki belirleyici etkisini açık bir şekilde ortaya koymaktadır. Genel olarak elde edilen sonuçlar, İzmir ili özelinde meteorolojik kuraklığın izlenmesinde **3, 6 ve 12 aylık SPI ve SPEI indekslerinin birlikte değerlendirilmesinin**, kuraklık koşullarının hem kısa süreli hem de birikimli etkilerinin daha kapsamlı ve gerçekçi biçimde ortaya konulmasını sağladığını göstermektedir. Özellikle Akdeniz iklim kuşağında yer alan bölgelerde, sıcaklık artışlarını ve potansiyel evapotranspirasyon etkisini dikkate alan SPEI'nin, kuraklık izleme ve erken uyarı çalışmalarında önemli bir tamamlayıcı gösterge olarak kullanılabileceği değerlendirilmektedir.

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HYDROCARBON POTENTIAL OF PALEOZOIC SEQUENCES (SE TÜRKİYE)

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ABSTRACT

In the northern part of the Gondwana continent, the Paleozoic sequences composed of carbonate and clastic rocks have high hydrocarbon potential. This study aims is to determine the depositional environments of source and reservoir rock units in the Derik region of Mardin and the Hazro region of Diyarbakır. The Telbesmi Formation, which forms the Neoproterozoic basement, unconformably faces the Early Cambrian continental Sadan Formation. The Zabuk Formation is a reservoir composed of sandstones representing a braided fluvial facies. The Middle Cambrian Koruk Formation was deposited in a stromatolitic limestone facies. The Early Ordovician Sosink Formation was deposited in a shallow marine environment where the sandstones were of poor reservoir quality. The Early Ordovician Konur Formation developed into a fluvial delta composed of thick sandstones deposited on channel-mouth bars to generate gas. The Middle Ordovician Bedinan Formation has a shale bottom and interbedded shale and sandstone facies above. The Yurteri Formation was deposited within glacial-fluvial channels deposited on braided deltas and deeply incised glacial valleys within the Bedinan Formation and is a very important reservoir rock facies. The Early Silurian Dadaş Formation is a typical deltaic sequence that thickens upwards. It is represented by organic-rich transgressive marine shales and pro-delta shales at the base and well-sorted, porous, and permeable delta-mouth sand bars at the top. The transgressive marine shales constitute an important source rock facies, and the oil and gas formed here migrated into the underlying glacial sandstones (Yurteri Formation) and the overlying delta-mouth sand bars (Hazro Reservoir). The Devonian Kayayolu Formation is represented by interbedded shales and carbonates. The Carboniferous sequence was eroded by the Hercynian Orogeny. The Middle Permian Kuşdamı Formation was deposited in a red-colored terrestrial mudstone facies. The uppermost part of the sequence is the Late Permian Kaş Formation, represented by dark gray shale, coal, and sandstone deposited within delta distributary channels.

Keywords: Arabian Plate, Energy, Gondwana, Petroleum, Reservoir rock, Source rock.

EKSTRÜZYON LAMİNASYON TEKNİĞİ KULLANILARAK MONO AMBALAJ YAPILARDA POLİPROPİLEN İÇERİĞİNİN ARTIRILMASI

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ÖZET

Ambalaj endüstrisinde geri dönüştürülebilir mono materyallerin geliştirilmesi, hem sürdürülebilirlik hedefleri hem de proses verimliliği açısından kritik öneme sahiptir. Kompozit yapılarda kullanılan farklı polimer katmanları, mekanik ayrıştırma gereksinimi nedeniyle geri dönüşüm verimini önemli ölçüde düşürmektedir. Bu bağlamda, polipropilen (PP) bazlı yapıların geliştirilmesi ve laminasyon süreçlerinde polietilen (PE) kullanımının azaltılması, malzemenin döngüsel ekonomiye uygunluğunu artırmaktadır.

Bu çalışma, ekstrüzyon laminasyon tekniği kullanılarak PP içeriği yükseltilmiş ve PE oranı minimize edilmiş mono-PP ambalaj yapılarının geliştirilmesini amaçlamaktadır. Ekstrüzyon sırasında PE ve PP arasındaki intermoleküler uyumsuzluğun kontrollü şekilde kullanılmasıyla, malzemenin easy-open davranışı göstermesi hedeflenmiştir. Bu mekanizma, iki polimer arasındaki düşük ara yüzey bağlanma enerjisinden kaynaklanan sınırlı adezyonun fonksiyonel bir avantaj olarak değerlendirilmesine dayanmaktadır. Böylece solvent bazlı yapıştırıcılara ihtiyaç duyulmadan laminasyon yapılabilmekte ve malzemenin geri dönüşüm kabiliyeti artırılmaktadır.

Gerçekleştirilen üretim denemelerinde, ekstrüzyon laminasyon ve tutkallı laminasyon süreçleri karşılaştırmalı olarak değerlendirilmiştir. Yapılan bond testlerinde, ekstrüzyon laminasyonlu yapılarda bağ kuvveti yaklaşık 0,2 N, tutkallı laminasyonlu yapılarda ise 8 N olarak ölçülmüş; kontrollü düşük bağlanma sayesinde istenen easy-open fonksiyonu başarıyla elde edilmiştir.

OTR ve WVTR ölçümleri, geliştirilen mono yapıların geleneksel ambalaj yapılarıyla benzer bariyer performansı sergilediğini göstermiştir. Optik mikroskop analizleri ile homojen laminasyon yapısı doğrulanmıştır. PP ve PE'nin birlikte işlenmesinden kaynaklanan akış kararsızlığı, proses parametrelerinin optimizasyonuyla giderilerek üretimde stabilite sağlanmıştır.

Bu çalışmanın, ekstrüzyon laminasyon teknolojisinin sürdürülebilir ambalaj üretimindeki potansiyelini güçlendirmesi ve çevre dostu mono yapıların sektörde daha geniş bir kullanım alanı bulmasına katkı sağlaması beklenmektedir.

Anahtar Kelimeler : Mono Ambalaj, Extrüzyon Laminasyon , Kolay Açılabilir Ambalaj, Sürdürülebilir Ambalaj

INCREASING POLYPROPYLENE CONTENT IN MONO PACKAGING STRUCTURES USING EXTRUSION LAMINATION TECHNOLOGY

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ABSTRACT

The development of recyclable mono-material structures in the packaging industry is of critical importance in terms of both sustainability objectives and process efficiency. The presence of multiple polymer layers in conventional composite packaging significantly reduces recycling efficiency due to the requirement for mechanical separation. In this context, the development of polypropylene (PP)-based structures and the reduction of polyethylene (PE) usage in lamination processes play a key role in improving material compatibility with circular economy principles.

This study focuses on the development of mono-PP packaging structures with increased PP content and minimized PE usage through extrusion lamination technology. By deliberately utilizing the intermolecular incompatibility between PP and PE during extrusion, the material was designed to exhibit easy-open behavior. This mechanism is based on controlled interfacial adhesion arising from the low interfacial bonding energy between the two polymers, allowing functionality to be achieved without the use of solvent-based adhesives and enhancing recyclability performance.

Production trials involved a comparative evaluation of extrusion-laminated and adhesive-laminated structures. Bond testing results indicated an interfacial strength of approximately 0.2 N for extrusion-laminated samples, whereas adhesive-laminated samples exhibited a bonding strength of 8 N, confirming that controlled low adhesion successfully enabled the desired easy-open functionality. OTR and WVTR measurements demonstrated that the developed mono structures maintained barrier performance comparable to conventional packaging materials. Optical microscopy confirmed homogeneous lamination and structural integrity. Furthermore, process instability associated with the co-processing of PP and PE was effectively mitigated through parameter optimization, resulting in stable melt flow and consistent production.

This study is expected to enhance the role of extrusion lamination technology in sustainable packaging manufacturing and contribute to the wider adoption of environmentally friendly mono-material solutions across the packaging industry.

Keywords : Mono Packaging, Extrusion Lamination, Easy-Open Packaging, Sustainable Packaging

POLİETİLEN İÇERİKLİ GERİ DÖNÜŞTÜRÜLEBİLİR AMBALAJLARDA RAFTA DİK DURUŞ VE YÜK TAŞIMA KAPASİTESİNİ ARTIRAN YENİLİKÇİ ÜRÜN TASARIMI

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ÖZET

Avrupa Birliği (AB) regülasyonları ve CEFLEX tasarım kriterleri, ambalaj sektöründe geri dönüştürülemez BOPP/PE gibi kompozitlerden, yüksek oranda geri dönüştürülebilir tek-malzeme Polietilen/Polietilen (PE/PE) yapılarına geçişi stratejik bir zorunluluk haline getirmiştir. Ancak, dik duran poşet (stand-up pouch) uygulamalarında, geleneksel BOPP dış filminin doğal ısıl yapışma özelliğinin, yeni PE/PE yapısının dış baskı filminde bulunmaması, ambalajın dolum sonrası dış-dış yapışma bütünlüğünü ve raf duruş performansını tehlikeye atan kritik bir teknik engeldir.

Bu çalışma, bu bariyeri aşarak polietilen içerikli ambalajların taşıma kapasitesini artırmak ve raflarda dik duruşunu sağlamak amacıyla yenilikçi bir ürün tasarımı sunmaktadır. Metodoloji, PE filmlerin doğası gereği düşük olan yüzey enerjisinden kaynaklanan adhezyon sorununu çözmeye odaklanmıştır. Bu amaçla, ambalajın kulakçık bölgesine uygulanacak özel fonksiyonel lak öncesinde, PE filmin yüzey enerjisi kontrollü bir korona ön işlemi ile yükseltilmiştir. Bu işlem, yüzeyde polar gruplar oluşturarak lakın PE matrisine kimyasal bağlanma potansiyelini önemli ölçüde artırmaktadır.

Ardından, dış-dış ısıl yapışmayı sağlamak için bu özel lakın filmin dış yüzeyine transferi, yüksek hassasiyetli gravür silindir teknolojisi kullanılarak gerçekleştirilmiştir. Lakın optimum

yapışma kuvvetini sağlaması için kritik parametreler olan aniloks açı ve çizgi değerleri deneysel olarak belirlenmiştir.

Geliştirilen bu yöntem, ilk ısıl yapışma testlerinde (145 °C, 170 ms) minimum 3,5 N/25 mm yapışma kuvveti hedefleyerek, tamamen geri dönüştürülebilir PE/PE ambalajların endüstriyel standartları karşılamasını ve AB mevzuatına tam uyum sağlamaktadır.

Anahtar Kelimeler : Polietilen Ambalaj, Isıl Yapışma Kuvveti, Sürdürülebilir Ambalaj

INNOVATIVE PRODUCT DESIGN FOR ENHANCED STAND-UP PERFORMANCE AND LOAD-BEARING CAPACITY IN RECYCLABLE POLYETHYLENE PACKAGING

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ABSTRACT

The sustainability goals stipulated by European Union (EU) regulations and CEFLEX (Circular Economy for Flexible Packaging) design criteria mandate a strategic transition in the packaging industry from non-recyclable composites like BOPP/PE to highly recyclable mono-material Polyethylene/Polyethylene (PE/PE) structures. However, in stand-up pouch applications, the absence of the inherent heat-seal property of the conventional BOPP outer film layer in the new PE/PE outer print film poses a critical technical hurdle, jeopardizing the outer-to-outer seal integrity and stand up performance after filling.

This study presents an innovative product design aimed at overcoming this barrier, thus increasing the load-bearing capacity and ensuring the stand up of polyethylene-containing packaging on shelves. The methodology focuses on resolving the adhesion problem from the intrinsically low surface energy of PE films. To achieve this, a controlled corona treatment is applied to elevate the surface energy of the PE film before the application of a special functional lacquer on the outside area of the packaging. This process significantly increases the chemical bonding potential of the lacquer to the PE matrix by generating polar groups on the surface.

Subsequently, the transfer of this special lacquer to the outer surface of the film—essential for achieving outer-to-outer heat sealing—is executed using high-precision gravure cylinder technology. Critical parameters, the anilox angle and line count values, were experimentally determined to ensure optimum seal strength.

The method developed targets a minimum 3.5 N/25 mm seal strength in initial heat-seal tests (145 °C, 170 ms) enabling fully recyclable PE/PE packaging to meet industrial standards and ensuring full compliance with EU regulations.

Keywords : Polyethylene Packaging, Thermal Sealing Strength, Sustainable Packaging

Elektrik Motorlarında Döngüsel Ekonomi Uyumluluğu: Geri Dönüştürülebilirlik Oranının PLM Tabanlı Hesaplanması

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ÖZET

Endüstriyel otomasyondan otomotiv sektörüne kadar geniş bir kullanım alanına sahip olan DC (Doğru Akım) elektrik motorları; stator sargılarındaki bakır, gövde yapısındaki çelik alaşımları ve rotor grubundaki kalıcı ferrit mıknatıslar nedeniyle döngüsel ekonominin kritik bir bileşenidir. Geleneksel üretim süreçlerinde, bir ürünün geri dönüştürülebilirlik analizi genellikle ürün fiziksel olarak üretildikten sonra veya kullanım ömrü sonunda (End-of-Life) yapılmaktadır. Ancak Avrupa Yeşil Mutabakatı ve sürdürülebilirlik regülasyonları, bu analizin tasarım aşamasına çekilmesini zorunlu kılmaktadır.

Bu çalışmanın amacı, Ürün Yaşam Döngüsü Yönetimi (PLM) altyapısına entegre edilebilecek bir veri modeli önerisiyle, DC motorların henüz tasarım aşamasındayken geri dönüştürülebilirlik oranlarının hesaplanmasını sağlamaktır. Çalışma kapsamında, motoru oluşturan parça ve montaj verileri (Ürün Ağacı - BOM); ferromanyetik malzemeler, iletkenler ve ayrıştırılması kritik polimerler gibi malzeme sınıflarına ayrılarak teorik bir çerçevede analiz edilecektir. Önerilen model ile tasarımcıların, malzeme seçimlerini yaparken ürünün çevresel etkisini öngörebilmeleri hedeflenmektedir. Çalışma, bir DC motorun BOM verisi üzerinden yapılacak vaka analizi ile desteklenerek, PLM tabanlı yaklaşımların sürdürülebilir tasarım süreçlerine katkısını ortaya koyacaktır.

Anahtar Kelimeler : Ürün Yaşam Döngüsü Yönetimi (PLM), Döngüsel Ekonomi, DC Motor, Geri Dönüşüm, Sürdürülebilir Tasarım.

Circular Economy Compliance in Electric Motors: PLM-Based Calculation of Recyclability Rates

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ABSTRACT

DC (Direct Current) electric motors, widely used from industrial automation to the automotive sector, are a critical component of the circular economy due to the copper in stator windings, steel alloys in casing structures, and permanent ferrite magnets in the rotor assembly. In traditional manufacturing processes, recyclability analysis is often conducted after the product is physically manufactured or at its end-of-life stage. However, the European Green Deal and sustainability regulations necessitate shifting this analysis to the design phase.

The aim of this study is to propose a data model suitable for integration into Product Lifecycle Management (PLM) infrastructure to calculate the recyclability rates of DC motors during the design phase. Within the scope of the study, the component and assembly data (Bill of Materials - BOM) constituting the motor will be analyzed within a theoretical framework by classifying them into material classes such as ferromagnetic materials, conductors, and polymers critical for separation. The proposed model aims to enable designers to foresee the environmental impact of the product while making material selections. The study will demonstrate the contribution of PLM-based approaches to sustainable design processes, supported by a case study on a DC motor BOM data.

Keywords: Product Lifecycle Management (PLM), Circular Economy, DC Motor, Recycling, Sustainable Design.

1. GİRİŞ

Küresel sanayi üretiminde ve enerji tüketiminde merkezi bir role sahip olan elektrik motorları, modern endüstrinin işleyen çarkları olarak kabul edilmektedir. Özellikle otomotiv yan sanayisi, beyaz eşya ve iklimlendirme sektörlerinde yaygın olarak kullanılan Doğru Akım (DC) motorları; içerdikleri bakır, çelik, alüminyum gibi kıymetli metaller ve mühendislik plastikleri nedeniyle döngüsel ekonomi açısından stratejik bir hammadde deposu niteliğindedir. Ancak, bu ürünlerin geleneksel üretim ve tüketim döngüsü, "Al-Yap-Kullan-At" (Doğrusal Ekonomi) modeline sıkışmış durumdadır.

Avrupa Birliği tarafından ortaya konan "Yeşil Mutabakat (Green Deal)" eylem planı ve devreye alınan "Dijital Ürün Pasaportu (DPP)" regülasyonları, üreticilere ürünlerinin sadece performansından değil, kullanım ömrü sonundaki (End-of-Life) akıbetinden de sorumlu oldukları yeni bir paradigma sunmaktadır. Mevcut endüstriyel uygulamalarda, bir ürünün geri dönüştürülebilirlik analizi genellikle prototip üretimi sonrasında veya ürün hurdaya ayrıldığında gerçekleştirilmektedir. Bu reaktif yaklaşım, geri dönüşümü zorlaştıran tasarım hatalarının (örneğin; ayrıştırılamayan yapıştırıcı kullanımı veya metal-plastik hibrit enjeksiyonlar) tespitinde geç kalınmasına neden olmaktadır.

Bu çalışmanın odak noktası, özellikle ferrit mıknatıs içeren DC fan motorlarının tasarım süreçleridir. Ferrit mıknatıslar, seramik ve kırılgan yapıları nedeniyle geleneksel parçalama (shredding) süreçlerinde tozlaşarak çelik hurdasının metalurjik kalitesini düşüren safsızlıklar (impurities) oluşturmaktadır. Bu kirlilik riski ve motoru oluşturan polimer aksamın (PA6, PP vb.) metalden ayrıştırılma zorluğu, tasarım aşamasında "Döngüsel Tasarım (Design for Circularity)" prensiplerinin işletilmesini zorunlu kılmaktadır.

Çalışmada, Ürün Yaşam Döngüsü Yönetimi (PLM) sistemleri bir veri omurgası olarak ele alınmıştır. Amaç, DC motorların bileşen verilerinin (Ürün Ağacı - BOM) PLM ortamında malzeme türlerine ve ayrıştırılabilirlik potansiyellerine göre sınıflandırılarak, henüz sanal tasarım aşamasındayken teorik bir "Geri Dönüşüm Skoru"nun hesaplanmasını sağlayan bir model önermektir.

2. LİTERATÜR TARAMASI

Ürün Yaşam Döngüsü Yönetimi (PLM) ve sürdürülebilirlik kavramlarının entegrasyonu, son yıllarda akademik literatürde artan bir ivmeyle tartışılmaktadır. Geleneksel olarak PLM sistemleri, ürünün pazara çıkış süresini (Time-to-Market) kısaltmak ve mühendislik değişikliklerini yönetmek amacıyla kullanılırken; güncel araştırmalar bu sistemlerin "Yeşil Üretim" hedefleri için bir karar destek mekanizmasına dönüşmesi gerektiğini vurgulamaktadır.

Stark ve arkadaşları (2020) yaptıkları çalışmada, "Kapalı Döngü PLM (Closed-Loop PLM)" kavramını ortaya atarak, kullanım ömrü sonu verilerinin tasarım aşamasına geri beslenmesi gerektiğini belirtmişlerdir. Benzer şekilde, elektrik motorlarının geri dönüşümü üzerine

yapılan araştırmalar, materyal geri kazanımındaki en büyük engelin "tasarım karmaşıklığı" olduğuna işaret etmektedir. Özellikle kalıcı mıknatıslı motorlarda, mıknatısın rotora yapıştırılması veya gömülmesi, malzemenin saf olarak geri kazanılmasını ekonomik olmaktan çıkarmaktadır (Gauchia vd., 2017).

Literatürdeki mevcut boşluk incelendiğinde, çalışmaların büyük çoğunluğunun Nadir Toprak Elementleri (Neodyum vb.) içeren motorlara odaklandığı, ancak endüstriyel hacmi çok daha yüksek olan ve çelik geri dönüşüm akışlarında "kirlilik (kontaminasyon)" riski yaratan Ferrit mıknatıslı motorların tasarım süreçlerinin nispeten geri planda kaldığı görülmektedir. Ayrıca, geri dönüşüm hesaplamalarının genellikle Ürün Yaşam Döngüsü Analizi (LCA) yazılımları ile "ürün bittikten sonra" yapıldığı, PLM içerisindeki BOM verisi üzerinden anlık ve dinamik bir hesaplama modelinin endüstriyel uygulamada eksik olduğu tespit edilmiştir. Bu çalışma, söz konusu boşluğu doldurmak amacıyla, BOM tabanlı proaktif bir değerlendirme modeli sunarak literatüre katkı sağlamayı hedeflemektedir.

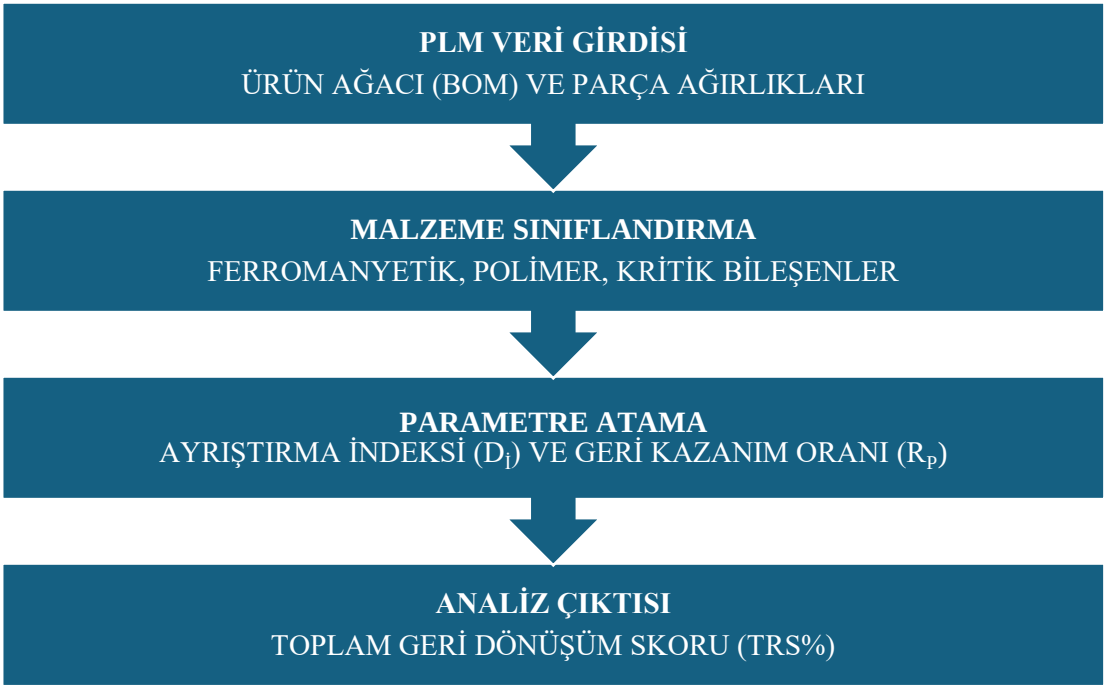
3. METODOLOJİ: PLM TABANLI GERİ DÖNÜŞÜM VERİ MODELİ

Bu çalışmada önerilen metodoloji, PLM sistemlerinde tutulan statik Ürün Ağacı (BOM) verilerini, dinamik birer çevresel etki göstergesine dönüştürmeyi amaçlamaktadır. Model, ürün hiyerarşisindeki her bir bileşene (i), malzeme türüne ve sökülebilirlik (disassembly) yöntemine bağlı olarak bir "Geri Dönüştürülebilirlik Potansiyeli (R_p)" katsayısı atanması prensibine dayanır.

3.1. Veri Yapılandırması ve Parametreler

PLM altyapısında, mevcut parça numarası ve tanım bilgilerine ek olarak aşağıdaki özniteliklerin (attributes) tanımlanması önerilmektedir:

1. Malzeme Sınıfı (M_c): Parçanın hammadde grubu (Örn: Ferromanyetik Metal, Demirdışı Metal, Termoplastik, Termoset, Kompozit/Seramik).
2. Ayrıştırma İndeksi (D_i): Parçanın ana montajdan ne kadar kolay ayrılabildiğini ifade eden 0 ile 1 arasında bir katsayıdır. (0: Ayrılamaz/Kimyasal Bağ, 1: Tamamen Sökülebilir/Mekanik Bağ).
3. Kirlilik Riski (C_r): Parçanın geri dönüşüm akışında diğer malzemeleri kirletme potansiyeli (Özellikle ferrit mıknatıslar ve bakır sargılar için kritiktir).



Görsel 1: Önerilen PLM tabanlı geri dönüşüm hesaplama modelinin veri akış şeması.

3.2. Hesaplama Algoritması

Bir montajın veya alt grubun Toplam Geri Dönüşüm Skoru (TRS), bileşenlerin ağırlıkları (W_i) ve geri kazanım katsayıları (R_{pi}) kullanılarak aşağıdaki formül ile hesaplanır:

$$TRS = \frac{\left(\sum_{i=1}^{n}(W_i \times R_{pi} \times D_i)\right)}{W_{total}} \times 100$$

Burada;

- TRS (Total Recycling Score): Ürünün nihai geri dönüştürülebilirlik skoru (%).
- W_i (Weight): Bileşenin ağırlığı (kg).
- R_{pi} (Recyclability Potential): Malzemenin teorik geri dönüşüm oranı (0-1 arası).
- D_i (Disassembly Index): Sökülebilirlik katsayısı (0-1 arası).
- W_{total}: Motorun toplam ağırlığı.

Bu algoritma sayesinde, tasarımcı henüz CAD aşamasındayken; "Kullandığım yapıştırıcı (D_i düşer) veya seçtiğim plastik türü (R_{pi} değişir) motorun genel skorunu nasıl etkiliyor?" sorusuna anlık yanıt alabilmektedir.

4. VAKA ANALİZİ

Önerilen modelin endüstriyel uygulanabilirliğini test etmek amacıyla, otomotiv ve iklimlendirme sektöründe yaygın olarak kullanılan 12V - 225W gücünde, davlumbazlı bir DC Fan Motoru Grubu referans ürün olarak seçilmiştir.

4.1. Referans Ürün Verileri (BOM Analizi)

İncelenen motor grubunun PLM sistemindeki Ürün Ağacı (BOM) verileri analiz edildiğinde, toplam ağırlığın malzeme gruplarına göre dağılımı şu şekildedir:

- Ferromanyetik Metaller (~%55): Rotor sac paketi (Silisli Sac), Gövde kovanı (DC05 Sac) ve motor mili. Bu grup geri dönüşüm değeri en yüksek olan kısımdır.
- Polimerler/Plastikler (~%35): Davlumbaz kafesi ve pervane kanatları (Elyaf Takviyeli Polyamid). Bu parçalar ağırlıkça önemli bir yer tutmakla birlikte, cam elyaf katkısı nedeniyle geri dönüşüm prosesleri saf polimerlere göre daha maliyetlidir.
- İletkenler (~%5): Bakır sargılar (Emaye Tel) ve komütatör dilimleri. Ekonomik değeri en yüksek gruptur.
- Kritik Bileşenler (~%5): Ferrit mıknatıslar ve yapıştırıcı kimyasallar.

Çizelge 1. Referans DC Fan Motorunun Malzeme ve Ağırlık Dağılımı

Malzeme Grubu	Ana Bileşenler	Tahmini Ağırlık (gr)	Oran (%)	Geri Dönüşüm Durumu
Ferromanyetik Metal	Rotor Sacı, Gövde Kovanı, Mil	850 gr	%56	Yüksek (Kolay Ayrışır)
Polimerler (Plastik)	Pervane, Kafes, Kapaklar	510 gr	%34	Orta (Cam Elyaf Katkılı)
İletkenler (Bakır)	Sargı Teli, Komütatör, Kablolar	120 gr	%8	Yüksek (Değerli)
Kritik/Diğer	Ferrit Mıknatıs, Yapıştırıcı, Boya	30 gr	%2	Düşük (Kirlilik Riski)
TOPLAM		1510 gr	%100	

4.2. Bulgular ve Senaryo Analizi

Mevcut tasarımda (Senaryo A), mıknatıslar gövde kovanına Loctite F246 yapıştırıcı ve hızlandırıcı kullanılarak sabitlenmektedir. Bu durum, "Ayrıştırma İndeksi (D_i)" değerini

düşürmektedir. Çünkü yapıştırıcı kullanımı, yaşam ömrü sonunda mıknatısın gövdeden temizlenmesini zorlaştırmakta ve "shredding" işlemi sırasında kırılan ferrit parçacıklarının gövde sacına (DC05) karışmasına neden olmaktadır. Bu senaryoda hesaplanan teorik Geri Dönüşüm Skoru %74 seviyesindedir.

PLM üzerinde simüle edilen iyileştirilmiş tasarımda (Senaryo B), yapıştırma prosesi yerine mekanik sabitleme (metal klips veya segman) yöntemi tercih edilmiştir. Bu değişiklik, mıknatısların (D_i) katsayısını 0.2'den 0.9'a yükseltmiştir. Böylece mıknatıslar kırılarak çeliği kirletmeden önce sökülebilir hale gelmiş ve gövde çeliğinin saf olarak geri kazanımı garanti altına alınmıştır. Sadece bu montaj değişikliği ile motorun Geri Dönüşüm Skoru %86 seviyesine yükselmiştir.

Bu vaka analizi, PLM tabanlı veri modelinin, mühendislere "malzeme değiştirmeden sadece birleştirme yöntemini değiştirerek" ürünün çevresel performansını nasıl artırabileceklerini somut verilerle gösterdiğini kanıtlamaktadır.

5. BULGULAR VE TARTIŞMA

Yapılan vaka analizi çalışması, PLM tabanlı veri modelinin ürün geliştirme süreçlerinde statik bir arşivleme aracı olmaktan çıkıp, dinamik bir karar destek mekanizmasına dönüşebileceğini göstermiştir. Elde edilen bulgular iki ana eksende değerlendirilmiştir:

5.1. Tasarım Kararlarının Sayısal Etkisi

Referans alınan DC fan motoru üzerinde gerçekleştirilen simülasyonlar, malzeme seçiminin ötesinde "birleştirme yöntemlerinin" (joining methods) döngüsel ekonomi performansında belirleyici rol oynadığını ortaya koymuştur. Senaryo A'da (yapıştırmalı montaj) mıknatıslar ve gövde sacı teorik olarak geri dönüştürülebilir malzemelerden oluşmasına rağmen, kimyasal bağlayıcı kullanımı nedeniyle sistemin bütünleşik geri dönüşüm skoru %74 seviyesinde kalmıştır. Buna mukabil, Senaryo B'de (mekanik montaj) yapılan değişiklikle bu skorun %86'ya yükselmesi, tasarımcının ürüne hiç yeni malzeme eklemeden sadece montaj stratejisini değiştirerek çevresel performansı %12 oranında artırabileceğini kanıtlamaktadır. Bu veri, AB Ekotasarım Direktifi hedeflerine ulaşmada tasarım mühendisliğinin kritik önemini doğrulamaktadır.

Senaryo	Geri Dönüşüm Skoru (%)
Senaryo A (Mevcut - Yapıştırmalı)	74
Senaryo B (Önerilen - Mekanik)	86

Çizelge 2: Tasarım değişikliğinin (montaj yöntemi) geri dönüşüm skoruna etkisi.

Mekanik bağlantı kullanımı, ferrit kirliliğini önleyerek skoru %12 artırmıştır.

5.2. PLM Entegrasyonunun Sürdürülebilirliğe Katkısı

Mevcut endüstriyel süreçlerde geri dönüşüm analizleri, genellikle ürün fiziksel olarak ortaya çıktıktan sonra harici uzmanlar tarafından yapılmaktadır. Bu çalışmada önerilen model ise söz konusu analizi, mühendisin günlük çalışma ortamı olan PLM arayüzüne taşımaktadır. Tasarımcı, BOM listesine "PA6 %30 GF" malzemesini eklediği anda, sistemin cam elyaf takviyesinden kaynaklı geri kazanım zorluğunu bir "uyarı" (alert) veya "düşük skor" olarak geri bildirmesi, farkındalığı artırmaktadır. Özellikle ferrit mıknatısların çelik hurdasında yarattığı kirlilik riski gibi metalurjik problemlerin henüz tasarım masasında öngörülmesi, "kirlilik önleyici tasarım" (design for purity) yaklaşımının endüstriye yerleşmesine zemin hazırlayacaktır.

6. SONUÇ VE ÖNERİLER

Bu çalışmada, elektrik motorları endüstrisinin döngüsel ekonomi gerekliliklerine uyum sağlaması amacıyla, tasarım aşamasında işletilebilecek PLM tabanlı bir geri dönüştürülebilirlik değerlendirme modeli sunulmuştur. Ferrit mıknatıslı bir DC fan motoru verileri üzerinden gerçekleştirilen vaka analizi, ürünün yaşam sonu (End-of-Life) senaryolarının tasarım parametreleri ile doğrudan ilişkili olduğunu somut verilerle ortaya koymuştur.

Çalışmanın temel çıkarımları şunlardır:

1. Veri Odaklı Dönüşüm: PLM sistemleri, sadece CAD verilerinin yönetildiği bir depo değil, ürünün çevresel kimliğinin (Dijital Ürün Pasaportu) oluşturulduğu bir platform olarak konumlandırılmalıdır.
2. Mıknatıs Yönetimi: DC motorlarda yaygın kullanılan ferrit mıknatıslar, ekonomik değerlerinden ziyade çelik geri dönüşüm akışlarında yarattıkları safsızlık riski nedeniyle, tasarımda "ayrıştırılabilir montaj" önceliğine sahip olmalıdır.
3. Proaktif Yaklaşım: Önerilen model, geri dönüşüm analizini reaktif bir süreçten (sonradan kontrol), proaktif bir sürece (tasarım anında kontrol) dönüştürmektedir.

Gelecek çalışmalarda, önerilen bu veri modelinin ERP (Kurumsal Kaynak Planlama) sistemlerindeki hurda maliyet verileriyle entegre edilmesi ve Yapay Zeka (AI) destekli algoritmalarla tasarımcıya "alternatif malzeme önerisi" sunabilecek otonom bir yapıya kavuşturulması önerilmektedir.

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YETİŞKİN BEZİNDE ADL İN REWET PERFORMANSI ÜZERİNDEKİ ETKİSİNİN İNCELENMESİ

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ÖZET

YETİŞKİN BEZİNDE ADL'İN REWET PERFORMANSI ÜZERİNDEKİ ETKİSİNİN İNCELENMESİ

ÖZET

Bebek ve yetişkin bezleri, toplum sağlığı ve yaşam kalitesini artırma açısından kritik öneme sahip hijyen ürünleridir. Bu ürünlerde performans, doğrudan kullanıcı konforunu ve ürünün tercih edilebilirliğini etkilemektedir. Tek kullanımlık yetişkin bezlerinde performansı belirleyen en kritik testlerden biri, cilt kuruluğu ile doğrudan ilişkili olan tekrarlı ıslatma (Rewet) testidir. Rewet test sonucunu etkileyen birçok parametre bulunmaktadır. Bu parametreler; selüloz (SAP–pulp) miktarı ve dağılımı, üst yüzey (topsheet) yapısı, tutkal uygulama yöntemi, ADL (Alıcı ve Dağıtıcı Tabaka) yapısı ve test uygulayıcısına bağlı değişkenler olarak sıralanabilir. Bu çalışma kapsamında söz konusu parametreler değerlendirilmiş, özellikle ADL üzerine yoğunlaşılmıştır.

Rewet testi, bez performansını ortaya koyan önemli ve kapsamlı bir test yöntemidir. Test, çocuk anatomisini simüle eden kanga aparatları yardımıyla gerçekleştirilmekte olup, dört tekrarlı ıslatma döngüsü ile idrar simülasyonu yapılmaktadır. Bu yöntemle, bezin sıvıyı emme miktarı ve emilim süresi ile birlikte, ıslatma sonrası yüzeye geri dönen sıvı miktarı ölçülmektedir.

Çalışmada, yetişkin hasta bezi üretimlerinde Rewet değerlerinin olumsuz yönde yüksek çıkmasına neden olan faktörlerden biri olan ADL materyali ele alınmıştır. Farklı gramajlarda (gsm), farklı üretim metodolojileriyle üretilmiş ve farklı en–boy ölçülerine sahip ADL materyalleri kullanılarak çeşitli denemeler gerçekleştirilmiştir. Belirlenen deneme sistematiği doğrultusunda farklı ADL versiyonları karşılaştırılmış ve elde edilen Rewet performans değerleri analiz edilmiştir. Test sonuçlarına göre en optimum ADL konfigürasyonu belirlenmiş, ardından örneklem sayısı artırılarak elde edilen etki değerleri istatistiksel olarak doğrulanmıştır.

Anahtar Kelimeler: Cilt kuruluğu, Rewet, ADL, Yalın Üretim

INVESTIGATION OF THE EFFECT OF ADL ON REWET PERFORMANCE IN ADULT DIAPERS

ABSTRACT

Baby and adult diapers are critical hygiene products that significantly contribute to public health and quality of life. In these products, performance directly affects user comfort and product preference. One of the most critical performance tests for disposable adult diapers is the repeated wetting (rewet) test, which is directly associated with skin dryness. Numerous parameters influence rewet test results, including the amount and distribution of cellulose (SAP–pulp), topsheet structure, adhesive application method, acquisition and distribution layer (ADL) properties, and operator-related variables. Within the scope of this study, these parameters were evaluated, with a particular focus on the ADL.

The rewet test is a comprehensive and essential method for evaluating diaper performance. The test is conducted using kanga devices that simulate child anatomy and consists of four repeated wetting cycles representing multiple urination events. This method enables the measurement of liquid absorption capacity and absorption time, as well as the amount of liquid returning to the surface after wetting.

In this study, the ADL material—identified as one of the key factors contributing to undesirably high rewet values in adult incontinence diaper production—was systematically investigated. ADL materials produced using different manufacturing methodologies, with varying basis weights (gsm) and different width and length dimensions, were evaluated on the diaper. Based on a defined experimental design, multiple ADL versions were tested and their rewet performance values were compared. The optimum ADL configuration was determined, and the observed performance improvements were statistically validated by increasing the sample size.

Keywords: Skin dryness, Rewet, ADL, Lean manufacturing

GERİ DÖNÜŞTÜRÜLMÜŞ MALZEME İLE YEŞİL DÖNÜŞÜM ODAKLI PAKETLEME UYGULAMASI

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ÖZET

Sektörlerin artan sürdürülebilirlik taleplerine yanıt olarak, beyaz eşya sektöründe paketleme süreçlerinde köklü bir yeşil dönüşüm konusu ele alınmaktadır. Mevcut uygulamada, ürün koruması için yaygın kullanılan Genişletilmiş Polistiren (EPS) malzemenin çevresel etkileri merkezdedir; özellikle zor geri dönüşüm, uzun çözünme süresi ve yüksek karbon ayak izi gibi sorunlar bulunmaktadır. Bu çalışmada, geri dönüştürülmüş kâğıt ve kartondan üretilen kalıplanmış lif bazlı viyol malzemesinin EPS yerine kullanılabilirliği araştırılmıştır. Viyol malzemesi, %100 geri dönüştürülmüş içeriği ve biyobozunur yapısıyla kapalı döngü ekonomisi hedeflerini desteklemektedir. Bu çalışma kapsamında elde edilen deneysel bulgular, ambalajın hamur bileşiminde ve geometrik tasarımında yapılan kritik iyileştirmeler (destek noktalarının ürünün kuvvetli sac bölgelerine kaydırılması ve destek yüksekliklerinin eşitlenmesi) sonucunda, geri dönüştürülmüş viyol malzemenin koruma performansı açısından EPS muadili ile rekabet edebilir seviyeye ulaştığını göstermiştir.

Anahtar Kelimeler : Yeşil Dönüşüm, Sürdürülebilirlik, Viyol Ambalaj (Kalıplanmış Lif), Geri Dönüştürülmüş Malzeme, EPS Alternatifi, Beyaz Eşya Sektörü

TERMİNAL DÖNEMDEKİ BİREYLERDE GÖRÜLEN CİLT DEĞİŞİKLİKLERİ VE HEMŞİRELİK BAKIMI

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ÖZET

Terminal dönem; yaşamının belli bir süre sonra sonlanacağı düşünülen bireyin psikolojik, fizyolojik, spiritüel ve sosyal açıdan iyilik halinin bozulduğu dönemdir. Yaşam sonundaki değişikliklerle birlikte yumuşak dokuların oksijenizasyonunun bozulması, dış etkenlere karşı hassasiyetin artması gibi durumlar ciltte değişiklik ve yaralanmalara neden olmaktadır. Literatürde Kennedy terminal ülserleri, Trombley Brenann terminal doku yaralanmaları, cilt yetmezliği, yaşam sonu cilt değişiklikleri kavramları yaşam sonunda meydana gelen cilt değişiklikleri ve ülserleri açıklamak için kullanılmaktadır. Kennedy terminal ülserleri sakral bölgede, kelebek ve at nalı gibi şekillerle karakterize hızlı gelişen ülserlerdir. Trombley Brenann terminal doku yaralanmaları ölümden günler önce oluşan ve daha çok renk değişikliği şeklinde görülen yüzeysel yaralanmalardır. Cilt yetmezliği, dokunun perfüzyonunun bozulması ile diğer organlar gibi cildin de yetmezliğe girmesi durumudur. Yaşam sonu cilt değişiklikleri ise etiyolojisi içsel ve dışsal pek çok faktöre bağlı gelişebilen genellikle distal organlarda oluşan yaralanmalardır. Bu kavramların birbiri ile ilişkisi, kapsayıcı bir kavramın bulunmaması gibi durumlar nedeniyle hala tartışmalıdır. Hemşirelik bakımında ise terminal dönem bakımı temel alınmaktadır. Ayrıca bu değişikliklerin kaçınılmaz olduğunu bilinmeli ve hasta yakınlarına da anlatılmalıdır. Bu bilgilendirme hasta yakınlarının sürece hazırlığı, kalite ve hukuki süreçlerde sorun yaşanmaması gibi durumlar için önemlidir.

Anahtar Kelimeler : Terminal Dönem, Kennedy Terminal Ülserleri, Trombley Brenann Terminal Doku Yaralanmaları, Cilt Yetmezliği, Yaşam Sonu Cilt Değişiklikleri, Hemşirelik Bakımı

SKIN CHANGES IN THE TERMINAL PHASE AND NURSING CARE

ABSTRACT

The terminal stage is defined as a period in which an individual is expected to reach the end of life after a certain time and during which psychological, physiological, spiritual, and social well-being deteriorates. Along with end-of-life changes, conditions such as impaired oxygenation of soft tissues and increased sensitivity to external factors lead to skin changes and injuries. In the literature, the concepts of Kennedy terminal ulcers, Trombley–Brennan terminal tissue injuries, skin failure, and end-of-life skin changes are used to explain skin alterations and ulcers that occur at the end of life. Kennedy terminal ulcers are rapidly developing ulcers, typically located in the sacral region and characterized by butterfly- or horseshoe-shaped appearances. Trombley–Brennan terminal tissue injuries are superficial lesions that occur days before death and are most commonly observed as discoloration. Skin failure refers to a condition in which the skin, like other organs, fails due to impaired tissue perfusion. End-of-life skin changes are injuries that usually develop in distal organs and may occur as a result of multiple intrinsic and extrinsic etiological factors. The relationships among these concepts remain controversial due to their interconnections and the lack of a comprehensive umbrella term. In nursing care, terminal care is taken as the primary focus. In addition, it should be recognized that these changes are inevitable and this should be communicated to patients' relatives. Such information is important for preparing family members for the process and for avoiding problems related to quality of care and legal procedures.

Keywords : Terminal Period, Kennedy Terminal Ulcers, Trombley Brennan Terminal Tissue Injuries, Skin Failure, End-Of-Life Skin Changes, Nursing Care

GİRİŞ

Terminal dönem; yaşamının belli bir süre sonra sonlanacağı düşünülen bireyin psikolojik, fizyolojik, spiritüel ve sosyal açıdan iyilik halinin bozulduğu dönemdir (Usta & Set, 2022). Literatürde yaşam sonu dönemde sıklıkla bildirilen klinik değişiklikler arasında; oral alımda bozulma, günlük yaşam aktivitelerini gerçekleştirememe, solunum örüntüsünde bozulma, uykuya eğilim ve bilinç değişiklikleri yer almaktadır (Lee et al., 2021). Yaşam sonunda bu değişikliklerin beraberinde yumuşak dokuların oksijenizasyonunun bozulması, vücutta metabolik artıkların birikmesi, basınç gibi dış etkenlere karşı hassasiyetin artması gibi durumlar ciltte de önemli değişikliklere neden olmaktadır (Sibbald et al., 2010). Cilt genel olarak fizyolojik değişiklikler, akut durumlar, kronik hastalıklar ve hayati sistemlerin yetmezliğe girmesi gibi durumlardan etkilenmektedir (Abreu et al., 2024). Terminal dönemde ise gerekli risklerin belirlenmesi ve önlemlerin alınmasına rağmen önlenemez yaralar gelişebilmektedir (Edsberg et al.,2014; Roca-Biosca et al., 2021).

Terminal Dönemde Görülen Cilt Değişiklikleri

Literatürde Kennedy Terminal Ülserleri, Trombley Brenann Terminal Doku Yaralanmaları, cilt yetmezliği, Yaşam Sonu Cilt Değişiklikleri kavramları yaşam sonunda meydana gelen cilt değişiklikleri ve ülserleri tanımlamak için kullanılmaktadır. Çalışmalarda terimlerin kullanıldığı durumlar farklılık gösterebilmektedir. Bu farklar ülserlerin ortaya çıkış zamanı, etiyolojisi, klinik görünümü gibi durumlar nedeniyle oluşmaktadır. Bu kavramların birbiri ile ilişkisi, birbirinin yerine kullanımı ve kapsayıcı bir kavramın bulunmaması gibi nedenlerle kullanımları hala tartışmalıdır (Gould et al., 2023).

Kennedy Terminal Ülserleri (KTU)

İlk olarak 1986 yılında Kennedy ve arkadaşları tarafından tanımlanmıştır. KTU'nun gelişiminde genellikle dolaşım yetersizliğine neden olan çoklu organ yetmezliği ve iç faktörlerden kaynaklanması nedeniyle önlenmesinde pozisyon değişikliği gibi girişimlerin etkili olmayacağı bildirilmiştir (Erbay & Erarı, 2019). Klinik literatürde tanımlayıcı bir ifade olarak '3:30 sendromu da denilmekte olup bu kavramın ortaya çıkışı hastalara bakım verenlerin sabah cilt değerlendirmesi yaptıklarında bir sorun fark etmedikleri ancak saat 15.30 da hastada ilerlemiş ülserler fark etmeleri ile olmuştur (Miller, 2017). Aniden ortaya çıkan bu ülserlerin yaşamın sonlanmasından haftalar önce oluştuğu ve genellikle koksis ve sakral bölgede görüldüğü belirtilmektedir (Sibbald & Ayello, 2020; Erbay & Erarı, 2019). Şekil açısından da armut, kelebek veya at nalı şeklinde oldukları bildirilmiştir (Sibbald & Ayello, 2020). Yara bakımı konusunda uzman sağlık profesyonelleri ile yapılan bir uzlaşı çalışmasında KTU'ların primer nedenin basınç değil iskemi olduğu ve KTU'ların ölümün yaklaştığı hakkında bir gösterge olduğu bildirilmiştir (Sibbald & Ayello, 2020).

Trombley Brennan Terminal Doku Yaralanmaları

Trombley Brennan Terminal Doku Yaralanmaları, 2009 yılında bir grup hemşire tarafından terminal dönemde olan hastaların ölmeden önce ciltlerindeki renk değişikliklerini fark etmeleri ile tanımlanmıştır. Ciltteki bu değişikliklerin genelde morarma gibi renk değişimi şeklinde olup çoğunlukla nekroz gelişimi olmaksızın yüzeyel seyir gösterdiği bildirilmiştir. Bu yaralanmalar gerçekleştikten sonra bireylerin genellikle 20 dakika ile 36 saat arasında öldükleri

belirlenmiştir. Yaralanmaların oluştuğu bölgeler genellikle klasik basınç bölgeleri dışında kaval kemiği, uyluk kemiği, gövde gibi bölgelerdir. Bölgelere göre şekillerinin de genellikle değiştiği gözlemlenmiştir. Sakrumda bulunan yaralar kelebek şeklinde iken kaval kemiği gibi bölgelerdekiler daha doğrusal çizgiler şeklinde görülmektedir. O dönemde Kennedy Terminal Ülserleri ile aralarındaki farklar üzerinde de durulmuştur. KTU'lar yara açıldıktan sonra tam derinlikli doku hasarına çok hızlı ilerlerken Trombley Brennan Terminal Doku Yaralanmalarında böyle bir ilerleme görülmemektedir. Bir diğer fark ise hastaların ölüm zamanlarıdır. KTU'lar ölümden haftalar önce oluşurken bu yaralanmalarda hastalar ortalama 36 saat içinde ölmektedirler (Brennan et al., 2019; Trombley et al., 2012). Yapılan bir uzlaşı çalışmasında bu alandaki uzman sağlık profesyonellerinden bazıları Trombley Brennan Terminal Doku Yaralanmalarında doku bütünlüğünde bozulma olmadığına dair bildirimin doğru olmadığını ve bazı olgularda doku bütünlüğünün bozulduğunu belirtmişlerdir (Sibbald & Ayello, 2020).

Cilt Yetmezliği

Kalp, böbrek, karaciğer gibi organlarda yetmezlik gelişmesi gibi ciltte de yetmezlik gelişebilmektedir. Bu yetmezliğin nedenleri dokunun perfüzyonunu bozan besin ve oksijen iletiminde bozulma, hipoksi ve atıkların uzaklaştırılamaması gibi nedenlerdir. Diğer sistemler yetmezliğe girdiğinde kan testi gibi biyobelirteçlerle durumu öngörebilirken cilt yetmezliğinde belirlenmiş herhangi bir test bulunmadığından bu durum tespitini zorlaştırmaktadır (Levine, 2017). Yara bakımı ve cilt konusunda uzman sağlık profesyonelleri ile yapılan bir uzlaşı çalışmasında cilt yetmezliğinin geliştiği akut, kronik durumlarla ilgili daha fazla araştırma yapılması gerektiği sonucuna varılmış ve çoğu kavram hakkında fikir birliği olmasına karşın cilt yetmezliğinin basınç yaralanmalarını içerip içermeyeceği konusunda fikir birliğine varılamamıştır (Sibbald & Ayello, 2020). Cilt yetmezliğinin basınç yaralanmalarını içerip içermediği konusu kalite kapsamı ve hukuki boyut açısından da önem arz etmektedir. Basınç yaraları bir kalite standardı olarak değerlendirilmektedir ancak kaçınılmaz olan yaraların belirlenememesi kalitenin olandan daha düşük olarak tespit edilmesine neden olacaktır bu nedenle önlenemez yaraların belirlenmesi için ortak olarak kullanılabilecek bir algoritma gereklidir (Levine, 2017).

Yaşam Sonu Cilt Değişiklikleri

Yaşam sonu cilt değişiklikleri terminal dönemde doku perfüzyonunun bozulması nedeniyle cilt ve yumuşak dokularda görülen değişikliklerdir. Çoğunlukla parmaklar, burun gibi distal bölgelerde görülmekle birlikte topuk, sakrum gibi diğer bölgelerde de görülebilmektedir. Bu değişikliklerin etiyolojisinde kaşeksi, aktivite intoleransı, bağışıklığın azalması, albümin ve hemoglobin düzeylerinde düşme gibi bireysel faktörlerin yanı sıra; cilde temas eden tıbbi ekipmanlar, basınç, sürtünme ve nemli ortam gibi çevresel faktörler de yer almaktadır. Bu nedenlerin sonucunda benekli renk değişiklikleri, bölgesel ısı değişimleri ve nekrotik doku gelişebilmektedir (Sibbald et al., 2010).

Terminal Dönem Cilt Değişiklikleri ve Hemşirelik Bakımı

1) Karşılaştırılan kavramların etiyolojisi birbirinden farklı olsa da önlenemez yaraları tanımladıkları ortaya konulmaktadır. Hemşirelik bakımında ise bu nokta özellikle dikkate alınmalıdır.

2) Gelişen yaranın önlenemez olarak sınıflandırılması ailenin ve sağlık ekibinin beklentilerini değiştirecektir (Roca-Biosca et al., 2021).

3) Sağlık ekibinin bu yaraların ölüm sürecinin yaklaşması nedeniyle önlenemez şekilde oluştuğunu öğrenmesi bakımın eksikliğini düşündüren suçluluk duygusunun oluşmasını önleyecektir (Roca-Biosca et al., 2021).

4) Bu bireylerde hemşirelik bakımının temelini ağrı yönetimi, hastanın konforu ve cilt bütünlüğünün sağlanması oluşturmaktadır (Abreu et al., 2024).

5) Cildin dış etkenlere karşı hassasiyeti artmış olduğu için hemşire, düzenli olarak cilt değerlendirmesi yapmalı, basınç bölgeleri desteklemeli ve burun gibi kıkırdak yapılı bölgelere dikkat etmelidir (Sibbald et al., 2010).

6) Hasta yakınlarına bu yaraların kaçınılmaz olarak geliştiği, tedavi ve bakım eksikliğinde kaynaklanmadığı açıklanmalıdır (Roca-Biosca et al., 2021).

SONUÇ

Hemşireler terminal dönem hasta bakımında aktif rol oynayan sağlık profesyonelleridir. Terminal dönem cilt değişiklikleri kavramlarının bilinmesi ve bu hastaların bakımında hangi noktalara dikkat edilmesi gerektiği önem arz etmektedir.

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PERİFERİK ARTER HASTALIĞI VE YÖNETİMİ

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ÖZET

Periferik arter hastalığı (PAH), genellikle alt ekstremitedeki periferik arterlerde görülen aterosklerotik bir hastalıktır. PAH'lı bireylerde iskemi-reperfüzyon döngüsü görülmekte ve fizyopatolojisinde mitokondriyal aktivitenin bozulması önemli rol oynamaktadır. Yaşlılarla ve sosyoekonomik düzeyi düşük bireylerde daha sık görülmekte olup etiyolojisinde aterosklerotik sürece neden olan sigara, obezite gibi durumlar yer almaktadır. PAH'lı bireylerde diğer aterosklerotik hastalıkların görülme ihtimali de daha yüksektir. PAH'lı bireylerin yarısının asemptomatik olması ve sağlık profesyonellerinin PAH hakkında bilgi eksikliğinin olması nedeniyle tanı gecikebilmektedir. PAH'ın değerlendirilmesinde fiziksel muayene, ayak bileği-kol indeksi, Rutherford ve Fontaine sınıflandırmaları, doppler ultrasonografi ve anjiyografi kullanılmaktadır. PAH'ın farmakolojik yönetiminde antiplatelet ajanlar, lipid düşürücü ilaçlar, periferik vazodilatörler, antihipertansifler ve antidiyabetik ilaçlar yer almaktadır. PAH'ın yönetiminde akdeniz tipi diyet, denetimli egzersiz terapisi, sigaranın bırakılması ve kilo verilmesi gibi yaşam tarzı değişiklikleri de önemli rol oynamaktadır. HbA1c kontrolü ve vasküler görüntüleme gibi önleyici girişimler de mortalite ve morbiditenin azaltılmasını sağlayabilmektedir. Ayrıca PAH'ın kronik bir hastalık olduğu ve kronik hastalıkların temel sorunlarına odaklanılması gerektiği, hastanın bulunduğu evreye göre bakım gereksinimlerinin değişeceği, yaşam tarzı değişiklikleri, ağrı, depresyon, anksiyete yönetimlerinin sağlanması ve olası amputasyon durumunda bireyin rehabilitasyonu önem taşımaktadır.

Anahtar Kelimeler : Periferik Arter Hastalığı, Hemşirelik Bakımı, Kronik Hastalık Yönetimi

PERIPHERAL ARTERIAL DISEASE AND ITS MANAGEMENT

ABSTRACT

Peripheral arterial disease (PAD) is an atherosclerotic disorder that most commonly affects the peripheral arteries of the lower extremities. In individuals with PAD, an ischemia–reperfusion cycle occurs, and impairment of mitochondrial activity plays a significant role in its pathophysiology. PAD is more frequently observed in older adults and individuals with low socioeconomic status, and its etiology includes factors that contribute to the atherosclerotic process, such as smoking and obesity. Individuals with PAD also have a higher likelihood of developing other atherosclerotic diseases. Because approximately half of individuals with PAD are asymptomatic and due to insufficient knowledge about PAD among healthcare professionals, diagnosis may be delayed. The evaluation of PAD includes physical examination, the ankle–brachial index, Rutherford and Fontaine classifications, Doppler ultrasonography, and angiography. Pharmacological management of PAD involves antiplatelet agents, lipid-lowering drugs, peripheral vasodilators, antihypertensive agents, and antidiabetic medications. Lifestyle modifications, such as adherence to a Mediterranean diet, supervised exercise therapy, smoking cessation, and weight loss, also play an important role in the management of PAD. Preventive interventions, including HbA1c control and vascular imaging, may contribute to reducing mortality and morbidity. Furthermore, as PAD is a chronic disease, it is essential to focus on the fundamental issues associated with chronic conditions. Care needs vary according to the stage of the disease, and the management of lifestyle changes, pain, depression, and anxiety is crucial. In cases of potential amputation, the rehabilitation of the individual is also of great importance.

Keywords : Peripheral Arterial Disease, Nursing Care, Chronic Disease Management

GİRİŞ

Periferik arter hastalığı (PAH), özellikle alt ekstremitedeki periferik arterlerin obstrüktif aterosklerotik hastalığıdır (Gornik et al., 2024). PAH'ta ateroskleroza neden olan durumlar genellikle serebral ve koroner damarların da aterosklerozuna neden olduğundan PAH sistemik bir aterosklerozun habercisi olabilmektedir. Bu nedenle PAH'ın tanımlanması, diğer aterosklerotik hastalıklar için de bireyin riskli olabileceğini düşündürmektedir (Shamaki et al., 2022; Verim & Taşçi, 2013). PAH'lı bireylerin yarısı asemptomatik olduğu için tespit edilmeleri daha zordur bununla birlikte sağlık sisteminden kaynaklı geç teşhisler de olabilmektedir. Birinci basamak sağlık hizmetlerinde PAH tanısı konulmasında çalışanların özgüvensiz olması, diğer tanıları dışladıktan sonra PAH'ı düşünmeleri, PAH'ı yaygın bir hastalık olarak görmemeleri sonucunda morbidite ve mortalitede artış olduğu saptanmıştır (Bridgwood & Sayers, 2023).

Periferik Arter Hastalığı Epidemiyolojisi

Dünyada 200 milyondan fazla kişinin PAH hastalığına sahip olduğu düşünülmektedir. PAH'ta asemptomatik vakaların tanıları genellikle hastalığın ilerlemesiyle konulmaktadır (Shamaki et al., 2022). Tanı konulduktan sonraki 5-15 yıl içerisindeki morbidite ve mortalite oranları %30 ila %70 arasında değişkenlik göstermektedir (Demsas et al., 2022). Yaşlılar, kırsal bölgelerde yaşayan bireyler, yerli ve Afrika kökenli Amerikalılar, sosyoekonomik düzeyi düşük olan bireyler riskli gruplardır. Bu bireylerde hastalık daha sık görülmekte ve amputasyon oranları daha yüksek seyretmektedir (Eid et al., 2021).

Periferik Arter Hastalığı Fizyopatolojisi

Periferik arter hastalığında kardiyovasküler risk faktörleri sigara, diyabet, hiperlipidemi gibi nedenlerden dolayı ateroskleroz gelişmektedir. PAH'ta arteriyel kan akışı bozulmaktadır ve bireylerde iskemi-reperfüzyon döngüsü görülmektedir. Mitokondriyal aktivite de bu süreçte önemli rol oynamaktadır. Ancak mitokondriyal aktivite bozulduğunda daha fazla reaktif oksijen türlerinin üretimine neden olarak oksidatif stres artmaktadır. Ayrıca mitokondriyal geçirgenliğin artmasıyla da apoptoz süreci tetiklenmektedir (Pizzimenti et al., 2019).

Periferik Arter Hastalığının Klinik Bulguları ve Semptomları

Periferik arter hastalığında görülen semptomlar; hareket ile tetiklenen alt ekstremite ağrısı ve hastalık ilerledikçe görülen istirahat ağrısıdır (Tehan et al., 2024). Hareketle tetiklenen ve dinlenmekle geçen bu ağrıya kladikasyon ağrısı denilmektedir. Ağrı kramp şeklinde olup ağrının görüldüğü yer etkilenen damara göre değişmektedir. Aortoiliak segmentin tutulumu sonucunda kalça ve uyluk ağrısı yaşanırken, femoropopliteal segmentin etkilenmesi sonucunda baldır ağrısı görülmektedir. Bu semptomlar değerlendirilirken özellikle bireyin ağrı yaşamadan yürüyebildiği mesafe dikkate alınmaktadır (Zemaitis et al., 2025).

Periferik Arter Hastalığı Tanısal Değerlendirme

Periferik arter hastalığının tanılamasında ayak bileği-kol indeksi yatak başı yapılan kolay bir testtir. Bu indekste dört ekstremitenin de sistolik kan basıncı ölçülür ve ayaklardaki en yüksek kan basıncı ile kollardaki en yüksek kan basıncı birbirine oranlanır. Oran 0.9'dan düşükse obstrüktif bir durum olduğu, 1.4'ün üzerinde ise kalsifikasyon nedenli ateroskleroz düşünülmelidir. Ayak bileği-kol indeksi birçok durumda olduğundan yüksek çıkarak yanıltıcı

olabilmektedir. Bu durumlar; diyabet, kronik böbrek yetmezliği, ileri yaş, alt ekstremite travmalarıdır. Bu durumlarda ayak parmağı-kol indeksi ile değerlendirme yapılmakta ve 0.7'den düşük değerler anormal kabul edilmektedir (Tran, 2021). Ayak parmağı sistolik kan basıncı Doppler, lazer veya fotopletismograf probu yardımıyla ölçülebilmektedir. Ayak parmağı-kol indeksinin güvenirliğinin düşük olduğu ve kullanılabilmesi için kanıt düzeyi yüksek daha fazla çalışmaya ihtiyaç olunduğu bildirilmiştir (Tehan et al., 2024). Tanısal değerlendirmede kladikasyon ağrısı da kullanılmaktadır ancak özellikle yaşlı bireylerde periferik eklemlerin dejenerasyonu gibi nedenlerle yanıltıcı olabilmektedir. Kullanılan diğer yöntemler ise; doppler ultrasonografi, bilgisayarlı tomografi anjiyografi ve manyetik rezonans anjiyografidir (Verim & Taşçi, 2013; Vlachopoulos et al., 2018).

Periferik Arter Hastalığı Sınıflaması

Periferik arter hastalığının değerlendirilmesinde en sık kullanılan sınıflamalar Fontaine ve Rutherford sınıflamalarıdır (Leelathanalerk et al., 2024). Fontaine sınıflamasında bireylerin semptom yaşama durumu, 200 metreyi yürüme kapasiteleri, istirahat ağrıları ve ülserin gelişme durumu değerlendirilmektedir (Hardman et al., 2014). Rutherford sınıflamasında ise bireylerin semptom yaşama durumu, kladikasyon şiddetleri, istirahat ağrıları ve nekroz boyutunun değerlendirilmesi yer almaktadır (Hardman et al., 2014; Rutherford et al., 1997).

Önleyici ve Erken Tanı İçin Girişimler

Periferik arter hastalığında önleyici ve erken tanıyı sağlayan girişimler hastalığın görülme sıklığını azaltabilmektedir. HgA1c kontrolü, vasküler görüntüleme ile değerlendirme, diyabetik ayak bakımı gibi girişimler uygulama kolaylığı ve maliyet açısından avantajlıdır ancak önleyici girişimlere gerekli önem verilmemektedir (Eid et al., 2021).

Periferik Arter Hastalığı Tedavisi ve Yönetimi

Periferik arter hastalığının tedavisi ve yönetiminde medikal tedavi, girişimsel yöntemler, cerrahi tedavi ve yaşam tarzı değişiklikleri yer almaktadır.

Medikal Tedavi

Periferik arter hastalığının farmakolojik yönetiminde antiplateletler, lipid düşürücü ilaçlar, periferik vazodilatörler, antihipertansifler ve antidiyabetik ilaçlar yer almaktadır(Ratchford, 2017). Farmakolojik tedavinin planlanmasında hastanın ateroskleroza neden ek kronik hastalıkları da dikkate alınmaktadır. Lipid düşürücü ilaçlardan en sık kullanılanı statinler olmakla birlikte çoklu aterosklerotik hastalıkların varlığında ek bir ajan eklenmesi önerilmektedir (Grundy et al., 2019). Semptomatik hastalarda periferik vazodilatörlerden Silostazol'un kullanımının kladikasyonu azalttığı ve yürüme mesafesini arttırdığı bildirilmiştir. Ancak bu ilaç da kısıtlamaları olan ve yan etkileri zorlayıcı olabilen bir ilaçtır. Kalp yetmezliği olan bireylerde kullanımı kontrendikedir. Karaciğer yetmezliği gibi bazı durumlarda ilaç dozunun tekrar ayarlanması gerekmektedir. Diyet kısıtlaması olarak da ilaçla etkileşimi nedeniyle greyfurt kısıtlaması bildirilmiştir (Dawson et al., 2000; Ratchford, 2017).

Girişimsel ve Cerrahi İşlemler

Periferik arter hastalığının tedavisinde endovasküler girişimler ve cerrahi kullanılmaktadır. Endovasküler girişimlerde en sık kullanılan yöntemler stentleme ve balon anjiyoplastidir. Bu girişimler kısa vadede morbidite ve mortalite riski açısından avantajlı olsa da akut komplikasyonlar görülmekte olup en sık görülen komplikasyonlar arasında; diseksiyon, arter perforasyonu ve hematom sayılabilir (Çiçek et al., 2023; Mumtaz et al., 2025). Cerrahi tedavide ise kısa vadede morbidite ve mortalite riski yüksek ancak uzun vadede özellikle tekrar herhangi bir girişime gerek kalınmadan damar açıklığının sağlanması açısından endovasküler girişimlere oranla avantajlıdır (Mumtaz et al., 2025). Son yıllarda hibrit yani her ikisinin kombine kullanıldığı tedavilerin daha etkili olduğu saptanmıştır (Toprak & Tüysüz, 2025).

Yaşam Tarzı Değişiklikleri

Periferik arter hastalığı olan bireylerde diyetin düzenlenmesi, egzersiz, sigaranın bırakılması gibi yaşam tarzı değişiklikleri önerilmektedir.

Diyetin düzenlenmesi: PAH'lı bireylerin; akdeniz tipi, kuruyemişleri içeren ve çoklu doymamış yağlarla beslenmesinin hastalığın gelişiminde ve prognozunda olumlu etkileri olduğu bildirilmiştir (Adegbola et al., 2022).

Denetimli egzersiz terapisi: PAH'lı hastalar için AHA/ACC tarafından önerilen, hastanede veya ayaktan tedavi merkezlerinde yürütülebilen, bağımsız ya da kardiyovasküler rehabilitasyonun bir parçası olarak planlanan egzersizdir. Bireyler, koşu bandında veya koşu bandına uygun değilse bisiklet gibi aletlerde gözetimli şekilde egzersiz yapmaktadır. Bu egzersizde önemli olan noktalar bireyin kladikasyon ağrısı olana kadar egzersize devam etmesi, orta seviyede ağrı yaşadığında ağrısı geçene kadar dinlenmesi ve egzersize devam etmesini içermektedir. Antrenman süresi 30-45 dakika arasında, haftada 3 gün ve 12 hafta devam edecek sekilde planlanmaktadır (Gerhard-Herman et al., 2017). Ayrıca evde bireysel yapılan yürüyüşlere kıyasla denetimli egzersiz terapisi daha etkili bulunmuştur (Treat-Jacobson & Ratchford, 2020).

Periferik Arter Hastalığı Olan Bireyin Hastalığının Yönetiminde Dikkat Edilmesi Gereken Noktalar

Kronik bir hastalık olması nedeniyle kronik hastalıkların bakımındaki temel sorunlar ele alınmalıdır (Smolderen et al., 2022)

Hasta asemptomatik, hafif veya orta düzey kladikasyona sahip veya amputasyon gerçekleştirilmiş bir hasta olabilir ve hastalığın hangi evresinde olduğu göz önünde bulundurulmalıdır (Smolderen et al., 2022)

Denetimli egzersiz terapisi hakkında hasta bilgilendirilmelidir.

Sigara kullanımı varsa sigara bırakma ile ilgili hasta yönlendirilmelidir (Smolderen et al., 2023).

Uygulaması gereken diyet hakkında bilgi verilmelidir.

Amputasyon gerçekleştirilen hastanın rehabilitasyonu sağlanmalıdır (Smolderen et al., 2023).

Ağrı yönetimi ve opioid kullanımı hakkında hastaya bilgi verilmelidir (Smolderen et al., 2023).

Depresyon ve anksiyete yönetimi sağlanmalıdır (Smolderen et al., 2023.)

SONUÇ

Periferik arter hastalığı morbidite ve mortalite oranı yüksek bir kardiyovasküler hastalıktır. PAH'ın yönetiminde önleyici ve erken tanı girişimleri, medikal tedavi, yaşam tarzı değişiklikleri, girişimsel yöntemler ve cerrahi kullanılmaktadır. Sağlık profesyonelleri bireylerin ağrısının yönetiminde, amputasyonun önlenmesinde, amputasyon yapılması durumunda ise bireylerin rehabilitasyonunda önemli rol oynamaktadır.

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KRONİK HASTALIKLAR VE HEMŞİRELİK BAKIMI

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ÖZET

Kronik hastalıklar; genellikle bir yıl veya daha uzun süren, sürekli tıbbi müdahale/izlem gerektiren ve günlük yaşam aktivitelerini kısıtlayabilen durumlar olup, yaşam kalitesini azaltırken sağlık sistemlerinde maliyet ve kaynak kullanımını artıran önemli bir halk sağlığı yükü oluşturur. Bütünleşik (multidisipliner) bakım programları ile e-sağlık/tele-tıp uygulamalarının, öz bakım ve öz yönetimi destekleyerek bakım kalitesi ve hasta memnuniyetini artırabileceği vurgulanmaktadır. Epidemiyolojik olarak kronik hastalıklar küresel ölümlerin yaklaşık %74'ünden sorumludur; yükün büyük kısmı kardiyovasküler hastalıklar, kanserler, kronik solunum yolu hastalıkları ve diyabete bağlıdır. Diyabetle yaşayan erişkin sayısının 1980'lerden 2021'e belirgin arttığı ve astımın da yüksek hasta sayılarıyla seyrettiği bildirilmektedir. Korunmada, DSÖ verilerine göre her yıl yaklaşık 41 milyon ölümle ilişkili bu yükü azaltmak için birincil (risk azaltma), ikincil (tarama-erken tanı) ve üçüncül (komplikasyonları azaltma-rehabilitasyon) yaklaşımlar önerilmektedir. Yönetimde Chronic Care Model (CCM) özellikle "öz-yönetim desteğini" öne çıkarır; hemşireler eğitim, danışmanlık ve bakım koordinasyonu rollerini üstlenir. mSağlık uygulamaları öz izlemeyi destekleyerek öz yönetimi güçlendirebilir; ancak uygun araç seçimi ve hasta katılımı için hedefli eğitim ve multidisipliner destek gereklidir. Kronik hastalıklarda hemşirelik tanıları (örn. etkisiz sağlık yönetimi, aktivite intoleransı, beslenmede dengesizlik, anksiyete, enfeksiyon riski, bilgi eksikliği) bireyselleştirilmiş bakım planlamasına rehberlik eder.

Anahtar Kelimeler: Kronik hastalık, epidemiyoloji, korunma, hemşirelik bakımı, mSağlık.

1. GİRİŞ

Kronik hastalıklar, dünya çapında önemli ve giderek artan bir halk sağlığı sorunu olup, uzun süreli olmasının yanında sıklıkla işlevsel kısıtlamalar ve yaşam kalitesinde düşüşle karakterizedir. Dünya Sağlık Örgütü, kronik hastalıkları diyabet, kardiyovasküler hastalıklar ve kronik solunum yolu rahatsızlıkları gibi bir yıl veya daha uzun süren ve sürekli tıbbi müdahale gerektiren veya günlük yaşam aktivitelerini kısıtlayan durumlar olarak tanımlar (Holman, 2020). Bu rahatsızlıklar yalnızca bireylere değil, aynı zamanda sağlık sistemlerine de önemli bir yük getirir; çünkü kronik hastalıklar artan sağlık hizmetleri maliyetleri ve kaynak kullanımıyla ilişkilendirilmiştir(Vogeli ve ark., 2007). Kronik hastalıklar için bakımın bütünleştirilmesi, hasta sonuçlarını iyileştirmek ve bakım kalitesini geliştirmek için önemli bir strateji olarak vurgulanmıştır. Bütünleşik bakım programları, sağlık hizmeti sağlayıcıları arasındaki koordineli çabalar yoluyla birden fazla kronik durumun daha iyi yönetilmesine olanak tanıyan çeşitli sağlık hizmetlerini birleştirmeyi amaçlar (Martínez-González vd., 2014). Kanıtlar, bu tür bütünleşik multidisipliner bakım yaklaşımlarının kronik hastalığı olan hastalar için iyileştirilmiş yönetim ve sonuçlara yol açabileceğini göstermektedir (Yeung vd., 2016). Dahası, sistematik incelemeler, elektronik sağlık müdahalelerinin ve tele-tıbbın kullanımının kronik hastalığı olan hastalar arasında öz bakım ve öz yönetimi kolaylaştırabileceğini ve sonuç olarak bakım kalitesini ve hasta memnuniyetini artırabileceğini ileri sürmüştür (Hamine vd., 2015).

2. KRONİK HASTALIKLARIN EPİDEMİYOLOJİSİ

Kronik hastalıkların epidemiyolojisi, bu hastalıkların toplumda görülme sıklığını, dağılımını ve nedenlerini inceleyerek halk sağlığı stratejilerinin geliştirilmesine katkı sağlamaktadır (WHO, 2023). Yaygınlık ve Küresel Yük: Kronik hastalıklar dünya çapında önde gelen ölüm nedenini oluşturmakta ve küresel ölümlerin yaklaşık %74'ünü oluşturmaktadır (WHO, 2023). Dört ana kronik hastalık grubu (kardiyovasküler hastalıklar, kanserler, kronik solunum yolu hastalıkları ve diabetes mellitus) bu ölümlerin büyük kısmını oluşturmaktadır; erken ölümlerin %80'inden fazlası düşük-orta gelirli ülkelerde görülmektedir (WHO, 2023). Küresel eğilimler artışa işaret etmektedir; diyabetle yaşayan erişkin sayısı 1980'lerde ~108 milyondan 2021'de 537 milyona yükselmiştir (Sun vd. 2022). Kronik solunum yolu hastalıklarında, özellikle astımın küresel hasta sayısı ~262 milyon olarak bildirilmektedir. Bu epidemiyolojik değişim, yaşlanan nüfusa, kentleşmeye ve davranışsal risk maruziyetlerine yönelen demografik geçişi yansıtmaktadır (Abrami,2024). Yaş Dağılımı: Yaş, kronik hastalık epidemiyolojisinde kritik bir belirleyicidir; yaş ilerledikçe, immün yaşlanma ve değiştirilebilir risk faktörlerine uzun süre maruz kalma nedeniyle kronik hastalık riski artmaktadır (Çelik et al., 2022). Son yıllarda ergen ve genç yetişkinler arasında obezite, tip 2 diyabet ve hipertansiyon gibi kronik hastalıkların görülme sıklığında endişe verici bir artış yaşanmaktadır (Akcan et al., 2023). Dünya genelinde 70 yaş altındaki ölümlerin yaklaşık %18'i kronik hastalıklara atfedilmektedir; bu, hastalıkların geriatrik popülasyon dışında da önemli bir sağlık sorunu olduğunu göstermektedir (Bozkurt & Bozkurt, 2022). Ayrıca, metabolik risklerin nesiller arası aktarımı, anne obezitesi ve gebelik diyabeti gibi faktörler nedeniyle, bu konuda önleyici stratejilerin çocukluk döneminde başlaması gerektiği vurgulanmaktadır (Filiz, 2020). Risk Faktörleri: Kronik hastalıkların etiyolojisi, davranışsal, metabolik, çevresel ve genetik bileşenleri içeren çok faktörlü bir yapıya sahiptir. Özellikle tütün kullanımı, sağlıksız beslenme, fiziksel hareketsizlik ve zararlı alkol

tüketimi gibi değiştirilebilir risk faktörleri, erken kronik hastalık ölümlerinin yaklaşık %80'inden sorumlu tutulmaktadır (Otorkpa et al., 2024). Metabolik risk faktörleri olarak yüksek kan basıncı, hiperglisemi, hiperlipidemi ve obezite öne çıkmaktadır (Mbata et al., 2024). Bunun yanı sıra, sosyal belirleyiciler (eğitim, gelir, meslek ve bakıma erişim) kişisel maruziyetleri şekillendirerek yaşam kalitesini doğrudan etkilemektedir (Park et al., 2025). Yeni iklim ve sağlık ilişkisi, aşırı sıcaklıklar ve hava kirliliği gibi faktörlerin kardiyovasküler ve solunum yolu morbiditesini artırması ile dikkat çekmektedir (Thrisharika et al., 2025). Coğrafi Dağılım: Kronik hastalık örüntüleri, bölgesel farklılıklar göstermekte olup, Doğu Akdeniz, Batı Pasifik ve Güneydoğu Asya bölgelerinde bu hastalıkların artış hızının belirgin olduğu gözlemlenmektedir (Zhou et al., 2025). Yüksek gelirli ülkelerde, ölüm oranları düşerken, yaygınlık artmaktadır; Avrupa ise iskemik kalp hastalığı ve felç gibi hastalıkların öncelikli ölüm nedenleri olduğu bir bölge olarak öne çıkmaktadır (Belo et al., 2024). Toplum temelli tarama, aşılama ve yaşam tarzı değişiklikleri, kronik hastalık kontrol programlarının temel komponentlerini oluşturmaktadır (He et al., 2025).

3. KRONİK HASTALIKLARIN İNSİDANSI

Kronik hastalık (NCD) insidansı; belirli bir popülasyonda, tanımlı bir zaman aralığında **yeni** olgu sayısını ifade eder ve yaş, cinsiyet, göç, tanı ölçütleri ile tarama programlarındaki değişimlerden etkilenir. Güncel küresel yük çalışmalarında (GBD 2021), NCD'lerin insidans ve prevalans tahminleri yüz binlerce veri kaynağı birleştirilerek yaş-standartlaştırılmış oranlar ve belirsizlik aralıklarıyla raporlanmaktadır.(Bray ve ark, 2024). Kronik hastalıklar, küresel çapta baskın bir halk sağlığı sorunu haline gelmiş ve farklı demografik gruplarda hastalık ve ölüm oranlarını etkilemektedir. Genetik, çevresel ve yaşam tarzı faktörlerinin karmaşık etkileşimi, bu rahatsızlıkların görülme sıklığına ve yaygınlığına katkıda bulunmaktadır. Kardiyovasküler hastalık, diyabet ve kronik solunum yolu rahatsızlıkları da dahil olmak üzere çeşitli kronik hastalıklar, yaşam tarzı seçimleriyle doğrudan bağlantılıdır ve bu durum, halk sağlığında önleme stratejilerinin önemli rolünü vurgulamaktadır. Kronik hastalıkların artan görülme sıklığı yaşlanan nüfusla yakından ilişkilidir. Faner ve ark. tarafından belirtildiği gibi yaşlanma, kronik obstrüktif akciğer hastalığı (KOAH) ve idiyopatik pulmoner fibrozis (İPF) dahil olmak üzere çeşitli kronik rahatsızlıkların önemli bir korelasyonudur ve her ikisinin de yaşlı yetişkinlerde görülme sıklığı artmaktadır (Faner ve ark., 2012) . Ek olarak, kronik böbrek hastalığı (KBH) giderek yaygınlaşmakta ve bu durum, son dönem böbrek yetmezliğine önemli katkıda bulunan diyabet ve hipertansiyon gibi yaşam tarzı faktörleri ve yaşlanma süreciyle daha da kötüleşmektedir (Coogan ve ark., 2012). Bu demografik geçiş, yaşlı yaş gruplarında yaygın olan belirli risk faktörlerini ele alan, kişiye özel halk sağlığı politikalarına olan ihtiyacı vurgulamaktadır. Obezite ve metabolik sendrom, çeşitli kronik hastalıklar için kritik risk faktörleridir. Rao ve ark., metabolik sendrom ile kronik hastalıkların yaygınlığı arasında bir ilişki olduğunu ve bu sendromdan etkilenen bireylerde teşhis edilmemiş rahatsızlıkların ve gelecekte sağlık risklerinin daha yüksek oranlarda görüldüğünü ortaya koymuştur (Rao ve ark., 2014) . Metabolik sendromun belirlenmesi ve yönetilmesi, yaygın kronik sağlık sorunlarını potansiyel olarak hafifletebileceğinden, halk sağlığı açısından önemli sonuçlar doğurmaktadır. Çevresel faktörler, özellikle hava kirliliği, kronik hastalık görülme oranlarının artmasında da rol oynamaktadır. Coogan ve ark., hava kirleticilerine uzun süreli maruz kalma ile hipertansiyon ve tip 2 diyabet risklerinin artması arasındaki ilişkiyi vurgulamıştır (Coogan ve

ark., 2012). Bu kanıtlar, çevresel müdahalelerin bu hastalıkların görülme sıklığını azaltmada hayati bir rol oynayabileceğini göstermektedir.

4. KRONİK HASTALIKLARDA KORUMA

Kronik hastalıkların küresel artışı, sürdürülebilir sağlık sistemleri için önemli bir zorluk teşkil etmektedir. Dünya Sağlık Örgütü verilerine göre, her yıl yaklaşık 41 milyon ölüm bu hastalıklardan kaynaklanmaktadır (Faizan et al. 2025). Bu bağlamda, kronik hastalıkların etkilerini azaltmak amacıyla birincil, ikincil ve üçüncül önleme stratejisi geliştirilmiştir. Birincil önleme, patofizyolojik değişiklikler oluşmadan önce değiştirilebilir risk faktörlerini hedef alarak hastalığın başlangıcını önlemeyi amaçlar. Tütün kullanımı, sağlıksız beslenme ve fiziksel hareketsizlik gibi davranışları dikkate alarak yaşam tarzı değişiklikleri teşvik edilmektedir. Ayrıca, şekerli içecek vergileri gibi mali önlemler de obezite ve diyabet insidansında düşüş sağlayabilmektedir (Yalçın & Çelikayar, 2024; WHO, 2023). İkincil önleme, mevcut ama asemptomatik hastalıkların erken teşhisine odaklanmaktadır. Bu aşamada, tarama programları ve risk sınıflandırmaları büyük önem taşımaktadır. Örneğin, kan basıncı ve kolesterol taraması, diyabet için HbA1c testi gibi kanıta dayalı stratejiler, erken tanı ile komplikasyonların azaltılmasına yardımcı olmaktadır (Ertürk et al., 2024). Mobil sağlık (mHealth) uygulamaları ve yapay zeka destekli tarama sistemleri, hasta takibini ve bakımını kolaylaştırarak sağlık hizmetlerine erişimi artırabilir.Üçüncül önleme, kronik hasta bireylerde hastalık komplikasyonlarını azaltmayı amaçlamaktadır. Bu strateji, fiziksel rehabilitasyon ve yaşam kalitesinin artırılmasına odaklanmaktadır. Örneğin, diyabet yönetiminde sıkı glisemik kontrol, ayak bakımı eğitimi ve düzenli tarama, komplikasyonları azaltmaya yardımcı olmaktadır (Nakilcioğlu et al., 2025). Ayrıca, hemşirelerin ve sağlık çalışanlarının rolü, hasta eğitimini ve tedaviye uyumu artırmakta önemli bir yer tutmaktadır (İncirkuş, 2024). Dahası bu üç önleme yöntemi ile etkin bir kronik hastalık yönetimi stratejisi oluşturulması, hem bireylerin sağlığını önemli ölçüde artırmakta hem de sağlık sistemine olan yükü azaltmaktadır.

5. DÜNYADA KRONİK HASTALIKLARDAN KORUNMAYA İLİŞKİN ÇALIŞMALAR

Kronik hastalıkları önlemeye yönelik süregelen küresel zorluk, yaşam tarzı değişiklikleri, sağlık hizmetlerindeki iyileştirmeler ve sosyal müdahaleleri kapsayan çok yönlü stratejilerin entegrasyonunu gerektirmektedir. Araştırmalar, beslenme düzenlemeleri ve fiziksel aktivitenin artırılması da dahil olmak üzere yaşam tarzı değişikliklerinin kronik hastalıklarla ilişkili riskleri azaltmada etkili bir araç olarak kritik rolünü vurgulamaktadır. Örneğin, Akdeniz diyeti veya DASH gibi diyetleri benimsemek, kardiyovasküler hastalık risklerinin azalması ve daha iyi metabolik sağlık sonuçlarıyla ilişkilendirilmiştir (Alorayf ve ark., 2024). Ayrıca, düzenli fiziksel aktivitenin çok sayıda kronik rahatsızlığın görülme sıklığını azaltma ve böylece genel sağlığı iyileştirme kapasitesi bilinmektedir (Heneweer ve ark., 2011). Sağlık okuryazarlığı, kronik hastalıkların önlenmesi ve yönetimini etkileyen bir diğer önemli faktördür. Duda-Sikuła ve Kurpas, bireyler arasında sağlık okuryazarlığını artırmak ve bilinçli sağlık kararları almalarını sağlamak için etkili iletişim ve eğitim stratejilerinin gerekliliğini vurgulamaktadır (Duda-Sikuła ve Kurpas, 2023). Daha geniş bir ölçekte, sağlığın sosyal belirleyicilerini ele alan müdahaleler, kronik hastalıkları önleme potansiyelleri nedeniyle giderek daha fazla kabul görmektedir. Airhihenbuwa ve ark., sağlık eşitsizliklerine ve kronik

hastalık yüklerine katkıda bulunan sosyal ve toplumsal dinamikleri anlamanın önemini vurgulamaktadır (Airhihenbuwa ve ark., 2021). Kronik hastalıkların küresel yükü, farklı nüfuslar arasında sağlık hizmetlerine erişim ve kalitedeki eşitsizlikleri de yansıtmaktadır. Kronik solunum yolu hastalıkları, özellikle önleyici tedbirlerin yeterince uygulanmadığı yüksek gelirli ülkelerde önemli bir sağlık yükü olmaya devam etmektedir (Soriano vd., 2020). Bazı önleyici tedbirlerdeki önemli gelişmelere rağmen kronik solunum yolu hastalığı yaygınlığının artmaya devam ettiğini ve bunun devam eden zorluklara işaret ettiğini belirtmek önemlidir (Zhao vd., 2022). Dahası, dijital sağlık uygulamaları gibi ileri teknolojilerin sağlık yönetimine entegrasyonu, sağlık davranışlarını teşvik etmede ve öz izlemeyi mümkün kılmada etkili olduğunu göstererek kronik hastalık yönetimi çabalarını artırmaktadır. (Soriano ve diğerleri, 2020; Zhao ve diğerleri, 2022). Politika açısından, etkili önleme programlarının oluşturulmasına rehberlik etmek için kanıta dayalı çerçeveler gereklidir. Küresel Bulaşıcı Olmayan Hastalıklar Eylem Planı; davranışsal risk faktörlerinin toplum düzeyinde ele alınmasının ve sağlık alanında çok sektörlü yaklaşımların teşvik edilmesinin önemini vurgulamaktadır (Labonté vd., 2013). Mevcut stratejilerin sistematik değerlendirmeleri, etkili kronik hastalık önlemenin sağlık sonuçlarını iyileştirirken kamu sağlığı harcamalarını önemli ölçüde azaltabileceğini göstermektedir (Soriano vd., 2020).

6. TÜRKİYE KRONİK HASTALIKLARDAN KORUNMAYA İLİŞKİN ÇALIŞMALAR

Kronik hastalıklar, dünyada olduğu gibi Türkiye'de de morbidite ve mortalitenin en önemli nedenlerinden birini oluşturmaktadır. Özellikle kardiyovasküler hastalıklar, diyabet, kanser ve kronik solunum yolu hastalıkları, hem sağlık sistemine ekonomik yük getirmekte hem de toplumun yaşam kalitesini olumsuz etkilemektedir (Sevimli, 2021). Türkiye'de bulaşıcı olmayan hastalıkların artışında hızlı kentleşme, sedanter yaşam tarzı, tütün kullanımı, obezite ve yetersiz fiziksel aktivite gibi faktörler belirleyici rol oynamaktadır (Üner, Balcılar ve Ergüder, 2018). Bu durum, ülkemizde kronik hastalıkların önlenmesine yönelik çok sektörlü stratejilerin geliştirilmesini zorunlu kılmıştır. Türkiye Cumhuriyeti Sağlık Bakanlığı, "Türkiye Bulaşıcı Olmayan Hastalıklar ile Mücadele için Çok Sektörlü Eylem Planı (2017–2025)" kapsamında kronik hastalıklardan korunmaya yönelik politikaları bütüncül bir yaklaşımla ele almaktadır (WHO, 2016). Bu eylem planı; tütün kontrolü, sağlıklı beslenme, fiziksel aktivitenin teşviki, alkol kullanımının azaltılması ve obeziteyle mücadele gibi temel risk faktörlerine odaklanmaktadır. Plan aynı zamanda tarama ve erken teşhis programlarının geliştirilmesini, toplum temelli sağlık hizmetlerinin güçlendirilmesini ve kronik hastalık yönetiminde hemşirelik rollerinin genişletilmesini hedeflemektedir. Sağlık Bakanlığı'nın "Türkiye Sağlıklı Beslenme ve Hareketli Hayat Programı (2014–2017)" ve Türkiye Obezite ile Mücadele ve Kontrol Programı" uygulamaları, kronik hastalıklardan korunmada yaşam tarzı değişikliklerinin önemini vurgulamaktadır. Bu programlar, bireylerin günlük yaşamlarında fiziksel aktiviteye yer vermelerini, enerji dengesini korumalarını ve toplum düzeyinde sağlıklı yaşam bilincinin oluşturulmasını amaçlamaktadır (Kaçmaz, 2024). Ayrıca, "Türkiye Kalp ve Damar Hastalıklarını Önleme ve Kontrol Programı (2021–2026)", kardiyovasküler hastalıkların önlenmesine yönelik çok disiplinli bir çerçeve sunmaktadır. Program; hipertansiyon, hiperlipidemi ve diyabetin erken tanılanması, tedaviye uyumun artırılması ve

birinci basamak sağlık hizmetlerinde kronik hastalık izleminin güçlendirilmesini önceliklendirmektedir (Çalıkuşu, 2023). Epidemiyolojik düzeyde, "Türkiye Bulaşıcı Olmayan Hastalıklar ve Risk Faktörleri Kohort Çalışması (2017–2023)", 15 yaş üzeri nüfusta tütün, alkol, tuz tüketimi, fiziksel aktivite, vücut kitle indeksi ve kan basıncı gibi göstergelerin izlendiği kapsamlı bir veri tabanı oluşturmuştur (Üner, Balcılar ve Ergüder, 2018). Bu çalışma, ülke genelinde bulaşıcı olmayan hastalıkların yükünü azaltmaya yönelik kanıta dayalı politika üretimi açısından önemli bir kaynak niteliği taşımaktadır. Elde edilen veriler, kronik hastalıkların önlenmesinde bireysel davranış değişikliklerinin yanı sıra toplumsal, çevresel ve kurumsal düzeyde müdahalelerin gerekliliğini de göstermektedir. Türkiye'de kronik hastalıklardan korunmaya ilişkin politikaların başarısı, yalnızca ulusal eylem planlarıyla değil, aynı zamanda birinci basamak sağlık hizmetlerinin etkinliği, toplum temelli eğitim programlarının sürekliliği ve sağlık profesyonellerinin aktif katılımı ile yakından ilişkili olduğunu göstermektedir. Bu bağlamda, hemşireler birey ve toplum düzeyinde koruyucu sağlık hizmetlerinin yürütülmesinde, risk faktörlerinin erken tanılanmasında ve yaşam tarzı değişikliklerinin desteklenmesinde kritik roller üstlenmektedir. Özellikle kronik hastalık yönetiminde hemşirelerin danışmanlık, eğitim ve izlem rollerinin güçlendirilmesi, ulusal sağlık politikalarının sürdürülebilirliğini artırmaktadır (Çalıkuşu, 2023; Sevimli, 2021). Bu yüzden Türkiye'de kronik hastalıklardan korunmaya yönelik yürütülen çalışmaların ortak hedefi, bireylerin sağlıklı yaşam davranışlarını benimsemesini sağlamak ve önlenebilir risk faktörlerini azaltmaktır. Sağlık Bakanlığı öncülüğünde yürütülen çok sektörlü eylem planları ve toplum temelli projelerin devam etmesi, politikaların sürdürülebilirliği, toplumsal farkındalık, sağlık okuryazarlığı ve multidisipliner iş birliği ile mümkün olacaktır.

7. KRONİK HASTALIKLAR YÖNETİMİ

Kronik hastalık yönetiminde en çok başvurulan çerçevelerden biri Chronic Care Model (CCM)'dir. Bu model; toplum kaynakları ve politikalar, karar destek sistemleri, sağlık bakım örgütlenmesi, öz-yönetim desteği, hizmet sistemi tasarımı ve klinik bilgi sistemlerinden oluşmaktadır(İncirkuş&Nahcivan;2015). Araştırmalar göstermektedir ki, bu modelin bileşenlerinden "öz-yönetim desteği" (self-management support) özellikle hasta düzeyinde sonuçlarda (yaşam kalitesi, işlevsellik gibi) anlamlı iyileşmelerle ilişkilidir(Reynolds et al. 2018). Sosyoekonomik durum da öz yönetim ve işsizlik yönetimi üzerinde önemli bir etkiye sahiptir. Araştırmalar, yüksek gelire sahip olacak sağlık hizmetlerine katılmada daha aktif analiz ve sağlık alımında daha etkin olanları göstermektedir (Dilekçi ve Aşiret, 2025; Bektaş ve Uysal, 2024). Bu nedenle, sağlık politikalarının oluşumu sosyoekonomik durum göz önünde bulundurulmalı, düşük gelirli bireylere özel destek programları geliştirilmelidir (Doğan ve Tamer, 2024). Ayrıca hasta aktifliğini artırmak için hastaların, hastalıkları ile ilgili sorumluluk almaları ve tedavilere dahil edilmesi gerekmektedir (Dilekçi ve Aşiret, 2025; Bektaş ve Uysal, 2024).

8. KRONİK HASTALIKLAR YÖNETİMİNDE HEMŞİRELERİN ROLÜ

Kronik hastalık yönetiminde hemşirelerin rolü, geleneksel akut bakımın ötesine geçerek çok boyutlu bir yaklaşım geliştirmektedir. Hemşireler, öz-yönetim davranışlarının teşvik edilmesinde ve sürdürülebilirliğinde merkezi bir fonksiyon üstlenmektedirler. Sürekli sağladıkları destek sayesinde bireylerin öz-yeterlikleri artmakta, tedaviye uyumları

güçlenmekte ve sağlık sonuçları iyileşmektedir (Umeano, 2023; Al Aateibi et al., 2024). Hemşireler, proaktif ve önleyici bir bakım modeli benimseyerek kronik hastalıkların yönetiminde önemli bir rol oynamaktadırlar (Dufour et al., 2023). Ayrıca, hemşireler meslekler arası ekiplerin içinde bakım koordinatörü olarak görev yapmaktadırlar. Bu çerçevede, sağlık hizmetleri arasındaki yönlendirmelerin kolaylaştırılması, hastaların değerlendirilmesi ve biyopsikososyal belirteçlerin izlenmesi gibi önemli işlevleri bulunmaktadır (Alanazi et al., 2024). Hemşirelik uygulamaları, ilaç yönetimi ve yaşam tarzı danışmanlığı gibi çok disiplinli yaklaşımlar gerektiren alanlarda bütünleşik destek sunmaktadır (Al Aateibi et al., 2024). Dahası hasta eğitimi, hemşirelerin üstlendiği kritik bir alandır ve bireysel şartlara uygun eğitim programları oluşturarak hastaları hedef belirleme ve davranış değişikliği süreçlerine dahil etmektedirler (Bashir, 2020). E-sağlık ve mobil sağlık teknolojilerinin kullanımında da hemşireler, sanal bakım yöntemleri ile hizmet sunumunu destekleyerek etkili bir rol üstlenmektedirler (Alqaflah et al., 2024). Son olarak, hemşireler toplum sağlığı yönetimi ve risk azaltma süreçlerine doğrudan katkıda bulunarak hipertansiyon, obezite ve diyabet gibi risk faktörlerinin taranmasında ve sağlıklı yaşam biçimlerinin teşvik edilmesinde aktif rol almaktadırlar. Bu durum, hemşirelerden gelen kanıta dayalı uygulamaların geliştirilmesine ve sağlık sistemlerinde yenilikçi liderlik rollerinin üstlenilmesine olanak tanımaktadır (Bashir, 2020; Kamdem et al., 2025).

9. HEMŞİRELİK TANILARI

Hemşirelik tanıları; bireyin mevcut sağlık sorunlarını, potansiyel riskleri ve sağlıkla ilgili güçlerini sistematik biçimde belirleyerek hemşirelik bakımının temelini oluşturmaktadır. Kronik hastalıklarda en sık karşılaşılan hemşirelik tanıları, bireyin hastalığa uyum süreci, tedaviye uyum, yaşam biçimi değişikliği ve öz yönetim becerileriyle yakından ilişkilidir (Herdman et al., 2024).

Etkisiz Sağlık Yönetimi: Kronik hastalıklarda bireylerin tedavi planına uyum gösterememesi, ilaç dozlarını karıştırması veya yaşam tarzı değişikliklerini sürdürememesi sık rastlanan bir durumdur. Hemşire, hastanın öz yönetim becerilerini değerlendirir, eğitim ve motivasyonel destek sağlamaktadır.

Aktivite İntoleransı: Kalp yetmezliği, KOAH veya diyabet gibi durumlarda görülen yorgunluk, efor kapasitesinde azalma ve dispne nedeniyle birey günlük aktiviteleri sürdüremeyebilir. Bu tanı, rehabilitasyon ve enerji yönetimi planlamasında temel oluşturmaktadır.

Beslenmede Dengesizlik: Özellikle diyabet, obezite ve metabolik sendrom gibi durumlarda enerji alımı ile harcaması arasındaki dengesizlik belirgindir. Hemşireler, bireye uygun diyet planı, beslenme eğitimi ve izlem programları geliştirmektedir.

Beden İmajında Bozulma: Amputasyon, diyaliz kateteri, stomalar veya obeziteye bağlı görünüm değişiklikleri bireyde psikososyal uyumsuzluk oluşturabilmektedir. Hemşire, destekleyici danışmanlık ve psikososyal yönlendirme sağlamaktadır.

Korku ve Anksiyete: Kronik hastalık tanısı, bireyde belirsizlik, ölüm korkusu veya bağımlılık endişesi oluşturabilir. Hemşire, etkili iletişim, gevşeme teknikleri ve destek sistemlerini kullanarak bireyin emosyonel uyumunu desteklemektedir.

Yetersiz Baş Etme: Kronik hastalık sürecinde stres, ekonomik yük, aile içi rol değişiklikleri gibi faktörler bireyin baş etme becerilerini zayıflatabilir. Hemşire, problem çözme ve sosyal destek ağlarını güçlendirmeye yönelik stratejiler uygulamaktadır.

Enfeksiyon Riski: Diyabet, immünsüpresyon, invaziv girişimler veya bası yaraları nedeniyle enfeksiyon riski yüksektir. Hemşire, aseptik teknik, yara bakımı ve erken belirti takibi ile koruyucu rol üstlenmektedir.

Bilgi Eksikliği: Tedavi rejimi, ilaç kullanımı veya hastalığın seyri hakkında yetersiz bilgi, yanlış uygulamalara neden olabilmektedir. Bu yüzden hemşire, eğitim planlarını bireyin öğrenme düzeyi ve kültürel özelliklerine göre uyarlamaktadır.

Hemşirelik tanıları, kronik hastalık yönetiminde hastanın yaşam deneyimi ile hemşirenin bakım planı arasında bir köprü oluşturarak müdahalelere yön vermekte, bakımın belgelenmesini ve ekip içi iletişimi kolaylaştırmakta, ayrıca sonuçların değerlendirilmesini desteklemektedir.

10. KRONİK HASTALIKLAR YÖNETİMİNİ GELİŞTİRMEYE YÖNELİK BAKIM STRATEJİLERİ

Kronik hastalık yönetimi, sağlık hizmetlerinin temel bir unsurudur ve hasta sonuçlarını iyileştirmek için yenilikçi stratejiler gerektirir. Mobil sağlık (mSağlık) uygulamalarının kullanımı, kronik rahatsızlıkları olan bireyler arasında öz yönetim davranışlarını iyileştirmek için önemli bir yöntem haline geldiği bilinmektedir. Öz yönetim hayati önem taşımaktadır, çünkü araştırmalar daha iyi sağlık sonuçları ve daha düşük sağlık hizmeti maliyetleriyle ilişkili olduğunu göstermektedir (Wang vd., 2021; Cheah vd., 2024). mSağlık cihazları, kullanıcıların kilo, kan basıncı ve beslenme alışkanlıklarını takip etmek gibi öz izleme faaliyetlerine katılmalarına olanak tanıyarak, kişisel sağlık hizmetlerine aktif katılımı etkili bir şekilde teşvik etmektedir(Cheah vd., 2024). Sistematik bir inceleme, değerlendirilen mSağlık uygulamalarının %83'ünün bulaşıcı olmayan hastalıkların uzun vadeli yönetimi için gerekli olan öz izlemeyi destekleyen özellikler içerdiğini göstermektedir (Cheah vd., 2024). Dahası, mSağlık uygulamalarının etkili kullanılabilirliği ve etkileşimi, hastaların öz yönetim protokollerine uyumunu büyük ölçüde etkilemektedir(Sneha vd., 2021). Bu durum, kullanıcıların davranış kalıpları ve tercihleriyle uyumlu, mSağlık araçları için düşünceli bir tasarım çerçevesinin gerekliliğini vurgular ve bu da uyum oranlarını potansiyel olarak artırabilmektedir (Choi vd., 2017). İlerlemelere rağmen, etkili uygulamanın önündeki bazı engeller varlığını sürdürmektedir. Araştırmalar, önemli bir zorluğun, genellikle hastalık yönetiminin önemi konusunda yetersiz eğitimle bağlantılı olan öz yönetim uygulamalarına hasta katılımının eksikliği olduğunu ortaya koymaktadır (Song vd., 2021; , Kruse vd., 2016). Mevcut sağlık uygulamalarının çokluğu da hastalar için kafa karıştırıcı bir ortam yaratmış ve uygun araçları seçme becerilerini zorlaştırmaktadır (Sneha vd., 2021; Choi vd., 2017). Bu nedenle, hastaların öz yönetimin önemini anlamalarına yardımcı olmak için hedefli sağlık eğitimi ve motivasyon stratejileri esastır, çünkü bunlar iyileştirilmiş sağlık sonuçlarına yol açabilmektedir (Hamine vd., 2015). Dahası, diyabet eğitimcileri ve vaka yöneticileri gibi destekleyici ekip üyelerini içeren çok disiplinli bir yaklaşımın entegre edilmesi, kronik hastalık yönetimi platformları için hayati önem taşımaktadır (Alotaibi vd., 2023; Lehnbom vd., 2009). Bu tür entegre bakım girişimleri, kronik hastalık yönetiminin kalitesi üzerinde olumlu etkiler göstermiştir ve mSağlık teknolojilerinin klinik ortamlarda etkili kullanımını

kolaylaştırmaktadır (Wootton, 2012). Son olarak, kronik hastalıkların yönetiminde öz yeterliliği geliştirmek için hasta aktivasyonunu ve katılımını sağlayan çerçeveler gereklidir. Bu çerçeveler, çeşitli hastaların bireysel ihtiyaçlarını karşılamak üzere tasarlanmış mSağlık platformları aracılığıyla sunulan sağlık eğitimini kapsayabilir ve sonuçta kronik hastalık sonuçlarında iyileşme sağlayabilir (Marcolino vd., 2018; Schmaderer vd., 2021). mSağlık uygulamalarının, eğitim stratejilerinin ve disiplinler arası katılımın kapsamlı entegrasyonu, çeşitli sağlık sistemlerinde kronik hastalık yönetimini ilerletmek için güçlü bir yaklaşım sunmaktadır.

11. SONUÇ

Kronik hastalıkların yönetiminde hemşireler, yalnızca bakım veren değil; eğitimci, koordinatör ve savunucu rollerle sürecin merkezinde yer almaktadırlar. Hemşirelik tanıları, hastanın yaşam deneyimi ile hemşirenin profesyonel bakım planı arasında etkili bir köprü kurarak, bireyselleştirilmiş ve bütüncül bakımın temelini oluşturmaktadır. Bu yaklaşım, öz-yönetim becerilerinin geliştirilmesi, yaşam kalitesinin artırılması ve komplikasyonların azaltılmasına önemli katkı sağlamaktadır.

Öneriler

- Kronik hastalık yönetiminde kanıta dayalı hemşirelik uygulamalarının yaygınlaştırılması,
- Dijital sağlık ve tele-sağlık teknolojilerinin etkin biçimde entegrasyonu,

Birinci basamak sağlık hizmetlerinde hemşirelerin danışmanlık ve eğitim rollerinin güçlendirilmesi önerilmektedir

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KRONİK OBSRÜKTİF AKCİĞER HASTALIĞI(KOAH) VE HEMŞİRELİK BAKIMI

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ÖZET

Kronik obstrüktif akciğer hastalığı (KOAH), dünya genelinde morbidite ve mortalitenin önde gelen nedenleri arasında yer almakta olup etkili yönetim stratejileri gerektirmektedir. KOAH yönetiminde hemşireliğin rolü; öz-yönetim eğitimi, semptom kontrolü ve destekleyici bakımın entegrasyonu üzerinden hasta yaşam kalitesini artırmaya odaklanır. Tanı sürecinde klinik semptomlar ve risk öyküsü temel ipuçlarıdır; kesin tanıda spirometri zorunlu olup post-bronkodilatör FEV1/FVC oranının 0,70'in altında olması hava akımı kısıtlılığını gösterir. KOAH'ın bütüncül tedavisi; risk etmenlerinin azaltılması ve hasta eğitimi/öz-yönetim desteğine ek olarak kanıta dayalı farmakolojik tedavi, uygun olgularda cerrahi veya bronkoskopik girişimler ve multidisipliner pulmoner rehabilitasyonu kapsar. Yönetimde farmakolojik tedavi, sigara bırakma girişimleri, oksijen tedavisi, pulmoner rehabilitasyon ve yaşam tarzı düzenlemeleri birlikte ele alınmalıdır. Hemşirelik bakımının temel bileşenleri; semptom değerlendirmesi, inhaler tekniğinin doğru uygulanması, sekresyon yönetimi, alevlenmenin erken tanınması, sigara bırakma danışmanlığı ve öz-bakım becerilerinin desteklenmesidir.

Anahtar Kelimeler: KOAH, hemşirelik bakımı, spirometri, öz-yönetim, pulmoner rehabilitasyon.

1. GİRİŞ

Kronik obstrüktif akciğer hastalığı (KOAH), dünya çapında önde gelen bir morbidite ve mortalite nedeni olmaya devam etmekte ve hasta sonuçlarını iyileştirmek için etkili yönetim stratejileri gerektirmektedir. KOAH yönetiminde hemşireliğin rolü çok yönlüdür ve etkilenen hastaların yaşam kalitesini (YK) artırmada hayati önem taşıyan öz yönetim eğitimi, semptom kontrolü ve destekleyici bakım modellerinin entegrasyonunu vurgulamaktadır(Aranburu-Imatz et al., 2022). Hemşirelerin liderliğindeki öz yönetim müdahalelerinin etkisini vurgulayan önemli kanıtlar bulunmaktadır. Araştırmalar, hemşire liderliğindeki öz yönetim programlarının, KOAH hastalarına semptomlarını yönetmeleri ve yaşam tarzı değişiklikleri yapmaları için gerekli araç ve bilgiyi sağlayarak onları güçlendirebileceğini ve böylece sağlık durumlarında çeşitli iyileşmelere yol açabileceğini göstermektedir (Helvaci & Metin, 2020). Hemşirelik bakımı, KOAH'ın yönetiminde kritik bir rol oynamaktadır. Sağlık eğitimi, psikolojik destek ve klinik bozulmanın erken teşhisi dahil olmak üzere bir dizi uygulamayı kapsamaktadır(Bentsen et al., 2012). Çalışmalar, hemşire liderliğindeki müdahalelerin, öz yönetim becerilerini ve tedavi rejimlerine uyumu iyileştirerek hasta sonuçlarını önemli ölçüde iyileştirdiğini göstermektedir. Örneğin, sistematik bir inceleme, hastaları durumları ve ilaç uyumunun önemi hakkında eğitmeyi içeren hemşirelik müdahalelerinin, normal bakıma kıyasla daha iyi sağlık sonuçlarıyla sonuçlandığını gösterdiği bilinmektedir (Aranburu-Imatz et al., 2022).

2. KOAH EPİDEMİYOLOJİSİ

Kronik obstrüktif akciğer hastalığı (KOAH), Dünya Sağlık Örgütü (DSÖ) verilerine göre 2021 yılında yaklaşık 3,5 milyon ölüme yol açarak dünya genelinde dördüncü önde gelen ölüm nedeni konumundadır (WHO, 2024). DSÖ'nün daha önceki projeksiyonlarında ise KOAH'ın 2030 yılında ölüm nedenleri arasında üçüncü sıraya yükselmesi beklenmektedir. Hastalık yükünün değerlendirilmesinde kullanılan engellilik ayarlı yaşam yılı (DALY) ölçütüne göre KOAH, dünya genelinde en sık sakat bırakan hastalıklar arasında 13. sırada**,** Türkiye'de ise 11. sırada yer almaktadır (Çelik, Dikmen, & Babayiğit, 2021). KOAH'ın küresel yükü, görülme sıklığı ve yaygınlık istatistikleriyle örneklendirilmektedir. KOAH epidemiyolojisi, dünya genelinde farklı popülasyonlarda artan hastalık yüküne yol açan çevresel, genetik ve yaşam tarzı faktörlerinin karmaşık bir etkileşimini ortaya koymaktadır(Liu et al., 2025)

3. KOAH ETİYOLOJİSİ

Kronik Obstrüktif Akciğer Hastalığının etyolojisi multifaktöriyel bir yapı göstermekte olup; çevresel maruziyetler, genetik yatkınlık ve bireysel özelliklerin etkileşimi sonucunda ortaya çıkmaktadır (Sutradhar et al., 2019; Pıhtılı et al., 2021). Hastalığın en baskın nedeni, tütün ürünlerine uzun süreli maruziyet olduğu bilinmektedir. Sigara kullanımı, KOAH olgularının %85–90'ını oluşturmakta, hem aktif hem de pasif içicilik hava yolu inflamasyonunu artırarak hastalık riskini belirgin şekilde yükseltmektedir (Beşir et al., 2012; Bondonno et al., 2022). Tütün dumanındaki toksik partiküller mukosiliyer klirensi bozmakta, epitel bütünlüğünü zayıflatmakta ve kronik inflamatuvar yanıtı tetiklemektedir (Çelik, Dikmen, & Babayiğit, 2021). Tütün dumanına ek olarak, özellikle düşük ve orta gelirli ülkelerde yaygın biçimde kullanılan biyoyakıtların kapalı alanlarda yakılması, KOAH için önemli bir çevresel risk faktörü oluşturmaktadır. Odun, tezek ve kömür gibi biyoyakıtların yanması sonucu ortaya çıkan

yoğun duman, yetersiz havalandırma ile birleştiğinde alveoler düzeyde hücresel hasara yol açmakta ve solunumsal fonksiyonları olumsuz etkilemektedir (Arslan Çilhoroz & Mansur, 2023; Ortiz-Quintero et al., 2022; Siddharthan, et al., 2018). Mesleki maruziyetler de KOAH etyolojisinde önemli bir yer tutmaktadır. Tarım, madencilik, inşaat ve metal işleme gibi sektörlerde çalışan bireylerin toz, kimyasal gazlar ve metal dumanlarına uzun süre maruz kalmaları, kronik inflamasyonu ve hava yolu yeniden yapılanmasını tetikleyerek KOAH riskini artırmaktadır (Safiri et al., 2022). Bu mesleki faktörlerin etkisi, tütün kullanımının eşlik ettiği durumlarda daha da belirginleşmektedir. Genetik faktörler arasında, alfa-1 antitripsin (A1AT) eksikliği KOAH ile ilişkilendirilen en güçlü bozukluk olarak tanımlanmaktadır. A1AT eksikliği elastaz aktivitesinin artmasına neden olarak alveoler duvarlarda geri dönüşümsüz hasara yol açmakta; özellikle sigara içen bireylerde hastalık gelişimini hızlandırmaktadır (Toumpanakis, 2023; Tural Onur et al., 2023). Bunun yanında, erken çocukluk döneminde geçirilen alt solunum yolu enfeksiyonları, prematürite, düşük doğum ağırlığı, astım öyküsü, ileri yaş, düşük sosyoekonomik düzey ve yetersiz beslenme gibi faktörler akciğer gelişimini ve solunumsal rezervleri etkileyerek hastalığa yatkınlığı artırmaktadır (Cai et al., 2020).

4. KOAH FİZYOPATOLOJİSİ

KOAH'ın patogenezinde iki temel fizyopatolojik süreç öne çıkmaktadır: kronik bronşit (küçük hava yolu inflamasyonu ve mukus hipersekresyonu ile ilişkili obstrüksiyon) ve amfizem (alveoler duvar yıkımı ile karakterize parankimal hasar) (Çelik, Dikmen, & Babayiğit, 2021). KOAH'ta hava yolu yeniden şekillenmesi, hava yolu duvarlarının kalınlaşması, hücre dışı matris birikiminin artması ve hava yolu düz kas fonksiyonunda değişiklikler gibi yapısal değişikliklerle karakterize edildiği bilinmektedir. Araştırmalar, FGF-1 ve FGF-2 gibi büyüme faktörlerinin ekspresyonunda da görüldüğü gibi, fibroblast aktivasyonunun bu yeniden şekillenme süreçlerinde temel bir rol oynadığını göstermektedir(Zhang et al., 2020). Bu bağlamda, özellikle dönüştürücü büyüme faktörü-beta (TGF-β) yolu çok önemlidir; fibroblast aktivasyonuna ve ardından kolajen birikimine katkıda bulunur ve bu da topluca hava yolu daralmasını ve akciğer parankiminde elastikiyet kaybını kolaylaştırmaktadır (Larsson-Callerfelt et al., 2013; Wang et al., 2019). Ayrıca, VEGF ve matriks metalloproteinazlar gibi çeşitli biyokimyasal aracıların bu yeniden şekillenme süreçlerini düzenlediği belirlenmiştir; bu da KOAH'ta inflamatuar ve yapısal hücreler arasında karmaşık bir etkileşimi göstermektedir (Zhang et al., 2020). KOAH'ın patofizyolojik evrimi, sürekli inflamatuar süreçle doğrudan bağlantılı olan alveol yıkımı ve hava boşluklarının genişlemesiyle karakterize edilen amfizemi de içermektedir. Amfizem tipik olarak sigara dumanı ile şiddetlenir ve alveol duvarlarına zarar veren proteolitik enzim aktivitesinin artmasına yol açmaktadır (Yang et al., 2021). Önemli olarak, KOAH modelleri üzerinde yapılan çalışmalar, inflamasyonu ve yapısal yeniden yapılanmayı hedefleyen terapötik stratejilerin hastalık ilerlemesini yavaşlatabileceğini ve akciğer fonksiyonunu iyileştirebileceğini ortaya koymaktadır (Richmond et al., 2016).

5. KOAH BELİRTİ VE BULGULARI

KOAH'ın başlıca semptomları arasında öksürük, balgam üretimi, nefes darlığı (dispne) ve hırıltı bulunur ve hastalık ilerledikçe bu semptomlar giderek şiddetlendiği bilinmektedir. Özellikle, en rahatsız edici semptomlardan biri olarak sıklıkla bildirilen nefes darlığı, yaşam kalitesini ve günlük işlevleri önemli ölçüde etkilemektedir (Lee et al., 2020). Öksürük ve balgam üretimi,

KOAH'ın tipik erken belirtileridir ve hastaların daha ciddi solunum güçlüğü başlamadan önce bu semptomları gösterebileceğini düşündürmektedir. KOAH'ta öksürük semptomu genellikle mukus üretimiyle ilişkilidir ve bu da hava yolu iltihabı ve tıkanıklığıyla bağlantılı olduğu bilinmektedir (Mebrahtom et al., 2024). Bu semptomları yaşayan hastalar, akciğer fonksiyonunu ve genel sağlığı daha da kötüleştirebilen akut kötüleşme atakları olan alevlenmeler açısından daha yüksek risk altında olduğu bilinmektedir. Ayrıca, uzunlamasına yapılan çalışmalar, gece nefes darlığı gibi gece semptomlarının gelecekteki alevlenme riskinin artmasıyla ilişkili olduğunu göstermektedir(Miravitlles & Feliu, 2017). Dahası, KOAH'ın semptomatolojisi değişkenlik gösterebilir ve bu da hastalar arasında farklı deneyimlere yol açabilmektedir. Bazıları belirgin hırıltı ve göğüs sıkışması yaşarken, diğerleri ana şikayetleri olarak kronik öksürük ve balgam üretimini bildirmektedir (JOHNSON et al., 2018). Bu nedenle, semptomların heterojenliği, tedavi ve yönetime kişiselleştirilmiş yaklaşımları gerektirir ve etkilenen bireyler için en uygun bakımı sağlamak üzere hedefli tedavi stratejilerine duyulan ihtiyacı vurgulamaktadır (Mebrahtom et al., 2024).

6. KOAH TANISI

Kronik Obstrüktif Akciğer Hastalığı (KOAH) tanısı, klinik semptomlar, risk faktörlerine ilişkin ayrıntılı öykü ve objektif solunum fonksiyon testlerinin birlikte değerlendirilmesi ile konulmaktadır. Hastalarda kronik öksürük, balgam çıkarma, dispne, efor kapasitesinde azalma ve zararlı partiküllere maruziyet öyküsü tanı için temel ipuçlarıdır (Arslan Çilhoroş & Mansur, 2023; Chen et al., 2025). KOAH'ın kesin tanısında spirometri zorunlu olup, post-bronkodilatör FEV1/FVC oranının 0.70'in altında olması hava akımı kısıtlılığını göstermektedir. Hastalığın şiddeti ise beklenen FEV1 değerinin yüzdesine göre sınıflandırılmaktadır (Cai et al., 2020). Chen et al., 2025). Radyolojik incelemeler tanıda destekleyici rol oynamaktadır. Akciğer grafisi özellikle alternatif tanıları ekarte etmekte kullanılırken, ileri evrelerde hiperinflasyon bulguları görülebilir. Yüksek çözünürlüklü bilgisayarlı tomografi (HRCT), amfizem şiddetinin değerlendirilmesinde ve ayırıcı tanıda yüksek duyarlılık sağlamaktadır (Wang et al., 2023; Dai et al., 2023). KOAH'ın klinik değerlendirmesinde, eşlik eden komorbiditelerin ve alevlenme şiddetinin tespiti amacıyla hemogram, C-reaktif protein (CRP) ve alfa-1 antitripsin düzeylerini içeren standart laboratuvar analizleri kullanılmaktadır. Özellikle CRP gibi biyobelirteçler, KOAH alevlenmelerinin şiddeti ve altta yatan enfeksiyon varlığı hakkında bilgi sağlamaktadır. Ayrıca etiyolojik ve yapısal ayırıcı tanıda ise astım, bronşektazi, konjestif kalp yetmezliği (KKY), interstisyel akciğer hastalıkları (İAH) ve eski tüberküloz sekelleri mutlaka değerlendirilmelidir (Waeijen-Smit et al., 2023; Tural Onur et al., 2023).).

7. KOAH TEDAVİSİ

KOAH'ın bütüncül tedavisi; başta tütün kullanımı olmak üzere risk etmenlerinin azaltılmasına yönelik girişimler ve hasta eğitimi/öz-yönetim desteği ile birlikte, kanıta dayalı farmakolojik tedaviyi, uygun seçilmiş ileri olgularda cerrahi (ör. akciğer volüm azaltıcı cerrahi, büllektomi, akciğer nakli) veya bronkoskopik girişimleri ve multidisipliner pulmoner rehabilitasyon programlarını kapsamaktadır(NICE, 2019). KOAH tedavisi, inhalasyon yoluyla uygulanan kortikosteroidler (ICS), uzun etkili beta-agonistleri (LABA) ve uzun etkili muskarinik antagonistleri (LAMA) içeren kombinasyon tedavilerinin ortaya çıkmasıyla önemli ölçüde geliştiği görülmektedir. Bu ilaçlar, kronik semptomları hafifletmeye ve daha şiddetli hastalığı

olan hastalarda alevlenme ve ölüm riskini azaltmaya hizmet etmektedir. (Zheng et al., 2018; Zayed et al., 2019) .

8. KOAH İÇİN SIK KULLANILAN HEMŞİRELİK TANILARI

Kronik Obstrüktif Akciğer Hastalığı (KOAH), solunum fonksiyonlarında kalıcı ve ilerleyici bir bozulmaya yol açması nedeniyle hemşirelik bakımında kapsamlı, bütüncül ve çok boyutlu bir yaklaşım gerektirmektedir. Bu doğrultuda, KOAH'lı bireylerde sıkça karşılaşılan temel hemşirelik tanılarından bazıları aşağıda sunulmuştur (Neşe 2023: NurseLabs, 2024).

1. Aktivite İntoleransı: Dispnenin fiziksel hareketsizliğe ve egzersiz intoleransına neden olması; yorgunluğun ve solunum sıkıntısının eforu minimum düzeye indirmeye zorlaması.

Hemşirelik Girişimi: Hastayı pulmoner rehabilitasyon programlarına yönlendirmek. Egzersiz eğitimi ile fiziksel gücü artırmak ve dispneyi azaltmak.

2. Etkisiz Solunum Deseni: Hava hapsine bağlı hiperinflasyonun inspiratuar kapasiteyi azaltması ve solunum kas fonksiyonunu bozması.

Hemşirelik Girişimi: Büzük dudak solunumu ve diyafragmatik solunum tekniklerini öğretmek ve uygulatarak ventilasyon mekaniklerini iyileştirmek.

3. Kaygı/Anksiyete: Dispnenin yaşamı tehdit eden bir semptom olarak algılanması, hastalık progresyonu ve alevlenme korkusu.

Hemşirelik Girişimi: Progresif Gevşeme Egzersizlerini (PGE) öğretmek ve uygulatarak anksiyete, stres ve kas gerginliğini azaltmak. Hastaya psikososyal destek sağlamak.

4. Enfeksiyon Riski: Akut alevlenmelerin çoğunun solunum yolu enfeksiyonları tarafından tetiklenmesi.

Hemşirelik Girişimi: Hastalara influenza ve pnömokok aşılarını almalarını önermek. Steroidli inhaler kullanımı sonrası ağız bakımının önemini vurgulamak. Balgam renginde değişim gibi enfeksiyon belirtilerinde hekime başvurma konusunda eğitim vermek.

5. Bilgi Eksikliği / Etkisiz Bireysel Sağlık Yönetimi: Hastaların basınç ölçülü doz inhalerleri etkin kullanamaması, tedaviye uyum güçlüğü ve sigarayı bırakmada zorlanmaları.

Hemşirelik Girişimi: İlaçların doğru teknikle ve doğru dozda alınıp alınmadığını kontrol etme ve demonstrasyon yoluyla öğretme. Sigarayı bırakmanın önemini sürekli iletişimle vurgulamak ve yöntemleri hastaya açıklamak.

6. Gaz Değişiminde Bozulma: Amfizem ve parankimal yıkımın gaz transfer kapasitesini azaltması sonucu hipoksemi ve hiperkapni gelişmesi. Anormal ABG değerleri, siyanoz, kafa karışıklığı ve huzursuzluk gibi bulgular hipoksi ve CO_2 retansiyonu ile ilişkilidir.

Hemşirelik Girişimi: Hastada gaz değişimi bozukluğunu erken tanımak için yakın izlem yapılır; oksijen tedavisi hekim istemine göre uygulanarak etkisi değerlendirilir. Hiperventilasyon veya solunum depresyonu belirtileri dikkatle takip edilir. Siyanoz, bilinç değişikliği gibi semptomların kötüleşmesi halinde hızlı müdahale süreci başlatılır. Ayrıca solunum egzersizleri uygulanarak oksijenlenmenin artırılması desteklenir.

7. Hava Yolu Temizliğinde Yetersizlik: Kronik öksürük ve balgam üretimi KOAH'ın temel bulgularındandır. Mukusun yeterince atılamaması, akciğerlerde sekresyon birikimine ve tıkanma riskinin artmasına yol açar. Oskültasyonda ronküs, hırıltı ve çatırtı gibi anormal sesler bu durumu doğrular.

Hemşirelik Girişimi: Hastaya etkili öksürme teknikleri öğretilir ve bu teknikleri doğru uygulaması desteklenir. Gereksinim halinde postüral drenaj ve perküsyon uygulamalarına yardımcı olunur. Sıvı alımının artırılmasına yönelik eğitim verilerek sekresyonların incelmesi sağlanır. Nebülizasyon ve inhaler tedavilerin doğru uygulanıp uygulanmadığı değerlendirilir. Balgam miktarı ve rengi düzenli olarak izlenir; enfeksiyon bulgularının gelişmesi halinde hastaya hekime başvurma konusunda rehberlik edilir.

8. Uyku Örüntüsünde Bozulma: Gece artan öksürük, dispne ve solunum hızındaki değişiklikler uyku bölünmelerine yol açarak uyku kalitesini bozar.

Hemşirelik Girişimi: Hastanın gece boyunca dispneyi artırabilecek çevresel uyaranlardan uzak tutulması sağlanır. Solunumu kolaylaştırmak için uygun pozisyonlama (yatak başının yükseltilmesi) yapılır. Gece öksürüğünü tetikleyen etkenler belirlenerek bunlara yönelik düzenlemeler yapılır. Solunum güçlüğü yaşayan hastaya gevşeme ve nefes egzersizleri öğretilir. Uyku hijyeni konusunda eğitim verilerek uyku kalitesinin artırılması desteklenir.

9. KOAH'DA HEMŞİRELİK BAKIMI

Kronik Obstrüktif Akciğer Hastalığı (KOAH), ilerleyici solunum semptomları ve hava akımı kısıtlılığıyla karakterize yaygın ve önlenebilir bir hastalıktır (NursesLabs, 2024). KOAH, dispne, kronik öksürük ve balgam üretimi ile yaşam kalitesini düşürür; bu nedenle hemşirelik bakımı, hastanın semptom kontrolünü optimize etmek ve klinik sonuçları iyileştirmek için önemli bir yere sahiptir (Neşe 2023). Hemşireler, bireyin solunum semptomlarını değerlendirmek ve uygun bakımı planlamak amacıyla kapsamlı bir klinik değerlendirme gerçekleştirmelidirler (Uslu & Canbolat, 2022). Hemşirelik bakım süreci, etkili hava yolu açıklığının sağlanması ve gaz değişiminin desteklenmesi ile başlar. Solunum egzersizleri, pozisyonlama ve doğru oksijen terapisi uygulamaları, hipoksemi ve dispneye bağlı semptomların azaltılmasında etkili olduğu bilinmektedir (Uslu & Canbolat, 2022; Aranburu-Imatz et al., 2022). Ayrıca inhaler ilaçların doğru teknikle uygulanması, sekresyonların etkili şekilde temizlenmesi ve hastanın ilaç tedavilerine uyumunun sağlanması hemşirelik bakımının temel hedeflerindendir. Eğitimler sırasında hastaya inhaler cihaz kullanım teknikleri öğretilmeli ve bu uygulamalar düzenli olarak değerlendirilmelidir (Okur, E., & Nural, N. (2022). Hemşirelik yönetimi, aynı zamanda bireyin öz-bakım becerilerini güçlendirmeye odaklanmalıdır. KOAH'lı hastalarda öz-bakım eğitimi; alevlenme belirtilerini tanıma, solunum egzersizlerini sürdürme, yaşam tarzı modifikasyonları ve rehabilitasyon programlarına uyum gibi konuları kapsamalıdır (Uslu & Canbolat, 2022; Aranburu-Imatz et al., 2022). Bu eğitimler, bireyin kendi semptomlarını yönetme kapasitesini artırarak hastalık seyri üzerindeki olumsuz etkileri azaltır ve yeniden hastaneye başvuru oranlarını düşürüldüğü bilinmektedir. Ayrıca hemşireler, KOAH'lı hastalarda psikososyal desteğin sağlanması ve anksiyete, depresyon gibi ek sorunların izlenmesi için de uygun değerlendirme araçlarını kullanmalıdır (Aranburu-Imatz et al., 2022). Güncel kanıta dayalı hemşirelik girişimleri, sadece semptom kontrolüne değil; aynı zamanda hastanın günlük yaşam aktivitelerini sürdürmesine, uyku kalitesinin korunmasına ve genel yaşam kalitesinin artırılmasına hizmet etmektedir (Neşe 2023: NurseLabs, 2024). Bu kapsamda hasta merkezli bakım planlarının oluşturulması ve düzenli değerlendirmeler, KOAH yönetiminde bütüncül hemşirelik bakımının ayrılmaz bileşenleri olduğunu açıkça göstermektedir.

10. SONUÇ

Kronik Obstrüktif Akciğer Hastalığı (KOAH), dünya genelinde morbidite ve mortalitesi giderek artan, önemli bir halk sağlığı sorunu niteliği taşımaktadır. Hastalığın ortaya çıkışında tütün kullanımı temel belirleyici olmakla birlikte, biyoyakıt dumanına maruziyet, mesleki inhalasyon riskleri, çevresel kirleticiler ve genetik yatkınlık da etiyolojide kritik rol oynamaktadır. KOAH'a özgü klinik bulgular olan kronik öksürük, balgam ve dispne, bireylerin günlük yaşam aktivitelerini ve yaşam kalitesini belirgin ölçüde sınırlandırırken; hastalığın ilerleyen evrelerinde hipoksemi, hiperkapni ve artan alevlenme sıklığı klinik yükü daha da ağırlaştırmaktadır. Tanı sürecinde spirometri temel belirleyici yöntem olup, klinik değerlendirme, radyolojik görüntüleme ve laboratuvar analizleri tanısal doğruluğu artıran tamamlayıcı unsurlardır. Hastalığın yönetiminde farmakolojik tedavi, sigara bırakma girişimleri, oksijen tedavisi, pulmoner rehabilitasyon ve yaşam tarzına yönelik düzenlemeler bütüncül bir yaklaşım gerektirmektedir. Bu kapsamda hemşireler, KOAH bakımının her aşamasında kritik bir role sahiptir. Solunum semptomlarının değerlendirilmesi, inhaler tedavilerin doğru teknikle uygulanmasının sağlanması, sekresyon yönetimi, alevlenme belirtilerinin erken tanınması, sigara bırakma danışmanlığı ve öz bakım becerilerinin desteklenmesi hemşirelik bakımının temel bileşenleridir. Bu nedenle KOAH'lı bireylerde sık karşılaşılan hemşirelik tanıları arasında etkisiz solunum deseni, gaz değişiminde bozulma, aktivite intoleransı, enfeksiyon riski, bilgi eksikliği ve kaygı gibi klinik durumlar ön plana çıkmaktadır. Bu çerçevede, KOAH'ın etkin yönetimi yalnızca tıbbi tedavi protokollerinin uygulanmasıyla sınırlı olmayıp, bireyin fiziksel, psikolojik ve çevresel gereksinimlerini kapsayan kapsamlı hemşirelik bakımını zorunlu kılmaktadır. Sistematik hemşirelik değerlendirmesi, risklerin erken dönemde belirlenmesi ve bireye özgü bakım planlarının geliştirilmesi; hastalığın seyrini iyileştirmeye, alevlenme sıklığını azaltmaya ve yaşam kalitesini artırmaya önemli katkı sağlamaktadır. Bu bağlamda hemşirelik uygulamalarının güçlendirilmesi, güncel kanıta dayalı yaklaşımların bakım süreçlerine entegrasyonu ve mesleki eğitim programlarının desteklenmesi, KOAH yönetiminde sürdürülebilir başarının temel bileşenleri arasında yer almaktadır.

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ÇOCUK YOĞUN BAKIM ÜNİTELERİNDE DELİRYUM BELİRLEME VE YÖNETİMİNDE HEMŞİRENİN ROLÜ

The role of nurses in determining and managing delirium in children's intensive care units

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Özet

Deliryum, Pediatrik Yoğun Bakım Ünitelerinde %22 ila %65.9 arasında görülen, akut ve dalgalı zihinsel durumdur. Bu durum, uzamış mekanik ventilasyon, artan morbidite ve mortalite, hastanede kalış süresinde uzama ve bakım maliyetlerinin artması gibi olumsuz sonuçlara yol açar. Bu sendromun erken teşhisi ve agresif tedavisi, olumsuz etkileri azaltır. Pediatrik Yoğun Bakım hemşireleri, hastaları uzun süre izlemeleri ve bilgili bakım sunmaları nedeniyle deliryumun erken tanınması ve önlenmesinde avantaja sahiptir. Bunun yanında yapılan çalışmalar, Pediatrik Yoğun Bakım hemşirelerinin deliryum hakkındaki bilgilerinin genellikle yetersiz olduğunu gösteriyor. Bu yetersizlikler özellikle klinik belirtiler, risk faktörleri ve kullanılan ilaçlar konusunda eksikliklerdir. Bilgi eksiklikleri, deliryum tedavisinin etkili bir şekilde uygulanmasının önündeki en büyük engellerden biri olarak kabul edilir. Bu çalışmanın temel amacı, Pediatrik Yoğun Bakım Üniteleri hemşirelerinin deliryum belirleme ve yönetimindeki rolünü, karşılaşılan zorlukları ve bu zorlukların üstesinden gelmek için uygulanabilecek kanıta dayalı yönetim ve eğitim stratejilerini incelemektir. Kanıtlar, eğitim programlarının hemşirelerin deliryum bilgi düzeylerini, özgüvenlerini, tutumlarını ve deliryum

tarama araçlarını doğru kullanmanın önemli ölçüde artırdığını göstermektedir. Ayrıca, Cornell Pediatrik Deliryum Değerlendirmesi (CAPD) gibi araçların sürekli ve güvenilir kullanımının sağlanması için eğitimlerin devamlılığının ve profesyonel işbirliğinin önemi büyüktür.

Anahtar Kelimeler: Pediatrik deliryum, Çocuk yoğun bakım ünitesi, Hemşire.

Abstract

Delirium is an acute, fluctuating mental state that occurs in 22% to 65.9% of pediatric intensive care units. This condition leads to adverse outcomes such as prolonged mechanical ventilation, increased morbidity and mortality, prolonged hospital stay, and increased healthcare costs. Early diagnosis and aggressive treatment of this syndrome mitigate its adverse effects. Pediatric intensive care nurses have an advantage in early recognition and prevention of delirium because of their ability to monitor patients for extended periods and provide knowledgeable care. Furthermore, studies have shown that pediatric intensive care nurses are generally inadequately informed about delirium. This is particularly true regarding clinical symptoms, risk factors, and medications used. This lack of knowledge is considered one of the greatest obstacles to effective delirium treatment. The primary objective of this study was to examine the role of pediatric intensive care unit nurses in the identification and management of delirium, the challenges encountered, and evidence-based management and educational strategies that can be implemented to overcome these challenges. Evidence suggests that educational programs significantly improve nurses' knowledge of delirium, their confidence, their attitudes, and their ability to use delirium screening tools effectively. Additionally, ongoing training and professional collaboration are crucial to ensuring the continued and reliable use of tools such as the Cornell Pediatric Delirium Assessment (CAPD).

Keywords: Paediatric delirium, Paediatric intensive care unit, Nurse.

Giriş

Deliryum, kritik hastalarda yaygın görülen ve önemi giderek artan bir sendromdur. Pediatrik Yoğun Bakım Ünitesi (PYBÜ) hastalarında deliryum, aniden başlayan, beynin işleyişini bozan bir durumdur. Kişinin dikkatini toplaması zorlaşır ve bilinci dalgalı bir şekilde değişebilir. (American Psychiatric Association 2013; Zhang et al., 2024). Hastaneye yatan çocuklarda deliryum görülme oranları %4.5 ile %65.9 arasında değişmektedir. (Meyburg et al., 2018; Patel et al., 2017; Zhang et al., 2024). PYBÜ'lerde ise bu oran %22 ila %44 arasında olduğu bilinmektedir. (Zhang et al., 2024).

Deliryum; hiperaktif, hipoaktif, mikst (karma) ve sınıflandırılamayan olmak üzere dörde tipe ayrılır. (Morandi & Jackson, 2011; Zhang et al., 2024). Klinikte hipoaktif (%45) ve karma deliryum (%46) PYBÜ'de hiperaktif deliryuma (%8) göre daha sık görülür. (Morandi & Jackson, 2011). Hipoaktif deliryumun belirtileri kolay fark edilmediği için tanı ve tedavide geç kalınabilir. (Zhang et al., 2024).

Deliryum tanısı, kritik durumdaki çocuklar için bakım maliyetini artırır ve mortalite ve morbidite gibi olumsuz sonuç riskini yükseltir. (Zhang et al., 2024; Traube et al., 2017). Deliryumlu çocuklar, uzamış mekanik ventilasyon ve hastanede kalış süresinde artış yaşar. (Zhang et al., 2024). Ayrıca, hastaneden taburcu olduktan sonra travma sonrası stres bozukluğu (TSSB) yaşama riski vardır. (Colville et al., 2008; Zhang et al., 2024). Deliryumun PYBÜ'de hastanede kalış süresini ve ventilasyon süresini 2-3 gün artırdığı ve hastane masraflarını 4 kattan fazla artırdığı gösterilmiştir (Traube et al., 2016; Zhang et al., 2024).

Pediatri Hemşiresinin Rolü

Deliryumun erken fark edilmesi ve hızlı tedavisi, durumun düzelmesini sağlayabilir. (Bettencourt & Mullen, 2017). Yoğun bakım ortamındaki hemşireler, uzun süre bakım sağladıkları ve çevre sürekli değerlendirdikleri için deliryumun erken tanınması ve önlenmesinde önemli bir rol alırlar. (Bettencourt & Mullen, 2017; Zilezinski et al., 2023). Ancak, PYBÜ'de deliryum tedavisinin yetersiz olduğu bildirilmiştir. Bu durumun, profesyoneller arasında deliryumla ilgili bilgi eksikliği ve tarama araçlarının kullanımına ilişkin düşük özgüven ile ilgili olduğu belirtilmektedir (Zhang et al., 2024).

Pediatri Hemşiresinin Deliryum Belirleme Rolü

Deliryum Tarama ve Tanılama Araçları

PYBÜ'de deliryumun düzenli olarak taranması erken teşhis için önemlidir. (Harris et al., 2016). Uluslararası kılavuzlar, bebek ve çocuklarda deliryum değerlendirmesi yapılmasını öneriyor. (Harris et al., 2016; Smith et al., 2022). Deliryum taraması için geçerliliği ve güvenilirliği kanıtlanmış iki ölçek vardır: Cornell Pediatrik Deliryum Değerlendirmesi (CAPD) ve Yoğun Bakım Ünitesi Pediatrik Konfüzyon Değerlendirme Yöntemi (pCAM-ICU). CAPD, PYBÜ'de deliryum taraması için geçerli, hızlı ve gözlemsel bir araçtır (Traube et al., 2014). Ancak çalışmalar deliryumun yetersiz yönetildiğini ve tarama araçlarının %85 oranında kullanılmadığını göstermektedir (Eastwood et al., 2012; Zhang et al., 2024).

Hemşire Bilgi ve Yeterlilik Düzeyi

PYBÜ hemşirelerinin deliryum bilgisinin yeterli düzeyde değildir. (Norman & Taha, 2019). Çin'de yapılan çok merkezli bir araştırmada hemşirelerin sadece %49,8'si bilgi

sınavından başarılı olmuştur. (Zhang et al., 2024). Bilgi eksiklikleri, deliryumun tedavi ve bakımında önemli engellerdir. (Rohmah et al., 2025). Hemşirelerin bilgi eksikliklerine yönelik öne çıkan temalar şunlardır:

1. Benzodiazepin Kullanımı: PYBÜ hemşirelerinin çoğu, benzodiazepinlerin deliryum tedavisine iyi geldiğini olduğunu savunmuştur. Oysa benzodiazepinler deliryum görülmesi için bir risk faktörüdür. (Uyar et al., 2023).

2. Deliryum Tipleri: Deliryumu sadece hiperaktif bir durum olarak tanımlamıştır. Bu, hipoaktif deliryumun bildisinin az olduğunu gösterir. (Uyar et al., 2023).

3. Hafıza: Hemşirelerin %79'u (Uyar et al., 2023) veya %51'i (Flaigle et al., 2016) çocukların genellikle deliryum anlarını hatırlamadığını düşünmektedir. Oysa çocuklar, deliryum deneyimlerini, hatta halüsinasyonları bile hatırlayabilirler (Colville et al., 2008).

Bilgi, tutum ve uygulama teorisi, hedef grupların ilgili profesyonel bilgiyi edinmesinin, güçlü inançlar oluşturmasının ve sonuç olarak davranışlarını değiştirmek için olumlu tutumlar benimsemesinin gerektiğini belirtir (Zhang et al., 2024; Li, 2012). Yetersiz bilgi, etkili deliryum yönetimini yürütmelerini engelleyebilir (Zhang et al., 2024).

Deliryum Yönetiminde Eğitim Programları ve Teorik Çerçeveler

PYBÜ hemşirelerinin yetkinliğini artırmak için deliryum eğitimi programlarının geliştirilmesi önemlidir (Norman & Taha, 2019). Deliryum eğitim programlarının tasarlanmasında teorik modellerin kullanılması, etkinliği artırmaktadır.

• Bilgiden Eyleme (Knowledge-to-Action - KTA) Çerçevesi: DELIMA (Deliryum Tanıtım ve Sürdürme Programı) adlı bir program, KTA çerçevesine göre geliştirilmiş ve hemşirelerin bilgi, özgüven, tutum ve CAPD ile tarama doğruluğunu önemli derecede iyileştirmiştir. Bu program, yüz yüze eğitim ve video kayıtlı vaka örnekleri gibi stratejileri kullanmıştır. (Rohmah et al., 2025).

• PRECEDE Modeli: Bu model temelli eğitim programları, önceden var olan faktörleri (bilgi, tutumlar), pekiştirici faktörleri (geri bildirim, teşvikler) ve etkinleştirici faktörleri (kaynaklar, beceriler) vurgular. PRECEDE temelli bir eğitim, hemşirelerin CAPD ölçeği kullanım becerilerini ve gözlemciler arası tutarlılığı (%66,12'den %87.31'e yükselmiştir) önemli ölçüde geliştirmiştir. (Zuo et al., 2025).

• Kotter'in Değişim Yönetimi İlkeleri: Deliryum taramasını uygulamak ve sürdürmek için Kotter'ın sekiz aşamalı değişim yönetimi modeli kullanılmıştır. Bu modelin uygulanması, PYBÜ'de deliryum tarama oranlarını yükseltmiştir. (Kupferschmid & Tripathi, 2021).

Eğitim materyallerinin içeriği, deliryumun tanımı, patogenezi, klinik belirtileri, risk faktörleri, deliryumun farmakolojik olmayan yönetimi ve CAPD ölçeği gibi araçların kullanımı hakkında temel bilgileri kapsamalıdır (Zuo et al., 2025).

Farmakolojik Olmayan Yönetim Stratejileri

Farmakolojik olmayan müdahaleler, deliryumu hızlandıran faktörlerin etkisini hedef aldığı için önlenmesi ve yönetimi için önerilmektedir (Zilezinski et al., 2023). Hemşireler, bu farmakolojik olmayan müdahaleleri uygulamak için en uygun pozisyondadır (Zilezinski et al., 2023).

Farmakolojik olmayan müdahalelerden Deliryumu Ortadan Kaldırma Paketi (Bundle to Eliminate Delirium- BED), PYBÜ'de uygulanmak üzere tasarlanmıştır. BED müdahaleleri, gündüz-gece döngüsünü normalleştirmeyi, hastaya uyanıklık sağlamayı, erken mobilizasyonu içerir. (Rohlik et al., 2021). Bu farmakolojik olmayan müdahaleler, Deliryum Yönetimi ve Erken Mobilite içeren daha kapsamlı bir uygulamanın parçası olarak da kabul edilmektedir (Waak et al., 2022).

Hemşirelik Uygulamaları: Uyku, Çevre ve Aile Merkezli Bakım

PYBÜ hemşiresinin rolü, deliryumu önlemek için çevrede değişiklik yapılabilecek faktörleri yönetmektir. PYBÜ ortamı (gürültü, ışık, sık bakım) uyku/uyanıklık döngüsünü bozar ve deliryum gelişimine neden olur. (Greenfield et al., 2020; Hassinger et al., 2023).

Uyku bozuklukları, deliryum tarama kriterleri arasında yer alır. Deliryumlu çocukların, deliryumu olmayan çocuklara göre gece vardiyasında u 42 dakika daha az uyku yaşadığı gözlemlenmiştir. Ayrıca, artan klinisyen bakım sıklığı ve süresi, daha kötü uyku kalitesi ve deliryum ile ilişkilendirilmiştir (Kalvas et al., 2023).

Hemşirelik Müdahaleleri: PYBÜ'de uyku bozukluğunu azaltmak için hemşireler aşağıdaki müdahaleleri uygulayabilir:

• Bakımın Kümelenmesi (Clustering Care): Gereksiz kesintileri ve gece hemşirelik müdahalelerini azaltmak için bakım aktivitelerinin planlanması ve kümelenmesi (Knauert et al., 2018).

• Çevresel Kontrol: Gündüz/gece ışık/ses döngüsünün desteklenmesi önemlidir (Rohlik et al., 2021). İspanyol PYBÜ'lerinde yapılan bir çalışmada, gece en sık tekrarlanan müdahalenin "yaşamsal belirtilerin takibi" olduğu, sonra "çevre yönetimi" geldiği tespit edilmiştir. Bu durum, dinlenmeyi iyileştirmeye yönelik endişeyi gösterir. (Gomez-Merino et al., 2025).

• Erken Mobilite: Yüksek düzeyde aktivitelerinin başlanmasıdır (örneğin, yatak kenarında sallanma, ayakta durma, yürüme) (Waak et al., 2022).

Aileyi Merkeze Alan Danışmanlık ve Destek

Aile merkezli bakım PYBÜ'de hasta ve aile deneyimini iyileştiren önemli bir yaklaşımdır. Hemşireler, aileleri deliryum yönetimine dahil eder ve danışmanlık yaparlar. (Alanko et al., 2025).

Aileyi merkeze alan deliryum danışmanlığının önemini artırmak için ele alınması gereken temel alanlar şunlardır:

• Kapsamlı Bilgi Sağlama: Deliryumun risk faktörleri, belirtlileri ve önlenmesi hakkında tüm bilgiler verilmelidir. (Alanko et al., 2025).

• Yöntemler ve Materyaller: Ailelerin bilgiyi daha kolay içselleştirmesine ve konuya geri dönmesine yardımcı olmak için yazılı materyaller (kağıt üzerinde veya dijital bakım yolları aracılığıyla) sağlanmalıdır. Dijital hizmetler, ulaşılabilir ve güvenilir sağlık bilgisi sunarak aile merkezli bakımı geliştirebilir (Alanko et al., 2025).

• Duygusal Destek: Ebeveynlere deliryum belirtileri ve çocuğun durumu hakkında dürüst ama dikkatli ve tedbirli bilgi verilmesi, kaygının azaltılmasına yardımcı olabilir (Alanko et al., 2025).

• Aile Katılımı: PYBÜ hemşireleri aile refakatini yönlendirme konusunda düşük düzeyde özgüven bildirmiştir. (Zhang et al., 2024).

PYBÜ hemşireleri, deliryumun tanınması ve yönetimi konusunda çeşitli engellerle karşılaşmaktadır.

Bilgi-Uygulama Boşluğu ve Yönetim Zorlukları

PYBÜ hemşirelerinin deliryum hakkındaki yetersiz bilgisi, deliryumun etkili yönetimini engelleyebilir (Norman & Taha, 2019). Bilgi eksiklikleri, deliryum kılavuzlarının uygulanmasındaki temel engeller olarak kabul edilmektedir (Rohmah et al., 2025). Ayrıca, hemşireler arasında tarama araçlarının karmaşık olduğu ve ek zaman/çaba gerektirdi belirlenmiştir. (Zhang et al., 2024; Eastwood et al., 2012).

PYBÜ'de deliryum yönetimi, disiplinler arası iletişim sorunları ve standardize edilmiş protokollerin eksikliği nedeniyle zorluklarla karşılaşır (Mattsson et al., 2022). İsveç'te yapılan bir çalışma, çekilme sendromu yaşayan çocukların bakımında tıbbi perspektif ile hemşirelik bakımı perspektifi arasında bir tutarsızlık olduğunu göstermiştir. Ortak kılavuz, dil ve hemşirelik tanılarının eksikliği, subjektif değerlendirmelere ve çocukların acısının artmasına yol açabilir (Mattsson et al., 2022).

Ayrıca, daha az deneyime sahip hemşireler, deliryum veya sedasyonla ilgili endişelerini kıdemli hemşirelere iletme konusunda, daha deneyimli meslektaşlarına göre anlamlı ölçüde daha az rahattır (%36.4'e karşın %84,6, p = 0.001) (Kolmar et al., 2025).

İyileştirme İçin Kurumsal ve Eğitimsel Stratejiler

Deliryum yönetiminin kalitesini artırmak ve bilgi-uygulama sorununu çözmek için stratejiler geliştirilmiştir:

1. Rutin Tarama Programlarının Kurulması: PYBÜ'nin sürekli deliryum değerlendirme programları oluşturması gereklidir (Kupferschmid & Tripathi, 2021).
2. Eğitim Programları: Hemşirelerin bilgi düzeyini, özgüvenini ve tutumunu artırmada en etkili yöntem olarak gösterilmiştir (Norman & Taha, 2019; Rohmah et al., 2025; Zuo et al., 2025).
3. İnterprofesyonel İşbirliği ve Ortak Dil: Deliryum değerlendirme sonuçlarının interprofesyonel vizitler sırasında tartışılması, taramanın önemini vurgular (Norman & Taha, 2019). Tıbbi ve hemşirelik perspektiflerinin birleştirilmesi ve ortak bir dil kullanılması için ekip tartışmaları ve ortak kılavuzlar önerilmektedir (Mattsson et al., 2022).
4. Sürdürülebilirlik: Uygulama değişikliklerinin devamlılığı, sürekli ölçüm ve geri bildirim gerektirir (Rohmah et al., 2025; Kupferschmid & Tripathi, 2021). Kotter'ın değişim yönetimi ilkeleri, sürdürülebilir bir kültürel değişimi amaçlar. (Kupferschmid & Tripathi, 2021).

PYBÜ hemşireleri, hastaları uzun süre bakım sağladıkları için deliryumun erken tanınması ve önlenmesinde önemli bir konuma sahiptirler. Hemşirenin bu konumu, sürekli eğitim, düzenli tarama araçlarının kullanımı ve ilaçsız müdahalelerin rutin uygulamaya dahil edilmesini gerektirir. (Valdivia & Carlin, 2019; Waak et al., 2022).

Sonuç

PYBÜ'deki deliryum, risk altındaki çocuklar için ciddi morbidite ve hastane masraflarını arttıran önemli bir sorundur (Traube et al., 2017; Traube et al., 2016; Zhang et al., 2024). Hemşireler, deliryumun erken tanınması ve farmakolojik olmayan tedavilerin uygulanmasında önemli rol oynar. (Rohlik et al., 2021; Waak et al., 2022; Zilezinski et al., 2023). Ancak, deliryum hakkında yetersiz bilgi düzeyi (Zhang et al., 2024; Uyar et al., 2023), bu kritik görevin etkin bir şekilde yerine getirilmesinin önündeki en büyük engeldir (Rohmah et al., 2025).

Çok bileşenli, teoriye dayalı eğitim programlarının uygulanması, hemşirelerin bilgi düzeylerini, özgüvenlerini ve standardize araçları kullanma doğruluğunu artırmada en etkili yöntem olarak kanıtlanmıştır (Rohmah et al., 2025; Norman & Taha, 2019; Zuo et al., 2025). Ayrıca, PYBÜ ortamında uyku hijyenini (Kalvas et al., 2023) ve çevresel faktörleri optimize

etmeye odaklanan farmakolojik olmayan müdahaleler (bakımın kümelenmesi ve erken mobilite) deliryumun önlenmesi için temel bileşenlerdir (Gomez-Merino et al., 2025; Waak et al., 2022).

Sonuç olarak, PYBÜ'de deliryum bakımının kalitesini iyileştirmek için, hemşirelik yönetiminin bir rutin haline getirilmesi, sürekli eğitim, standardize edilmiş tarama protokollerinin zorunlu hale getirilmesi ve interprofesyonel işbirliğinin güçlendirilmesi gerekmektedir.

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TÜRKİYE'DE AKILLI TELEFON BAĞIMLILIĞI VE UYKU İLE İLGİLİ LİSANSÜSTÜ TEZLERİNİN İNCELENMESİ: SİSTEMATİK DERLEME

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ÖZET

Sistematik derlemenin amacı, Yüksek Öğretim Kurumu Ulusal Tez Merkezi'nde bulunan, Türkiye'de akıllı telefon bağımlılığı ve uyku konularını ele alan lisansüstü tezlerin incelenmesidir. Derleme, literatür taraması yöntemiyle, Aralık 2024-Mart 2025 tarihleri arasında arasında yürütülmüş olup, "akıllı telefon bağımlılığı" ve "uyku" anahtar kelimeleriyle gerçekleştirilmiştir. Tezlerin uygunluğu başlık ve özetlere göre değerlendirilmiş ve derlemeye dahil edilmiştir. Çalışmalar, PICOS yöntemine göre derlemeye dâhil edilmiştir. Derleme bulguları, PRISMA kontrol listesine uygun olarak raporlanmıştır. Tarama sonucunda on beş tez incelenmiştir. Tezlerin %47'si yüksek lisans, %6'sı doktora, %47'si tıpta uzmanlık tezidir. Tezler 2018-2024 arasında yapılmış, toplam on iki bin beş yüz yetmiş yedi katılımcı yer almıştır. Çoğu (%86) tanımlayıcı ve kesitsel türde olup, örneklemlerinin %80'i öğrencilere aittir. En sık kullanılan veri toplama araçları Akıllı Telefon Bağımlılığı Ölçeği (%30) ve Pittsburg Uyku Kalitesi İndeksi (%22) olmuştur. Türkiye'deki akıllı telefon bağımlılığı ve uyku üzerine yapılan deneysel çalışmalar sınırlıdır. Daha geniş örneklemlerle yapılacak araştırmalar, bu konuda derinlemesine bilgi sağlayarak etkili müdahaleler geliştirilmesine katkı sunabilir.

Anahtar Kelimeler : Akıllı telefon, bağımlılık, uyku.

REVIEW OF POSTGRADUATE THESES ON SMARTPHONE ADDICTION AND SLEEP IN TURKEY: A SYSTEMATIC REVIEW

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ABSTRACT

The aim of the systematic review is to examine postgraduate theses on smartphone addiction and sleep in Türkiye, located in the National Thesis Center of the Council of Higher Education. The review was carried out between December 2024 and March 2025 using the literature review method and the keywords "smartphone addiction" and "sleep". The suitability of the theses was assessed according to their titles and abstracts and they were included in the review. Included studies were included in the review according to the PICOS method. The review findings were reported in accordance with the PRISMA checklist. Fifteen theses were examined as a result of the review. 47% of the theses were master's theses, 6% were doctoral theses, and 47% were medical specialty theses. The theses were written between 2018 and 2024, and a total of twelve thousand five hundred and seventy-seven participants were included. Most of them (86%) were descriptive and cross-sectional, and 80% of the samples belonged to students. The most frequently used data collection tools were the Smartphone Addiction Scale (30%) and the Pittsburg Sleep Quality Index (22%). Experimental studies on smartphone addiction and sleep in Türkiye are limited. Studies with larger samples can contribute to the development of effective interventions by providing in-depth information on this subject.

Keywords : Smartphone, addiction, sleep.

1. GİRİŞ

Teknolojinin hızla ilerlemesiyle akıllı telefonlar, günümüzün modern dokunmatik ekranlı ve çok yönlü cihazları olarak yaşamın ayrılmaz bir parçası olmuş ve yıllar içinde toplumsal olarak geniş bir yayılım göstermiştir ve her alanda bu cihazlara ihtiyaç duyulmaktadır.[1-3] Ayrıca internet bağlantısı sayesinde, her an ve her yerden erişim sağlanabilmektedir.[4] Dünya genelinde 6.6 milyar akıllı telefon kullanıcısı bulunmakta ve bu sayının 2028'de 7.8 milyara çıkması tahmin edilmektedir.[2] Türkiye'de de nüfusun %92'isini mobil abonesi olduğu ve bireylerin günlük ortalama 7 saat 29 dakika internet kullanmakta olduğu bildirilmektedir.[4]

Akıllı telefonlar, internete bağlanabilme özellikleri sayesinde normal cep telefonlarına göre pek çok avantaj sunar.[5] Mesajlaşma, multimedya, video paylaşımı gibi iletişim avantajları dışında, oyun, sosyal medya, bilgiye ulaşma, alışveriş, navigasyon, müzik dinleme gibi çeşitli özellikler de sunmaktadır.[5] Yapılan çok uluslu bir çalışmada, akıllı telefon kullanımında en sık yapılan etkinliklerin sosyal faaliyetler (kısa mesajlaşma, fotoğraf/video çekme ve sosyal medya paylaşımı) olduğu, ardından sağlık ve eğitimle ilgili bilgi arayışının geldiği belirlenmiştir.[6] Fakat bu faydalı yönlerinin yanı sıra fazla kullanımı zamanla artmakta ve günlük hayatta olumsuz etkilemektedir.[7] İnternete her zaman erişim sağlama kolaylığı ve akıllı telefonların yaygın kullanımı, iş, eğitim, eğlence, iletişim ve ticaret gibi alanlarda bağımlılık ve sorunlu kullanım endişelerini gündeme getirmiştir.[8,9] Akıllı telefonların fazla kullanımına bağlı bağımlılık oluşur.[6] "Akıllı telefon bağımlılığı" terimi, klinik bir tanı olarak kabul edilmemekle birlikte, problemli kullanımın olumsuz etkileri artmış ve bağımlılıkla ilgili davranış kalıpları gözlenmektedir.[10] Akıllı telefon nedeniyle sürekli telefon kontrol etme ve iletişimsizlik korkusu gibi tekrarlayan davranış bozukluklarını içeren, günlük yaşam ve ilişkilerde işlevselliği bozabilen durumlar meydana gelmektedir.[9] Ayrıca akıllı telefonun uzun süre kullanımı, geç saatlere kadar uyanık kalmaya ve buna bağlı olarak uyku sorunlarına da neden olmaktadır.[11]

Uykunun, beden ve zihin üzerinde yenileyici etkileri vardır. Yeterli uyku, sinir sistemi ve bağışıklık fonksiyonlarını dengede tutar.[12] Yetersiz ve düşük kaliteli uyku, hafıza kaybı, uzun vadede bilişsel performans düşüşü, kardiyovasküler hastalık riski, metabolizmanın yavaşlaması, halsizlik ve kilo sorunları ile ilişkilendirilmektedir.[9,12] Ayrıca yeterli ve kaliteli uyku, özellikle ergenlikte fiziksel ve zihinsel refah için hayati olup, büyüme hormonu salgılanmasını etkileyerek fiziksel gelişime katkı sağlar.[13] Literatür incelendiğinde akıllı telefon bağımlılığının uyku problemlerine sebep olduğu ve uyku kalitesini olumsuz etkilediği bildirilmektedir.[7,14] Üniversite öğrencileri ve genç yetişkinlerde akıllı telefon bağımlılığı ile kötü uyku kalitesi arasında ilişki olduğu belirtilmektedir.[6] Ayrıca akıllı telefon bağımlılığı olan gençlerin, uyku problemi yaşama konusunda daha fazla risk altında olduğu saptanmıştır.[15] Uzun süre akıllı telefon kullananlarda ise uyku kalitesinde düşme, daha geç uyanma ve uykuya dalma süresinde uzama gözlenmektedir.[16] Akıllı telefon bağımlılığına bağlı olarak, yetersiz uykunun gündüz uykululuğuna neden olduğu da belirtilmektedir.[3] Literatürde akıllı telefon bağımlılığının uyku kalitesini olumsuz etkilediğini belirten benzer çalışmalar da bulunaktadır.[6,9,11]

Sonuç olarak literatürde akıllı telefon kullanımının özellikle genç nüfus arasında yaygınlaşarak, bağımlılık oluşturma potansiyeli nedeniyle önemli bir halk sağlığı sorunu haline geldiği belirtilmekte olup, akıllı telefon kullanımı ile uyku düzeni arasında olumsuz etkiler olduğu

çeşitli çalışmalarda bildirilmiştir. Ancak, Türkiye'de bu konuları lisansüstü tezler bağlamında sistematik olarak değerlendiren güncel bir derleme çalışmasına rastlanmamaktadır. Bu eksikliği gidermek ve literatürün genel durumunu ortaya koymak amacıyla Türkiye'deki lisansüstü tezler üzerinden akıllı telefon bağımlılığı ve uyku ilişkisi incelenmiştir. Bu bağlamda, bu araştırmanın amacı, Türkiye'de akıllı telefon bağımlılığı ve uyku konularında yapılmış lisansüstü tezlerin türünü, yayın yılını, amacını, örneklem büyüklüğünü, kullanılan ölçme araçlarını, araştırma yöntemlerini ve elde edilen sonuçları incelemektir. Araştırmacılara rehberlik edebilecek ve gelecekte yapılacak çalışmalara yeni bakış açıları kazandırabilecek bir perspektif sunmaktadır. Bu alanda gerçekleştirilen çalışmaların kapsamı, hangi yıllarda yapıldıkları, hangi araştırma yöntemlerinin kullanıldığı ve hangi açılardan ele alındığı gibi unsurlar üzerinde durularak, ileride yapılacak araştırmalara rehberlik edilebilir. Bu sayede araştırmacıların, planlanan çalışmalarına daha hızlı ve etkili bir şekilde yön verebilmeleri sağlanacaktır. Bu açıdan, çalışmanın bulguları, gelecekteki lisansüstü araştırmalara önemli katkılar sunarak, yönlendirici bir rol üstlenmektedir.

2. GEREÇ VE YÖNTEM

2.1 Araştırma Türü ve Amacı

Bu derleme, Türkiye'de akıllı telefon bağımlılığı ve uyku konularında yapılmış lisansüstü tezleri sistematik bir biçimde inceleyerek; tezlerin yayımlandığı yılları, araştırma türlerini, amaçlarını, örneklem büyüklüklerini, kullanılan ölçme araçlarını, araştırma yöntemlerini ve elde edilen temel bulguları belirlemeyi amaçlayarak tanımlayıcı sistematik derleme olarak gerçekleştirilmiştir.

Bu çalışmada yanıtlanması hedeflenen ana problem şudur: Türkiye'de akıllı telefon bağımlılığı ve uyku konularında yapılmış lisansüstü tezler hangi yönleriyle ele alınmakta ve bu tezlerde öne çıkan temel araştırma özellikleri nelerdir?

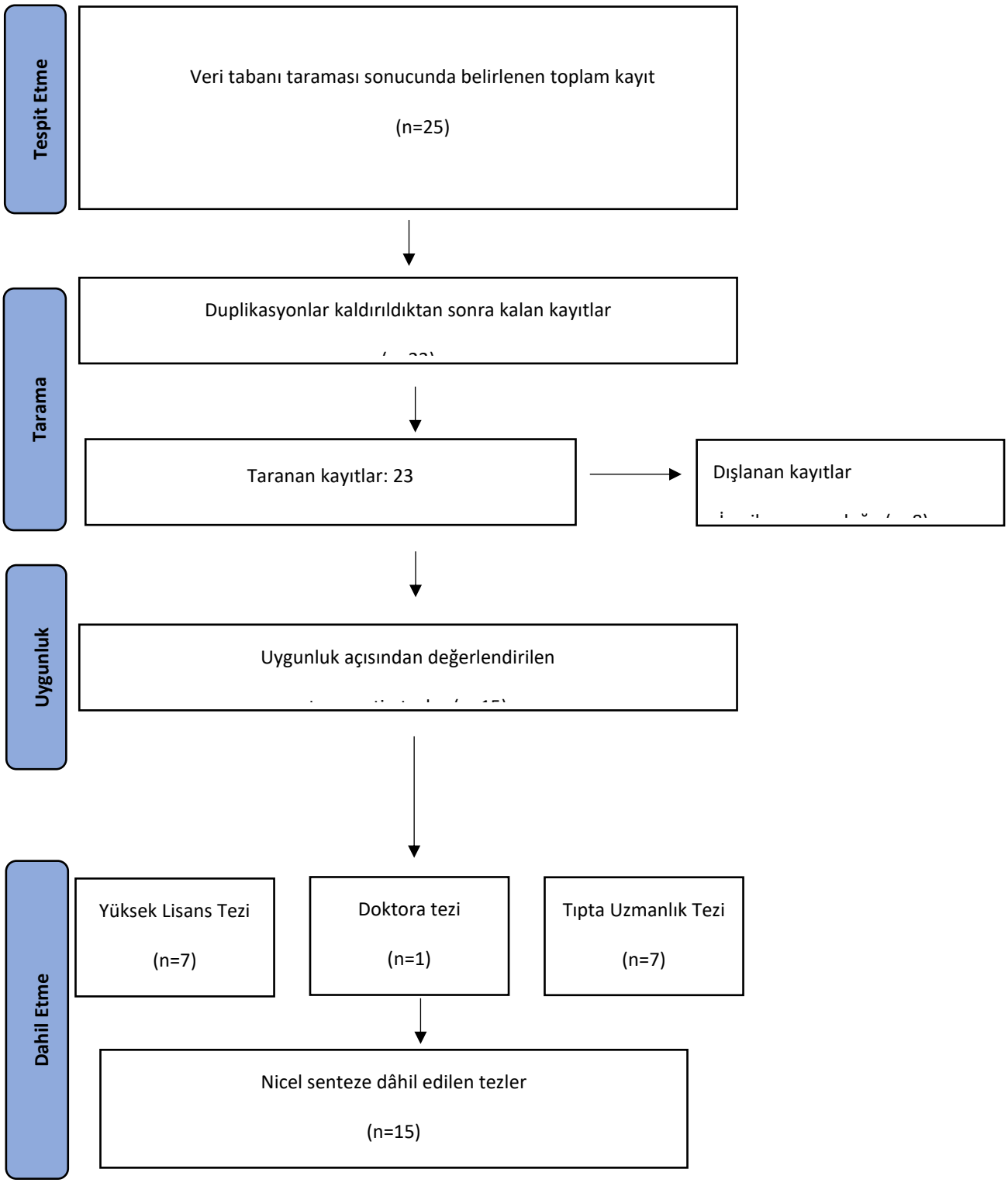
Bu ana problem doğrultusunda aşağıdaki alt problemlere yanıt aranmıştır:

1. Türkiye'de akıllı telefon bağımlılığı ve uyku konusuyla ilgili yürütülen lisansüstü tezler hangi yıllar arasında yapılmıştır?
2. Türkiye'de akıllı telefon bağımlılığı ve uyku konusuyla ilgili yürütülen lisansüstü tezlerde hangi araştırma yöntemleri kullanılmıştır?
3. Türkiye'de akıllı telefon bağımlılığı ve uyku konusuyla ilgili yürütülen lisansüstü tezlerde hangi örneklem grupları üzerinde çalışmalar yapılmıştır?
4. Türkiye'de akıllı telefon bağımlılığı ve uyku konusuyla ilgili yürütülen lisansüstü tezlerde hangi veri toplama yöntemleri kullanılmıştır?

2.2. Araştırma Evreni ve Örneklemi

Bu derlemenin verileri, Yükseköğretim Kurulu (YÖK) Başkanlığı Ulusal Tez Merkezi'nin veri tabanında yapılan tarama ile toplanmıştır. Derlemenin evrenini, başlıklarında 'akıllı telefon bağımlılığı' ve 'uyku' terimlerini içeren tüm lisansüstü tezler oluşturmuştur. Tez taraması yapılırken, belirli bir tarih aralığı sınırlaması getirilmeden, YÖK tez sisteminde yer alan tüm

tezler araştırmaya dâhil edilmiştir. Bu derleme, sistematik derlemeler için önerilen raporlama standartlarını içeren PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) bildirimi doğrultusunda metodolojik olarak yapılandırılmış ve PRISMA akış şeması kullanılarak sunulmuştur (Görsel 1).



Görsel 1. PRISMA Akış Şeması

2.3. Verilerin Belirlenmesi

Dahil edilme kriterleri PICOS kullanılarak belirlenmiştir. Çalışmaların belirlenmesinde, katılımcılar (P-Participants), müdahaleler (I-Interventions), karşılaştırma grupları (C-Comparators), sonuç ölçütleri (O-Outcomes) ve araştırma tasarımı (S-Study Designs) bileşenlerini temel alan PICOS yaklaşımı doğrultusunda ayrıntılı bir inceleme protokolü oluşturulmuştur (Tablo 1). Dahil edilme kriterlerini karşılamayan, "akıllı telefon bağımlılığı" ve "uyku" konularını birlikte ele almayan, tez formatında olmayan ve belirlenen dil kriterlerine uymayan çalışmalar araştırma kapsamına dahil edilmemiştir. Ayrıca, erişime kapalı olan veya tam metnine ulaşılamayan tezler de çalışmaya dahil edilmemiştir.

Çizelge 1. İnceleme Protokolü ve PICOS Ögeleri

Amaç /Hedef	
Türkiye'de "akıllı telefon bağımlılığı" ve "uyku" konularında yapılmış lisansüstü tezleri inceleyerek, bu tezlerde kullanılan araştırma yöntemlerini, örneklem gruplarını, veri toplama araçlarını ve elde edilen sonuçları değerlendirmektir.	
P (Katılımcılar)	Türkiye'de yürütülen, başlıklarında "akıllı telefon bağımlılığı" ve "uyku" kavramlarına yer verilen lisansüstü tezlerde incelenen örneklem grupları
I (Müdahaleler)	Tezlerde ele alınan akıllı telefon bağımlılığına veya kullanımına ilişkin durumlar, etkenler ya da değerlendirmeler
C (Karşılaştırmalar)	Akıllı telefon kullanımı/bağımlılığı ile ilişkili farklı değişken grupları, karşılaştırmalı analizler veya varsa kontrol grupları
O (Çıktılar)	Uykuya ilişkin bulgular (örneğin: uyku kalitesi, uyku süresi, uyku bozuklukları vb.)
S (Çalışma Tasarımı)	Tam metnine ulaşılabilen, tanımlayıcı, deneysel, yarı deneysel, nitel ya da karma yöntem kullanılan lisansüstü tez çalışmaları

2.4. Verilerin Toplanması

Araştırma kapsamındaki tezlere erişebilmek için veri tabanında "akıllı telefon bağımlılığı" ve "uyku" anahtar kelimeleri kullanılmıştır. Elde edilen tezler, EndNote X9 (Clarivate Analytics, ABD) referans yönetim aracı kullanılarak araştırma havuzuna dahil edilmiştir. Ayrıca elde edilen tezler bilgisayar ortamında kodlanarak PDF formatında saklanmıştır.

2.5. Verilerin Değerlendirilmesi

Elde edilen tezlerin kalitesini değerlendirmek için Critical Appraisal Skills Programme (CASP) aracı kullanılmıştır. Bu araç, derlemenin sonuçlarının dikkatlice incelendiği ve her biri farklı bir konuyu ele alan on sorudan oluşan bir kontrol listesinden meydana gelmektedir. Listede, puanlama sistemi bulunmamaktadır ve her soru için yanıtlar yalnızca "evet" olarak belirtilmiştir. "Hayır" cevabı verilen sorular için ise detaylı bir açıklama yapılması gerekmektedir (https://casp-uk.net/casptools-checklists/). Değerlendirme süreci, her araştırmacı tarafından bağımsız bir şekilde yapılmıştır. Elde edilen verilerin istatistiksel analizinde SPSS for Windows Versiyon 21.00 (SPSS Inc., Chicago, IL, USA) yazılımı kullanılmıştır. Verilerin betimsel analizinde, sayı ve yüzde oranları kullanılmıştır.

2.6. Araştırmanın Etik Boyutu

Bu derlemede, Yükseköğretim Kurulu Başkanlığı Ulusal Tez Merkezi'nde yayımlanan ve kamuya açık erişime sunulan lisansüstü tezler, araştırma kapsamına dahil edilmiştir. Bu sebeple, etik kurul izni alınması gerekliliği söz konusu olmamıştır.

3. BULGULAR

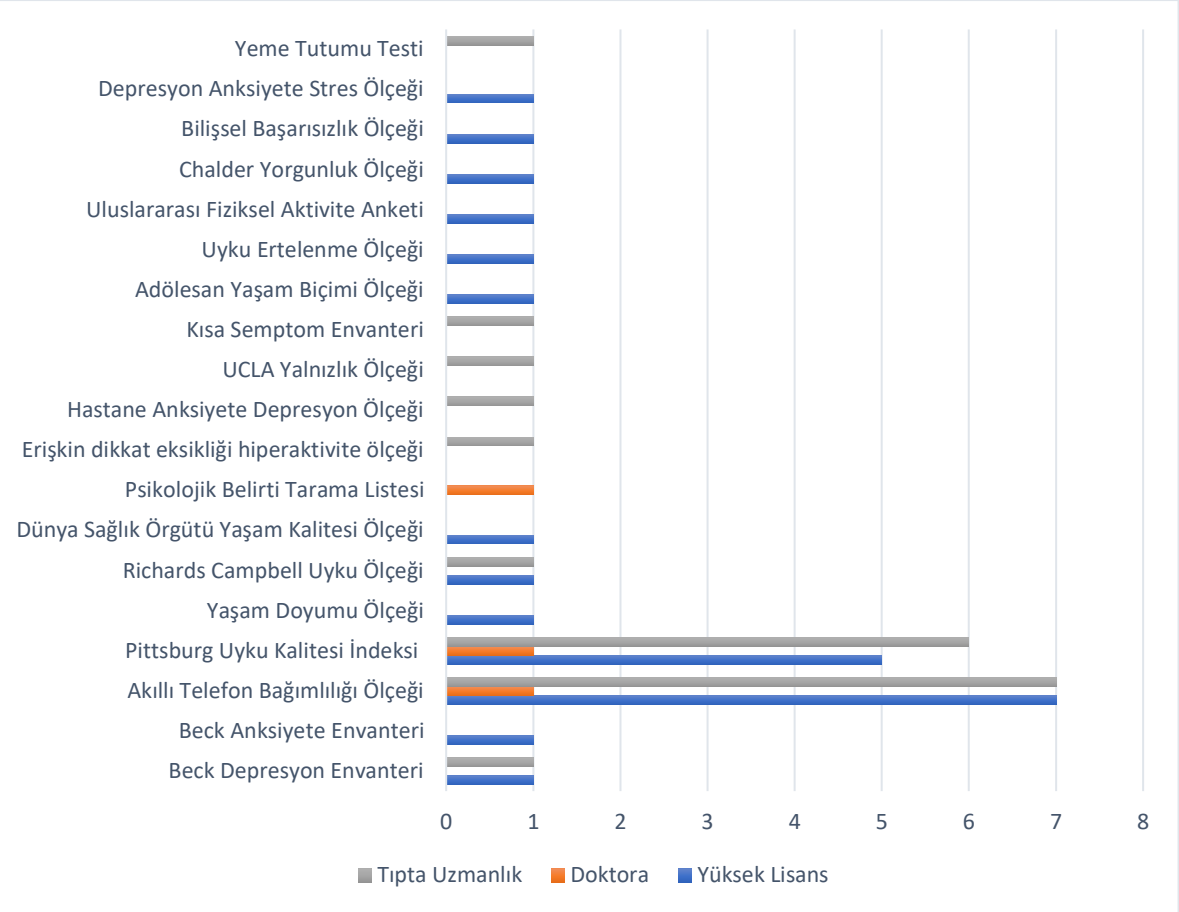
Bu bölümde Türkiye'de akıllı telefon bağımlılığı ve uyku konularını ele alan lisansüstü tezlere ilişkin bulgular yer almaktadır. “Akıllı telefon bağımlılığı” veya “uyku” kelimesi ile yapılan tarama sonucunda toplam iki bin üç yüz doksan yedi adet teze ulaşılmıştır. Ulaşılan tezlerden on beşinin başlığında “akıllı telefon bağımlılığı” ve “uyku” kelimesi birlikte geçmektedir. Toplam on beş lisansüstü tezi incelemeye alınmıştır. İncelenen tezler herkesin erişimine açık olduğundan, tamamı değerlendirme kapsamına alınmıştır. İncelenen tezlerin 7’sinin yüksek lisans, 1’inin doktora, 7’sinin tıpta uzmanlık tezidir. Tezlerin tamamının 2018-2024 yılları arasında yayımlandığı ve toplamda on iki bin beş yüz yetmiş yedi katılımcının bu çalışmalarda yer aldığı tespit edilmiştir. İncelenen tezlerin araştırma tipi, yayınlanma yılı ve anabilim dallarına göre dağılımı Tablo 2’de verilmiştir. İncelenen yüksek lisans tezlerinin %42.88’i tanımlayıcı, %14.28’i tanımlayıcı analitik, %14.28’i betimsel, %14.28’i tanımlayıcı ve kesitsel, 14.28’i kesitsel ve ilişki arayıcı türdedir. Doktora tezlerinin %100’ü ise tanımlayıcı kesitsel türdedir. Tıpta uzmanlık tezlerinin %57.15’i, kesitsel, %28.57 tanımlayıcı kesitsel, %14.28’i ise prospektif türdedir. Yüksek lisans tezlerinin yayınlanma yılları incelendiğinde ise, %42.86’sının 2018-2019 yıllarında, %28.57’sinin 2020-2021 yıllarında, %28.57’sinin de 2022-2023 yıllarında yayınlandığı belirlenmiştir. Tıpta uzmanlık tezlerinin ise yarısına yakınının (%42.87) 2020-2021 yılları arasında yayınlandığı saptanmıştır. Yüksek lisans tezlerinin anabilim dallarına göre dağılımında ise sırasıyla Klinik Psikoloji (%28.58), Hemşirelik (%28.58), Psikoloji (%14.28) olduğu belirlenmiştir. Tıpta Uzmanlık tezlerinin ise yarısına yakınının (%42.87) Aile Hekimliği Anabilim Dalında olduğu saptanmıştır. İncelenen yüksek lisans (%42.86), doktora (%100) ve tıpta uzmanlık tezlerinin (%71.44) örneklemini büyük oranda üniversite öğrencileri oluşturmaktadır.

Çizelge 2. İncelenen Tezlerin Araştırma Tipi, Yayınlanma Yılı, Anabilim Dalı ve Örneklem Gruplarına Göre Dağılımı

Tezlerin Türü						
Değişken	**Yüksek Lisans**		**Doktora**		**Tıpta Uzmanlık**	
	n	**%**	**n**	**%**	**n**	**%**
Araştırma tiplerine göre dağılımları						
Tanımlayıcı	3	42.88	0	0	0	0
Tanımlayıcı Analitik	1	14.28	0	0	0	0
Kesitsel	0	0	0	0	4	57.15
Betimsel	1	14.28	0	0	0	0
Tanımlayıcı Kesitsel	1	14.28	1	100	2	28.57
Prospektif	0	0	0	0	1	14.28
Kesitsel ve İlişki Arayıcı	1	14.28	0	0	0	0
Toplam	**7**	**%100**	**1**	**%100**	**7**	**%100**
Yayınlandıkları yıllara göre dağılımları						
2018-2019	3	42.86	1	100	1	14.28
2020-2021	2	28.57	0	0	3	42.87
2022-2023	2	28.57	0	0	2	28.57
2024-2025	0	0	0	0	1	14.28
Toplam	**7**	**%100**	**1**	**%100**	**7**	**%100**
Anabilim dallarına göre dağılımları						
Klinik Psikoloji	2	28.58	0	0	0	0
Hemşirelik	2	28.58	0	0	0	0
Halk Sağlığı	0	0	1	100	2	28.57
Psikoloji	1	14.28	0	0	0	0

Ruh Sağlığı ve Hastalıkları	0	0	0	0	2	28.57
Aile Hekimliği	0	0	0	0	3	42.86
Çocuk Sağlığı ve Hastalıkları Hemşireliği	1	14.28	0	0	0	0
Fizyoterapi ve Rehabilitasyon	1	14.28	0	0	0	0
Toplam	**7**	**%100**	**1**	**%100**	**7**	**%100**
Örneklem gruplarına göre dağılımları						
Üniversite Öğrencileri	3	42.86	1	100	5	71.44
Lise Öğrencileri	2	28.57	0	0	1	14.28
18 yaş üzeri bireyler	2	28.57	0	0	1	14.28
Toplam	**7**	**%100**	**1**	**%100**	**7**	**%100**

İncelenen tezlerde kullanılan veri toplama araçlarının dağılımı Görsel 2'de gösterilmiştir. Bu tezlerde en yaygın şekilde kullanılan veri toplama araçları, Akıllı Telefon Bağımlılığı Ölçeği (%30) ve Pittsburg Uyku Kalitesi İndeksi (%22) olarak tespit edilmiştir.



Görsel 2. İncelenen Tezlerde Kullanılan Veri Toplama Araçlarının Dağılımı

Akıllı telefon bağımlılığı ve uyku ile ilgili tezlerin özellikleri ise kronolojik olarak Tablo 3'de sunulmuştur.

Çizelge 3. Akıllı Telefon Bağımlılığı ve Uyku ile İlgili Tezlerin Özellikleri

No	Yazar/Yılı/AD/Danışman	Tez Türü	Araştırma Türü	Amaç	Örneklem Sayısı	Veri Toplama Araçları
1.	Ceren ÇEVİK 2018 Klinik Psikoloji Anabilim Dalı Emre TOLUN ARICI	Yüksek Lisans	Tanımlayıcı	Akıllı telefon bağımlılığı olan kişilerin uyku kalitesi, depresyon ile anksiyete seviyeleri arasındaki ilişkiyi incelemek.	294 öğrenci	*Demografik Bilgi Formu *Beck Depresyon Envanteri *Beck Anksiyete Envanteri *Akıllı Telefon Bağımlılığı Ölçeği *Pittsburgh Uyku Kalitesi İndeksi
2.	Mustafa YUMUŞAK 2019 Hemşirelik Anabilim Dalı Öznur BAŞDAŞ	Yüksek Lisans	Tanımlayıcı ve analitik	Üniversite öğrencilerinin uyku kalitesi, akıllı telefon bağımlılığı ve yaşam doyumu düzeylerini araştırmak.	1030 öğrenci	*Kişisel Bilgi Anketi *Akıllı Telefon Bağımlılığı Ölçeği-Kısa Versiyon *Pittsburgh Uyku Kalitesi İndeksi *Yaşam Doyumu Ölçeği

3.	Betül ÖZCAN 2019 Halk Sağlığı Anabilim Dalı Nurhan MEYDAN ACIMIŞ	Tıpta Uzmanlık Tezi	Kesitsel	Üniversitesi öğrencilerinin uyku ile akıllı telefon bağımlılığı ilişkisini incelenmek.	1545 öğrenci	*Veri formu *Akıllı Telefon Bağımlılığı Ölçeği-Kısa Formu *Pittsburgh Uyku Kalitesi İndeksi
4.	Merve ÖZATA 2019 Psikoloji Anabilim Dalı Süleyman KAHRAMAN	Yüksek Lisans	Betimsel	Akıllı telefon bağımlılığına dair belirtilerin uyku kalitesi ve yaşam kalitesi üzerindeki etkilerini araştırmak.	406 katılımcı	*Sosyo-demografik Form *Akıllı Telefon Bağımlılığı Ölçeği-Kısa Formu *Richards Campbell Uyku Ölçeği *Dünya Sağlık Örgütü Yaşam Kalitesi Ölçeği-Kısa Formu
5.	Nursel ÜSTÜNDAĞ ÖCAL 2019 Halk Sağlığı Anabilim Dalı Ahmet ÖZTÜRK	Doktora Tezi	Tanımlayıcı ve kesitsel	Üniversite öğrencilerindeki akıllı telefon bağımlılığı riskinin, uyku kalitesi ve ruhsal belirtilerle olan ilişkisini araştırmak.	1181 öğrenci	*Sosyo-demografik Anket Formu *Akıllı Telefon Bağımlılığı Ölçeği-Kısa Formu *Pittsburgh Uyku Kalitesi

						Ölçeği *Psikolojik Belirti Tarama Listesi
6.	Bilge UZUN 2020 Ruh Sağlığı ve Hastalıkları Anabilim Dalı Mustafa ARI	Tıpta Uzmanlık Tezi	Prospektif	Üniversite öğrencilerindeki akıllı telefon bağımlılığı ile dikkat eksikliği hiperaktivite bozukluğu, depresyon ve uyku kalitesi arasındaki ilişkiyi incelemek.	200 öğrenci	*Sosyo-demografik Veri Formu *Akıllı Telefon Bağımlılığı Ölçeği *Erişkin Dikkat Eksikliği Hiperaktivite Ölçeği *Beck Depresyon Ölçeği *Pitssburgh Uyku Kalitesi İndeksi
7.	Hatice AYGAR 2020 Halk Sağlığı Anabilim Dalı Alaettin ÜNSAL	Tıpta Uzmanlık Tezi	Kesitsel	Lise öğrencilerindeki akıllı telefon bağımlılığı, psikolojik durum ve uyku kalitesini değerlendirmek.	4088 öğrenci	*Akıllı Telefon Bağımlılığı Ölçeği-Kısa Versiyonu *Hastane Anksiyete Depresyon Ölçeği *UCLA Yalnızlık Ölçeği-Kısa Formu *Pittsburgh Uyku Kalitesi İndeksi

8.	Muhammet ÖZMEN 2021 Aile Hekimliği Anabilim Dalı Kamile MARAKOĞLU	Tıpta Uzmanlık Tezi	Tanımlayıcı ve kesitsel	Tıp fakültesi öğrencilerinin akıllı telefon bağımlılığı, psikolojik belirti ve uyku kalitesi arasındaki ilişkiyi araştırmak.	1177 öğrenci	*Sosyodemografik Veri Formu *Akıllı Telefon Bağımlılığı Ölçeği-Kısa Formu *Kısa Semptom Envanteri *Pittsburgh Uyku Kalitesi İndeksi
9.	FEYZA DEVECİ 2021 Hemşirelik Anabilim Dalı Selmin Köse	Yüksek Lisans	Kesitsel ve ilişki arayıcı	Akıllı telefon bağımlılığı ile uyku kalitesi ilişkisini ergenlerde değerlendirmek.	152 öğrenci	*Kişisel Bilgi Formu *Pittsburg Uyku Kalite Ölçeği *Akıllı Telefon Bağımlılığı Ölçeği
10.	Berrin GÖGER 2021 Çocuk Sağlığı ve Hastalıkları Hemşireliği Anabilim Dalı lknur KAHRİMAN	Yüksek Lisans Tezi	Tanımlayıcı	Adölesanlarda akıllı telefon bağımlılığının, uyku kalitesi ve yaşam tarzı alışkanlıkları üzerindeki etkilerini değerlendirmek.	546 öğrenci	*Akıllı Telefon Bağımlılığı Ölçeği-Kısa Formu *Pittsburg Uyku Kalite İndeksi *Adölesan Yaşam Biçimi Ölçeği

11.	Sergen ATBAŞ 2022 Aile Hekimliği Kliniği Güzin Zeren ÖZTÜRK	Tıpta Uzmanlık Tezi	Kesitsel	18 ile 64 yaş arasındaki bireylerde akıllı telefon bağımlılığının uyku kalitesi ile ilişkisini değerlendirmek.	261 katılımcı	*Sosyo-demografik Özellikler Formu *Akıllı Telefon Bağımlılığı Ölçeği-Kısa Formu *Pittsburg Uyku Kalitesi İndeksi
12.	Barış BURAK 2022 Aile Hekimliği Anabilim Dalı Mehmet Emin LAYIK	Tıpta Uzmanlık Tezi	Kesitsel	Tıp fakültesi öğrencilerinde akıllı telefon bağımlılığının uyku kalitesi ve akademik başarı üzerindeki etkisinin değerlendirilmesi.	484 öğrenci	*Sosyo–demografik Form, *Richard Campbell Uyku Ölçeği *Akıllı Telefon Bağımlılığı Ölçeği–Kısa Formu
13.	Gökçe KELEŞ 2023 Klinik Psikoloji Ayşe Berna SARI ARASIL	Yüksek Lisans Tezi	Tanımlayıcı	Akıllı telefon bağımlılığı ile uyku vaktini ertelemenin, bilinçli farkındalık ve uyku kalitesi arasındaki ilişkiye aracılık rolünün incelenmesi.	385 katılımcı	*Demografik Bilgi Formu *Akıllı Telefon Bağımlılık Ölçeği, *Uyku Ertelenme Ölçeği *Pittsburgh Uyku Kalitesi İndeksi

14.	Nisa TÜRÜTGEN 2023 Fizyoterapi ve Rehabilitasyon Tarık ÖZMEN	Yüksek Lisans Tezi	Tanımlayıcı ve kesitsel	Üniversite öğrencilerinde akıllı telefon bağımlılığıyla yorgunluk, fiziksel aktivite, uyku kalitesi, bilişsel durum, anksiyete ve depresyon ilişkisini incelemek.	421 öğrenci	*Akıllı Telefon Bağımlılığı Ölçeği-Kısa Formu *Uluslararası Fiziksel Aktivite Anketi-Kısa *Chalder Yorgunluk Ölçeği *Bilişsel Başarısızlık Ölçeği *Depresyon Anksiyete Stres Ölçeği
15.	Deniz DOLAŞ 2024 Ruh Sağlığı ve Hastalıkları Anabilim Dalı Ali ERDOĞAN	Tıpta Uzmanlık Tezi	Tanımlayıcı ve kesitsel	Yeme tutumu, obezite ve uyku kalitesiyle akıllı telefon bağımlılığı arasındaki ilişkiyi incelemek.	407 öğrenci	*Sosyo-demografik Veri Formu *Akıllı Telefon Bağımlılığı Ölçeği-Kısa Form *Pittsburgh Uyku Kalitesi İndeksi *Yeme Tutumu Testi

Üstündağ Öcal, araştırmasında öğrencilerin yaklaşık olarak üçte birinin akıllı telefon bağımlılığı riski taşıdığını belirtmiştir.[17] Lise öğrencileri arasında akıllı telefon bağımlılığı sıklığı ise %44.2 olarak bulunmuştur.[18] Çevik, araştırmasında üniversite öğrencilerinin akıllı telefon bağımlılığı puanları yükseldikçe, anksiyete, depresyon ve uyku kalitesi ölçeklerinden aldıkları puanların da arttığını ifade etmiştir.[19] Yumuşak'ın çalışmasında da akıllı telefon bağımlılığı ve uyku kalitesi düzeylerinin birbirini etkilediği belirtilmiştir.[20] Özcan benzer şekilde, akıllı telefon bağımlılığı yaşayan üniversite öğrencilerinin kötü uyku kalitesi sıklığının, diğer öğrencilere kıyasla daha yüksek olduğunu belirtmiştir.[21] Ayrıca akıllı telefon bağımlılığına dair ölçek puanlarının, uyku kalitesi ve yaşam kalitesi üzerinde etkili olduğu ifade edilmiştir.[22] İncelenen tezlerde, üniversite öğrencilerinin yarısından fazlasının uyku kalitesinin kötü olduğu ve akıllı telefon bağımlılığı puanları arttıkça uyku kalitesi puanlarının da yükseldiği bildirilmiştir.[23] Bunun yanı sıra, akıllı telefon bağımlılığının üniversite öğrencilerinin uyku kalitesi ve akademik başarısı üzerinde olumsuz etkiler yarattığı ifade edilmiştir.[24] Deveci çalışmasında, ergenlerde akıllı telefon bağımlılığı ile uyku kalitesi arasında olumsuz yönde anlamlı bir ilişki tespit edilmiştir.[25] Adölesanlarda da akıllı telefon bağımlılığının uyku kalitesi ve yaşam tarzı davranışları üzerinde olumsuz etkiler yarattığı ifade edilmektedir.[26] Genç ve bekar bireylerin akıllı telefon bağımlılıklarının daha yüksek ve uyku kalitelerinin daha kötü olduğu bildirilmektedir.[27] Keleş, bilinçli farkındalığın akıllı telefon bağımlılığının uyku kalitesi ile ilişkili olan rolünü desteklediğini bildirmiştir.[28] Farklı olarak öğrencilerindeki akıllı telefon bağımlılığı ile uyku kaliteleri arasında ilişki olmadığını bildirilmektedir.[29] Türütgen'in çalışmasında, akıllı telefon bağımlılığı ile vücut kitle indeksi arasında fark bulunmadığı belirlenmiştir.[30] Dolaş'ın çalışmasında da, akıllı telefon bağımlılığı ve obezite arasında herhangi bir ilişki bulunmadığı ifade edilmiştir.[31]

4. TARTIŞMA

Akıllı telefon bağımlılığı ve uyku konularında yapılan tezlerin incelendiği bu sistematik derlemede, yüksek lisans, doktora ve tıpta uzmanlık tezlerinde tanımlayıcı/kesitsel, prospektif, ilişki arayıcı ve betimsel türlerin tercih edildiği görülmüştür. Farklı örneklem türleri ve büyüklükleri ile çeşitli veri toplama araçları kullanılarak yapılan bu tezlerde, akıllı telefon bağımlılığının uyku kalitesi üzerinde etkili olduğu tespit edilmiştir.

İncelenen tezlerde, öğrencilerin akıllı telefon bağımlılık risklerinin ve düzeylerinin yüksek olduğu bildirilmektedir.[17,18] Ayrıca incelenen 1 doktora, 6 yüksek lisans ve 5 tıpta uzmanlık tezinde de akıllı telefon bağımlılığı ile uyku arasında ilişki olduğu, akıllı telefon bağımlılığının kötü uyku kalitesine neden olduğu bildirilmektedir. [17,19-27,30,31] Literatür incelendiğinde, akıllı telefon bağımlılığının uyku kalitesi, gündüz uykululuk hali ile ilişkili olduğu saptanmıştır.[9] Bir diğer araştırmada, akıllı telefon kullanımının düşük uyku kalitesiyle bağlantılı olduğu, uykuya geçişin gecikmesine neden olabileceği belirlenmiştir.[11] Londra'da yapılan bir çalışmada, 18-30 yaş arasındaki 1043 kişinin %68.7'sinin akıllı telefon bağımlılığı ve düşük uyku kalitesi yaşadığı belirtilmiştir.[6] Akıllı telefon bağımlılığı, kullanım süresi fark etmeksizin yetersiz uyku ile ilişkilendirilmiştir.[32] Literatürün aksine Uzun'un çalışmasında öğrencilerindeki akıllı telefon bağımlılığı ve uyku kalitesi arasında ilişki olmadığı bildirilmektedir.[29] Farklılığın çalışma tasarımı, örneklem türü ve büyüklüğü, kullanılan veri toplama araçlarından kaynaklanabileceği

düşünülmektedir. Tüm bulgular göze alındığında, akıllı telefon ve uyku kalitesini ele alan çalışmaların farklı ülke ve kültürlerde tekrarlanması önerilebilir.

Yüksek lisans ve tıpta uzmanlık kapsamında yürütülen çalışmalarda akıllı telefon bağımlılığını etkileyen durumlar üzerinde durulmuştur.[18,22,24,30] Türütgen, çalışmasında akıllı telefon bağımlılığının alkol tüketimi, bölüm, sınıf düzeyi, gelir durumu ve ikamet edilen yer ile ilişkili olduğunu, ancak yaşla ilgili bir ilişki saptanmadığını ifade etmiştir.[30] Özata ise yaş, medeni durum ve eğitim durumu gibi faktörlerin akıllı telefon bağımlılığını etkilediğini belirtmektedir.[22] Burak da bağımlılık durumunun, cinsiyet ve sınıf değişkenlerinden etkilenmezken, ikamet yeri değişkeni tarafından etkilendiğini belirtmiştir.[24] Literatürdeki tanımlayıcı ve kesitsel çalışmalar incelendiğinde, kadınların akıllı telefon bağımlılığı düzeylerinin erkeklerden yüksek olduğu bildirilmektedir.[4] Farklı olarak, cinsiyet, yaş, sigara, alkol kullanımı ve fiziksel aktivite gibi değişkenlerin akıllı telefon bağımlılığı ile ilişkisi bulunmadığını bildiren çalışma sonuçları da bulunmaktadır.[2] Acharya 'nın çalışma bulguları da bu bulguyla paralellik göstermektedir.[13] Literatürdeki farklı sonuçlar dikkate alındığında akıllı telefon bağımlılığı ve uyku konularını ele alan girişimsel ve deneysel çalışmalara olan ihtiyaç ortaya çıkmaktadır.

Tıpta uzmanlık tezi kapsamında yürütülen çalışmada anksiyete, depresyon ve yalnızlık gibi faktörlerin de akıllı telefon bağımlılığı için risk faktörü olduğu ifade edilmektedir.[18] İncelenen 2 yüksek lisans tezinde de akıllı telefon bağımlılığı ve depresyon arasındaki ilişkinin anlamlı olduğu bildirilmektedir.[19,30] Uzun'un çalışmasında ise ilişki olmadığı bildirilmektedir.[29] Depresyon ve anksiyete, akıllı telefon bağımlılığı için bağımsız pozitif öngörücülerdir.[33] Literatür incelendiğinde, aşırı telefon kullanımının, depresyon ve anksiyeteye yol açarak uyku problemlerine neden olabileceği belirtilmektedir.[34] Üniversite öğrencilerinde akıllı telefon bağımlılığı, uyku kalitesi, depresyon, anksiyete ve stresle ilişkili olduğu bildirilmektedir.[9] Ayrıca ergenlerde de akıllı telefon bağımlılığı riski artışı, depresyon ve anksiyete gibi psikopatolojik sorunlara yol açmaktadır.[12] Aşırı telefon kullanımı kontrol edilemeyebilir, bu da endişe, kaygı ve depresyon gibi olumsuz duygulara yol açarak uyku kalitesini etkileyebilir.[15] İncelenen tezlerde akıllı telefon bağımlılığının uyku kalitesi ve yaşam kalitesi üzerine etki ettiği ifade edilmektedir.[22] Adölesanlarda da akıllı telefon bağımlılığının uyku kalitesini ve yaşam biçimi davranışlarını olumsuz etkilediği belirtilmektedir.[26] Literatür incelendiğinde, kötü uyku kalitesinin yaşam kalitesinin azalması gibi ciddi sorunlara yol açtığı bildirilmektedir.[35] Ayrıca ele alınan çalışmalarda akıllı telefon bağımlılığı ve beslenme, BKİ (Beden Kitle İndeksi) arasındaki ilişkiye vurgu yapılmaktadır. Türütgen'in çalışmasında, akıllı telefon bağımlılığı ile vücut kitle indeksi arasında fark bulunmadığı belirlenmiştir. [30] Dolaş'ın çalışmasında da akıllı telefon bağımlılığı ile obezite arasında ilişki olmadığı belirtilmiştir.[31] Benzer olarak üniversite öğrencilerinin BKİ ve uyku süreleri arasında fark bulunmamıştır.[36] Literatürde farklı sonuçlar da göze çarpmaktadır. Genç yetişkinlerde akıllı telefon bağımlılığı, azalan fiziksel aktivite ve artan BKİ ile kötü uyku kalitesi arasında ilişkiden bahsedilmektedir.[37] Çalışmalarda ele alınan örneklem gruplarının farklı olması, beslenme değişkenleri dışında fiziksel aktivite düzeylerinin yeterince ele alınmaması literatürdeki farklılığı açıklayabilir.

5. SONUÇLAR

Teknolojinin ilerlemesi ve akıllı telefonların günlük yaşantımıza entegrasyonu ile birlikte, akıllı telefon bağımlılığı ve uyku arasındaki ilişki son yıllarda dikkat çeken bir araştırma konusu haline gelmiştir. Bu çalışmada, 2018-2024 yılları arasında gerçekleştirilen tezlerde akıllı telefon bağımlılığı ve uyku konularının ele alındığı, incelemeye alınan tezlerin büyük çoğunluğunun lise ve üniversite öğrencilerini kapsadığı tespit edilmiştir. Tez çalışmalarının büyük bir kısmı yüksek lisans ve uzmanlık tezlerinden oluşurken, doktora düzeyinde bu konuya yeterince odaklanılmadığı görülmüştür. Ayrıca, incelenen tezlerin çoğunun kesitsel, tanımlayıcı, betimsel, ilişki arayıcı ve prospektif yöntemlerle yapıldığı belirlenmiş; ancak deneysel ve yarı deneysel araştırmalara rastlanmamıştır. Akıllı telefon bağımlılığı ve uyku arasındaki ilişkiyi farklı örneklemlerle incelemek ve bu konuda etkileyen faktörleri belirlemek için daha fazla araştırmanın yapılması, özellikle doktora düzeyinde yarı deneysel ve deneysel çalışmalara yer verilmesi önerilmektedir. Ayrıca, on sekiz yaş altı ve yetişkin bireyler üzerinde konuya özgü daha fazla araştırma yapılması ve daha geniş örneklemlerle çeşitli araştırma türlerinin gerçekleştirilmesi, bu alandaki bilgi birikimine önemli katkılar sağlayabilir.

Çalışmanın güçlülük ve sınırlılıkları

Araştırmanın bazı güçlü yönleri ve sınırlılıkları bulunmaktadır. Akıllı telefon bağımlılığı ve uyku konusundaki tüm tezlerin, anabilim dalı ve dil ayrımı yapılmaksızın incelenmesi, çalışmanın güçlü yönlerinden birini oluşturmuştur. Ancak, yalnızca tek bir veri tabanının kullanılması, araştırmanın sınırlılıklarını ortaya koymaktadır. Bu durum, daha geniş bir literatür taraması yapılabilmesi için farklı veri tabanlarının da kullanılması gerektiğini göstermektedir.

Çalışma literatüre ne kattı?

Bu çalışma, Türkiye'de akıllı telefon bağımlılığı ve uyku ile ilgili yazılmış lisansüstü tezlerin konu eğilimleri ve sonuçlarını ortaya koyması açısından literatüre katkı sağlayacağı düşünülmektedir.
Akıllı telefon bağımlılığının yaygın olarak görülmesi ve bu durumun uyku üzerine etkileri, hemşirelerin de bireylerle iç içe olarak bu süreçte bakım, tedavi ve yeni hayatlarına uyumlanmalarında hemşirelerin etkililiğinin öneminin vurgulanmaktadır.

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BEYİN SİSİ VE HEMŞİRELİK ARASINDAKİ İLİŞKİ THE RELATIONSHIP BETWEEN BRAIN FOG AND NURSING

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ÖZET

Beyin Sisi “brain fog”, bireylerin bilişsel işlevlerde önceki performans düzeylerine kıyasla belirgin bir zorlanma ve klinikte kesin tanı ölçütleri olmayan bir durumdur. Bu durum çoğunlukla dikkat süresinde kısalma, konsantrasyon bozukluğu/güçlüğü, bellek/hafıza işlevlerinde zorlanma ve bilgi işleme, düşünme gibi fonksiyonlarda şeklindeki belirtiler ile kendini göstermektedir. Son yıllardaki bazı çalışmalarda görüldüğü üzere beyin sisi belirtilerinin kronik rahatsızlık, enfeksiyon, psikososyal stresör ve yoğun çalışma koşulları ile doğru orantılı olduğu ve daha sık bildirildiği görülmektedir.

Sağlık hizmetlerinde büyük bir rol oynayarak sürekliliğinde kilit rol üstlenen hemşireler; vardiyalı çalışma düzeni, gece nöbetleri, uzun çalışma saatleri ve yüksek sorumluluk gerektiren görevleri nedeni ile bilişsel yük açısından risk altında bulunmaktadır. Zihin bulanıklığı ve bilişsel işlev bozukluğu yaşayan hemşireler; klinik karar verme ve muhakeme süreçlerinin zorlaşarak bakım uygulamalarında etkinliklerinin azalabildiğini ve hasta güvenliğinin olumsuz yönde etkilenebileceği bildirilmektedir. Bu derlemenin amacı, beyin sisi kavramının son zamanlarda yapılan çalışmalar doğrultusunda ele alınarak hemşirelik ile ilişkisini değerlendirmek, uygulanan tedavi yaklaşımlarını hemşirelik uygulamaları açısından bütüncül bir bakış açısı ile tartışmaktır.

Anahtar Kelimeler: Beyin sisi, hemşirelik, hasta güvenliği, bilişsel işlevler

ABSTRACT

Brain fog is a condition characterized by a noticeable decline in individuals' cognitive functioning compared to their previous performance levels and lacks clearly defined diagnostic criteria in clinical practice. This condition commonly manifests through symptoms such as a reduced attention span, difficulties or impairments in concentration, challenges in memory functions, and disruptions in processes such as information processing and thinking. As demonstrated in several recent studies, symptoms of brain fog are reported more frequently and are positively associated with chronic illnesses, infections, psychosocial stressors, and intensive working conditions.

Nurses, who play a major role in healthcare services and are essential to the continuity of care, are at risk of increased cognitive load due to shift-based work patterns, night duties, long working hours, and responsibilities that require a high level of accountability. It has been reported that nurses experiencing mental clouding and cognitive dysfunction may face difficulties in clinical decision-making and reasoning processes, leading to decreased effectiveness in care practices and potentially adverse effects on patient safety. The aim of this review is to address the concept of brain fog in light of recent studies, evaluate its relationship with nursing, and discuss current treatment approaches from a holistic perspective in terms of nursing practice.

Keywords: Brain fog, nursing, patient safety, cognitive functions

GİRİŞ

Bilişsel işlevler; dikkat, bellek, öğrenme, problem çözme ve karar verme gibi bireyin günlük yaşamını ve mesleki performansını doğrudan etkileyen zihinsel süreçleri kapsamaktadır. Bu işlevlerde meydana gelen bozulmalar, özellikle hata toleransının son derece düşük olduğu sağlık hizmetleri alanında, yalnızca bireysel sonuçlar doğurmakla kalmamakta; hasta güvenliği ve bakım kalitesi üzerinde de önemli etkiler oluşturmaktadır. Son zamanlarda yapılan çalışmalarda, sağlık çalışanlarının yoğun iş yükü ve stres altında bilişsel performanslarının olumsuz yönde etkilendiği bildirilmektedir (Korkmaz & Tel, 2020; Akgün & Yıldız, 2021; Pappa et al., 2022).

Beyin sisi (*brain fog*), bireylerin zihinsel performanslarında önceki dönemlere kıyasla belirgin bir azalma yaşadıklarını ifade etmek amacıyla kullandıkları ve klinik olarak kesin sınırlarla tanımlanmamış bir kavramdır. Son zamanlarda yapılan çalışmalarda, beyin sisinin yalnızca nörolojik ya da psikiyatrik hastalıklara özgü olmadığı; enfeksiyonlar, kronik hastalıklar, uzun süreli stres ve yoğun çalışma koşulları gibi çok sayıda faktörle ilişkili olduğu gösterilmiştir (Boldrini et al., 2021; Graham et al., 2021; Davis et al., 2023).

Hemşireler, vardiyalı çalışma düzeni, gece nöbetleri ve yüksek hasta yükü gibi nedenlerle bilişsel açıdan riskli meslek grupları arasında yer almaktadır. Türkiye'de yapılan çalışmalarda, hemşirelerin stres ve tükenmişlik düzeyleri arttıkça dikkat, bellek ve klinik karar verme süreçlerinin olumsuz etkilendiği bildirilmiştir (Korkmaz & Tel, 2020; Kaya et al., 2021; Özdemir & Taşcı, 2023). Bu bağlamda beyin sisi, hemşirelik uygulamalarını ve hasta güvenliğini doğrudan etkileyebilen önemli bir mesleki sorun alanı olarak değerlendirilmektedir.

1. BEYİN SİSİ KAVRAMI

Beyin sisi, bireylerin dikkat, bellek ve bilgi işleme hızında yaşadıkları öznel zorlanmaları tanımlamak için kullanılan bir kavramdır. Literatürde bu durum; dikkat dağınıklığı, odaklanmada güçlük, kısa süreli bellek sorunları, zihinsel yavaşlama ve bilişsel esneklikte azalma gibi belirtilerle ilişkilendirilmektedir (Asadi-Pooya et al., 2020; Becker et al., 2021; Hampshire et al., 2021). Bu belirtiler, bireyin günlük yaşam aktivitelerini sürdürme kapasitesini ve mesleki işlevselliğini belirgin biçimde azaltabilmektedir.

Beyin sisi, belirli bir nörolojik ya da psikiyatrik hastalığa özgü tekil bir tanı olarak kabul edilmemekte; daha çok çok faktörlü bir bilişsel durum olarak ele alınmaktadır. Son zamanlarda yapılan çalışmalarda, enfeksiyon hastalıkları sonrası dönemde, kronik yorgunluk durumlarında ve uzun süreli stres maruziyetinde beyin sisi belirtilerinin daha sık rapor edildiği bildirilmektedir (Rogers et al., 2020; Graham et al., 2021; Zhou et al., 2022). Bu durum, beyin sisinin bireyin yaşam kalitesi üzerinde önemli bir yük oluşturabileceğini düşündürmektedir.

Türkçe literatürde beyin sisi kavramı çoğunlukla bilişsel bulanıklık veya zihinsel yorgunluk bağlamında ele alınmakta; özellikle sağlık çalışanlarında stres, iş yükü ve tükenmişlik ile ilişkisi vurgulanmaktadır (Korkmaz & Tel, 2020; Akgün & Yıldız, 2021; Gül & Özdemir, 2022).

Bu doğrultuda beyin sisinin, yalnızca öznel bir bilişsel yakınma olarak ele alınmasının ötesinde, farklı biyolojik, psikolojik ve çevresel etkenlerle ilişkili çok boyutlu bir yapıya sahip olduğu görülmektedir. Bu durum, beyin sisinin etyolojik açıdan ayrıntılı biçimde incelenmesini gerekli kılmaktadır.

2. BEYİN SİSİNİN ETİYOLOJİSİ

Beyin sisinin etyolojisi biyolojik, psikolojik ve çevresel faktörlerin etkileşimiyle şekillenen çok boyutlu bir yapı göstermektedir. Son zamanlarda yapılan çalışmalarda, nöroinflamatuar süreçlerin, bağışıklık sistemi yanıtlarındaki değişimlerin ve oksidatif stresin bilişsel işlevler üzerinde olumsuz etkiler oluşturabileceği bildirilmektedir (Boldrini et al., 2021; Kumar et al., 2021; Davis et al., 2023).

COVID-19 sonrası dönemde yapılan araştırmalar, beyin sisi belirtilerinin uzun süre devam edebildiğini ve özellikle frontal ve temporal beyin bölgelerinde metabolik aktivite azalmasıyla

ilişkili olabileceğini göstermektedir (Graham et al., 2021; Guedj et al., 2021). Ayrıca serotonin düzeylerinde azalma ve nörotransmitter dengesizliklerinin de bilişsel yakınmalara katkı sağlayabileceği ileri sürülmektedir (Tavee, 2024).

Psikososyal faktörler de beyin sisinin gelişiminde önemli rol oynamaktadır. Uzun süreli stres, anksiyete, depresyon ve tükenmişlik durumlarının dikkat, bellek ve karar verme süreçlerini olumsuz etkilediği bildirilmektedir (Pappa et al., 2022; Garcia et al., 2022). Türkiye'de sağlık çalışanları üzerinde yapılan çalışmalarda, artan iş yükü ve psikolojik baskının bilişsel performansı zayıflattığı gösterilmiştir (Korkmaz & Tel, 2020; Gül & Özdemir, 2022).

Bu etyolojik faktörler dikkate alındığında, bilişsel işlevleri etkileyebilen beyin sisinin, yüksek düzeyde dikkat ve zihinsel süreç gerektiren meslek grupları açısından özel bir önem taşıdığı anlaşılmaktadır. Bu bağlamda, sağlık hizmetlerinin sunumunda temel bir role sahip olan hemşirelik mesleğinin bilişsel gerekliliklerinin ele alınması, beyin sisi ile hemşirelik arasındaki ilişkinin anlaşılmasına katkı sağlayacaktır.

3. HEMŞİRELİK KAVRAMI VE BİLİŞSEL BOYUTU

Hemşirelik; bireyin, ailenin ve toplumun sağlığını korumayı, geliştirmeyi ve hastalık durumlarında bakım gereksinimlerini karşılamayı amaçlayan bilimsel ve uygulamalı bir sağlık mesleğidir. Uluslararası Hemşireler Konseyi, hemşireliği eleştirel düşünme, klinik muhakeme ve sürekli bilişsel dikkat gerektiren profesyonel bir uygulama alanı olarak tanımlamaktadır (ICN, 2021).

Hemşirelik uygulamaları; hasta değerlendirme, bakım planlama, girişimlerin uygulanması ve bakımın değerlendirilmesi gibi aşamalarda yüksek düzeyde bilişsel işlev gerektirmektedir. Bu nedenle hemşirelerin bilişsel yeterlilikleri, hasta bakımının güvenli ve etkili biçimde sürdürülebilmesi açısından temel bir belirleyici olarak kabul edilmektedir (Melnyk et al., 2020; Kaya et al., 2021).

Son zamanlarda yapılan çalışmalarda, hemşirelerin bilişsel yükünün artmasının hata yapma riskini yükselttiği ve bakım kalitesini olumsuz etkilediği bildirilmektedir (Garcia et al., 2022; Wei et al., 2023). Bu bulgular, beyin sisi gibi bilişsel zorlanmaların hemşirelik uygulamaları açısından önemini artırmaktadır.

Hemşireliğin yüksek düzeyde bilişsel dikkat, klinik muhakeme ve karar verme süreçlerini içeren bir meslek olması, bilişsel işlevleri etkileyen durumların hemşirelik uygulamaları üzerindeki olası etkilerinin ayrıntılı biçimde ele alınmasını gerekli kılmaktadır.

4. BEYİN SİSİ VE HEMŞİRELİK ARASINDAKİ İLİŞKİ

Beyin sisi, hemşirelerin klinik uygulamalarında dikkat, bellek, bilgi işleme hızı ve karar verme gibi temel bilişsel süreçleri doğrudan etkileyebilen bir durumdur. Hemşirelik mesleği; hasta güvenliği açısından kritik kararların hızlı ve doğru biçimde alınmasını gerektirdiğinden, bilişsel işlevlerde meydana gelen zorlanmalar bakım süreçlerinde önemli riskler oluşturmaktadır. Beyin sisi belirtileri hemşirelerde sıklıkla dikkat dağınıklığı, unutkanlık, zihinsel yavaşlama ve odaklanma güçlüğü şeklinde ortaya çıkmakta; bu durum özellikle ilaç uygulamaları, hasta izlemi ve acil müdahale gerektiren klinik durumlarda hata riskini artırmaktadır (Garcia et al., 2022; Wei et al., 2023; Lockley et al., 2020).

Son zamanlarda yapılan çalışmalarda, bilişsel yorgunluk ve zihinsel bulanıklık yaşayan hemşirelerde ilaç dozunun yanlış hesaplanması**,** ilaç–hasta–zaman doğrulama adımlarının atlanması**,** hasta izleminde kritik bulguların geç fark edilmesi **ve** klinik önceliklendirme hatalarının artması gibi hasta güvenliğini tehdit eden durumların daha sık görülebildiği bildirilmektedir (Rogers et al., 2020; Lockley et al., 2020). Ayrıca dikkat ve bellek süreçlerinde yaşanan bozulmaların, acil durumlarda müdahalede gecikmeye**,** hasta dosyaları ve elektronik kayıt sistemlerinde veri giriş hatalarına ve ekip içi iletişim kopukluklarına yol açabildiği belirtilmektedir. Bu tür bilişsel hataların özellikle yoğun bakım ve acil servis gibi yüksek bilişsel yük gerektiren klinik ortamlarda bakım kalitesini belirgin biçimde olumsuz etkilediği vurgulanmaktadır (West et al., 2018; Garcia et al., 2022).

Türkiye'de yapılan çalışmalarda, iş yükü ve stres düzeyi yüksek olan hemşirelerde dikkat sorunlarının daha sık görüldüğü ve bunun bakımın niteliğini olumsuz etkilediği bildirilmektedir (Kaya et al., 2021; Özdemir & Taşcı, 2023). Vardiyalı çalışma düzeni ve gece nöbetleri, hemşirelerin uyku–uyanıklık döngüsünü bozarak bilişsel performansı zayıflatmakta; uyku yoksunluğunun dikkat ve karar verme süreçlerini olumsuz etkilediği hem ulusal hem de uluslararası çalışmalarda ortaya konmaktadır (Lockley et al., 2020; Gül & Özdemir, 2022).

Beyin sisi ile tükenmişlik arasındaki ilişki de hemşirelik mesleği açısından önemli bir boyut oluşturmaktadır. Tükenmişlik yaşayan hemşirelerde zihinsel yorgunluk, motivasyon kaybı ve duygusal tükenme ile birlikte bilişsel performansta belirgin bir düşüş görülebilmektedir (Akgün & Yıldız, 2021; Pappa et al., 2022). Bu durum, beyin sisinin yalnızca bireysel bir bilişsel yakınma değil; çalışma koşulları, örgütsel faktörler ve mesleki yük ile yakından ilişkili, çok boyutlu bir mesleki sağlık sorunu olduğunu göstermektedir.

Beyin sisinin hemşirelik uygulamaları ve hasta güvenliği üzerindeki olası etkilerinin ortaya konulması, bu durumun yönetimine yönelik etkili tedavi ve destekleyici yaklaşımların ele alınmasını gerekli kılmaktadır.

5. BEYİN SİSİNDE TEDAVİ YÖNTEMLERİ

Beyin sisinin tedavisinde temel yaklaşım, altta yatan nedenlerin belirlenmesi ve bu nedenlere yönelik bütüncül müdahalelerin planlanmasıdır. Son zamanlarda yapılan çalışmalarda, beyin sisinin yalnızca farmakolojik yaklaşımlarla değil; yaşam tarzı düzenlemeleri, bilişsel

rehabilitasyon ve psikososyal destek uygulamalarını içeren çok boyutlu stratejilerle ele alınması gerektiği vurgulanmaktadır (Davis et al., 2023; Tavee, 2024).

Yaşam tarzı düzenlemeleri, tedavinin ilk basamağını oluşturmaktadır. Düzenli ve kaliteli uyku, bilişsel işlevlerin korunmasında temel bir faktör olarak değerlendirilmektedir. Uyku süresi ve kalitesindeki bozulmaların dikkat ve bellek performansını olumsuz etkilediği bildirilmektedir (Kumar et al., 2021; Lockley et al., 2020). Dengeli beslenme ve fiziksel aktivitenin artırılmasının da bilişsel performansı desteklediği gösterilmiştir (Zhou et al., 2022).

Bilişsel rehabilitasyon programları, dikkat ve bellek egzersizleri ile mindfulness temelli stres azaltma yaklaşımları, beyin sisi belirtilerinin hafifletilmesinde etkili yöntemler arasında yer almaktadır (Bennett et al., 2021; Gorenshtein et al., 2024). Uzun COVID bağlamında yapılan çalışmalarda, invaziv olmayan beyin stimülasyonu yöntemlerinin de umut verici sonuçlar sunduğu bildirilmektedir (Guedj et al., 2021; Tavee, 2024).

6. SONUÇ

Beyin sisi, hemşirelerin bilişsel işlevlerini, mesleki performanslarını ve bakım süreçlerindeki etkinliklerini olumsuz yönde etkileyebilen önemli bir mesleki sağlık sorunudur. Yoğun iş yükü, vardiyalı çalışma düzeni, gece nöbetleri ve psikososyal stresörler, hemşirelerde beyin sisi gelişimini kolaylaştırmaktadır. Bu durum, hasta güvenliği ve bakım kalitesi üzerinde doğrudan etkiler oluşturmaktadır. Bu nedenle beyin sisi, yalnızca bireysel bir bilişsel yakınma olarak değil, hemşirelik bakımının niteliğini ve sağlık hizmetlerinin sürdürülebilirliğini etkileyen çok boyutlu bir sorun alanı olarak ele alınmalıdır. Hemşirelerin bilişsel sağlıklarının korunmasına yönelik önleyici ve destekleyici yaklaşımların geliştirilmesi, güvenli ve kaliteli hasta bakımının sağlanması açısından kritik öneme sahiptir.

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ACİL SERVİS HEMŞİRELİĞİNDE HASTA GÜVENLİĞİ RİSKLERİ

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ÖZET

Acil servisler, sağlık hizmetlerinin en dinamik ve kritik alanlarından biri olup hızlı karar verme, çoklu görev yürütme ve sürekli değişen klinik koşullara uyum sağlama gerekliliği ile karakterizedir. Bu nedenle acil serviste çalışan hemşireler, özellikle gece vardiyalarında fizyolojik sınırlarını zorlayan, psikolojik dayanıklılık gerektiren ve çevresel faktörlerle şekillenen çok boyutlu bir çalışma yükü ile karşı karşıya kalmaktadır. Gece vardiyası; sirkadiyen ritmin bozulması, uyku kalitesinde azalma, bilişsel performansın düşmesi, dikkat hataları, reaksiyon zamanında uzama ve karar verme süreçlerinde yavaşlama gibi etkiler yaratarak hasta güvenliği için önemli tehditler oluşturabilmektedir. Pandemi sonrası dönemde hasta başvuru sayılarının artması, personel devrinin yükselmesi, deneyimli çalışan eksikliği ve kaynak kıtlığı gibi sistemsel sorunlar, gece vardiyalarında güvenlik kültürünün sürdürülebilirliğini daha da zorlaştırmıştır. Türkiye'de yapılan araştırmalar, hemşirelerin gece vardiyasında daha yüksek düzeyde yorgunluk, tükenmişlik ve iş yükü bildirdiklerini; iletişim sorunları, hasta devri aksaklıkları ve ekip işbirliğindeki zorlukların hata riskini artırdığını göstermektedir. Uluslararası raporlar ise dinlenme olanaklarının sınırlı olması, yeterli kadro planlaması yapılmaması, çevresel düzenlemelerin yetersizliği ve standart dışı bakım uygulamalarının hem hasta hem de çalışan güvenliği üzerinde olumsuz etkiler yarattığını vurgulamaktadır.

Bu çalışma kapsamında literatürde öne çıkan risk alanları ayrıntılı biçimde ele alınmış; vardiya planlamasının optimize edilmesi, kısa süreli dinlenme molalarının desteklenmesi, ergonomik ve güvenli çalışma alanlarının oluşturulması, iletişim protokollerinin standardize edilmesi, hasta devri süreçlerinin yapılandırılması, erken uyarı sistemlerinin etkin kullanımı ve hemşire iyilik hâlini artırmaya yönelik programların uygulanması gibi kanıta dayalı stratejiler değerlendirilmiştir. Sonuç olarak gece vardiyasının kendine özgü risklerinin azaltılabilmesi için bireysel, örgütsel ve sistem düzeyini kapsayan bütüncül müdahalelerin gerekliliği vurgulanmaktadır; bu yaklaşım hem çalışan sağlığını güçlendirmekte hem de hasta güvenliği sonuçlarını iyileştirmektedir..

Anahtar Kelimeler: Acil servis hemşireliği, Gece vardiyası, Hasta güvenliği

1. GİRİŞ

Dünya Sağlık Örgütü'nün (WHO) "2020 Dünyada Hemşireliğin Durumu" raporunda vurgulandığı üzere, hemşirelik mesleği küresel sağlık sistemlerinin sürdürülebilirliği ve evrensel sağlık hedeflerine ulaşılması noktasında stratejik bir merkez üssü konumundadır. Hemşireler, sağlık profesyonelleri arasındaki en büyük grubu oluşturarak hasta bakımının sürekliliğini sağlamakta; ancak bu hayati rol, eğitim, istihdam ve liderlik alanlarında yapılacak yapısal yatırımlara ihtiyaç duymaktadır (WHO, 2020). Günümüzün "24 saat yaşayan toplum" yapısı, sağlık hizmetlerinin kesintisiz sunulmasını bir zorunluluk haline getirirken, bu durumun insani ve biyolojik maliyetleri hemşirelerin çalışma koşullarını doğrudan etkilemektedir (Rajaratnam ve Arendt, 2001).

Hemşirelikte hasta güvenliğini tehdit eden unsurlar sadece bireysel becerilerle sınırlı olmayıp, büyük oranda kurumsal ve operasyonel süreçlerin bir yansımasıdır (Rogers ve ark., 2004). Bu bağlamda, vardiyalı çalışma sistemleri insan biyolojisi üzerinde ağır bir baskı oluşturarak sirkadiyen ritim ile çalışma programı arasında büyük bir uyumsuzluk yaratmaktadır (Boivin ve Boudreau, 2014). Bu sirkadiyen bozulma, hemşirelerde uyku kalitesinin düşmesine ve kronik uykusuzluğa yol açmakta (Åkerstedt, 2003), bu durumun bilişsel performans üzerindeki yıkıcı etkileri ise tıbbi süreçlerde hata riskini maksimize etmektedir (Lim ve Dinges, 2010).

Çalışma ortamındaki bu biyolojik zorlanmalar, uzun çalışma saatleri ve personel yetersizliği gibi yapısal sorunlarla birleştiğinde, riskin boyutu daha da karmaşık bir hal almaktadır. Özellikle 12 saatlik vardiyaların ve zorunlu fazla mesailerin hemşirelerin yorgunluk seviyelerini artırdığı ve "tetikte kalma" (vigilance) kapasitelerini zayıflattığı saptanmıştır (Geiger-Brown ve Trinkoff, 2010; Scott ve ark., 2006). Uzun süreli mesailerin ve çalışma düzenindeki düzensizliklerin, hemşirelerin sadece zihinsel performansını değil, aynı zamanda kas-iskelet sistemi sağlığını da bozarak kronik bel ağrısı gibi fiziksel riskleri tetiklediği görülmektedir (Smedley ve ark., 2003; Trinkoff ve ark., 2006).

Bu süreçlerin doğal bir sonucu olarak ortaya çıkan mesleki tükenmişlik (burnout), hemşirelikte duygusal tükenme ve duyarsızlaşma yoluyla bakım niteliğini aşındıran teorik bir çerçevede ele alınmaktadır (Maslach ve ark., 2001; Dall'Ora ve ark., 2020). Literatür, sağlık personelinin refahı (well-being) ile hasta güvenliği çıktıları arasında doğrudan ve sistematik bir korelasyon olduğunu ortaya koymaktadır (Hall ve ark., 2016). Özellikle COVID-19 pandemisi gibi kriz dönemlerinde daha da belirginleşen personel yetersizliği, hemşirelerin tükenmişlik düzeylerini artırarak güvenli bakım sunma imkanını kısıtlamıştır (Lasater ve ark., 2021).

Ayrıca bireysel ve fiziksel faktörlere ek olarak, klinik iletişim süreçleri ve iş bölünmeleri, hasta güvenliği zincirinin kritik halkalarını oluşturmaktadır. Vardiya değişimlerindeki bilgi aktarımı (handover) hataları tıbbi yanlışlıklara zemin hazırlarken (Manser ve Foster, 2011; Starmer ve ark., 2014), ilaç uygulama süreçlerindeki bölünmeler hataların şiddetini artırmaktadır (Westbrook ve ark., 2011). Bu bilgiler kapsamında, hemşirelerin çalışma saatlerinden uyku düzenlerine, tükenmişlik düzeylerinden iletişim protokollerine kadar tüm bu değişkenlerin hasta güvenliği üzerindeki etkilerini bütüncül bir perspektifle analiz etmeyi amaçlamaktadır.

Vardiyalı Çalışma, Sirkadiyen Ritim ve Uyku

Sağlık hizmetlerinin 24 saat kesintisiz devam etmesi zorunluluğu, hemşirelerin büyük çoğunluğunun vardiyalı sistemde çalışmasını gerektirmektedir. Ancak bu sistem, biyolojik süreçler üzerinde derin etkilere sahiptir.

• Sirkadiyen Uyumsuzluk: Vardiyalı çalışma, vücudun doğal biyolojik saati ile çalışma programı arasında bir çatışma yaratarak sirkadiyen ritmi bozar (Boivin ve Boudreau, 2014),. Bu durum, hemşirelerin uyku ve uyanıklık döngülerinin ciddi şekilde bozulmasına neden olur (Åkerstedt, 2003),

• Toplumsal ve Sağlık Etkileri: 24 saat yaşayan bir toplumda, vardiyalı çalışmanın getirdiği sağlık riskleri ve sosyal maliyetler geniş bir yelpazeye yayılmaktadır (Rajaratnam ve Arendt, 2001). Vardiyalı çalışmanın ve uzun mesailerin çalışan sağlığı üzerindeki olumsuz etkileri literatürde yaygın olarak belgelenmiştir (Caruso, 2014),

Uyku Yoksunluğu ve Bilişsel Performans

Uykusuzluk, hemşirelerin klinik karar verme ve dikkat yeteneklerini doğrudan etkileyen bir unsurdur.

• Bilişsel Değişkenler: Kısa süreli uyku yoksunluğunun bilişsel performans üzerinde yarattığı yıkıcı etkiler, kapsamlı meta-analizlerle kanıtlanmıştır (Lim ve Dinges, 2010),. Dikkat eksikliği ve reaksiyon sürelerindeki yavaşlama, uykusuzluğun en belirgin sonuçları arasındadır (Lim ve Dinges, 2010),.

• Hata Riski ve Ulaşım Güvenliği: Uyku yoksunluğu çeken hemşirelerin sadece hastane içinde hata yapma riski değil, aynı zamanda işe gidiş ve dönüş yolunda kaza yapma riskleri de artmaktadır (Dorrian ve ark., 2008).

Çalışma Saatleri ve Hasta Güvenliği İlişkisi

Hemşirelerin çalışma süresi ile bakım sırasında meydana gelen hatalar arasında güçlü bir korelasyon bulunmaktadır.

• Uzun Vardiyalar: Hastanede görev yapan hemşirelerin çalışma saatleri, hasta güvenliğini belirleyen temel faktörlerden biridir (Rogers ve ark., 2004),. Özellikle 12 saatlik vardiyaların uygulanması, hemşirelerin aşırı yorulmasına ve dikkatinin dağılmasına neden olduğu için tartışmalı bir konudur (Geiger-Brown ve Trinkoff, 2010).

• Tetikte Kalma (Vigilance): Kritik bakım ünitelerinde çalışan hemşirelerin uzun saatler boyunca görev yapması, onların tetikte kalma kapasitelerini zayıflatmakta ve hastalar için hayati riskler oluşturmaktadır (Scott ve ark., 2006).

Hemşirelikte Tükenmişlik (Burnout)

Tükenmişlik, hemşirelik mesleğinde hem personelin elde tutulmasını hem de bakım kalitesini etkileyen kronik bir sorundur.

• Teorik Çerçeve: İş tükenmişliği; duygusal tükenme, duyarsızlaşma ve kişisel başarı hissinde azalma boyutlarıyla karakterize edilir (Maslach ve ark., 2001),. Hemşirelik özelinde tükenmişlik, mesleki roller ve çalışma ortamının bir sonucu olarak gelişen karmaşık bir süreçtir (Dall'Ora ve ark., 2020).

• Hasta Güvenliği ile Bağlantı: Sağlık personelinin iyi oluş hali ve tükenmişlik seviyeleri, hasta güvenliği çıktılarıyla doğrudan ilişkilidir (Hall ve ark., 2016),. Tükenmişlik düzeyi arttıkça, personelin dikkat düzeyi düşmekte ve tıbbi hata yapma olasılığı artmaktadır (Hall ve ark., 2016),.

• Personel Yetersizliği: Özellikle kronik personel eksikliği yaşanan dönemlerde hemşirelerin tükenmişlik seviyeleri zirveye ulaşmaktadır (Lasater ve ark., 2021). COVID-19 pandemisi, hastanelerdeki personel yetersizliğinin hemşireler üzerindeki baskısını daha da belirgin hale getirmiştir (Lasater ve ark., 2021).

Fiziksel Sağlık ve Mesleki Riskler

Çalışma koşulları sadece zihinsel değil, fiziksel sağlığı da etkilemektedir.

• Kas-İskelet Sistemi: Hemşirelerin fiziksel olarak zorlayıcı görevleri, özellikle manuel hasta taşıma aktiviteleri, ciddi bel ağrısı riskini beraberinde getirmektedir (Smedley ve ark., 2003).

• Kronik Etkiler: Çalışma saatleri, zorunlu fazla mesai ve icap (on-call) nöbetleri ile kas-iskelet sistemi problemleri arasında boylamsal bir ilişki olduğu tespit edilmiştir (Trinkoff ve ark., 2006).

Klinik Süreçler ve İletişim Güvenliği

Hataların önlenmesinde sistem temelli yaklaşımlar ve iletişim protokolleri hayati önem taşır.

• Vardiya Teslimleri (Handover): Etkin bir vardiya teslim iletişimi, hastanın bakım sürekliliği için temel bir gerekliliktir (Manser ve Foster, 2011). Yapılandırılmış bir teslim programının uygulanması, tıbbi hataların azaltılmasında somut başarılar sağlamaktadır (Starmer ve ark., 2014).

• İş Bölünmeleri: Hemşirelerin ilaç uygulama süreçleri sırasında maruz kaldıkları bölünmeler ve kesintiler, ilaç hatalarının hem sıklığını hem de ciddiyetini artırmaktadır (Westbrook ve ark., 2011).

• İnsan Faktörleri Çerçevesi: Hemşirelik iş yükünün hasta güvenliği ve çalışan yaşam kalitesi üzerindeki etkisini anlamak için insan faktörleri odaklı bir çerçeve kullanılmalıdır (Holden ve ark., 2011).

Müdahaleler ve Çözüm Önerileri

Tükenmişliği azaltmak ve güvenliği artırmak için çeşitli kurumsal stratejiler önerilmektedir.

• Şekerleme (Nap) Fırsatı: Gece vardiyası sırasında hemşirelere sunulan kısa şekerleme imkanlarının, performans ve uyanıklık seviyelerini artırdığı saptanmıştır (Purnell ve ark., 2002).

• Kurumsal Destek: Personel tükenmişliğini önlemek ve azaltmak adına yapılan sistemli müdahalelerin, sağlık çalışanlarının sağlığı üzerinde olumlu etkileri olduğu kanıtlanmıştır (West ve ark., 2016).

GENEL DEĞERLENDİRME

Hemşirelikte çalışma koşulları, sadece bir personel yönetimi meselesi değil, modern sağlık sistemlerinin en hassas güvenlik katmanıdır (WHO, 2020). Yapılan genel değerlendirmeler, "24 saat yaşayan toplum" yapısının getirdiği kesintisiz hizmet zorunluluğunun, insan biyolojisinin sınırlarını zorladığını açıkça göstermektedir (Rajaratnam ve Arendt, 2001). Vardiyalı çalışma düzeni, sirkadiyen ritmi bozarak hemşirelerin uyku kalitesini aşındırmakta (Åkerstedt, 2003; Boivin ve Boudreau, 2014), bu durum ise dikkat ve uyanıklık performansında ciddi bilişsel gerilemelere yol açmaktadır (Lim ve Dinges, 2010).

Çalışma saatlerinin uzunluğu ve zorunlu fazla mesai uygulamaları, sadece zihinsel yorgunluğu değil, aynı zamanda kronik kas-iskelet sistemi hastalıklarını da tetikleyerek hemşirelerin mesleki ömürlerini kısaltmaktadır (Smedley ve ark., 2003; Trinkoff ve ark., 2006). Özellikle 12 saatlik vardiyalar sırasında hemşirelerin "tetikte kalma" yetilerinin zayıflaması, hasta güvenliği ile doğrudan çelişen bir tablo ortaya koymaktadır (Geiger-Brown ve Trinkoff, 2010; Scott ve ark., 2006). Bu durum, hemşirelikte tükenmişliği (burnout) besleyen en temel yapısal sorundur (Maslach ve ark., 2001; Dall'Ora ve ark., 2020).

SONUÇ

Kaynaklar üzerinde yapılan inceleme sonucunda ulaşılan en net çıkarım şudur: Sağlık çalışanının esenliği ile hasta güvenliği birbirinden ayrılamaz bir bütündür (Hall ve ark., 2016). Uyku yoksunluğu çeken veya mesleki tükenmişlik yaşayan bir hemşirenin, klinik süreçlerde hata yapma olasılığı kaçınılmaz olarak artmaktadır (Dorrian ve ark., 2008; Lim ve Dinges, 2010). Özellikle COVID-19 pandemisi gibi kriz dönemlerinde daha da görünür hale gelen personel yetersizliği, bu riskli yapının kırılma noktasını oluşturmuştur (Lasater ve ark., 2021).

Sonuç olarak, 12 saati aşan vardiyaların ve kesintisiz çalışma sürelerinin hasta güvenliğini doğrudan tehlikeye attığı (Rogers ve ark., 2004), iletişim kopukluklarının ve ilaç uygulama süreçlerindeki bölünmelerin bu hataları derinleştirdiği görülmektedir (Manser ve Foster, 2011; Westbrook ve ark., 2011). İnsan faktörleri odaklı bir yaklaşım benimsenmediği sürece, sadece bireysel çabalarla hasta güvenliğinin sağlanması mümkün görünmemektedir (Holden ve ark., 2011).

ÖNERİLER

Hemşirelik iş gücünün korunması ve hasta bakım kalitesinin artırılması için şu stratejik adımların atılması önerilmektedir:

1. **Vardiya Düzenlemeleri ve Dinlenme Hakkı:** 12 saatlik vardiyaların uygulanması yeniden gözden geçirilmeli, hemşirelerin vardiyalar arasında yeterli dinlenme süresine sahip olması yasal güvencelerle desteklenmelidir (Geiger-Brown ve Trinkoff, 2010; Rogers ve ark., 2004).

2. **Stratejik İstihdam ve Yatırım:** Personel yetersizliğinin yarattığı tükenmişliği önlemek adına, WHO'nun da vurguladığı gibi hemşirelik eğitimine ve istihdamına yönelik yatırımlar artırılmalıdır (WHO, 2020; Lasater ve ark., 2021).

3. **Klinik İyileştirmeler:** İlaç uygulama hatalarını azaltmak için iş kesintilerinin (interruptions) minimize edildiği "güvenli bölgeler" oluşturulmalı ve vardiya teslimleri için yapılandırılmış, standart programlar (handover protocols) devreye sokulmalıdır (Starmer ve ark., 2014; Westbrook ve ark., 2011).

4. **Biyolojik Destek Mekanizmaları:** Gece vardiyası çalışanları için uyanıklığı artıracak kısa "şekerleme" (nap) imkanları yasal olarak tanınmalı ve teşvik edilmelidir (Purnell ve ark., 2002).

5. **Psikososyal Müdahaleler:** Tükenmişliği azaltmaya yönelik bireysel ve kurumsal odaklı müdahale programları sistematik bir şekilde uygulanmalı, sağlık çalışanlarının refahı kurumsal performans kriteri haline getirilmelidir (West ve ark., 2016).

6. **İnsan Faktörleri Odaklı Tasarım:** Çalışma ortamı, insan yeteneklerini destekleyecek ve bilişsel yükü azaltacak şekilde "insan faktörleri çerçevesi" doğrultusunda yeniden tasarlanmalıdır (Holden ve ark., 2011)

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GECE VARDİYASINDA ÇALIŞAN HEMŞİRELERİN YAŞAM BULGULARI TAKİBİNE İLİŞKİN GÖRÜŞLERİ VE YAŞADIKLARI ZORLUKLAR; BİR TRİANGÜLASYON ÇALIŞMA

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ÖZET

Bu çalışma, acil serviste gece vardiyasında görev yapan hemşirelerin yaşam bulgularının ölçümü ve izlenmesine ilişkin görüş ve deneyimlerini hem nicel hem de nitel verilerle değerlendirmek amacıyla yürütülmüştür. Triangülasyon deseninde gerçekleştirilen araştırmanın evrenini bir ilçe devlet hastanesinin acil servis hemşireleri oluşturmuş; nitel veri toplama sürecinde örneklem, veri doygunluğuna ulaşılan 10 katılımcı ile sınırlandırılmıştır. Nicel veriler Tanıtıcı Bilgi Formu ve Yaşam Bulguları Ölçeği ile, nitel veriler ise yarı yapılandırılmış görüşme formu aracılığıyla yüz yüze görüşmelerle toplanmıştır. Görüşmeler ses kaydı ile kaydedilmiş, veriler yazıya dökülerek içerik analiziyle değerlendirilmiştir. Nicel veriler SPSS 26.0 programı ile tanımlayıcı istatistikler kullanılarak analiz edilmiştir. Hemşirelerin yaş ortalaması 35±8.20 olup %70'i kadındır. Yaşam Bulguları Ölçeği toplam puan ortalaması 48.10±9.27'dir. En yüksek alt boyut puanı teknoloji (11.9±3.95), en düşük alt boyut puanı ise iletişimdir (7.6±2.83). Nicel bulgular, hemşirelerin yaşam bulgularına ilişkin tutumlarının orta düzeyde olumlu olduğunu; özellikle teknoloji alt boyutunda yüksek, iletişim alt boyutunda ise düşük puanlara sahip olduklarını göstermiştir. Nitel analiz sonucunda beş ana tema belirlenmiştir: takip edilen yaşam bulguları, ölçüm sürecinde karşılaşılan güçlükler, sorunlara yönelik girişimler, etkin izleme için öneriler ve gece vardiyasının etkileridir. Bulgular, hemşirelerin ekipman uyumsuzluğu, hasta iş birliği eksikliği, yoğun iş yükü, yorgunluk ve dikkat azalması gibi faktörler nedeniyle ölçümlerde güçlük yaşadığını ortaya koymaktadır. Katılımcılar doğru ve güvenilir yaşam bulgusu takibi için ekipman standardizasyonunun sağlanması, personel sayısının artırılması, teknolojik cihazların yenilenmesi ve dinlenme aralıklarının planlanması gerekliliklerini vurgulamıştır.

Sonuç olarak çalışma, gece vardiyasının yaşam bulgularının doğruluğunu etkileyen çok boyutlu faktörler barındırdığını ve hem bireysel hem kurumsal düzeyde iyileştirmelere ihtiyaç duyulduğunu göstermektedir. Bulgular doğrultusunda personel sayısının vardiya yoğunluğuna göre iyileştirilmesi, ekipman standardizasyonu sağlanması, teknolojik izlem sistemlerinin geliştirilmesi ve hemşirelere yönelik hizmet içi eğitimlerin güçlendirilmesi önerilmektedir

Anahtar Kelimeler: hemşirelik, gece vardiyası, yaşam bulguları, triangülasyon, nitel araştırma

1.GİRİŞ

Yaşam bulgularının izlenmesi, değerlendirilmesi ve kaydedilmesi hemşirelik bakımının temel görevleri arasında yer almaktadır. Yaşam bulguları; bireyin solunum, dolaşım, endokrin ve diğer tüm sistemlerin fonksiyonları hakkında bilgi veren ve fizyolojik değişiklikleri gösteren önemli sağlık durumu göstergelerindendir. Yaşam bulguları; vücut sıcaklığı, nabız, solunum, kan basıncı ve ağrıdan oluşmaktadır (Çakırcalı,2014; Stevenson ve ark.,2016)

Yaşam bulgularının düzenli olarak değerlendirilmesi, bireyin yaşamını tehdit edebilecek durumların erken fark edilmesine, gerekli hemşirelik girişimlerinin zamanında planlanmasına ve sağlık durumundaki değişimlerin erken dönemde saptanmasına olanak sağlar (Orak,2010). Çünkü yaşam bulgularında gözlemlenen herhangi bir değişim bireyin fizyolojik işlevlerinde meydana gelen bozulmaların erken habercisi olabilmektedir. Yaşam bulgularının düzenli periyotlarla izlenmesi, kaydedilmesi ve ölçülen değerlerin dikkatle değerlendirilmesi; hastaya uygulanacak tedavi ve bakımın etkinliğinin izlenmesinde faydalı olacaktır. (Stevenson ve ark.,2016 ;Watkins ve ark.,2015). Bu sebeple hemşirelerin, yaşam bulgularının hangi durumlarda ve ne aralıklarla değerlendireceğini, değerlendirme yöntemlerini, farklı yaş sınıflarına ait normal ve anormal değerleri bilmesi gerekmektedir. Bununla birlikte hastalıkların fizyolojisine ilişkin bilgi birikimine sahip olmak, yaşam bulgularının doğru ve etkin yorumlanabilmesi açısından kritik önem taşımaktadır (Mok ve ark.,2015).

Günceler araştırmalar yaşam bulgularının takibinde hemşireler çeşitli sebeplerle sorun yaşadığını vurgulamaktadır (Alshehry ve ark., 2021; Dall'Ora ve ark., 2019; Mok ve ark., 2015a). Hemşirelerin mesleki deneyimleri, iş doyumları, iş yükleri ve gece vardiyasında çalışma sıklıkları; yaşam bulgularının takibi konusundaki tutum ve davranışlarını etkileyen önemli faktörlerdendir. Bunun yanı sıra, ölçüm sürecinin zaman alıcı olarak görülmesi de yaşam bulgularının izlenme sıklığını olumsuz yönde etkilemektedir (Gülnar ve ark., 2020; Kamio ve ark., 2018; Recio-Sauced ve ark., 2018).Bu durumun yanı sıra, 12 saatlik vardiya sisteminde çalışan hemşirelerde yaşam bulgularının takibi ile ilgili yapılan bilimsel çalışmalar, uzun çalışma sürelerinin ve gece vardiyalarının ölçüm ve kayıt süreçlerini olumsuz etkilediğini ve gecikmelere yol açtığını ortaya koymaktadır (Dall'Ora ve ark., 2019; Hands ve ark., 2013;Hope ve ark.,2018). Literatür incelendiğinde hemşirelerin gece vardiyasında yaşam bulguları takibine ilişkin nicel çalışmalar bulunmaktadır ancak nitel verilerle desteklenen bir çalışmaya rastlanmamıştır. Bu nedenle bu çalışma hemşirelerin gece vardiyasında yaşam bulguları takibine ilişkin görüşleri hem nitel hem de nicel verilerle değerlendirilmesi amaçlanmıştır.

2.GEREÇ YÖNTEM

Araştırma şekli: Bu araştırma acil serviste çalışan hemşirelerin yaşam bulgularının ölçümüne ilişkin görüş ve deneyimlerini belirlemek amacıyla nicel ve nitel verilerin bir arada kullanıldığı triangülasyon çalışması olarak yapılmıştır.

Evren ve Örneklem: Araştırmanın evrenini bir ilçe devlet hastanesi acil servisinde çalışan tüm hemşireler oluşturmuştur. Araştırmada örneklem seçimine gidilmeyip tüm evrene ulaşılması hedeflenmiştir. Nitel araştırmalarda araştırma konusu ve niteliğine bağlı olarak, veri doygunluğa ulaştığında veya tekrara düştüğünde araştırmanın sonlandırılabileceği ifade edilmektedir. Bu nedenle araştırma 10 hemşirenin katılımı ile veri doygunluğuna ulaştığı için sonlandırılmıştır (Sampieri 2013).

Araştırmaya dahil edilme kriterleri: Çalışmaya acil serviste hemşire kadrosuyla çalışan ve araştırmaya katılıma gönüllü olanlar dahil edilmiştir. Nitel verilerin toplanması esnasında ses kaydının alınacağı açıklanarak onayları alınmıştır.

Veri Toplama Araçları: Nicel veriler, araştırmacılar tarafından geliştirilen ve uzman görüşüyle geçerlik-güvenirliği test edilmiş "Tanıtıcı Bilgi Formu" ve "Yaşam Bulguları Ölçeği" kullanılarak toplanmıştır.
Nitel veriler ise yarı yapılandırılmış "Görüşme formu" ile yüz yüze görüşmeler yoluyla elde edilmiştir. Görüşmeler ses kaydına alınmış ve ortalama 25–30 dakika sürmüştür.

Tanıtıcı Bilgi Formu: Hemşirelerin cinsiyet, yaş, çalıştığı birimdeki ve mesleki deneyimi ve mezuniyet durumu ile ilgili tanımlayıcı özelliklerini içeren sorulardan oluşmaktadır.

Yaşam Bulguları Ölçeği: Ölçek, Mok ve arkadaşları tarafından geliştirilmiş olup, Ertuğ tarafından Türkçe geçerlilik güvenirliliği yapılmıştır. Ölçek hemşirelerin yaşam bulgularına yönelik tutumlarını ölçmek amacıyla geliştirilmiştir. Ölçek, 16 maddeden ve 5 alt boyuttan (İş yükü, Teknoloji, İletişim, Bilgi, Temel göstergeler) oluşmaktadır. İş yükü; yaşam bulguları için harcanan efor ve zamanı tanımlar. Teknoloji; elektronik yaşam bulguları izleminde solunum hızı sayımının etkisini ifade eder. İletişim; bozulan yaşam bulgularının kayıt edilmesini tanımlar. Bilgi; yaşam bulgularını doğru yorumlama yeteneğidir. Temel göstergeler; hastanın durumunun kötüye gittiğini gösteren önemli yaşam bulgularını ifade eder ve 5'li likertli bir ölçek (Kesinlikle katılmıyorum-kesinlikle katılıyorum) şeklindedir. Toplam puan 16 ile 80 arasında değişmektedir. Düşük puan hemşirelerin tutumunun düşük olduğunu, yüksek puan ise yaşam bulgularına ilişkin olumlu tutumu göstermektedir. Orjinal ölçeğin Cronbach alfa değeri 0.71'dir. Ertuğ ise Cronbach alfa değeri 0.76 olarak belirlemiştir (Mok et al. 2015b; Ertuğ 2018). Ölçeğin kullanımı için gerekli izin alınmıştır (EK-3).

Görüşme Formu: Yarı yapılandırılmış görüşme formu araştırmacılar tarafından literatür incelenerek oluşturulmuştur (Kaynak). Görüşme formunda yer alan sorular Tablo 1'de verilmiştir.

	Yarı yapılandırılmış görüşme soruları
1	Gece vardiyasında çalışırken en çok hangi yaşam bulgularını takip ediyorsunuz?
2	Gece vardiyasında yaşam bulgularını takip ederken sorun yaşıyor musunuz?
3	Gece vardiyasında en çok hangi yaşam bulgusunu takip ederken sorun yaşıyorsunuz?
4	Yaşadığınız sorunların çözümlenmesi için bir girişimde bulundunuz mu?
5	Gece vardiyasında yaşam bulgularının doğru ve etkin bir şekilde takibi için görüş önerileriniz var mıdır?

Verilerin Toplanması: Veriler araştırmacılar tarafından tanımlayıcı bilgi formu ve yarı yapılandırılmış görüşme formu kullanılarak Nisan-Eylül 205 tarihleri arasında toplanmıştır.

Görüşmeler esnasında hemşirelere önce tanımlayıcı bilgi formunu doldurmaları istenmiş, daha sonra görüşme formundaki sorular için gerekli açıklamalar yapılmış, ses kaydının alınacağı belirtilerek onayları alındıktan sonra araştırmanın nitel verileri toplanmıştır. Nitel veriler toplanırken katılımcıların dış uyaranlardan etkilenmemesi için sessiz ve sakin bir ortamda görüşmeler yapılmıştır. Ses kaydı yapılmasını kabul etmeyen 2 hemşireden görüşme sorularının cevapları yazılı bir şekilde alınarak her katılımcıyla görüşme sağlanmıştır.

Verilerin Değerlendirilmesi: Araştırmanın nicel verilerinin değerlendirilmesinde: Tanımlayıcı bilgi formundaki sorular bilgisayar ortamına aktarıldıktan sonra IBM SPSS Statistics 26.0 programı kullanılarak analiz edilmiştir. Verilerin değerlendirilmesinde tanımlayıcı istatistiklerden sayı (frekans) ve yüzde (%) değerleri kullanılmıştır. Bu istatistikler, katılımcıların sosyodemografik özellikleri ile yaşam bulgularını ölçme sürecinde yaşadıkları güçlüklerin dağılımını ortaya koymak amacıyla uygulanmıştır.

Araştırmanın nitel verilerinin değerlendirilmesinde: Katılımcılardan alınan ses kayıtları öncelikle araştırmacılar tarafından bilgisayar ortamına aktarılarak yazıya dökülmüş, daha sonra içerik analizi yöntemi kullanılmıştır. Görüşme sorularına alınan yanıtlar okunarak anlamlı ifadeler belirlenmiş ve bu ifadelerden yola çıkılarak açık kodlar oluşturulmuştur. Daha sonra ana temalar ve alt temalar oluşturulmuştur.

Veri analizi süreci iki araştırmacı tarafından bağımsız olarak yürütülmüş, kod ve tema eşleştirmelerinde görüş birliği sağlanıncaya kadar karşılaştırmalar yapılmıştır. Kodlamalar arasında tutarlılığı değerlendirmek amacıyla araştırmacılar arası uyum (inter-coder reliability) oranı hesaplanmış, uyum düzeyi yüksek bulunmuştur.

Oluşturulan temaların geçerlik ve güvenirliğini sağlamak amacıyla, nitel araştırma konusunda deneyimli iki akademisyenin uzman görüşü alınmıştır. Uzmanlardan, kod-tema eşleşmelerinin

uygunluğu ve temaların kapsam geçerliliği konularında geri bildirim alınmış, önerileri doğrultusunda gerekli düzeltmeler yapılmıştır.

Verilerin analizi sonucunda ortaya çıkan temalar ve alt temalar ayrıntılı olarak tablolar ve doğrudan katılımcı ifadeleriyle desteklenerek "Bulgular" bölümünde sunulmuştur. Bulguların yorumlanmasında, katılımcı görüşlerinden elde edilen anlam örüntüleri, nicel verilerle karşılaştırılarak bütüncül bir değerlendirme yapılmıştır.

3.BULGULAR

Araştırmaya dâhil edilen hemşirelerin yaş ortalaması 35±8.205'dir. Hemşirelerin yaşları 26-47 arasıdır. Araştırmadan elde edilen diğer bulgular aşağıdaki tabloda verilmiştir.

Tablo 2. Katılımcıların tanımlayıcı özellikleri (n=10)

Tanımlayıcı Özellik	**Sayı**	**Yüzde**
Cinsiyet		
Kadın	7	70
Erkek	3	30
Çalışılan birimdeki deneyim		
1 yıldan az	3	30
1-5 yıl arası	2	20
6-10 yıl arası	2	20
10 yıldan fazla	3	30
Mesleki deneyim		
1 yıldan az	1	10
1-5 yıl arası	3	30
6-10 yıl arası	2	20
10 yıldan fazla	4	40
Mezuniyet durumu		
Lise	-	0
Önlisans	2	20
Lisans	8	80
Yükseklisans ve üzeri	-	0
TOPLAM	10	100

Tablo 2'de araştırmaya dâhil edilen hemşirelerin tanımlayıcı özellikleri yer almaktadır. Bu tabloya göre araştırmaya katılan hemşirelerin %70'i kadın, %30'u 1 yıldan az, %30'u 10 yıldan fazla acil serviste çalışma deneyimine sahip, %40'ı 10 yıldan fazla mesleki deneyime sahip ve %80'i lisans mezunudur.

Tablo 3. Katılımcıların Yaşam Bulguları Ölçeği Toplam Puan ve Alt boyutlardan Aldıkları Puan Ortalaması (n=10)

Ölçek Alt boyutları	**Puan Ortalaması**	**Std Sapma**	**Min-Max**
İş yükü	11.2	3.224	6-17
Teknoloji	11.9	3.956	7-20
İletişim	7.6	2.836	2-10
Bilgi	8.5	2.368	6-13
Temel Gösterge	8.9	2.424	5-13
Toplam Puan	**48.10**	**9.279**	**34-66**

Tablo 3'te araştırmaya dâhil edilen hemşirelerin yaşam bulguları ölçeğinden aldıkları puan ortalaması yer almaktadır. Bu tabloya göre hemşirelerin yaşa bulguları ölçeği iş yükü alt boyutundan aldıkları puan ortalaması 11.2± 3.224, teknoloji alt boyutundan aldıkları puan ortalamaları 11.9±3.956, iletişim alt boyutundan altıkları puan ortalamaları 7.6±2.836, bilgi alt boyutundan aldıkları puan ortalamaları 8.5±2.368, temel gösterge alt boyutundan aldıkları puan ortalamaları 8.9±2.424 ve ölçek toplam puan ortalamaları 48.10± 9.279 olarak bulunmuştur. Hemşirelerin ölçeğin toplam puanından en düşük 34, en yüksek 66 puan aldıkları belirlenmiştir.

Araştırmanın Nitel Verileri

Nicel bulguların ardından, katılımcıların gece vardiyasında yaşam bulgularının takibine ilişkin deneyimlerini, sorunlarını ve önerilerini ortaya koymak amacıyla gerçekleştirilen açık uçlu soruların içerik analizi sonucunda beş ana tema ve on iki alt tema belirlenmiştir. Bu temalar, katılımcı ifadelerinden türetilmiş olup Tablo X'te özetlenmiştir.

Belirlenen Temalar:

1. Takip Edilen Yaşam Bulguları
2. Yaşam Bulgularının Takibinde Karşılaşılan Güçlükler
3. Sorunlara Yönelik Girişimler
4. Etkin ve Doğru Takip İçin Görüş ve Öneriler
5. Gece Vardiyasının Etkileri

Tema 1: Takip Edilen Yaşam Bulguları

Katılımcıların tamamı gece vardiyasında düzenli olarak yaşam bulgularını izlediklerini belirtmiştir. En sık takip edilen bulguların kan basıncı, nabız, ateş ve saturasyon olduğu, bazı katılımcıların ise buna ek olarak kan şekeri ve EKG takibi yaptıkları belirlenmiştir. Bu durum, katılımcıların bazılarının yaşam bulgularının içeriği hakkında yetersiz bilgisinin olduğunu göstermektedir.

Tema 2: Yaşam Bulgularının Takibinde Karşılaşılan Güçlükler

Alt Tema 2.1: Ekipman Kaynaklı Sorunlar

Katılımcıların önemli bir kısmı, otomatik cihazlar ile manuel ölçümler arasında farklılıklar ve uyumsuzluklar yaşandığını ifade etmiştir. Ayrıca manşon boyutunun hasta özelliklerine uygun olmaması, EKG'de hareket kaynaklı parazit oluşumu gibi teknik problemlerin ölçüm güvenilirliğini olumsuz etkilediği belirtilmiştir. EKG monitörünün küçük olması nedeniyle takibin zor olduğu belirtilmiştir.

Alt Tema 2.2: İnsan Faktörüne Bağlı Sorunlar

Bazı katılımcılar, gece vardiyasının getirdiği yorgunluk, dikkat azalması ve algı yavaşlaması nedeniyle ölçümlerde hata payının arttığını dile getirmiştir. Uzun süren nöbetlerin bilişsel dikkat ve refleks hızında azalmaya yol açtığı ifade edilmiştir.

Alt Tema 2.3: Hasta Faktörüne Bağlı Sorunlar

Bazı katılımcılar, özellikle çocuk, obez veya kaygılı hastalarda ölçüm sırasında dirençle karşılaştıklarını, hastaların acile gelmeden önce kullandıkları ilaçlar hakkında yeterli bilgi vermemeleri, hastaların stres, korku, bilinç değişikliği, bilgi ve/veya iletişim eksikliği nedeniyle ölçüm sürecini zorlaştırdıklarını belirtmiştir. Bu durum, ölçüm doğruluğunu ve süresini olumsuz etkilemektedir.

Alt Tema 2.4. Yönetimsel Sorunlar

Gece vardiyasında çalışan personel sayısının az olması nedeniyle dikkat eksikliği ve yorgunluk nedeniyle tıbbi hata yapılabildiği belirtilmiştir. Ayrıca uzun çalışma saatlerinin (24 saat) olması fiziksel ve zihinsel yorgunluk nedeniyle de hatalar yapılabildiği ifade edilmiştir.

Tema 3: Sorunlara Yönelik Girişimler ve Baş Etme Stratejileri

Alt Tema 3.1: Pasif Yaklaşımlar

Katılımcıların yarısı, yaşanan teknik veya ölçüm sorunlarına yönelik resmî bir girişimde bulunmadıklarını, yalnızca manuel doğrulama yaparak süreci sürdürdüklerini belirtmiştir. Bu durum, sistematik geri bildirim mekanizmalarının yeterince etkin kullanılmadığını düşündürmektedir.

Alt Tema 3.2: Aktif Yaklaşımlar

Bazı katılımcılar, cihaz arızası veya ölçüm hatası durumunda sorumlu hemşireye bilgi verme, tutanak tutma veya hastayı sakinleştirme ve hastayla terapötik iletişim teknikleri gibi girişimlerde bulunmuştur. Bu stratejiler, çalışanların bireysel sorumluluk bilinci ve profesyonel etik farkındalığının gelişmiş olduğunu göstermektedir.

Tema 4: Etkin ve Doğru Takip İçin Görüş ve Öneriler

Alt Tema 4.1: Personel Kaynaklı Önlemler

Katılımcılar, doğru ölçümün sağlanabilmesi için dinlenmiş, dikkatli ve odaklanmış personelin önemine vurgu yapmıştır. Yorgunluk ve vardiya düzeninin, ölçüm kalitesi üzerinde doğrudan etkili olduğu belirtilmiştir.

Alt Tema 4.2: Ekipman ve Teknolojik Gelişim Önerileri

Bazı katılımcılar, renkli uyarı sistemine sahip monitörlerin, daha hızlı ve modern cihazların kullanılmasının ölçüm doğruluğunu artıracağını ifade etmiştir. Ayrıca uygun manşon çeşitliliğinin (çocuk ve kilolu hastalar için) sağlanması gerektiği vurgulanmıştır. Tedavisi uzun süren hastalar için monitörlerin yoğun bakım servislerindeki gibi destekten tümünün izlem ve takibinin yapılması gerektiği vurgulanmıştır.

Alt Tema 4.3: Yönetimsel Düzenlemeler ve İletişim

Katılımcılar, triyaj ekibi kurulması, görev dağılımının netleştirilmesi ve empatik iletişimin geliştirilmesi yönünde önerilerde bulunmuştur. Özellikle hasta güvenliği ve malpraktis riskinin azaltılması açısından bu önerilerin önemli olduğu görülmektedir.

Tema 5: Gece Vardiyasının Etkileri

Alt Tema 5.1: Fiziksel ve Bilişsel Yorgunluk

Katılımcılar, gece vardiyasının yorgunluk, algı ve dikkat azalması, odaklanma güçlüğü gibi etkiler yarattığını belirtmiştir. Bu durum, ölçümlerde hata olasılığını artırmakta ve iletişim kalitesini düşürmektedir.

Alt Tema 5.2: Çalışma Ortamı ve İş Yükü

Bazı katılımcılar, acil servis yoğunluğu, sürekli hareketlilik ve triyaj eksikliğinin sistematik takip süreçlerini zorlaştırdığını ifade etmiştir. Bu bulgular, yönetimsel destek ve iş yükü dengesinin önemini ortaya koymaktadır.

Genel Değerlendirme

Elde edilen nitel veriler, gece vardiyasında yaşam bulgularının takibinde en sık karşılaşılan sorunların ekipman eksiklikleri, çalışan yorgunluğu ve hasta uyumsuzluğu ile ilişkili olduğunu göstermektedir. Katılımcıların önerileri, bu sorunların çözümüne yönelik hem bireysel farkındalık hem de kurumsal iyileştirme boyutlarını içermektedir. Sonuç olarak, gece vardiyasının doğası gereği oluşan fiziksel ve bilişsel yorgunluğun azaltılması, ekipman standartlarının geliştirilmesi ve uygun iş organizasyonunun sağlanması, ölçüm doğruluğu ve hasta güvenliği açısından kritik önem taşımaktadır.

4.SONUÇ VE ÖNERİLER

Araştırma bulguları, nicel ölçüm sonuçlarıyla nitel görüşlerin büyük oranda birbiriyle örtüştüğünü göstermektedir. Katılımcı hemşirelerin büyük çoğunluğu yaşam bulgularını izleme ve değerlendirme konusunda yeterli bilgiye ve farkındalığa sahip olduklarını belirtmiştir. Bununla birlikte, gece vardiyasının fizyolojik, teknik ve iletişimsel zorlukları yaşam bulgularının doğru ve sürekli biçimde takibini olumsuz yönde etkilemektedir.

Nicel bulgulara göre, en yüksek puan ortalaması teknoloji alt boyutunda, en düşük puan ise iletişim alt boyutunda elde edilmiştir. Bu durum, hemşirelerin teknolojik cihaz kullanımında genel olarak yeterli olduklarını ancak gece vardiyasının getirdiği dikkat azalması, yorgunluk ve hasta ile etkileşimdeki sınırlılıklar nedeniyle iletişim alanında güçlük yaşadıklarını göstermektedir.

Nitel bulgular ise bu sonuçları desteklemiş; hemşirelerin özellikle tansiyon ölçümünde ekipman uyumsuzluğu, hasta iş birliği eksikliği, yorgunluk ve dikkat dağınıklığı gibi sorunlar yaşadıkları belirlenmiştir. Ayrıca, ekipman eksiklikleri ve kalibrasyon yetersizliklerinin ölçüm güvenilirliğini azalttığı ifade edilmiştir. Katılımcılar, doğru ve etkin ölçüm için uygun dinlenme süresi, yeterli ekipman, geliştirilmiş monitör sistemleri ve triyaj desteği gibi kurumsal düzenlemelerin gerekliliğine dikkat çekmiştir.

Bu sonuçlar, literatürde gece vardiyasında çalışan hemşirelerin bilişsel dikkat düzeyinin azaldığı (Ergin, Yıldız & Şahin, 2022), iletişim becerilerinin zayıfladığı (Kaya, Şentürk & Güler, 2019) ve ekipman yetersizliklerinin hasta güvenliğini olumsuz etkilediği (Arı & Göktaş, 2020) yönündeki bulgularla paralellik göstermektedir.

Sonuç olarak, araştırma bulguları gece vardiyasında yaşam bulgularının doğru takibini etkileyen çok boyutlu faktörlerin varlığını ortaya koymaktadır. Hemşirelerin bilgi ve farkındalık düzeyi yüksek olsa da, iş yükü, vardiya yorgunluğu ve teknik koşullar ölçüm doğruluğunu sınırlamaktadır.

Bu sonuçlar doğrultusunda ;

- Gece vardiyalarında görev yapan hemşire sayısı, hasta yoğunluğu ve iş yükü dikkate alınarak yeniden planlanması,

- Ekipman standardizasyonunun sağlanması,
- Teknolojik sistemlerde, ölçüm hatalarını azaltacak renkli uyarı sistemleri ve merkezi monitör takibi gibi yenilikçi çözümler uygulanması,
- Gece vardiyalarında hemşirelerin kısa süreli dinlenme aralıkları planlanarak dikkat ve algı düzeyinin korunması desteklenmesi,
- Kurumlar, hemşirelerin yaşadığı teknik ve psikolojik sorunları raporlayabileceği etkili bir geri bildirim sistemi oluşturması,
- Hemşirelere yönelik yaşam bulgularının doğru ölçümü, cihaz kullanımı, acil durum farkındalığı ve iletişim becerileri konularında hizmet içi eğitimler düzenlenmesi,
- Özellikle yeni başlayan hemşirelere, farklı hasta gruplarında (çocuk, obez, yaşlı vb.) doğru ölçüm teknikleri konusunda uygulamalı eğitimler verilmesi,
- Dikkat ve farkındalık temelli eğitim programları (ör. mindfulness, vardiya öncesi kısa odaklanma egzersizleri) desteklenmesi,
- Gelecekteki çalışmalar, farklı hastane türlerinde (devlet, üniversite, özel) ve daha geniş örneklem gruplarıyla yürütülmesi önerilmektedir.

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AŞI TEREDDÜTÜ, AŞI OKURYAZARLIĞI VE HALK SAĞLIĞI HEMŞİRELİĞİ

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ÖZET

Aşılar, bulaşıcı hastalıkların önlenmesinde en etkili halk sağlığı müdahaleleri arasında yer almaktadır. Bununla birlikte son yıllarda aşı tereddütünün küresel ölçekte önemli bir halk sağlığı sorunu haline geldiği görülmektedir. Aşı tereddütü, bağışıklama programlarının etkinliğini olumsuz yönde etkileyerek toplum sağlığı açısından önemli sonuçlar doğurabilmektedir. Bu durumun; yanlış ve eksik bilgiye maruz kalma, sağlık sistemine duyulan güven, sosyokültürel etmenler ve bireylerin bilgiyle etkileşim biçimleriyle ilişkili olabileceği değerlendirilmektedir. Bu bağlamda, bireylerin aşılarla ilgili bilgiye erişme, anlama ve değerlendirme becerilerini ifade eden aşı okuryazarlığı kavramı giderek öne çıkmaktadır. Aşı okuryazarlığı, bireylerin bilinçli ve sağlıklı kararlar alabilmesini destekleyen temel bir yeterlilik alanı olarak değerlendirilmektedir. Bu derleme çalışmasının amacı, aşı tereddütü ve aşı okuryazarlığı kavramlarını ele almak ve halk sağlığı hemşireliğinin bu süreçteki rolünü literatür doğrultusunda değerlendirmektir. Toplumla doğrudan temas hâlinde olan halk sağlığı hemşirelerinin, aşı okuryazarlığının geliştirilmesi ve aşı tereddütünün azaltılmasında önemli bir role sahip olduğu düşünülmektedir. Nitekim halk sağlığı hemşirelerinin, bireylerin bilgi gereksinimlerini belirleme ve bu gereksinimlere uygun eğitim ve danışmanlık yaklaşımları geliştirme açısından avantajlı bir konumda olduğu ifade edilebilir. Bu doğrultuda halk sağlığı hemşireleri; güven temelli iletişim kurma, bireylerin kaygılarını dikkate alma, yanlış bilgileri düzeltme ve danışmanlık sağlama yoluyla aşıya yönelik tutumların olumlu yönde şekillenmesine katkı sağlayabilirler. Ayrıca toplum temelli eğitim ve izlem faaliyetleri aracılığıyla aşı tereddütünün azaltılmasında, aşılar konusunda uygun sağlıklı karar verilebilmesinde etkin bir sorumluluk üstlenebilecekleri söylenebilir.

Anahtar Kelimeler: Aşı tereddütü, aşı okuryazarlığı, halk sağlığı hemşiresi.

VACCINE HESITANCY, VACCINE LITERACY, AND PUBLIC HEALTH NURSING

Abstract

Vaccines are among the most effective public health interventions for preventing infectious diseases. However, in recent years, vaccine hesitancy has become a significant public health issue on a global scale. Vaccine hesitancy can negatively impact the effectiveness of immunization programs, leading to significant consequences for public health. This situation may be related to exposure to incorrect and incomplete information, trust in the health system, sociocultural factors, and individuals' ways of interacting with information. In this context, the concept of vaccine literacy, which refers to individuals' ability to access, understand, and evaluate information about vaccines, is becoming increasingly prominent. Vaccine literacy is considered a fundamental competency area that supports individuals in making informed and healthy decisions. The aim of this review is to address the concepts of vaccine hesitancy and vaccine literacy and to evaluate the role of public health nursing in this process in line with the literature. Public health nurses, who are in direct contact with the community, are considered to play an important role in developing vaccine literacy and reducing vaccine hesitancy. Indeed, public health nurses are in an advantageous position to identify individuals' information needs and develop appropriate education and counseling approaches to meet those needs. In this regard, public health nurses can contribute to shaping positive attitudes toward vaccination by establishing trust-based communication, addressing individuals' concerns, correcting misinformation, and providing counseling. Furthermore, it can be said that they can take on an effective responsibility in reducing vaccine hesitancy and enabling appropriate health decisions regarding vaccines through community-based education and monitoring activities.

Keywords: Vaccine hesitancy, vaccine literacy, public health nurse.

INTRODUCTION

The Turkish Language Association Dictionary defines literacy as “the state of being literate”.[1] The concept of vaccine literacy encompasses individuals being knowledgeable about vaccines, being able to convey this knowledge to others, and being able to advocate for vaccination practices.[2] Furthermore, vaccine literacy is related to the skill, motivation, and competence levels individuals possess in accessing, understanding, and applying information about vaccines in their daily lives.[3] In this context, vaccine literacy comprehensively addresses the processes of acquiring information about vaccines, experiencing vaccine hesitancy, and making the final vaccine decision.[4] In addition, vaccine literacy is considered a multidimensional structure that is not limited to the level of knowledge but also includes individuals' ability to generate solutions and communicate effectively in complex and uncertain situations.[5] The World Health Organization has ranked vaccine hesitancy among the top ten risks threatening global health.[6]

Regarding vaccine literacy, various studies have been conducted in Turkish and English literature, particularly in recent years.[3,7-9] In addition, it is noteworthy that academic studies addressing the concept of vaccine hesitancy and examining this phenomenon in its various dimensions are also present in the literatüre.[10,11] Here, the concept of hesitancy can be discussed. The concept of hesitancy is defined as “indecision” in the Turkish Language Association dictionary.[1] It is known that vaccine hesitancy is increasing worldwide.[10,12] The concept of “vaccine hesitancy” means delaying or refusing to accept vaccination despite the availability and accessibility of vaccination services.[13] Vaccine hesitancy is a term coined by the World Health Organization's Strategic Advisory Group of Experts on Immunization (SAGE) and has been on the rise in more than 90% of countries since 2014.[14,15]

Factors influencing vaccine hesitancy include beliefs that vaccines are toxic due to their ingredients, concerns that vaccine manufacturers may have ulterior motives due to the high financial gains they derive from this field, and the perception that natural immunity or natural methods are more effective in protecting against disease.[16] However, it is stated that reduced vaccine availability or accessibility, poor health literacy, fear of side effects, distrust of health authorities or healthcare providers, and personal spiritual/religious beliefs play an important role in supporting the modern anti-vaccine movement.[17] Attitudes toward vaccines vary among individuals in society; some individuals accept vaccines quickly, some prefer to delay vaccination, and some individuals reject vaccines entirely.[18] However, it is noted that factors such as beliefs that the substances in vaccines are religiously inappropriate, thoughts that vaccine companies develop vaccines for financial gain, and the assumption that natural immunity is more effective in overcoming disease are influential in the emergence of vaccine hesitancy in individuals.[19]

Vaccine hesitancy is a complex and multifaceted issue that is difficult to address at both the individual and community levels. Current evidence on best practices and strategies to increase vaccine acceptance, although more research is needed, suggests that dialogue-based and multi-component interventions are the most effective approach.[17,20] A study conducted with students

of the Faculty of Health Sciences reported that no significant difference was found between vaccine hesitancy and vaccine literacy in terms of gender, age, total income, and class variables; however, significant differences were found in vaccine hesitancy and vaccine literacy levels according to department variables. Furthermore, the study determined that there was a low-level, positive, and statistically significant relationship between vaccine literacy and vaccine hesitancy. Similarly, it was concluded that vaccine literacy had a significant and positive effect on vaccine hesitancy.[21] Another study found that 40.60% of participants were reluctant and hesitant about vaccination, that the primary reason for hesitation or refusal was concern about side effects (65.00%), and that healthcare professionals influenced vaccination decisions in 83.80% of cases.[20] On the other hand, another study found that Family Health Centers ranked last among the sources individuals consulted when seeking information about vaccines.[22]

Concerns about vaccine safety and efficacy, expectations that more information about safety and efficacy will emerge, concerns about the speed of vaccine development and rollout, distrust of government and institutions, perceived violations of personal freedoms, and the belief that vaccination is unnecessary are cited as key reasons for vaccine hesitancy.[23,24] Another study suggested that concerns about vaccine safety and efficacy are among the reasons for vaccine hesitancy.[25] Scientific evidence shows that, in addition to religious beliefs, various reactions to vaccination, such as vaccine hesitancy, are caused by religious beliefs.[26] Zimmerman and colleagues (2023) found that misinformation based on politics, religion, and the media is associated with vaccine hesitancy, that scientific approaches and evidence alone are not sufficient to combat COVID-19 vaccine hesitancy, and that intervention by public health authorities is therefore necessary.[27]

CONCLUSION

Vaccination is currently one of the most economical and effective public health interventions worldwide.[28] Understanding the importance of vaccines plays a key role in preventing the emergence of preventable health problems. Although vaccines are often perceived solely as a means of individual protection today, they essentially contribute to the protection of public health by providing community immunity. In this context, strengthening the knowledge, awareness, and advisory roles of public health nurses, especially those working in primary health care, is of great importance. This is because health education is an indispensable element of health services, and the information, guidance, and advocacy activities carried out for individuals and communities during this education process are among the fundamental responsibilities of public health nursing. In this regard, supporting the educational and advisory roles of public health nurses in increasing vaccine literacy can contribute to reducing vaccine hesitancy at the individual and community levels. Furthermore, it is thought that the widespread implementation of practices that support the active role of public health nurses in the planning and execution of vaccination services will contribute to strengthening community immunity by increasing the effectiveness of preventive health services.

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EVDE SAĞLIK HİZMETLERİNDE UZAKTAN SAĞLIK HİZMETLERİ VE UYGULAMALARI

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ÖZET

Uzaktan sağlık hizmeti sunumu; tele-tıp, tele-sağlık, mobil sağlık (m-sağlık) ve giyilebilir teknolojiler gibi farklı uygulamaları kapsayan, bilgi ve iletişim teknolojileri temelli bir sağlık hizmeti yaklaşımıdır. Özellikle evde sağlık hizmetleri bağlamında uzaktan sağlık uygulamaları, bireylerin sağlık durumlarının izlenmesi, klinik önerilerin sunulması, danışmanlık, tedavi takibi, sağlık eğitimi gibi süreçlerin yürütülmesi açısından önemli fırsatlar sunmaktadır. Tele-sağlık uygulamaları sayesinde hastalar, sağlık profesyonelleriyle iletişim kurmak için evlerinden çıkmak zorunda kalmadan hizmet alabilmekte; bu durum coğrafi erişim güçlüğü yaşayan, kronik hastalığı bulunan, yaşlı veya hareket kısıtlılığı olan bireyler için evde sağlık hizmetlerinin etkinliğini artırmaktadır. Evde sağlık hizmetlerinde uzaktan sağlık sistemleri, bakımın sürekliliğini desteklemekte, erken risk belirleme ve zamanında müdahale olanağı sağlayarak sağlık sonuçlarını iyileştirmektedir. Bununla birlikte uzaktan sağlık hizmetlerinin evde sağlık hizmetlerine etkin biçimde entegre edilebilmesi; güçlü bir teknik altyapı, veri güvenliği ve gizliliğinin sağlanması ile bu sistemleri kullanacak sağlık çalışanlarının bilgi, beceri ve tutumlarına bağlı olduğu düşünülmektedir. Bu doğrultuda sağlık profesyonellerinin dijital uyumu ve teknolojiye yönelik olumlu yaklaşımları, uzaktan sağlık uygulamalarının başarısında kritik rol oynayacağı söylenebilir. Bu bağlamda evde sağlık hizmetlerinde uzaktan sağlık sistemleri, nitelikli, erişilebilir ve sürdürülebilir bakım sunumunun önemli bir bileşeni olarak değerlendirilebilir. Bu derleme çalışmasının amacı, evde sağlık hizmetlerinde uzaktan sağlık hizmetleri ve teknolojik uygulamalarının evde sağlık hizmetlerindeki rolünü ve önemini literatür doğrultusunda değerlendirmektir.

Anahtar Kelimeler: Evde sağlık hizmetleri, uzaktan sağlık hizmetleri, evde bakım.

REMOTE HEALTHCARE SERVICES AND APPLICATIONS IN HOME HEALTHCARE SERVICES

ABSTRACT

The provision of remote healthcare services is an information and communication technology-based healthcare approach that encompasses various applications such as telemedicine, telehealth, mobile health (m-health), and wearable technologies. Especially in the context of home healthcare, remote healthcare applications offer significant opportunities for monitoring individuals' health conditions, providing clinical recommendations, counseling, treatment follow-up, and health education. Thanks to telehealth applications, patients can receive services without having to leave their homes to communicate with healthcare professionals; this increases the effectiveness of home healthcare services for individuals who experience geographical access difficulties, have chronic illnesses, are elderly, or have limited mobility. In home healthcare, remote healthcare systems support continuity of care, improve health outcomes by enabling early risk identification and timely intervention. However, the effective integration of remote healthcare services into home healthcare services is thought to depend on a robust technical infrastructure, ensuring data security and privacy, and the knowledge, skills, and attitudes of the healthcare workers who will use these systems. In this regard, it can be said that healthcare professionals' digital readiness and positive attitudes toward technology will play a critical role in the success of remote healthcare applications. In this context, remote healthcare systems in home healthcare services can be considered an important component of providing qualified, accessible, and sustainable care. The aim of this review study is to evaluate the role and importance of remote healthcare services and technological applications in home healthcare services in line with the literature.

Keywords: Home healthcare services, remote healthcare services, home care.

INTRODUCTION

The effective planning and implementation of home care services play a critical role in the sustainability of healthcare systems and have become an increasingly accepted service model for meeting care needs both globally and in Türkiye.[1] The primary goal of home health services is to improve individuals' health outcomes and quality of life by ensuring continuity of care.[2] The current legal framework for telehealth applications in Türkiye was established by the “Regulation on the Provision of Remote Healthcare Services” published in the Official Gazette dated February 10, 2022, and numbered 31746. Under this regulation, the basic principles and fundamentals regarding the provision of remote healthcare services have been determined;

provisions regarding the licensing processes of healthcare institutions, the registration and supervision of information systems, and the protection of patient privacy and personal data have been defined.[3] In addition, the "Regulation on the Provision of Home Healthcare Services," which entered into force on June 2, 2023, clarifies the scope of home healthcare services, the structure of the teams involved in service delivery, and service standards, aiming to increase the accessibility of services and enhance the quality of care.[4]

With the rapid development and digitization of today's world, IT-based applications have become widely used, especially in the management of chronic diseases, due to their contribution to cost management, increased accessibility, and their ability to offer a service model that is adoptable and sustainable by target users. The use of technology in healthcare services has contributed not only to the restructuring of care processes but also to the dynamics of social transformation.[5] Various technological tools are used in the transmission of health data, such as video conferencing systems, internet-based camera applications, telephone lines, home monitoring systems, social alarm devices, and scheduled telephone calls.[6] The integration of these technological approaches, particularly telehealth, into home care processes has yielded positive results in the management of chronic diseases; it enables the remote monitoring of patients' treatment and care processes, thereby improving their quality of life and supporting treatment compliance.[7] In this context, telehealth is defined as "the use of electronic information and telecommunications technologies to support long-distance clinical healthcare, patient and healthcare professional education, public health applications, and healthcare management".[8]

Telehealth applications are emerging as a widely used approach by healthcare professionals to meet care needs, aiming to reduce hospital visits by enabling remote monitoring of individuals with chronic conditions and those in high-risk groups.[7,9] These applications are effectively used in areas such as monitoring blood glucose levels in individuals with diabetes mellitus, monitoring patients diagnosed with dementia, and preventing fall-related injuries in elderly individuals.[10] In the home care processes of patients with heart failure, telephone monitoring, tele-monitoring systems, wearable technologies, and mobile health software are frequently used.[11,12] Providing information and training on the technologies used in this process to patients and caregivers by nurses contributes to the development of an integrated care model that ensures continuity and consistency between center-based and home care services.[13] Education and counseling services conducted in the home environment strengthen individuals' self-care skills, increase treatment compliance, and support their active participation in the care process. Evidence is growing that remote patient monitoring and tele-nursing applications have positive effects on both health outcomes and patient experience.[14,15] Furthermore, it is noted that these applications enable patients and caregivers to adapt to daily life more quickly, reduce hospital transfers, and contribute to reducing the financial burden on the healthcare system in the long term by preventing complications.[16] Telemedicine applications are also considered an effective method for meeting patients' care needs, monitoring them, and detecting possible complications early in the postoperative period. In this respect, it offers an important care approach that improves individuals' quality of life in the post-discharge period.[17] Maintaining constant communication between patients and caregivers and the healthcare team increases accessibility to the care process and strengthens the sense of trust.[16] A study conducted in the field of

gynecological oncology showed that biofeedback-assisted pelvic floor muscle exercises provided via telehealth are feasible and acceptable for managing urinary and/or fecal incontinence that occurs after gynecological cancer treatment.[17] Studies focusing on the cost dimension of telehealth applications also report positive findings. Piera-Jiménez and colleagues (2020) reported that telehealth applications reduced healthcare costs.[18] The study by Bowser and colleagues (2018) found that telephone-supported prenatal care reduced the cost per life saved compared to the home birth group by increasing access to services such as tetanus vaccination and malaria prophylaxis.[19] Mas et al. (2022) stated that pediatric telemedicine care provided meaningful savings to the healthcare system at a cost 9% lower than traditional hospital care.[20]

In light of these assessments, home health services offer a person-centered, cost-effective, and accessible care approach aimed at reducing hospital admissions and readmissions, improving quality of life, and ensuring continuity of care.[2,21,22] However, limited access to technological applications and their use pose significant barriers for some individuals.[16] The fact that telemedicine is a relatively new field of application in Türkiye highlights factors such as advanced age, level of technological literacy, rural living conditions, and socioeconomic status as disadvantages.[23] In addition, the storage of patient data in digital environments increases cybersecurity risks; the use of technological applications in situations requiring urgent intervention can cause delays in treatment processes.[24] Furthermore, difficulties in adapting to technology, as well as issues related to privacy, security, and system failures, are among the main limitations of telehealth applications for both healthcare professionals and service users.[25]

CONCLUSION

Home healthcare services are becoming increasingly important for the sustainability of healthcare systems in line with the growing burden of chronic diseases and the care needs of an aging population. The integration of remote healthcare services and telehealth applications into home care processes offers a cost-effective approach that supports continuity of care, enhances patient safety, and improves quality of life. Telehealth applications have been shown to reduce hospital visits and contribute to the healthcare system, particularly in the management of chronic diseases, postoperative care, and monitoring of elderly individuals. Legal regulations regarding home healthcare and remote healthcare services in Turkey have created an important infrastructure for the standardization and dissemination of these services. However, factors such as technological literacy, differences in access to technological services, and data security can limit the effectiveness of these applications. In this context, it is important to strengthen the training of healthcare professionals and service recipients on the use of technology and to integrate remote patient monitoring and tele-nursing applications into care protocols for chronic diseases, elderly care, and postoperative processes. Furthermore, it is believed that developing technological infrastructure for disadvantaged groups, strengthening nurses' professional roles in home health and remote care processes, and addressing the health outcomes and cost-effectiveness of telehealth applications in future studies could contribute to improving the quality of home health services.

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SLEEP DISORDERS DURING MENOPAUSE: BIOSYCHOSOCIAL DETERMINANTS, PHYSIOLOGICAL MECHANISMS, AND CLINICAL MANAGEMENT

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ABSTRACT

Sleep disorders during menopause are a common problem seen in a significant number of women and significantly reduce quality of life. The prevalence of insomnia is reported to increase during peri- and postmenopausal, manifesting particularly as difficulty falling asleep, frequent nighttime awakenings, early morning awakenings, and the inability to fall back asleep. This condition is not due to a single cause; it is shaped by the interaction of hormone changes, hot flashes and night sweats, circadian rhythm disruption, physiological hyper-alertness, increased stress, anxiety and depressive symptoms, relationship problems, poor sleep hygiene, and lifestyle habits. Longitudinal and cross-sectional studies show that poor sleep during the premenopausal period is a significant predictor of more severe insomnia during the menopausal transition, while sleep quality is worse in women who undergo surgical menopause than in those who experience natural menopause. Polysomnography findings reveal that insomnia during menopause is not merely a subjective perception but is also supported by objective indicators such as decreased sleep efficiency and increased cortical arousal. Sleep disturbances have negative consequences on cognitive performance, work life, emotional well-being, and cardiometabolic health. In addition to pharmacological treatments, cognitive behavioral therapy, sleep restriction approaches, mindfulness, and sleep hygiene practices stand out as important and effective options for managing insomnia during menopause.

Keywords: Menopause, insomnia, sleep disorders

1. INTRODUCTİON

Menopause is a physiological process in women's lives that marks the end of reproductive life and is characterized by a significant decrease in estrogen and progesterone levels. Common complaints during this period include hot flashes, night sweats, mood swings, cognitive difficulties, and sleep disturbances. While sleep disruptions are considered a "natural part of menopause" by many women, they are actually a significant clinical problem affecting quality of life, functionality, and long-term health outcomes (Vigeta et al., 2012; Freeman et al., 2015).

Sleep disturbance has been described as one of the most common and "disruptive" symptoms for women during the menopausal transition (Maki et al., 2024). Sleep disorders encompass problems related to initiating and maintaining sleep, and waking up refreshed in the morning. The prevalence of insomnia in perimenopause and postmenopause has been reported to range from 16–47% and 35–60%, respectively (Tandon et al., 2022; Arakane et al., 2011). The purpose of this article is to discuss sleep disorders observed during menopause within a biopsychosocial framework, explain mechanisms, and offer implications for clinical practice, based solely on the findings of quantitative, qualitative, and compilation studies examining the relationship between menopause and sleep.

2. CLINICAL PRESENTATION OF SLEEP DISORDERS DURİNG MENOPAUSE

Menopause-related sleep disorders often manifest as frequent nocturnal awakenings, difficulty falling asleep after waking, and increased wakefulness time after falling asleep (WASO) (Maki et al., 2024). Jones et al. (2018) reported poor sleep quality (PSQI > 5) in 42% of women in late premenopause and early perimenopause, with the most common motivator being the need to go to the toilet at night (81%), followed by the complaint of "feeling too hot" (26%). Women in early perimenopause reported shorter sleep duration and poorer subjective sleep quality compared to premenopausal women of similar age (Jones et al., 2018).

Freeman et al. (2015) conducted a 14-year follow-up study, which found that the prevalence of moderate/severe poor sleep remained between 28% and 35% across years, and that poor sleep only increased significantly with menopause in a small subgroup. Women who reported poor sleep during premenopause were shown to have an approximately 3.5-fold increased risk of experiencing moderate/severe poor sleep during menopause. This finding suggests that sleep disturbances during menopause cannot be explained solely by changes in ovarian function, and that premenopausal sleep history is a strong determinant (Freeman et al., 2015; Luo et al., 2020).

3. BIOLOGICAL AND PHYSIOLOGICAL MECHANISMS

Hormonal changes are a significant component of menopausal sleep disorders. Estrogen withdrawal affects hypothalamic networks involved in thermoregulation, mood, and circadian regulation of sleep (Maki et al., 2024). Estrogen-sensitive kisspeptin/neurokinin B/dynorphin (KNDy) neurons, in particular, are proposed to integrate gonadotropin secretion, body

temperature control, circadian rhythm, and the sleep-wake cycle, thus forming the common neural basis of both vasomotor symptoms and sleep disorders (Maki et al., 2024). Polysonography-based studies strengthen the physiological basis of menopausal sleep disorders. Baker et al. (2015) showed that total sleep time measured by PSG was an average of 43.5 minutes shorter, sleep efficiency was reduced, and WASO was increased in women who developed insomnia during the menopausal transition compared to those who did not. The same study found that the number of physiological hot flashes significantly predicted the number of awakenings detected by PSG (Baker et al., 2015).

Matthews et al. (2021), in a study monitoring the transition from pre/early perimenopause to postmenopause, reported significantly increased EEG beta power during NREM sleep in postmenopausal women, whereas no significant differences were found in classical PSG measures such as sleep duration and WASO due to menopausal status. These findings suggest that the menopausal transition may be associated with "physiological hyper-alertness," suggesting that some women may experience increased cortical arousal despite visually normal sleep patterns (Matthews et al., 2021). Xu et al. (2011) reported that menopausal women diagnosed with insomnia had longer total wake time and lower sleep efficiency compared to non-menopausal women. There were no significant differences in objective sleep measurements between menopausal women who were and were not taking hormone replacement therapy. These findings suggest that HRT alone does not normalize sleep. Luo et al. (2020) showed that in middle-aged Chinese women, both difficulty falling asleep and early morning awakenings increased significantly during the menopausal transition and postmenopause compared to premenopause, and that anxiety, depression, and FSH levels were independently associated with insomnia.

4. VASOMOTOR, PSYCHOSOCIAL, AND PARTNER-RELATED FACTORS

Vasomotor symptoms, particularly hot flashes, are the most frequently cited biological determinant of menopause-related insomnia (Tandon et al., 2022; Maki et al., 2024). Arakane et al. (2011) showed that insomnia severity, as assessed by the ISI, was significantly associated with hot flash severity, sedentary lifestyle, and psychotropic medication use. In the same study, partner variables were also found to be significant; partner erectile dysfunction was positively associated with insomnia, while partner fidelity was negatively associated (Arakane et al., 2011).

Psychosocial factors also play a significant role in menopausal sleep disturbances. Cuadros et al. (2012) reported that insomnia severity increased with perceived stress in middle-aged Spanish women, and that insomnia severity was linked to both stress and menopausal symptoms, as well as partner-related factors. Vigeta et al. (2012) conducted a qualitative study with postmenopausal women, showing that insomnia complaints can begin in childhood or during stressful periods of life, and that hormonal changes, psychosocial burdens, and potential sleep-breathing disorders during menopause exacerbate this condition. A significant portion of women are unaware of basic sleep hygiene behaviors, and habits such as watching television in bed, consuming caffeine late into the night, and irregular bedtimes perpetuate sleep disorders (Vigeta et al., 2012).

5. SURGICAL MENOPAUSE AND SLEEP

Because surgical menopause is characterized by a more abrupt and pronounced drop in estrogen levels, it is known that symptoms may be more severe compared to natural menopause. Cho et al. (2019) studied 526 postmenopausal women and found that women who experienced surgical menopause reported poorer sleep quality, shorter sleep duration, and lower sleep efficiency compared to those who experienced natural menopause. The likelihood of insomnia was approximately 2.1 times higher in the surgical menopause group than in the natural menopause group. Furthermore, the association between sleep-interfering behaviors and insomnia was stronger in the surgical menopause group (Cho et al., 2019). These findings suggest that sleep assessment in women after surgical menopause should be particularly careful.

6. TREATMENT AND MANAGEMENT APPROACHES

Both pharmacological and psychological approaches are used in the management of menopause-related sleep disorders. Tandon et al. (2022) note that benzodiazepines remain one of the main treatment options for many sleep disorders; however, tricyclic antidepressants, SSRIs, SNRIs, melatonin, ramelteon, gabapentin, and other psychotropic agents can also be used in selected cases. However, the same review emphasized that there is no "conclusive evidence" for hormone replacement therapy in improving sleep (Tandon et al., 2022).

Psychological and behavioral approaches are gaining increasing importance. Carmona et al. (2023) reported the effectiveness of cognitive behavioral therapy (CBT-i) for menopausal insomnia, with positive effects on mood, functioning, and dysfunctional beliefs about sleep. They also reported that sleep restriction therapy, while effective, was more limited in terms of secondary outcomes compared to CBT-i. While mindfulness-based approaches and relaxation techniques are also promising, evidence regarding their long-term effects is reported to be limited (Carmona et al., 2023). Maki et al. (2024) pointed out that new therapeutic targets acting on KNDy neurons may be a promising avenue for both vasomotor symptoms and sleep disorders.

7. CONCLUSİON

Sleep disorders during menopause are a clinical condition with a high prevalence, multidimensional causes, and far-reaching consequences. The current study, based solely on qualitative, quantitative, and compilation studies examining the relationship between menopause and sleep, demonstrates that hormonal changes, vasomotor symptoms, physiological hyper-alertness, psychosocial stressors, sleep hygiene deficiencies, and partner-related factors play significant roles in this condition. It is noteworthy that women undergoing surgical menopause are particularly at risk, and that sleep problems present during the premenopausal period are a strong predictor of poor sleep during menopause.

In clinical practice, it is crucial to thoroughly assess the sleep history of menopausal women, to avoid viewing insomnia as solely an "age-related" condition, and to appropriately utilize both pharmacological and cognitive-behavioral interventions and mindfulness-based

interventions. Future studies will further elucidate biological mechanisms and address experiences across different cultural contexts, contributing to the diversification of treatment approaches.

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HPV VACCINE ACCEPTABILITY AND DECISION-MAKING: AN UMBRELLA THEMATIC SYNTHESIS OF FINDINGS FROM QUALITATIVE SYSTEMATIC REVIEWS

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ABSTRACT

Aim: This study aims to thematically synthesise common factors shaping HPV vaccine acceptance and hesitancy by integrating the findings of 11 qualitative systematic reviews on HPV vaccination and HPV-related prevention processes (including experiences of HPV testing/cervical screening). Method: Findings from 11 qualitative systematic reviews focusing on HPV vaccination and related experiences were examined comparatively, and similar findings were grouped under overarching themes to produce an umbrella thematic synthesis. Results: Findings were organised into seven main themes: (1) Lack of knowledge and misinformation, (2) Fear, concerns about side effects, and trust/mistrust, (3) Associations with sexuality, stigma, and gender dynamics, (4) Healthcare professional recommendation and communication competence, (5) Access/logistics, cost, and policy/program-level determinants, (6) Family, peer, and community influence, and (7) Need for culturally safe and inclusive services. Conclusion: HPV vaccine acceptance is shaped by multilevel determinants. Effective strategies should combine stigma-sensitive communication, trust-building, strengthening healthcare professionals' recommendation and communication capacity, and system-level arrangements that facilitate access.

Keywords: HPV vaccination, acceptability, vaccine hesitancy, thematic synthesis

1. INTRODUCTION

Although HPV vaccination is an effective primary prevention strategy for reducing the risk of HPV-related cancers, vaccine coverage and series completion remain below target levels across many settings (Ferrer et al., 2014; Mantina et al., 2025). Qualitative systematic reviews indicate that decision-making processes cannot be explained solely by "level of knowledge"; rather, multilevel factors such as fears and concerns about side effects, associations with sexuality and stigma, trust relationships, the quality of healthcare professionals' recommendations, and barriers to access play important roles (Urrutia et al., 2023; Marshall et al., 2019; Deignan et al., 2021). In addition, in the context of HPV testing/cervical screening, the association of HPV with sexually transmitted infections (STIs) may increase anxiety through concerns about disclosure and impacts on relationships, thereby hindering informed decision-making (Hendry et al., 2012). Therefore, integrating the findings of qualitative systematic reviews that include diverse groups within a comprehensive framework is important for identifying actionable intervention areas (Rosen et al., 2018; Sethi et al., 2021).

2. AIM AND METHOD

The aim of this study is to bring together the findings of 11 qualitative systematic reviews on HPV vaccination and related prevention processes in order to thematically identify common themes and intervention areas that influence vaccine acceptance and decision-making. This study is an umbrella thematic synthesis based on the findings of qualitative systematic reviews addressing HPV vaccination and HPV-related experiences and decision-making processes. The main themes and key conclusions reported in the reviews were extracted; similar findings were integrated to develop overarching themes, and population-specific emphases were considered as subthemes under the relevant overarching themes.

3. FINDINGS

The findings are reported under seven overarching themes: (1) lack of knowledge and misinformation, (2) fear, concerns about side effects, and trust/mistrust, (3) associations with sexuality, stigma, and gender dynamics, (4) healthcare professional recommendation and communication competence, (5) access/logistics, cost, and policy/program-level determinants, (6) family, peer, and community influence, and (7) the need for culturally safe and inclusive services.

Theme 1: Lack of knowledge and misinformation

Limited knowledge about HPV and HPV vaccination is a recurring barrier for both healthcare professionals and target groups (Leung et al., 2019; Rosen et al., 2018). It has been reported that healthcare professionals may have low levels of HPV/vaccine knowledge, which is associated with their vaccine recommendation behaviours (Leung et al., 2019). In the Sub-Saharan African context, knowledge about HPV vaccination and cervical cancer may be

intertwined with misinformation, thereby complicating decision-making (Deignan et al., 2021). In the context of HPV testing, women's low knowledge levels and attempts to interpret limited information through existing understandings of sexually transmitted infections (STIs) and cervical cancer have been described as mechanisms that increase anxiety (Hendry et al., 2012). The meta-summary on acceptability highlights "information about the vaccine" as one of the most critical domains (Urrutia et al., 2023).

Theme 2: Fear, concerns about side effects, and trust/mistrust

"Fears and side effects" constitute one of the central axes shaping acceptability (Urrutia et al., 2023). Among parents, "fear of the unknown" and uncertainty emerge as factors that make vaccination decisions more difficult (Marshall et al., 2019). In Sub-Saharan Africa, fear can generate contradictory perceptions and hesitancy, often fuelled by misinformation and broader social narratives (Deignan et al., 2021). Among Indigenous communities, in addition to "lack of correct knowledge," mistrust in the healthcare system has been reported as an important barrier (Poirier et al., 2021). Collectively, these findings indicate that interventions should address not only information provision but also trust-building and anxiety management.

Theme 3: Associations with sexuality, stigma, and gender dynamics

Associating HPV vaccination with sexuality may complicate parental decision-making (Marshall et al., 2019). On the provider side, discomfort in discussing sexuality-related issues and problems with counselling self-efficacy have been reported (Leung et al., 2019). In HPV testing experiences, perceiving HPV as an STI may heighten anxiety by triggering concerns about disclosure, impacts on relationships, and fear of stigma (Hendry et al., 2012). In Sub-Saharan Africa, gender dynamics have been emphasised as a major theme influencing how stakeholders understand HPV vaccination (Deignan et al., 2021). Among GBMSM (gay, bisexual and other men who have sex with men), the "feminisation" of HPV through an emphasis on cervical cancer and women may hinder perceived personal relevance of HPV risk and reduce vaccine engagement (Pow et al., 2025).

Theme 4: Healthcare professional recommendation and communication competence

Clinician recommendation is a critical determinant of parents' vaccination decisions. However, inconsistencies between clinicians' intentions, recommendation practices, and actual vaccination rates have been reported (Rosen et al., 2018). Provider-focused education (e.g., didactic sessions and communication training) can increase knowledge and has been associated with improvements in vaccine series initiation/completion indicators (Leung et al., 2019). These findings suggest that a strong and consistent recommendation style, alongside communication skills to address parental concerns, is fundamental to programme success.

Theme 5: Access/logistics, cost, and policy/program-level determinants

Vaccine acceptance is closely linked to access conditions that shape whether intention translates into behaviour (Ferrer et al., 2014; Mantina et al., 2025). Among young adults, practical barriers such as scheduling appointments, multi-dose requirements, and vaccine cost have been reported; additionally, perceptions of being "too old/not eligible" and viewing condoms/screening as alternatives to vaccination are among factors influencing decision-making (Mantina et al., 2025). In high-income countries, policy arrangements such as free vaccine provision can reduce financial barriers, whereas healthcare professionals' judgements about whether to recommend the vaccine may restrict access (Ferrer et al., 2014). Therefore, multilevel intervention design is emphasised.

Theme 6: Family, peer, and community influence

Parents often act with a motivation to "protect their child," yet knowledge gaps, fear, and sexuality-related meanings can make decisions more complex (Marshall et al., 2019). Although young adults are in an autonomous age group, parents may continue to influence their decision-making processes (Mantina et al., 2025). In Indigenous communities, family support and a supportive community environment are reported as factors that can enhance acceptability (Poirier et al., 2021). These findings indicate that interventions targeting only individuals may be insufficient and that family and community levels should also be addressed.

Theme 7: Need for culturally safe and inclusive services

HPV-related prevention processes among Indigenous communities and Indigenous women should be addressed within a social-ecological framework that considers individual, interpersonal, institutional/organisational, community/sociocultural, and policy levels together (Sethi et al., 2021). For GBMSM, recommendations include risk communication that covers anal/penile/oropharyngeal cancer risks, stigma-sensitive service delivery, and proactive vaccine offering through access points not limited to sexual health clinics (Pow et al., 2025). In Sub-Saharan Africa, the combination of gender dynamics and fear/misinformation points to the need for locally adapted strategies (Deignan et al., 2021).

4. DISCUSSION

This umbrella synthesis demonstrates that HPV vaccine acceptance is a multilevel phenomenon (Ferrer et al., 2014; Sethi et al., 2021). The three core domains highlighted in Urrutia et al.'s meta-summary information about the vaccine, fears/side effects, and associations with sexuality also emerge as recurring determinants across other reviews and diverse populations (Urrutia et al., 2023; Marshall et al., 2019; Hendry et al., 2012).

The quality and consistency of healthcare professionals' recommendations can represent a "turning point" in vaccination decisions; however, intention–practice gaps and challenges related to communication self-efficacy may lead to missed opportunities (Rosen et al., 2018; Leung et al., 2019). Among young adults, access barriers and the perception of being

"too old" or no longer eligible make programme design even more critical for catch-up vaccination (Mantina et al., 2025). For groups such as Indigenous communities and GBMSM, trust, cultural congruence, and stigma-sensitive services are emphasised as central to improving engagement (Poirier et al., 2021; Pow et al., 2025). Therefore, effective interventions should integrate both individual-level information strategies and system-/policy-level arrangements that facilitate access (Ferrer et al., 2014; Urrutia et al., 2023).

5. CONCLUSION

HPV vaccine acceptance is a multilevel process shaped by the interplay of knowledge, fears and concerns about side effects, associations with sexuality and stigma, trust relationships, the strength of healthcare professionals' recommendations, and access conditions. Effective programmes should integrate stigma-sensitive communication and trust-building with healthcare professional training and system-/policy-level arrangements that facilitate access. For groups such as Indigenous communities and GBMSM, culturally safe and inclusive approaches should be treated as a core priority.

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İNFERTİLİTE YÖNETİMİNDE YOGANIN ROLÜ: PSİKOLOJİK VE ÜREME SAĞLIĞINA YÖNELİK KANITLAR

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ÖZET

Amaç: Bu çalışma, infertilite yaşayan kadınlarda yoganın psikolojik iyilik hâli, stres yönetimi ve üreme sağlığı üzerindeki olası etkilerini güncel literatür doğrultusunda ele almak ve bu alandaki kanıtları bütüncül bir bakış açısıyla değerlendirmek amacıyla hazırlanmıştır.

Yöntem: Yoga, infertilite, stres, yaşam kalitesi ve üreme sonuçları ile ilişkili araştırmalar ulusal ve uluslararası literatürden taranmış; randomize çalışmalar, gözlemsel çalışmalar ve ilgili derlemeler incelenmiştir. Çalışma bir sistematik derleme niteliği taşımamakta olup alandaki mevcut bulguların tematik olarak sentezlenmesine dayanmaktadır.

Bulgular: Literatür, yoganın infertilite sürecinde kadınların psikolojik dayanıklılığını artırdığını, stres ve anksiyete düzeylerini azalttığını ve yaşam kalitesini iyileştirdiğini göstermektedir. Mind–body temelli yaklaşımların, özellikle kortizol düzeylerini düşürerek otonom sinir sisteminde denge sağladığına dair bulgular mevcuttur. Bazı çalışmalar yoganın yardım arama davranışını, tedavi sürecine uyumu ve ART gibi üreme tıbbı uygulamalarının kabulünü desteklediğini belirtmektedir. Üreme sonuçlarına ilişkin kanıtlar sınırlı olmakla birlikte, yoganın dolaylı yoldan üreme fonksiyonlarını olumlu etkileyebileceği ileri sürülmektedir.

Sonuç: Yoga, infertilite yönetiminde psikolojik iyilik hâlini güçlendiren ve stres kaynaklı üreme fonksiyonu bozulmalarını hafifletebilecek tamamlayıcı bir yaklaşım olarak değerlendirilmektedir. Mevcut literatür, yoganın klinik süreçlere entegrasyon potansiyeli olduğunu göstermektedir; ancak bu alanda daha fazla ve daha güçlü metodolojik tasarıma sahip çalışmalara gereksinim vardır.

Anahtar Kelimeler: Yoga; İnfertilite, Psikolojik İyilik Hâli, Stres Yönetimi, Üreme Sağlığı

GİRİŞ

İnfertilite, Uluslararası İnfertilite ve Fertilite Bakımı Sözlüğü'ne göre, bireyin kendisinin ya da eşinin üreme kapasitesindeki bozulma nedeniyle, bir yıl veya daha uzun süre düzenli ve korunmasız cinsel ilişkiye rağmen klinik olarak gebelik elde edilememesi durumudur (Özbaş vd., 2025; Zegers-Hochschild vd., 2017). Dünya genelinde çiftlerin yaklaşık %10-15'inin infertil olduğu tahmin edilmektedir (UNFPA, 2025). İnfertilite, yalnızca üreme sistemine ilişkin bir sorun değil, aynı zamanda bireyin fiziksel, duygusal ve sosyal yaşamını etkileyen önemli bir sağlık sorunu olarak kabul edilmektedir (Özbaş vd., 2025). İnfertilite, dışlanma, boşanma, sosyal izolasyon ve psikolojik sıkıntı gibi olumsuz sonuçlara yol açabilen, sosyal damgalanma ile ilişkilendirilen önemli bir gelişimsel kriz olarak değerlendirilebilir (Taebi vd., 2021). İnfertilite her iki cinsi de eşit derecede etkilese de, en sık suçlanan kadınlardır ve kadınlar için çeşitli psikolojik ve sosyal gerilimlerle ilişkili bir olgudur. İnfertilite tanısı alan bireylerde anksiyete, depresyon, stres, suçluluk ve kontrol kaybı duygularının daha sık görüldüğü; bu durumun yaşam kalitesini ve tedaviye uyumu olumsuz yönde etkilediği bildirilmektedir (Ağırbaş, 2022; Braverman vd., 2024; Kamışlı vd., 2021).

Psikolojik stres ile infertilite arasındaki ilişkinin çift yönlü olduğu bilinmektedir. İnfertilite süreci bireylerde yoğun stres yaratırken, kronik stresin hipotalamo-hipofizer-adrenal (HPA) aks üzerinden hormonal dengeyi bozarak ovulasyon, spermatogenez ve implantasyon süreçlerini olumsuz etkileyebileceği öne sürülmektedir (Simionescu vd., 2021). Bu kısır döngü, infertilite tedavisinde yalnızca farmakolojik ve cerrahi yaklaşımların değil, aynı zamanda psikolojik iyilik hâlini destekleyen tamamlayıcı ve bütüncül yöntemlerin de önemini artırmaktadır (Hwang vd., 2019; Özcan & Kızılkaya Beji, 2016).

Son yıllarda infertilite yönetiminde tamamlayıcı ve integratif sağlık yaklaşımlarına olan ilgi giderek artmaktadır. Bu yaklaşımlar arasında yer alan yoga; bedensel duruşlar (asana), nefes teknikleri (pranayama) ve meditasyon uygulamalarını içeren, zihin–beden bütünlüğünü hedefleyen kadim bir uygulamadır (Yadav vd., 2024). Yoganın otonom sinir sistemi üzerinde düzenleyici etkiler göstererek parasempatik aktiviteyi artırdığı, stres hormonlarını azalttığı ve duygusal dengeyi desteklediği bildirilmektedir (Wang & Szabo, 2020). Bu fizyolojik ve psikolojik etkiler, yoganın infertilite sürecinde potansiyel bir destekleyici müdahale olarak değerlendirilmesine zemin hazırlamaktadır.

Literatürde yoganın infertiliteye bağlı anksiyete ve depresyon düzeylerini azalttığı, yaşam kalitesini ve öz yeterlilik algısını artırdığına yönelik bulgular giderek artmaktadır (Kirca & Pasinlioglu, 2019). Ayrıca bazı çalışmalar, yoganın hormonal profiller, ovulatuar fonksiyonlar, menstrual düzen ve yardımcı üreme tekniklerinin sonuçları üzerinde olumlu etkiler gösterebileceğini ortaya koymaktadır (Yadav vd., 2024). Erkek infertilitesi bağlamında ise yoganın stres düzeylerini azaltarak sperm parametrelerini ve oksidatif stres göstergelerini iyileştirebileceği bildirilmiştir (Yadav vd., 2025).

Bu derleme makalesinin amacı, infertilite yönetiminde yoganın rolünü psikolojik ve üreme sağlığına yönelik kanıtlar çerçevesinde bütüncül bir bakış açısıyla ele almak; kadın ve erkek infertilitesi bağlamında yoganın potansiyel etkilerini ortaya koymak ve mevcut literatürdeki boşlukları tartışmaktır. Ayrıca, sağlık profesyonelleri özellikle ebelik ve kadın sağlığı alanında çalışanlar için yoganın infertilite bakımına entegrasyonuna yönelik çıkarımlar sunulması hedeflenmektedir.

İnfertilite ve Psikolojik Yük

İnfertilite, yalnızca biyolojik bir sağlık sorunu olmayıp, bireyler ve çiftler üzerinde önemli psikolojik ve sosyal etkiler yaratan çok boyutlu bir durumdur (Zaręba vd., 2025). İnfertil bireyler yoğun stres, anksiyete, depresyon, suçluluk ve yetersizlik duyguları yaşayabilmekte; özellikle kadınlar, toplumsal roller ve beklentiler nedeniyle daha fazla psikolojik yük altında kalabilmektedir (Jiang vd., 2024; Xie vd., 2023).

İnfertiliteye eşlik eden psikolojik stresin, hipotalamo-hipofizer-adrenal (HHA) eksen üzerinden kortizol düzeylerini artırarak üreme hormonlarını olumsuz etkileyebileceği ve böylece fertilite üzerinde dolaylı bir baskı oluşturabileceği bildirilmektedir (Simionescu vd., 2021). Bu karşılıklı etkileşim, infertilite yönetiminde yalnızca tıbbi tedavilerin değil, aynı zamanda psikolojik iyilik halini destekleyen tamamlayıcı yaklaşımların da önemini ortaya koymaktadır (Bulut vd., 2024). Stres azaltma, duygusal düzenleme ve beden farkındalığını artırmaya yönelik farkındalık temelli uygulamalar, infertilite sürecinde tamamlayıcı müdahaleler olarak giderek daha fazla ilgi görmektedir (Channawar, 2023). Yoga, hem psikolojik hem de fizyolojik boyutlarıyla infertilite yönetiminde potansiyel yarar sağlayabilecek bütüncül bir yaklaşım olarak öne çıkmaktadır.

Yoganın Psikolojik İyi Oluş Üzerindeki Etkileri

Yoga, beden ve zihin arasındaki etkileşimi merkeze alan bütüncül bir yaklaşım olarak, stresle ilişkili psikolojik belirtilerin yönetiminde tamamlayıcı bir uygulama olarak öne çıkmaktadır (Chauhan vd., 2025; Dhanvijay & Chandan, 2018; Schleinzer vd., 2024). Nefes egzersizleri,

fiziksel duruşlar (asanalar) ve meditasyon (gevşeme) tekniklerini içeren yoganın, bireylerin farkındalık düzeyini artırarak duygusal zeka becerilerini güçlendirdiği bildirilmektedir (Chu, 2010; Kumari & Sahu, 2018). Bu özellikleriyle yoga, infertilite sürecinde sık karşılaşılan anksiyete, depresyon ve algılanan stres düzeylerinin azaltılmasında potansiyel bir destek aracı olarak değerlendirilmektedir (Khandekar & Sundarajan, 2024).

Literatürde yer alan çalışmalar, yoga temelli müdahalelerin infertilite tanısı almış kadınlarda psikolojik iyilik halini artırdığını ve stres düzeylerini anlamlı ölçüde azalttığını göstermektedir (Dumbala vd., 2020; Kirca & Pasinlioglu, 2019; N. Singh vd., 2024). Özellikle düzenli yoga pratiğinin, algılanan stres ve kaygı düzeylerinde azalma sağladığı, yaşam kalitesi ve öznel iyi oluş üzerinde olumlu etkiler oluşturduğu bildirilmektedir. Bu iyileşmenin, bireylerin infertilite tedavisine yönelik tutumlarını ve tedavi sürecine uyumlarını da olumlu yönde etkileyebileceği öne sürülmektedir (N. Singh vd., 2024).

Yoganın psikolojik etkileri, nörofizyolojik mekanizmalarla da açıklanmaktadır. Yoga ve meditasyonun parasempatik sinir sistemi aktivitesini artırarak gevşeme yanıtını güçlendirdiği, stresle ilişkili kortizol düzeylerini azalttığı ve hipotalamo-hipofizer-adrenal (HHA) aksın düzenlenmesine katkı sağladığı bildirilmektedir. Bu mekanizmalar, infertilite sürecinde stresin üreme fonksiyonları üzerindeki olumsuz etkilerinin azaltılmasında dolaylı bir rol oynayabilmektedir (Reddy vd., 2025).

Erkek infertilitesine yönelik sınırlı sayıda çalışmada da yoga ve benzeri zihin–beden temelli uygulamaların psikolojik stresin azaltılması yoluyla üreme sağlığına katkı sağlayabileceği belirtilmektedir (Şahin, 2018). Stres düzeylerindeki azalmanın, sperm parametreleri ve hormonal denge üzerinde dolaylı iyileştirici etkiler oluşturabileceği öne sürülmektedir (Gade vd., 2024). Yoga, hem kadın hem de erkek infertilitesinde psikolojik yükü hedefleyen tamamlayıcı bir yaklaşım olarak ele alınmaktadır.

Yoganın Fizyolojik ve Nöroendokrin Mekanizmalar Üzerine Etkisi

İnfertilite yönetiminde yoganın etkileri yalnızca psikolojik iyilik hali ile sınırlı olmayıp, üreme sistemini etkileyen çeşitli fizyolojik mekanizmalar üzerinden de değerlendirilmektedir. Yoga uygulamalarının, nöroendokrin ve otonom sinir sistemi üzerindeki düzenleyici etkileri aracılığıyla üreme fonksiyonlarını dolaylı ve doğrudan biçimde etkileyebileceği öne sürülmektedir.

Kadın infertilitesi bağlamında, yoga uygulamalarının menstrual döngü düzeni, ovulatuar fonksiyonlar ve polikistik over sendromu (PKOS) ile ilişkili hormonal düzensizlikler üzerinde olumlu etkiler gösterebileceğine dair bulgular mevcuttur (D. Singh vd., 2022). Ayrıca

yoga uygulamalarının pelvik bölge kan akımını artırarak uterin ve overyal perfüzyonu destekleyebileceği, bunun da endometrial reseptivite üzerinde olumlu etkiler yaratabileceği belirtilmektedir (Yadav vd., 2024). Nefes ve gevşeme tekniklerinin, sempatik aktiviteyi azaltarak vasküler tonusu düzenlemesi bu mekanizmanın olası açıklamalarındandır.

İnfertilite sürecinde psikolojik stres, nöroendokrin sistem üzerinde önemli etkiler oluşturarak üreme fonksiyonlarını olumsuz yönde etkileyebilmektedir. Stresin kronik hale gelmesi, hipotalamo-hipofizer-adrenal (HHA) aksın aşırı aktivasyonuna yol açmakta; artan kortizol düzeyleri gonadotropin salgılatıcı hormon (GnRH) pulslarını baskılayarak hipotalamo-hipofizer-gonadal (HHG) aksın işleyişini bozabilmektedir (Sona vd., 2022). Bu durum, kadınlarda ovulasyon düzensizlikleri ve luteal faz defektleri, erkeklerde ise spermatogenez üzerinde olumsuz etkilerle ilişkilendirilmektedir (Ramya vd., 2023).

Yoganın temel etkilerinden biri, otonom sinir sistemi üzerinde dengeleyici bir rol üstlenmesidir. Yapılan çalışmalar araştırmalar yoganın stresi ve kaygıyı azaltma, serotonin ve dopamin hormonlarını artırma ve modern yaşamda sağlıklı başa çıkma mekanizmalarını kolaylaştırma yeteneğini vurgulamaktadır (Çetinoğlu & Pehlivan, 2024). Yoga ve meditasyonun parasempatik sinir sistemi aktivitesini artırarak sempatik baskınlığı azalttığı; böylece gevşeme yanıtını güçlendirdiği bildirilmektedir (Khajuria vd., 2023). Bu fizyolojik yanıtın, stresle ilişkili kortizol ve katekolamin düzeylerinde azalmaya katkı sağladığı ve HHA aksının düzenlenmesini desteklediği belirtilmektedir (Shobana vd., 2022). Başka bir çalışmada yogadaki nefes teknikleri ve farkındalık temelli meditasyon uygulamalarının, vagal tonusu artırarak kalp atım hızı değişkenliğini iyileştirdiği ve stres yanıtının fizyolojik göstergelerini azalttığı gösterilmiştir (Rawat vd., 2024; Sharma vd., 2025). Bu değişimlerin, üreme hormonlarının salgılanmasında dolaylı bir düzenleyici etki oluşturabileceğini düşündürmektedir. Kadınlarda östrojen ve progesteron dengesinin korunması, erkeklerde ise testosteron düzeylerinin stres kaynaklı baskılanmasının azaltılması bu mekanizmalarla ilişkilendirilmektedir.

Yoga endokrin sistem üzerindeki etkileri, prolaktin ve tiroid hormonları gibi üreme ile ilişkili diğer hormonlar üzerinden de değerlendirilmektedir. Özellikle stresle ilişkili hiperprolaktineminin, ovulatuar fonksiyonlar üzerindeki olumsuz etkileri göz önünde bulundurulduğunda, yoganın stres azaltıcı etkileri aracılığıyla hormonal dengeyi destekleyebileceği öne sürülmektedir. Benzer şekilde, tiroid fonksiyon bozukluklarının infertilite ile ilişkisi dikkate alındığında, yoga ve meditasyonun genel hormonal denge üzerindeki düzenleyici potansiyeli önem kazanmaktadır.

Mevcut literatür, yoga temelli müdahalelerin nöroendokrin sistem üzerindeki etkilerinin doğrudan nedensel ilişkiler kurmaktan ziyade, stres yanıtının modülasyonu yoluyla dolaylı mekanizmalar üzerinden gerçekleştiğini göstermektedir. Bu bağlamda yoga, infertilite yönetiminde farmakolojik ve tıbbi tedavilere alternatif değil; psikolojik ve fizyolojik dengeyi destekleyen tamamlayıcı bir yaklaşım olarak değerlendirilmektedir.

SONUÇ

Bu derleme, infertilite yönetiminde yoganın psikolojik ve fizyolojik boyutlarıyla bütüncül bir yaklaşım sunduğunu ortaya koymaktadır. Mevcut kanıtlar, yoga uygulamalarının stres, anksiyete ve depresif belirtileri azaltarak psikolojik iyilik halini desteklediğini; bu etkinin hipotalamo-hipofizer-adrenal ve hipotalamo-hipofizer-gonadal eksenler üzerinden üreme fonksiyonları üzerinde dolaylı katkılar sağlayabileceğini düşündürmektedir. Özellikle kadınlarda insülin duyarlılığı ve hormonal denge üzerinde olumlu etkiler ile ovulatuar fonksiyonların desteklenmesi, erkeklerde ise oksidatif stresin azalması ve semen parametrelerinde iyileşme gibi bulgular, yoganın infertilite sürecinde tamamlayıcı bir müdahale olarak değerlendirilebileceğini göstermektedir. Bununla birlikte literatürdeki çalışmaların yöntemsel heterojenliği, örneklem büyüklüklerinin sınırlı olması ve müdahale protokollerinin standartlaştırılmamış olması, elde edilen sonuçların genellenebilirliğini kısıtlamaktadır. Bu nedenle gelecekte, özellikle ebelik bakım modelleriyle entegre edilmiş, randomize kontrollü ve uzun dönemli çalışmalara ihtiyaç bulunmaktadır. Yoga temelli uygulamaların, infertil bireylerin tedavi sürecine uyumunu ve yaşam kalitesini artırma potansiyeli göz önünde bulundurulduğunda, infertilite bakımında bütüncül ve kadın merkezli yaklaşımların önemli bir bileşeni olabileceği düşünülmektedir.

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EMZİRME SONLANDIRMA SÜRECİNİN DESTEKLENMESİNDE YENİ BİR YAKLAŞIM: EBE-LİDERLİĞİNDE DİJİTAL DESTEKLİ EMZİRME SONLANDIRMA DANIŞMANLIĞI

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ÖZET

Amaç

Emzirmenin başlatılması ve sürdürülmesine yönelik geniş literatüre rağmen, emzirme sonlandırma döneminde ebe desteğini temel alan bakım modellerine ilişkin araştırmalar sınırlıdır. Bu çalışma, emzirme sonlandırma sürecinde ebelerin danışmanlık rolünü güçlendirmeye yönelik Ebe-Liderliğinde Dijital Destekli Emzirme Sonlandırma Danışmanlığı modeli önerisini literatür doğrultusunda tartışmayı amaçlamaktadır.

Gereç ve Yöntem

Bu çalışma, emzirmenin sürdürülmesi ve sonlandırılması süreçlerinde ebe liderliğinde bakım modellerini ele alan ulusal ve uluslararası araştırmaların derlenmesine dayalı bir literatür incelemesidir. İlgili veri tabanlarında 2010–2025 yılları arasında yayımlanan çalışmalar taranmış, nitelikli kanıta dayalı bulgular tematik olarak değerlendirilmiştir.

Bulgular

Ebe-Liderliğinde Sürekli Bakım (ELSB) modelinin emzirme süresini uzattığı, maternal memnuniyeti artırdığı ve postpartum uyum süreçlerine olumlu katkılar sağladığı saptanmıştır. Ancak emzirme sonlandırma dönemine yönelik profesyonel rehberlik eksikliği dikkat çekmektedir. Dijital danışmanlık, tele-laktasyon uygulamaları ve ebe moderatörlüğünde oluşturulan destek gruplarının erişilebilir, sürdürülebilir ve maliyet etkin bir bakım yaklaşımı sunduğu bulunmuştur. Bu bileşenleri içeren yeni model önerisi; kademeli sütten kesme,

emosyonel destek, meme sağlığı izlem ve aile katılımını temel alan çok boyutlu bir bakım yaklaşımıdır.

Sonuç

Emzirme sonlandırma süreci; fizyolojik olduğu kadar psikososyal boyutları da içeren kritik bir dönemdir. Bu dönemde ebe liderliğinde dijital destekli danışmanlık modeli, anne-bebek sağlığını koruyan, planlı ve güvenli geçişe olanak tanıyan yenilikçi ve uygulanabilir bir yaklaşım sunmaktadır. Modelin klinik ortamlarda pilot çalışmalarla etkinliğinin değerlendirilmesi ve sağlık sistemine entegrasyonuna yönelik çalışmaların artırılması önerilmektedir.

Anahtar Kelimeler: Emzirme, Sütten Kesme, Ebe-Liderliğinde Bakım, Dijital Sağlık, Tele-danışmanlık

GİRİŞ

Emzirme bilindiği gibi bağışıklık, anne–bebek bağlanması ve uzun dönem pozitif sağlık sonuçları açısından vazgeçilmez bir uygulamadır. Bununla birlikte, birçok annenin emzirme sürecini ideal süre olan ilk altı ay yalnız anne sütüyle beslenme ve 2 yaş civarına kadar emzirmeyi sürdüremediği görülmektedir (Güder & Nezire, 2023). Bazen anneler ve bebeklerle ilgili sorunlar, emzirmenin erken sonlandırılmasına neden olmaktadır. Bu sorunların bazıları, anne sütünün yetersiz olduğu düşüncesiyle ilk altı ay dolmadan ek beslenmeye başlanması, anne sütünde azalma, annenin emzirmenin desteklenmediği ortamlarda çalışması, çocuğun emmeyi sonlandırması, gebe kalma, meme ile ilgili sorunlardır (Kartal & Demir Acar, 2022). Bu dönem, bu sorunları aşan ve emzirme süresinin tadını başarı göstererek çıkaran anneler ve bebekleri için değerli ve özeldir. Anne bebek arasındaki ilişkinin kurulduğu ve güçlendirildiği bu özel dönem, ömür boyu sürmeyeceği için bir yerde sonlandırılmalıdır. Bu nedenle, sütten kesme anneler ve bebekler için doğal ve kaçınılmaz bir sondur. Bu kaçınılmaz süreç, anne ve bebeğin hazır olduğu iki yaş civarında tercih edilmelidir. Bir sistematik derlemede, emzirmeyi sonlandırma zamanını etkileyen faktörleri; bireysel (süt eksikliği, meme sorunları), bebeğe ait, psikososyal (stres, düşük özgüven) ve çevresel (sosyal destek eksikliği, çalışma koşulları) başlıkları altında toplamaktadır (Altıntaş vd., 2025). Ebeler, emzirme sonlandırma sürecinde kanıta dayalı bilgilendirme yaparak, ideal zamanlama ve yöntem seçimine rehberlik etmelidir. Emzirmenin ani sonlandırılması anne-bebek sağlığında mastit, sütün aşırı baskılanması, bebekte uyku ve davranış sorunları gibi olumsuz sonuçlara yol açabilmektedir. Bu süreçte aşamalı geçişin desteklenmesi, alternatif beslenme planlaması, anne-bebek bağının korunması

ve emosyonel yükün yönetilmesi ebe rehberliğinin temel içeriklerindendir. Ayrıca sosyal medya ve çevresel baskıların emzirme sonlandırma kararını etkilediği görülmekte olup, ebe danışmanlığı annelerin doğru bilgiye ulaşmasını ve kendine güvenini artırmaktadır.

Son yıllarda dijital sağlık uygulamalarının yaygınlaşması, doğum sonu bakım ve emzirme danışmanlığı alanında yeni olanaklar sunmuştur. Özellikle ebe liderliğinde yürütülen dijital destekli danışmanlık modelleri, anne merkezli bakım anlayışını güçlendiren yenilikçi yaklaşımlar olarak öne çıkmaktadır. Literatürde emzirme sonlandırma danışmanlığına ilişkin çalışmaların sınırlı olduğu, mevcut araştırmaların ise daha çok emzirmenin başlatılması ve sürdürülmesine odaklandığı görülmektedir (Harting vd., 2025; Subekti & Rosalia, 2025). Bu durum, ebelerin emzirmenin tüm yaşam döngüsünde aktif rolünün güçlendirilmesi gerekliliğini ortaya koymaktadır. Emzirme sonlandırma sürecinde ebe liderliğinde geliştirilecek eğitim ve destek programlarının, hem anne hem bebek sağlığı üzerinde olumlu etkiler yaratacağı düşünülmektedir.

Bu dönemde, emzirme düzeninde gündüz emzirme kademeli olarak azaltılmalı, aniden kesilmemeli ve gündüz emzirmeleri azaltılmalıdır. Çünkü gündüzlerde oyun gibi yöntemlerle çocuğun dikkatinin annenin göğsünden uzaklaştırılması mümkündür. Sütten kesme döneminde anneler bebeklerinden ayrılmamalıdır. Emzirme aniden kesilirse, annede süt birikmesi nedeniyle meme sorunları ve prolaktin seviyesindeki hızlı düşüş nedeniyle depresif belirtiler ortaya çıkabilir (Kartal & Demir Acar, 2022). Bu süreçte annelerin ebeler tarafından desteklenmesi ve danışmanlık alması büyük önem taşımaktadır.

Ebeler gebelik, doğum ve doğum sonrası bakım süreci başta olmak üzere kadının emzirme boyunca ve hatta emzirme sonlandırma döneminde de profesyonel destek sağlayabilecek profesyonellerdir (Olalere & Clare, 2024). Bu bakış açısıyla, Ebe Liderliğinde Sürekli Bakım (ELSB) ve danışmanlık hem emzirme süresini uzatma hem de emzirme sonlandırma sürecini bilinçli, planlı ve desteğe dayalı kılma potansiyeli açısından son derece önemli bir bakım modelidir (Shipton EV, Callaway L, Foxcroft K, Lee N, 2023).

Bu makale; mevcut literatürü derleyerek, ebe-liderliğinde bakım modellerinin emzirmeyi sürdürme ve sonlandırma üzerindeki etkilerini; bu alandaki boşlukları ve ebelerin danışmanlık ve bakım rolünü genişletmeye yönelik dijital bir model taslağını önererek analiz etmeyi amaçlamaktadır. Aynı zamanda emzirme sonlandırma süreçlerinde ebe rehberliğinin kanıt temelli önemini vurgulamakta, gelecekteki araştırmalar için öneriler sunmaktadır.

Ebe-Liderliğinde Bakım ve Emzirme Sürekliliği: Literatür İncelemesi

ELSB gebelik, doğum ve doğum sonu dönemde kadının ihtiyacı bulunan bakım ve danışmanlığın aynı ebe ya da ebe grubu tarafından verilmesidir (Fikre vd., 2025). Bu modelde ebe, doğum öncesi, doğum ve doğum sonu dönemde kadına verilen bakımın planlanmasından, düzenlenmesinden sorumlu olan lider sağlık bakım uzmanıdır (Yurtsal & Eroğlu, 2020). Düşük ve orta gelirli ülkelerde geçen 1932–2023 yılları arasında yapılmış çalışmaların incelendiği bir makalede, ELSB modelinin maternal ve yenidoğan sağlık sonuçlarını iyileştirdiği, tıbbi müdahale oranlarını azalttığı, fizyolojik doğumları ve emzirme oranlarını artırdığı bildirilmiştir (Estiningtyas vd., 2025). 13 nitel çalışmanın meta-analizi, "ebe-kadın ilişkisi, kişiselleştirilmiş bakım, güven geliştirme ve güçlendirmenin" kadınların bakış açısından ELSB modelinin önemli bileşenleri olduğunu göstermiştir (Perriman vd., 2018). Ebe ve kadın arasında kurulan ilişki, doğum öncesi, doğum ve doğum sonrası dönem boyunca bir güvenlik ve destek duygusu yaratır. ELSB modelinde yer alan ebeler, annelerin doğum öncesi dönemden doğum sonrası döneme kadar, evlerinde de destek dahil olmak üzere, sürekli bakım ve eğitim almasını sağlayarak, günün her saati sürekli bakım ve destek sağlamaktadır (Shahshahani vd., 2024). Sistematik bir inceleme, doğum öncesi bakımdan başlayıp doğum sonrası döneme kadar devam eden müdahalelerin, doğum sonrası dönemde başlayanlara kıyasla emzirmeyi teşvik etmede ve anne sağlığını iyileştirmede daha etkili olduğunu göstermiştir (D'haenens vd., 2019). Emziren anneler, yargılayıcı olmayan ve güven verici bir şekilde erişilebilir, ihtiyaç duyulduğunda ulaşılabilir ve tutarlı profesyonel destek aldıklarında daha memnun kalmışlardır. Daha yakın dönemde yapılan bir çalışma sezaryen ile doğum yapan kadınlarda ELSB modeli ile laktasyon sürecinin daha olumlu geçtiği, bu bakım modeli ile anne memnuniyetinin ve yaşam kalitesinin yükseldiği gözlenmiştir (Cai vd., 2025). Başka bir randomize kontrollü çalışma; doğum sonrası dönemde, ebeler liderliğindeki emzirme destek gruplarının 4. ayda emzirme oranını kontrol grubuna göre anlamlı biçimde artırdığını, postpartum depresyon skorlarını düşürdüğünü ve annenin emzirme öz-yeterlik algısını yükselttiğini ortaya koymuştur (Rodríguez-Gallego vd., 2024). Ayrıca, emzirme danışmanlığı ve destek hizmetlerinin yalnızca anne-bebek değil, aile ve çevreyi de kapsayan bütüncül bakım anlayışının emzirmenin başlatılması ve sürdürülmesi üzerinde önemli etkisi olduğu vurgulanmaktadır (Öcalan vd., 2024). Bu çalışmalar, ebe-liderliğinde sürekli bakım ve danışmanlık modellerinin emzirme başlangıcı, sürdürülmesi ve desteklenmesi konusunda umut verici olduğunu; fakat literatürde "emzirme sonlandırma dönemi desteği" özelinde yapılan çalışmaların oldukça sınırlı olduğu görülmektedir.

Emzirme Sonlandırma Sürecinde Ebe-Liderliğinde Bakım

Ebeler ile anne arasında gebelikten başlayıp postpartum döneme kadar süren bir bağ, annede güven, danışmanlık ve takip hissi oluşturur. Bu bağ, emzirme sonlandırma kararı alırken özellikle sorun ya da bilgi eksikliği olduğunda annenin yalnız olmadığını hissetmesini sağlar. Literatürde, "bireyselleştirilmiş destek" ve "sürekli takip" ile emzirme deneyiminden ve desteğinden memnun kaldıklarını belirtmişlerdir (Bäckström vd., 2010). Özellikle sezaryen sonrası doğumlarda, anne konforu, meme sağlığı, sütün gelme zamanı ve erken emzirme kritik önemdedir. ELBM ile bireyselleştirilmiş bakım modelinde, bu konular özel olarak ele alınmış, laktasyon süreci ve emzirme başarısı anlamlı biçimde iyileşmiştir (Cai vd., 2025).

Emzirmeyi sonlandırma sadece memeden beslenmenin kesilmesi değil, anne bebek bağlanması, sosyal beklentiler ve psikolojik durumlarla da ilişkilidir. Ebelerin sadece fiziksel değil, psikososyal desteği de içeren bir bakım sağlamaları önemlidir. Örneğin ebe liderliğindeki emzirme grubu müdahalesinin, öz-yeterlik geliştirme, emzirme süresini uzatabilir ve sonlandırma sürecini daha bilinçli hale getirdiği saptanmıştır (Rodríguez-Gallego vd., 2024). Özellikle düşük ve orta gelirli ülkelerde ELSB modelinin fizyolojik doğumu ve emzirme oranlarını artırdığını; ancak uygulamanın uzun vadeli sürdürülebilirliği için toplumsal kabul, kültürel uygunluk, altyapı ve finansal destek gerektiğini bildirilmiştir (Estiningtyas vd., 2025). Literatürdeki boşluk ve potansiyelli alanlar göz önüne alındığında, aşağıdaki model emzirmeyi sonlandırmaya yönelik bir ebelik bakım modeli önerisidir:

Gebelik öncesi ve antenatal planlama: Ebeler, doğum öncesi dönemde anne adaylarıyla emzirme istekleri, beklentileri ve olası emzirmeyi sonlandırma zamanlarını konuşmalı; süt verme süresi ve destek mekanizmaları önceden tartışılmalı.

Postpartum dönem sürekli takip: İlk 12–24 ay boyunca ebeler tarafından düzenli aralıklarla izlem ve danışmanlık hizmeti sunulmalı bu hem fiziksel (süt durumu, meme sağlığı, bebek beslenmesi) hem psikososyal (anne memnuniyeti, bağlılık, destek ihtiyacı) alanları kapsamalı.

Dijital destek & tele-laktasyon: Ebeler ve emziren anneler için çevrimiçi platformlar, online görüşmeler, mesajlaşma, mobil uygulamalar ve e-danışmanlık ile coğrafi ya da zaman kısıtı olan annelere erişim sağlanmalı. Dijital danışmanlık, emzirmeyi sonlandırma süreci yaklaşırken özel "emzirmeyi sonlandırma rehberi", "süt sağma/saklama önerileri", "alternatif beslenme planı" gibi içerikler içermelidir. Bu yaklaşım, sağlık hizmetini daha erişilebilir, sürdürülebilir ve yaygın kılar. Son yıllarda ebe ve hemşirelerin emzirme eğitim ve danışmanlığında teknolojiyi kullanmasının yararları vurgulanmaktadır (Dağlı vd., 2023).

Destek grupları: Ebeler moderatörlüğünde düzenli emzirme ve emzirmeyi sonlandırma destek grupları hem yüz yüze hem dijital ortamlarda oluşturulmalıdır. Bu gruplar, destek alma,

sorularını sorma, kaygılarını dile getirmelerine ve annelerin deneyimlerini paylaşmalarına olanak sağlamalı. Bu tür grup müdahaleleri, hem emzirmeyi sürdürme, doğru zamanda sağlıklı emzirmeyi sonlandırma ve anne ruh sağlığı için olumlu sonuçlar sağlamaktadır.

Ebelerin Eğitimi ve protokoller: Ebeler, hem klasik doğum-emzirme hem de emzirmenin sonlandırılması sürecindeki danışmanlık konusunda özel eğitim almalı; sağlık sistemi içinde bu model için protokoller oluşturulmalı; ebe-hemşire/hekim iş birliği ve yönlendirme mekanizmaları kurulmalıdır. Bu model, hem bireysel hem sistematik düzeyde emzirme sonlandırma sürecini planlı, destekli ve anne-bebek sağlığı odaklı hale getirilmelidir.

SONUÇ

Mevcut literatür, ebe-liderliğinde sürekli bakım ve danışmanlık modellerinin emzirme başarısı ve sürdürülmesine katkı sağladığını, bununla birlikte emzirme sonlandırma döneminde ebe liderliğinde ve sürekli destek modeline dair yeterli araştırmanın olmadığını göstermektedir.

Bu eksikliği gidermek ve emzirme sonlandırma sürecini daha sağlıklı, planlı ve destekli kılmak için önerilen "Ebe-Liderliğinde Dijital Destekli Emzirme Sonlandırma Danışmanlığı" modeli umut verici bir yaklaşımdır. Bu model, hem anne hem bebek sağlığı, anne memnuniyeti ve toplumsal sağlık açısından potansiyel faydalar sunmaktadır. Bundan sonrası için, bu modelin pilot çalışmaları, nicel ve nitel değerlendirmeleri, etkililiğinin izlenmesi ve yayımlanması önerilmektedir.

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GEBELİKTE AŞI UYGULAMALARI

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ÖZET

Gestasyonel dönem, annenin ve fetüsün enfeksiyon etkenlerine karşı daha savunmasız hale geldiği bir fizyolojik adaptasyon sürecidir. Bu dönemde uygulanan aşılar, doğum öncesi hem annenin hem de fetüsün doğum sonrası da yenidoğanın bakteriyel ve viral enfeksiyonlara karşı korunmasında önemli rol oynamaktadır. Etkinliği kanıtlanmış ve güvenli aşılar, pasif bağışıklık sağlayarak morbidite ve mortalite yönünden anne ve fetüsün korunmasında rol oynar. Gebelikte aşılanmada, gebelik haftası ve aşı tipi dikkat edilmesi gereken durumlardır. Gebelikte uygulanmasında bir sakınca olmayan rutinde önerilen inaktif grip aşısı ve Tdap aşısı, maternal antikor geçişi ile yenidoğanı koruyup bağışıklık sisteminin güçlenmesinde yarar sağlamaktadır. Canlı atenüe aşıların uygulanması, olası fetal riskler nedeniyle kontrendike kabul edilmiş olup gebelikte yapılması önerilmemektedir. Gebelik öncesi ve gebelik döneminde aşı uygulamaları doğru planlanıp uygun zamanda yapılması büyük önem taşımaktadır.
Anahtar Kelimeler: Gebelik, aşılar, yenidoğan, korunma

VACCINATIONS DURING PREGNANCY

ABSTRACT

The gestational period is a physiological adaptation process during which the mother and fetus become more vulnerable to infectious agents. Vaccines administered during thisperiod play an important role in protecting both the mother and fetus before birth and the newborn after birthfrom bacterial and viral infections. Proven effective and safe vaccines play a role in protecting the mother and fetus from morbidity and mortality by providing passive immunity.When vaccinating during pregnancy, the week of pregnancy and the type of vaccine are important factors to consider. The routine recommended inactivated influenza vaccine and Tdap vaccine, which are safe to administer during pregnancy, protect the newborn through maternal antibody transferand help strengthen the immune system. Live attenuatedvaccines are contraindicated due to possible fetal risksand are not recommended during pregnancy.

Vaccinations before and during pregnancyshould be properly planned and administered at the appropriate time.
Keywords: Pregnancy, vaccinations, newborn, protection

1. GİRİŞ

Gebelik, fizyolojik ve psikolojik açıdan kendine özgü dinamiklere sahip olan bir dönemdir. Bu dönemde hem annenin hem de fetüsün sağlığı bütüncül bir yaklaşım benimsenerek öncelikli olarak gözetilmelidir (1). Gebelik döneminde hem bebeğin hem de annenin hastalıklara karşı korunmada immün sisteminin yetersiz olmasından dolayı gebelik dönemi aşı ile korunmada kritik bir dönemdir (2). Gebelik döneminde aşılanmanın iki önemli faydası vardır. Birincisi gebelere aşı yapılması bu dönemde ortaya çıkan gebeliğe özgü immünolojik değişiklikler, kalp hızında yükselme, akciğer kapasitesinde azalma ve oksijen tüketiminde artma nedeniyle artmış enfeksiyon duyarlılığına karşı hem gebe hem de fetüs ve yenidoğanın sağlığını güvence altına almaktadır (3, 4, 10). İkincisi ise gebeye uygulanan aşılar, maternal bağışıklık sistemini hem hücre aracılı savunma mekanizmaları yolu hem de antikor üretimi ile güçlendirerek, enfeksiyonun fetüse dikey bulaşma oranını azaltır. Maternal kaynaklı immünoglobulin G (IgG) antikorları transplasental yol ile fetüse geçer, kolostrum ve anne sütünde bulunan mukozal IgM, IgG ve IgA antikorları da doğum sonrası dönemde pasif bağışıklık sağlayarak, yenidoğanın aktif bağışıklık sağladığı döneme kadar enfeksiyonlara karşı koruma sağlar (5,6).

Advisory Committee on Immunization Practices (ACIP), gebelik döneminde uygulanan inaktif ve toksoid aşılar fetal güvenlik açısından risk barındırmadığını, canlı attenue aşıların teorik teratojenik potansiyeli nedeniyle bu dönemde kontrendike olduğunu vurgulamaktadır. Bu bilgi doğrultusunda ACIP tetanoz, difteri, boğmaca, hepatit B ve grip aşısının yapılmasını gebelikte rutin olarak uygulanmasını tavsiye etmektedir. Dünya Sağlık Örgütü'de gebelere tetanoz ve influenza aşınsının güvenilir olduğunu belirtmektedir (7). Ülkemizde Sağlık Bakanlığı, gebelikte bağışıklık durumu yetersiz olan bireylerin uygun aşılarla desteklenmesini önermekte; kızamık, kabakulak ve kızamıkçık gibi canlı aşıların ise gebelik süresince yalnızca zorunlu hallerde uygulanmasını tavsiye etmektedir (8).

Tıbbi gereklilik halinde, bağışıklık durumu yeterli olmayan anne adayına ve fetüse, gebelik haftasından bağımsız olarak inaktif aşılar ve immunglobulin preparatları uygulanabilir (9). Var olan bilimsel verilerin sonuçlarına göre, inaktif aşıların gebeler, fetüsler veya yenidoğanlar üzerinde zararlı etkileri olduğuna dair bir kanıt bulunmamaktadır (1). Aşının yapılmasında uygun zaman olarak ortada acil bir durum yok ise ikinci trimester beklenmelidir. Bunun nedeni gebelikte ilk trimesterda gebelik ve fetüse dair komplikasyonlar daha sık olmaktadır ve bunun sebebinin aşıdan kaynaklı olmadığını göstermektir. Ayrıca transplasental antikor geçişi daha güçlü olacağından yenidoğanın bağışıklık yanıtını destekler (9). Özellikle gebelik döneminde yapılan aşılanmalar doğumdan sonra ki 5 yaş altı çocuklarda ölüm ve hastalık oranlarının azaltılmasında büyük katkı sağlar. Gebelikte Bağışıklama Güvenliği Değerlendirmesinin Küresel Uyumlaştırılması projesi Dünya Sağlık Örgütü tarafından gebelik döneminde yapılacak olan aşıların güvenlik profilinin uluslararası değerlendirilmesini ve izlenmesini hedeflemektedir (10).

2. AŞILAR

2.1. Rutin Aşılar

Tetanos Aşısı: Clostridium tetani bakterisinin ürettiği tetanospazmin toksiniyle ortaya çıkan, şiddetli kas spazmlarıyla ilerleyen potansiyel olarak ölümcül bir enfeksiyon hastalığıdır (11). Tetanos aşısının gebelikte büyük önemi vardır. Gebelikte yapılan tetanoz aşısı ile doğumdan sonra bebeklerin ölümcül olan yenidoğan tetanosuna karşı koruma sağlanır. Çocukluk döneminde hiç tetanos aşısı yapılmamış, aşı durumu belirsiz olan, eksik doz aşı yapılmış ya da tüm doz aşıları yapılmış fakat son 10 yıl içerisinde rapel doz yapılmamış olan bütün gebelere tetanos aşısı uygulanması önerilmektedir (12). Sağlık Bakanlığı kontrollerde tüm gebelere tetanos aşısının olup olmadığı sorgulanıp ihtiyaç halinde gebeliğin 12. haftasından sonra tetanos aşısının yapılması gerektiğini vurgulamıştır (13). Gebeliğinde aşı geçmişi olmayan ya da aşılanma durumu belirsiz olan tüm gebelere en az bir ay ara ile iki doz tetanos aşısı uygulanması önerilmektedir. Bu iki doz aşının koruyuculuğu 1-3 yıl olduğu, ikinci dozdan 6 ay sonrasında yapılan üçüncü doz aşının koruyuculuğu 5 yıl olduğu belirtilmiştir (14). Gelişmiş ülkelerde Tetanos-Difteri aşısına ek olarak aşı dozlarından en az bir tanesine Tdap (Tetanos, difteri, aselüler boğmaca) aşı dozu eklenmesi gerektiğini önermektedir (15). Ülkemizde 2 Nisan 2025 tarihinde Sağlık Bakanlığının almış olduğu bir karar ile yenidoğan ve anneyi bulaşı hava yolu ile olan kalıcı hasarlara yol açan ve ölümcül bir hastalık olan boğmacaya karşı korumak için her gebelik döneminde Td aşılarının bir dozuna ek olarak aselüler boğmaca aşısı bileşeni de eklenerek Tdap aşısı şeklinde yapılmasına karar verilmiştir (16).

İnaktif İnluenza Aşısı: Grip enfeksiyonu, gebelik ve lohusalık dönemdeki kadınlarda immünolojik değişiklikler sebebiyle gebe olmayanlara kıyasla daha şiddetli seyredebilir. Gebelikte grip enfeksiyonu ciddi seyretmesi nedeniyle preterm doğum olasılığını arttıran bir risk faktörü olarak değerlendirilmektedir (17). Toplumda grip salgını vakaları görülmeye başlamadan önce bütün gebe ve gebe kalabilecek kadınlara grip aşısı yapılması tavsiye edilmektedir (18). Grip aşısı gebeliğin tüm trimesterlerinde tek doz olarak güvenle uygulanabilir ve bu aşı her gebelikte bir kez tekrarlanmalıdır (12). Sağlık Bakanlığı Bağışıklama Danışma Kurulu ülkemizde gebelere grip aşısının yapılmasını tavsiye etmekte ve Doğum Öncesi Bakım Yönetim Rehberi'ne göre grip aşısının tercihen ikinci veya üçüncü trimesterde uygulanmasını önermektedir (1).

Gebelikte uygulanan grip aşısının etkinliğini gösteren çalışmalarda aşının maternal, fetal ve neonatal düzeyde koruyucu etkiler sağlayarak enfeksiyon kaynaklı komplikasyon riskini azalttığı ve gebede grip oluşmasını önlediği bulunmuştur (19). Güney Afrika, Nepal ve Mali'de gerçekleştirilen bir çalışmada gebelere grip aşısı yapılmış ve doğum sonrasında anneler ve bebekler 6 ay kadar izlenmiştir. Aşının anneleri %50 bebekleri ise %35 oranında gribe karşı koruduğu bulunmuştur (20). Yapılan bir diğer çalışmasının sonucunda grip aşısının yenidoğanlarda grip görülme oranını %34 azalttığını saptamışlardır (21). 2017 ve 2019 yıllarında İspanya'da yapılan bir çalışmada gebelere grip aşısı yapılmış ve doğumdan sonraki süreçte grip aşısının bebeklerde hastaneye yatış riskini %61 oranında azalttığı ortaya konmuştur (22).

2.2. Özel Durumlarda Aşılama

Gebelere bir kronik hastalık ya da riskli bölgelere yapılacak olan zorunlu seyahat gibi bazı özel durumlarda aşılama yapmak gerekebilir. Anne ve bebek için özel durumdan korunmada daha güvenilir bir yol var ise ilk olarak bu tercih edilmelidir. Eğer hastalık oluşturacak risk etmenin anne ve bebekte bırakacağı tahribat kaçınılmaz ise aşı zorunlu olarak uygulanmalıdır (23).

Hepatit B Aşısı: İnaktif bir aşı olan Hepatit B aşısı güvenilir ve bebek/anne için herhangi bir yan etkisi olduğu bildirilmemiştir bu yüzden gebelikte zorunlu hallerde yapılabilir. Hepatit B açısından yüksek risk taşıyan kişilerde, aşılama üç dozluk bir şema ile tamamlanmalıdır.

Hepatit A Aşısı: Güvenilir bir inaktif aşı olduğundan gebelikte uygulanmasında herhangi bir sakınca yoktur ve bir yan etkisi olduğu bildirilmemiştir. Gebelik sürecinde morbidite oranı fazla olan akut Hepatit A enfeksiyonu, fetal asit, polihidramnios, mekonyum peritoniti ile giden intrauterin enfeksiyonu bildirilmiştir. HAV maruziyeti durumunda, duyarlı gebelere koruyucu aşı ve immunglobulin yapılması endikedir (1).

Pnömokok Aşısı: Bir gebeye pnömokok aşısı yapılması zorunlu ise PPSV23 yani Polisakkarit Pnömokok Aşısı yapılması gerekir. Yapılmasındaki doğru zaman gebelik başlamadan önceki zamandır fakat gebelikte yapılması gerekiyorsa ikinci ya da üçüncü trimesterda yapılması daha güvenilirdir. İlk trimesterda aşı yapılan vakalarda herhangi bir yan etki gözlenmemiştir (24).

Meningokok Aşısı: Duyarlı erişkinler için tanımlanmış aşılama endikasyonları, gebeler için de aynı şekilde uygulanabilmektedir. Aşının güvenli olduğu bildirilmiş olup yapılması gerekiyorsa tercihen ikinci trimester ve sonrasında yapılabilir (25).

Kuduz Aşısı: Gebelikte kuduz temasında, inaktif bir aşı olma özelliği sayesinde uygulama açısından herhangi bir sakınca bulunmamaktadır (1).

Tifo Aşısı: Tifo açısından riskli bölgelere ziyaret edilmemesi gerekir. Kaçınılmaz risk durumlarında, gebelerde İnaktif Polisakkarit Tifo aşısının uygulanması uygundur (1).

Poliovirus Aşısı: Gebenin polio açısından endemik bölgelere seyahat etmesi gerekiyorsa erişkin bireylerde uygulanan IPV uygulaması aşılama protokolüne göre gebelere de yapılabilmektedir. OPV aşısı gebelere yapılması önerilmez (1).

Covid Aşısı: Covid aşıları arasında mRNA olanlarının gebelere uygunluk çalışmalarında hayvan deneylerinde embriyonel toksisite veya konjenital anomaliler yönünden bir sorun ile karşılaşılmamıştır. Gebelikte mRNA Covid aşısının kullanımı hakkında net bir bilgi olmasa da Avrupa İlaç Ajansı (EMA) gibi kurumlarda yapılan çalışmalarda deneklerin bir bölümünün gebeler olduğu görülmüş ve çalışma sonuçlarında aşı yapılan kişilerde herhangi bir yan etki görülmemiştir. Yapılan bir araştırma sonucunda ABD' de 20.000'den fazla gebeye mRNA aşısı yapılmış ve sonucunda hayatı tehdit edecek bir durumun ortaya çıkmadığı görülmüştür (31).

Japon Ensefaliti Aşısı: Canlı bir aşı olmadığından elzem durumlarda gebelere yapılabilir (1).

Haemophilus İnfluenzae Tip B Aşısı: Aşılanma serisi eksik kalan duyarlı bireyler için uygulama endikasyonu mevcuttur. İnaktif bir aşıdır ve gebelikte üçüncü trimesterde uygulanması önerilmektedir (9).

Şarbon Aşısı: Hastalığın yüksek mortalite riski göz önüne alındığında, gebelik ve postpartum dönemdeki bireylerde, gebe olmayan erişkinlerle benzer tedavi ve koruma rejimleri uygulanması önerilmektedir. Şarbon enfeksiyonunun gebelikteki yönetimi, doğru tedavi protokollerinin uygulanması ve erken doğum riskinin azaltılması açısından büyük önem taşır. Şarbon aşılama programları çalışma sonuçlarında bir çalışmada kadınlara bir doz aşı yapılmış ve sonucunda şarbon aşısının gebelik, doğum ve advers gebelik sonuçlarıyla

ilişkilendirilmediğini göstermiştir. Diğer bir çalışmada bir grup kadına gebelik öncesinde, bir grup kadına da birinci trimesterda aşılama yapılmış. Birinci trimesterda aşılama yapılan kadınların bebeklerinde diğer bebeklere kıyasla daha yüksek oranda doğumsal malformasyon olduğu ortaya çıkmıştır (26). Şarbonun emziren kadınlarda ve hamilelerde ciddi oranda fetal ve maternal mortalite ile sonuçlandığı bildirilmiş olup uygun tedavi ve ilaç seçimi yapılıp, fetal riskleri belirlenmesi gerekmektedir. Bu konu ile ilgili çalışmalar yetersiz olup daha fazla araştırma yapılması gerektiği bildirilmiştir (27).

2.3. Kontrendike Aşılar

Kızamık, Kızamıkçık, Kabakulak (KKK): Kızamıkçık aşısı canlı bir aşı olduğu için gebelikte kondrendikedir. Bir kadının gebelikten önce kızamıkçık açısından bağışık olup olmadığı belirlenmesi gerekir. Aşılanma gebelikten en az 3 ay öncesinde yapılmış olması gerekir (28). Gebenin kızamıkçık enfeksiyonuna yakalandığı gebelik yaşı önemlidir. Anneden bebeğe geçişte ilk olarak plasenta enfeksiyonu gerçekleşir. Sonrasında fetüsün vasküler sisteminde sonrasında da iskemi gelişerek organ hasarı olur. Birinci trimesterda kızamıkçık enfeksiyonuna yakalanan gebenin fetal bulaş olma olasılığı %80 iken ikinci trimesterda bu oran % 25'e kadar düşer. Üçüncü trimesterda ise bu oran tekrar artarak %35 hatta %100'e kadar çıkabilir. Aile ile konuşulup uygun danışmanlık verilmeli, gebelik sonlandırılması düşünülmelidir (29, 30).

Kızamık: Kızamık, gebelikte ciddi sağlık sorunlarına yol açabilir. Fetal ve maternal komplikasyon riski fazladır. Eğer bağışıklığı olmayan bir gebe bu virüsle temas etmişse, enfeksiyonun etkilerini azaltmak amacıyla 6 gün içinde immünglobulin verilmesi gereklidir (1).

BCG Aşısı: Veriler doğrultusunda herhangi bir yan etkisi bildirilmemesine rağmen canlı bir aşı olması nedeniyle gebelikte yapılması uygun görülmemektedir (1).

Suçiçeği Aşısı: Suçiçeği enfeksiyonu gebelikte geçirildiğinde, anne ve fetüs sağlığı açısından ciddi riskler oluşturabilir. Annede pnömoni, fetüste kalça hipoplazisi, mikrosefali, konjenital varisella sendromu gibi komplikasyonlar ortaya çıkabilir. Gebelikten en az 4 hafta öncesinde aşılanma yapılmış olması gerekir. Gebelikte suçiçeğine maruziyet geliştiyse immunglobulin yapılması önerilir (1).

İnsan Papillomavirüs Aşısı: Bu aşı canlı bir aşı değildir. Fakat gebelikte HPV aşısının yapılması ile ilgili bulgular yeterli olmadığından gebelikte yapılması önerilmemektedir. Eğer kişi gebelikten önce aşılanmaya başlamışsa ve sonrasında gebelik geliştiyse kalan dozlar gebelik bitimine ertelenmesi gerekir (1).

3. SONUÇ VE ÖNERİLER

Bir hastalık etkeni gebe kadınları gebe olmayanlara göre daha çok etkisi altında bıraktığından gebelikte bağışıklama hem anne hem de fetüs açısından büyük önem taşımaktadır. Tdap ve cansız grip aşısının gebelikte kullanımı anne ve fetüs açısından zararsız olduğu için güvenle uygulanabilir. Fakat canlı aşıların kullanımı gebelikte teratojenik etki yarattığından gebelikte kullanımı önerilmemektedir. Eğer canlı aşı dozu uygulanmaya başlandığında gebelik oluştuysa kalan dozlara gebelikten sonra devam edilmesi gerekmektedir. Özel durumlarda yapılan aşılarda hastalığa maruz kalma ve anne bebek sağlığı açısından değerlendirme yapılıp duruma uygun şekilde bağışıklama yapılmalıdır. Aşılanmanın önündeki en büyük engel aşının bebeğe

zarar vereceği düşüncesidir. Gebelikte aşılama oranlarının artırılabilmesi için sağlık profesyonellerine büyük roller düşmektedir. Bunlar, çalışanların bilgi düzeyinin yükseltilmesi, aşıya dair yanlış inanışların giderilmesi, gebelerin bilimsel temelli ve doğru bir şekilde bilgilendirilmesidir. Yapılan araştırmalar ile aşılama ile sezaryen doğum, prematürite veya ilk altı ayda görülen neonatal sağlık sorunları arasında anlamlı bir ilişki bulunmadığı ortaya koyulmuştur. Gebelikte aşılama, anne, fetüs ve toplum sağlığının korunmasında temel bir halk sağlığı hizmeti olup, bu uygulamaların sürdürülebilirliği kanıta dayalı uygulamalar ve ulusal stratejilerle güvence altına alınmalıdır.

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GEBELİK DÖNEMİNDE GENİTAL HİJYEN DAVRANIŞLARI

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ÖZET

Gebelikte genital hijyen, kadın ve üreme sağlığının korunmasında temel bir alışkanlıktır. Doğru hijyen uygulamaları enfeksiyonların önlenmesine ve sağlıklı bir hamileliğin kolaylaştırılmasına katkıda bulunur. Genital hijyen kurallarına uyulmaması, idrar yolu ve vajinal enfeksiyon riskini arttırır. Bu durum hem anne hem de bebek için ölüm veya hastalığa yol açabilir. Gebeler hijyen için kullandıkları ürünlere dikkat etmeli, kimyasal tahriş edici maddelerden kaçınmalı, uygun iç çamaşırı seçmeli ve genital bölgeyi kuru ve temiz tutmalıdır. Hijyen eğitimi ve profesyonel bilgilendirme, gebelikte hem anne hem de bebek sağlığını korumak için önemli destek mekanizmalarıdır. Bu nedenle, genital hijyen bilincinin artırılması ve sürekliliğinin sağlanması, gebelerin özgüven duygusunu güçlendirir ve öz bakım becerilerini geliştirerek sağlıklı gebeliğe katkıda bulunur.

Anahtar Kelimeler: Genital hijyen, kadın sağlığı, gebelik, ebe

GENITAL HYGIENE BEHAVIORS DURING PREGNANCY

ABSTRACT

Genital hygiene during pregnancy is a fundamental habit in maintaining women's and reproductive health. Proper hygiene practices contribute to the prevention of infections and facilitate a healthy pregnancy. Failure to adhere to genital hygiene rules increases the risk of urinary tract and vaginal infections. This can lead to mortality or morbidity for both mother and baby. Pregnant women should be careful about the products they use for hygiene during this period, avoid chemical irritants, choose appropriate underwear, and keep the genital area dry and clean. Hygiene education and professional information are important support mechanisms for protecting the health of both mother and baby during pregnancy. Therefore, increasing and ensuring the sustainability of genital hygiene awareness strengthens pregnant women's sense of confidence and enhances self-care, contributing to a healthy pregnancy.

Keywords: Genital hygiene, women's health, pregnancy, midwife

1. GİRİŞ

Genital hijyen, bireyin sahip olduğu bilgi, tutum ve de alışkanlıkların yön verdiği öz bakım davranışlarını kapsamaktadır. Bu davranışların uygulanması kişiden kişiye farklı olup, bu farklılık uygulama sıklığı ve kullanılan yöntem açısından çeşitlilik göstermektedir. Genital hijyen davranışları her iki cinsiyet içinde dikkat edilmesi gereken bir konudur (1, 2). Üreme sisteminin fizyolojik savunma mekanizmalarının zayıflamasıyla gelişen genital enfeksiyonlar, kadın hastalıkları ve doğum polikliniklerine başvuran gebe ve üreme çağında bulunan kadınlarda en sık ortaya çıkan sorunlardan biridir. Dünya genelinde genital enfeksiyon yaygınlığı %62.4 - %74 iken bu oran Türkiye'de %37.1 - %50.7 aralığındadır (3).

Vajinanın asidik özelliğe sahip florası patojen mikroorganizmaların üremesini büyük ölçüde engellese de kadınlarda anatomik yapı, hijyen alışkanlıklarını belirleyen kişisel ve çevresel etmenler nedeniyle genital sistem enfeksiyonları ortaya çıkabilmektedir (4, 5).

Gebelik süreci fiziksel değişikliklerin yaşandığı uzun bir süreçtir. Kadın bedeninin bu değişikliklere adapte olması zaman gerektiren bir durumdur (6). Yetersiz genital hijyenin yanı sıra gebelik, kadınlarda genital enfeksiyon riskini artıran önemli bir faktördür. Gebelik sürecinde ortaya çıkan yapısal ve anatomik değişiklikler, idrar bileşimindeki farklılıklar ile fizyolojik ve hormonal adaptasyonlar genital enfeksiyon gelişimine zemin hazırlayabilmektedir (7, 11). Vajina, değişimin gerçekleştiği bölgelerden biridir. Vajinada olan değişiklikler nedeniyle genital enfeksiyonlara eğilim artar (6).

Hijyen davranışlarının yetersiz olması sonucu ortaya çıkan üriner ve genital sistem enfeksiyonları yaşam kalitesinin azalmasına, aile ve cinsel yaşamda güçlüklere ve toplumsal dışlanmaya neden olabilmektedir (8). Enfeksiyon kaynaklı hastalıkların süreci gebe olan kadınlarda daha ağır geçmesi nedeniyle anne/fetüs sağlığı büyük risk altındadır. Gebelikte üriner sistemdeki işlevsel ve anatomik değişimler, biyolojik ve endokrin değişimler ve idrar kompozisyonundaki farklılıklar nedeni ile enfeksiyona yatkınlık oranı artar. Bu nedenle gebelikte klinik bulgulara yol açan ve en sık karşılaşılan enfeksiyon üriner sistem enfeksiyonlarıdır. Genital hijyen davranışlarını doğru bir şekilde uygulamak gebeleri idrar yolu enfeksiyonlarından büyük oranda koruyacaktır (7). Çalışmalarda görüldüğü üzere genital hijyen uygulamalarının yetersiz olması ya da hatalı uygulamaların yapılması kadınlarda vajinal akıntı sorununa neden olmaktadır. Uygun kişisel hijyen uygulamaları sayesinde bazı enfeksiyonların engellenebileceği ve genel sağlık seviyesinin iyileştirilebileceği bildirilmektedir. Özellikle idrar yolu enfeksiyonu tanısı almış gebeler başta olmak üzere bütün kadınlara yönelik eğitimler, enfeksiyonun tekrar yaşanmasında önlemede etkili olabilir ve uygun genital hijyen davranışları geliştirilebilir (6, 7). Bu sayede kadınların gebelik sürecini daha sağlıklı geçirmesi ve güvenli doğum gerçekleştirmesi mümkün olabilir (7).

Genital hijyene dikkat edilmediği durumlarda vajinal enfeksiyonlar özellikle gebeliklerde ciddi sorunlara yol açabilir. Çeşitli gebelik komplikasyonlarına, serviks anormalliklerine, cerrahi girişim sonrası ve de pelvik enfeksiyonlara sebep olur. Doğru ve zamanında bir tedavi ile iyileşme olmaz ise bu durumlar dış gebelik, ölü veya preterm doğum, düşük doğum ağırlığı, kısırlık, membranların erken açılması, preeklampsi, pelvik inflamatuarına, salpinjit, kanser, servisit ve neonatal serebral palsi gelişimine yol açabilir (9, 10). Türkiye'de anne ölüm

sıralamasında ilk sırada kanama, devamında eklampsi, komplikasyonlar ve dördüncü sırada enfeksiyonlar yer alır. Gebelikte geçirilen enfeksiyon hastalıkları fetüs ve gebe için çok geçerli mortalite ve morbidite sebepleridir (12).

Gebelikte görülen enfeksiyon kaynaklı hastalıkların önüne geçilmesindeki en önemli kuralın doğru bireysel hijyen davranışlarının olduğu unutulmamalıdır (13). Yanlış iç çamaşırı tercihi, el temizliğine dikkat edilmemesi, hijyen açısından yetersiz ortak banyo ve tuvaletlerin kullanımı, tuvaletten sonra genital bölge temizliğinin yeterli yapılmaması gibi davranışlar kötü hijyen davranışları arasında yer alıp genital enfeksiyonlara neden olmaktadır. Fakat bunların yanı sıra yapılmış olan çalışmalarda kadınların ruhsal sağlık hallerinin iyi veya kötü olması da hijyen uygulamalarında etkili olabileceği gösterilmiştir (4, 5, 14). Stres oranı yüksek, anksiyete ve depresyon problemi olan kadınlarda yeterli hijyen sağlanamamaktadır. Gebelik süreci de kadınlar açısından stres, anksiyete ve depresyonun yoğun olarak yaşandığı bir dönemdir (15). Bu olumsuz durumların sonucunda gebelerde de kişisel hijyen davranışlarında bir düşüş yaşanabileceği tahmin edilmektedir. Eren ve arkadaşlarının yapmış oldukları çalışmaların sonucunda, gebelerin stres ve depresyon oranının artması ile genital hijyen davranışlarında azalma olduğunu ortaya koymuşlardır (10).

2. DOĞRU GENİTAL HİJYEN DAVRANIŞLARI

Kadınlara doğru genital hijyen davranışlarının öğretilmesi ve hatalı uygulamaların düzeltilmesi, genital ve üriner sistem enfeksiyonlarının önlenmesinde kritik bir basamaktır. Genital hijyenin korunması için kadınların tuvalet öncesi ve sonrasında el hijyenine özen göstermesi gereklidir. Tuvaletteyken perine temizliği önden arkaya doğru silinerek yapılması dışkının üretra ve vajina girişine engellemesi açısından son derece önemlidir. Duştan ve tuvaletten sonra genital bölge iyi bir şekilde kurulanmalı ıslak bırakılmamalıdır (16). Genital hijyenin korunmasında düzenli banyo alışkanlığı önemli bir rol oynar. Gebe olmayan kadınlarda menstruasyon dönemlerinde oturarak duş almaktan kaçınmak, hijyenin sürdürülmesi açısından önerilmektedir. Oturarak banyo yapıldığında kirli su birikir ve vajinal mikrobiyota kirli suya maruz kalmış olur. Böylece enfeksiyon hastalıkların oluşmasına zemin hazırlanmış olur. Bunu önlemek için bütün kadınlar ayakta banyo yapmalıdır (12). Genital hijyen sağlanırken pH açısından dengeli temizlik ürünleri kullanılmalıdır. Yapılan bir çalışmada gebelerin %75.8'i vajinal duş yaptıklarını bunların %66'sı sadece su ile %34'ü ise vajinal duş esnasında su ve sabun kullandıklarını belirtmişlerdir. Vajinal duş yapıldığında vajinanın Ph dengesi bozulur ve vajinal enfeksiyonlar ortaya çıkabilir (7). Vajinal enfeksiyonların gelişimini önlemek için vajinal duş kesinlikle yapılmamalıdır (17).

Perine bölgesindeki kılların düzenli olarak temizlenmesi gerekmektedir. Temizleme sırasında cildi tahriş etmeyecek ürünlerin kullanılmasına özen gösterilmelidir (18). Perine bölgesini sıkmayacak, rahat hava alacak, sentetik olmayan iç çamaşırların kullanılması önerilmektedir (12). İç çamaşırların her gün değiştirilmesi ve ütülenerek giyilmesi gerekir. Yapılmış olan bir çalışma verilerine göre sentetik iç çamaşırı kullanan kadınların vajinal enfeksiyona yakalanma oranı 4.5, iç çamaşırının düzenli değiştirilmediğinde bu oranın 1.7 kat daha fazla olduğu saptanmıştır (19). Günlük pedlerin kullanılması o bölgenin hava almasını engelleyebileceğinden kullanılmaması önerilmektedir (12).

3. GENİTAL HİJYEN DAVRANIŞI VE EBELİK BAKIMI

Gebelerde kişisel sağlık sorumluluğunun gelişmesi, toplum sağlığının güçlendirilmesinde kritik bir rol oynamaktadır. Sağlığın güçlendirilmesinde ve koruma altına alınmasına yönelik öz bakım hizmetlerinin etkili biçimde sunulduğu yer, birinci basamak sağlık kuruluşlarıdır. Burada görev yapan ebeler, kontrole gelen gebelerin düzenli takipleri sırasında öz bakım alanındaki eksikliklerini belirleyip onlara eğitim desteği sağlayarak gebelerin öz bakım becerilerini geliştirirler. Gebelik sürecinde pozitif yaşam alışkanlıklarını teşvik eden ebeler, öz bakımın desteklenmesinde önemli bir yere sahiptir. Gebeye ihtiyacı olan destek ve eğitimi vererek doğru öz bakım uygulamaları kazandırıp gebeliğin hem anne hem de bebek açısından sağlıklı ilerlemesini sağlar (20).

Ebeler, kadınların hijyen konusunda bilinçlenmesinde önemli bir görev üstlenirler. Kadınlara doğru hijyen yöntemleri öğretilmeli, hatalı uygulamaların enfeksiyonlara yol açabileceği belirtilmelidir. Enfeksiyon varlığında tedavi süresince cinsel ilişkiye girmemeleri gerektiği açıklanmalı ve düzenli sıvı tüketiminin, doğru beslenmenin ve dinlenmenin iyileşmeyi desteklediği anlatılmalıdır (2).

Genital sistem enfeksiyonlarının önlenmesi ve üreme sağlığının korunması için hijyen davranışlarının benimsetilmesi büyük önem taşır (21). Yapılan çalışmalarda görüldüğü üzere kadınların hijyen davranışlarında eksiklik olduğunda üriner ve genital sistem enfeksiyon oranı artmaktadır. Bu bağlamda kadınlara sağlıklı genital hijyen davranışlarının benimsetilmesi ve sürekliliğinin desteklenmesi önem arz etmektedir (2).

4. SONUÇ VE ÖNERİLER

Kadınların özellikle de gebelerin genital hijyen konusundaki bilgi düzeyleri ve davranışlarının değerlendirilmesi, ortaya çıkan sonuçlar ışığında farkındalıklarının arttırılması açısından büyük önem taşımaktadır. Ebelerin görevi kadınlara, gebelere genital hijyen konusunda eğitimler vermek, uygulamaların geliştirilmesine yardımcı olmaktır. Genital hijyen davranışları ile yaşam kalitesi arasında pozitif ilişki bulunmaktadır. Kazanılan doğru genital hijyen davranışları ile enfeksiyon riski azalmakta, psikososyal ve fiziksel iyilik hali güçlenmektedir. Bu kazanımların sürdürülebilir ve devamlı olması büyük önem taşımaktadır.

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EBELERİN CİNSEL SAĞLIK VE DANIŞMANLIK ROLÜ: HİZMET ALANLAR VE POTANSİYEL SORUMLULUKLAR

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ÖZET

Cinsel sağlık, bireylerin fiziksel, duygusal ve sosyal refahını etkileyen temel bir sağlık boyutudur ve özellikle kadın sağlığı bağlamında kritik öneme sahiptir. Kadınların üreme sağlığının korunması ve geliştirilmesinde merkezi bir role sahip olan ebeler, sadece doğum ve gebelik süreçlerinde değil, aynı zamanda gebelik öncesi, gebelik dönemi ve doğum sonrası dönemde de cinsel sağlık danışmanlığı ve yönlendirme hizmetlerinden de sorumludur.

Bu derleme çalışmada, ebelerin cinsel sağlık ve danışmanlık alanındaki hizmetleri, potansiyel sorumlulukları ve rol fonksiyonları incelenmiştir. Literatür taraması, Web of Science ve TR Dizin hakemli dergilerden son on yılda elde edilen çalışmalar üzerinden gerçekleştirilmiş; tematik analiz yaklaşımı ile elde edilen veriler MAXQDA programı kullanılarak kodlanmış ve haritalandırılmıştır. Analiz sonucunda, iki ana tema belirlenmiştir: (1) Hizmet Alanları ve (2) Potansiyel Sorumluluklar. Her tema altında 5 alt kod tanımlanmıştır. Elde edilen bulgular, ebelerin gebelik öncesi danışmanlık, aile planlaması, gebelik dönemi cinsel sağlık, doğum sonrası danışmanlık ve kadın cinsel işlev bozukluklarının yönetiminde kritik rol oynadığını göstermektedir. Ayrıca, eğitim ve bilgilendirme, risk tespiti ve yönlendirme, hak temelli cinsel sağlık savunuculuğu, kültürel duyarlılık ve sürekli mesleki gelişim gibi sorumluluk alanları da ön plana çıkmaktadır. Çalışma, ebelerin cinsel sağlık hizmetlerindeki rolünün, kadın sağlığının geliştirilmesi ve toplumsal cinsel farkındalığın artırılmasında merkezi bir öneme sahip olduğunu vurgulamaktadır.

Anahtar Kelimeler: Ebeler, Cinsel Danışmanlık, Haritalandırma, Tematik Analiz.

1. GİRİŞ

Cinsel sağlık, bireylerin fiziksel, duygusal ve sosyal refahını etkileyen sağlığın temel bir boyutudur (WHO, 2024; Bozdemir & Özcan, 2011). Ebeler yalnızca doğum odaklı sağlık çalışanları değil, kadın sağlığının her aşamasında kritik rol oynayan cinsel sağlık danışmanlarıdır. Dünya Sağlık Örgütü (WHO) ve Uluslararası Ebeler Konfederasyonu (ICM) standartlarına göre ebeler; ergenlikten menopoza kadar olan süreçte cinsel sağlığın korunması ve geliştirilmesinden sorumludur (ICM, 2025). Literatür, ebelerin sadece doğum ve gebelik süreçlerinde değil, aynı zamanda gebelik öncesi, gebelik dönemi ve doğum sonrası dönemde

de cinsel sağlık danışmanlığı ve yönlendirme hizmetleri sunduğunu göstermektedir (Kahraman vd., 2022; Bradfield vd., 2022).

Ebelerin Cinsel Sağlık ve Danışmanlık Rolleri

Cinsel sağlık danışmanlığı, bireylerin ve çiftlerin cinsel hakları, güvenli cinsel yaşam, üreme sağlığı ve gebelik planlaması konularında bilinçlendirilmesini kapsar (Üstgörül, 2022; Toker, 2023). Ebelerin cinsel sağlık ve danışmanlık rolleri;

- ✓ Üreme Sağlığı ve Aile Planlaması Danışmanlığı

Ebeler, bireylerin ve çiftlerin üreme hakları konusunda bilinçlenmesinde ilk basamaktaki sağlık profesyonelleridir. Bireylerin yaşam tarzına, tıbbi öyküsüne, genel sağlık durumuna ve gelecek planlarına en uygun korunma yöntemini seçmesine yardımcı olurlar (Güner ve ark., 2021).

- ✓ İstenmeyen Gebeliklerin Önlenmesi

Güvenli olmayan kürtajların ve riskli gebeliklerin azaltılması için özellikle risk grubunda olan kişilere (adolesanlar, dezavantajlı gruplar gibi) eğitim verirler (Sehatlioğlu ve Ceri, 2024).

- ✓ İnfertilite) Farkındalığı

Gebelik planlayan çiftlere üreme döngüsü ve gebelik planlamaları konusunda rehberlik ederler.

- ✓ Cinsel Yolla Bulaşan Enfeksiyonların (CYBE) Önlenmesi

Cinsel yolla bulaşan hastalıkların önlenmesi ve erken teşhisinde kadınlar ile en temas halinde olan ebeler çoğu zaman yol göstericidirler. HPV, HIV, frengi ve klamidya gibi enfeksiyonlar hakkında bilgi verir, düzenli Pap-smear testi ve taramalar hakkında eğitim verirler.

- ✓ Güvenli Cinsellik Eğitimi

Bariyer yöntemlerin (kondom vb.) doğru kullanımı konusunda uygulamalı eğitim sağlarlar.

- ✓ Psikoseksüel Danışmanlık

Cinsellik sadece fiziksel değil, aynı zamanda psikolojik bir süreçtir. Ebeler bu noktada "yol gösterici" rolü üstlenirler. Toplumdaki yanlış inanışları (şehir efsaneleri) konusunda farkındalık eğitimleri yaparlar.

- ✓ Disparoni (Ağrılı Cinsel İlişki) ve Vajinismus

Özellikle doğum sonrası dönemde sıkça görülen cinsel işlev bozukluklarında ilk değerlendirmeyi yapar ve gerekirse uzmana (cinsel terapist veya jinekolog) yönlendirirler (Demirezen ve Karaçam, 2021).

- ✓ Cinsel Şiddet ve Savunuculuk

Ebeler, cinsel istismar veya aile içi şiddet vakalarını tespit etmede en stratejik noktadadırlar. Şiddete maruz kalmış bireyleri tespit eder, mahremiyeti koruyarak gerekli psikolojik ve hukuki birimlere yönlendirirler (Sökmen, 2022).

Ebelerin bu alanlardaki rolü, toplumsal cinsel farkındalığın artırılmasında, risklerin erken tespitinde ve kadınların yaşam kalitesinin yükseltilmesinde kritik bir işlev görmektedir (Hacivelioğlu & Demirci, 2022; UNFPA, 2023).

Ancak literatürde, ebelerin cinsel sağlık danışmanlığı rolünün kapsamı ve sorumluluk alanlarının sistematik olarak derlenmesi sınırlıdır. Bundan dolayı bu çalışma, ebelerin hizmet alanlarını ve potansiyel sorumluluklarını tematik analiz yöntemi ile incelemeyi amaçlamaktadır.

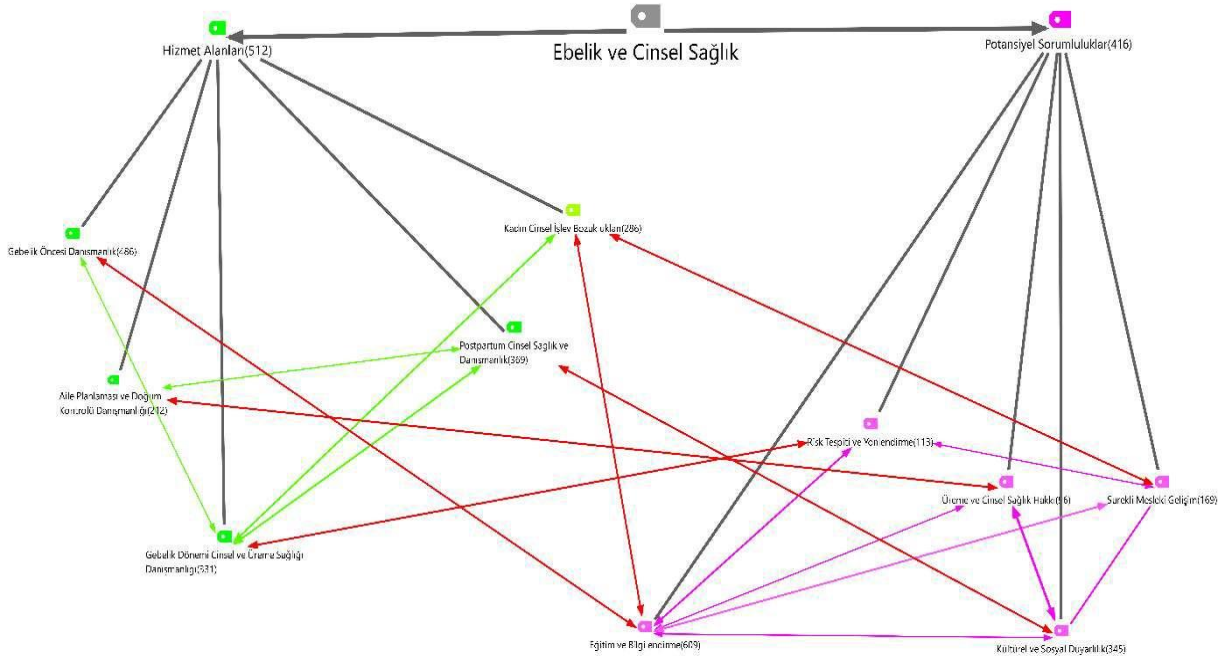
2. YÖNTEM

Bu çalışma bir derleme ve tematik analiz çalışmasıdır. Çalışmada, Web of Science hakemli dergilerden 2020–2025 yılları arasında yayımlanmış makaleler tarandı. Arama kriterleri son "midwives" AND "sexual health" OR "sexual counseling" OR "women's health" OR "reproductive health" OR "maternal care" anahtar kelimelerini kapsamaktadır. Bu kriterleri sağlayan 3.698 makalenin özetleri ve içerikleri MAXQDA programı aracığıyla incelendi, uygun bulunan çalışmalar tam metin olarak analiz edildi ve görselleştirildi. Daha sonra MAXQDA 12 programı ile tematik analiz yaklaşımı kullanılarak değerlendirildi.
Kodlama sürecinde iki ana tema belirlendi ve her tema altında 5 alt kod tanımlandı. Kodlama sırasında ilgili literatür atıfları, hizmet alanları ve sorumluluk türleri bağlamında sınıflandırıldı. Temalar ve kodlar arasındaki ilişkiler, literatürdeki kalıplar ve boşluklar dikkate alınarak belirlendi (Braun & Clarke, 2019) ve MAXQDA'nın görselleştirme araçlarından biri olan MAXmaps kullanılarak haritalandırıldı.

3. BULGULAR

Analiz sonucunda, Hizmet Alanları ve Potansiyel Sorumluluklar olarak iki ana tema belirlenmiştir. Her tema altında 5 alt kod tanımlanmıştır. Tema ve kodların haritalandırılması Şekil 1'de görülmektedir.

Şekil 1. Tema ve Alt Kodlar Arası İlişki



Yeşil renkte olanlar hizmet alanları temasının alt kodları arasındaki ilişkili değişkenleri gösterirken mor renkte olanlar ise potansiyel sorumluluklar temasının alt kodları arasındaki

ilişkili değişkenleri göstermektedir. Kırmızı renkteki çizgiler ise hizmet alanları ve potansiyel sorumluluklar temasının alt kodları arsındaki ilişkiyi göstermektedir. Çizginin kalınlığı ilişkinin gücünü göstermekte ve rakamlar ise makalelerde kaç kere tekrarlandığını göstermektedir.

Tema 1: Hizmet Alanları

Alt Kod 1: Gebelik Öncesi Danışmanlık
Gebelik öncesi danışmanlık, çiftlerin veya bireylerin üreme sağlığı, risk faktörleri ve cinsel haklar konusunda bilinçlendirilmesini kapsar (Hall vd., 2023; Welshman vd., 2023). Ebeler, bu dönemde yaşam tarzı değişiklikleri, folik asit takviyesi ve genetik risklerin değerlendirilmesi gibi konularda yönlendirici rol üstlenir (Bahri Khomami vd.,2021).

Alt Kod 2: Aile Planlaması ve Doğum Kontrolü Danışmanlığı
Ebeler, bireylere doğum kontrolü yöntemleri hakkında bilgi sunar ve uygun yöntemi seçmede rehberlik eder (UNFPA, 2023; Walker vd., 2021). Aile planlaması danışmanlığı hem gebelik planlamasında hem de istenmeyen gebeliklerin önlenmesinde kritik bir öneme sahiptir.
Alt Kod 3: Gebelik Dönemi Cinsel ve Üreme Sağlığı Danışmanlığı
Gebelik sürecinde cinsel sağlık, hormonal ve psikososyal değişimlerden etkilenir. Ebeler, bu dönemde güvenli cinsel yaşam ve üreme sağlığı konusunda kadınları bilgilendirir ve adaptasyonlarını destekler (Bradfield vd., 2022; Azar vd., 2022).

Alt Kod 4: Postpartum Cinsel Sağlık ve Danışmanlık
Doğum sonrası dönemde cinsel işlev ve çift ilişkisi ebeler tarafından takip edilmelidir. Literatürde, postpartum dönemde ebeler tarafından verilen danışmanlığın kadınların yaşam kalitesini artırdığı belirtilmektedir (WHO, 2024; Jeong vd., 2021).

Alt Kod 5: Kadın Cinsel İşlev Bozuklukları
Vajinismus, düşük libido ve cinsel ağrı gibi durumlarda ebeler, danışmanlık ve yönlendirme hizmeti sunar (Pithavadian vd., 2024; Banaei vd., 2023). Bu rol, kadın cinsel sağlığının korunmasında önleyici ve destekleyici bir hizmet olarak öne çıkar.

Tema 2: Potansiyel Sorumluluklar

Alt Kod 1: Eğitim ve Bilgilendirme
Ebeler, cinsel sağlık ve üreme sağlığı konusunda bireyleri ve toplumu bilinçlendirme sorumluluğuna sahiptir (Bradfield vd., 2022; UNFPA, 2023). Eğitim hem bireylerin bilgi düzeyini artırmak hem de toplumsal farkındalığı yükseltmek için kritik bir araçtır.

Alt Kod 2: Risk Tespiti ve Yönlendirme
Ebeler, gebelik öncesi, gebelik ve doğum sonrası dönemde risk faktörlerini belirler ve gerektiğinde uzmanlara yönlendirir (Bahri Khomami vd.,2021; WHO, 2024). Erken tespit, maternal ve neonatal sağlık açısından hayati öneme sahiptir.

Alt Kod 3: Üreme ve Cinsel Sağlık Hakkı
Ebeler, kadınların cinsel ve üreme haklarını koruma ve farkındalık yaratma görevini üstlenir (Shiindi-Mbidi vd., 2023; Azar vd., 2022). Bu sorumluluk, etik ve toplumsal boyutu olan bir rol olarak öne çıkar.

Alt Kod 4: Kültürel ve Sosyal Duyarlılık
Ebeler, danışmanlık verirken kültürel ve toplumsal değerleri dikkate alır; cinsellik konusundaki tabulara karşı farkındalık yaratır (Atallah vd., 2023; Mohseni vd., 2023; UNFPA, 2023). Bu yaklaşım, hizmet kalitesini ve erişilebilirliği artıran bir faktördür.

Alt Kod 5: Sürekli Mesleki Gelişim
Ebeler, cinsel sağlık danışmanlığı alanındaki güncel bilgi ve becerilerini sürdürmekle kritik önem arz etmektedir (Bradfield vd., 2022; WHO, 2024;). Profesyonel yeterlilik, hizmet kalitesinin korunması için çok önemlidir.

4. TARTIŞMA ve SONUÇ

Bu derleme, ebelerin cinsel sağlık ve danışmanlık alanındaki rolünü kapsamlı bir biçimde ortaya koymaktadır. Analiz sonuçları, ebelerin hizmet alanlarının sadece gebelik ve doğum ile sınırlı olmadığını, aynı zamanda cinsel sağlık, aile planlaması ve kadın cinsel işlev bozuklukları yönetimi gibi geniş bir yelpazeye yayıldığını göstermektedir.

Potansiyel sorumluluklar açısından, ebelerin eğitim ve bilgilendirme, risk tespiti ve yönlendirme, hak temelli savunuculuk ve kültürel duyarlılık gibi alanlarda aktif rol aldığı görülmektedir. Literatürde, bu sorumlulukların etkin biçimde yerine getirilmesinin, kadınların cinsel sağlık bilincini artırdığı ve hizmetlere erişim eşitliğini geliştirdiği vurgulanmaktadır (Walker vd., 2021; Bradfield vd., 2022; UNFPA, 2023).

Bu bulgular, ebelerin mesleki gelişim programlarına cinsel sağlık ve danışmanlık modüllerinin entegre edilmesi gerektiğini göstermektedir. Ayrıca, kültürel duyarlılık ve tabu ve mitlere yaklaşım, hizmetin etkinliği ve kabul edilebilirliği için kritik bir faktördür.

Ebeler, kadın sağlığının geliştirilmesinde ve cinsel farkındalığın artırılmasında merkezi bir role sahiptir. Hizmet alanları ve sorumlulukları geniş bir yelpazeyi kapsamakta olup, gebelik öncesinden postpartum döneme kadar kesintisiz bir cinsel sağlık danışmanlığı sürecini içermektedir. Ebelerin bu rollerinin güçlendirilmesi, mesleki eğitim ve kültürel duyarlılık bağlamında desteklenmelidir

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EBE ADAYLARININ YAPAY ZEKA KAYGI DÜZEYLERİ ÜZERİNE BİR ARAŞTIRMA

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ÖZET

Yapay zekanın sağlık sektöründeki kullanımı özellikle teşhis ve tedavide önemli bir dönüşüm yaratmıştır. Ancak yapay zeka sağlık profesyonelleri ve hastalar arasında güvenilirliği ve etik kullanımı konusunda bazı endişelere yol açmaktadır. Ebe adayları, yapay zeka doğum süreçlerindeki rolü konusunda çeşitli kaygılar taşımakta, bu da sağlık hizmetlerinde yapay zeka kullanımının yaygınlaşmasını zorlaştırmaktadır. Bu çalışmanın amacı, ebe adaylarının yapay zeka kaygı düzeylerini belirlemek ve bu kaygıların sosyo-demografik değişkenler ile yapay zekaya korkuları doğrultusunda farklılaşıp farklılaşmadığını incelemektir. Veriler ankete toplanmıştır. Örneklemi Manisa Celal Bayar üniversitesinde eğitim alan 184 ebe adayları oluşturmuştur. Verilerin analizinde ortalama, standart sapma, bağımsız örneklem t-testi, ANOVA ve pearson korelasyon analizleri kullanılmıştır. Anlamlılık düzeyi $p<.05$ olarak belirlenmiştir. Bulgular, ebe adaylarının yapay zeka kaygılarının yüksek olduğu bulunmuştur. Araştırmaya katılan öğrencilerin cinsiyet, sınıf düzeyi, yaşları, yapay zeka eğitimi alam durumu ile yapay zeka kaygısı arasında istatiksel olarak anlamlı bir farklılık saptanmamıştır ($p>.05$). Bu araştırmanın sonuçları, ebelerde belirgin düzeyde yapay zeka kaygısı bulunduğunu ortaya koymaktadır. Katılımcıların büyük bir bölümünde, yapay zekanın mesleki rolleri değiştirme potansiyeline ilişkin belirsizlik algısı dikkat çekmektedir. Bu bulgular, yapay zeka uygulamalarının sağlık hizmetlerine uyumlu biçimde entegre edilebilmesi için ebelerin bilgi düzeyini artırmaya ve kaygılarını azaltmaya yönelik eğitim ve farkındalık çalışmalarına ihtiyaç olduğunu göstermektedir.

Anahtar Kelimeler: Yapay zeka, yapay zeka kaygısı, ebelik, ebelikte yapay zeka, ebe adayları

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1. GİRİŞ

Yapay Zeka (YZ), tek bir yaygın, evrensel teknoloji değildir; aksine, tek tek veya bir arada uygulamalara zeka katan birkaç alt alanı (makine öğrenimi ve derin öğrenme gibi) temsil eder. YZ, algoritmalar veya bir dizi kural aracılığıyla, öğrenme ve problem çözme gibi insan bilişsel işlevlerini taklit etmek için makinenin izlediği akıllı makineler yapma bilimi ve mühendisliğini ifade eder (Bajwa ve ark., 2021). YZ sistemleri, sorunları önceden tahmin etme veya ortaya çıktıkça bunlarla başa çıkma potansiyeline sahiptir ve bu nedenle kasıtlı, akıllı ve uyarlanabilir bir şekilde çalışır. YZ'nın gücü, büyük çok boyutlu ve çok modlu veri kümelerinden kalıpları ve ilişkileri öğrenme ve tanıma yeteneğinde yatmakta olup, dinamik ve özerktir. Örneğin; YZ sistemleri bir hastanın tüm tıbbi kayıtlarını olası bir tanıyı temsil eden tek bir sayıya çevirebilir (Quinn ve ark., 2021). Karmaşık tıbbi veri setindeki anlamlı ilişkileri kullanma potansiyelleri, birçok klinik senaryoda tanı, tedavi ve sonuçların tahmin edilmesi gibi tıbbın birçok farklı dalında kullanılabilir (Al Fadeel ve ark.,2021).

Dünya çapındaki sağlık sistemleri, sağlık hizmetlerinde; halk sağlığını iyileştirmek, hastaların bakım deneyimini iyileştirmek, bakım verenlerin deneyimini geliştirmek ve artan bakım maliyetlerini azaltmak gibi "dörtlü hedef"e ulaşmak konusunda önemli zorluklarla karşı karşıyadır. Yaşlanan nüfus, artan kronik hastalık yükü ve dünya çapında yükselen sağlık hizmetleri maliyetleri, hükümetleri, ödeme kurumlarını, düzenleyicileri ve hizmet sağlayıcıları sağlık hizmetleri sunum modellerini yenilemeye ve dönüştürmeye zorlamaktadır.
Sağlık hizmetlerinde teknoloji ve YZ uygulamaları, bu arz ve talep sorunlarının bir kısmını çözme potansiyeline sahiptir. Çok modlu verilerin (genomik, ekonomik, demografik, klinik ve fenotipik) artan kullanılabilirliği, mobil teknolojiler, nesnelerin interneti, bilgi işlem gücü ve veri güvenliği alanındaki teknolojik yeniliklerle birleştiğinde, sağlık hizmetleri ve teknoloji arasında bir yakınlaşma dönemi başlamakta ve YZ ile güçlendirilmiş sağlık hizmetleri sistemleri aracılığıyla sağlık hizmetleri sunum modelleri kökten dönüşüme uğramaktadır (Bajwa ve ak., 2021).
Bununla birlikte diğer birçok sektörde olduğu gibi sağlık alanında da, yapay zekanın etkileri, sonuçları ve nasıl kullanılacağı hakkında bilgi eksikliği ve potansiyel işgücü endişeleri nedeniyle yapay zeka kaygısı ortaya çıkabilir (Takıl ve ark., 2022). Bu çalışma, ebelik öğrencilerinin yapay zeka kaygı düzeylerini belirlemeyi amaçlamaktadır.

2. YÖNTEM

Bu araştırmanın verileri etik izni alınmış ve katılımcıların gönüllü katıldığı yüz yüze ve çevrimiçi olarak bir kamu üniversitesinde eğitim alan 184 ebelik bölümü öğrencisinden anket yoluyla toplanmıştır. Verilerin analizinde ortalama, standart sapma, bağımsız örneklem t-testi, ANOVA ve pearson korelasyon analizleri kullanılmıştır. Anlamlılık düzeyi $p<.05$ olarak belirlenmiştir. Demografik soruları içeren anket ve Wang ve Wang (2019) tarafından geliştirilen ve Akkaya vd. (2021) tarafından Türkçeye uyarlanan Yapay Zeka Kaygı ölçeği ile toplanmıştır. Ölçek 16 soruda ve dört boyuttan oluşmaktadır. Ölçek 5'li likert tiplidir. 1=Kesinlikle katılmıyorum- 5=Kesinlikle katılıyorum. Ölçekte alınabilecek en yüksek puan 80; en düşük puan ise 16 ve ölçeğin kesim noktası ise 48 puandır.

3. BULGULAR

Verileri analiz etmeden önce normal dağıldığını test etmek için istatistiksel parametrelerin kontrol edilmesi gerekmektedir. Parametrik testlerin uygulanabilmesi için veri dağılımının normal olması gerekmektedir. Skewness ve Kurtosis verilerin normal dağılımı gösteren testlerindendir. Literatüre göre Çarpıklık ve basıklık değerleri +1 ile -1 arasında olmalıdır Çizelge 1'de de görüldüğü gibi veriler normal dağılım göstermektedir (Gliem & Gliem, 2003).

Çizelge 1. Normal dağılım

				Skewness		Kurtosis	
	N	Ort.	Standart Sapma	İstatistik	Standart Hata	İstatistik	Standart Hata
YZ Kaygı	184	3,09	0,79969	0,303	0,179	0,21	0,356
Öğrenme Boyutu	184	3,41	0,9515	0,53	0,179	0,295	0,356
İş Değiştirme Boyutu	184	2,40	0,90993	-0,282	0,179	-0,265	0,356
Sosyoteknik Körlük Boyutu	184	3,55	0,93971	-0,431	0,179	0,013	0,356
YZ Yapılandırması Boyutu	184	3,22	1,11731	-0,107	0,179	-0,765	0,356
Valid N (listwise)	184						

Verilerin normal dağıldığı için parametrik testler uygulanarak analizler gerçekleştirilmiştir. Ayrıca verilerin güvenirliği için Cronbach Alpha değerlerine de bakılmış ve bu değerleri ise sırasıyla; Öğrenme boyutu 0,91; İş Değiştirme boyutu 0,84; Sosyoteknik Körlük boyutu 0,83; YZ Yapılandırması boyutu 0,91 ve YZ Kaygı Ölçek Toplam 0,94 olarak bulunmuştur. Cronbach Alpha değerinin ise 0,70 ve üzeri olması literatüre göre ölçeğin tüm boyutların güvenilir olduğunu göstermektedir.

Öğrencilerin sosyo-demografik özelliklerinin dağılımı ve yapay zeka kaygısı ile ilişkisi Çizelge 2'de sunulmuştur. Araştırmaya katılan toplam 184 öğrencinin toplam yapay zeka kaygısı ortalaması 3.09 ± 0.79 olarak bulunmuştur. Alt boyutlara göre ortalamalar ise; öğrenme kaygısı 2.40 ± 0.95, iş değiştirme kaygısı 3.41 ± 0.90, sosyo-teknik körlük kaygısı 3.55 ± 0.93 ve yapay zeka yapılandırması kaygısı 3.22 ± 1.11 olarak hesaplanmıştır. Bu sonuçlar katılımcıların öğrenme yapay zeka kaygısı düşük, diğer boyutlarda orta ve yüksek düzeyde yapay zeka kaygılarının olduğunu göstermektedir.

Yapay eğitim alma durumuna göre yapay zeka kaygısı incelendiğinde ise yapay zekayı kullanan ebe adaylarının kaygı ortalaması 3.08 ± 0.86, eğitim almayanların kaygı ortalaması 3.10 ± 0.75'tir. Bu fark istatiksel olarak anlamlı bulunmamıştır (F=1,065; t = 0.239, p = 0.811).

Sınıf düzeyine göre yapay zeka kaygısı incelendiğinde 3. sınıf ebelerin yapay zeka kaygı ortalaması 3.05 ± 0.78, 4. sınıf ebelerin yapay zeka kaygı ortalaması ise 3.15 ± 0.82 olup analiz sonuçları sınıf düzeyine göre istatiksel olarak anlamlı bir fark bulunmamıştır (F=0,266; t = 0.895, p = 0.377).

Yapak zeka korkusuna göre ebelerin yapay zeka kaygıları incelendiğinde kaygısı yüksek olan ebelerin yapay zeka kaygı ortalaması 3.64 ± 0.59, kaygısı düşük olan ebelerin yapay zeka kaygı ortalaması ise 2.45 ± 0.46 olup analiz sonuçları istatiksel olarak anlamlı bir fark tespit edilmiştir (F=9,205; t = 15.153, p = 0.000). Bunun yanı sıra ebelerin yapay zeka puanlarına da bakılmıştır Analiz sonuçlarına ebe adayların toplam yapay zeka kaygısı puanlarının ortalaması 49,53 ± 12,79 olarak bulunmuştur. Bunun yanı sıra katılımcıların % 53,8'i yüksek kaygıya sahipken %46,2'si düşük kaygıya sahip olduğu, bu farkın istatiksel olarak anlamlı olduğu tespit edilmiştir (p = 0.000) (Çizelge 2).

Çizelge 2. Demografik Özelliklerin Dağılımı ve Yapay Zeka Kaygı İlişkisi (n=184)

Demografik Özellikler			**YZ KAYGISI**		
			Ort.	**ss**	
YZ Eğitimi Alma	Evet	42	3,08	0,86	F=1,065 t= -0,239 p= 0,811*
	Hayır	142	3,10	0,75	
Sınıf	3	76	3,05	0,78	F=0,266 t= -0,895 p= 0,372*
	4	108	3,15	0,82	
YZ Kaygısı	Yüksek	99	3,64	0,59	F=9,205 t= 15,153 **p= 0,000***
	Düşük	85	2,45	0,46	
Yaş	20	9	2,63	0,80	F=1,041 p=0,388**
	21	43	3,19	0,85	
	22	36	3,17	0,850	
	23	57	3,07	0,77	
	24	39	3,09	0,71	

* Bağımsız Örneklem t Testi
**Tek Yönlü ANOVA Testi

Bunun yanı sıra ebe adalarının hangi ifade ile yapay zeka kaygılarının daha yüksek veya düşük olduğunu görmek için ölçeği oluşturtan tüm maddeler analiz edilip sonuçları Çizelge 3'te sunulmaktadır. En yüksek ortalama ölçeğin 12. ifadesi olan "*Bir yapay zeka tekniğinin /*

ürününün kontrolden çıkmasından ve arızalanmasından endişe ediyorum." Olduğu (3,94±1,03) ve en düşük ortalama ise ölçeğin 3. ve 4. ifadesi olan "*Bir yapay zeka tekniğinin / ürününün belirli işlevlerini kullanmayı öğrenmek beni endişelendiriyor"*(2,28±1,02), *"Bir yapay zeka tekniğinin / ürününün nasıl çalıştığını öğrenmek beni kaygılandırıyor.*" olduğu (2,28±1,00), görülmektedir.

Çizelge 3'te de görüldüğü gibi ebe adayların yapay zeka ile ilişkili kaygı düzeyleri incelendiğinde, dört alt boyuta ilişkin ortalamalarda belirgin farklılıklar bulunmuştur. Öğrenme alt boyutunda yer alan maddelerin (1-5) ortalamalarının 2.28 ile 2.75 arasında değiştiği ve bu da ebe adaylarının yapay zeka temelli uygulamaları öğrenmeye yönelik kaygılarının düşük–orta düzeyde seyrettiğini anlamına gelmektedir. İş değiştirme alt boyutunda yer alan maddelerin (6-9) ortalamalarının 3.15 ile 3.62 arasında olduğu saptanmış ve ebe adaylarının yapay zeka ve otomasyonun çalışma yaşamında rol değişikliklerine yol açabileceğine ilişkin daha yüksek düzeyde kaygı taşıdıkları görülmektedir. Sosyoteknik Körlük alt boyutunda (10-13) ortalamaların 3.30 ile 3.95 arasında yer aldığı bulunmuş; bu durum ebe adaylarının yapay zekanın etik, sosyal ve insani etkilerinin göz ardı edilmesi olasılığına yönelik kaygılarının yüksek olduğunu göstermektedir. Yapay Zeka Yapılandırması alt boyutundaki maddelere (14-16) ilişkin ortalamaların ise 3.14 ile 3.28 arasında değiştiği belirlenmiştir ve ebe adaylarının yapay zeka sistemlerinin işleyişi, veri temeli ve güvenilirliğine ilişkin orta-yüksek düzeyde kaygı yaşadıkları tespit edilmiştir. Bu sonuçlar, ebe adaylarının en düşük kaygıyı öğrenme süreçlerine, en yüksek kaygıyı ise teknolojinin sosyoteknik etkilerine yönelik olarak kaygılandıklarını göstermektedir.

Çizelge 3. Ölçek ifadelerin analizi

	Yapay Zeka Kaygısı	**Ort ± (ss)**
1	Bir yapay zeka tekniği / ürünü ile ilgili tüm özel işlevleri anlamayı öğrenmek beni endişelendiriyor.	2,75±1,09
2	Yapay zeka tekniklerini / ürünlerini kullanmayı öğrenmek beni kaygılandırıyor.	2,39±1,09
3	Bir yapay zeka tekniğinin / ürününün belirli işlevlerini kullanmayı öğrenmek beni endişelendiriyor.	2,28±1,02
4	Bir yapay zeka tekniğinin / ürününün nasıl çalıştığını öğrenmek beni kaygılandırıyor.	2,28±1,00
5	Bir yapay zeka tekniği / ürünü ile etkileşime girmeyi öğrenmek beni endişelendiriyor.	2,29±1,05
6	Bir yapay zeka tekniğinin / ürününün insanların yerini alabileceğinden endişe ediyorum.	3,31±1,10
7	İnsansı robotların yaygın kullanımı, işleri insanlardan uzaklaştıracağından korkuyorum.	3,55±1,03
8	Yapay zeka tekniklerini / ürünlerini kullanmaya başlarsam, onlara bağımlı hale geleceğim ve bazı muhakeme becerilerimi kaybedeceğimden korkuyorum.	3,15±1,21

9	Yapay zeka tekniklerinin / ürünlerinin birilerinin mesleğini elinden almasından endişe ediyorum.	3,61±1,11
10	Bir yapay zeka tekniğinin / ürününün kötüye kullanılabileceğinden endişe ediyorum.	3,48±1,13
11	Bir yapay zeka tekniği / ürünü ile potansiyel olarak ilişkili çeşitli sorunlardan endişe ediyorum.	3,46±1,11
12	Bir yapay zeka tekniğinin / ürününün kontrolden çıkmasından ve arızalanmasından endişe ediyorum.	3,94±1,03
13	Bir yapay zeka tekniğinin / ürününün robot özerkliğine yol açabileceğinden endişe ediyorum.	3,30±1,12
14	İnsansı yapay zeka tekniklerini / ürünlerini (örneğin insansı robotları) ürkütücü buluyorum.	3,28±1,14
15	İnsansı yapay zeka tekniklerini / ürünlerini (örneğin insansı robotları) göz korkutucu buluyorum.	3,25±1,18
16	Nedenini bilmiyorum ama insansı yapay zeka teknikleri / ürünleri (örneğin insansı robotları) beni korkutuyor.	3,14±1,29

4. TARTIŞMA ve SONUÇ

Ebelik mesleği, insan ilişkileri ve duygusal destek gerektiren bir meslek olduğundan, YZ'nın bu alanlardaki etkisini değerlendirmek önemlidir. Özellikle YZ sistemlerinin, hastalar hakkında gerçekleştirdiği sonuçların ve önerilerin doğruluğu ile güvenilirliği hakkında kaygılar doğurabilir.

Bu araştırmada yaş yapay zeka kaygısı üzerinde istatistiksel olarak anlamlı etkisinin olmadığı bulunmuştur ve literatürdeki çalışma sonuçları ile benzerlik göstermektedir (Al Fadeel ve ark., 2021).

Filiz ve Karagöz'ün (2024) yaptığı bir çalışmada, sağlık çalışanlarının yapay zeka kullanımına yönelik kaygılarının olduğu ve teknolojik gelişmeler ile birlikte ortaya çıkan belirsizlikler ve endişelerin artabileceği ifade edilmiştir. Bu çalışmada da yapay zeka kaygısı anlamlı derecede yüksek bulunmuş olup, uluslararası ve ulusal çalışma sı-onuçları ile uyumludur (Castagno ve Khalifa, 2020; Filiz ve Karagöz, 2024).

Ebelik ve sağlık alanındaki YZ uygulamalarının benimsenmesi, sağlık çalışanlarının bu teknolojiye adaptasyon süreçlerini etkilemektedir. Ebelerin YZ kaygılarını azaltabilmek için YZ'nın mesleki faydalarının ele alınması, iş yükünü hafifletme üzerindeki etkilerinin incelenmesi ve sağlık hizmetlerini iyileştirmedeki pozitif yönlerinin de göz önünde bulundurulması ve ebelere bunun aktarılması oldukça önemlidir. Bu aktarımın yapılabilmesi için YZ'nın eğitime entegrasyonu sağlanmalı ve YZ kullanımı ile ilgili politika geliştirme ve destek mekanizmaları oluşturulması gerekmektedir.

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Perinatal Kayıp Sonrası Yas Sürecinde Yayın Trendlerinin ve Araştırma Odak Noktalarının Haritalandırılması: 45 Yıllık Bibliyometrik Analiz

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ÖZET

Bu araştırma, perinatal yas literatürünün kavramsal ve temel yapısını incelemeyi amaçlamıştır. Bu bağlamda, bibliyometrik yöntemler kullanılarak perinatal yas literatürünün büyüme yörüngesi, etkili yazarlar, ülkelerin, dergilerin, makalelerin, anahtar kelimelerin ve ortak atıf ağlarının yayın performansı incelenmiştir. Veri seti, Web of Science veritabanından alınan ve 1981 ile 2025 yılları arasında yayınlanan 964 makaleden oluşmaktadır. Veri analizi için R-bibliometrix paketi ve VOSviewer kullanılmıştır. Sonuçlar, araştırmanın 2000'li yıllarda arttığını ancak 2018'den itibaren hızlı bir yükseliş trendine ulaştığını göstermiştir. Amerika Birleşik Devletleri üretkenlikte birinci sırada yer almakta ve uluslararası işbirliklerinin merkezinde bulunmaktadır. Bununla birlikte, perinatal yas konusunda uzmanlaşma eksikliği ve yazar üretkenliği açısından yeterli üretkenliğe ulaşılmadığı görülmüştür. Araştırma sonuçları ayrıca en etkili yazarları, makaleleri ve dergileri de ortaya koymuştur. Atıf ve anahtar kelime analizleri, perinatal yas literatürünün güncel gelişmelere açık bir alan olduğunu ve özellikle son yıllarda perinatal yas yaşayan ailelerin psikolojik iyilik halleri üzerine yapılan çalışmaların yoğun ilgi gördüğünü göstermiştir. Bu çalışma, perinatal yas literatürüne katkıda bulunacak ve gelecekte bu alanda ilerleme sağlayacak önerilerle sonuçlandırılmıştır.

Anahtar Kelimeler : Doğum sonrası yas, Bibliyometrik, Bilim haritalama, Araştırma trendleri, Web of Science

PSYCHOSOCIAL INTERVENTIONS TO SUPPORT POST-TRAUMATIC GROWTH IN WOMEN VICTIMS OF VIOLENCE

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ABSTRACT

Violence against women is a life event that goes beyond threatening women's physical safety, it profoundly affects their mental well-being and can lead to long-term psychosocial consequences. Following experiences of violence, many women may suffer from post-traumatic stress disorder symptoms, feelings of loss, and breakdowns in trust relationships. However, recent studies in the field of trauma show that some women not only recover from these difficult experiences but also undergo positive transformations in their understanding, empowerment, and relationship with life. This process is addressed within the framework of post-traumatic growth.

Post-traumatic growth refers to the positive changes that occur in an individual's self-perception, relationships, and the meaning they assign to their lives after a traumatic experience. For women victims of violence, this growth can manifest as a strengthening of self-efficacy, the development of boundary-setting skills, the restructuring of social relationships, and the acquisition of a new orientation in life. However, it is known that this process is difficult to achieve spontaneously and develops more easily when supported by appropriate psychosocial support mechanisms. The aim of this review is to present the theoretical framework of psychosocial interventions aimed at supporting post-traumatic growth in women victims of violence and to discuss the potential impact of these interventions on women's well-being. In this context, psychosocial interventions are addressed in terms of creating a safe space, supporting emotional expression and meaning-making processes, empowerment-based approaches, rebuilding social support networks, and a rights-based perspective. In conclusion, psychosocial interventions conducted with women victims of violence should not only focus on reducing trauma symptoms but also create space for women to reinterpret their life stories, recognize their own strengths, and develop hope for the future. Holistic and sensitive approaches that center on post-traumatic growth support women's healing process and enable long-term psychosocial empowerment.

Key words: Women survivors of violence, Post-traumatic growth, Psychosocial interventions, Women’s mental health, Psychosocial empowerment

1. INTRODUCTION

Domestic violence is a serious social problem affecting one in three women worldwide (WHO 2021). The forms of violence against women vary, and its causes are multifaceted, including social, cultural, economic, and political factors (Krahé, 2018). Intimate partner violence (IPV) is the most common type of violence against women and involves physical and psychological aggression, controlling behavior, and/or sexual coercion, the perpetrator is usually a current or former intimate partner (WHO 2021; Stewart, 2016).

Global studies have shown that women are more likely than anyone else to be assaulted, injured, raped, or killed by their male partners or former male partners. Although the typologies of IPV vary (Stark, Ager, 2011; Ali et al., 2016), the consequences of IPV exposure are generally serious and have a devastating effect on a woman's physical and psychological health (Yim & Kofman, 2019; Monahan et. al. 2019; Loxton et. al., 2017; Zara & Gino, 2018) and may even lead to the victim being killed by the perpetrator (Zara & Gino, 2018). Exposure to IPV also negatively impacts the victim's social well-being, and that of their children (Russo et al., 2006). It also negatively impacts the social well-being of women exposed to IPV and their loved ones (Krahé, 2018; Stewart, 2016; Chiesa et al., 2018) and their loved ones (Krahé, 2018; WHO 2021). Women exposed to IPV have a higher disease burden, a higher incidence of comorbidities, a higher likelihood of being diagnosed with mental illness, and a higher risk of substance use disorders compared to women who have not been exposed to IPV or abuse (Stewart, 2016; Kishton et al., 2022).

Domestic violence is now considered a clear violation of human rights, directly or indirectly affecting the lives of all segments of society, not just a specific group (Kishton et al., 2022). Therefore, it is no longer seen merely as an individual problem, but as a serious public health and social justice issue. According to the World Health Organization's "Women's Health and Domestic Violence Against Women Survey," conducted in ten different countries and fifteen different social settings, classic sociodemographic variables such as age, marital status, and education level alone are insufficient to explain the differences in the prevalence of domestic violence (WHO, 2018). This result reveals that domestic violence is a multidimensional phenomenon deeply linked to cultural, economic, and social norms. Domestic and sexual violence is not only a problem directly affecting victims, it also leaves lasting scars on the overall health and economy of society. The economic burden created by violence is not limited to expenditures in areas such as health, law, and social services. In addition, the income loss experienced by victims and their families, the decreased labor productivity, and the stagnation in human capital development negatively impact economic growth in the long term (Duvvury et al., 2013). Another dimension of violence, economic exploitation, is often invisible but is an extremely destructive form of abuse. Frequently seen in close partner relationships, this situation restricts the victim's economic independence, takes away their control over their life, damages their mental health, and profoundly undermines their overall psychological well-being. It is known that this has negative effects not only on the individual but also on family structure, parenting styles, children's behavior, and the developmental processes of young people (Stylianou, 2018). In conclusion, domestic violence is not only an individual tragedy, it

is a social rupture that fuels societal inequalities, hinders economic development, and can persist for generations. Therefore, strengthening social policies and achieving societal transformation are as vital as individual awareness in combating violence.

2. POST-TRAUMATIC GROWTH

Human life is intertwined with vulnerabilities and unexpected shocks. Many people experience psychological trauma at some point in their lives. Such traumas are often shaped by experiences where life feels threatened, a sense of control is lost, and the future becomes unpredictable (Weathers & Keane, 2007; Cai et al., 2014). While traumatic experiences can lay the groundwork for various psychological problems such as anxiety, depression, and post-traumatic stress disorder (Boals et al., 2012; Brown et al., 2014; Dar et al., 2015), many people are able to develop remarkable adaptation and resilience after these experiences (Olff et al., 2005; Anderson et al., 2012).

The psychological consequences that arise after trauma are closely related to the extent to which an individual was physically and emotionally exposed to the traumatic event (Dar et al., 2015; Wozniak et al., 2020; May & Wisco, 2016; Pooley et al., 2013). Domestic violence, in particular, stands out as a complex and profoundly traumatic experience due to its continuous nature and occurrence within close relationships (Sinko et al., 2021). In such relationships, the perpetrator gradually takes control of the victim's living space and decisions, forcing them to live in a constant *"survival mode"* (Sinko et al., 2021). Therefore, the decision to stay in or leave an abusive relationship, although seemingly simple from the outside, is an extremely complex process for the victim, involving intense emotional, economic, and social risks (Reisenhofer & Taft, 2013; Kim & Gray, 2008).

Post-traumatic growth (PTG) is defined as a psychological transformation process in which an individual, following traumatic events and profound difficulties, begins to recognize the positive transformations triggered by these experiences in their life, rather than focusing solely on loss, damage, or psychopathology (Calhoun & Tedeschi, 2014). This concept does not advocate for the denial of trauma or the disregard of pain, rather, it emphasizes the meaningful changes that the traumatic experience creates in a person's perspective on the world, themselves, and their relationships. PTG is structured around five core components: experiencing positive spiritual or existential changes, becoming aware of new possibilities in life, increasing the value of life, feeling an increase in personal strength and resilience, and being able to establish deeper and more fulfilling relationships with other people (Calhoun & Tedeschi, 2014). Numerous studies in the literature reveal that a significant proportion of individuals experiencing symptoms of post-traumatic stress disorder (PTSD) describe such comprehensive and positive changes in their lives despite all the difficulties (Pico-Alfonso, 2005; Wozniak et al., 2020; Carman et al., 2022). These findings demonstrate that trauma not only leads to devastating consequences but also holds transformative potential for some individuals.

3. POST-TRAUMATIC GROWTH IN VICTIMS OF VIOLENCE AGAINST WOMEN

For many women, leaving an abusive relationship is not only a physical separation but also a turning point that radically changes the direction of their lives. This process signifies a transition from a survival situation where control is in the hands of others to a new period where the individual begins to take control of their own life again (Sinko et al., 2021). When describing their recovery processes, women prefer to focus on their own lives and daily experiences rather than abstract psychological concepts frequently used in academic literature. The themes that stand out when defining recovery are: rebuilding a sense of security and survival, regaining freedom, progressing step by step, striving to build a better life, and relationships with children and parenting experiences (Bryngeirsdottir & Halldorsdottir, 2022). However, many women also openly state that recovery is not a linear process; that there are setbacks, difficulties, and emotional ups and downs from time to time. The convergence of these themes reveals that recovery from domestic violence is not a process completed quickly; rather, it is a long-term, individualized, and multifaceted journey. This journey is sustained not only through individual efforts but also through social, psychological, and institutional support (Carman et al., 2022). Therefore, understanding and supporting the recovery processes of victims of domestic violence requires holistic and sensitive approaches that center on the complexity of the human experience.

A large part of the PTG literature focuses on different types of trauma such as war, natural disasters, serious illnesses, or accidents; however, information regarding post-traumatic growth therapy (PTS) after domestic violence remains limited. This suggests a significant gap in the literature regarding how PTG is experienced, particularly in the context of domestic violence against women. Furthermore, the general framework of PTG theory becomes open to criticism when applied to specific trauma groups such as female victims of domestic violence. Domestic violence, unlike most traumas, is a persistent, close-relational phenomenon involving dynamics of power, control, and dependence. Therefore, it is increasingly argued that current PSI (Post-Traumatic Stress Therapy) models may not adequately address this unique context, and that there is a need for contextually sensitive PTG approaches specific to the trauma.

On the other hand, the recognition of domestic violence as a major social problem seriously threatening public health has contributed to changes in social and academic attitudes towards violence against women over time (Brown et al., 2014; Dar et al., 2015). This increased awareness has strengthened interest in research in the field of domestic violence (Wisco, 2016; Gray, 2008) and has led to a steady increase in the number of publications on the subject in the international literature over the last twenty years (Wu et al., 2020).

In particular, there are studies suggesting that women who have experienced IPV experience PTG. The study by Bryngeirsdottir & Halldorsdottir (2022) reveals how women who have experienced IPV experience PTG and the dynamics that facilitate growth through their own narratives. The same study reported that participants demonstrated concrete coping steps, such as seeking information, recognizing triggers, setting boundaries, choosing a supportive social environment, and avoiding controlling relationships, as they shifted from a “victim” identity to

a *"winner/coper"* identity. The study highlights that PTG is not accidental but a process that develops through a combination of internal strengths, meaning-making, and the reorganization of the social environment (Bryngeirsdottir & Halldorsdottir, 2022). In their study, Bryngeirsdottir et al. (2022) argue that PTG is not a single *"positive outcome"* but a process shaped by stages/essential components, obstacles, and facilitators. In this study, the authors offer a framework to help professionals (in the fields of social work, mental health, and women's health) systematically consider the barriers women face and the points of contact that accelerate empowerment while supporting PTG (Bryngeirsdottir et al., 2022). The study by Dyjakon & Rajba (2022) included a sample where both women and the perpetrator of violence underwent therapy. It was noted that some participants' decision to remain in the relationship was influenced by factors that increased their sense of security, such as the partner changing through therapy. The research also provides insight into how therapeutic processes and behavioral change relate to women's experiences of positive post-traumatic transformation (Dyjakon & Rajba, 2022).

A study focusing on how the relationship between negative traumatic effects (PTSD) and PTG in women experiencing domestic violence is shaped by "cognitive processing" processes argues that post-traumatic cognitive coping strategies (ways of dealing with trauma) can play a mediating role in understanding the complex picture where PTSD and PTG can coexist. The study also emphasizes that when designing interventions, it is necessary to focus not only on symptom reduction but also on meaning-making and cognitive restructuring dimensions (Ogińska-Bulik & Michalska, 2021). A study by Gonzalez-Mendez & Hamby (2021) contributes to a power-based intervention approach by examining *"strengths"* associated with PTG and well-being in women who have experienced IPV. It was reported that women's PTG levels increased along with various personal/social power indicators. Furthermore, while supporting post-violence recovery, it points to the importance of practices that highlight individuals' strengths and enhance their skills and resources, rather than focusing solely on risks and symptoms (Gonzalez-Mendez & Hamby, 2021).

Guggisberg et al. (2021) emphasize that post-violence recovery cannot be explained solely by the severity of trauma, highlighting the importance of a holistic assessment in field practice that centers on the "woman's life context," including her social environment, support, access to services, and conditions of meaning-making. Similarly, Kirkner & Ullman (2020) point out that post-violence recovery should not be reduced solely to therapeutic/individual processes, but that environmental conditions such as security, social capital, and access to resources should also be considered.

Doherty & Scannell-Desch (2023) reveal how women who have experienced post-traumatic stress disorder (PTSD) describe indicators of "growth" in the post-traumatic period, such as generating new meanings, transforming self-perception, and changing boundaries and choices in relationships. This study concludes that, from a psychosocial care perspective, a work-focused, safe-space, listening, validation, and empowerment-oriented approach provides a clinical foundation that can support PTG (Doherty & Scannell-Desch, 2023). It is stated that improving the quality of accessibility, continuity, and trauma-informed approaches in service

systems, instead of "uniform intervention," is important in the development of PTG (Claeson et al., 2024). Finally, Hsieh & Garthe (2025) reported that some women may show a more "stable" PTG course, with some showing a higher, while others show a moderate or lower level. Therefore, beyond one-off measurements, they emphasize the importance of a "change over time" perspective, planning who needs psychosocial support, when, and at what intensity, and ensuring sustainability. (Hsieh & Garthe, 2025).

Post-traumatic growth following violence against women, and especially interpersonal traumas like IPV, is not a singular and spontaneous “positive outcome,” but rather a process that unfolds over time, with ups and downs, and involves both individual and contextual factors. Women’s narratives show that growth often occurs through developments such as moving away from the “victim” identity, becoming the subject again, setting boundaries, and structuring life according to their own values. PTG does not mean the absence of trauma symptoms, rather, it is a complex experience that can coexist with PTSD symptoms and is nourished by cognitive processing, meaning-making, and social support. Theoretical and empirical findings in the literature, especially in the context of IPV, highlight that the unique dynamics of PTG are not sufficiently explained and that there is a need for trauma-specific, context-sensitive approaches.

From the perspective of health professionals, the findings in the literature speak of the inadequacy of approaches that limit recovery solely to symptom control. Professionals working in women’s health, mental health, nursing, midwifery, and social work need to address the challenges in post-traumatic care. It is valuable to consider the possibility of trauma-related traumatic experiences not as a "mandatory goal," but as a potential that can be supported. First and foremost, ensuring safety, strengthening the woman's sense of control, and avoiding re-traumatization are fundamental conditions. Growth cannot be discussed without establishing a safe relationship foundation. Therefore, trauma-informed care principles such as non-judgmental listening, validation, respect for privacy, and unconditional respect for the woman's decisions should form the basis of the approach.

In practice, interventions that create space for women to make sense of their experiences are of great importance. Interviews that support cognitive processing processes can help reconstruct the place of trauma in their life story. However, "forcing positive thinking" or creating early expectations of growth should be particularly avoided in this process. Allowing women to progress at their own pace, making it clear that relapses and emotional fluctuations are a natural part of healing, will strengthen the healing nature of the professional relationship.

4. CONCLUSION AND RECOMMENDATIONS

The review findings show that PTG is closely related not only to individual characteristics but also to social environment, safety, access to support networks, and continuity of services. Therefore, it is recommended that healthcare professionals evaluate women not only in a clinical context but also in their life contexts, and provide guidance that strengthens social support, facilitates access to resources, and prioritizes interdisciplinary collaboration. Empowerment-based approaches can support PTG by making visible not only the harm women have suffered but also the skills, resilience, and values they have developed. In conclusion,

supporting PTG is not about imposing the ideal of the "recovered woman," but about accompanying women in their efforts to rebuild their own lives. For healthcare professionals, this sometimes requires witnessing rather than intervening, and sometimes standing by rather than providing solutions. This growth, which blossoms in the shadow of trauma, is often silent, fragile, and unfolds over time. However, with appropriate support, it has the potential to transform into a lasting empowerment and sense of meaning in women's lives.

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GAMIFICATION IN HEALTH EDUCATION AND TREATMENT

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ABSTRACT

This study aims to examine the conceptual bases of the gamification approach in health sciences, its application areas, and the problems it provides solutions for. Gamification is a strategy that aims at increasing the motivation and participation of individuals by integrating game-specific elements such as score, badge, level, feedback, and competition into non-game areas. Recently, especially in digital health applications, mobile follow-up systems, online patient education programs, and interactive learning tools developed for healthcare professionals, gamification has begun to be widely used.

Hence, a critical review of the literature shows that gamification significantly contributes to changing health behavior, increasing treatment adherence, promoting physical activity, and improving learning outcomes in medical education. However, for such a result, it is important that gamification be designed based on psychological theories, taking into account user-centered design principles. The examples presented in this compilation illustrate that gamification can be implemented both in children and adults, both at the clinical and public health levels.

The findings indicate that, in today's world where healthcare systems are shifting towards patient-centered and sustainable interventions, gamification should be considered an innovative and effective tool. However, further research is needed regarding the long-term effects of the method, its cost-effectiveness, and its varying outcomes across different demographic groups.

Keywords: gamification, health education, treatment adherence, behavior change, digital health, motivation in healthcare

1. INTRODUCTION

In recent years, healthcare has evolved from an approach focused solely on treating diseases to a more holistic understanding that aims to transform individuals' health behaviors and instill lifelong, sustainable behaviors. This transformation strives to ensure that individuals are not merely passive recipients of services, but actively participate in treatment processes and integrate preventive health behaviors into their daily lives (Fitzpatrick, 2023). However, achieving these goals is not always possible, particularly in areas such as chronic disease management, patient education, and continuous participation in healthcare services. At this point, methods that strengthen individuals' intrinsic motivation for healthy lifestyle behaviors are increasingly gaining prominence in the healthcare field (Xu et al., 2022; Fitzpatrick, 2023).

Gamification, one of the prominent approaches in this context, has become a noteworthy application in the field of health sciences in recent years. Gamification refers to the integration of game-specific mechanisms (such as points, badges, levels, and leaderboards) into non-game contexts to enable individuals to perform health-related tasks more willingly, regularly, and sustainably (Xu et al., 2022). This approach, which has a wide range of applications from education to treatment, rehabilitation to mental health, has been reported to be effective in increasing individuals' participation and commitment to the process (Johnson et al., 2016; Wang et al., 2025).

This review examines the concept of gamification within the context of health sciences, discussing its potential through its contributions to different health problems and current application examples. The review examines current scientific studies published in the PubMed database, addressing the place and effects of gamification in the health field from a holistic perspective.

1.1. What is Gamification?

Gamification allows participants to engage more willingly in the process compared to traditional health education and behavior change programs. Deterding et al. (2011) define gamification as "*the use of game design elements in non-game contexts*." These design elements include motivational components such as scoring systems, badges, levels, competitive elements, leaderboards, teamwork, and instant feedback (Deterding et al., 2011). In general, gamification is considered in the relevant literature as a strategy aimed at changing individuals' behavior more permanently by adapting intrinsic motivational elements found in fun games to health applications (Priesterroth et al., 2019).

Compared to traditional health education and behavior change strategies, gamification can more easily attract the attention of participants and increase their interest in the process. The main reason for this is that this approach takes into account the basic psychological needs of individuals such as autonomy, competence, and social belonging. For example; in a health application, users receiving instant feedback, leveling up, representing themselves through virtual avatars, or interacting with other users can strengthen their commitment to the process (Deterding et al., 2011; Priesterroth et al., 2019).

Gamification, when compared to serious games, stands out by adding a game-like layer on top of existing systems, rather than offering a completely independent environment based on game design. Thanks to this feature, it can be more easily integrated into individuals' daily lives and provides an advantage in terms of sustainability (Jhonson et al., 2016). Van Gaalen et al. (2020) also define gamification as the use of game elements to improve students' learning performance, emphasizing the importance of this approach, especially in health education.

1.2.Gamification in Health Sciences

Chronic diseases and unhealthy lifestyle behaviors brought about by modern lifestyles are among the main problems that health systems struggle to solve today. Behaviors such as inactivity, unhealthy eating, and non-compliance with treatment form the basis of many health problems such as diabetes, obesity, cardiovascular diseases, and depression (Johnson et al., 2016). To cope with these problems, individuals need to change their behaviors and maintain these changes. Gamification stands out as an approach that can offer solutions in various fields in this regard. Promoting healthy lifestyle behaviors: Studies show that gamified interventions have positive effects in increasing physical activity and healthy lifestyle habits. According to a systematic review by Johnson et al. (2016), gamification-based applications have a particularly positive impact on behavioral outcomes. It creates positive effects in these areas. In the meta-analysis of Wang et al. (2025), it was reported that interventions including gamification increased moderate-intensity physical activity in children and adolescents and showed effects that reduced body mass index.

Treatment adherence and self-management: Adherence to treatment and maintaining daily care is a significant challenge for individuals with chronic diseases. Gamified digital applications can support individuals in this process and increase motivation. Priesterroth et al. (2019) reported that gamification elements used in diabetes management strengthened user experience and treatment adherence. Mechanisms such as earning points and obtaining badges can encourage patients to take regular measurements and adhere to the treatment plan (Rose et al., 2013; Hoffmann et al., 2017).

Patient education and health literacy: Willing participation of learners in the process is an important factor for health education to be effective. Gamification supports learning by making materials for patient and community education more engaging. Bas-Sarmiento et al. (2025) reported that gamified e-health interventions significantly improved health knowledge, motivation, and attitudes in children and adolescents.

Healthcare professional training: Gamification is also an important tool in the training of healthcare professionals. Van Gaalen et al. (2021) showed that training programs enriched with game elements improved learning outcomes in healthcare professional training. Kerfoot and Kissane (2014), in their study among surgical assistants, reported that competitive game mechanics significantly increased participation in simulation training.

Rehabilitation and therapy participation: Maintaining patient motivation in rehabilitation processes is often difficult. Platforms such as Nintendo Wii and Microsoft Kinect contribute to the rehabilitation process by making exercises fun tasks (Levac et al., 2018). Similarly, Zlotnik

et al. (2023) emphasized that the integration of such game-based systems into therapeutic processes can increase patient participation.

Psychological well-being: Gamification is also yielding promising results in the field of mental health. Aschentrup et al. (2024) reported that digitally gamified interventions have positive effects on mental well-being and can reduce symptoms of depression. These studies have demonstrated that gamification can provide psychological benefits such as stress management and the reduction of anxiety or depression symptoms. These findings generally demonstrate how gamification can address key health-related issues such as lack of motivation, lack of adherence, and educational challenges. Gamification facilitates learning and adaptation by actively engaging users in the process at both behavioral and cognitive levels (Priesterroth et al., 2019).

2. CONCLUSIONS

The findings show that gamification can be an important tool in overcoming problems of lack of motivation and adherence to the process in health sciences. Findings in the literature show that gamified interventions generally have positive effects on health behaviors (Johnson et al., 2016; Priesterroth et al., 2019). However, it appears that the success achieved largely depends on the quality of the game elements used and the theoretical frameworks adopted in the design process. Considering psychological approaches that support intrinsic motivation is among the key elements that increase the effectiveness of gamification (Aschentrup et al., 2024). In this context, health professionals and educators consciously and purposefully integrating gamification strategies into their practices has the potential to increase the effectiveness of health interventions. Gamification is gaining traction in the health sciences community as an innovative method for encouraging patient engagement and learning. Current findings in the literature show that gamification provides positive results, especially in applications targeting behavioral change. In this context, health professionals and educators can make health interventions more effective by appropriately integrating gamification strategies (Bas Sermiento et al., 2025).

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Elucidating the Molecular Ecology of *Euroleon judaeus* and *Euroleon nostras*: Implications for the Evolutionary History of Mediterranean Phylogeography

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Abstract

The antlion species *Euroleon judaeus* and *Euroleon nostras* occupy ecologically diverse habitats across the Eastern Mediterranean and wider Palaearctic, yet their molecular ecology and evolutionary dynamics remain almost completely unexplored. This knowledge gap is especially pronounced in Türkiye—a major biogeographical nexus that has functioned both as a climatically stable Pleistocene refugium and a dispersal corridor linking Europe, Anatolia, and the Levant. The absence of genomic-scale data for *Euroleon* species limits our ability to infer population connectivity, detect cryptic lineages, reconstruct historical demographic shifts, and understand mechanisms of microhabitat-driven adaptation. By integrating multilocus mitochondrial and nuclear markers with high-resolution genomic approaches such as ddRAD-seq and ultraconserved elements (UCEs), researchers can resolve fine-scale phylogeographic structure, identify loci underlying adaptation to heterogeneous substrates and microclimates, and test hypotheses related to refugial persistence, ecological specialization, and potential incipient speciation. Given the complex topography and environmental gradients of the Eastern Mediterranean, *Euroleon* species provide an exceptional model for evaluating how climatic oscillations, habitat heterogeneity, and geographic barriers jointly shape insect diversification. Advancing the molecular ecology of these taxa will refine Mediterranean phylogeographic frameworks and position Anatolia as a key system for understanding evolutionary processes in Neuroptera and other arthropods inhabiting semi-arid and fragmented landscapes.

Keywords: Mediterranean phylogeography, Population genomics, Myrmeleontidae, *Euroleon* spp.

Introduction

The Mediterranean Basin is globally recognized as a major biodiversity hotspot and a mosaic of microclimates that has shaped the evolutionary histories of countless taxa (Médail & Diadema, 2009). Within this region, Anatolia occupies a particularly critical position. Nestled at the intersection of Europe, the Middle East, and the Caucasus, it has functioned both as a Pleistocene refugium and a biogeographical corridor, facilitating the persistence, admixture, and diversification of terrestrial organisms during repeated climatic oscillations (Hewitt, 2011; Bilgin, 2011). Despite this significance, many insect groups remain vastly understudied from a molecular perspective. Neuroptera an order featuring ecologically important predators such as antlions are among the most neglected (Badano et al., 2017).

Within the antlion family Myrmeleontidae, the species *Euroleon judaeus* and *Euroleon nostras* represent two ecologically relevant but poorly characterized taxa. While widely distributed across the Eastern Mediterranean and western Palaearctic, their population structure,

phylogeographic history, and adaptive responses to heterogeneous environmental conditions remain essentially unknown. This research gap is especially pronounced in Türkiye, where published molecular data for these species are almost entirely absent. Considering the region's exceptional role in supporting relictual lineages and harboring cryptic genetic diversity, such an absence of genomic-scale studies imposes a severe limitation on our understanding of Mediterranean evolutionary dynamics.

In recent years, the integration of multilocus mitochondrial and nuclear markers, ddRAD-seq, and ultraconserved elements (UCEs) has markedly transformed phylogeography and molecular ecology (Harvey et al., 2016; Andrews et al., 2016). These tools enable researchers to reconstruct fine-scale demographic histories, detect genome-wide signatures of selection, and test explicit hypotheses about ecological divergence. For taxa like *E. judaeus* and *E. nostras*, which inhabit microhabitats ranging from shaded forest edges to xeric open dunes, such genomic approaches provide an unprecedented opportunity to evaluate how environmental heterogeneity shapes population connectivity and adaptive evolution.

The overarching goal of analyzing these species is not limited to documenting lineage divergence. Instead, this endeavor aims to situate antlion evolutionary history within broader Mediterranean phylogeographic frameworks, ultimately offering a model for understanding diversification processes in poorly studied insect clades.

1. Biogeographic Importance of the Eastern Mediterranean

The Eastern Mediterranean represents a region of exceptional biogeographic significance due to its complex topography, heterogeneous climate, and long-term environmental stability, which have collectively shaped the evolutionary trajectories of numerous taxa. During Pleistocene glacial cycles, this region repeatedly functioned as a climatic buffer, providing refugial habitats that allowed the persistence of plant and animal lineages that were otherwise displaced or extirpated in surrounding areas (Şekercioğlu et al., 2011; Hewitt, 2011). The combination of stable microclimates, mountain ranges, and riverine systems facilitated both allopatric divergence and subsequent secondary contact, resulting in the maintenance of high levels of genetic diversity and the establishment of complex phylogeographic patterns (Bilgin, 2011).

For insect taxa, and specifically antlion species such as *Euroleon judaeus* and *Euroleon nostras*, the ecological characteristics of the Eastern Mediterranean—ranging from xeric open habitats to mesic forest edges—likely exert strong selective pressures on behavior, life history traits, and microhabitat specialization. Their sensitivity to substrate composition, thermal variation, and prey availability may allow these species to act as fine-scale indicators of historical population processes, including refugial persistence, local adaptation, and dispersal limitation. Previous studies of other Mediterranean arthropods have demonstrated that such species frequently exhibit cryptic genetic lineages corresponding to microrefugia or environmental gradients, emphasizing the potential for antlions to similarly reflect the legacy of past climatic fluctuations (Taberlet et al., 1998; Médail & Diadema, 2009).

Furthermore, the Eastern Mediterranean's role as a biogeographical crossroads has likely facilitated repeated episodes of gene flow between Anatolian, Levantine, and Balkan populations, resulting in intricate patterns of admixture that can now be resolved using genomic-scale datasets. Integrating high-resolution molecular data with ecological and environmental variables offers the potential to disentangle the relative contributions of

historical vicariance, contemporary connectivity, and selection pressures to current patterns of population structure and species divergence (Andrews et al., 2016; Harvey et al., 2016). In this context, *Euroleon* species provide an ideal model for examining how microhabitat heterogeneity and landscape complexity interact with historical climate stability to generate and maintain genetic diversity across the Eastern Mediterranean.

2. Ecology and Distribution of *Euroleon* Species

The genus *Euroleon* encompasses a suite of ecologically specialized antlion species that exhibit distinct biogeographic patterns across Europe and the Mediterranean Basin. *Euroleon nostras* is broadly distributed throughout continental Europe, typically inhabiting forest edges, riverine corridors, and sheltered sandy or loamy substrates that provide suitable microhabitats for pit construction and prey capture (Stange, 2004; Badano et al., 2017). This species appears to tolerate a range of environmental conditions, including variations in soil texture and microclimatic regimes, reflecting its relatively wide ecological amplitude. In contrast, *Euroleon judaeus* demonstrates a more restricted geographic range, occurring primarily within the Eastern Mediterranean, encompassing Levantine and Anatolian regions. Its occurrence in xeric and semi-arid habitats, often associated with sparse vegetation and loose sandy substrates, suggests adaptations to local environmental constraints and potentially stronger microhabitat specialization (Bilgin, 2011).

Despite their morphological similarity, anecdotal ecological observations indicate that these two species may occupy different ecological niches, a pattern frequently associated with cryptic genetic structuring in other insect taxa (Stange, 2004; Taberlet et al., 1998). Such niche differentiation may involve subtle behavioral, physiological, or developmental adaptations that allow co-occurring populations to exploit distinct microhabitats, thereby reducing interspecific competition. Additionally, the geographic restriction of *E. judaeus* to the Eastern Mediterranean implies a history of regional endemism and potential isolation in climatically stable refugia during Pleistocene glacial cycles. In turn, these factors may have promoted allopatric divergence and the maintenance of genetically distinct lineages, despite limited morphological differentiation.

The comparative analysis of these species provides an opportunity to investigate the interplay between ecological specialization, microhabitat selection, and evolutionary history. By combining detailed ecological observations with high-resolution genomic datasets, researchers can elucidate the mechanisms underlying local adaptation, detect cryptic diversity, and assess the extent to which environmental heterogeneity shapes population structure and species boundaries within the *Euroleon* complex (Andrews et al., 2016; Harvey et al., 2016). This integrative framework is particularly relevant in Mediterranean landscapes, where complex topography and historical climatic stability have repeatedly promoted the persistence of narrow endemic lineages and microhabitat-driven diversification.

3. Molecular Gaps and the Need for Genomic Tools

Past studies on antlions have largely relied on morphology or limited mitochondrial markers, which often underestimate lineage boundaries or fail to resolve recent divergence (Badano et al., 2017). Modern genomic tools allow:

a)identification of unrecognized lineages,

b)detection of gene flow barriers,

c)reconstruction of postglacial expansion routes, and

d)evaluation of local adaptation.

For *Euroleon* species, no such comprehensive genomic study has yet been conducted.

Aims and Significance

This study proposes a multi-tiered framework to investigate the molecular ecology of *E. judaeus* and *E. nostras* using multilocus and genomic datasets. The research aims to:

1. Resolve population genetic structure across Anatolia, Levant, and the Palaearctic range.
2. Identify cryptic diversity and test for previously undetected phylogeographic lineages.
3. Reconstruct demographic histories, including potential refugia, bottlenecks, and postglacial expansions.
4. Detect genomic signatures of selection associated with microhabitat heterogeneity.
5. Contextualize findings within broader Mediterranean evolutionary paradigms, enhancing the role of Neuroptera in biogeographical research.

Together, these aims will shed light on how environmental gradients, climatic oscillations, and geographic barriers shape the evolutionary outcomes of two ecologically important but neglected insect taxa.

Implications for Mediterranean Phylogeography

1. Testing Refugial Stability and Secondary Contact Zones

If Anatolia functioned as a long-term refugium for *Euroleon* species, populations from central and southern Türkiye are expected to exhibit high haplotype diversity, deep coalescent splits, and signatures of stable population size across glacial cycles. Conversely, European and northern populations may show patterns consistent with postglacial expansion: low diversity, star-like haplotype networks, and shallow differentiation (Taberlet et al., 1998).

2. Exploring Microhabitat-Driven Divergence

Antlion species exhibit pronounced associations with specific microhabitats, which may impose strong selective pressures on morphological, physiological, and behavioral traits. Genomic approaches, including FST outlier analyses and environmental association studies, provide a robust framework for detecting loci under selection that correspond to these microhabitat-specific adaptations. For instance, loci associated with thermal tolerance could reveal how populations withstand extreme temperature fluctuations characteristic of arid and semi-arid environments, whereas genes related to substrate preference may underlie differential habitat occupancy driven by soil composition and texture. Furthermore, allelic variation influencing humidity-sensitive behaviors or moisture-dependent foraging strategies may facilitate the persistence of local populations under heterogeneous microclimatic conditions. Morphological

and behavioral traits, such as camouflage effectiveness and the efficiency of pit-fall construction, are likely to be influenced by the selective regimes imposed by prey availability and substrate characteristics. By integrating genomic signatures with ecological parameters, these analyses enable rigorous testing of hypotheses related to ecological speciation, providing insights into the evolutionary mechanisms by which microhabitat heterogeneity drives diversification in Mediterranean antlion populations.

3. Evaluating Cryptic Species Hypotheses

Given morphological similarity and the presence of highly structured habitats, current taxonomy may mask cryptic diversity. Genomic data (e.g., clustering, coalescent-based species delimitation) can clarify whether *E. judaeus* or *E. nostras* comprise multiple evolutionarily independent lineages.

Conclusion

Elucidating the molecular ecology of *Euroleon judaeus* and *Euroleon nostras* offers a critical opportunity to advance our understanding of evolutionary diversification within one of the world's most complex biogeographic regions. Genomic-scale analyses—including multilocus sequencing, ddRAD-seq, and UCE approaches—provide the resolution necessary to uncover cryptic phylogeographic structure, reconstruct demographic histories shaped by Pleistocene climatic oscillations, and identify selective pressures associated with microhabitat specialization. Within Anatolia, where long-term climatic stability, rugged topography, and intersecting migration corridors have repeatedly promoted the persistence and admixture of diverse lineages, *Euroleon* species serve as ideal models for testing hypotheses regarding refugial stability, ecological divergence, and the formation of secondary contact zones.

By integrating genomic data with ecological and environmental variables, researchers can disentangle the relative roles of historical vicariance, contemporary gene flow, and local adaptation in shaping genetic diversity. These insights not only enhance our understanding of Mediterranean evolutionary dynamics but also elevate antlions—long neglected in molecular research—to emerging model organisms for studying diversification in Neuroptera. Ultimately, this research framework contributes to broader comparative studies of arthropods across Mediterranean and semi-arid ecosystems and establishes a foundation for future work on adaptive evolution, species boundaries, and functional ecological divergence in the region.

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Genome Skimming in *Chrysoperla* (Neuroptera: Chrysopidae): A Comprehensive Review of Current Advances, Challenges, and Future Directions

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Abstract

Genome skimming has rapidly emerged as a low-cost, high-efficiency tool for recovering mitochondrial genomes, ribosomal DNA arrays, and other repetitive nuclear markers in non-model insects. Within Neuroptera, the genus *Chrysoperla* represents an exceptional system in which cryptic speciation, acoustic divergence, and complex biogeographical histories converge, yet genomic resources have remained limited. Here, we provide the first comprehensive synthesis of genome-skimming applications in *Chrysoperla* and evaluate their implications for taxonomy, phylogenomics, and behavioral evolution. We review methodological advances that facilitate data recovery from both fresh and degraded specimens, compare mitogenomic and nuclear high-copy markers for resolving cryptic species in the *carnea* group, and highlight emerging conflicts between mitochondrial and nuclear datasets linked to incomplete lineage sorting and introgression (e.g., Winterton et al., 2022; Zhao et al., 2023). Furthermore, we outline how integrating genomic, acoustic, and ecological datasets can illuminate the genetic basis of mate-recognition systems and accelerate the discovery of undescribed lineages in major refugial regions such as Anatolia. Collectively, this review establishes *Chrysoperla* as a model genus for low-coverage genomics in insects and defines key research priorities for the next decade in neuropteran systematics and evolutionary biology.

Keywords: Chrysopidae, *Chrysoperla*, genome skimming, mitochondrial phylogenomics, integrative taxonomy

Introduction

The green lacewings (Neuroptera: Chrysopidae) comprise more than 1,300 described species globally, many of which play essential roles as biological control agents. Within the family, *Chrysoperla* stands out for its widespread distribution, ecological importance, and notorious taxonomic complexity. The carnea species-group, in particular, represents one of the best-known cases of cryptic speciation in insects, where species boundaries often correlate more strongly with mating songs than with morphology (Henry, 2019).

Traditional Sanger-based molecular approaches have provided valuable insights but remain insufficient for resolving complex phylogenetic histories, distinguishing cryptic lineages, or reconstructing detailed evolutionary patterns. Genome skimming—low-coverage whole-genome sequencing targeting high-copy loci such as mitochondrial genomes, ribosomal clusters, and repetitive elements—has thus become a transformative tool. Its ability to extract large genomic datasets from both fresh and degraded tissues makes it especially well suited for neuropteran research.

Why Chrysoperla is a Model Genus for Genome Skimming

The genus *Chrysoperla* represents an exemplary system for genome skimming because it integrates high ecological significance with tractable genomic features and a well-resolved behavioral taxonomy. As key predatory agents in diverse agroecosystems, *Chrysoperla* lacewings exert substantial top-down control on aphids, whiteflies, and mites, making them indispensable indicators for genomics-driven biological control research (Tauber et al., 2000; McEwen & New, 2019). Their widespread distribution across temperate and subtropical regions, coupled with their capacity to colonize complex agro-landscapes, also provides a natural framework for comparative population genomics and adaptive trait evolution (Bozsik et al., 2021). Importantly, species within the *Chrysoperla carnea* complex display cryptic speciation, with reproductive boundaries defined primarily through species-specific substrate-borne courtship songs rather than classical morphological traits (Henry et al., 2013). This unique "acoustic speciation" has created a natural experimental system for testing hypotheses about the genomic correlates of behavioral divergence and incipient speciation (Henry, 2020).

From a methodological standpoint, *Chrysoperla* is unusually well suited for genome skimming approaches. Their mitochondrial genomes are compact, evolutionarily informative, and have been consistently recoverable at high coverage even from ethanol-preserved or historical museum specimens (Wei et al., 2022). Nuclear repetitive fractions—particularly ribosomal DNA arrays and transposable element signatures—are also sufficiently abundant to enable robust genome profiling from low-input DNA extractions, a major advantage when working with small-bodied neuropterans (Zhang & Liu, 2021). Additionally, the growing availability of annotated mitogenomes and partial nuclear scaffolds across multiple *Chrysoperla* species provides a comparative backbone for phylogenomic reconstruction and species delimitation, which is particularly crucial for the taxonomically challenging *C. carnea* group (Winterton & Breitkreuz, 2020).

Collectively, the combination of ecological importance, behavioral complexity, and genomic accessibility positions *Chrysoperla* as a model genus for implementing genome skimming in evolutionary ecology, systematics, and applied biological control genomics.

Biological and evolutionary significance

Chrysoperla species are distributed broadly across Holarctic ecosystems, occupying a range of habitats from agricultural landscapes to natural forests and riparian zones, which reflects their ecological plasticity and adaptability (Tauber et al., 2000; McEwen & New, 2019). These lacewings exhibit highly specialized sensory modalities, including acute visual, olfactory, and mechanosensory systems, enabling precise prey detection, predator avoidance, and mate recognition under diverse environmental conditions (Henry et al., 2013). Among these adaptations, the substrate-borne acoustic courtship duets of the *carnea* group stand out as a rare example of nonvisual communication in Neuroptera, facilitating species-specific mate recognition and reproductive isolation (Henry & Wells, 2020). These courtship signals are thought to have played a critical role in rapid speciation within the group, highlighting the interplay between behavioral innovation and evolutionary divergence driven by sexual selection (Henry, 2020; Henry & Wells, 2020).

Genome skimming offers a powerful approach to elucidate the genomic foundations underlying these unique behavioral traits. Mitochondrial genomes can reveal patterns of historical

biogeography and population structure, while repetitive nuclear elements, ribosomal DNA, and candidate genes for neural and sensory function can be profiled even from small tissue samples (Wei et al., 2022; Zhang & Liu, 2021). By integrating genomic, behavioral, and ecological data, researchers can begin to link specific genetic architectures to acoustic signaling, mate choice, and speciation dynamics in *Chrysoperla*, providing a comprehensive framework for understanding how sensory and behavioral innovations drive evolutionary diversification in insects (Winterton & Breitkreuz, 2020; Bozsik et al., 2021).

Taxonomic and systematic challenges

Taxonomic delimitation within the genus *Chrysoperla* remains difficult due to extensive morphological homogeneity. Traditional diagnostic characters—such as wing venation, general body coloration, or even male genitalic morphology—often fail to reliably distinguish among closely related species (Breitkreuz & Garzón-Orduña, 2021). Even male genitalic characters—often considered a last resort in difficult neuropteran taxa—sometimes lack sufficient divergence, particularly among cryptic lineages of the *Chrysoperla carnea* group, making species boundaries ambiguous (Brooks & Barnard, 1990).

Molecular methods have alleviated some difficulties, but single-locus approaches (e.g., COI barcoding) also have limitations. For example, studies on the *Chrysoperla nipponensis* species-complex revealed multiple genetically distinct clades that were not distinguished by morphology alone (Li et al., 2019). Similarly, commercial populations of the *C. carnea* group have been shown to consist of multiple genetically divergent lineages when analyzed using mitochondrial markers (Zhang et al., 2019). These findings highlight the persistent gap in taxonomic resolution for many *Chrysoperla* species.

Genome skimming offers a powerful approach to address these gaps. High-copy elements such as mitochondrial genomes and ribosomal DNA arrays can be recovered even from low-quality or small tissue samples. Complete mitochondrial genomes have already been sequenced for some lacewing species, including *Chrysoperla sinica*, demonstrating feasibility (Zhang et al., 2015). Despite these advances, mitogenomic data remain sparse for many *Chrysoperla* species, limiting robust phylogenetic inference and species delimitation (Winterton & Breitkreuz, 2020).

By applying genome skimming across multiple *Chrysoperla* taxa—including type specimens, geographically diverse populations, and cryptic lineages—researchers can: (1) generate complete mitochondrial genomes and rDNA arrays, enabling more reliable species delimitation; (2) uncover cryptic species within morphologically homogeneous groups; (3) reconcile conflicting morphological and molecular evidence; and (4) provide genomic scaffolds for linking genotype to phenotype, such as acoustic courtship traits or ecological adaptations (Henry & Wells, 2020). Overall, genome skimming offers a scalable solution to the persistent taxonomic and systematic challenges in *Chrysoperla*.

Mitochondrial phylogenomics

Mitogenomes derived from skimming have clarified relationships within and between several Chrysopidae genera. For example, Haruyama et al. (2019) demonstrated the phylogenetic stability of mitochondrial protein-coding genes across *Chrysoperla* and *Chrysopa*, supporting their historical separation. However, comprehensive sampling remains limited, and only a subset of species has been sequenced to date.

Ribosomal DNA (rDNA) cluster evolution

Ribosomal DNA (rDNA) arrays—typically the 45S units containing 18S, 5.8S, and 28S rRNA genes separated by internal transcribed spacers (ITS1 and ITS2)—are among the most abundant and evolutionarily conserved genomic regions in eukaryotes, arranged in tandem repeats and usually located in nucleolus-organizing regions (NORs) (Gokhman & Kuznetsova, 2024). Because of their high copy number, rDNA clusters are readily captured by genome-skimming approaches, which often recover complete or near-complete 18S–ITS–28S units, even from low-input DNA or degraded specimens (Denver, Brown, Howe, & Peetz, 2016).

This high copy number makes rDNA especially valuable for cross-genus comparisons, phylogenetics, and species delimitation. However, rDNA evolution is dynamic: arrays often exhibit substantial copy number variation (CNV) and intragenomic sequence heterogeneity, which can complicate phylogenetic analyses. For example, population-genomic studies in *Daphnia pulex* revealed that rDNA copy number can vary by more than an order of magnitude and that intragenomic sequence variation is concentrated in intergenic spacers, while core rRNA sequences remain more conserved (Long et al., 2023). Similarly, intragenomic variation in ITS and spacer regions has been reported across fungi and ciliates, underscoring the need for careful interpretation in phylogenetic studies (Šíchová, Nguyen, & Marec, 2014).

Mechanistically, rDNA cluster evolution is shaped by unequal crossover, gene conversion, chromosomal rearrangements, transposition, and extrachromosomal rDNA circles (ecc-rDNA) (Gokhman & Kuznetsova, 2024). In Lepidoptera, rDNA loci have diversified across chromosomes, sometimes including B-chromosomes, suggesting high mobility mediated by repetitive elements rather than major karyotype changes (Nguyen et al., 2022).

The evolutionary plasticity of rDNA clusters has several implications. First, phylogenetic and taxonomic inference must proceed with caution, as paralogous repeats and intragenomic variation may produce conflicting signals (Ó Carroll et al., 2012). Second, CNV may have functional and ecological relevance, influencing ribosome biogenesis, protein synthesis capacity, growth rate, and life-history strategies (Garrick et al., 2022; Murray et al., 2023). Finally, genome skimming enables comprehensive recovery of rDNA arrays, allowing estimation of copy number, detection of intragenomic variants, and comparisons across individuals, populations, or species (Gokhman & Kuznetsova, 2024).

For *Chrysoperla*, integrating rDNA cluster data with mitogenomes, nuclear markers, behavioral, and ecological datasets could provide novel insights into diversification, adaptation, and the genomic architecture of speciation.

Integrative taxonomy and species delimitation

The combination of mitogenomes, rDNA clusters, acoustic signals, and ecological data has begun to reveal previously undetected diversity within Chrysoperla. For instance, expanded sampling in the Mediterranean Basin has suggested at least two undescribed lineages within the *C. carnea* clade (Zhao et al., 2023). Genome skimming is expected to accelerate such discoveries by generating comprehensive genetic datasets.

Resolution of cryptic species complexes

Complete mitochondrial genomes (mitogenomes) have substantially improved the resolution of long-standing taxonomic ambiguities within the *Chrysoperla carnea* species group—one of the most challenging cryptic species complexes in Neuroptera. Traditional mitochondrial barcodes such as COI often fail to discriminate among *C. carnea s. str.*, *C. pallida*, *C. lucasina*, and *C. agilis*, because these taxa diverged relatively recently and exhibit pervasive incomplete lineage sorting and introgressive mitochondrial capture associated with their overlapping ecological niches and shared overwintering strategies (Henry et al., 2019; Haruyama et al., 2021). Mitogenomes, however, provide a ~16–17 kb multi-locus dataset that enhances phylogenetic signal by incorporating protein-coding genes, rRNA clusters, and control-region variation, thereby increasing discriminatory power—particularly for geographically structured, low-divergence lineages (Duelli et al., 2023).

Geographic population genomics studies indicate that mitochondrial lineages within the *carnea* complex are not randomly distributed but instead show robust biogeographical structuring across the Western Palearctic, Central Anatolia, and the Levant. This structuring often corresponds to ecological discontinuities such as montane–steppe transitions, xeric habitat mosaics, and refugial microclimates, suggesting that cryptic diversification is linked to historical climatic oscillations and habitat fragmentation (Bozsó et al., 2022). Several deeply divergent mitochondrial haplogroups have been identified in Türkiye—one of the world's major refugial hotspots—implying potential unrecognized speciation events or secondary contact zones with asymmetric female-mediated gene flow (Şengül et al., 2024).

However, mitochondrial evidence alone is insufficient to delimit species boundaries in lacewings. Recent nuclear genomic datasets, including anchored hybrid enrichment (AHE), ultraconserved elements (UCEs), and whole-genome resequencing, reveal that several *carnea*-group lineages that appear well differentiated in their mitogenomes show shallow or incomplete divergence in the nuclear genome—a classic signature of cryptic species radiations in insects with high dispersal capacity (Winterton et al., 2022; Letardi et al., 2024). Conversely, some acoustically distinct taxa (e.g., *C. agilis*) exhibit strong reproductive isolation and clear nuclear-genomic structuring despite sharing nearly identical mitochondrial haplotypes, highlighting the limitations of mitochondrial markers for species delimitation.

Integrating mitogenomes with nuclear genomic data indicates that **cryptic speciation in the *carnea* group is a multi-layered process**, driven by:

1. **Behavioral isolation** through species-specific courtship songs (Henry, 2020).
2. **Ecological partitioning**, particularly in overwintering and larval predation niches.

3. **Historical climatic cycles**, which promote refugial fragmentation and secondary contact.
4. **Sex-biased dispersal**, where male-mediated gene flow homogenizes nuclear genomes, while maternally inherited mitogenomes retain localized structure.

Therefore, a combined mitogenomic + nuclear genomic framework—supplemented with acoustic and morphological datasets—is essential for accurately delineating cryptic lacewing species, reconstructing their evolutionary trajectories, and informing biological control programs that rely on species-specific functional traits.

Incomplete lineage sorting

Incomplete lineage sorting (ILS) represents one of the central challenges in reconstructing evolutionary history in rapidly diversifying insect clades. ILS occurs when alleles fail to coalesce within the temporal window separating successive speciation events, resulting in gene trees that do not match the species tree. This discordance—long recognized in vertebrates—has become especially evident in insects as whole-genome sequencing, multilocus phylogenomics, and population genomic datasets increasingly reveal high levels of ancestral polymorphism and complex demographic histories (Maddison, 2020; Suvorov et al., 2022).

6.2.1 Causes and Prevalence of ILS in Insects

ILS is exceptionally common in insects for several biological and ecological reasons:

1. **Large effective population sizes (Ne).** Many insects maintain very large Ne due to high fecundity and short generation times. Large Ne prolongs the time required for alleles to coalesce, increasing the likelihood that ancestral polymorphisms persist across multiple speciation events.
2. **Rapid radiations.** Numerous insect radiations—such as *Chrysoperla*, *Bactrocera*, *Anopheles*, *Heliconius*, and Hawaiian *Drosophila*—exhibit extremely short internode distances. When divergence times between lineages are on the order of 10^4–10^5 generations, ancestral alleles often fail to sort, producing pervasive phylogenomic discordance.
3. **Ecological shifts and climatic oscillations.** Pleistocene fluctuations, refugial dynamics, and repeated range contractions/expansions in Palearctic and Mediterranean insect faunas result in fragmented populations with complex demographic histories that promote retention of ancestral polymorphism.
4. **Hybridization and introgression.** Although introgression is conceptually distinct from ILS, the two often co-occur in insects. Reticulated histories (e.g., *Anopheles gambiae* complex; *Heliconius* butterflies) create patterns that mimic or amplify ILS, making the two processes difficult to disentangle.

6.2.2 Genomic Signatures of ILS

Identifying ILS in insects requires careful interpretation of genomic patterns, including:

- **High gene tree heterogeneity** even among unlinked loci.
- **Discordance between mitochondrial and nuclear phylogenies**, commonly observed in Lepidoptera, Hymenoptera, and Neuroptera.

- **Quartet-based conflict** detected in ASTRAL, SVDquartets, or NJst analyses.
- **Symmetric vs. asymmetric allele sharing patterns**, useful for distinguishing ILS from introgression.

In Chrysopidae (green lacewings), for example, genome-skimming and UCE data frequently reveal discordant topologies that cannot be explained by gene flow alone and are consistent with deep ancestral polymorphism maintained across the *Chrysoperla carnea* group.

6.2.3 Distinguishing ILS from Introgression in Insects

A major analytical problem is that both processes can produce similar patterns. However, several approaches help evaluate their relative contributions:

- **D-statistics (ABBA–BABA tests)** quantify asymmetric allele sharing and can detect introgression beyond ILS expectations.
- **Phylogenetic network inference** (PhyloNet, SNaQ) evaluates reticulation events characteristic of hybridization.
- **f4-ratio tests and fd statistics** measure the genomic extent of introgression.
- **Coalescent simulations** under varying Ne and divergence times allow researchers to model expected ILS patterns for comparison.
- **Genome-wide cline analyses** can differentiate hybrid zone processes from stochastic sorting of ancestral polymorphisms.

Crucially, ILS produces *random, symmetric allele sharing*, whereas introgression often generates *directional, locus-specific patterns*. Entomological studies commonly reveal both processes acting concurrently—for example, in the *Anopheles gambiae* species complex and in North American *Gryllus* crickets.

6.2.4 Consequences of ILS for Insect Phylogenomics and Taxonomy

ILS has major implications for evolutionary inference:

1. **Species delimitation complications.**
   In insects with weak morphological differentiation (e.g., many Chrysopidae, Aphididae, Cicadellidae), persistent ancestral variation can obscure species boundaries unless genomic and behavioral traits (e.g., courtship calls) are integrated.
2. **Trait evolution misinterpretation.**
   Discordant gene trees may falsely suggest convergent evolution or trait reversal if species tree uncertainty is not accounted for.
3. **Overestimation of hybridization.**
   When ILS is mistaken for introgression, researchers may infer “ghost” hybridization events that never occurred.
4. **Reduced resolution in phylogenomic datasets.**
   Even thousands of loci may not overcome the “anomaly zone”—conditions where the most common gene tree is not the true species tree.

Integrating genomic and acoustic data

Integrating genomic datasets with acoustic phenotypes has become a high-resolution framework for understanding diversification in insects—particularly in taxa where acoustic communication is a primary driver of mate recognition, sexual selection, and species boundaries. In many insect groups (Orthoptera, Hemiptera, Diptera, Neuroptera), acoustic signals evolve under a mixture of genetic, ecological and cultural/learned components, and may decouple from genome-wide divergence under certain evolutionary pressures. Thus, combining these two complementary data streams provides an essential multi-modal perspective on entomological speciation processes, behavioral ecology, and population structure (Stankowski et al., 2024; Ambu et al., 2024).

Conclusion

Genome skimming has become a transformative approach for resolving long-standing taxonomic and evolutionary questions in *Chrysoperla*. By enabling efficient recovery of complete mitogenomes, rDNA arrays, and high-copy nuclear elements from even minimal or degraded specimens, this method provides a robust foundation for addressing the persistent challenges of cryptic speciation, incomplete lineage sorting, and mitochondrial–nuclear discordance within the *carnea* group. When combined with emerging nuclear genomic datasets—such as UCEs, AHE loci, and whole-genome resequencing—genome skimming reveals that speciation in *Chrysoperla* is shaped by multilayered processes involving behavioral isolation, climatic oscillations, demographic complexity, and sex-biased gene flow.

Moving forward, integrative frameworks that synthesize genomic, acoustic, ecological, and morphological data will be essential for refining species boundaries and reconstructing the evolutionary history of this behaviorally unique genus. Standardizing genomic workflows, expanding mitogenome and rDNA sampling across the full Palearctic range, and increasing representation of type specimens should be prioritized to reduce taxonomic instability. Additionally, linking genomic variation with functional and behavioral traits—particularly the neural and sensory substrates underlying species-specific courtship duets—represents a major frontier in Neuroptera evolutionary biology. As sequencing technologies continue to advance, *Chrysoperla* is poised to serve as a model system for integrative insect systematics, offering unprecedented opportunities to explore how genomic architecture, behavior, and ecology interact to drive diversification.

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USE OF ZINC CHELATES IN REDUCING CADMIUM STRESS IN WHEAT

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ABSTRACT

Industrial activities, intensive use of chemical fertilizers and pesticides, and irrigation with contaminated water lead to cadmium (Cd) accumulation in agricultural soils, posing significant threats to both plant growth and human health. This study aimed to determine the effectiveness of zinc (Zn) chelates in alleviating Cd stress in the widely cultivated wheat cultivar *Triticum aestivum* L. cv. Gün-91 in Türkiye. Pot experiments were conducted under controlled greenhouse conditions using a sterilized perlite growth medium. Plants were exposed to 0, 10, and 20 mg/L Cd, followed by foliar applications of Zn-EDTA at concentrations of 0, 20, and 40 mg/L. Plant height, chlorophyll content (as measured by SPAD), dry weight, and spike dry weight were determined, and the data were statistically analyzed. The results showed that Cd did not significantly affect plant height in wheat but caused a significant reduction in chlorophyll content ($p < 0.05$). In contrast, Zn application, particularly under Cd stress, significantly increased plant height, dry weight, and spike dry weight. Among the treatments, the 20 mg/L Zn application was the most effective in promoting plant growth. These findings suggest that Zn chelate application may be a practical and effective strategy for improving wheat yield and physiological performance in Cd-contaminated agricultural soils.

Keywords: Cadmium stress, Zinc chelate, Wheat, Heavy metal toxicity

1. INTRODUCTION

Increased industrial activities, excessive and indiscriminate use of chemical fertilizers and pesticides, and the mixing of wastewater with irrigation water or its use as irrigation water are increasing cadmium (Cd) accumulation in agricultural soils. Cadmium accumulated in the soil can be transferred to the human body through plants grown in these soils, animal products obtained from animals fed on these plants, and drinking water, thereby damaging various organs, especially the kidneys (Kara & Kara, 2018). Excessive Cd intake in humans as a result

of agricultural production damages the lungs, kidneys, liver, bones, and heart; its accumulation causes emphysema, kidney and liver dysfunction, osteoporosis, and cardiovascular diseases.

For human Cd intake, the European Food Safety Authority (EFSA) has recommended a provisional tolerable weekly intake of a maximum of 2.5 µg per kg of body weight. The permitted Cd concentration in cereals varies from country to country (Zhou & Li, 2022). One of the most important factors in the emergence of the negative biological effects of cadmium is its mixing with the soil and its uptake by plants.

Cd is a mobile element, and Cd ions absorbed from the roots can be transported to the stem and leaves, thus affecting the edible parts of the plant. Cd has important physiological effects on plants, such as closing stomata, reducing transpiration and water loss, inhibiting enzymes involved in chlorophyll synthesis, and altering cell membrane permeability (Çılgın, 2022). Due to the vast amount of Cd-contaminated agricultural soils worldwide, cost-effective and practical solutions are needed for safe food production (Wu et al., 2020). One of the most basic needs of society is access to sufficient quantities of food with high nutritional value. In Turkey, cereal farming is carried out on 57.37% of the area allocated to field farming, and wheat constitutes approximately 59.75% of cereal production. Approximately 48.25% of production is used in human nutrition, and wheat constitutes 91.11% of human consumption among cereals (Güneş & Turmuş, 2020). Considering the production of cereals and their role in nutrition, as well as the extent of Cd-contaminated agricultural soils, the importance of studies aimed at reducing Cd accumulation in these products and increasing production becomes apparent. In this context, the aim of this research is to determine the effect of zinc chelates on Cd uptake in wheat and on Cd stress in selected plants, and to examine the effect of foliar-applied zinc chelates on Cd-stressed plants morphologically in terms of plant height, chlorophyll values, dry weight, and spike weights. For this purpose, pot experiments were conducted with *Triticum aestivum* L. cv. Gün-91, one of the most widely grown bread wheat varieties in Turkey, and zinc chelate (Zn-EDTA (Ethylenediamine Tetraacetic Acid)) was applied to wheat grown in perlite medium containing different levels of Cd. This study aimed to propose an alternative method for mitigating cadmium stress in a commonly cultivated wheat variety. The significance level of the relationship between the application dose of zinc chelates and the changes in the examined characteristics was statistically analyzed.

2. MATERIALS AND METHODS

Wheat seeds were obtained from the Field Crops Central Research Institute, Ankara. The research was conducted in a glass greenhouse at the Faculty of Agriculture, Kocaeli University. The plant arrangement in the greenhouse is shown in Figure 1. Sterilized perlite was used as the medium in the experiment. Equal volumes of perlite were placed in each pot, and wheat seeds were grown in perlite to ensure that each plant benefited from the same nutrients and that the variables could be better controlled. Three seeds were sown in each pot in sterilized perlite.

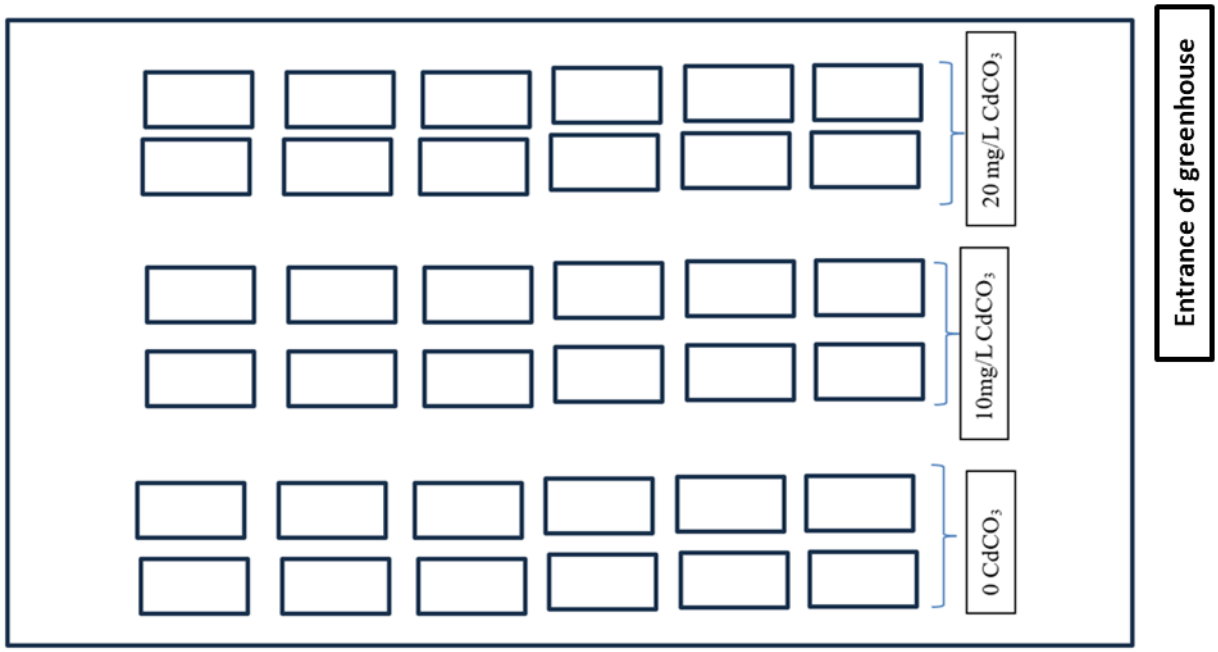


Figure 1. Plant arrangement in the greenhouse.

Hoagland nutrient solution was used as the nutrient solution (210 ppm nitrogen, 31 ppm phosphorus, 235 ppm potassium, 200 ppm calcium, 64 ppm sulfur, 48 ppm magnesium, 0.5 ppm boron, 5 ppm iron, 0.5 ppm manganese, 0.1 ppm zinc, 0.02 ppm copper, 0.01 ppm molybdenum) (Atlas & Sümer, 2016). Irrigation was carried out with 200 ml of water every two days, and Hoagland nutrient was added to the irrigation water. Electrical conductivity (EC) values were measured at regular intervals and kept within the appropriate range for plant growth. The effect of the Hoagland nutrient solution used on the EC values of the water for healthy plant development is shown in Table 1.

Table 1. EC values of the waters used in the study

	EC value (dS/cm)
Irrigation water	0.248
Irrigation water + nutrient solution	1.336

According to the US Salinity Laboratory salinity classification, water with a salinity of 0.1-0.25 dS/cm has low, 0.25-0.75 dS/cm has medium, 0.75-2.25 dS/cm has high, and 2.25-5 dS/cm has very high electrical conductivity values (Taşan, 2021). According to Table 1, it can be said that the irrigation water used in the study has a low EC value, while the irrigation water with added nutrient solution has a high EC value. It was determined that adding 4 ml/L of nutrient solution to the irrigation water significantly increased the EC value of the irrigation water. Since the use of nutrient solution is necessary in soilless cultivation, the drainage in the pots used was checked to try to tolerate the negative effect of the high EC value on plant development.

The experiment was designed to include full factorial (3×3) combinations of Cd (0, 10, 20 mg L^{-1}) and Zn-EDTA (0, 20, 40 mg L^{-1}) applications and was conducted in a split-plot design due to the arrangement required by the application method. Cd applications were applied as the main plot factor, and Zn applications as the subplot factor. A total of nine applications were obtained with the combination of these two factors, and each application was carried out with four replicates. The factorial design allowed for the evaluation of the main effects of Cd and Zn-EDTA, as well as the effects of the interaction between the two factors on the physiological and growth parameters of wheat (*Triticum aestivum* L., cv. Gün-91). Pots were randomly placed in the greenhouse. Cd was applied to the plants in the form of $CdCO_3$ (Cadmium carbonate) in a nutrient solution at doses of 0 mg/L (0 Cd), 10 mg/L (10 Cd), and 20 mg/L (20 Cd). The first Cd application was made 24 days after seed sowing at different concentrations in the nutrient-water mixture, and height measurements were taken. Stem length and chlorophyll content (SPAD) were measured during plant development. Chlorophyll measurements were taken from the three uppermost open leaves, and the values were recorded as averages of the three measurements. The second Cd application was made 31 days after seed sowing. To determine the difference in chlorophyll and height of the plants before and after cadmium application, chlorophyll and height measurements were taken again 13 days after the second Cd application.

Subsequently, to investigate the effect of Zn-EDTA on Cd stress, Zn-EDTA was applied to the leaves at different concentrations 20 days after the last Cd application. Zn-EDTA applications were performed on wheat three times at five-day intervals via foliar application at doses of 0 mg/L (0 Zn), 20 mg/L (20 Zn), and 40 mg/L (40 Zn). After the applications, wheat height was measured again, and the plants reached the harvest stage 82 days after sowing. Spike weight and dry weight of the harvested plants (Figure 2a) were evaluated on a group basis as total spike weight (Figure 2b) and total dry weight of wheat (Figure 2c) per treatment. For dry weight measurement, the harvested plants were placed in aluminium foil in an incubator and dried at 70 °C until a constant weight was reached. Differences between the obtained results were statistically analyzed using one-way analysis of variance with the SPSS software package, and evaluated using Duncan's Multiple Comparisons test at a significance level of 0.05.

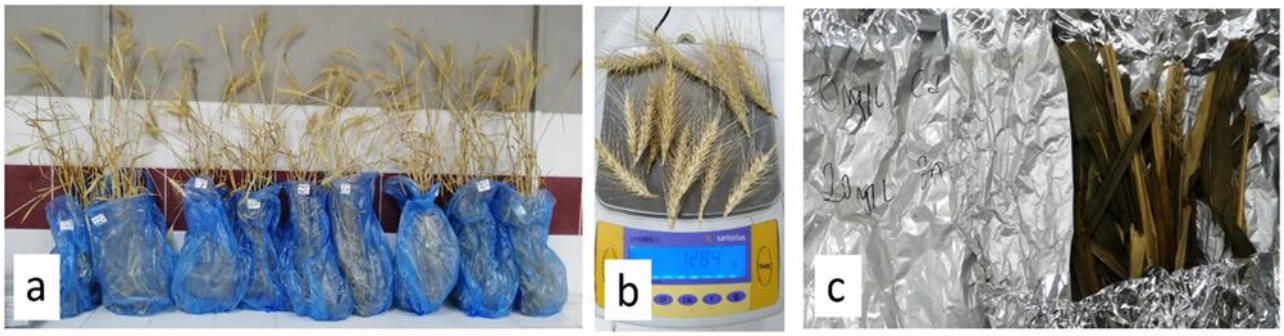


Figure 2. Harvest and post-harvest measurements of wheat. a) Wheat plants harvested at maturity and prepared for analysis; b) measurement of total spike weight per treatment group; c) determination of plant dry weight after oven-drying to constant weight.

3. RESULTS AND DISCUSSION

3.1. Height Measurement

Since different Cd concentrations were to be applied to the wheat plants, the pots were divided into three groups, and the average height of the plants in the same pot was taken. The height of the wheat plants before Cd application was compared between the groups. It was determined that the average height values of the groups ranged from 12-24 cm, and in the statistical evaluation performed at a 95% confidence interval, no statistically significant difference was found between the groups ($p = 0.25 > 0.05$). This result shows that the experimental groups were homogeneous in terms of plant height before Cd application and that the initial conditions were comparable. The developmental stages of the wheat plant are shown in Figure 3.

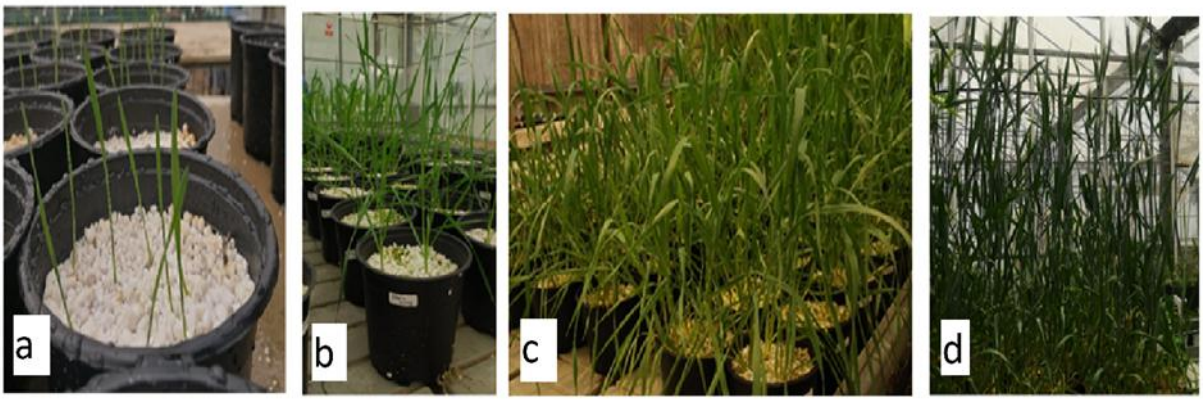


Figure 3. Growth stages of wheat plants at different time points. Photographs were taken at different growth stages on a) 02.06.2025; b) 15.06.2025; c) 08.07.2025; d) 26.07.2025.

Height measurements were not taken after the first Cd application. After the second Cd application, the height of wheat plants was compared between the control (0 mg/L Cd), 10 mg/L Cd, and 20 mg/L Cd application groups. In the control group, plant heights ranged from 50-64 cm, while in the 10 mg/L Cd group they ranged from 50-60 cm, and in the 20 mg/L Cd group they ranged from 50-61 cm. Despite the observed differences between the measurement values of the groups, considering the $p = 0.43$ value, the statistical analysis performed at a 95% confidence level ($\alpha = 0.05$) determined that Cd application doses did not have a significant effect on plant height ($p > 0.05$). This result shows that Cd application at these doses did not statistically significantly affect wheat plant height.

In the study conducted by Okutan-Hamarat (2019) regarding wheat plant height, it was stated that in wheat where Cd was applied in the form of $CdCl_2$ (cadmium chloride) at Cd concentrations of 2.81, 5.63 and 8.44 mg/L, root and shoot length development decreased in direct proportion to the Cd concentration (Okutan-Hamarat, 2019). In our study, although the Cd concentration was higher, it was concluded that the cadmium taken up by the plant did not have a significant effect on height. This may be related to the wheat variety used, or it may be due to the application of cadmium in a different form. In addition, it is thought that the application of cadmium carbonate in the nutrient solution may have affected the results due to the interaction of elements in the irrigation water. In the study, zinc application was performed foliarly at one-week intervals after Cd application; the effect of the application is shown in

Figure 4. When the effects of Cd and Zn applications on plant height in wheat were evaluated, it was observed that Zn application significantly increased plant height, especially under Cd stress. In the groups without Cd application (0 Cd), plant heights ranged from 59–90 cm, and no significant statistical difference was observed depending on the Zn dose ($p > 0.05$). In contrast, in the group treated with 10 mg/L Cd, Zn addition showed a significant effect on plant height; a statistically significant difference was found at the 95% confidence level between the 10 Cd-0 Zn group and both the 10 Cd-20 Zn and 10 Cd–40 Zn groups ($p = 0.01$). Similarly, in the groups treated with 20 mg/L Cd, Zn application significantly increased plant height, and highly significant differences were determined between the 20 Cd-0 Zn group and the 20 Cd-20 Zn and 20 Cd-40 Zn groups ($p = 0.00$). These results show that Zn application has a positive effect on wheat plant height under Cd stress conditions and can partially offset the negative effects of Cd. A study by Akay and Uzun (2019) reported that plant height and spike length increased significantly at a Zn dose of 8 mg/kg compared to the control group. Compared to the relevant literature, it can be said that Zn application up to 20 mg/L positively affects wheat height. When comparing the 0 mg/L, 10 mg/L, and 20 mg/L Cd samples, it is seen that Zn application has a positive effect on plant height. In conclusion, the findings obtained in this study reveal that Zn application significantly alleviates the negative effects of Cd stress on wheat plant height. The increase in plant height observed with Zn addition, especially in the Cd-treated groups, can be explained by Zn-Cd antagonism.

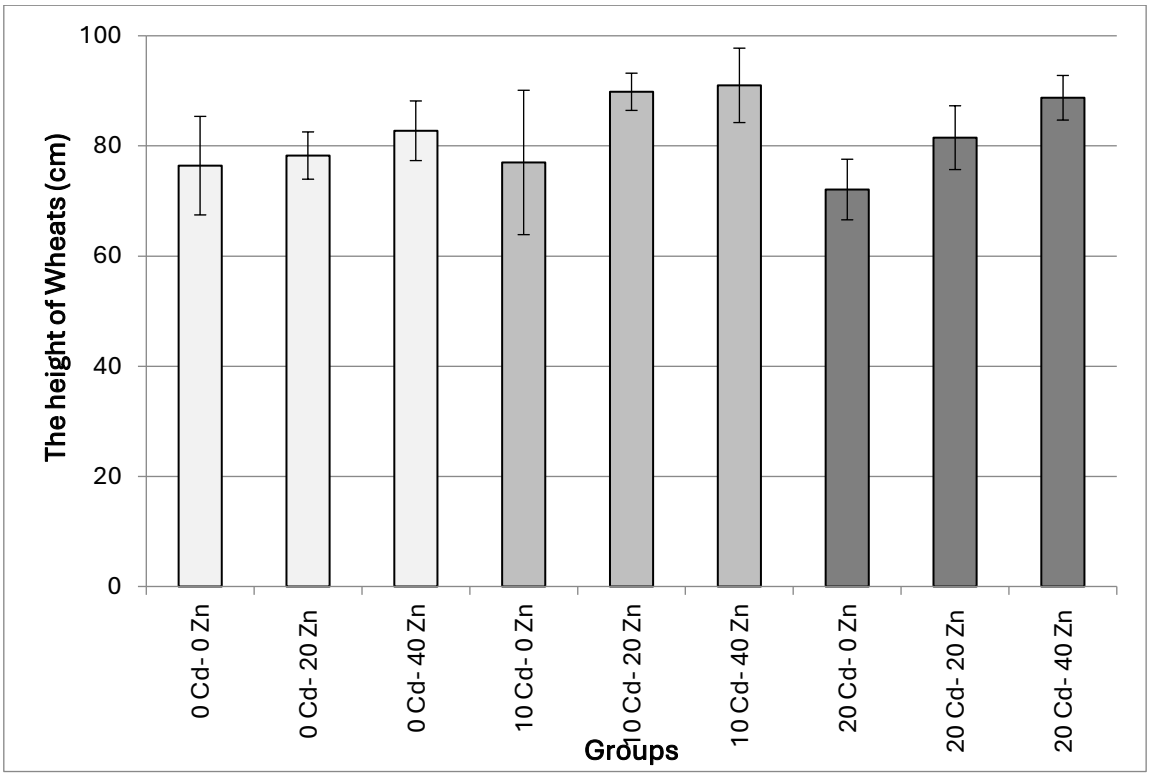


Figure 4. Plant heights in wheat samples treated with different concentrations of Cd and Zn. Data are presented as mean ± SD, n=12.

3.2. Chlorophyll Measurement

The effect of Cd application on chlorophyll content in wheat was evaluated using SPAD values (Figure 5). In the control group (0 mg/L Cd), chlorophyll values ranged from 47.1-56.3 SPAD, while in the group treated with 10 mg/L Cd, they ranged from 45.3–52.1 SPAD, and in the group treated with 20 mg/L Cd, they ranged from 44.1-50.5 SPAD. A decreasing trend in chlorophyll values was observed depending on Cd application, and as a result of the statistical analysis, statistically significant differences were found between the control group and both the 10 mg/L Cd and 20 mg/L Cd groups at a 95% confidence interval ($p = 0.001 < 0.05$). However, no significant difference was found between 10 mg/L Cd and 20 mg/L Cd administrations ($p > 0.05$).

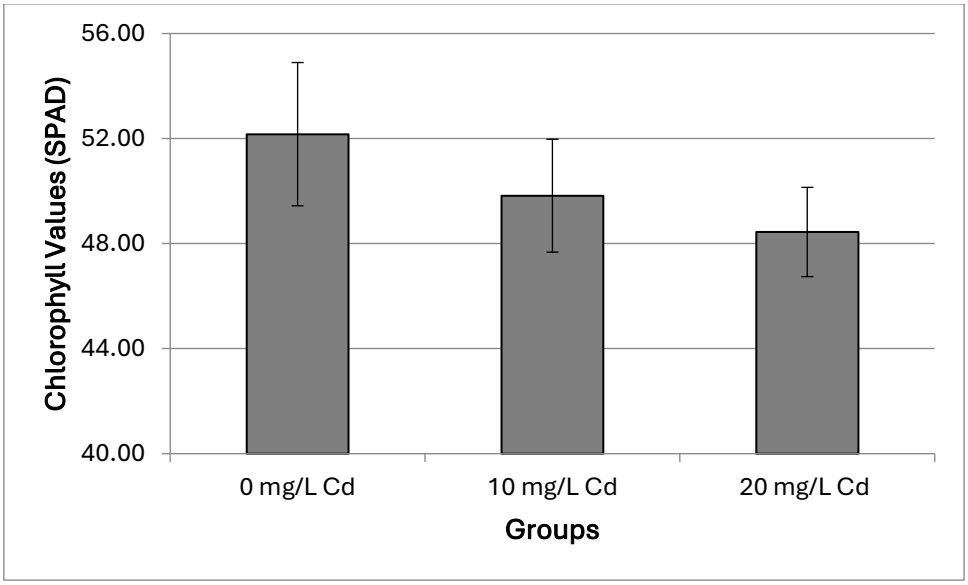


Figure 5. Chlorophyll values after cadmium application in wheat. Data are presented as mean ± SD, n=12.

These results show that Cd stress negatively affects chlorophyll content in wheat and that photosynthetic capacity is suppressed with increasing Cd doses. Images of wheat plants treated with different Cd doses are shown in Figure 6.

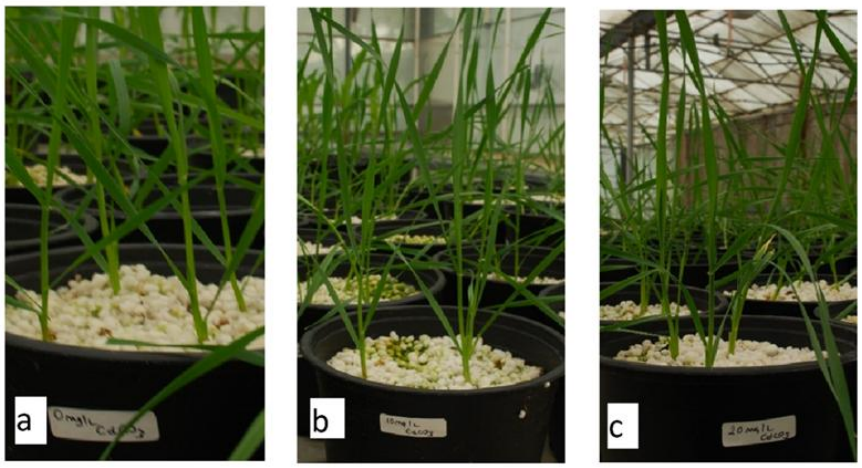


Figure 6. Effects of Cd treatments on wheat plant growth. a) Wheat plants grown without Cd treatment (0 mg /L, control); b) wheat plants treated with 10 mg/ L Cd; c) wheat plants treated with 20 mg/ L Cd.

In a study by Çılgın (2022), it was concluded that wheat plants exposed to 22.5 mg/L and 45 mg/L Cd stress were negatively affected in terms of leaf length, width, surface area, fresh and dry weight, and the total chlorophyll content decreased (Çılgın, 2022). This was explained by the inhibition of chlorophyll biosynthesis. In this study, the wheat variety used also showed a negative effect on chlorophyll content at lower Cd concentrations. In another study by Ci et al. (2010), it was stated that the effect of Cd application up to 2.25 mg/L on the decrease in chlorophyll content was slow; however, a sudden decrease in chlorophyll content occurred with Cd applications between 2.25 and 3.38 mg/L (Ci et al., 2010). Although this depends on the wheat variety, it can be said that the chlorophyll content begins to decrease with a Cd concentration of 2.25 mg/L.

Since the vegetation period of wheat was completed quickly after Cd application, the effect of zinc application on chlorophyll content in wheat could not be measured.

3.3. Dry Weight

After three repeated zinc applications, the dry weights of the harvested wheat were measured by an analytical balance when they had completed their development period and dried, and the measurement results are shown in Figure 7.

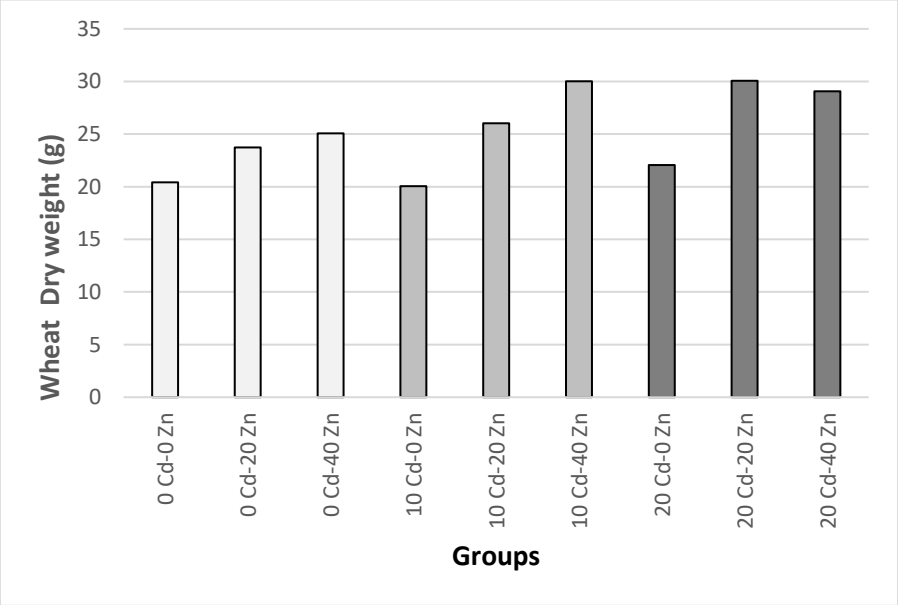


Figure 7. Comparison of dry weight in wheat samples treated with different concentrations of Cd and Zn. For each treatment group, dry weight was recorded as the cumulative weight of all wheat plants harvested (n=12).

When Figure 7 is examined, it is seen that there is no significant difference between the 0 Cd-0 Zn, 10 Cd-0 Zn, and 20 Cd-0 Zn samples. In this case, it can be said that Cd toxicity does not have a significant effect on the dry weight of wheat. However, when comparing the samples with and without Zn application, it is seen that Zn application positively affects the dry weight

of wheat. While increasing Zn application was more effective on dry weight in plants treated with 10 mg/L Cd; this effect was less significant in samples containing 20 mg/L Cd.

3.4. Effect of Zinc and Cadmium Application on Wheat Spike Weight

After three repeated zinc applications, the wheat harvested was measured with a balance when the wheat spikes had completed their development period and dried, and the measurement results are shown in Figure 8.

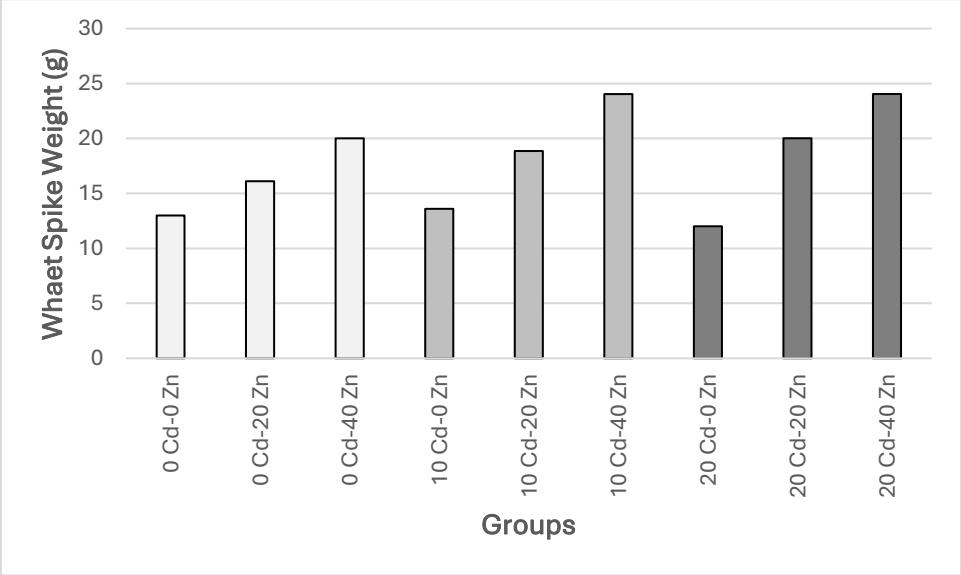


Figure 8. Wheat spike weights in wheat plant samples treated with different concentrations of Cd and Zn. For each treatment group, spike weight was recorded as the cumulative weight of all wheat spikes harvested (n=12).

According to Figure 8, it can be said that when comparing 10 Cd-0 Zn and 20 Cd-0 Zn samples with 0 Cd-0 Zn samples, the amount of Cd does not have a significant effect on grain weight. However, it is clearly seen that the spike weight in the zinc-containing samples is higher than in the zinc-free samples; therefore, it can be said that zinc application increases grain yield in wheat. Zinc is vital for many physiological processes in wheat, including enzyme activation, protein synthesis, and nucleic acid and carbohydrate metabolism. It is also an integral part of many proteins in plants, as a structural component of Zn finger proteins that control cell differentiation and proliferation. Zinc fertilization increases the protein content and quality of wheat grains by increasing albumin, glutenin, gliadins, and globulin concentrations (Rehman et al., 2018). In a study by Dhaliwal et al. (2019), it was reported that foliar zinc application increased grain yield by up to 5.22% and the zinc content in the grain by 29.3 to 62.4 mg kg-1 in bread wheat, triticale, and durum wheat varieties (Dhaliwal et al., 2019). A study by Akay and Uzun (2019) also found that zinc application increased grain yield (Akay & Uzun, 2020). However, a study by Ivanovic et al. (2021) indicated that a single application of zinc to the leaves did not increase grain yield but increased the zinc content in the grains; suggesting that zinc application to wheat could be beneficial in providing the zinc necessary for the human body (Ivanović et al., 2021). Considering these results together, it can be said that repeated zinc

application is effective in increasing grain yield. If the soil has sufficient zinc content, foliar zinc chelates may have more effect on the amount of Zn in the grains than on grain yield.

4. CONCLUSION

In conclusion, this study found that foliar zinc chelate applications against Cd toxicity had positive effects on wheat plants in terms of plant height, chlorophyll content, weight of spikes, and plant dry weight. Literature reports that Zn competes with Cd during root uptake, limits Cd transport via the xylem, and reduces Cd toxicity by stimulating the synthesis of metallothioneins and phytochelatins within cells (Clemens, 2006; Hasan et al., 2009). Furthermore, it has been reported that Zn reduces Cd-induced oxidative stress by increasing the activity of antioxidant enzymes such as superoxide dismutase, catalase, and peroxidase, and protects cell division and elongation (Broadley et al., 2007; Cakmak, 2000). In this context, the significant differences determined between the 10 Cd–0 Zn group and the 10 Cd–20 Zn and 10 Cd–40 Zn groups ($p = 0.01$), and between the 20 Cd–0 Zn group and the 20 Cd–20 Zn and 20 Cd–40 Zn groups ($p = 0.00$), support the idea that Zn balances Cd-dependent growth suppression through antagonistic mechanisms. Similarly, it is consistent with previous studies that Zn maintains cell membrane integrity and supports plant growth by sustaining photosynthetic capacity (Cakmak, 2000; Rizwan et al., 2017). These results demonstrate that Zn supplementation may be an effective strategy for improving wheat development in Cd-contaminated environments.

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PLANT DISEASES CAUSED BY *Rhizopus oryzae*

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ABSTRACT

Rhizopus oryzae, a member of the order Mucorales, has long been recognized as a saprophytic fungus; however, increasing evidence demonstrates its significant role as an aggressive plant pathogen affecting a wide range of crops. This review summarizes recent reports documenting the involvement of *R. oryzae* in economically important plant diseases, including fruit rot, leaf blight, root rot, seedling wilt, and postharvest decay. The pathogen has been associated with diverse hosts such as wheat, tobacco, pumpkin, strawberry, pak choy, sunflower, mulberry, cassava, citrus, ornamental plants, and several vegetable and fruit crops across Asia, Africa, and Europe. Pathogenicity studies consistently fulfill Koch's postulates and reveal that disease development is often facilitated by wounds, high humidity, and postharvest handling practices. The virulence of *R. oryzae* is closely linked to its ability to rapidly colonize host tissues through the production of extracellular lytic enzymes, leading to extensive cell wall degradation and tissue maceration. This review emphasizes the emerging importance of *R. oryzae* as a phytopathogen and underscores the need for improved disease surveillance, accurate diagnostics, and integrated management strategies to reduce crop losses caused by this opportunistic yet destructive fungus.

Keywords: *Rhizopus oryzae*, Plant pathogenic fungi, Postharvest diseases

1. INTRODUCTION

Rhizopus, in particular, is a versatile fungus that functions as both a saprotrophic decomposer. *Rhizopus* species are extensively dispersed in soil and plant habitats, and they are renowned for their diverse metabolic profiles. They may produce a number of extracellular enzymes, including lipases and cellulases, which help with organic matter decomposition and nutrient mineralization (Agbor et al., 2021; Torres et al., 2003).

Through submerged fermentation and biotransformation, *Rhizopus* species generate a range of industrial products, such as enzymes (lipases, proteases, glucoamylase, and celluloytic enzymes), organic acids (lactic acid, fumaric acid), steroids, terpenoids, and alkoloids, pesticides and herbicides, and antibiotics (Londoño-Hernández et al., 2017; Meussen et al., 2012). While some species in this genus are used as fermentation agents in traditional cuisines or as manufacturers of industrially significant enzymes and metabolites, others can cause to plant diseases that harm crops (Muszewska et al., 2014). Some of them significantly harm post-harvest agricultural produce by degrading the flavor and attractiveness of crops, especially strawberries and sweet potatoes (Tournas, 2005).

Reports from different geographical regions indicate that this fungus is responsible for pre- and postharvest diseases, leading to severe yield losses and reduced market quality. This review summarizes current knowledge on the host range, disease symptoms, pathogenic mechanisms, and management strategies related to *R. oryzae*–induced plant diseases.

2. TAXONOMY, MORPHOLOGY, AND GENERAL CHARACTERISTICS

Rhizopus species are classified in the order of Mucorales in the phylum Mucoromycota. They are filamentous fungi with a network of branching hyphae, such as stolons, rhizoids, and sporangiophores (Figure 1) (Gryganskyi et al., 2018; Jerez Lazo et al., 2024). On potato dextrose agar (PDA), colonies usually develop quickly, becoming fluffy and cotton-like within five days. The sporangiospores are initially white, but as they mature, they progressively become brown. Sporangiospores are short-ellipsoidal, and apophyses, columellae, pigmented rhizoids, and sporangiophores frequently collapse to produce an umbrella-like structure. These hyphae create a mycelial network that is necessary for the absorption and delivery of nutrients, and *R. oryzae*, mainly known as a lactic acid producer, generates long networks, which enables it to flourish on a greater variety of substrates (Gryganskyi et al., 2018; Jerez Lazo et al., 2024).



Figure 1. *R. oryzae* morphology. A: The emergence of colonization on PDA during a seven-day incubation period; B: Sporangium; C: Columella; D: Sporangiospores; E: Rhizoids (Kwon et al., 2011).

3. DISEASE SYMPTOMS AND HOST RANGE

Disease symptoms caused by *R. oryzae* generally include water-soaked lesions, soft rot, tissue maceration, rapid decay, and the development of gray to black fungal growth. In many cases, infection is strongly associated with wounds caused by harvesting, handling, or insect damage. High humidity and warm temperatures lead to rapid colonization and disease progression, particularly in postharvest environments.

The host range of *R. oryzae* is remarkably broad. It has been reported to cause fruit rot in pumpkin, strawberry, wild peach, pear (Li et al., 2023), citrus (*Citrus medica*) (Manghwar et al., 2015), yellow oleander (Arif et al., 2017), apple (Kwon et al., 2011), tomato (Liaquat et al., 2019) (Figure 2) across different countries such as China, Pakistan, and Korea. According to Patel et al. (2020), fruit rot has a significant negative impact on fruit quality and economic value. In extreme circumstances, it can even result in plant mortality (Patel et al., 2020). Understanding the processes behind fruit softening and disease development in harvested fruits is crucial to extending their shelf life (Li et al., 2023).

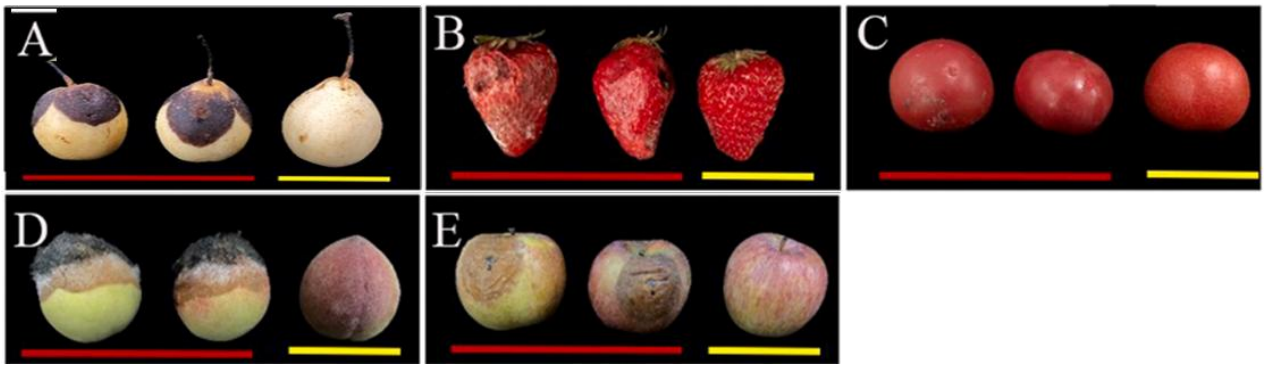


Figure 2. Fruit rot on common fruits is caused by *R. oryzae*. A: White pear. B: Strawberry (*Fragaria ananassa* Duch.). C: Tomato (*Solanum lycopersicum* L.). D: Wild peach (*Amygdalus persica* L. Batsch). E: Apple (*Malus pumila* Mill.). The yellow line in each image represents the control fruits, whereas the red line represents the *R. oryzae*-inoculated diseased fruits (Li et al., 2023).

In 2022, an uncommon postharvest fruit rot of pumpkin (*Cucurbita moschata*) was observed in China (Figure 3), and the causal agent was identified as *R. oryzae* based on morphological, molecular, and phylogenetic analyses, representing the first report of this pathogen on pumpkin in the country (Li et al., 2023).



Figure 3. The appearance of *R. oryzae*-infected pumpkin fruit A: Pumpkin fruit rot symptoms in commercial storage facilities. B and C: *R. oryzae*-inoculated pumpkin fruit. D: *R. oryzae*-infected pumpkin fruit appearance after 72 hours (Li et al., 2023).

In 2017, leaf rot symptoms were observed on pak choy (*Brassica campestris* ssp. chinensis) grown in greenhouses in China (Figure 4) (Arif et al., 2019). The causal agent was isolated and identified as *R. oryzae* through morphological characteristics and rRNA gene sequence analysis, showing 99% sequence similarity. Pathogenicity tests confirmed the fungus as the disease agent by fulfilling Koch's postulates, marking the first report of *R. oryzae* causing leaf rot on pak choy in China.



Figure 4. Typical disease symptoms of pak choy caused by *R. oryzae* were observed after A: 4 days, B: 6 days and C:8 days after inoculation (Arif et al., 2019).

Milky white leaf spots were observed on red bean plants in a cultivation area in Korea (Figure 5) (Lee et al., 2023). The causal agent was isolated, morphologically and molecularly identified as *R. oryzae*, and its pathogenicity was confirmed through reinoculation tests that reproduced the original symptoms. Based on these findings, the disease was identified as a previously unreported case of red bean brown leaf blight caused by *R. oryzae*.



Figure 5. Symptoms of red bean abnormalities caused by *R. oryzae*. A: Initial, B: middle, and C: final symptoms (Lee et al., 2023).

Moreover, root rot have been reported in mulberry (Gnanesh et al., 2020). Gnanesh et al. (2020) collected rotted root samples from the mulberry gardens from four states of Southern India. The majority of the isolates identified were *R. oryzae* (Figure 6).

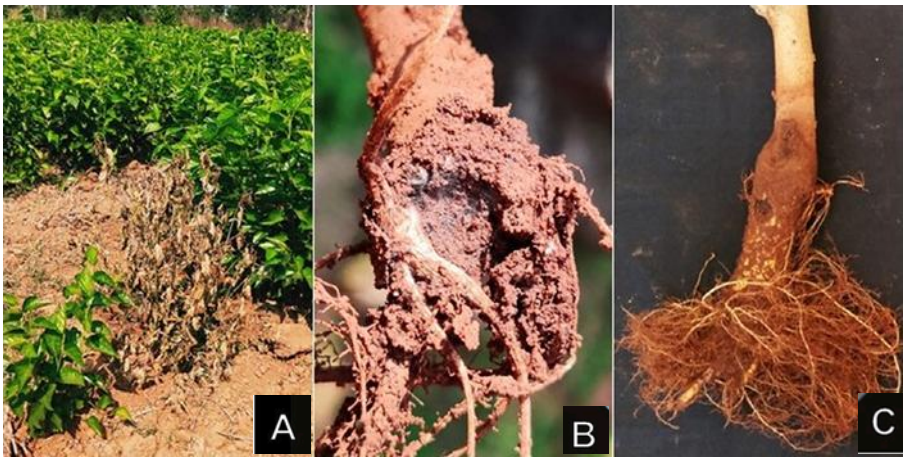


Figure 6. The disease symptoms of Rhizopus rot of mulberry caused by *R. oryzae* A: Infested mulberry plant along with the healthy plants in farmers field; B: Close up view of diseased mulberry roots; C: Healthy mulberry roots (Gnanesh et al., 2020).

A study provides the first confirmed report of *R. oryzae* causing seedling wilt and death in sunflower (*Helianthus annuus*) in Kazakhstan (Figure 7). The pathogen was isolated from seeds of different sunflower hybrids and identified using a combination of morphological characteristics and molecular approaches, including ITS sequencing and gene-specific PCR assays. Pathogenicity was verified through re-inoculation experiments, which reproduced typical symptoms such as brown lesions, tissue desiccation, and gray mold. Phylogenetic analyses showed high similarity with known *Rhizopus* species (Uakhit et al., 2025).

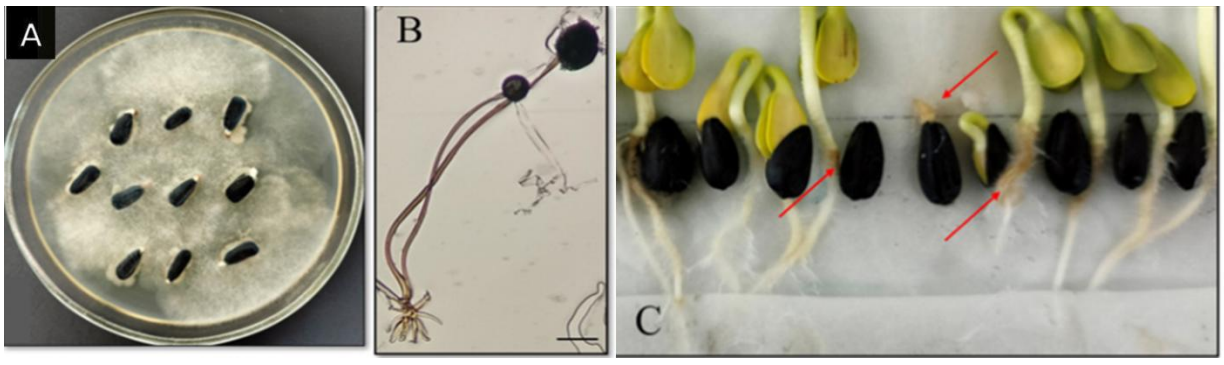


Figure 7. Morphological characteristics and growth features of the causative agent of *R. oryzae*: A: colonies after 7 days at 28°C on PDA; B: microscopic characters of *R. oryzae* (mycelium and sporangiospores); C: Growth results in rolls on the 7th day (arrows indicate lesion sites) (Uakhit et al., 2025).

In addition, *R. oryzae* is a major postharvest pathogen of flue-cured tobacco, where it causes tobacco pole rot during curing, sometimes resulting in losses approaching 100% under favorable conditions. The pathogen primarily infects through wounds formed during harvest and handling (Kortekamp, 2007).

4. PATHOGENICITY AND VIRULENCE FACTORS

Pathogenicity assays consistently demonstrate that *R. oryzae* fulfills Koch's postulates in diverse host plants. The fungus exhibits aggressive colonization of host tissues, which is largely attributed to its ability to produce a wide array of extracellular lytic enzymes. These include cutinases, polygalacturonases, pectinesterases, pectin lyases, cellulases, hemicellulases, and β-galactosidases. The concerted action of these enzymes leads to rapid degradation of plant cell walls, tissue softening, and nutrient release, facilitating fast fungal growth. For example, pumpkin fruit rot is primarily caused by *R. oryzae*, which increases the activity of cell wall-degrading enzymes (pectinesterases, pectin lyases) in pumpkin fruit. This accelerates the breakdown of key cell wall components, reducing fruit hardness, softening, and decay while also speeding up *R. oryzae*'s further growth (Li et al., 2023).

5. DISEASE MANAGEMENT STRATEGIES

Management of diseases caused by *R. oryzae* relies on an integrated approach. Chemical fungicides such as azoxystrobin, pyraclostrobin and other commercial formulations demonstrating strong inhibitory effects on mycelial growth, sporangiospore germination, and disease severity in pumpkin and tobacco (Kortekamp, 2007; Kortekamp et al., 2003; Li et al., 2023). Calcium-based salts, especially calcium chloride, were also effective in reducing disease development, either alone or in combination with other treatments (Kortekamp, 2007). Biological control strategies have gained increasing attention, with fluorescent pseudomonas significantly suppressing Rhizopus rot in tobacco, particularly when combined with calcium treatments (Kortekamp, 2007). In addition, plant-derived extracts from *Piper nigrum*, *Aframomum meleguata*, *Ageratum conyzoides*, *Azadirachta indica*, *Cymbopogon citratus*, and *Ocimum gratissimum* showed strong antifungal activity against *R. oryzae* both *in vitro* and *in vivo*, highlighting their potential as eco-friendly alternatives for storage disease management (Amadioha, 2008; Amadioha & Markson, 2007). Novel approaches such as chitosan–iron oxide nanoparticles also exhibited high antifungal efficacy against *R. oryzae* causing fruit rot in strawberry, suggesting promising applications of nanotechnology-based control strategies (Saqib et al., 2019). Physical control methods, such as the combined application of UVC irradiation and ethanol treatment, were found to effectively inactivate *R. oryzae* spores, with the combined treatment producing synergistic effects and significant reductions in spore viability (Özer Uyar & Uyar, 2019). Furthermore, cultural and preventive strategies, such as minimizing mechanical injuries, intercropping host and non-host plants, and monitoring seed and planting material health, were emphasized as essential components of integrated disease management programs (Li et al., 2023; Uakhit et al., 2025). Overall, the literature supports the use of integrated approaches combining chemical, biological, physical, and cultural methods for sustainable management of *R. oryzae*-induced diseases.

6. CONCLUSIONS

Collectively, available evidence clearly establishes *R. oryzae* as an important and emerging plant pathogen with a broad host range and significant economic impact. Advances in molecular diagnostics and genomics have greatly improved our understanding of its taxonomy, pathogenicity, and adaptive potential. Future research should focus on elucidating host–

pathogen interactions at the molecular level, identifying key virulence determinants, and developing sustainable, integrated disease management strategies. Improved surveillance and accurate identification are essential to mitigate the growing threat posed by *R. oryzae* to global crop production.

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YENİ KONSERVELİK BEZELYE ÇEŞİTLERİNİN EGE VE MARMARA BÖLGESİNDEKİ PERFORMANSLARININ DEĞERLENDİRİLMESİ

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ÖZET

Küresel iklim değişikliği ve doğal kaynakların azalması, tarımsal üretimde birim alandan yüksek verim alırken çevresel sürdürülebilirliği de gözeten tarım sistemlerinin de önemini artırmıştır. Yeni ıslah edilen çeşitlerin ekolojik koşullara uygunluğu, yüksek verim ve kalite, endüstriyel işlenebilirlik özellikleri taşıması gibi birtakım kriterlere sahip olması yanı sıra sürdürülebilir tarım sistemlerinde de kullanılabilir olması arzu edilir. Bu bağlamda Bezelye, *Rhizobium* bakterileri ile kurdukları simbiyotik ilişki sayesinde bitkisel üretimde kimyasal gübre ihtiyacını azaltması özelliği ile sürdürülebilir tarımda önemli sebze türlerinden biridir. Bezelye bu özelliği ile iyi bir münavebe bitkisidir. Kendisinden sonra gelen bitkiler için de ideal bir toprak ortamı yaratmaktadır.

Bu çalışma, Türkiye'nin önemli sebze üretim merkezlerinden biri olan Küçük Menderes Havzası ile Bursa bölgesinde sanayi ve dondurulmuş gıda sektörüne yönelik geliştirilen yeni bezelye (*Pisum sativum* L.) çeşitlerinin adaptasyon yeteneklerini belirlemek amacıyla yürütülmüştür. Bitkisel materyal olarak, "SVQ0823G" ve "Romance" çeşitleri ile günümüz bezelye üretim bölgelerinde genel olarak tercih gören Bogie çeşidi kullanılmıştır. Çalışma, her iki lokasyonda da üretici tarlalarında ve tesadüf blokları deneme desenine göre 3 tekerrürlü kurulmuş, her parselde 50 adet bitki bulundurulmuştur. Çalışmada bitki boyu (cm), bitkideki bakla sayısı (adet/bitki), tane verimi (g/bitki; kg/da), tane iriliği (adet/g) ve sanayi kalitesi için kritik öneme sahip tenderometre değerleri incelenmiştir.

Elde edilen verilerin değerlendirilmesi sonunda, en yüksek dane verim değeri (554,44 kg/da) Bursa bölgesinden elde edilmiştir. Yine çalışmada yer alan her 3 çeşidin de verim değeri yine aynı bölgede en yüksek bulunmuştur. Bursa bölgesinde SVQ0823G çeşidi yüksek bitki boyu (70,27 cm), yüksek sayıdaki salkım sayısı (5,17 adet/bitki) ve toplam çiçek sayısı (14,67 adet/bitki) ile ön plana çıkmıştır. Bu gelişimi ile de adı geçen çeşit (SVQ0823G) en yüksek dane verimi (564,77 kg/da) değeri göstermiştir. Yine SVQ0823G çeşidinin her iki lokasyonda da yüksek verim değeri göstermesi adı geçen çeşidin günümüz gıda sanayisine uygunluğu açısından umut verici bir alternatif oluşturduğu görülmüştür.

Anahtar Kelimeler : bezelye, çeşit, adaptasyon, verim, kalite

AGRICULTURAL RESIDUES AS A REGIONAL ENERGY RESOURCE: BIOMASS ENERGY POTENTIAL OF MANİSA PROVINCE

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ABSTRACT
The aim of this study is to determine the number of agricultural residues in Manisa province and the amount of energy that can be produced from these residues. The province of Manisa is located within the Aegean Region of Turkey and is further divided into a total of 17 districts, of which two are central districts. The quantity of residues obtained from a selection of agricultural products commonly cultivated in the Manisa province was calculated using production data and tree presence data for the year 2024. The annual potential of agricultural residues was calculated using the residue rate and the amount of crops or number of trees. The energy potential of residues for each district was calculated by multiplying the calorific value of agricultural residues by the amount of usable residues. The total amount of agricultural residues based on the products commonly cultivated in the province was determined as approximately 953.67 kt per year. The total calorific value of these agricultural residues was calculated as 17,441.13 TJ. When the districts are ranked according to the amount of agricultural residues, the first three districts are Akhisar (167.93 kt), Saruhanlı (151.90 kt) and Salihli (115.51 kt). According to the total heating values, the main crop residues were vineyard pruning residues (30.8%), olive pomace and pruning residues (30.4%) maize residues (15.4%) and cotton residues (12.3%).

Keywords: Biomass Energy, Agricultural Residues, Manisa

BÖLGESEL ENERJİ KAYNAĞI OLARAK TARIMSAL ARTIKLAR: MANİSA İLİNİN BİYOKÜTLE ENERJİ POTANSİYELİ

ÖZET
Bu çalışmanın amacı Manisa ilinde tarımsal artıkların miktarını ve bu atıklardan üretilebilecek enerji miktarının belirlemektir. Manisa ili, Türkiye'nin Ege Bölgesi'nde 2 adet merkez ilçe olmak üzere toplam 17 ilçesi bulunan bir ilidir. Manisa ilinde yoğun olarak yetiştirilen bazı tarım ürünlerinden elde edilen artık miktarları, 2024 yıllarına ait üretim verileri ve ağaç varlığı verileri kullanılarak hesaplanmıştır. Tarımsal artıkların yıllık potansiyeli, artık ürün oranı ve ürün miktarı veya ağaç sayıları kullanılarak hesaplanmıştır. Her ilçe için artıkların enerji potansiyeli, tarımsal artıkların ısıl değerlerinin kullanılabilir artık miktarı ile çarpılmasıyla hesaplanmıştır. İlde yoğun olarak yetiştiriciliği yapılan ürünlerin baz alındığı toplam tarımsal artık miktarı yıllık yaklaşık 953.67 kt olarak belirlenmiştir. Bu tarımsal artıkların toplam ısıl değeri 17,441.13 TJ olarak hesaplanmıştır. İlçeler tarımsal artık miktarına göre sıralandığında, ilk üç ilçe Akhisar (167.93 kt), Saruhanlı (151.90 kt) ve Salihli (115.51 kt) olarak belirlenmiştir.

Toplam ısıl değerlere göre başlıca ürün artıkları bağ budama artığı (%30,8), zeytin posası ve budama artığı (%30,4), mısır artıkları (%15,4) ve pamuk artıkları (%12,3) şeklinde sıralanmıştır.

Anahtar Kelimeler: Biyokütle Enerjisi, Tarımsal Artıklar, Manisa

1. INTRODUCTION

Energy is central to economic development, and there is a clear correlation between energy consumption and living standards. Energy sources are split into three categories: fossil fuels, renewable sources and nuclear sources (Karaca, 2015). Fossil fuels are limited resources, collected in few regional areas of the world.

Turkey is an agricultural country, with special emphasis on the Central Anatolia, Çukurova and Southern Anatolia regions, and has significant forestry potential. Agricultural waste is a major source of biomass due to its high potential (Karaca and Başçetinçelik, 2014). Biomass energy includes agricultural residues, domestic waste, fuelwood, animal waste and other fuel derived from biological sources (Başçetinçelik et. al. 2006). Agricultural residues are defined as a biomass by-product from the agricultural system and include straws, husks, shells, and stalks. These residues can be divided into two groups: crop residues, which remain in the field after harvest including cotton stalk, and agricultural residues, which are the by-products of the industrial processing of crops such as rice husk (Karaca, 2015).

The objective of this study is to determine the biomass potential derived from agricultural residues in Manisa province and to quantify the corresponding energy value. The utilization of agricultural biomass offers significant environmental advantages, including the mitigation of greenhouse gas emissions, the preservation of natural resources, and the reduction of dependence on fossil fuels. These environmental gains are further supported by notable economic benefits, such as decreased reliance on imported energy sources, enhanced regional development, and increased investment opportunities.

2. MATERIALS AND METHODS

The province of Manisa is located within the Aegean Region of Turkey and is further divided into a total of 17 districts, of which two are central districts. The districts of Manisa province are Ahmetli, Akhisar, Alaşehir, Demirci, Gölmarmara, Gördes, Kırkağaç, Köprübaşı, Kula, Salihli, Sarıgöl, Saruhanlı, Selendi, Soma, Turgutlu, Yunusemre and Şehzadeler.

The province has 5,039,626 decare of agricultural land. The agricultural land consists of 49.2% orchards, 41.8% field crops, 6.6% vegetable production, and the remaining areas are fallow lands. The most important crops grown throughout the province are wheat, barley, maize, cotton, tobacco, grapes, cherries and olives (TURKSTAT, 2025a).

The quantity of crop residue in Manisa province was determined through the calculation of data pertaining to the production of crops, as reported by the Turkish Statistical Institute for the 2024 season. (TURKSTAT, 2025b). The annual gross potential of agricultural residues was determined by calculating the residue-to-product ratio (RPR) (Table1). The net potential of residues was determined by using the availability of residues. The availability of residues refers entirely to the unused portion of the residues. (Table1). The available potential of the agricultural residues in each district of Manisa was calculated using the Eq.1. (Karaca, 2015)

$$(AAR)_I = (AAP)_I \times (RPR)_I \times (A)_I \quad (1)$$

where $(AAR)_I$ is the available amount of agricultural residues of I^{th} crop in ton, $(AAP)_I$ the amount of agricultural product in tons or number of tree for pruning wastes, $(RPR)_I$ residue-to product ratio of the I^{th} crop and $(A)_I$ the availability of residues.

Agricultural residues are materials left in the field after agricultural production. Some of these residues are used for domestic purposes such as heating, animal feed or bedding. The main agricultural residues are divided into two categories: residues in the field during the agricultural production process and industrial residues generated after the processing of agricultural products. These include corn stalks, sunflower stalks, grain straw, pruning residues, etc.

The energy potential of each district's residual materials was determined through a calculation process involving the multiplication of the heating values of a selection of agricultural residues. The heating value of each residue was determined according to the values presented in Table 1, and the available residue amount was then considered in the subsequent calculation. (Eq. 2). (Karaca, 2015)

$$(THV)_i = (AAR)_i \; x \; (LHV)_i \qquad (2)$$

where $(THV)_i$ the total heating value of agricultural residues of i^{th} crop in GJ, $(AAR)_i$ is the available amount of agricultural residues of i^{th} crop in tons and $(LHV)_i$ lower heating value of air-dry residues of i^{th} crop in MJ kg^{-1}.

The energy content of the selected products for each district was calculated using the above equations. For each district, the calculated values that the total amount and the total energy potential of agricultural crop residues were mapped using the GIS software. The produced maps were provided to see more clearly in the differences of data among the districts. The mapping can provide the rise of public awareness and policy-makers reference about these subjects.

Table 1. The ratio of product to residue, availability and heating values of a selection of agricultural crop residues (Başçetinçelik et. al., 2006; Bilandzija et. al., 2012; Karaca, 2015)

Field Crops	Residues	Ratio of Product to Residue (*RPR*)	Availability (*A*) (%)	Heating Value (*LHV*) (MJ kg^{-1})
Wheat	Straw	1.50	15	17.9
Barley	Straw	1.50	15	17.5
Rye	Straw	1.00	15	17.5
Oats	Straw	1.00	15	17.4
Chickpea	Straw	1.10	60	18.1
Maize	Stalk	2.00	60	18.5
	Cob	0.30	60	18.4
Tobacco	Stalk	2.28	60	16.1
Sunflower	Stalk	3.00	60	14.2
Cotton	Stalk	2.00	60	16.7
	Ginning residues	0.30	60	13.0
Fruit Crops				
Apple	Pruning	2.50*	80	17.0
Pear	Pruning	2.50*	80	16.7
Apricots	Pruning	5.80*	80	19.3
Sweet cherry	Pruning	5.90*	80	16.7
Peach	Pruning	7.00*	80	19.4
Plum	Pruning	7.00*	80	17.3

Almonds	Pruning	5.80*	80	18.4
Walnuts	Pruning	3.50*	50	19.0
Pomegranate	Pruning	9.00*	80	17.0
Fig	Pruning	4.50*	80	15.8
Vineyard	Pruning	425**	80	18.0
Olive	Pomace	0.40	90	19.7
	Pruning	9.00*	50	18.1

* RPR kg/tree
** RPR kg/da

3. RESULT AND DISCUSSION

The total amount of agricultural residues, including field crop residues (grains, maize, cotton, tobacco) and orchard residues (tree pruning) were calculated to be about 953,671 tons in Manisa (Table 2). Its distribution by the source is fruit crops (63%) and field crops (37%). The main products with the largest share of the total residue amount were determined to be vineyard (31.3%), olive (29.2%), maize (15.2%) and cotton (12.3%).

Table2. The amount of agricultural product and available residues of Manisa

Field Crops	**Amount of Agricultural Product (*AAP*) (tons)**	**Residues**	**Available Residues (*AAR*) (tons)**
Wheat	216,089	Straw	48,620
Barley	74,545	Straw	16,773
Rye	7,348	Straw	1,102
Oats	5,308	Straw	796
Chickpea	1,664	Straw	1,098
Maize	105,073	Stalk	126,088
	105,073	Cob	18,913
Tobacco	11,931	Stalk	16,322
Sunflower	3,163	Stalk	5,693
Cotton	81,684	Stalk	98,021
	81,684	Ginning residues	19,604
Fruit Crops	**Number of trees / Planting area**		
Apple	202,281*	Pruning	405
Pear	205,323*	Pruning	411
Apricots	205,237*	Pruning	952
Sweet cherry	2,140,349*	Pruning	10,102
Peach	348,781*	Pruning	1,953
Plum	553,421*	Pruning	3,099
Almonds	839,965*	Pruning	3,897
Walnuts	867,971*	Pruning	1,519
Pomegranate	132,880*	Pruning	957
Fig	133,108*	Pruning	479
Vineyard	877,598**	Pruning	298,383
Olive	435,892	Pomace	156,921
	27,013,773*	Pruning	121,562
	TOTAL	**Residues**	**953,671**

* Number of trees
** Planting Area (da)

When all districts of Manisa are aligned according to the amounts of residue, an alignment is achieved, as illustrated in Table 3. Also, the distribution of these calculated residue amounts on the map and the pie charts showing the shares of the crops that constitute the residue in each district are given in Figure 1.

It is evident from the results that, Akhisar (167.93 kt) is the district with the highest agricultural residue potential in Manisa province. Additionally, a substantial agricultural residue potential has been observed in Saruhanlı (151.9 kt) and Salihli (115.61 kt). It is apparent that there will be no shortage of raw materials for the facilities to be established in these three regions to generate energy from agricultural residues.

Table 3. The alignment of districts according to amount of agricultural residues

Districts	Field Crops Residues (tons)	Fruit Crops Residues (tons)	Total Residues (tons)	Share in Total Residues (%)
Ahmetli	2,257	19,942	22,199	2.33
Akhisar	53,913	114,017	167,930	17.61
Alaşehir	6,913	71,506	78,419	8.22
Demirci	8,450	7,589	16,039	1.68
Gölmarmara	7,460	12,765	20,225	2.12
Gördes	5,445	9,173	14,618	1.53
Kırkağaç	34,945	21,386	56,331	5.91
Köprübaşı	5,409	25,470	30,879	3.24
Kula	9,930	3,490	13,420	1.41
Salihli	42,162	73,343	115,506	12.11
Sarıgöl	1,775	42,441	44,216	4.64
Saruhanlı	46,504	105,396	151,900	15.93
Selendi	7,904	1,401	9,305	0.98
Soma	12,907	10,761	23,668	2.48
Turgutlu	37,707	35,153	72,860	7.64
Yunusemre	28,754	10,260	39,015	4.09
Şehzadeler	40,595	36,547	77,142	8.09
TOTAL	**353,030**	**600,641**	**953,671**	**100.00**

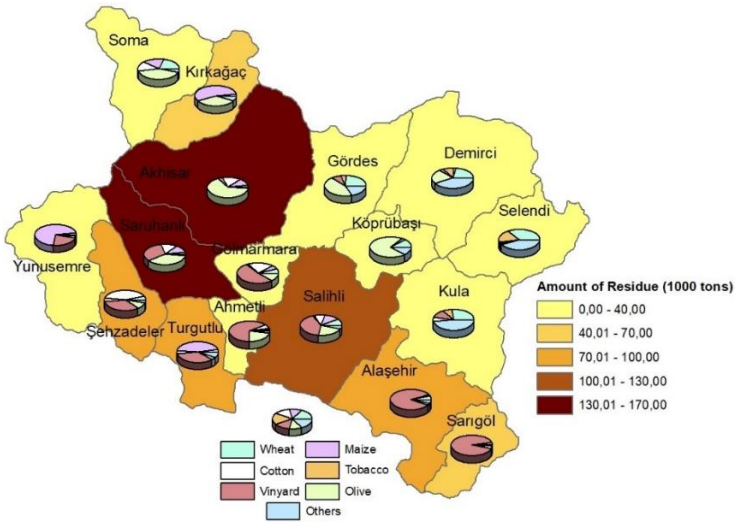


Figure 1. The distribution map of agricultural residues in Manisa

Some studies conducted on this subject have yielded the following results.

The potential of biomass from agricultural residues was determined in Samsun province. The total biomass potential was determined as 366.6 kt in the province. (Karaca et. al., 2017).

A study carried out by Karaca and Öztürk (2017) in Osmaniye province indicated that the total biomass potential from agricultural residues was 491 kt.

Karaca (2022) reported the amount of biomass from agricultural residues was about 124.54 kt, equivalent to about 2,182 TJ of heating value in Sivas.

Similarly, in another study conducted by Karaca (2023), the total agricultural residue potential of Gaziantep province was determined as 373.42 kt.

Another study conducted by Karaca (2024) indicates that the agricultural residue potential of Kayseri province has been determined to be 297.52 kt.

It is observed that the agricultural residues potential of Manisa province is significantly higher than that of the provinces examined in these studies.

It was calculated that the total heating value of the agricultural residues was about 17,411.13 TJ (415.86 ktoe) in Manisa. The heating value of agricultural residues that calculated separately for each product is given in Table 4. The distribution map was given Figure 2.

Table 4. Total heating value of agricultural residues of Manisa

Field Crops	Residues	Total Heating Value (THV) (GJ)
Wheat	Straw	870,298
Barley	Straw	293,521
Rye	Straw	19,289
Oats	Straw	13,854
Chickpea	Straw	19,878
Maize	Stalk	2,332,621
	Cob	348,002
Tobacco	Stalk	262,778
Sunflower	Stalk	80,846
Cotton	Stalk	1,783,979
	Ginning residues	306,805
Fruit Crops		
Apple	Pruning	6,878
Pear	Pruning	6,858
Apricots	Pruning	18,379
Sweet cherry	Pruning	168,711
Peach	Pruning	37,892
Plum	Pruning	53,615
Almonds	Pruning	71,713
Walnuts	Pruning	28,860
Pomegranate	Pruning	16,265
Fig	Pruning	7,571
Vineyard	Pruning	5,370,900
Olive	Pomace	3,091,346
	Pruning	2,200,272
	TOTAL	**17,411,129**

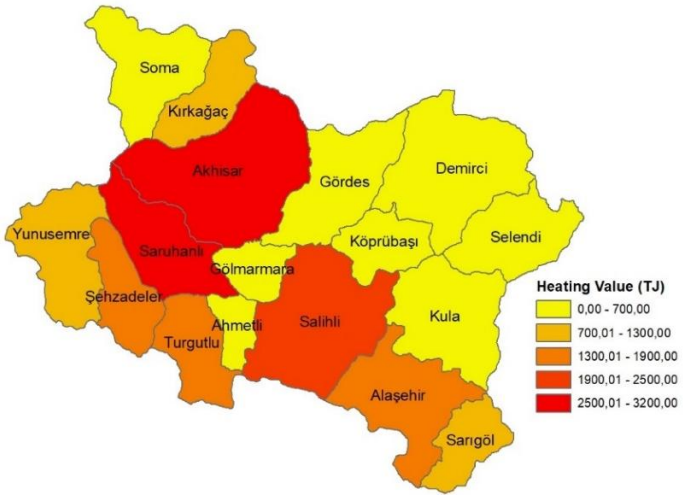


Figure 2. The distribution map of heating value based on agricultural residues in Manisa

These maps (Figure1 and 2) showed that the potential of agricultural residues concentrated in Akhisar and Saruhanlı districts. Especially, it is observed that the type and distribution of residues in Akhisar district, the distribution of agricultural residues according to heating value is ranked as olive (2005 TJ) cotton (583.6 TJ) and maize (294.28 TJ) respectively. In Saruhanlı, this ranking consists of olive residues (1,174.43 TJ) vineyard residues (787.64 TJ) and cotton residues (454.33 TJ) respectively. It has also been observed that there are significant amounts of agricultural residues in some districts. Heating values of vinyard residues are 1,229.57 TJ in Alaşehir and 739.91 TJ in Sarıgöl. In addition, it is evident that maize residues represent a significant potential energy source, with estimates suggesting an output of 604.92 TJ in Turgutlu, 558.64 TJ in Kırkağaç and 505.47 TJ in Yunusemre. Furthermore, cotton residue has a heating value of 591.27 TJ, creating significant potential in the district of Şehzadeler.

4. CONCLUSION AND RECOMMENDATIONS

The aim of this study is to show the potential of agricultural residues in the districts of Manisa and its distribution by mapping them. The importance of this study is increasing because Turkey is an energy importing country.

The total amount of agricultural residues was approximately 953.67 kt. It was found that the total heating value of the agricultural residues was around 17,441.13 TJ for the agricultural production period of 2024. It was determined that this potential concentrate in Akhisar, Saruhanlı and Salihli districts. It was seen that the majority of agricultural residues originate from field crops. According to the amount of residues of agricultural products, it is listed as, vineyard residues (31.3%), olive residues (29.2%), maize residues (15.2%) and cotton residues (12.3%).

Manisa province has a big biomass energy potential. The results of this study show that the biomass potential could be utilized by establishing modern facilities.

In summary, the present study identifies the utilization of agricultural residues as an energy source as a specific opportunity for Manisa, given its economic and sustainability advantages, along with associated environmental benefits.

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THE CONVERSION OF LIVESTOCK MANURE INTO ENERGY AND THE ENVIRONMENTAL BENEFITS: THE CASE OF MANİSA PROVINCE

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ABSTRACT

The objective of this study is to determine the biogas amount and energy value of biogas produced from livestock manure in Manisa province and its effects on greenhouse gas emissions (GHG). For this purpose, biogas potential was calculated considering the number of cattle, broiler chickens and laying hens in the province. According to 2024 data, there are approximately 261.67 thousand cattle, 35.6 million broiler chickens and 11.36 million laying hens in Manisa province. The livestock in the province produces a total of 3 million tons of manure per year. This includes 2.6 million tons of cattle manure, 70.56 thousand tons of broiler manure and 331.68 thousand tons of laying hen manure. From the usable amount of these manures, 67.33 Mm^3 of biogas can be produced annually. The heating value of the biogas produced from these manures is approximately 1,528.3 TJ and the amount of electricity that can be produced from this biogas is calculated as approximately 169.81 GWh_{el}. It is estimated that this value can supply 2.76% of the annual electricity consumption of Manisa province (6,162 GWh_{el}). The calculated amount of manure and energy values are mapped by district. When districts are ranked according to biogas production amounts, the districts with the highest potential are Salihli (18%), Akhisar (13%), Kula (12.1%) and Saruhanlı (11.1%). Also, greenhouse gas emission reduction values were calculated to indicate the environmental benefits of biogas production from farm manure. It was determined that CO_2 equivalent emission reductions ranging between 593.28 – 930.96 thousand tons per year could be achieved by utilizing the calculated biogas potential.

Keywords: Biogas, Sustainability, Livestock Manure, Greenhouse Gas Emission, Manisa

HAYVAN GÜBRESİNİN ENERJİYE DÖNÜŞTÜRÜLMESİ VE ÇEVRESEL FAYDALARI: MANİSA İLİ ÖRNEĞİ

ÖZET

Bu çalışmanın amacı Manisa ilinde çiftlik gübresinden üretilen biyogazın miktarını ve enerji değeri ile bunun sera gazı emisyonlarına (GHG) etkilerini belirlemektir. Bunun için ildeki sığır, et tavuğu ve yumurta tavuğu sayıları dikkate alınarak biyogaz potansiyeli hesaplanmıştır. Manisa ilinde 2024 verilerine göre toplam yaklaşık 261.67 bin sığır, 35.6 milyon et tavuğu ve 11.36 milyon yumurta tavuğu varlığı bulunmaktadır. İldeki bu hayvan varlığından yılda 2.6 milyon ton sığır gübresi, 70.56 bin ton et tavuğu gübresi ve 331.68 bin ton yumurta tavuğu gübresi olmak üzere toplam 3 milyon ton çiftlik gübresi elde edilmektedir. Bu gübrenin kullanılabilir miktarından yılda 67.33 Mm^3 biyogaz üretilebilir. Bu gübreden üretilen biyogazın ısıl değeri yaklaşık 1,528.3 TJ, bu biyogazdan üretilebilecek elektrik miktarı yaklaşık 169.81 GWh_{el} olarak hesaplanmıştır. Bu değerler Manisa ilinin yıllık elektrik enerjisi tüketiminin (6,162 GWh_{el}) %2.76'sını karşılayabilmektedir. Hesaplanan gübre miktarları ve enerji değerlerinin ilçelere göre dağılımı haritalanmıştır. Biyogaz üretim miktarına göre ilçeler sıralandığında en büyük potansiyele sahip ilçeler Salihli (%18), Akhisar (%13), Kula (%12.1) ve Saruhanlı (%11.1). şeklinde sıralanmıştır. Ayrıca çiftlik gübresinden biyogaz üretiminin çevresel faydalarını göstermek için sera gazı emisyon azaltımı değerleri hesaplanmıştır. Hesaplanan biyogaz potansiyelinin

değerlendirilmesi ile yıllık 593.28 – 930.96 bin ton arasında değişen CO_2 eşdeğeri emisyon azaltımının sağlanabileceği belirlenmiştir.

Anahtar Kelimeler: Çiftlik Gübresi, Biyogaz Potansiyeli, Sera Gazı Emisyonu, Manisa

1. INTRODUCTION

Energy plays an important role in the world's future. Energy is central to economic development, and there is a clear correlation between energy consumption and living standards. Energy sources are split into three categories: fossil fuels, renewable sources and nuclear sources (Karaca, 2015).

Increase in energy demand and the issues about current non-renewable energy resources led researchers to investigate alternative energy sources during the last two decades. Renewable energy resources draw attention all over the world because they are sustainable, improve the environmental quality and provide new job opportunities in rural areas (Isci and Demirer, 2007).

Biomass can be either used by direct combustion or mixed with an appropriate fossil fuel and be combusted or it can be converted into solid, liquid and gaseous fuels using conversion technologies such as fermentation to produce alcohols, bacterial digestion to produce biogas and gasification to produce a natural gas substitute (Dumanlı et al., 2007)

Biogas is a mixture of methane and carbon dioxide. It also has traces of hydrogen sulphide, ammonia, oxygen, hydrogen, water vapor etc., depending upon feed materials and other conditions. Biogas is generated by fermentation of cellulose rich organic matter under anaerobic conditions. In anaerobic conditions, the methane-producing bacteria become more active. Thus, the gas produced becomes rich in methane (NIIR, 2004).

Biogas is supplied to a variety of uses or markets, including electricity, heat and transportation fuels. In many countries, the gas is used for direct combustion in household stoves and gas lamps are increasingly common. However, producing electricity from biogas is still relatively rare in most developing countries. In industrialized countries, power generation is the main purpose of most biogas plants; conversion of biogas to electricity has become a standard technology. Leading countries in producing biogas include Germany, India and China (WEC, 2016).

The objective of this study was to determine the production potential of biogas from animal manure (cattle, broiler chicken and laying hens) and mapping in Manisa with separate districts. For these purposes, biogas potential and its energy potential of animal manure were evaluated by ArcMap which is a geographical information system (GIS) program. The differences in data among the districts for seeing more clearly were created maps in GIS. A database was created within the GIS for Manisa and its districts. The number of animals, calculated biogas potential, and its heating value in the province for the year 2024 were inputs to this database.

2. MATERIALS AND METHODS

The province of Manisa is located within the Aegean Region of Turkey and is further divided into a total of 17 districts, of which two are central districts. The districts of Manisa province are Ahmetli, Akhisar, Alaşehir, Demirci, Gölmarmara, Gördes, Kırkağaç, Köprübaşı, Kula, Salihli, Sarıgöl, Saruhanlı, Selendi, Soma, Turgutlu, Yunusemre and Şehzadeler.

In the scope of this study, Turkish Statistical Institute's data on the number of livestock in 2024 were used. (TURKSTAT, 2025). The data used in the calculation of the biogas production potential were

considered only cattle, broiler chicken and laying hen population. Because the attainability of animal manures, as determined by staying time in the barn, provides the highest value in a cattle farm (65%), broiler and laying hens farm (99%) (Başçetinçelik *et al*., 2006). Since the collectability and availability of manure from other livestock is very low, it was not used in the calculations.

2.1. Animal manure and biogas production calculation methods

The following methods were used to calculate the amount of animal manure and biogas production (Başçetinçelik *et al*., 2006; Karaca and Gürdil, 2019; Karaca, 2023).

$$AFM = NA \times MPPA/1000 \quad (1)$$

where;
AFM: amount of fresh manure per day (t/day)
NA: number of animals
MPPA: daily manure production per animal (kg/day)
The *MPPA* is 27.24 for cattle, 0.0476 for broiler and 0.08 for laying hens.

$$ASM = AFM \times SMR \quad (2)$$

where;
ASM: amount of daily solid manure (t/day)
SMR: solid manure ratio (%)

$$TSUM = ASM \times AOM \times AGP \quad (3)$$

where;
TUSM: annual total usable solid manure (t/year)
AOM: attainability of manure (%)
AGP: yearly growing period (day)

The AGP is 365 for dairy cattle and laying hens, 42 for broiler. Because, assuming that six cycles were produced in a year and that broilers are reared for up to six weeks of age, the yearly amount of broiler litter is calculated as 42 days.

$$AB = TSUM \times BCR_{SM} \quad (4)$$

where;
AB: amount of biogas (m^3/year)
BCR_{SM}*:* biogas conversion ratio of solid manure (200 m^3/t)

$$THV = AB \times HV \quad (5)$$

where:
THV: total heating value (MJ)
HV: heating value of unit biogas (22.7 MJ/m^3)

Electricity generation from biogas with a gas engine was calculated by the following equation:

$$EP = (THV \times EPE_{Net})/3.6 \quad (6)$$

where;
EP: electricity production (kWh_{el}/year)
EPE_{Net}*:* net electricity production efficiency of a biogas engine (40%) (Clarke Energy, 2021)

For each district, the calculated values, the total amount, the total biogas production, and the total energy potential of animal manures, were mapped using ArcMAP Software.

2.2. Calculation methods of GHG emission abatement from biogas system

GHG emission reduction effect of biogas production is based on two factors, ERMM (emission reduction by manure management) and ERES (emission reduction by energy substitution).

ERMM (emission reduction by manure management)

Under anaerobic conditions (in the absence of oxygen) the extrication of animal manure produces methane (CH_4) throughout storage. The most significant benefit of a biogas system is preventing the uncontrolled methane emissions. The following methods were used to calculate the CH_4 production from uncovered lagoon manure storage systems (IPCC, 2006; Guo Guo, 2010). This calculation was done according to annual average temperature.

$$CH_{4Manure} = EF_{(T)} \, x \, N_{(T)} \qquad (7)$$

where;
$CH_{4Manure}$ *:* methane emissions from manure management (kg CH_4/year)
$EF_{(T)}$ *:* emission factor for livestock category T, (kg CH_4/animal year)
$N_{(T)}$ *:* the number of animal of livestock species/category T
T : species/category

$$EF_{(T)} = \left(VS_{(T)} \, x \, 365\right) x \left(B_{O(T)} \, x \, 0.67\right) x \left(\frac{MCF_{S,k}}{100} \right) \qquad (8)$$

where;
$VS_{(T)}$ *:* volatile solid for livestock category per day T, (kg dry matter/animal day)
$B_{o(T)}$ *:* maximum methane production capacity (m^3/kg)
0.67 : conversion multiplier from m^3 CH_4 to kg CH_4
$MCF_{S,k}$ *:* methane conversion parameters for manure management system S, by climate region k, (%)

$$ERMM_{CO_2} = CH_{4Manure} \, x \, 27.2 \qquad (9)$$

where;
$ERMM_{CO2}$: CO_2 emission reduction from manure management (kg CO_2 $year^{-1}$)
27.2 : Coefficient of the CO_2 equivalent of CH_4 (ERC Evolution, 2023).

ERES (emission reduction by energy substitution)

In rural regions biogas can use instead of solid fossil fuels and other biomass resources, because of high heat value (22.7 MJ/m^3). Therefore, the effect of CO_2 emission reduction of biogas system depends on the amount of fossil fuel replacement. The ERES is computed as GHG emissions produced by biogas-substituted fuel consumption. In this part, CO_2 emission reduction was calculated separately for each fossil fuel, which substituted instead of the estimated biogas potential. The following equations were used for this (Guo Guo, 2010)

$$ERES_{CO_2\,fuel} = FS \, xCE_{fuel} x \, EF_{CO_2\,fuel} \qquad (10)$$

where;
$ERES_{CO2\,fuel}$: CO_2 emission reduction for substituted fuel, (kg/year)
FS : Fuel substitution value of biogas energy equivalent, (GJ/year)
CE_{fuel} *:* Combustion efficiency of fuels

$EF_{CO2\ fuel}$: CO_2 emission factors (kg/GJ)

$FS=THV\ x\ 0.6$ (11)

where;
THV : Total heating value of biogas potential (GJ/year)
0.6 : Combustion efficiency of biogas

3. RESULT AND DISCUSSION

3.1. Potential of animal manure, biogas production and energy value

Total animal manure potential of Manisa in 2024 as a solid matter depending on the number of cattle, broiler and laying hens is presented in Table 1.

Table 1. Number of animals, and total amount of animal manure as fresh and solid matter

Animal	NA	AFM (t/year)	SMR (%)	ASM (t/year)	AOM (%)	TUSM (t/year)
Cattle	261,671	2,601,690	12.7	330,415	65	214,770
Broiler	35,301,623	70,575	12.7	40,176	65	39,774
Laying hens	11,358,792	331,677	25.0	82,919	99	82,090
TOTAL		**3,003,942**		**453,510**		**336,634**

According to Table 1, the total amount of usable solid manure, obtained from cattle, broiler and laying hens, is 336.63 thousand tons in 2024. Its distributions by the sources are cattle (63.80%), broiler (11.82%) and laying hens (24.39%).

The amount of biogas which can be obtained from the total animal manure as a solid matter along with the electricity generation from this biogas is presented in Table 2.

Table 2. The biogas potential and the energy potential of biogas in Manisa

Animal	TUSM (t/year)	AB (m^3/year)	THV (GJ/ year)	EP (MWh_{el}/ year)
Cattle	214,770	42,953,903	975,054	108,339
Broiler	39,774	7,954,844	180,575	20,064
Laying hens	82,090	16,417,998	372,689	41,410
TOTAL	**336,634**	**67,326,745**	**1,528,317**	**169,813**

Table 2 shows that the total biogas potential of Manisa is estimated at 67.33 million m^3/year. Furthermore, the heating value was calculated as 1,528.32 TJ/year. It has been determined that 169.81 GWh_{el} of electrical energy can be obtained annually by converting the whole biogas potential obtained from animal manure into electrical energy by means of a gas engine. These values can provide 2.76 % of Manisa's annual electricity consumption (6,162 GWh_{el}).

Several studies carried out by Karaca (2016, 2017, 2018, 2019, 2023, 2024) in Afyonkarahisar, Hatay, Balıkesir, Adana, Ankara, Konya and Kayseri provinces, indicated that the total biogas derived from animal manure was 84.8, 14.5, 153.4, 26.3, 40.3, 105.67 and 76.4 Mm^3/ and year respectively.

The potential of biogas from animal manure was determined in Samsun province. The total biogas potential was determined as 53.6 Mm^3/year in the province. (Karaca & Gürdil, 2019).

The biogas potential that can be obtained from animal fresh manure and solid manure, the calorific value of this biogas potential and the amount of electrical energy generated from this biogas are presented in Table 3 for the 17 districts of Manisa for the year 2024.

Table 3. Amount of fresh manure, biogas potential and energy values in the districts of Manisa

Districts	Fresh Manure (t/year)	Biogas Potential (m^3/year)	Heating Value (GJ/year)	Electrical Energy (MWh_{el})	Share in total (%)
Ahmetli	52,823	1,223,462	27,773	3,086	1.8
Akhisar	268,050	8,735,035	198,285	22,032	13.0
Alaşehir	126,081	2,458,807	55,815	6,202	3.7
Demirci	135,136	2,422,554	54,992	6,110	3.6
Gölmarmara	37,729	684,899	15,547	1,727	1.0
Gördes	142,726	2,319,830	52,660	5,851	3.4
Kırkağaç	59,081	1,235,713	28,051	3,117	1.8
Köprübaşı	60,872	1,742,012	39,544	4,394	2.6
Kula	464,417	8,164,629	185,337	20,593	12.1
Salihli	497,343	12,150,298	275,812	30,646	18.0
Sarıgöl	107,063	1,897,081	43,064	4,785	2.8
Saruhanlı	180,095	7,501,220	170,278	18,920	11.1
Selendi	173,648	2,970,225	67,424	7,492	4.4
Soma	99,067	2,201,305	49,970	5,552	3.3
Turgutlu	309,903	6,448,728	146,386	16,265	9.6
Yunusemre	151,791	2,701,592	61,326	6,814	4.0
Şehzadeler	138,116	2,469,354	56,054	6,228	3.7
TOTAL	3,003,942	67,326,745	1,528,317	169,813	100

Salihli districts have the highest potential with 12.15 Mm^3. This is followed by Akhisar, Kula and Saruhanlı districts with 8.74 Mm^3, 8.16 Mm^3 and 7.50 Mm^3, respectively.

The distribution of animal manure potentials in the provinces of Manisa is given in Figure 1. In all districts, it is observed that in the majority of cattle manure. In addition, it has been determined that the amount of laying hens manure in Akhisar (37.1%) and Saruhanlı (66.4%) districts are higher than the other districts. It was determined that there was a small amount broiler litter in Köprübaşı (11.8%) district.

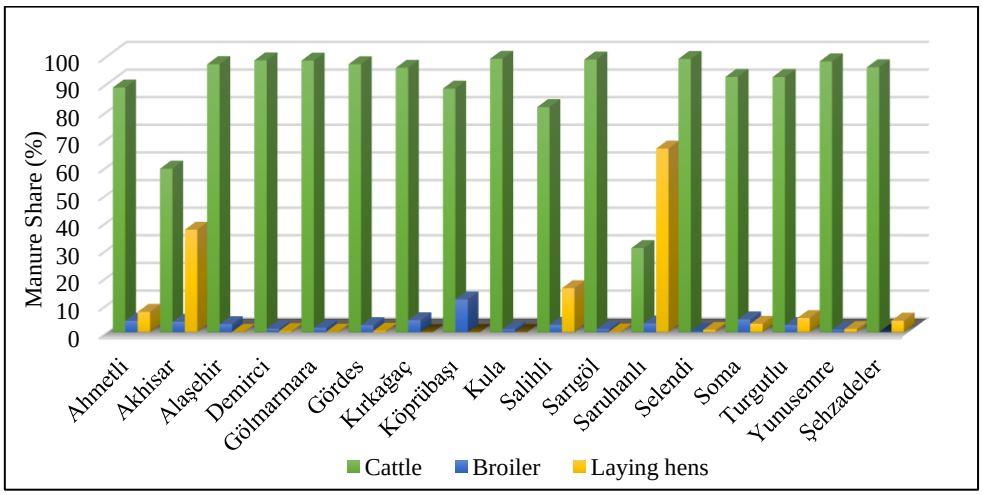


Figure 1. The distribution of animal manure potentials per district

The amount of biogas and its energy value was calculated for each district and mapped. Figure 2 and Figure 3 show the distribution of biogas potential and its energy values for 17 districts of Manisa.

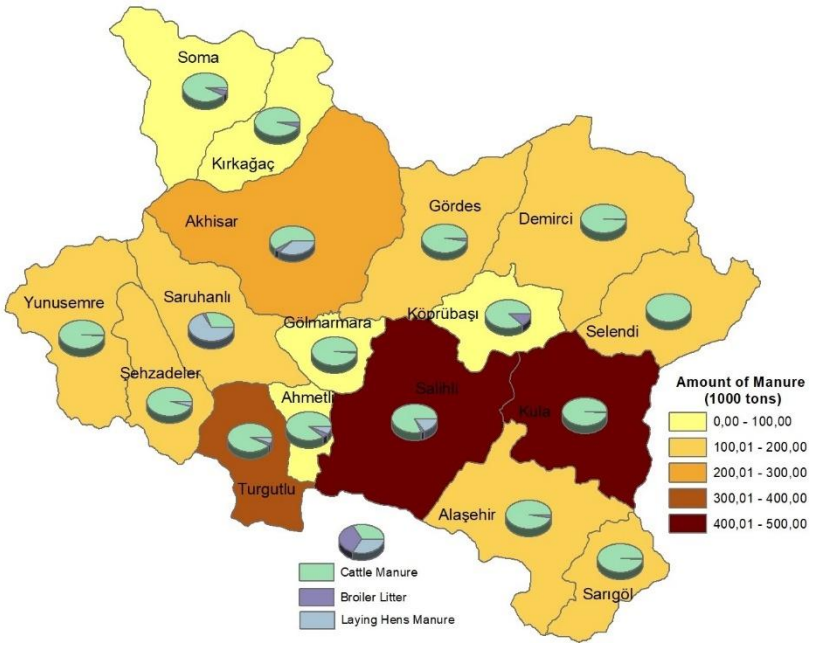


Figure 2. The distribution map of biogas potential in Manisa

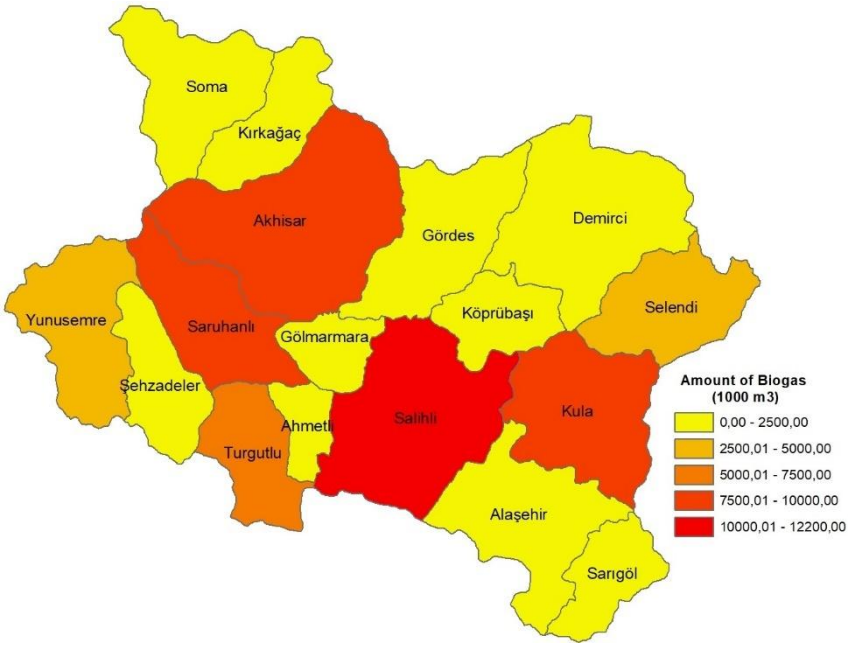


Figure 3. The biogas production potential map of Manisa

These maps show that the biogas potential is concentrated in the locations of Salihli and Kula districts, together with in the locations of Akhisar and Saruhanlı districts. This means that the biogas production plants can be established between these locations of districts. This situation is an advantage in terms of raw material supply for biogas production plants.

3.2. GHG Emission Abatement from Biogas System

The result of this computation is called ERMM, which are shown in Table 4. The result of this computation can be observed as GHG emission reduction substituted by biogas, which is offered as $ERES_{CO2\ fuel}$ (Table 5). Total CO_2 emission abatement from manure biogas system is given in Table 7.

Table 4. CH_4 emission reduction from manure management in Manisa

T	N	VS (kg/animal day)	B_o (m^3CH_4/kg)	MCF (%)	EF ($kgCH_4$/year)	CH_4 (kg/year)	$CO_{2\text{-eqv.}}$ (kg/year)
Cattle	261,671	2.8	0.13	76	67.6523	17,702,648	481,512,029
Broiler	35,301,623	0.01	0.36	1.5	0.0132	466,183	12,680,168
Laying hens	11,358,792	0.02	0.39	1.5	0.0286	325,002	8,840,047
Total						**18,493,833**	**503,032,244**

Methane emissions from manure are shown in Table 5. Cattle manures were the largest emitters of methane with 481,512 ton $CO_{2\text{-eqv}}$. The research shows that cattle are the main source of methane emissions from farm waste in Manisa, accounting for 95.7% of the total emissions.

Table 5. CO_2 emission reduction from energy substitution in Manisa

Fuels	FS (GJ/year)	$EF_{CO2\ fuel}$ (kg/GJ)	CE_{fuel}	CO_2 emission (kg/year)
Firewood	916,990	112	0.24	427,928,792
Coal	916,990	94.6	0.40	216,868,199
Biogas	916,990	0	0.60	0
Natural gas	916,990	56.1	0.57	90,251,147

The CO_2 emissions from the conventional fuels that would be displaced by biogas were estimated. The substitution of firewood for biogas has the potential to engender a total annual reduction in CO_2 emissions of 427.93 kt. Moreover, the utilisation of this biogas as a fuel source helps to eliminate methane emissions that would have been produced by the manure of cattle and poultry.

Table 6. Total CO_2 emission abatement from manure biogas system in Manisa

ERMM $CO_{2\text{-eqv.}}$ (t/year)	Fuels	$ERES_{CO2\ fuel}$ (t/year)	Total CO_2 emission abatement (t/year)
503,032.24	Firewood	427,928.8	930,961.04
	Coal	216,868.2	719,900.44
	Natural Gas	90,251.15	593,283.39

GHG emission from manure can be reduced by 503.03 kt $CO_{2\text{-eqv}}$ by manure management with biogas systems. In addition, when fuel substitution is added, the total emission reduction can vary from 593.28 to 930.96 kt CO_2 equivalent according to the fuel to be substituted.

4. CONCLUSION AND RECOMMENDATIONS

In this study, it was detected that the biogas potential of Manisa from cattle, broiler litter and laying hens manures was 67.33 Mm^3 depending on the number of the animals in the years 2024.

Salihli districts have the highest biogas potential. Akhisar, Kula and Saruhanlı districts follow this. If the whole biogas potential from animal manure is converted into electricity by means of a gas engine, approximately 169.81 GWh_{el}/year of electricity can be generated. It is estimated that this value can provide 2.76% of Manisa's annual electric energy consumption (6,162 GWh_{el}).

At present in the province, there are 2 biogas plant investments with a total rate of 6 MW (Biyogazder, 2025). These biogas plants are Ege Biyogaz with an installed capacity of 3 MW in Salihli district and Turgutlu Biyogaz with an installed capacity of 3 MW in Turgutlu district. The installed power potential of biogas obtained from animal manure in Manisa province has been calculated as approximately 24 MW. With the full operational capacity of these two biogas plants, it is evident that only a quarter (25%) of the province's total biogas capacity is being utilised. This potential of Manisa is not enough evaluated with the biogas plant currently installed. It is possible to construct biogas plants in the Akhisar (3 MW), Kula (3 MW) and Saruhanlı (2.7 MW) districts with the existing animal manure potential.

The utilisation of biogas is regarded as a sustainable and environmentally beneficial substitute for fossil fuels. In addition to its capacity to reduce greenhouse gas (GHG) emissions, the use of biogas contributes to energy security owing to its substantial energy potential. The capture and utilisation of biogas constitute an effective approach for mitigating GHG emissions, which are among the principal drivers of anthropogenic climate change. Such mitigation is achieved through two primary mechanisms: first, biogas serves as a renewable energy source capable of substituting fossil fuels; second, the controlled capture of biogas prevents the atmospheric release of methane, a greenhouse gas with a high global warming potential.

The creation of maps was an integral component of this study, with the primary objective being to provide a more lucid visual representation of the variances in data from the respective districts. The utilization of maps has the potential to enhance public awareness and offer a reference point for policy makers and investors.

Turkey has considerable potential in terms of renewable energy resources. To achieve energy independence, it is imperative that the country increase its reliance on renewable energy sources. Consequently, biogas emerges as a highly compelling option for Turkey, given its status as a sustainable, environmentally friendly, and domestic energy source.

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KUZUKULAĞINDA (*Rumex acetosella* L.) FARKLI BİYOSTİMULANT UYGULAMALARININ TUZLULUĞA TOLERANS ÜZERİNDEKİ ETKİSİ

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ÖZET

Kuzukulağında (*Rumex acetosella* L.) farklı biyostimulant uygulamalarının (mikroalg, bakteri ve deniz yosunu) tuza toleransın artırılmasındaki etkinliğinin incelendiği çalışmada, tohumlar 2:1 oranında torf perlit karışımı içeren 11 L'lik plastik saksılara ekilmiş, fideler 3-4 yapraklı aşamaya ulaştıklarında 100 mM NaCl ve biyostimulant uygulamaları gerçekleştirilmiştir. Mikroalg ve deniz yosunu uygulamaları yapraktan püskürtme şeklinde, bakteri uygulaması ise kök bölgesine gerçekleştirilmiştir. Stres sonunda hasat edilen bitkiler yeşil aksam, yaş ve kuru ağırlıkları, bitki boyu, yaprak alanı, yaprak su oransal içeriği (YOSİ), SPAD değeri, yeşil aksam Na, Cl, K ve Ca içeriği bakımından incelenmiştir. Tuz stresi bitki büyüme parametreleri, SPAD değeri, YOSİ, K, Ca içeriğinde azalmaya neden olmuş; Na ve Cl iyon konsantrasyonu bakımından ise artış meydana gelmiştir. Buna karşın, tuz stresi ile birlikte biyostimulant uygulamalarında tuz stresine oranla ortalama olarak yaş ve kuru ağırlıkta %50-316; bitki boyunda %7-65; bitki yaprak alanında %44-131; YOSİ değerlerinde %37-58; K içeriğinde %38-84; Ca içeriğinde %40-87 iyileşme sağlanmıştır. Ayrıca Na iyon alımı %20-42, Cl iyon alımı %22-43 düzeyinde sınırlanmıştır. Çalışma sonucunda, biyostimulant uygulamalarının tuz stresi ile ortaya çıkan zararlanmayı değişen oranlarda iyileştirdiği ve toleransı artırmada etkili olduğu, uygulamalar arasında bu olumlu etki açısından bakteri ve mikroalg uygulamalarının ön plana çıktığı belirlenmiştir.

Anahtar Kelimeler: Bakteri, Biyostimulant, Mikroalg, *Rumex acetosella* L., Tuz Stresi

1. GİRİŞ

Bitkiler, doğal koşullar altında tohum çimlenmesinden itibaren büyüme, gelişme ve verimliliklerini olumsuz yönde etkileyen çok sayıda biyotik (böcek, nematod, virüs, fungus, bakteri vb.) ve abiyotik (kuraklık, tuzluluk, ekstrem sıcaklıklar, ağır metaller, bitki besin elementi dengesizliği, radyasyon vb.) stres etmenlerine maruz kalabilmekte, bu da bitki savunma mekanizmalarının şekillenmesine ve bitki metabolizmasının yeniden yapılandırılmasına neden olmaktadır. Özellikle abiyotik stres faktörleri, küresel gıda güvenliği, gıda kalitesi ve bitki verimliliği üzerinde sınırlayıcı etkilere sahiptir (Kumar and Verma, 2018; Ghazaryan et al. 2024). Günümüzde bitki türü ve ekolojik koşullara bağlı olarak, %50 ile %80 arasında görülen verim kayıplarının ana nedeni abiyotik stres faktörleridir. Dolayısıyla, tarım sektöründe bitkisel üretimin sürdürülebilirliğini ve kalitesini garanti altına alırken, abiyotik stres faktörlerinin bitkiler üzerindeki olumsuz etkilerini azaltacak yeni arayışlar içine girilmiştir. Bu yeni biyoteknolojik gelişmeler arasında yer alan biyostimülantlar; tarımsal, kentsel ve endüstriyel atık malzemeleri döngüsel ekonomi perspektifinde kullanma kabiliyetleri nedeniyle de son on yılda artan şekilde ilgi görmektedir (Bulgari et al. 2019, Andreotti 2020, Nephali et al. 2020).

Tuzluluk bitkilerde büyüme ve gelişmeyi, ürünün nitelik ve niceliğini olumsuz etkileyen önemli çevresel stres unsurlarından biridir. Bitkisel üretimde, ürün kayıplarının yaklaşık olarak %50'si abiotik stres faktörleri nedeni ile ortaya çıkmaktadır. Günümüzde, sulanabilir alanların %30'u olmak üzere toplamda %6 lık bir alan toprak tuzluluğu ile karşı karşıya durumdadır. Bununla birlikte tarım arazilerinde yanlış sulama uygulamalarının sebep olduğu tuzluluk probleminin gelecek 20 yıl içerisinde %50 oranında artış göstereceği ön görülmektedir (Hasanuzzaman et al. 2013). Toprak çözeltisinde tuz konsantrasyonunun artması ve su potansiyelinin azalması, bitki hücrelerinin ozmotik potansiyelini düşürmektedir. Bunun sonucunda tuz stresinin yoğunluk ve süresine bağlı olarak bitkilerde büyüme, gelişme, çimlenme, hücre bölünmesi, fotosentez gibi pek çok biyolojik olay etkilenmekte (Bressan et al. 2008) ve bu durum tarımsal alanlarda bitki verimliliği ile ürün kalitesini sınırlandırmaktadır.

Biyostimülantlar, bitkilerde besin elementi kullanım etkinliğini artıran, abiyotik stres koşullarına karşı tolerans sağlayan, ürün kalitesini iyileştiren, toprakta ve kök bölgesinde sınırlı miktarda bulunan besin elementlerinin bitkiler tarafından etkin bir şekilde kullanımına katkı sağlayan maddeler olarak tanımlamaktadır. Bu tanımlamaya göre biyostimülantlar; mikrobiyal ve mikrobiyal olmayanlar olarak iki ana gruba ayrılmaktadır. Mikrobiyal stimülantlar; N-bağlayan faydalı bakterileri ve arbusküler mikorizal mantarları içerirken, mikrobiyal olmayan stimülantlar ise; amino asitler, hümik asitler ve mineraller, deniz yosunu özleri, bitki özleri, biyopolimerler ve protein hidrolizatları gibi hem organik hem de inorganik kökenli çeşitli kompleks maddeleri veya karışımları ifade etmektedir (Andreotti 2020).

Kuzukulağının yüksek okzalik asit içeriği ve eksi tadı, zengin C vitamini içermesi sağlık üzerine olumlu etkileri sebze türü ve tıbbi otsu bitki olarak kullanımına neden olmaktadır (Sezer, 2015; Uludağ ve ark. 2017). Gerçekleştirilen bu çalışmada, farklı biyostimulantların kuzukulağında tuza toleransın sağlanması üzerindeki etkinliği incelenmiştir.

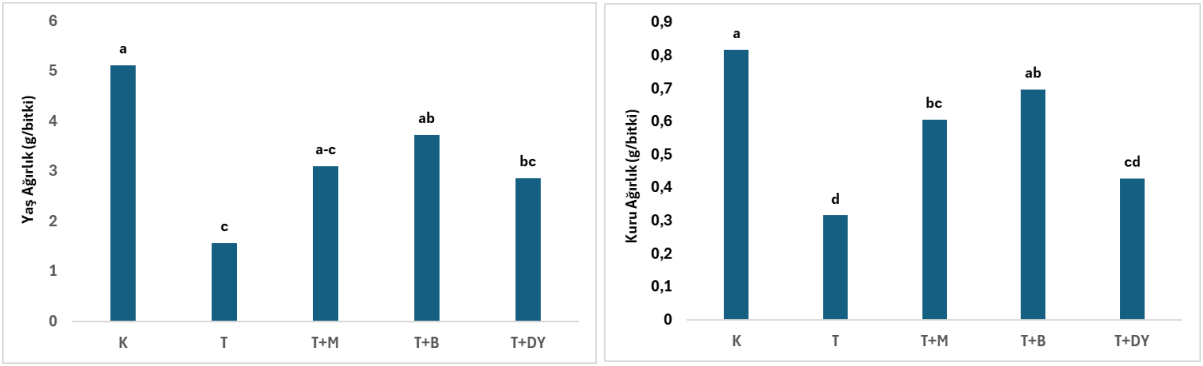
2. MATERYAL ve YÖNTEM

Çalışmada materyal olarak Merve çeşidi (Genta Prestige) kullanılmıştır. Tohumlar 2:1 oranında torf:perlit karışımı içeren 11 litre hacmindeki plastik saksılara (m^2'ye 1.5 g tohum) ekilmiştir. Bitkiler 3-4 yapraklı aşamaya ulaştıklarında stres uygulamalarına başlanmış ve başlangıçta 50 mM NaCl dozu kullanılarak tuz konsantrasyonu kademeli şekilde artırılarak nihai olarak 100 mM NaCl seviyesine ulaşılmıştır. Bitkiler standart besin çözeltisi ile sulanmıştır (İkiz ve ark. 2024). Sulamada "drene olan çözelti/uygulanan çözelti" oranı esas alınmıştır (Schröder ve Lieth, 2002). Günlük olarak drenaj seviyeleri belirlenmiş ve bu oran deneme süresince bitkilerin büyümesine göre %30 civarında tutulmuştur. Biyostimulant olarak Denge Tarım firmasına ait algacell (M), bactofeed (B), foster 650 (DY) ürünleri kullanılmıştır.

Uygulamalara tuz stresi ile birlikte başlanmış ve her 15 günde bir tekrarlanmıştır. Bactofeed kökten olmak üzere diğer biyostimulatlar yapraktan spreyleme şeklinde gerçekleştirilmiştir. Yirmi iki gün süreyle strese maruz bırakılan bitkiler, hasat edilerek çeşitli ölçüm ve analizler gerçekleştirilmiştir. Bu amaçla bitkiler yeşil aksam yaş ve kuru ağırlığı, gövde boyu, yaprak alanı, yaprak oransal su içeriği (Sanchez et al. 2004; Türkan et al. 2005), SPAD değeri, yeşil aksamda Na, Cl, K ve Ca (Dasgan ve Koc, 2009) iyon içerikleri bakımından incelenmiştir. Çalışma tesadüf parselleri deneme desenine göre 3 tekrarlamalı olarak yürütülmüştür. Verilerin istatistiksel analizinde JMP (versiyon 8.0) programı kullanılmış, ortalamalar arasındaki farklılıklar LSD testine ($p \leq 0.05$) göre gruplandırılmıştır.

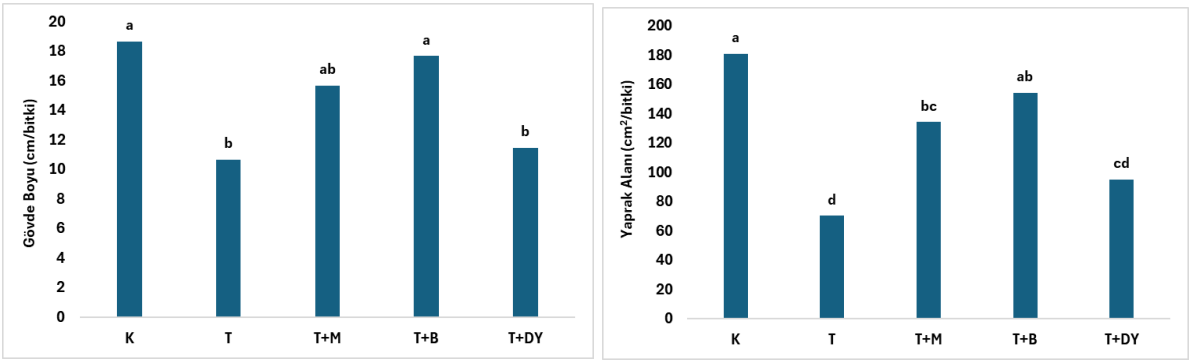
3. BULGULAR ve TARTIŞMA

Kuzukulağında farklı biostimulantların tuza toleransın sağlanmasındaki etkinliğinin incelendiği çalışmada, tuz stresi yaş ve kuru ağırlık değerlerinde azalmaya neden olmuş bu azalma kontrol bitkilerine oranla yaş ağırlıkta %69.46, kuru ağırlıkta ise %61.27 düzeyinde gerçekleşmiştir. Biyostimulant uygulamalarında ise yaş ağırlık bakımından azalma T+M'de %39.38, T+B uygulamasında %27.16 ve T+DY uygulamasında %44.17 düzeyinde gerçekleşmiştir. Kuru ağılık bakımından ise T+M uygulamasında %25.89, T+B uygulamasında %14.74, T+DY uygulamasında ise %47.59 oranından meydana gelmiştir. Yaş ağırlık değerleri incelendiğinde tuz stresi koşullarında biyostimulant uygulaması ile %82-138; kuru ağırlık değerlerinde ise %35-120 oranında iyileşme sağlanmıştır (Şekil 3.1).



Şekil 3.1. Kuzukulağında farklı biyostimulant uygulamalarının yaş ve kuru ağırlık değerleri bakımından ortaya koyduğu değişimler

Tuz stresi gövde boyu (%42.85 azalma), yaprak alanı (%61.27 azalma) ve YOSİ (%43.48) bakımından kontrol bitkilerine oranla azalmaya yol açarken bu değişim T+M uygulamasında %13-46, T+B uygulamasında %5-46, T+DY uygulamasında ise %22-49 oranlarında meydana gelmiş biyostimulant uygulaması tuz stresine oranla gövde boyu ve yaprak alanı bakımından ortalama olarak %40-89 oranında azalmayı sınırlandırmada etkili olmuştur (Şekil 3.2 ve 3.3).



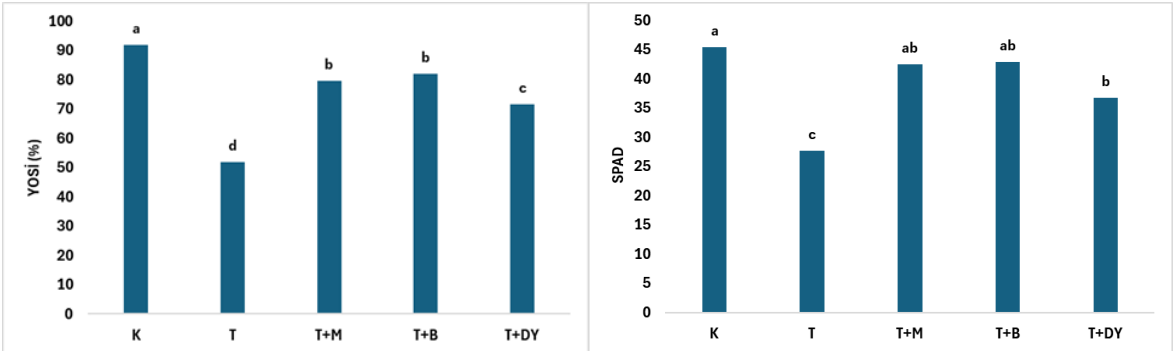
Şekil 3.2. Kuzukulağında farklı biyostimulant uygulamalarının gövde boyu, yaprak alanı ve YOSİ üzerindeki etkisi

Ciriello ve ark. (2022), tuz stresinin yaş ve kuru biyokütle, bitki boyu, yaprak alanı ve yaprak oransal su içeriği değerlerini düşürdüğünü bildirmiştir. Kuşvuran ve Yılmaz (2023), marulda yaptıkları çalışmalarda, tuz stresine bağlı olarak bitkilerin yaş ve kuru ağırlıkları ile yaprak alanı, SPAD ve YOSİ değerlerinde azalma gözlemlendiğini belirtmişlerdir. Benzer şekilde, İkiz ve ark. (2025) fesleğende tuzluluk stresinin bitki verimi, bitki boyu ve yaprak oransal su içeriği üzerinde baskılayıcı etkilere sahip olduğunu rapor etmiştir. Domateste deniz yosunu ekstraktı (SE) ile muamele edilen domateste hem kontrol hem de tuzluluk stresi koşulları altında kök ve sürgün uzunluklarında, kök ve sürgün alanları ile sürgün ve kök yaş ağırlıklarında artış meydana geldiği, tuzluluk stresine bağlı olarak verimde (meyve sayısı) meydana gelen azalışın, SE

uygulamasıyla %28,7'den yalnızca %3,4 düzeyine gerilediği belirlenmiştir (Hernández-Herrera ve ark. 2022). Kuşvuran ve Kuşvuran (2021) farklı PGPR'lerin köklere aşılanması ile bitkilerde yaş ve kuru ağırlık, fosfor ve potasyum içeriği ile fotosentetik pigmentlerde artış olduğunu, Gupta ve ark. (2024) ve İkiz (2025) bakteri uygulamalarının bitki boyu, yaş ve kuru ağırlık gibi morfolojik parametreler ile YOSİ bakımından iyileşme sağlanmasında etkili olduğunu ifade etmişlerdir. Kuşvuran ve ark (2024) dereotunda gerçekleştirmiş oldukları çalışmalarında tuz stresi ile birlikte morfolojik ve fizyolojik parametreler bakımından azalma meydana gelirken mikroalg uygulamalarının bitki büyüme ve gelişmesini artırdığını belirtmişlerdir.

SPAD değeri en yüksek kontrol bitkilerinde 45.42 olarak belirlenmiştir. Tuz stresine bağlı olarak %39 oranında azalmanın meydana geldiği çalışmada, bu azalma T+M uygulamasında %6.38, T+B uygulamasında %5.64 ve T+DY uygulamasında %19.04 oranında görülmüştür. Biyostimulant uygulamaları ile birlikte SPAD değerinde ortalama %47 oranında tuz stresi etkisi azalmıştır. Tuzluluk stresi, bitkilerde fotosentez ve solunum başta olmak üzere temel fizyolojik süreçleri baskılayarak metabolik dengenin bozulmasına yol açmaktadır (Jiang ve ark. 2021). Kuzukulağı bitkilerinde tuz stresi sonucunda SPAD değerleri %30 oranında bir azalma göstermiştir. Bu azalış; klorofil biyosentezinin sınırlandırılması, klorofil yıkım hızının artması ve tuzluluğun tetiklediği oksidatif hasar ile ilişkilendirilmektedir.

Artan tuzluluk düzeyleri, bitkilerde su alımını kısıtlayarak stomatal iletkenliğin azalmasına neden olmakta; buna bağlı olarak fotosentetik elektron taşınımı ile karbon fiksasyonunda görev alan enzimlerin aktivitesi düşmekte ve fotosentez etkinliği belirgin şekilde gerilemektedir (Zhang ve ark. 2022; Ciriello ve ark. 2024). Stres koşulları altında yetiştirilen ve deniz yosunu ekstraktı ile muamele edilen domates bitkilerinde, vejetatif büyüme özelliklerinin iyileştiği ve fotosentetik aygıtın işlevselliğinin arttığı, yapraklardaki klorofil konsantrasyonunu artırarak bitkinin fotosentetik potansiyelini güçlendirdiği ifade edilmiştir (Hernández-Herrera ve ark. 2022). Biberde tuz stresi SPAD değerlerinde azalmaya yol açarken bakteri uygulamaları SPAD değerlerinde artışa imkan sağlamıştır (İkiz, 2024). Ayrıca, brokolide mikroalg uygulamalarının tuzluluk stresine maruz kalan bitkilere kıyasla klorofil bileşenleri üzerinde olumlu etkiler gösterdiği ve klorofil içeriklerinde %35 ile %44 arasında değişen artışlar sağlandığı belirlenmiştir (Kuşvuran 2019).

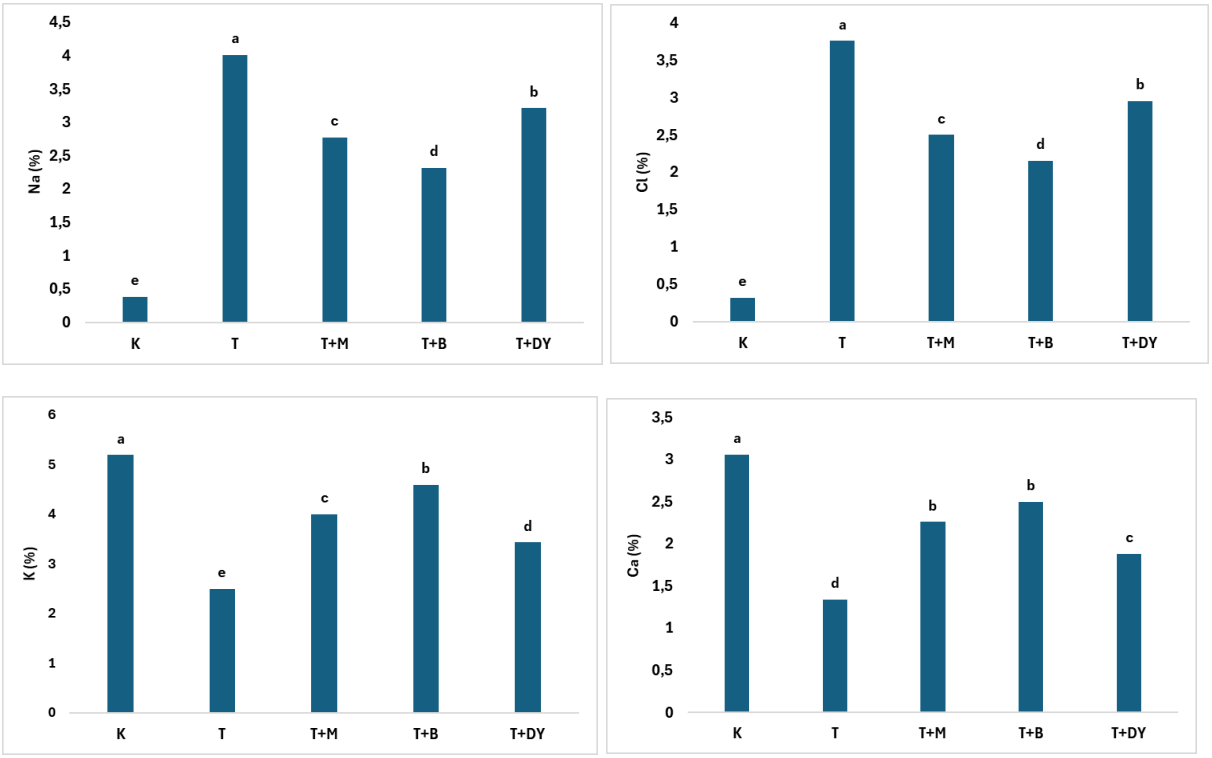


Şekil 3.3. Kuzukulağında farklı biyostimulant uygulamalarının yaprak alanı ve SPAD üzerindeki etkisi

Kuzukulağında 100 mM NaCl uygulaması, Na (%955 artış) ve Cl (%1075 artış) iyon içeriklerinde artışa yol açarken K (%52 azalma) ve Ca (%56 azalma) iyon içeriklerinde değişen oranlarda azalma meydan gelmiştir. Biyostimulant uygulamaları, tuz stresinin olumsuz etkisini genel olarak azaltmış, kontrol bitkilerine oranla Na içeriğinde ortalama olarak %628; Cl içeriğinde ise %691 oranında artış meydana gelmiştir. Bununla birlikte K içeriğinde ortalama olarak %23 düzeyinde azalma meydana gelirken bu oran Ca iyon içeriğinde %28 düzeyinde azalma şeklinde kendini göstermiştir. Uygulamalar açısından incelendiğinde T+M uygulamasında Na ve Cl iyonlarında %628 ve %681 artış olurken; K ve Ca iyon içeriğinde %22 ve %26 oranında azalma meydana gelmiştir. T+B uygulamasında Na ve Cl iyonlarında %510 ve %571 artış olurken; K ve Ca iyon içeriğinde %11 ve %18 oranında azalma meydana gelmiştir. T+DY uygulamasında ise Na ve Cl iyonlarında %744 ve %821artış olurken; K ve Ca iyon içeriğinde %33 ve %38 oranında azalma meydana gelmiştir. Biyostimulant uygulamaları genel olarak tuz stresi karşında Na ve Cl iyon alımının %19-42 oranında sınırlandırılmasında etkili olmuş, K ve Ca iyon içeriği ise %37-86 düzeyinde korunmuştur (Şekil 3.4).

Tuzluluk stresine maruz kalan bitkilerde büyümenin baskılanmasında etkili olan başlıca mekanizmalardan biri, stomatal kapanmaya bağlı olarak yaprak dokularında toksik düzeylerde Na ve Cl birikmesi ve buna paralel olarak fotoasimilat üretiminin azalmasıdır (Wang ve ark., 2024). Kök bölgesinde biriken tuz, potasyum ve kalsiyum gibi temel besin elementlerinin alımını sınırlandırırken, sodyum ve klorür iyonlarının bitki bünyesine girişini artırarak iyonik dengenin bozulmasına neden olmaktadır. Nitekim kuzukulağı bitkilerinde K ve Ca iyon içeriklerinde sırasıyla ortalama %52 ve %56 oranında azalma belirlenmiştir. Benzer şekilde, Ciriello ve ark. (2022) fesleğende tuzluluk stresi altında Na ve Cl iyon birikiminin arttığını rapor etmiş; İkiz ve ark. (2025) ise stres koşullarında Na içeriğinde %751,61 düzeyinde artışa eşlik eden K (%47) ve Ca (%34) iyonlarındaki azalışın, sodyumun besin elementi alımı üzerindeki antagonistik etkisinden kaynaklandığını bildirmiştir. Yarşı (2023), biberde deniz yosunu uygulamasının, tuzluluk stresinin olumsuz etkilerini hafifleterek bitkilerde K, Ca ve Mg alımını artırdığını, Na'nın bitki bünyesine taşınımını sınırladığını rapor etmiştir. Mikroalg–siyanoPGPR temelli biyostimülantların tuzluluk tolerans mekanizmaları, besin elementi alımı ve tuz stresi koşullarında domates bitkisinin büyümesi üzerindeki etkilerini inceleyen Mutale-Joan ve ark. (2021), 120 ve 150 mM NaCl uygulamalarına maruz bırakılan bitkilerde %5 MEF uygulamasının sodyum iyonu birikimini belirgin şekilde azalttığını bildirmiştir. *Dunaliella salina, Chlorella ellipsoidea, Aphanothece* sp. ve *Arthrospira maxima* türlerinden hazırlanan kombine mikroalg–siyanobakteri ekstraktı formülasyonunun, Na düzeylerinde sırasıyla %41,93 ve %14,08 oranlarında sınırlandığı rapor edilmiştir (İkiz, 2024). Kavunda ise mikroalg uygulamaları tuz stresi koşullarında artan Na ve Cl içeriğinin sınırlandırılması ve K ve Ca alımının sağlanmasında etkili olduğu, mikroalglerin, bitkinin besin gereksinimlerine bağlı olarak azot (N), fosfor (P) ve potasyumun (K) yavaş ve kontrollü şekilde salınmasını sağlayan

organik gübre niteliği sayesinde, besin elementi kayıplarını önleyebileceği değerlendirilmiştir (Kuşvuran ve Tuna, 2021).



Şekil 3.4. Kuzukulağında farklı biyostimulant uygulamalarının Na, Cl, K ve Ca iyon içerikleri üzerindeki etkisi

4. SONUÇ

Bu çalışmada, kuzukulağında (Rumex acetosella L.) 100 mM NaCl ile oluşturulan tuzluluk stresinin bitki büyüme, fizyolojik özellikler ve iyon dengesi üzerindeki etkileri ile farklı biyostimülant uygulamalarının (mikroalg, bakteri ve deniz yosunu) bu olumsuz etkileri hafifletme potansiyeli ortaya konmuştur. Elde edilen sonuçlar, tuz stresinin kuzukulağında bitki gelişimini belirgin şekilde baskıladığını; ancak biyostimülant uygulamalarının bu baskıyı değişen oranlarda azalttığını açıkça göstermiştir. Tuz stresi koşullarında yaş ve kuru ağırlık, bitki boyu, yaprak alanı, yaprak oransal su içeriği (YOSİ) ve SPAD değerlerinde gözlenen önemli azalmalar, tuzluluğun bitkide hem ozmotik stres hem de iyon toksisitesi yoluyla büyümeyi sınırlandırdığını ortaya koymuştur. Buna karşın, biyostimülant uygulamaları ile birlikte söz konusu morfolojik ve fizyolojik parametrelerde anlamlı iyileşmeler sağlanmış; özellikle bakteri (T+B) ve mikroalg (T+M) uygulamaları, bitki biyokütlesinin ve vejetatif gelişmenin korunmasında daha etkili bulunmuştur. Bu durum, mikrobiyal kökenli biyostimülantların kök bölgesinde besin alımını ve kök–sürgün iletişimini güçlendirerek stres koşullarında bitki performansını artırabildiğini düşündürmektedir. Fizyolojik açıdan değerlendirildiğinde, tuz stresinin yaprak su durumunu ve klorofil içeriğini olumsuz etkilediği;

buna karşılık biyostimülant uygulamalarının YOSİ ve SPAD değerlerini önemli ölçüde iyileştirdiği belirlenmiştir. Özellikle bakteri ve mikroalg uygulamalarının, yaprak su içeriğini koruyarak stomatal fonksiyonların ve fotosentetik kapasitenin sürdürülebilmesine katkı sağladığı anlaşılmaktadır. Deniz yosunu uygulaması da olumlu etki göstermiş olmakla birlikte, bu etkinin diğer iki biyostimülanta kıyasla daha sınırlı kaldığı görülmüştür. İyon içerikleri bakımından elde edilen sonuçlar, biyostimülantların tuzluluk toleransındaki temel rolünün iyon dengesinin düzenlenmesiyle ilişkili olduğunu ortaya koymuştur. Tuz stresi Na^+ ve Cl^- iyonlarının bitki bünyesinde aşırı birikimine yol açarken, K^+ ve Ca^{2+} iyonlarının alımını belirgin şekilde sınırlandırmıştır. Biyostimülant uygulamaları ise Na ve Cl iyonlarının alımını önemli ölçüde sınırlandırmış; buna karşılık K ve Ca iyonlarının korunmasını sağlayarak iyonik dengenin sürdürülmesine katkıda bulunmuştur. Bu etki özellikle bakteri uygulamasında daha belirgin olup, kök bölgesinde Na^+ taşınımının sınırlandırılması ve yararlı besin elementlerinin alımının desteklenmesi açısından öne çıkmıştır.

Genel olarak değerlendirildiğinde, bu çalışmadan elde edilen bulgular, biyostimülant uygulamalarının kuzukulağında tuzluluk stresine karşı toleransın artırılmasında etkili bir strateji olduğunu ortaya koymaktadır. Özellikle bakteri ve mikroalg temelli biyostimülantların, bitki büyümesini sürdürme, su ilişkilerini koruma ve iyon toksisitesini azaltma açısından daha güçlü bir iyileştirici etki gösterdiği belirlenmiştir. Bu sonuçlar, tuzluluk problemi bulunan veya tuzluluk riski taşıyan üretim alanlarında kuzukulağı yetiştiriciliğinde biyostimülant kullanımının sürdürülebilir üretim açısından önemli bir potansiyele sahip olduğunu göstermektedir. Ayrıca, ilerleyen çalışmalarda antioksidan enzim aktiviteleri, ozmolit birikimi ve moleküler stres yanıtlarının incelenmesi, biyostimülantların tuz toleransını hangi mekanizmalarla artırdığının daha ayrıntılı olarak açıklanmasına katkı sağlayacaktır.

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FARKLI FESLEĞEN ÇEŞİTLERİNDE TUZ STRESİNİN ETKİLERİ

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ÖZET

Tuz stresi bitkisel üretimi olumsuz etkileyen en önemli abiyotik stres faktörlerinden biridir. Farklı fesleğen çeşitlerinin (Midnight, Arge Sweet, Compact) tuz stresine tolerans düzeylerinin incelendiği çalışmada, tohumlar 2:1 oranında torf:perlit içerek viyollere ekilmiş, bitkiler 3-4 yapraklı aşamaya ulaştıklarında yine 2:1 oranında torf:perlit içerek 11 L hacmindeki saksılara şaşırtılmıştır. Şaşırtmadan 11 gün sonra stres uygulamalarına başlanmış ve başlangıçta 50 mM NaCl dozu kullanılarak tuz konsantrasyonu kademeli şekilde artırılarak nihai olarak 100 mM NaCl seviyesine ulaşılmıştır. Tuz stresine yirmi sekiz gün süreyle maruz bırakılan bitkiler, hasat edilerek yeşil aksam yaş ve kuru ağırlığı, gövde uzunluğu, yaprak alanı, yaprak oransal su içeriği, SPAD değeri, yaprakta pH, SÇKM, EC değerleri ile yeşil aksamda Na, Cl, K ve Ca iyon içerikleri bakımından değerlendirilmiştir. Uygulanan 100 mM NaCl tuz stresi, yeşil aksam yaş ve kuru ağırlığı, gövde boyu, yaprak alanı, yaprak oransal su içeriği (YOSİ) ve SPAD değerlerinde farklı oranlarda azalmaya yol açmış, Arge Sweet kontrol bitkileriyle karşılaştırıldığında, kayıpların daha düşük düzeyde gerçekleştiği görülmüştür. Tüm çeşitlerde stres uygulaması sonucunda Na ve Cl iyon içeriklerinde kontrol bitkilerine kıyasla sırasıyla ortalama %863 ve %929 oranında artış meydana gelmiştir. Toksik iyon birikimi bakımından daha seçici davranarak bünyesinde daha düşük düzeyde Na ve Cl iyonu biriktiren Midnight ve Arge Sweet çeşitleri olmuştur. Öte yandan, K ve Ca iyon içerikleri, 100 mM NaCl uygulamasıyla sırasıyla %25 ve %38 oranında azalmıştır. Bu azalma Arge Sweet çeşidinde daha sınırlı düzeyde kalmıştır. Yapraklarda pH değerleri stres koşullarında tüm çeşitlerde azalmış ancak istatistiksel olarak önemsiz bulunmuştur. SÇKM ve EC değerleri ise artış gösterirken bu artış SÇKM bakımından Midnight, EC değeri ise en yüksek Compact çeşidinde tespit edilmiştir. Elde edilen tüm veriler ışığında, erken gelişim döneminde gerçekleştirilen bu çalışmada çeşitlerin tuz stresine tolerans düzeylerinin farklılık gösterdiği Midnight ve Arge Sweet çeşitlerinin tuz stresine toleransının daha yüksek olduğu görülmüştür.

Anahtar Kelimeler: *Ocimum basilicum*, Sodyum, Tuz Stresi, Yaprak Oransal Su İçeriği

1. GİRİŞ

Toprak tuzluluğu, tarımsal üretim ve gıda güvenliği açısından en ciddi tehditlerden biri olarak kabul edilmekte olup, günümüzde tarım alanlarının %20'sinden fazlasını etkilemekte ve bu oranın 2050 yılına kadar %50'ye ulaşması beklenmektedir (AbuQamar ve ark. 2024). Tuz stresi, bitkilerin morfolojik, fizyolojik ve biyokimyasal işlevleri üzerinde olumsuz etkiler ortaya koymaktadır. Topraktaki yüksek tuz konsantrasyonu, su iletkenliği ve toprak gözenekliliğini azaltmakta bununla birlikte, bitkilerde besin alımı, fotosentez hızı, stomaların açılması, tohum çimlenmesi ve genel büyümeyi olumsuz etkilemektedir. (Semida ve ark. 2021, Ahmad ve ark. 2023, Seleiman ve ark. 2023, AbuQamar ve ark. 2024). Toprak tuzluluğu, reaktif oksijen türlerinin (ROS) oluşumunu artırarak; lipidler, nükleik asitler, proteinler ve diğer hücresel bileşenlerde ilerleyici oksidatif zararlara yol açar ve sonuç olarak bitki ölümüne neden olabilir. Tuzluluk stresine maruz kalan bitkilerde ozmotik stres, iyon toksisitesi ve besin dengesizlikleri gözlemlenir (AbuQamar ve ark. 2024). Ozmotik stres, vakuollerde çözücülerin aktif birikimiyle ilişkili yaygın bir fizyolojik olay olan hipertonik dehidrasyona yol açar ve bitkilerin su alımını engeller (Alkharabsheh ve ark. 2021). İyon toksisitesi ise hücrelerde sodyum (Na) ve klor (Cl) iyonlarının aşırı birikimiyle ortaya çıkar. Na ve Cl iyonlarının bitki hücre duvarlarına zarar vermesi, osmotik dengesizlik oluşturması ve iyon dengesini bozması sonucunda terleme, fotosentez, besin taşınımı ve diğer metabolik süreçlerde bozulmalar meydana gelir (AbuQamar ve ark. 2024).

Fesleğen (*Ocimum basilicum* L.), Lamiaceae familyasında yer alan tek yıllık veya çok yıllık olarak yetiştirilebilen bir bitkidir. Fesleğen hem baharat hem de hoş kokusuyla birlikte süs bitkisi olarak yetiştiriciliği yapılmaktadır. Anavatanı İran, Güney Asya ve özellikle Hindistan orjinli olan fesleğen sıcak iklim koşullarına sahip yerlerde doğal olarak yetiştiği gibi ayrıca Fransa, İspanya ve İtalya gibi bazı Avrupa ülkelerinde de önemli yetiştiriciliği vardır. Dünyada yılda ortalama 90-95 ton civarında üretimi yapılan fesleğen bitkisinin, ülkemiz de dahil olmak üzere İtalya ve Brezilya gibi Akdeniz ülkelerinin yanında Amerika, Fransa, İsrail ve Kuzey Afrika'da da yoğun bir şekilde üretimi ve tüketimi gerçekleştirilmektedir. 2021 yılında Çin en fazla fesleğen ihracatı yapan, Amerika Birleşik Devletleri en fazla fesleğen ithalatı yapan ülke olmuş; ihracat değeri 3.52 bin dolar, ithalat değeri 3.39 bin dolar olarak kayıtlara geçmiştir (Sayın, 2023). Fesleğen, sadece aromatik özelliğiyle değil aynı zamanda tıbbi potansiyele sahip olmasıyla da dikkat çeker. Artık sağlık tedavilerinde de sıklıkla kullanılmaktadır. Son dönemlerde, fesleğenle ilgili çalışmalar, güçlü antioksidan aktivite gösteren organik bileşikler içeren uçucu ekstrelerin artan ilgisini çekmektedir. Bu durum, fesleğenin sadece bir baharat bitkisi değil aynı zamanda tıbbi bir bitki olarak da görülmesine ve yetiştirilmesine yol açmıştır (Karacaoğlu, 2023).

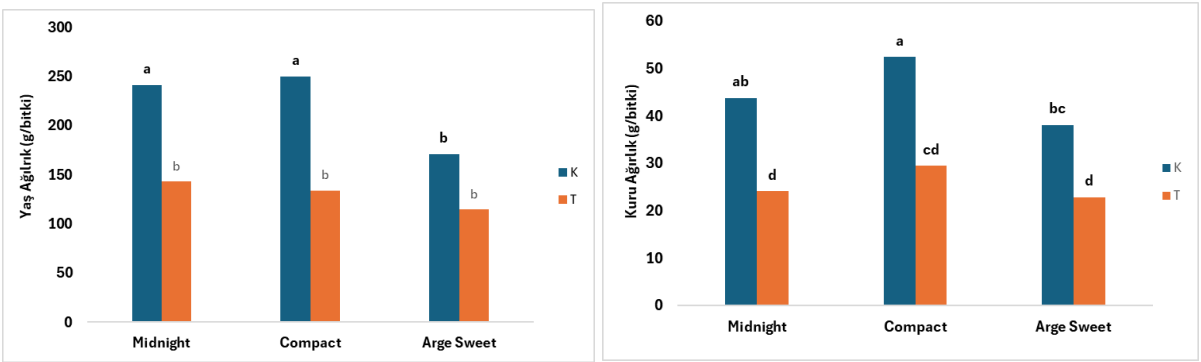
Bu çalışma ile farklı fesleğen çeşitlerinin tuz stresine karşı tolerans düzeylerinin belirlenmesi ve elde edilen bulgular doğrultusunda tuzluluk sorunu bulunan yetiştirme alanlarında sürdürülebilir fesleğen üretimine yönelik önerilerin geliştirilmesi amaçlanmıştır.

2. MATERYAL ve YÖNTEM

Çalışmada Midnight, Arge Sweet, Compact olmak üzere 3 farklı fesleğen çeşidi (Genta Prestige) kullanılmıştır. Çeşitlere ait tohumlar 2:1 oranında torf:perlit karışımı içeren viyollere ekilmiştir. Tohum ekiminden 36 gün sonra fideler 11 litre hacmindeki plastik saksılara (torf:perlit) her saksıda dört adet bitki olacak şekilde şaşırtılmıştır. Bitkiler saksılara şaşırtıldıktan on bir gün sonra stres uygulamalarına başlanmış ve başlangıçta 50 mM NaCl dozu kullanılarak tuz konsantrasyonu kademeli şekilde artırılarak nihai olarak 100 mM NaCl seviyesine ulaşılmıştır. Bitkiler standart besin çözeltisi ile sulanmıştır (İkiz ve ark. 2024). Sulamada "drene olan çözelti/uygulanan çözelti" oranı esas alınmıştır (Schröder ve Lieth, 2002). Günlük olarak drenaj seviyeleri belirlenmiş ve bu oran deneme süresince bitkilerin büyümesine göre %30 civarında tutulmuştur. Yirmi sekiz gün süreyle strese maruz bırakılan bitkiler, hasat edilerek çeşitli ölçüm ve analizler gerçekleştirilmiştir. Bu amaçla bitkilerde yeşil aksam yaş ve kuru ağırlığı, gövde uzunluğu, yaprak alanı, yaprak oransal su içeriği (Sanchez ve ark. 2004; Türkan ve ark. 2005), SPAD değeri, yaprakta pH, SÇKM, EC değerleri ile yeşil aksamda Na, Cl, K ve Ca (Dasgan ve Koc, 2009) iyon içerikleri incelenmiştir. Çalışma tesadüf parselleri deneme desenine göre 3 tekrarlamalı olarak yürütülmüştür. Verilerin istatistiksel analizinde JMP (versiyon 8.0) programı kullanılmış, ortalamalar arasındaki farklılıklar LSD testine ($p \leq 0.05$) göre gruplandırılmıştır.

3. BULGULAR ve TARTIŞMA

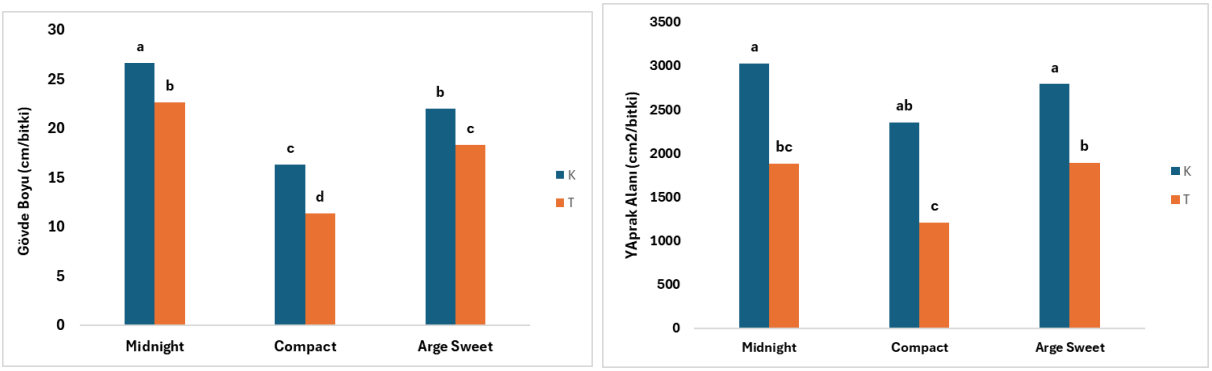
Kontrol koşullarında fesleğen çeşitleri yeşil aksam yaş ağırlıkları 170.79- 250.01 g/bitki ve kuru ağırlıkları 38.10- 52.41 g/bitki arasında değişmiş; en yüksek yaş ve kuru ağırlık değerleri Compact (250.01 g/bitki ve 52.41 g/bitki) çeşidinde, en düşük değerler ise Arge Sweet (170.79 g/bitki ve 38.10 g/bitki) çeşidinde saptanmıştır. Tuz stresi (100 mM NaCl), yeşil aksam yaş ve kuru ağırlıklarında farklı oranlarda azalmaya yol açmış olup bu azalmalar çeşitler arasında değişkenlik göstermiştir (Şekil 3.1). Buna göre, kontrol bitkilerine kıyasla en az oranda azalma gösteren çeşit Arge Sweet (%32.93 ve %40.00 azalma), bunu sırasıyla Midnight (%40.70 ve %44.97 azalma) ve Compact (%46.37 ve %50.12 azalma) çeşitleri izlemiştir.



Şekil 3.1. Farklı fesleğen çeşitlerinin tuz stresi koşullarında yaş ve kuru ağırlık bakımından ortaya koyduğu değişimler

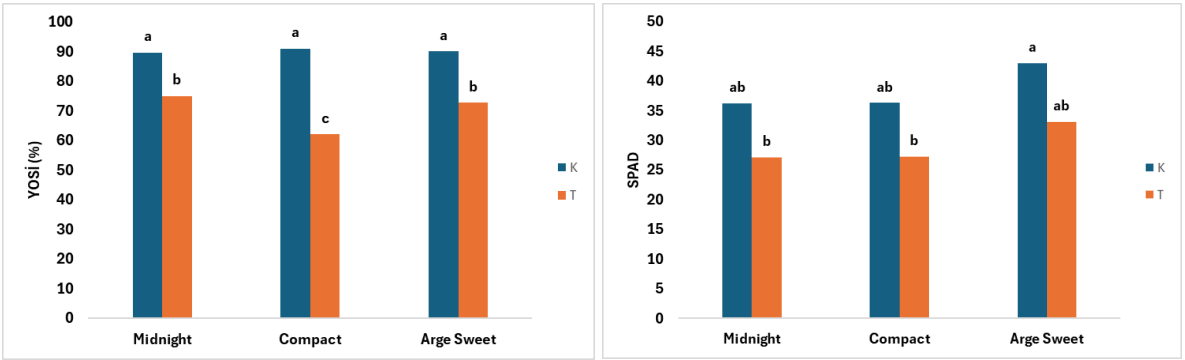
Farklı fesleğen çeşitlerinin yer aldığı çalışmada 100 mM NaCl uygulaması gövde boyu, yaprak alanı ve SPAD değerlerinde azalmaya yol açmış bu azalma çeşitler arasında farklılıklar

göstermiştir. Tuz stresine koşullarında gövde boyu bakımından kontrol bitkilerine en yakın gelişme dolayısıyla % değişimin en az olduğu çeşit %15.00 azalma ile Midnight olurken bu çeşidi %16.68 ile Arge Sweet, %30.62 ile Compact izlemiştir. Yaprak alanı bakımından değişimin sınırlı olduğu çeşit %32.36 ile Arge Sweet olmuş, kontrol bitkilerine oranla kayıpların en fazla olduğu çeşit %48.67 azalma ile Compact çeşidi belirlenmiştir. Klorofil SPAD değerleri tuz stresi ile birlikte ortalama olarak %24.37 oranında azalma göstermiş, bu azalma Midnight %28.19; Compact %24.81, Arge Sweet %23.09 düzeyinde saptanmıştır (Şekil 3.2 ve 3.3).



Şekil 3.2. Farklı fesleğen çeşitlerinin tuz stresi koşullarında gövde boyu ve yaprak alanı bakımından ortaya koyduğu değişimler

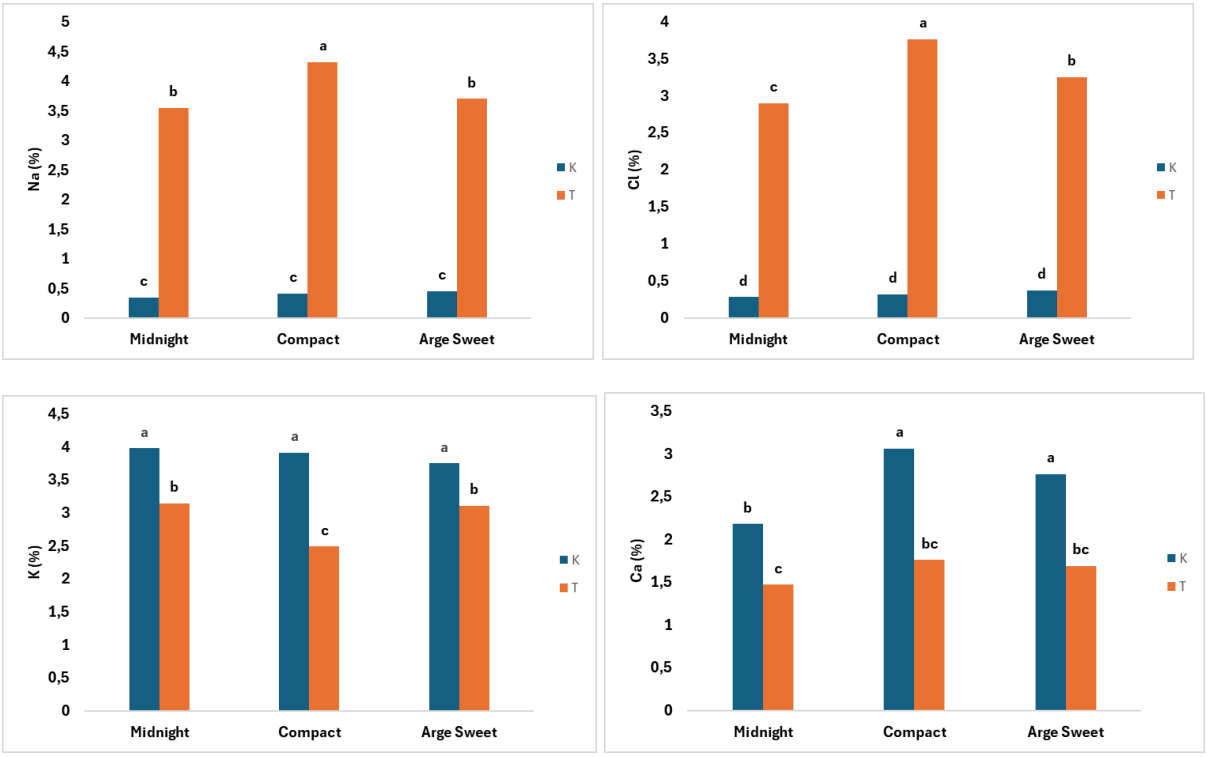
Yaprak oransal su içeriği (YOSİ) değerleri tuz uygulamasıyla ortalama olarak %22.49 oranında azalma göstermiştir. En düşük kayıp, dolayısıyla stres koşullarında su içeriğini koruyabilen çeşit Midnight çeşidi (%16.36 azalma) olurken; YOSİ'de en belirgin azalma %31.87 oranında azalma ile Compact fesleğen çeşidinde gözlenmiştir (Şekil 3.3).



Şekil 3.3. Farklı fesleğen çeşitlerinin tuz stresi koşullarında yaprak oransal su içeriği ve SPAD bakımından ortaya koyduğu değişimler

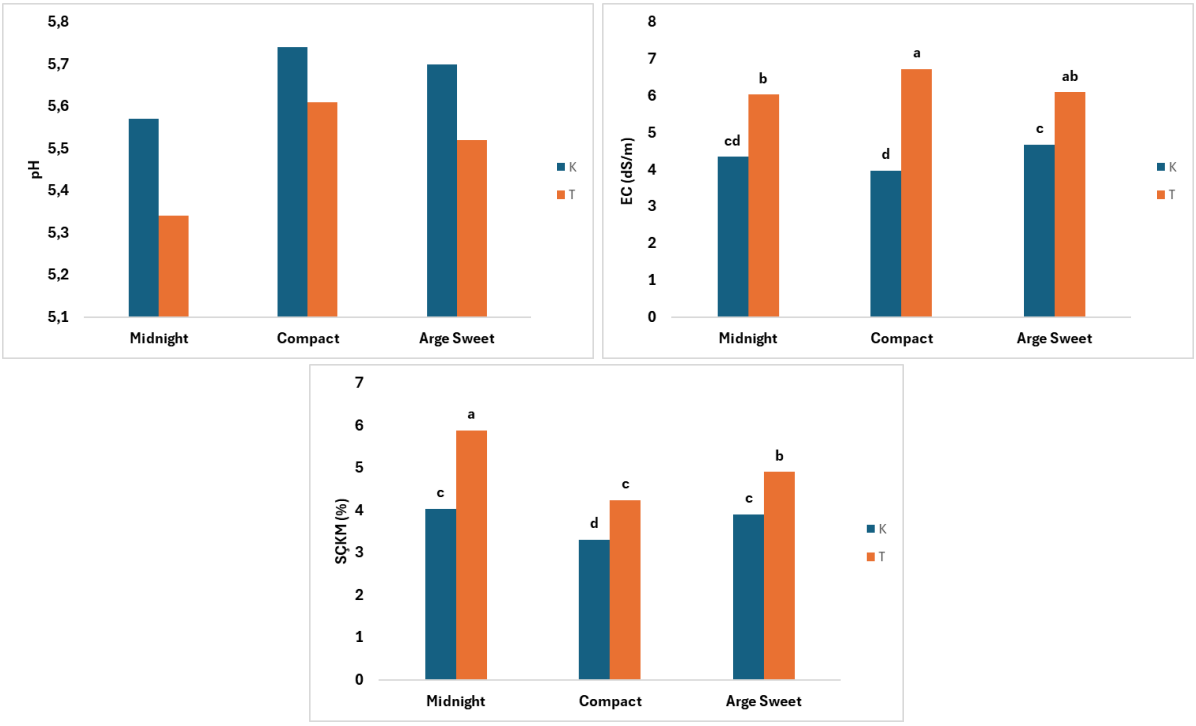
Fesleğende 100 mM NaCl uygulaması ortalama olarak, Na (%863.39 artış) ve Cl (%664.58 artış) iyon içeriklerinde artışa yol açarken K (%24.83 azalma) ve Ca (%37.94 azalma) iyon içeriklerinde azalma meydana gelmiştir (Şekil 3.4). Çeşitler açısından incelendiğinde Midnight

çeşidinde Na ve Cl iyonlarında %914.29 ve %635.71 artış olurken; K ve Ca iyon içeriğinde %21.11 ve %32.57 oranında azalma meydana gelmiştir. Compact fesleğen çeşidinde Na ve Cl iyonlarında %953.66 ve %809.98 artış olurken; K ve Ca iyon içeriğinde %36.32 ve %42.48 oranında azalma meydana gelmiştir. Arge Sweet fesleğen çeşidinde ise Na ve Cl iyonlarında %722.22 ve %548.65 artış olurken; K ve Ca iyon içeriğinde %17.07 ve %38.77 oranında azalma meydana gelmiştir.



Şekil 3.4. Farklı fesleğen çeşitlerinin tuz stresi koşullarında Na, Cl, K ve Ca iyon içerikleri bakımından ortaya koyduğu değişimler

Fesleğen çeşitlerinde yaprak pH, EC ve SÇKM değerlerinin de belirlendiği çalışmada, pH düzeyi ortalama olarak %3.18 oranında azalma göstermekle birlikte belirlenen değişim istatistiksel olarak önemsiz bulunmuştur. EC ve SÇKM değerleri stres koşullarında artış göstermiştir. Kontrol bitkileri ile karşılaştırıldığında meydana gelen değişim Midnight çeşidinde %38.94 ve %45.91; Compact çeşidinde %69.27 ve %28.10, Arge Sweet fesleğen çeşidinde ise %30.41 ve %25.64 düzeyinde gerçekleşmiştir (Şekil 3.5).



Şekil 3.5. Farklı fesleğen çeşitlerinin tuz stresi koşullarında pH, EC ve SÇKM bakımından ortaya koyduğu değişimler

Toprak tuzluluğu, bitkilerde morfolojik yapıların yanı sıra biyokimyasal işlevler üzerinde de olumsuz etkilere yol açmaktadır. Tuz stresi, tohum çimlenmesinden başlayarak bitkilerin büyüme, gelişme ve verim performansını önemli ölçüde düşürmektedir (Zhang ve Dai 2019). Ayrıca, klorofil ve karotenoid pigmentlerinin içeriğini azaltarak kloroplast yapısını ve fotosistem II'nin işleyişini bozmakta, dolayısıyla fotosentetik mekanizmaların etkinliğini kısıtlamaktadır (Pan ve ark. 2021). Toprak tuzluluğu hem toprak su potansiyelinin hem de yaprak su potansiyelinin azalmasına sebep olarak bitkinin su ilişkilerinde dengesizliklere ve nihayetinde ozmotik stresin oluşmasına zemin hazırlamaktadır (Navada ve ark. 2020). Tuzluluk, özellikle sodyum (Na) ve klor (Cl) iyonlarının birikimine bağlı olarak ozmotik stresin şiddetlenmesine neden olmaktadır. Stres koşulları altında, bitki büyüme ve gelişmesinde gerileme yaşanmakta; bununla birlikte reaktif oksijen türlerinin (ROS) düzeyinde artış gözlenmekte ve bu süreç sonucunda oksidatif stres ortaya çıkmaktadır (Arif ve ark. 2020; Abdel Latef ve ark. 2021).

Fesleğen çeşitlerinde 100 mM NaCl uygulamasına yönelik etkilerin değerlendirildiği bu çalışmada, tuz stresinin morfolojik parametreler üzerinde belirgin olumsuz etkiler yarattığı saptanmıştır. Özellikle yaş ve kuru ağırlık, gövde uzunluğu ile yaprak alanı gibi özelliklerde dikkate değer azalmalar gözlenmiştir. Kontrol bitkileriyle karşılaştırıldığında, ortalama olarak

yaş ağırlık %40, kuru ağırlık %45, gövde boyu %21, ve yaprak alanında %40 oranında azalma meydana gelmiştir. Bu değişimler, çeşitler arasında farklı tolerans düzeylerini ortaya koymuştur. Tuz stresinin fizyolojik ve biyokimyasal değişimler üzerindeki etkisini inceleyen Garrido ve ark. (2014), stres koşullarında yaş ağırlık, yaprak alanı, yaprak oransal su içeriği gibi fizyolojik parametreler bakımından azalma meydana geldiğini ifade etmişlerdir. Ciriello ve ark. (2022) farklı fesleğen çeşitlerinde gerçekleştirmiş oldukları çalışmalarında tuz stresi koşullarında (60 mM NaCl) tüm çeşitlerde yaş ve kuru ağılık, bitki boyu, yaprak alanı ve yaprak oransal su içeriği değerlerinde azalma meydana geldiğini bu değişimin çeşitlere arasında farklılıklar ortaya koyduğunu; İkiz ve ark. (2025) ise fesleğende tuz stresinin bitki verimi, bitki boyu ve YOSİ değerlerinde azalmaya neden olduğunu bildirmişlerdir.

Tuz stresi, bitkilerde fotosentez ve solunum süreçlerini olumsuz etkileyerek metabolik dengenin bozulmasına neden olmaktadır (Jiang ve ark. 2021). Fesleğende, tuz stresinin etkisiyle SPAD ölçümleriyle belirlenen yaprak klorofil içeriklerinde ortalama %24 oranında azalma tespit edilmiştir. Klorofil biyosentezinin baskılanması, klorofilin parçalanma hızının artması ve tuzluluğun yol açtığı oksidatif hasar, klorofil içeriğindeki azalmaların temel nedenleri arasında gösterilmektedir. Artan tuzluluk, bitkilerde su alımını kısıtlayarak stomaların kapanmasına sebep olmakta; bu durum ise fotosentetik elektron taşıma zinciri ile karbon fiksasyonunda görevli enzimlerin aktivitelerini düşürerek fotosentez verimliliğinin azalmasına yol açmaktadır (Zhang ve ark. 2022). Ciriello ve ark. (2024), tuz stresine maruz bırakılan fesleğen bitkilerinde klorofil a, klorofil b ve toplam klorofil içeriklerinde azalma meydana geldiğini, bu azalmanın, klorofil biyosentezinde görev alan aminolevulinik asit sentaz ve/veya aminolevulinik asit dehidrataz enzimlerinin aktivitelerindeki düşüş ile klorofil parçalanmasından sorumlu klorofilaz enziminin artan etkisiyle ilişkili olabileceği bildirmiştir.

Tuz stresine maruz kalan bitkilerde büyüme gerilemesinin temel nedenlerinden biri, stomaların kapanması sonucu yapraklarda toksik Na ve Cl birikimine bağlı olarak fotoasimilat üretiminde meydana gelen azalmadır. Farklı fesleğen çeşitlerinin yer aldığı çalışmada tüm çeşitlerde Na ve Cl iyonlarında ortalama olarak %863 ve %664 düzeyinde artış meydana gelmiştir. Kök bölgesinde biriken tuz, potasyum ve kalsiyum gibi temel besin maddelerinin emilimini kısıtlarken, sodyum ve klorür iyonlarının girişini artırarak bitkilerde iyon dengesini bozar. Nitekim fesleğen gerçekleştirilen bu çalışmada K iyon içeriği ortalama olarak %24 ve Ca iyon içeriği ise %38 oranında azalma göstermiştir. Ciriello ve ark. (2022) fesleğende tuz stresine bağlı olarak Na ve Cl iyonlarında artış meydan geldiğini, İkiz ve ark. (2025) stres koşullarında Na oranındaki artış (%751.61 artış) ile birlikte K iyon içeriğinde %47 ve Ca içeriğinde %34 oranında azalma meydana geldiğini bu durumun sodyumun besin emilimi üzerindeki antagonistik etkisinden kaynaklandığını ifade etmişlerdir.

4. SONUÇ

Bu çalışmada, üç farklı fesleğen çeşidinin (Midnight, Arge Sweet ve Compact) erken gelişim döneminde 100 mM NaCl tuz stresine verdikleri morfolojik, fizyolojik ve iyonik tepkiler karşılaştırmalı olarak değerlendirilmiştir. Elde edilen bulgular, tuz stresinin tüm çeşitlerde bitki

büyüme ve gelişimini baskıladığını; ancak bu baskının şiddetinin çeşitlere bağlı olarak önemli farklılıklar gösterdiğini açıkça ortaya koymuştur. Tuz stresi koşullarında yeşil aksam yaş ve kuru ağırlığı, gövde boyu, yaprak alanı, yaprak oransal su içeriği (YOSİ) ve klorofil içeriğini yansıtan SPAD değerlerinde meydana gelen azalmalar, bitkilerin ozmotik stres ve iyon toksisitesine verdikleri duyarlılığı göstermiştir. Bu parametreler açısından değerlendirildiğinde, Arge Sweet ve Midnight çeşitlerinin, Compact çeşidine kıyasla stres koşullarında büyüme ve su dengesini daha iyi koruyabildiği belirlenmiştir. Özellikle Arge Sweet çeşidinde yaş ve kuru ağırlık kayıplarının daha sınırlı olması, bu çeşidin tuzluluk koşullarında biyokütle üretim kapasitesini görece daha iyi sürdürebildiğini göstermektedir. İyon içerikleri bakımından elde edilen sonuçlar, çeşitler arasındaki tuz toleransının temelinde iyon düzenleme mekanizmalarının yer aldığını ortaya koymuştur. Tuz stresi altında tüm çeşitlerde Na^+ ve Cl^- iyonlarında belirgin artışlar gözlenirken, bu artışın Compact çeşidinde daha yüksek düzeyde gerçekleşmesi, bu çeşidin iyon toksisitesine daha duyarlı olduğunu düşündürmektedir. Buna karşılık Midnight ve Arge Sweet çeşitlerinde Na ve Cl birikiminin daha sınırlı düzeyde kalması, bu çeşitlerin toksik iyonların yeşil aksamda birikimini kısmen engelleyebilen daha seçici bir iyon alım ve taşınım sistemine sahip olabileceğini göstermektedir. Aynı zamanda K^+ ve Ca^{2+} iyonlarındaki azalmaların Arge Sweet çeşidinde daha düşük düzeyde olması, bu çeşidin besin iyon dengesini stres koşullarında daha iyi koruduğunu ortaya koymaktadır. Fizyolojik parametreler incelendiğinde, yaprak pH değerlerinde gözlenen ancak istatistiksel olarak anlamlı olmayan düşüş, tuz stresinin hücresel metabolizma üzerinde sınırlı bir asidifikasyon etkisi yarattığını düşündürmektedir. Buna karşın EC ve SÇKM değerlerindeki artışlar, stres koşullarında ozmotik düzenlemenin çözünebilir iyonlar ve organik bileşikler üzerinden sağlanmaya çalışıldığını göstermektedir. Özellikle EC değerinin Compact çeşidinde daha yüksek artış göstermesi, bu çeşitte yaprak dokularında daha yoğun iyon birikiminin gerçekleştiğini desteklemektedir. Genel olarak değerlendirildiğinde, bu çalışmadan elde edilen veriler, Midnight ve Arge Sweet fesleğen çeşitlerinin 100 mM NaCl tuz stresine karşı daha yüksek tolerans düzeyi sergilediğini; Compact çeşidinin ise hem morfolojik gerileme hem de iyon toksisitesi açısından daha hassas bir yapı gösterdiğini ortaya koymuştur. Bu farklılıkların, çeşitlerin su ilişkileri, iyon seçiciliği ve besin dengesini sürdürme kapasitelerindeki genetik ve fizyolojik farklılıklardan kaynaklandığı düşünülmektedir. Sonuç olarak, tuzluluk problemi bulunan veya tuzluluk riski taşıyan üretim alanlarında, Midnight ve özellikle Arge Sweet çeşitlerinin yetiştiricilik açısından daha uygun olduğu söylenebilir. Bununla birlikte, ilerleyen çalışmalarda bu çeşitlerde antioksidan enzim aktiviteleri, ozmolit birikimi ve moleküler düzeyde stres yanıtlarının incelenmesi, tuz toleransının altında yatan mekanizmaların daha ayrıntılı olarak ortaya konmasına katkı sağlayacaktır.

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ÜŞÜME STRESİNİN ASTER (*Aster amellus* L.) BİTKİLERİNDE BAZI BÜYÜME PARAMETRELERİNE YANSIMALARI

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ÖZET

Bu çalışmanın amacı, Aster (*Aster amellus* L.) bitkisinin, bitki organlarına göre üşüme stresine maruz kalma performansını belirlemektir. Çalışmada Aster (*Aster amellus* L.) ait tohumlar kullanılmıştır. Tohumlar Torf/perlit (3/1) karışımı ile hazırlanan fide yetiştirme harcı viyollere doldurulduktan sonra aynı derinlikte olacak şekilde ekilmiştir. Kaplar 23±2 ºC'de sıcaklık, 12 saat ışık (450 µmol/m^2 /s ışık şiddeti) ve 12 saat karanlık ve % 60-70 hava oransal nem bulunan normal atmosferin sağlandığı iklim odasına alınmıştır. Tohumlar çimleninceye kadar saf su ile sulama yapılmıştır. Viyollerin üzeri kağıtla örtülmüştür, çimlenmeyi takiben bu örtüler kaldırılmıştır. İlk gerçek yaprakları çıkan bitkicikler çapları 15 cm, yükseklikleri 12 cm ve taban çapları 10 cm çapındaki saksılara alınmıştır. Fideler, dört beş yapraklı olunca kontrol grubu (23±2 º C) iklim odasında bırakılmış, üşüme stresi uygulamak içinde inkübatöre alınmış ve kademeli olarak üşüme stresine tabi tutulmuştur. Her bir üşüme sıcaklığı uygulaması sonrası (12 saatlik fotoperiyotta 10 ºC gündüz /4 ºC gece; 8 ºC gündüz /3 ºC gece; 6 ºC gündüz /2 ºC gece; 4 ºC gündüz /1 ºC gece; 3 ºC gündüz /0 ºC gece) alınan bitkilerin kök, gövde, yaprakların yaş ağırlığı, yaprak sayısı, gövde çapı ve uzunluğu, kök uzunluğu ölçülmüştür. Araştırma sonucunda, Aster bitkilerinin gelişimlerinde kontrollere göre farklılıklar olduğu bulunmuştur. Bitkilerin gelişim performanslarının üşüme sıcaklığı düştükçe önemli ölçüde azaldığı tespit edilmiştir.

Anahtar Kelimeler: Aster, büyüme, üşüme stresi,

1. GİRİŞ

Üşüme stresi, bitkilerin büyümesini ve gelişmesini etkileyen verim kayıplarına sebep olan önemli bir abiyotik stres faktörüdür. Yüksek bitkilerin üşüme stresine verdiği fizyolojik tepkilerin tam olarak bilinmemesine rağmen, yapılan bilimsel çalışmalarda fotosentez olayının üşüme stresinden en kritik düzeyde etkilenen metabolik bir süreç olduğunu bildirmişlerdir. [1,2,3]. Düşük sıcaklığın fotosentez üzerine olumsuz etkisi ışık yoğunluğuna bağlıdır. Bunun önemi de mekanizmanın zarar görme derecesi ile ortaya çıkar. Yüksek ışık şiddetinin düşük

sıcaklıkla birlikte uygulanması durumunda, fotosistem II (PS II) ciddi düzeyde zarar görmektedir. Bu tür bir stres koşulu, fotosentezde geri dönüşü olmayan bir inhibisyona yol açmaktadır. Düşük sıcaklık kaynaklı fotosentetik inhibisyonun derecesi, ışık yoğunluğu ile doğrudan korelasyon gösteren ve fotosentetik aygıtın hasar boyutunu belirleyen kritik bir sinerjik faktör olarak öne çıkmaktadır. [4,5,6]. Donma derecesinin üzerindeki düşük sıcaklıklara maruz kalan fidelerde, kök iletkenliğinin ve su alımının azalmasıyla birlikte kök ucu düşüşü ve kök büyümesinde gerileme gibi fizyolojik bozulmalarına neden olur. [7,8]. Kök, rizom ve soğan gibi toprak altı organlarının soğuğa karşı sürgünlerden inherent olarak daha duyarlı olmasına rağmen, toprağın sıcaklığını hafifletme kapasitesi sayesinde tarla koşullarında korunduğu, ancak saksı deneylerinde bu hafifletici etkinin ortadan kalktığı yapılan bilimsel çalışmalarla ortaya konmuştur [9]. Üşüme zararının ilk belirtilerinden biri de kökten su alımı ve transpirasyon arasındaki dengenin değişmesi nedeniyle meydana gelen gövde susuz kalır. [2,10]. Ayrıca, köklerdeki yavaş gelişim gövde de görülmeye başlar. Üşüme stresine maruz kalan bitkilerde, yaprak genişliğinin azalması gibi morfolojik değişimlerin yanı sıra, şiddetli stresin tetiklediği hücresel otoliz ve yaşlanma süreçleri, genellikle epidermal hücre çöküşüne bağlı çukur/batık lezyonlar şeklinde kendini gösteren doku hasarına, ayrıca ışık varlığında fotooksidasyon sonucu klorofil bozulmasına bağlı klorozis (sararma) ve nekrotik benekler oluşumuna sebep olur [11, 10]. Üşüme stresinin şiddet, süre, genotip ve gelişme dönemine bağlı olarak büyüme ve gelişmeyi olumsuz etkilemesi ve özellikle Türkiye'nin iç/doğu bölgelerinde erken ilkbahar/sonbahar fide dikimlerinde ciddi kayıplara yol açması nedeniyle, bu olumsuzlukları gidermenin en kesin yolu, üşümeye toleranslı bitki tür ve çeşitleri geliştirmek ve olumsuz etkileri hafifletici kültürel uygulamaları hayata geçirmektir. Bu bilgilerden yola çıkarak tasarlanan çalışmada Aster (*Aster amellus* L.) bitkisinin, üşüme stresine maruz kalma performansını belirlemek amaçlanmıştır.

2. MATERYAL ve YÖNTEM

Tohum ekimi için hazırlanan fide yetiştirme ortamı, torf ve perlitin 3/1 oranındaki karışımıyla oluşturulmuş ve viyollere doldurulduktan sonra tohumlar eşit derinlikte yerleştirilmiştir. Kaplar, 23±2 °C sıcaklıkta, 12 saat 450 µmol/m²/s ışık şiddetinde aydınlatma ve 12 saat karanlık döngüsü ile %60–70 bağıl nemin sağlandığı iklim odasında tutulmuştur. Çimlenme gerçekleşene kadar sulama saf su ile yapılmıştır. Viyollerin üzeri başlangıçta kağıtla kapatılmış, çimlenmenin ardından bu örtüler kaldırılmıştır. İlk gerçek yaprakları çıkan bitkicikler 15 cm, yükseklikleri 12 cm ve taban çapları 10 cm çapındaki saksılara alınmıştır. Fideler, dört beş yapraklı olunca kontrol grubu bitkiler iklim odasında optimum yetişme koşullarında bırakılmış diğer grup bitki ise inkübatöre alınmış ve kademeli olarak (4’ er gün arayla) üşüme stresine tabi tutulmuştur. Her bir üşüme sıcaklığı uygulaması sonrası (12 saatlik fotoperiyotta 10 ^{o}C gündüz /4 ^{o}C gece; 8 ^{o}C gündüz /3 ^{o}C gece; 6 ^{o}C gündüz /2 ^{o}C gece; 4 ^{o}C gündüz /1 ^{o}C gece; 3 ^{o}C gündüz /0 ^{o}C gece) alınan bitkilerin kök, gövde, yaprakların yaş ağırlığı, yaprak sayısı, gövde çapı ve uzunluğu, kök uzunluğu ölçülmüştür. Bitkilerdeki morfolojik zararlanmayı gösteren skala belirlenmiştir.

2.1.Fidelerin gelişim ölçümleri

Bitkilerin yaş kök, gövde ve yaprak ağırlıkları, 0.1 g duyarlılığa sahip hassas terazide tartılarak kaydedilmiştir. Gövde uzunluğu ile kök boyu cetvel yardımıyla ölçülmüş ve santimetre cinsinden ifade edilmiştir. Gövde çapı, dijital kumpas kullanılarak belirlenmiştir. Hasat sonrası elde edilen bitkilerin yaprakları tek tek sayılarak toplam yaprak sayısı tespit edilmiştir.

2.2. 1-5 Skalası ile değerlendirme

Bitkilerde gözlenen morfolojik zararların şiddetini belirlemek amacıyla bir değerlendirme skalası geliştirilmiştir. Bu kapsamda, Korkmaz [12] tarafından tanımlanan kriterler esas alınarak bitkilere 1 ile 5 arasında puan verilmiştir.

1: Bitkilerin üşüme stresinden hiç etkilenmemesi (kontrol bitkileri) 2: Yapraklarda lokal sararma ve kıvrılma ve %5 den daha az nektrotik lekelenmeler 3: Yapraklarda sararma ve % 25 oranında nekrotik lekelenmeler 4: Yapraklarda % 50-75 oranında nekrotik leke göstermesi (fakat bitkinin canlılığı sürdürmesi) 5: Yapraklarda % 90-100 oranında şiddetli nekrozlar bitkinin tümünde görülmesi, tümüyle ölmesi.

2.3. Verilerin değerlendirilmesi

Çalışmadan elde edilen bulgular, Statgraphics istatistik paket programı aracılığıyla varyans analizine tabi tutulmuştur. Denemelerde istatistiksel açıdan anlamlı farklılıklar belirlendiğinde, bu sonuçlar %5 güven düzeyinde Duncan çoklu karşılaştırma testiyle gruplandırılmıştır.

3. BULGULAR

3.1.Büyüme Parametrelerinin Belirlenmesi

Çalışmadan kök parametrelerinden elde edilen değerler Çizelge 1' de, gövde ve çap parametrelerinden elde edilen değerler Çizelge 2'de, yaprak parametrelerinden elde edilen değerler Çizelge 3'de, bitki skalası Çizelge 4'te belirtilmiştir.

Çizelge 1. Uygulamaların kök parametreleri üzerine etkileri

UYGULAMALAR	Sıcaklık aralığı (Gündüz/Gece) ±2°C	Kök Uzunluğu (cm)	Kök Yaş Ağırlığı (g)
kontrol	23 ° C	24.333±4.04 A	2.063±0.09 A
1	10°C/4 °C	16.333±1.53 B	0.863±0.17 B
2	8°C/3 °C	15.667±1.15 B	0.807±0.15 B
3	6°C/2 °C	14.667±1.15 B	0.647±0.15 BC
4	4°C/1 °C	13.333±0.58 B	0.557±0.11 C
5	3°C/0°C	13.667±0.58 B	0.520±0.05 C
Ortalama		16.333±4.16	0.909±0.56
P değeri		0.0001	0.0000

*Aynı sütunda farklı harfi alan ortalamalar arasındaki farklılık önemlidir ($p \leq 0.05$).
*Değerler (ortalama ± standart sapma) olarak verilmiştir.

Farklı uygulamaların aster bitkisi, kök uzunluğu ve yaş ağırlığı, üzerinde istatistiksel olarak anlamlı bir etki yarattığı ve kontrol bitkilerine kıyasla; kontrol (23±2 °C), bütün (1,2,3,4,5)

uygulamalar istatistiksel olarak anlamlı bir azalış görüşmüştür. Kök uzunluğu, kök yaş ağırlığı, sıcaklığın düşmesi ile birlikte istatistiksel olarak anlamlı azalmalar gözlemlenmiştir. Özellikle 5. uygulamasında bütün parametrelerde en düşük değer kaydedilmiştir.

Çizelge 2. Uygulamaların gövde parametreleri üzerine etkileri

UYGULAMALAR	Sıcaklık aralığı (Gündüz/Gece) ±2ºC	Gövde Boyu (cm)	Gövde Yaş Ağırlığı (g)	Gövde Çapı (mm)
kontrol	23 º C	6.131±1.61 A	0.609±0.22 A	3.369±0.27 A
1	10°C/4 ºC	3.010±0.47 B	0.293±0.06 B	3.328±0.33 A
2	8°C/3 ºC	3.263±0.20 B	0.290±0.05 B	3.155±0.19 A
3	6°C/2 ºC	3.008±0.32 B	0.240±0.04 B	2.923±0.35 AB
4	4°C/1 ºC	2.883±0.22 B	0.230±0.04 B	2.853±0.56 AB
5	3°C/0ºC	2.305±0.76 B	0.165±0.04 B	2.483±0.42 B
Ortalama		3.819±1.75	0.348±0.21	3.068±0.45
P değeri		0.0000	0.0001	0.0080

*Aynı sütunda farklı harfi alan ortalamalar arasındaki farklılık önemlidir (p≤0.05).
*Değerler (ortalama ± standart sapma) olarak verilmiştir.

Farklı uygulamaların aster bitkisi, gövde boyu, gövde yaş ağırlığı, gövde çapı, üzerinde istatistiksel olarak anlamlı bir etki yarattığı ve kontrol bitkilerine kıyasla; kontrol (23±2 ºC), bütün (1,2,3,4,5) uygulamalar istatistiksel olarak anlamlı bir azalış görüşmüştür. Gövde boyu, gövde yaş ağırlığı, gövde çapı, sıcaklığın düşmesi ile birlikte istatistiksel olarak anlamlı azalmalar gözlemlenmiştir. Özellikle 5. uygulamasında bütün parametrelerde en düşük değer kaydedilmiştir.

Çizelge 3. Uygulamaların yaprak parametreleri üzerine etkileri

UYGULAMALAR	Sıcaklık aralığı (Gündüz/Gece) ±2ºC	Yaprak Yaş Ağırlığı (g)	Yaprak Sayısı (Adet)
kontrol	23 º C	8.198±1.42 A	21.750±3.06 A
1	10°C/4 ºC	3.405±0.45 B	12.500±2.38 B
2	8°C/3 ºC	3.200±0.33 BC	11.750±0.96 B
3	6°C/2 ºC	2.573±0.67 BC	12.500±3.32 B
4	4°C/1 ºC	2.303±0.28 BC	11.500±0.58 B
5	3°C/0ºC	2.060±0.36 C	10.250±0.50 B
Ortalama		4.276±2.68	14.571±5.13
P değeri		0.0000	0.0000

*Aynı sütunda farklı harfi alan ortalamalar arasındaki farklılık önemlidir (p≤0.05).
*Değerler (ortalama ± standart sapma) olarak verilmiştir.

Farklı uygulamaların aster bitkisi, yaprak yaş ağırlığı, yaprak sayısı, üzerinde istatistiksel olarak anlamlı bir etki yarattığı ve kontrol bitkilerine kıyasla; kontrol (23±2 ºC), bütün (1,2,3,4,5) uygulamalar istatistiksel olarak anlamlı bir azalış görüşmüştür. Yaprak yaş ağırlığı, yaprak sayısı, sıcaklığın düşmesi ile birlikte istatistiksel olarak anlamlı azalmalar gözlemlenmiştir. Özellikle 5. uygulamasında bütün parametrelerde en düşük değer kaydedilmiştir.

3.2. 1-5. Skalası ile değerlendirme

Morfolojik zararlanmanın şiddetini ortaya koymak için uygulanan skala sisteminde, fideler 1'den 5'e kadar değerlendirilmiştir.

Çizelge 4. Üşüme uygulamalarının görsel hasar indeksi olan skala değerleri üzerine etkileri

Uygulamalar	Sıcaklık aralığı (Gündüz/Gece) ±2ºC	Skala değeri
kontrol	23 º C	1
1	10°C/4 ºC	2.87
2	8°C/3 ºC	3.25
3	6°C/2 ºC	3.37
4	4°C/1 ºC	3.5
5	3°C/0ºC	3.75

*Skala değeri, 1: etkilenmemiş, 2: hafif, 3: orta, 4: şiddetli, 5: ölü

Skala değerlerinden de görüleceği gibi morfolojik olarak en fazla zararlanma 3°C/0ºC üşüme uygulaması yapılan aster bitkilerinde meydana gelmiştir. Bitkilerde morfolojik zararlanmanın 10°C/4 ºC sıcaklıklardan sonra arttığı dikkati çekmektedir.

4. TARTIŞMA ve SONUÇ

Literatürde, donma derecesinin üzerindeki düşük sıcaklıkların fidelerde kök iletkenliği, su alımı ve kök büyümesinde gerileme gibi fizyolojik bozulmalara yol açtığı bilinmektedir [7,8]. Bu çalışmada da, aster bitkisinde kontrol grubuna (23±2°C) kıyasla, düşük sıcaklık uygulamaları (10/4°C, 8/3°C, 6/2°C, 4/1°C ve 3/0°C gündüz/gece) ile hem kök uzunluğunda hem de kök yaş ağırlığında istatistiksel olarak anlamlı azalmalar gözlemlenmiş, en belirgin düşüşün 3/0°C uygulamasında kaydedilmesi, soğuk stresinin şiddeti arttıkça kök gelişiminin de daha fazla inhibe olduğunu göstermiştir. Toprak altı organlarının tarla koşullarında toprağın sıcaklık tamponlaması sayesinde korunabildiği [9] , ancak saksı koşullarında bu etkinin ortadan kalktığı düşünüldüğünde, saksıda yetiştirilen aster fidelerinde gözlenen bu belirgin kök gelişimi azalması, saksı ortamının kökleri sıcaklık stresine karşı daha savunmasız bıraktığını ve literatürdeki bulgularla uyumlu şekilde, düşük sıcaklığın doğrudan kök morfolojisi ve biyokütlesi üzerinde zararlı bir etkiye sahip olduğunu ortaya koymaktadır. Çalışmamızda yaprak, kontrole (23±2 °C) kıyasla gündüz/gece sıcaklıklarının kademeli olarak düşürüldüğü

bütün soğuk uygulamalarının aster bitkisinin gövde boyu, gövde yaş ağırlığı ve gövde çapı üzerinde istatistiksel olarak anlamlı azalmalara yol açtığını ve özellikle en düşük sıcaklık rejimi olan 3/0 °C'de tüm parametrelerde minimum değerlerin kaydedildiğini tespit edilmiştir. Bu bulgular, üşüme koşullarında bitki büyümesinin baskılanmasını açıklayan mevcut literatürle uyumludur. Wang [2], Toğay ve ark. [10] tarafından da vurgulandığı gibi, soğuk stresinin ilk belirtilerinden biri, köklerden su alımı ile terleme (transpirasyon) arasındaki dengenin bozulması sonucu gövdenin susuz kalmasıdır. Kök sistemindeki gelişimin yavaşlaması, bizim gözlemlediğimiz gövdedeki büyüme parametrelerindeki gerilemeyle kendini gösterir. Dolayısıyla, elde ettiğimiz sonuçlar, düşük sıcaklıkların neden olduğu su dengesizliği ve bunun tetiklediği büyüme inhibisyonunun, gövde morfogenezinde ölçülebilir bir düşüşe yol açtığını desteklemektedir. literatürde soğuk stresinin bitkiler üzerinde tanımlanan yaygın fizyolojik ve morfolojik etkileriyle uyumludur. Çalışmamızda, aster bitkilerinde sıcaklığın kontrol (23±2°C) seviyesinden özellikle 3°C gündüz/0°C gece gibi düşük seviyelere kademeli olarak düşürülmesiyle, yaprak yaş ağırlığı ve yaprak sayısında istatistiksel olarak anlamlı azalmalar gözlenmiştir. Bu morfolojik gerileme, Saltveit ve Morris [11] ile Toğay ve ark. [10] 'nın da belirttiği gibi, üşüme stresine bağlı olarak genellikle yaprak genişliğinin azalması şeklinde kendini gösteren morfolojik değişimleri destekler niteliktedir. Özellikle en şiddetli soğuk uygulamasında (3°C/0°C) tüm parametrelerde kaydedilen en düşük değerler, şiddetli stresin tetiklediği hücresel otoliz, dokusal yaşlanma ve bunun sonucunda epidermal hücre çöküşüne bağlı doku hasarı süreçleriyle [11,10] ilişkilendirilebilir. Bu koşullar altında, fotooksidatif stresin de devreye girmesiyle, ileri aşamalarda klorofil bozulması (kloroz) ve nekrotik benek oluşumu gibi semptomların ortaya çıkması beklenebilir. Dolayısıyla, bulgularımız soğuk stresinin aster bitkilerinde büyümeyi baskılayıcı ve doku bütünlüğünü bozucu etkisini açıkça ortaya koymakta ve bu süreçlerin literatürde belgelenen hücresel mekanizmalarla bağlantısını kurmaktadır.

Bu çalışmada, saksıda yetiştirilen aster fidelerinde uygulanan kademeli düşük sıcaklıkların kök ve gövde gelişimini belirgin şekilde inhibe ettiği gözlemlenmiştir. Saksı koşullarında toprağın sıcaklık tamponlama etkisinin ortadan kalkması, kök sistemini soğuk stresine karşı daha savunmasız hale getirmiş ve bunun sonucunda kök iletkenliği ile su alımında azalma meydana gelmiştir. Kök fonksiyonlarındaki bu bozulma, su dengesinin bozulmasına ve dolayısıyla gövde boyu, çap ve ağırlığında istatistiksel olarak anlamlı düşüşlere yol açmıştır. Aynı şekilde, yaprak yaş ağırlığı ve sayısındaki azalmalar, soğuk stresinin neden olduğu morfolojik gerilemeyi ve fotosentetik dokularda meydana gelen hasarı doğrulamaktadır. Özellikle en düşük sıcaklık rejiminde (3/0°C) tüm parametrelerde kaydedilen minimum değerler, stres şiddeti arttıkça hücresel düzeydeki bozulmaların (fotooksidatif stres, kloroz, dokusal yaşlanma) artışıyla uyumludur. Sonuç olarak, çalışma bulguları, düşük sıcaklıkların aster bitkisinde su ilişkilerini bozarak büyümeyi baskıladığını ve saksı yetiştiriciliğinin bu süreci şiddetlendirdiğini ortaya koymaktadır.

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TUZ STRESİ ALTINDAKİ ASTER (*Aster amellus* L.) BİTKİLERİNDE GA_3 UYGULAMALARININ BAZI BİTKİ BÜYÜME PARAMETRELERİ ÜZERİNDEKİ ETKİLERİ

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ÖZET

Yapılan çalışma tuz stresinin bitki gelişimi üzerine olumsuz etkisini azaltmada GA_3 (gibberellik asit) uygulamalarının etkisini belirlemek amacıyla yapılmıştır. Çalışmada Aster (*Aster amellus* L.) ait tohumlar kullanılmıştır. Tohumlar Torf/ perlit (3/1) karışımı ile hazırlanan fide yetiştirme harcı viyollere doldurulduktan sonra aynı derinlikte olacak şekilde ekilmiştir. Viyoller 23±2 ^oC'de sıcaklık, 12 saat ışık (450 µmol/m^2 /s ışık şiddeti) ve 12 saat karanlık ve % 60-70 hava oransal nem bulunan normal atmosferin sağlandığı iklim odasına alınmıştır. Tohumlar çimleninceye kadar saf su ile sulama yapılmıştır. Viyollerin üzeri kağıtla örtülmüştür, çimlenmeyi takiben bu örtüler kaldırılmıştır. İlk gerçek yaprakları çıkan bitkicikler, Hoagland besin çözeltisi içeren hidroponik sisteme alınmıştır. Fideler, dört beş yapraklı olunca aşamalı olarak 100 mM NaCl uygulanmış ve tuz uygulamaları, haftalık olarak yenilenen çözeltilerin tazelenmesi aşamasında aynı konsantrasyonlarda devam ettirilmiştir. Tuzun bitki gelişimi üzerindeki olumsuz etkisini azaltmak için, Aster fidelerine tuzla birlikte 5 ppm, 7,5 ppm ve 10 ppm dozlarında GA_3 eklenmiştir. Bu uygulamanın 21. gününde alınan örneklerde, bitki gelişim parametrelerinden olan bitki kök, gövde, yaprakların yaş ağırlığı, yaprak sayısı, gövde çapı ve uzunluğu, kök uzunluğu ve boğum arası mesafe ölçülmüştür. Yapılan ölçüm ve gözlemler sonucunda 5 ppm GA_3 uygulamalarının tuz stresinin bitki gelişimi üzerine olumsuz etkilerini azaltmada etkili olduğu yönde kanı oluşturmuştur.

Anahtar Kelimeler: Aster, gibberellik asit, skala, tuz

1. GİRİŞ

Gibberellik asit (GA_3) ve sitokinin gibi büyümeyi düzenleyici hormonlar, bitkilerde tuz stresinin olumsuz etkilerini hafifletmede önemli bir rol oynamaktadır [1]. Lin ve Kao [2]. (1995) tarafından yapılan bir araştırmada, GA_3 uygulamasının tuzlu koşullarda yetiştirilen pirinç fidelerinin çimlenmesinde görülen olumsuzlukları azalttığı ortaya konmuştur. Ashraf ve ark.,[3] ise tuz stresine maruz bırakılan iki buğday genotipinde (Barani-83 ve SARC-1) kök ve sürgünlerde Na^+ ile Cl^- birikiminin arttığını, ancak GA_3 uygulamasıyla bu birikimin daha da yükseldiğini belirtmiştir. Çalışmada, tuza duyarlı Barani-83 genotipinde iyon birikiminin, dayanıklı SARC-1 genotipine kıyasla daha fazla olduğu gözlemlenmiştir. Her iki genotipte de artan tuz konsantrasyonu ile net CO_2 özümlemesi düşmüş, ancak GA_3 uygulaması tuz stresinin bu olumsuz etkisini kısmen telafi etmiştir.

Son yıllarda yürütülen çalışmalar, bitkilerin tuzluluk gibi abiyotik stres faktörlerine karşı verdiği tepkide hormonların kritik bir işlevi olduğunu vurgulamaktadır [4,5]. Ayrıca, dışarıdan uygulanan büyüme düzenleyicilerinin bitkilerin içsel hormon düzeylerini değiştirebildiği genel kabul görmektedir [6]. Rodriguez ve ark. [7], pirinç fidelerinde gözlemlenen tuz toleransının, siyanobakterilerce üretilen ekzopolisakkaritlerde bulunan hormonlardan kaynaklanabileceğini ileri sürmüştür. Tuz stresi altında GA_3 uygulamasının ABA üretimini teşvik ettiği ve büyüme düzenleyicilerinin dengesini değiştirdiği bildirilmiştir.

Bu bulgulardan hareketle, mevcut çalışmada Aster bitkisinde tuz stresinin gelişim üzerindeki olumsuz etkilerinin azaltılmasında GA_3 uygulamalarının etkinliğinin araştırılması amaçlanmıştır.

2. MATERYAL ve YÖNTEM

Çalışma, Van Yüzüncü Yıl Üniversitesi Ziraat Fakültesi Bahçe Bitkileri Bölümü Fizyoloji laboratuvarında gerçekleştirilmiştir. Aster (*Aster amellus* L.) ait tohumların kullanıldığı çalışma, normal atmosferi sağlayan split klima bulunan bir iklim odasında ve hidroponik kültürde gerçekleştirilmiştir.

Tohumlar torf/ perlit (3/1) karışımı ile hazırlanan fide yetiştirme harcı viyollere doldurulduktan sonra aynı derinlikte olacak şekilde ekilmiştir. Viyoller 23±2 ºC'de sıcaklık, 12 saat ışık (450 µmol/m^2 /s ışık şiddeti) ve 12 saat karanlık ve % 60-70 hava oransal nem bulunan normal atmosferin sağlandığı iklim odasına alınmıştır. Tohumlar çimleninceye kadar saf su ile sulama yapılmıştır. Viyollerin üzeri kağıtla örtülmüştür, çimlenmeyi takiben bu örtüler kaldırılmıştır. İlk gerçek yaprakları çıkan bitkicikler, Hoagland besin çözeltisi içeren Hoagland ve Arnon [8], hidroponik sisteme alınmıştır. Hoagland besin çözeltisi ile doldurulmuş 25x25x18 cm plastik kaplara yerleştirilmiştir (hidroponik kültür). Aster fideleri küçük sünger parçalarıyla sarılmış ve özel olarak delikli plastik panellerin üzerine yerleştirilmiştir. Bitki kökleri besin çözeltisine daldırılmıştır. Çözeltinin, bir akvaryum pompası ile havalandırılması sağlanmıştır.

Bitkiler 4-5 gerçek yaprak verdiğinde tuz uygulamaları başlatılmıştır. Deneme tesadüf perselleri deneme desenine göre, 3 tekerrürlü ve her tekerrürde 5 bitki olacak şekilde gerçekleştirilmiştir. Tuz uygulamaları için, besin çözeltisine 100 mM konsantrasyonuna ulaşacak şekilde NaCl 50+50 mM şeklinde iki günde kademeli olarak uygulanmıştır. Çözeltiler

her hafta yenilenmiştir. Bu aşamada, aynı tuz konsantrasyonları korunmuştur. Tuz uygulamalarıyla birlikte, Aster bitkileri ayrıca 5.0, 7.5 ve 10 ppm Gibberellik asit (GA_3) uygulamalarına tabi tutulmuştur. Kontrol, sadece tuz (100 mM), tuz (100 mM) + gibberellik asit (5.0, 7.5 ve 10 ppm), sadece GA_3 (5,0, 7,5 ve 10 ppm) uygulamaları olmak üzere toplam 8 farklı uygulama yapılmıştır. Ölçüm ve analizler için numune alma işlemi, tuz uygulamalarının 21. gününde gerçekleştirilmiştir.

Çalışmadan elde edilen bulgular, Statgraphics istatistik paket programı aracılığıyla varyans analizine tabi tutulmuştur. Denemelerde istatistiksel açıdan anlamlı farklılıklar belirlendiğinde, bu sonuçlar %5 güven düzeyinde Duncan çoklu karşılaştırma testiyle gruplandırılmıştır.

3. BULGULAR

Çalışmadan kök parametrelerinden elde edilen değerler Çizelge 1' de, gövde parametrelerinden elde edilen değerler Çizelge 2'de, yaprak parametrelerinden elde edilen değerler Çizelge 3'de, bitki skalası Çizelge 4'te belirtilmiştir.

Çizelge 1. Uygulamaların kök parametreleri üzerine etkileri

UYGULAMALAR	Kök Uzunluğu (cm)	Kök Yaş Ağırlığı (g)
KONTROL	14.800±2.28 B	2.402±0.94 A
TUZ	20.333±1.51 A	2.465±0.64 A
GA-1	22.000±4.77 A	1.907±0.68 A
GA-2	20.000±2.53 A	2.875±0.68 A
GA-3	21.833±2.32 A	2.765±0.71 A
TUZ+GA-1	21.667±2.34 A	2.460±0.71 A
TUZ+GA-2	22.667±3.56 A	2.643±0.90 A
TUZ+GA-3	22.167±0.98 A	2.630±0.40 A
ORTALAMA	20.809±3.42	2.518±0.72
P DEĞERİ	0.0011	0.4429

*Aynı sütunda farklı harfi alan ortalamalar arasındaki farklılık önemlidir ($p \leq 0.05$).
*Değerler (ortalama ± standart sapma) olarak verilmiştir.

Kök uzunluğu bakımından tuz uygulamaları ve GA_3 (giberellik asit) uygulamaları kontrol grubuna kıyasla istatistiksel olarak anlamlı artışlar sağlarken, kök yaş ağırlığında ise gruplar arasında istatistiksel olarak bir farklılık gözlenmemiştir.

Çizelge 2. Uygulamaların gövde parametreleri üzerine etkileri

UYGULAMALAR	Gövde Boyu (cm)	Gövde Yaş Ağırlığı (g)	Gövde Çapı (mm)	Boğum Arası (mm)
KONTROL	5.833±2.04 AB	0.512±0.31 CD	2.477±0.63 CB	4.583±1.23 CB
TUZ	2.500±0.84 C	0.298±0.12 D	1.787±0.46 D	2.092±0.40 D
GA-1	3.833±1.94 BC	0.338±0.18 D	1.937±0.55 CD	3.552±0.99 CD
GA-2	6.750±2.23 AB	0.670±0.25 B-D	2.748±0.76 AB	7.093±2.19 A
GA-3	6.600±1.77 AB	0.455±0.16 CD	1.870±0.25 CD	4.763±1.14 BC
TUZ+GA-1	8.717±3.37 A	1.098±0.59 A	3.162±0.38 A	5.5520±1.76 AB
TUZ+GA-2	8.517±2.71 A	0.987±0.33 AB	2.457±0.49 BC	5.532±0.92 BC
TUZ+GA-3	6.433±2.84 AB	0.788±0.35 A-C	2.930±0.34 AB	4.978±1.51 BC
ORTALAMA	6.148±2.94	0.643±0.41	2.421±0.67	4.742±1.87
P DEĞERİ	0.0004	0.0003	0.0001	0.0000

*Aynı sütunda farklı harfi alan ortalamalar arasındaki farklılık önemlidir ($p \leq 0.05$).
*Değerler (ortalama ± standart sapma) olarak verilmiştir.

Sadece tuz stresi uygulanan bitkilerin gövde boyunda belirgin bir azalmaya neden olurken, özellikle tuz ile birlikte GA_3'ün GA-1 ve GA-2 kombinasyon uygulamaları gerek kontrole gerekse tek başına tuz uygulamasına kıyasla gövde uzamasını istatistiksel olarak anlamlı düzeyde artırmıştır. Tek başına tuz uygulaması gövde yaş ağırlığını düşürmüş olsa da tuz stresi altında yapılan GA_3 uygulamaları (özellikle Tuz+GA-1) bu parametrede kontrole kıyasla dahi belirgin ve istatistiksel olarak anlamlı bir artış sağlamıştır. Tuz stresi gövde çapını kontrol grubuna göre azaltırken, Tuz+GA-1 uygulaması en yüksek değeri kaydederek gövde kalınlaşmasını anlamlı düzeyde iyileştirmiştir. Boğum arası mesafesi, tek başına tuz uygulamasında en düşük değeri almış ancak GA-1 gibi giberellik asit uygulamaları hem tuz stresini hafifletmiş hem de bu parametreyi kontrole kıyasla dahi önemli ölçüde artırarak sürgün gelişimini desteklemiştir.

Çizelge 3. Uygulamaların yaprak parametreleri üzerine etkileri

UYGULAMALAR	Yaprak Yaş Ağırlığı (g)	Yaprak Sayısı (Adet)
KONTROL	6.203±2.48 A	11.833±1.72 B
TUZ	3.102±0.92 C	7.167±2.14 C
GA-1	5.600±2.96 AB	11.333±2.25 B
GA-2	6.403±0.77 A	13.667±1.03 AB
GA-3	5.367±1.13 AB	12.333±1.75 B
TUZ+GA-1	5.225±0.91 AB	15.333±1.75 A
TUZ+GA-2	3.972±0.82 BC	14.833±2.40 A
TUZ+GA-3	4.345±1.06 A-C	13.333±1.21 AB
ORTALAMA	5.027±1.82	12.479±2.95
P DEĞERİ	0.0112	0.0000

*Aynı sütunda farklı harfi alan ortalamalar arasındaki farklılık önemlidir ($p \leq 0.05$).

*Değerler (ortalama ± standart sapma) olarak verilmiştir.

Tuz stresi, yaprak yaş ağırlığını kontrole kıyasla belirgin şekilde düşürmüş olsa da GA_3 uygulamaları özellikle Tuz+GA-1 ile bu düşüş telafi edilmiş ve gruplar arasındaki farklılık istatistiksel olarak anlamlı bulunmuştur. Tuz stresi yaprak sayısında en belirgin azalmaya neden olurken, tuz stresi altında yapılan GA_3 uygulamaları, sırasıyla Tuz+GA-1 ve Tuz+GA-2, yaprak sayısını kontrole göre anlamlı düzeyde artırarak bitkinin vejetatif gelişimini teşvik etmiştir.

4. TARTIŞMA ve SONUÇ

Kök parametreleri açısından değerlendirildiğinde, çalışmamızda tuz uygulamalarının kök uzunluğunu kontrol grubuna kıyasla istatistiksel olarak anlamlı şekilde artırması dikkat çekicidir. Bu durum, tuz stresi altında bitkilerin su ve besin arayışı nedeniyle kök sistemini geliştirme eğiliminde oldukları ve kök/sürgün oranının arttığı yönündeki literatür bilgileriyle [9], örtüşmektedir. Bununla birlikte, kök yaş ağırlığında anlamlı bir farklılık gözlenmemesi, kök uzamasının hücre genişlemesinden ziyade hücre bölünmesi ve ince kök oluşumu yönünde gerçekleştiğini düşündürmektedir. GA_3 uygulamalarının kök uzunluğu üzerindeki pozitif etkisi, gibberellinlerin hücre uzamasını teşvik edici rolü [10], ile açıklanabilir, ancak kök biyokütlesinde (yaş ağırlık) belirgin bir artış sağlamaması, tuz stresinin kök metabolizması üzerindeki baskılayıcı etkisinin GA_3 ile tam olarak giderilemediğini göstermektedir. Yıldırım ve ark., [11]. de sorgumda GA_3 uygulamasının kök kuru ağırlığı dışındaki parametrelerde sınırlı etki gösterdiğini bildirmiş ve bunun tür ve doza bağlı olabileceğini vurgulamıştır.

Gövde parametreleri incelendiğinde, tuz stresinin gövde boyu, çapı ve boğum aralığı üzerinde belirgin baskılayıcı etkisi, tuzluluğun osmotik stres yaratarak hücre turgorunu ve uzamasını azalttığı gerçeğiyle (Parida ve Das [12], uyumludur. Ancak, Tuz+GA-1 ve Tuz+GA-2 gibi kombinasyon uygulamalarının bu parametrelerde hem kontrole hem de tek başına tuz uygulamasına kıyasla anlamlı iyileşme sağlaması, GA_3'ün tuz stresinin neden olduğu büyüme inhibisyonunu kısmen ortadan kaldırabildiğinin güçlü bir göstergesidir. Gibberellik asitin hücre bölünmesi ve uzamasını uyarması, hücre duvarı esnekliğini artırması Tuna ve ark. [10], ve endojen gibberellin seviyelerini desteklemesi, bu iyileşmenin temel mekanizmaları olarak düşünülebilir. Özellikle boğum aralığındaki belirgin artış, GA_3'ün internodyal uzamayı teşvik edici klasik etkisini yansıtmaktadır. Bu sonuçlar, GA_3 uygulamalarının tuz stresi altındaki bitkilerde sürgün gelişimini iyileştirebileceğini gösteren çalışmalarla Forghani ve ark., Uzal ve Yasar [13,14], paralellik göstermektedir.

Yaprak parametreleri bakımından, tuz stresinin yaprak yaş ağırlığını ve sayısını önemli ölçüde azaltması, tuzluluğun fotosentez ve asimilat dağılımı üzerindeki olumsuz etkilerinin bir

sonucudur. Yaprak yaş ağırlığındaki azalma, osmotik düzenleme için hücrelerde su içeriğinin düşmesi ve yaprak gelişiminin kısıtlanmasıyla ilişkilendirilebilir. Buna karşın, GA_3 uygulamalarının (özellikle Tuz+GA-1) bu düşüşü kısmen telafi etmesi ve yaprak sayısını kontrole göre dahi artırması önemli bir bulgudur. GA_3'ün hücre bölünmesini ve yaprak primordiyumu oluşumunu uyarması, ayrıca stres koşullarında bitkinin vejetatif üreme eğilimini artırması bu sonucu açıklayabilir. jamil ve Rha [15], şeker pancarında GA_3 uygulamasının tuz stresinin neden olduğu büyüme azalmasını hafiflettiğini bildirmiştir. Çalışmamızda yaprak sayısındaki artış, bitkinin fotosentetik alanını koruma ve genişletme stratejisinin bir parçası olarak değerlendirilebilir.

Sonuç olarak, bulgularımız GA_3 uygulamalarının, özellikle tuz stresi koşullarında, kök mimarisi, gövde büyümesi ve yaprak gelişimi üzerinde düzenleyici ve iyileştirici bir role sahip olduğunu ortaya koymaktadır. Etkinin parametreye özgü olması, bitki organlarının tuz stresine ve hormon uygulamalarına farklı fizyolojik ve morfolojik tepkiler verdiğini göstermektedir. Bu nedenle, tuz stresinin hafifletilmesinde GA_3 kullanımının optimizasyonu için doz, uygulama zamanı ve bitki türü/varyetesi gibi faktörlerin dikkate alındığı ileri çalışmalara ihtiyaç bulunmaktadır.

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ORGANİK SOFRALIK DOMATES ÜRÜNÜNE YÖNELİK BLOCKCHAİN GIDA İZLENEBİLİRLİĞİ TEKNOLOJİSİ KULLANIMI

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ÖZET

Güvenilir gıdaya erişim, modern toplumlarda tüketici davranışlarını önemli ölçüde etkileyebilmektedir. Son yıllarda yaşanan gıda güvenliği skandalları, tüketici algısında güvensizlik ve kaygı oluşturabilmektedir. Bu durum, tüketicileri yalnızca "organik" sertifikalara değil, aynı zamanda ürünlerin şeffaf ve doğrulanabilir biçimde izlenebilir olmasına yönlendirebilmektedir. Bu noktada blockchain (blokzinciri) teknolojisi, gıda tedarik zincirlerinde şeffaflık, izlenebilirlik ve güven unsurlarını güçlendirebilecek yenilikçi bir altyapı olarak değerlendirilebilir.

Blockchain teknolojisi; değiştirilemez kayıt yapısı, merkeziyetsizlik ve kriptografik güvenlik özellikleri sayesinde, gıdanın üretimden tüketime kadar olan tüm aşamalarının güvenli şekilde izlenmesine imkân sağlayabilir. Tüketiciler açısından bu sistem, ürünlere ait dijital sertifikaların ve üretim bilgilerinin eşzamanlı ve şeffaf biçimde sunulmasına olanak tanıyarak bilinçli tüketim kararlarını destekleyebilir.

Türkiye'de sebze üretiminde ilk sırada yer alan domatesin, yaklaşık 13 milyon tonluk üretim miktarıyla önemli bir paya sahip olduğu ve bunun %58,3'ünün sofralık domatesten oluştuğu bilinmektedir. Bu çalışmada, organik üretime duyulan güvensizliğin blockchain tabanlı izlenebilirlik sistemleriyle desteklenen, organik domates ürünlerinin benimsenmesi üzerindeki etkisi araştırılacaktır.

Araştırmanın temel amacı, tüketicilerin blockchain teknolojisine duydukları güvenin ve bu teknolojiyi kullanmaya yönelik isteklilikleriniin organik domates tercihleri üzerindeki etkilerini incelemektir. Bu çalışma tüketicilerin sürdürülebilirlik bilinci ve güvenilir gıda talebi ile blokchain tenoloji kullanma isteklilikleri arasında ilişkiyi ortaya koyarak literatüre katkı sunabilir.

Anahtar Kelimeler: Blockchain teknolojisi, Gıda güvenliği, Organik Sofralık Domates ürünü, Tüketici alışkanlıkları, Teknolojik güvenilirlik

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1. GİRİŞ

Tarım insan beslenmesi için vazgeçilmez bir sektördür. Ancak yanlış uygulamalar bu sektörde bazı riskleri geliştirmektedir. Son yıllarda gıda güvenliği, küresel ölçekte en önemli sorunlardan biri haline gelmiştir. Dünya Sağlık Örgütü'nün (WHO) 30 Nisan 2020 tarihinde yayımladığı verilere göre, her yıl yaklaşık 600 milyon insan – yani dünya nüfusunun yaklaşık %10'u – kontamine gıdalar tükettiği için hastalanmaktadır. Bu durum doğrudan 420 bin kişinin ölümüne neden olurken, dolaylı etkileriyle 33 milyon kişinin hayatını kaybetmesine yol açmaktadır. 2022 RASFF (AB Gıda ve Yem Hızlı Alarm Sistemi) verilerine göre AB'ye ihraç edilen ürünlerde en fazla pestisit kalıntısı bildirilen ülke Türkiye olmuştur. Bu veriler, gıda güvenliği sorunlarının yalnızca sağlık boyutunda değil, toplumsal ve ekonomik boyutlarda da büyük bir tehdit oluşturduğunu göstermektedir.

Üretim süreçlerindeki pestisit kullanım miktarı açısından en riskli ürünlerden birisi sofralık domatestir. Türkiye'de 13 milyon ton üretimle sebze üretiminde en yüksek payı oluşturan domates, %4 lük ihracat oranı ile iç piyasa da ençok tüketilen sebze konumundadır. Kişi başına yıllık ortalama 106 kg tüketimle (TEBGE,2024), toplam sebze tüketiminin %39'unu oluşturmaktadır. Türkiyedeki domates üretimi, 2023 yılında %58,3 sofralık domates (taze tüketim) ve %41,7 salçalık domates (işlenmek üzere, örneğin salça, konservasyon) olarak gerçekleşmiştir (TEBGE,2024). Üretilen domateslerin %99' kısmı geleneksel (konvansiyonel), %1 lik kısmı ise organik olarak üretilmektedir(ÇELİK,2021).

Türkiye iç pazarı (bağımsız saha taraması, 2025): Türkiye'nin Akdeniz bölgesinde serada yetiştirilen domateslerde yapılan çalışmada; örneklerin %61,5'inde bir veya birden fazla pestisit kalıntısı tespit edilmiştir(HEPSAĞ,2021). Türkiye' deki bireylerin, en çok tükettiği sebze nedeniyle uzun vadede sağlık problemleriyle karşılaşma olasılıkları hızla artabilir. Bu durumlar göz önüne alındığında, bireyler sağlıklı gıdaya yönelmekte ve organik ürün talebinde artış gözlenmektedir. Bu ürünün sağlıklı bir şekilde üretilmesinin bir yolu da organik üretimdir.

Ancak organik ürünlerin izlenebilirliğinin sağlanamaması, tüketicilerin organik ürün tercihlerini etkilemektedir. Bu durum tüketicilerin organik sofralık domatese güven duymamalarından kaynaklı olabilir.

Gıdaya olan güveni arttırmak için tüketicilerin satın aldıkları ürünlerin kökeni ve üretim süreçleri hakkında daha fazla bilgi sahibi olmaları önemlidir.

Günümüzde küresel gıda ticareti, üreticiler ve tüketiciler arasında ciddi bilgi asimetrilerini beraberinde getirmektedir. Bu asimetriler, tüketicilerin güvenilir bilgiye ulaşmasını zorlaştırmakta ve bilinçli tercih yapma imkânlarını kısıtlamaktadır. Sonuç olarak gıda güvenliğine olan güven azalmakta, tüketiciler ise satın aldıkları ürünlerin kökeni ve üretim süreçleri hakkında daha fazla bilgi talep etmektedir. Bu bilgiye erişim isteği, tüketicilerin alışveriş alışkanlıklarını doğrudan etkilemekte ve şeffaflık ihtiyacını artırmaktadır.

Bu noktada blockchain teknolojisi öne çıkmaktadır. Blockchain, üretim ve tedarik zincirlerinde şeffaflığı artırarak, ürünlerin kaynağının ve üretim aşamalarının güvenli bir şekilde takip edilmesine imkân tanımaktadır. Merkezi bir otoriteye bağlı olmaksızın işleyebilen bu sistem, tüm işlem kayıtlarını güvenli dijital ortamda saklamakta ve doğrulamaktadır. Yalnızca finans sektöründe değil; gıda güvenliği, lojistik yönetimi, akıllı sözleşmelerin yürütülmesi, resmi belgelerin saklanması gibi çok farklı alanlarda da uygulanabilmektedir.

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Bu çalışmada, blockchain teknolojisinin gıda ürünlerinin güvenilirliği üzerindeki etkileri ele alınacaktır. Özellikle tüketicilerin bu teknolojiye yönelik tutumları, blockchain kullanımına ilişkin güven düzeyleri ve isteklilikleri incelenecektir. Ayrıca, bireylerin yaşam tarzları, sürdürülebilirlik bilinci ve etik dışı üretim yöntemlerine karşı tutumlarının, bu teknolojiyi benimseme eğilimleri üzerinde ne ölçüde etkili olduğu ortaya konulacaktır.

2. KONU ve AMAÇ

Günümüzde bilgi ve iletişim teknolojilerinin hızlı gelişimi, toplumsal ve ekonomik alanlarda pek çok yapısal değişimi beraberinde getirmektedir. Özellikle küreselleşme ile birlikte ortaya çıkan blockchain teknolojisi, 2000'li yıllardan bu yana etkisini giderek artıran bir yenilik olarak görülmektedir. İlk olarak kripto para üretiminde kullanılan bu teknoloji, zamanla finans dışındaki birçok sektörde altyapı sağlayan bir çözüm olarak kullanılmaktadır. Güçlü şifreleme yöntemleriyle merkezi bir otoriteye ihtiyaç duymadan işlem yapılmasına imkân tanıması, blockchain'i güvenlik ve veri bütünlüğü açısından dikkat çekici kılmaktadır (Cangur, 2024).

Artan rekabet koşullarında işletmelerin kârlarını sürdürülebilir şekilde artırabilmeleri, teknolojik yenilikleri benimsemeleriyle mümkündür. Bu bağlamda blockchain teknolojisi, işletmelere pek çok avantaj sunan bir araç olarak öne çıkmaktadır. Özellikle ödeme sistemleri, tedarik zinciri yönetimi, hız, maliyet azaltımı, veri güvenliği ve şeffaflık gibi alanlarda sunduğu faydalar sayesinde işletmelerin verimliliğini artırabilmektedir (Babur, 2022).

Blockchain'in en önemli katkılarından biri, tedarik zincirlerinde şeffaflık ve izlenebilirliği sağlamasıdır. Bu durum, yalnızca üretici ve dağıtıcılar açısından değil, aynı zamanda tüketicilerin güvenini kazanmak açısından da kritik öneme sahiptir. Özellikle organik ürünlerde, tüketicilerin blockchain tabanlı sistemlere bakış açısı, ürün tercihlerini doğrudan etkileyebilir. Dolayısıyla izlenebilirlik ve şeffaflık unsurları, tüketicilerin satın alma niyetleri üzerinde belirleyici faktörler haline gelebilir (Lin, 2021).

Gıda tedarik zincirinde blockchain tabanlı izlenebilirlik sistemleri, hem üretici hem de tüketici için güvenliği artırıcı işlev görebilir. Bu sistemler sayesinde üretim ve lojistik süreçlerinde meydana gelebilecek sorunlar erken teşhis edilerek gerekli önlemler zamanında alınabilmektedir. Ayrıca organik ürünlerin kalitesinin korunması, güvenli olmayan ürünlerin piyasaya çıkmasının engellenmesi ve tüketicilere güvenilir bilgi sunulması gibi faydalar da sağlanmaktadır. Böylece blockchain, gıda sektöründe şeffaflığı artırarak tüketici güveni ve sadakatini pekiştirebilir. (Xiong, 2020).

Araştırmanın temel amacı, tüketicilerin blockchain teknolojisine duydukları güvenin ve bu teknolojiyi kullanmaya yönelik istekliliklerinin organik domates tercihleri üzerindeki etkilerini incelemektir.

3. SONUÇLAR VE DEĞERLENDİRME

Bu araştırma ile Aydın ilindeki tüketicilerin blockchain sertifikalı organik domates ürününü tercih etme istekliliklerini ölçmeye yönelik bir ölçek geliştirilmesi hedeflenmektedir. Çalışma kapsamında bireylerin yaşam standartları, yaşları, eğitim ve çalışma düzeyleri, meslekleri, davranış kalıpları ve konuya bakış açıları gibi sosyo-demografik değişkenlerin, blockchain teknolojisine yönelik tutumları üzerindeki etkileri incelenecektir.

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Günümüzde teknolojik dönüşümün hız kazanmasıyla birlikte, tüketicilerin sağlıklı, güvenilir ve izlenebilir gıdaya ulaşma isteği daha da önem kazanmıştır. Bu noktada blockchain teknolojisi, özellikle organik gıda ürünlerinde şeffaflık, izlenebilirlik ve güvenilirlik sağlamada kritik bir araç olarak öne çıkmaktadır. Çalışma, tüketicilerin sürdürülebilirlik bilinci ve güvenilir gıda talebi ile blockchain teknolojisini kullanma isteklilikleri arasındaki ilişkiyi ortaya koyarak literatüre katkı sağlayacaktır.

Araştırma, şu temel sorulara cevap arayacaktır: Blockchain teknolojisi güvenilir gıdaya ulaşmada ne derece etkili olabilir? Günümüz gıda üretim süreçlerinde şeffaflığı ne ölçüde sağlayabilir? Tüketiciler, güvenilir ve sürdürülebilir gıdaya ulaşmak için bu teknolojiyi ne ölçüde tercih edecektir? Bu soruların yanıtlanması, hem tüketici davranışlarını anlamak hem de tarım-gıda sektöründe blockchain tabanlı uygulamaların benimsenmesini kolaylaştırmak açısından önemli yararlar sunmaktır.

Araştırma, hem yerel düzeyde (Aydın ili) hem de Türkiye'de organik gıda güvenliğine yönelik tüketici davranışlarını yenilikçi bir teknoloji perspektifiyle ilk kez değerlendirecektir.

Ayrıca, blokzinciri temelli izlenebilirlik teknolojilerinin halk nezdinde algılanışına dair politika ve uygulayıcılara yönelik stratejik veri sağlayacaktır.

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TOPRAKSIZ KÜLTÜR SİSTEMLERİNDE MİKRO FİLİZ YETİŞTİRİCİLİĞİ

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ÖZET

Artan kentleşme, değişen yaşam tarzları ve sürdürülebilir gıda üretimine yönelik artan gereksinimler, kontrollü çevre koşullarında gerçekleştirilen üretim sistemlerine olan ilgiyi artırmaktadır. Bu kapsamda, kısa yetiştirme süresi, düşük girdi gereksinimi ve yüksek besin içeriği ile öne çıkan mikro filizler, modern üretim sistemleri içerisinde önemli bir yer edinmiştir. Mikro filizler, özellikle topraksız kültür sistemlerinde; alan kullanımının optimize edilmesi, su ve besin maddelerinin etkin yönetimi ve yıl boyunca üretim olanağı sunması nedeniyle dikkat çekmektedir. Topraksız kültür sistemlerinde mikro filiz yetiştiriciliği; yetiştirme ortamı, besin çözeltisi yönetimi, ışık kalitesi ve çevresel koşullar gibi birçok faktörün etkileşimi altında şekillenmektedir. Literatürde yer alan çalışmalar, bu faktörlerin mikro filizlerin verimi, besin değeri ve fitokimyasal bileşik içeriği üzerinde belirleyici olduğunu ortaya koymaktadır. Uygun şekilde optimize edilen topraksız üretim sistemlerinin, mikro filizlerde yüksek verim ve üstün kalite özelliklerinin elde edilmesine olanak sağladığı bildirilmektedir. Bu derlemenin amacı, topraksız kültür sistemlerinde mikro filiz yetiştiriciliğine ilişkin güncel literatürü değerlendirerek, üretim teknikleri ve kaliteyi etkileyen temel faktörleri bütüncül bir bakış açısıyla ele almaktır.

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Anahtar Kelimeler: Mikro filiz, topraksız kültür, hidroponik

MICROGREEN CULTIVATION IN SOILLESS CULTURE SYSTEMS

ABSTRACT

Increasing urbanization, changing lifestyles, and the growing demand for sustainable food production have intensified interest in production systems conducted under controlled environmental conditions. In this context, microgreens, which are characterized by a short cultivation cycle, low input requirements, and high nutritional value, have gained a prominent position within modern production systems. Microgreens have attracted particular attention in soilless culture systems due to their potential for optimized space utilization, efficient water and nutrient management, and year-round production. Microgreen cultivation in soilless culture systems is shaped by the interaction of multiple factors, including growing media, nutrient solution management, light quality, and environmental conditions. Studies reported in the literature indicate that these factors play a decisive role in determining microgreen yield, nutritional value, and phytochemical composition. It has been reported that appropriately optimized soilless production systems enable the achievement of high yields and superior quality attributes in microgreens. The aim of this review is to evaluate the current literature on microgreen cultivation in soilless culture systems and to comprehensively address the production techniques and key factors affecting quality from a holistic perspective.

Keywords: Microgreens, soilless culture, hydroponics

1. GİRİŞ

Dünya, hızla artan nüfusun beslenme gereksinimlerini karşılamak, gıda güvenliğini artırmak ve gıda üretiminin karbon ayak izini azaltmak amacıyla akıllı tarıma yönelik küresel bir yönelim içerisindedir (Ebert, 2012). Sağlıklı beslenme rehberlerinde günlük sebze tüketimi önerisinin beş porsiyondan yedi porsiyona çıkarılması, çevresel etkileri azaltırken yüksek besin değeri sunabilen sürdürülebilir sebze üretim sistemlerine olan ilgiyi daha da artırmıştır. Bu bağlamda, mikro filizler, bazı olgun sebzelere kıyasla daha yüksek besin içeriğine sahip olmaları ve dikey

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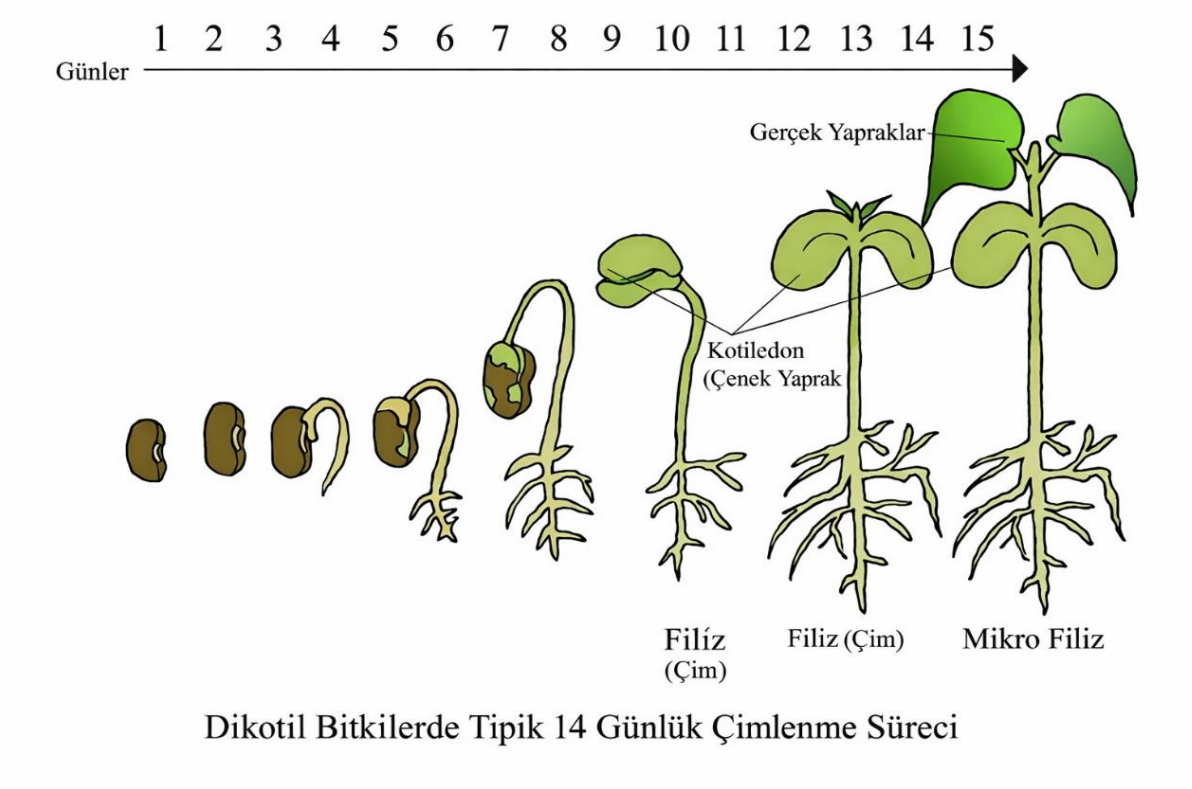
tarım sistemlerinde yetiştirilebilmeleri nedeniyle umut verici bir alternatif olarak öne çıkmaktadır.

Mikro filizler, yenilebilir yapraklı sebzelerin ve otların tohumlarından elde edilen genç fidecikler olup genellikle çiğ olarak tüketilmektedir. Yüksek düzeyde biyoaktif bileşik içermeleri nedeniyle beslenme açısından önemli bir potansiyele sahiptirler ve ayrıca kozmetik gibi katma değerli ürünlerin üretiminde kullanılmak üzere yağ formunda da işlenebilmektedirler. Son yıllarda mikro filizler, özellikle şefler arasında yaygın olarak tanınmakta ve üst segment marketlerde giderek daha fazla yer bulmaktadır (Treadwell ve ark., 2020). Bu durum, mikro filiz yetiştiriciliğini küresel ölçekte önemli bir pazar fırsatı hâline getirmiştir. Besinsel faydaları, üretiminin kolay olması ve kısa yetiştirme süresi, mikro filizleri üreticiler için cazip kılan başlıca unsurlar arasındadır. Mikro filizlerin büyümesi ve kalitesi; sıcaklık, bağıl nem, fotoperiyot ve gübreleme gibi mikro ve makro iklim koşullarından önemli ölçüde etkilenmektedir. Bu derlemenin amacı, topraksız kültür sistemlerinde mikro filiz yetiştiriciliğine ilişkin güncel literatürü değerlendirerek, üretim teknikleri ve kaliteyi etkileyen temel faktörleri bütüncül bir bakış açısıyla ele almaktır.

2. MİKRO FİLİZ VE YETİŞTİRİCİLİĞİ YAPILAN TÜRLER

Mikro filizler, sıklıkla “sebze konfetisi” olarak adlandırılan ve Batı ülkelerinde yeni bir gıda kaynağı olarak öne çıkan sebze veya aromatik bitki ürünleridir (Kyriacou ve ark., 2020). Mikro filizler, yenilebilir bitkilerin tohumlarından elde edilen fidecikler olup, genellikle ekimden sonra 7–14 gün içerisinde hasat edilmektedir (Turner ve ark., 2020) ya da türe bağlı olarak fide çıkışından 10–20 gün sonra, kökleri alınmış şekilde hasat edilirler (Lee ve ark., 2004; Xiao ve ark., 2012; Choe ve ark., 2018) (Şekil 1). Çoğunlukla ilk gerçek yapraklarını oluşturdukları dönemde hasat edilirler (Bergšpica et al., 2020; Turner et al., 2020). Bununla birlikte, bazı türlerde bir veya iki kotiledon yaprağının tamamen geliştiği, ilk gerçek yaprakların çıkışı olsun ya da olmasın dönemlerde de hasat edilebilmektedir (Xiao ve ark., 2012). Monokotil bitkilerde ise yalnızca bir kotiledon yaprağının tamamen gelişmiş olması hasat için yeterli kabul edilmektedir (Fry, 2016; Zhang ve ark., 2021).

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Şekil 1. Mikro filiz hasadına kadar bitkinin gelişim evresi

Mikro filizler, sebzeler ve aromatik bitkiler dâhil olmak üzere çok geniş bir bitki grubunun tohumlarından yetiştirilebilmektedir (Ebert, 2014). Bu bitkiler farklı familyalara ait türleri kapsamaktadır; Brassicaceae familyasından brokoli ve lahana, Asteraceae familyasından marul, Amaryllidaceae familyasından sarımsak ve Apiaceae familyasından havuç mikro filiz üretiminde yaygın olarak kullanılan türler arasında yer almaktadır (Tablo 1) (Kaiser ve Ernst, 2018; Turner ve ark., 2020).

Tablo 1. Mikro filiz üretiminde yaygın olarak yetiştirilen türler

Ticari Adı	**Familya**	**Cins ve Tür (Bilimsel Ad)**	**Bitki Rengi**
Roket (Arugula)	Brassicaceae	*Eruca sativa* Mill.	Yeşil
Boğa Kanı Pancar (Bull's blood beet)	Chenopodiaceae	*Beta vulgaris* L.	Kırmızımsı-yeşil
Kereviz (Celery)	Apiaceae	*Apium graveolens* L.	Yeşil
Çin Turpu (China rose radish)	Brassicaceae	*Raphanus sativus* L.	Morumsu-yeşil
Kişniş (Cilantro)	Apiaceae	*Coriandrum sativum* L.	Yeşil
Nar Amarantı (Garnet amaranth)	Amaranthaceae	*Amaranthus hypochondriacus* L.	Kırmızı

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Ticari Adı	Familya	Cins ve Tür (Bilimsel Ad)	Bitki Rengi
Altın Bezelye Filizi (Golden pea tendrils)	Fabaceae	*Pisum sativum* L.	Sarı
Yeşil Fesleğen (Green basil)	Lamiaceae	*Ocimum basilicum* L.	Yeşil
Yeşil Daikon Turpu	Brassicaceae	*Raphanus sativus* L. var. *longipinnatus*	Yeşil
Ispanak (Magenta spinach)	Chenopodiaceae	*Spinacia oleracea* L.	Kırmızı
Opal Fesleğen (Opal basil)	Lamiaceae	*Ocimum basilicum* L.	Yeşilimsi-mor
Opal Turp (Opal radish)	Brassicaceae	*Raphanus sativus* L.	Yeşilimsi-mor
Bezelye Filizi (Pea tendrils)	Fabaceae	*Pisum sativum* L.	Yeşil
Biber Otu (Peppercress)	Brassicaceae	*Lepidium bonariense* L.	Yeşil
Mısır Filizi (Popcorn shoots)	Poaceae	*Zea mays* L.	Sarı
Mor Besin Lahanası (Nutrient purple kohlrabi)	Brassicaceae	*Brassica oleracea* L. var. *gongylodes*	Morumsu-yeşil
Mor Hardal (Purple mustard)	Brassicaceae	*Brassica juncea* (L.) Czern.	Morumsu-yeşil
Kırmızı Pancar (Red beet)	Chenopodiaceae	*Beta vulgaris* L.	Kırmızımsı-yeşil
Kırmızı Lahana (Red cabbage)	Brassicaceae	*Brassica oleracea* L. var. *capitata*	Morumsu-yeşil

3. TOPRAKSIZ KÜLTÜRDE MİKRO FİLİZ

Son yıllarda, iç mekan topraksız yetiştirme gibi modern yüksek teknolojili yetiştirme stratejilerinin benimsenmesi, su kullanım verimliliğinin iyileştirilmesine katkıda bulunmuştur (Pignata ve ark., 2017). Topraksız tarım, bitkilerin toprak kullanılmadan sulama suyu veya besin çözeltisi ile besin maddelerinin sağlandığı bir ortamda yetiştirilmesi yöntemlerini ifade eder (Olympios, 1999). İç mekân çiftlikleriyle uyumlu olmaları ve minimum alan gereksinimine sahip olmaları, mikro filizleri dikey tarım sistemleri ve bitki fabrikaları gibi kapalı alan topraksız üretim sistemlerinde yetiştirilmek için ideal bir ürün grubu hâline getirmektedir (Kyriacou ve ark., 2016).

Mikro filizlerin üretiminde kullanılan yöntemler arasında hidroponik sistemler öne çıkmaktadır. Hidroponik, yani topraksız tarım, bitki yetiştiriciliğinde toprak kaynaklı birçok hastalık ve zararlı, toprak ve su tuzluluğu, kimyasal kalıntı, besin elementi noksanlığı ve kuraklık gibi sorunlara alternatif bir çözüm sunmaktadır. Hidroponik sistemler genellikle kapalı devre ve besin eriyiklerinin sirküler olarak sürekli kullanılması şeklinde tasarlanır. Bu nedenle, hidroponik sistemlerde bitkiler su ile taşınabilen patojenlerin neden olduğu hastalıklara maruz kalabilmektedir (Sevik, 2011). Ancak, hidroponik üretim ortamı, mikro filizlerin hızlı ve

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hijyenik şekilde yetiştirilmesi için uygun bir platform sunar. Hidroponik mikro filiz üretimi, kontrollü ortamda kısa sürede yüksek verim ve kalite elde edilmesine olanak tanır (Moraru ve ark., 2022). Hidroponik sistemlerde mikro filizlerin yetiştirilmesi, üretim sürecinin standardizasyonu, bitki sağlığının korunması ve besin içeriğinin optimize edilmesi açısından avantajlıdır. Yapılan bir çalışmada, hidroponik olarak yetiştirilen brokoli mikro yeşilliklerinin, olgun sebzelere kıyasla daha yüksek düzeylerde Cu, Zn, Mg ve Mn içerdiği belirlenmiştir (Weber, 2017). Mikro filiz yetiştiriciliği için ideal koşullar; nötr ile hafif asidik pH'a sahip suyun sürekli temini, optimum su tutma kapasitesi (%55–70, v/v), yeterli havalanma (%20–30, v/v) ve düşük elektriksel iletkenlik (0,5–1,0 mS cm^{-1}) olarak bildirilmektedir (Abad ve ark., 2001; Kyriacou ve ark., 2016).

Mikro filiz yetiştiriciliğinde substrat kültürü; turba, hindistancevizi lifi ve organik ya da sentetik kökenli farklı yetiştirme ortamlarının kullanımıyla, kök bölgesi koşullarının optimize edilmesine olanak sağlamaktadır. Substrat seçimi, mikro filizlerin verimi, morfolojik özellikleri ve besin içeriği üzerinde belirleyici bir faktör olarak öne çıkmaktadır. İnce vermikülit kullanılarak −1 MPa ve 12 °C'de 6 gün süreyle yapılan matriks primingi uygulamasının, sofra pancarı ve pazı (Beta vulgaris L.) tohumlarında çimlenme süresini %50 oranında kısaltarak nihai çimlenme yüzdesini artırdığı bildirilmiştir (Lee ve ark., 2004). Sofra pancarı ve roka tohum toplarına, %150 su ile emdirilmiş ince dereceli genleştirilmiş vermikülit kullanılarak 20 °C'de 5 gün süreyle uygulanan ön çimlendirme işlemi, ekimden 15 gün sonra sürgün taze ağırlığında, işlem görmemiş tohumlara kıyasla m^{-2} başına %26 artış sağlamıştır (Murphy ve ark., 2010). Mikro filizlerin verimi ve kalitesi; yetiştirme ortamı, ekim öncesi gübreleme, çıkış sonrası fertigasyon veya bu uygulamaların kombinasyonundan etkilenebilmektedir. Turba esaslı ortamda yetiştirilen roka mikro filizlerinde, ekim öncesi 1000 mg/L kalsiyum nitrat uygulaması ile düzenli olarak 75 ve 150 mg/L N içeren fertigasyon uygulamalarının taze verimi artırdığı rapor edilmiştir (Murphy ve Pill, 2010).

SONUÇ VE ÖNERİLER

Topraksız kültür sistemlerinde mikro filiz yetiştiriciliği, kısa üretim süresi, yüksek besin değeri ve kontrollü çevre koşullarında üretime olanak sağlaması nedeniyle sürdürülebilir gıda üretimi açısından önemli bir potansiyel sunmaktadır. Literatürde yer alan çalışmalar, yetiştirme ortamı, besin çözeltisi yönetimi, ışık kalitesi ve çevresel koşulların mikro filizlerin verimi, kalite özellikleri ve fitokimyasal bileşik içeriği üzerinde belirleyici olduğunu açıkça ortaya koymaktadır. Bu faktörlerin uygun şekilde optimize edilmesi hem ürün performansının

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artırılmasına hem de kaynak kullanımının daha etkin hâle getirilmesine katkı sağlamaktadır. Gelecekte yapılacak çalışmaların, farklı mikro filiz türleri için optimum substrat–besin çözeltisi–ışık kombinasyonlarının belirlenmesine, üretim maliyetlerinin düşürülmesine ve kalite sürekliliğinin sağlanmasına odaklanması önerilmektedir. Bunun yanı sıra, hasat sonrası kalite ve raf ömrünü uzatmaya yönelik stratejilerin geliştirilmesi, mikro filizlerin ticari potansiyelini artıracak önemli bir araştırma alanı olarak öne çıkmaktadır.

KAYNAKLAR

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SEBZELERDE ABİYOTİK STRES TOLERANSININ ARTIRILMASINDA BİTKİ EKSTRAKTLARININ ROLÜ

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ÖZET

Günümüzde iklim değişikliği ve çevresel stres faktörlerinin şiddetlenmesi, sebze yetiştiriciliğinde abiyotik stres kaynaklı sorunların artmasına neden olmaktadır. Kuraklık, tuzluluk, yüksek sıcaklık ve ağır metal stresi gibi çevresel kısıtlayıcılar, bitkilerin fizyolojik ve biyokimyasal süreçlerini olumsuz etkileyerek verim ve kalite kayıplarına yol açmaktadır. Bu kapsamda, çevreyle uyumlu ve sürdürülebilir uygulamaların geliştirilmesi, modern sebze üretim sistemlerinde önemli bir gereklilik hâline gelmiştir. Son yıllarda bitki ekstraktları, içeriklerinde yer alan biyolojik olarak aktif bileşenler sayesinde sebzelerde stres toleransının artırılmasına yönelik umut verici uygulamalar arasında değerlendirilmektedir. Farklı bitki kaynaklarından elde edilen ekstraktların; antioksidan savunma sistemlerini desteklediği, ozmotik dengeyi iyileştirdiği ve stres koşulları altında bitki performansını olumlu yönde etkilediği çeşitli çalışmalarda rapor edilmiştir. Bu etkiler, bitkilerin abiyotik stres koşullarına uyum yeteneğinin güçlendirilmesinde bitki ekstraktlarının potansiyel rolüne işaret etmektedir. Bu derlemenin amacı, sebzelerde abiyotik stres toleransının artırılmasında bitki ekstraktlarının kullanımına ilişkin güncel literatürü ele alarak, bu uygulamaların sürdürülebilir sebze üretimi açısından önemini değerlendirmektir.

Anahtar Kelimeler: Abiyotik stres, bitki ekstraktları, sebzeler, stres toleransı

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THE ROLE OF PLANT EXTRACTS IN ENHANCING ABIOTIC STRESS TOLERANCE IN VEGETABLES

ABSTRACT

In recent years, the intensification of climate change and environmental constraints has led to an increased prevalence of abiotic stress factors in vegetable production systems. Abiotic stresses such as drought, salinity, high temperature, and heavy metal toxicity adversely affect plant physiological and biochemical processes, resulting in significant reductions in yield and product quality. Therefore, the development of environmentally friendly and sustainable strategies to mitigate stress-induced damage has become a priority in modern vegetable cultivation. Plant extracts have recently gained considerable attention as natural and sustainable tools for enhancing abiotic stress tolerance in vegetables due to their rich content of biologically active compounds. Extracts derived from various plant species have been reported to improve antioxidant defense mechanisms, regulate osmotic balance, and enhance overall plant performance under stress conditions. These positive effects highlight the potential of plant extracts as biostimulants capable of improving stress resilience in vegetable crops. The aim of this review is to evaluate current literature on the use of plant extracts for increasing abiotic stress tolerance in vegetables and to discuss their potential role in sustainable vegetable production systems.

Keywords: Abiotic stress, plant extracts, vegetables, stress tolerance

1. GİRİŞ

Abiyotik stresler, bitki büyüme ve gelişimini önemli ölçüde azaltabilmekte; ürün kalitesi ve verimliliğini olumsuz yönde etkileyebilmektedir. İklim değişikliğinin bir sonucu olarak, abiyotik streslerin önümüzdeki yıllarda şiddetinin ve sıklığının artması beklenmekte olup bu durum tarımsal sistemler üzerinde daha yoğun bir baskı oluşturacaktır. Bu bağlamda, özellikle dünya nüfusunun giderek artan gıda ihtiyacının karşılanması gerekliliği de göz önünde bulundurulduğunda, ürün üretiminde ciddi düşüşler yaşanması olasılığı endişe verici bir durumdur. Bu nedenle, abiyotik streslerin etkilerini en aza indirirken tarımsal üretimin sürdürülebilirliğini ve dayanıklılığını koruyacak ya da artıracak, düşük ya da sıfır iklim etkisine sahip yeni ve etkili yaklaşımların geliştirilmesi gerekmektedir (Buono ve ark., 2023). Sebzeler,

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hassas fizyolojileri nedeniyle abiyotik streslere karşı özellikle duyarlıdır ve bu nedenle bu bitkilerde stres toleransının artırılması, günümüz tarımının en önemli araştırma alanlarından biri haline gelmiştir (Bulgari ve ark., 2019). Abiyotik streslerin sebze bitkilerinde oluşturduğu olumsuz etkiler, bitkinin metabolizmasında, fizyolojisinde ve morfolojisinde çok katmanlı değişikliklere yol açar. Kuraklık stresi, bitkilerde su kaybını artırırken, stomataların kapanmasına, fotosentez hızının azalmasına ve büyümenin yavaşlamasına neden olur (Buragohain ve ark., 2024). Tuzluluk ise iyon dengesizliği ve ozmotik stres oluşturarak bitki hücrelerinde toksisiteye ve besin maddesi alımında bozulmalara yol açar (Aiswarya ve ark., 2025). Aşırı sıcaklık ve soğuk gibi diğer abiyotik stresler de protein denatürasyonu, membran bütünlüğünün bozulması ve metabolik süreçlerin aksamasına neden olur (Kopecká ve ark., 2023).

Son yıllarda artan ilgi gören agronomik yaklaşımlardan biri, biyostimülanlar olarak tanımlanan ve belirli organik materyaller ile mikroorganizmaların farklı formülasyonlarını içeren uygulamalardır. Biyostimülanlar, üretimlerinde kullanılan hammaddelere göre genellikle farklı gruplar altında sınıflandırılmaktadır. Bunlar arasında hümik maddeler, kompleks organik materyaller, yararlı kimyasal elementler (örneğin silikon), inorganik tuzlar, alg ve bitki ekstraktları, protein hidrolizatları, kitin ve kitosan türevleri, terlemeyi azaltıcı maddeler (örneğin kaolin), amino asitler ve diğer bileşikler yer almaktadır (Rouphael ve Colla, 2020). Bu maddeler; bitkilerin stres toleransını artırabilmekte, besin maddelerinin kullanım etkinliğini ve toprak ya da rizosferdeki biyoyararlanımını iyileştirebilmekte ve kalite özelliklerini olumlu yönde etkileyebilmektedir. Bu nedenlerle biyostimülanlar, hem optimal çevre koşullarında hem de abiyotik ve biyotik stres durumlarında uygulandıklarında bitkisel üretime önemli katkılar sağlayabilmektedir (Buono ve ark., 2023).

2. ABİYOTİK STRES UYGUALAMALARINDA KULLANILAN BİTKİ EKSTRAKTLARI

Sebzelerde abiyotik stres toleransının artırılmasında kullanılan bitki ekstraktları arasında *Moringa oleifera* (moringa), *Ascophyllum nodosum* ve *Ecklonia maxima* (deniz yosunları), *Allium sativum* (sarımsak), *Aloe barbadensis* (aloe vera), *Glycyrrhiza glabra* (meyan kökü), *Azadirachta indica* (neem) ve meşe yaprağı özütü öne çıkmaktadır. Bu bitkilerden elde edilen ekstraktların, antioksidan savunma sistemlerini güçlendirdiği, ozmotik dengeyi düzenlediği, besin elementi alımını artırdığı ve stres koşulları altında bitki fizyolojisini desteklediği bildirilmektedir. Özellikle moringa ve deniz yosunu ekstraktlarının, kuraklık, tuzluluk ve

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yüksek sıcaklık stresi altında yetiştirilen sebzelerde büyüme ve verimi iyileştirdiği; aloe vera, sarımsak ve meyan kökü ekstraktlarının ise fotosentetik aktivitenin sürdürülmesi ve metabolik dengenin korunmasında etkili olduğu rapor edilmiştir. Neem ekstraktının da çevresel stres faktörlerine karşı koruyucu etkiler sunduğu ve bitki performansını artırdığı literatürde vurgulanmaktadır (Khan ve ark., 2009; Bulgari ve ark., 2015; Yasmeen ve ark., 2013; Desoky ve ark., 2019; Bahgat ve ark., 2023; Naz ve ark., 2022; Tahir ve ark., 2022).

3. ABİYOTİK STRESLERDE BİTKİ EKSTRAKTI UYGULAMALARI

Son yıllarda, abiyotik stresle mücadelede geleneksel ıslah ve genetik mühendislik yöntemlerinin yanı sıra, bitki ekstraktları ve doğal bileşiklerin kullanımı ön plana çıkmıştır. Bitki ekstraktları, çeşitli biyoaktif bileşenler içermeleri sayesinde bitkilerde stres toleransını artırıcı etkilere sahiptir. Bu ekstraktlar, ozmotik dengeyi koruyan maddelerin birikimini teşvik eder, antioksidan enzim aktivitelerini yükseltir, iyon alımını düzenler, hormon sinyal yollarını modüle eder ve fotosentetik sistemlerin stabilitesini sağlar. Ayrıca, bitki ekstraktlarının yapraktan uygulama, tohum muamelesi ve toprak uygulaması gibi farklı yöntemlerle kullanılması, sebze bitkilerinde stres toleransının artırılmasında esnek ve etkili bir yaklaşım sunar (Feng ve ark., 2025). Bitki ekstraktlarının abiyotik stres koşulları altındaki olumlu etkileri, bünyelerinde bulunan fenolik bileşikler, flavonoidler, alkaloidler, terpenoidler ve diğer sekonder metabolitlerden kaynaklanmaktadır. Fenolik bileşikler, bitkilerde antioksidan savunma sistemlerinin güçlendirilmesinin yanı sıra, ışık ve UV toleransının artırılması, toksik etkilere karşı korunma ve hücresel sinyal iletim süreçlerinde önemli işlevler üstlenmektedir. Fenilpropanoid ve flavonoid biyosentez yolaklarının düzenlenmesi ve yönlendirilmesi, stres toleransının geliştirilmesine yönelik biyoteknolojik yaklaşımlar arasında öne çıkmaktadır. Özellikle sebze türlerinde fenolik bileşik birikiminin artırılması, bitkilerin stres koşullarına dayanıklılığını güçlendirmenin yanı sıra ürünlerin besinsel ve fonksiyonel değerinin yükseltilmesine katkı sağlayabilmektedir (Ahlawat ve ark., 2024). Bitki ekstraktlarının etkinliği, yalnızca içerdiği biyoaktif bileşenlere değil, aynı zamanda kullanılan ekstraksiyon teknikleri ve uygulama yöntemlerine de bağlıdır. Güncel çalışmalarda solvent ekstraksiyonu, ultrason destekli ekstraksiyon ve mikrodalga destekli ekstraksiyon gibi ileri tekniklerin, ekstraktların biyoaktif bileşen konsantrasyonunu ve kimyasal stabilitesini artırmada etkili olduğu bildirilmektedir. Bununla birlikte, aktif bileşenlerin uygulama sürecinde stabilitesinin korunması ve üretim maliyetlerinin azaltılması, bitki ekstraktlarının tarımsal kullanımı açısından hâlen çözülmesi gereken önemli kısıtlar arasında yer almaktadır (Feng ve ark., 2025).

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Sebze bitkilerinde abiyotik stres toleransının artırılmasında bitki ekstraktlarının etkili olmasının temel nedeni, bitki metabolizması üzerindeki çok yönlü düzenleyici etkileridir. Stres koşulları altında bitkilerde amino asitler, çözünür şekerler ve organik asitler gibi temel metabolitlerin düzeylerinde önemli değişimler meydana gelmektedir. Bu bileşikler hem enerji metabolizmasının sürdürülmesinde hem de hücresel ozmotik dengenin sağlanmasında kritik roller üstlenmektedir (Taziun ve ark., 2024). Bitki ekstraktlarının uygulanması, söz konusu metabolitlerin birikimini destekleyerek bitkilerin stres koşullarına uyum yeteneğini artırmaktadır (Feng ve ark., 2025). Ayrıca, fotosentez, solunum ve diğer temel metabolik yolaklarda görev alan enzimlerin aktivitesinin düzenlenmesi yoluyla bitkinin genel metabolik dengesinin korunmasına katkı sağlamaktadır (Taziun ve ark., 2024). Bitki ekstraktlarının uygulanması, kök büyümesini destekleyerek ve besin elementlerinin alımını artırarak bitkilerin beslenme durumunun iyileştirilmesine katkı sağlamaktadır. Bunun yanı sıra, ekstraktlar metabolik kaynakların yeniden dağılımını düzenleyerek, stres koşullarında bitkinin hayatta kalması ve adaptasyonu açısından kritik öneme sahip bileşiklerin biyosentezinin önceliklendirilmesini teşvik etmektedir (Feng ve ark., 2025). Ayrıca çevresel faktörlerin, uygulanan doz miktarının ve uygulama zamanının, ekstrakt uygulamalarının etkinliği üzerinde belirleyici olduğu da bildirilmektedir (Yıldırım ve ark., 2008). Su stresine maruz bırakılan domates bitkisinde yapılan bir çalışmada, meşe yaprağı özütü uygulamasının sadece kuraklık uygulamasına kıyasla bazı morfo-fizyolojik ve meyve fizikokimyasal özelliklerinde hafif bir azalma gösterdiği tespit edilmiştir. Bununla birlikte, meşe yaprağı tozu ve meşe yaprağı özütünün uygulanmasının, düşük maliyetli, kullanımı kolay, zaman alıcı olmaları ve bitkilerin abiyotik strese karşı direncini artırmak için çevresel olarak sürdürülebilir teknikler sağlayarak tarım sektörünün artan taleplerini karşılayabilmeleri nedeniyle yeni tarım uygulamaları olarak tanımlamışlardır (Tahir ve ark., 2022). Isı stresinin hıyar bitkisinde büyüme ve fizyolojik süreçleri önemli ölçüde baskıladığı bilinmektedir. Yapılan çalışmalar, guava (*Psidium guajava*), aloe (*Aloe vera*), sarımsak (*Allium sativum*) ve yonca (*Medicago sativa*) ekstraktlarının hıyarda ısı stresine karşı toleransı artırdığını göstermektedir. Özellikle guava ve aloe ekstraktları klorofil ve karotenoid içeriklerini artırarak fotosentetik kapasitenin korunmasına katkı sağlamıştır. Guava ve sarımsak ekstraktlarının antioksidan enzim aktivitelerini yükseltmesi ve oksidatif stres göstergelerini azaltması, bu uygulamaların hücresel hasarı sınırlandırdığını ortaya koymaktadır (Ei ve ark., 2025).

SONUÇ VE ÖNERİLER

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Bu derleme kapsamında ele alınan çalışmalar, bitki ekstraktlarının sebzelerde abiyotik stres toleransının artırılmasında önemli bir potansiyele sahip olduğunu ortaya koymaktadır. Kuraklık, tuzluluk, yüksek sıcaklık ve ağır metal stresi gibi çevresel kısıtlayıcılar altında, farklı bitki kaynaklarından elde edilen ekstraktların; antioksidan savunma sistemlerini güçlendirdiği, ozmotik dengeyi desteklediği, fotosentetik aktiviteyi koruduğu ve metabolik süreçlerin sürekliliğini sağladığı görülmektedir. Bununla birlikte, bitki ekstraktlarının etkinliği; kullanılan bitki türü, ekstraksiyon yöntemi, uygulama şekli, doz ve çevresel koşullara bağlı olarak değişkenlik göstermektedir. Bu durum, ekstrakt uygulamalarının standartlaştırılmasını ve optimum kullanım stratejilerinin belirlenmesini gerekli kılmaktadır. Gelecekte yapılacak çalışmalarda, bitki ekstraktlarının moleküler düzeyde etki mekanizmalarının aydınlatılması, farklı stres faktörlerinin birlikte görüldüğü koşullarda performanslarının değerlendirilmesi ve ekonomik fizibilite analizlerinin yapılması önem taşımaktadır. Ayrıca, bitki ekstraktlarının konvansiyonel tarım uygulamaları ve diğer biyostimülanlarla entegre kullanım olanaklarının araştırılması, sürdürülebilir sebze üretim sistemlerinin geliştirilmesine katkı sağlayacaktır. Sonuç olarak, bitki ekstraktları; çevre dostu, doğal ve sürdürülebilir yaklaşımlar arasında yer alarak, iklim değişikliği koşullarında sebze üretiminin dayanıklılığını artırabilecek umut verici araçlar olarak değerlendirilmektedir.

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IN VITRO KOŞULLARDA *TRİCHODERMA HARZİANUM* TARAFINDAN ÜRETİLEN UÇUCU ORGANİK BİLEŞİKLERİN TOHUM ÇİMLENMESİ ÜZERİNE ETKİLERİ

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ÖZET

Bu çalışmada, *Trichoderma harzianum* tarafından üretilen uçucu organik bileşiklerin (VOCs), in vitro koşullarda *Arabidopsis thaliana* tohumlarının çimlenmesi üzerindeki etkileri araştırılmıştır. Denemeler, fiziksel temas olmaksızın yalnızca gaz fazı etkileşimine izin veren iki odalı Petri sistemi kullanılarak yürütülmüştür. Tohumlar, *T. harzianum* VOC'lerine farklı sürelerde maruz bırakılmış ve çimlenme oranı ile erken gelişim parametreleri değerlendirilmiştir. Elde edilen bulgular, VOC maruziyetinin tohum çimlenmesi üzerinde zamana bağlı olarak değişen etkiler oluşturduğunu göstermiştir. Bazı maruziyet sürelerinde çimlenme oranının arttığı, daha uzun süreli maruziyetlerde ise çimlenme ve erken fide gelişiminin baskılandığı belirlenmiştir. Bu sonuçlar, *T. harzianum* VOC'lerinin tohum fizyolojisi üzerinde hem uyarıcı hem de baskılayıcı etkilere sahip olabileceğini ortaya koymaktadır. Çalışma, uçucu organik bileşiklerin tohum–mikroorganizma etkileşimlerindeki rolüne ışık tutmakta ve Trichoderma temelli biyolojik uygulamaların kontrollü kullanımına yönelik temel veriler sunmaktadır.

Anahtar Kelimeler : *Arabidopsis thaliana,* tohum çimlenmesi, T*richoderma harzianum,* uçucu organik bileşikler.

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EFFECTS OF VOLATILE ORGANIC COMPOUNDS (VOCs) PRODUCED BY TRICHODERMA HARZIANUM ON SEED GERMINATION UNDER IN VITRO CONDITIONS

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ABSTRACT

In this study, the effects of volatile organic compounds (VOCs) produced by *Trichoderma harzianum* on the germination of *Arabidopsis thaliana* seeds were investigated under in vitro conditions. The experiments were conducted using a dual-plate Petri system that allows only gas-phase interactions without physical contact. Seeds were exposed to *T. harzianum* VOCs for different durations, and germination rate as well as early seedling development parameters were evaluated. The results demonstrated that VOC exposure exerted time-dependent effects on seed germination. While certain exposure periods promoted germination, prolonged exposure led to inhibition of both germination and early seedling growth. These findings indicate that *T. harzianum* VOCs may exert both stimulatory and inhibitory effects on seed physiology. Overall, this study provides insights into the role of volatile organic compounds in seed–microorganism interactions and offers fundamental information for the controlled use of Trichoderma-based biological applications.

Keywords: *Arabidopsis thaliana*, seed germination, *Trichoderma harzianum*, volatile organic compounds.

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1. GİRİŞ

Toprak kökenli *Trichoderma* cinsine ait funguslar, bitkilerle karşılıklı yarar esasına dayalı etkileşimler kurabilen ve sahip oldukları biyolojik mücadele potansiyeli nedeniyle bitki koruma ve tarımsal mikoloji alanlarında temel ve uygulamalı araştırmalarda yaygın olarak incelenen mikroorganizmalardır (Demirer Durak, 2018; Hilje-Rodríguez ve ark., 2020). Bu fungusların fitopatojenlere karşı etkili olmasında parazitizm, rekabet ve bitki savunma mekanizmalarının indüksiyonu gibi farklı mekanizmaların yanı sıra, uçucu organik bileşiklerin (VOCs) üretimi önemli bir rol oynamaktadır (Srivastava ve ark., 2016). Antibiyotik etki, *Trichoderma* tarafından salınan uçucu ve uçucu olmayan ikincil metabolitlere dayanmaktadır. VOCs, düşük molekül ağırlıklı, hidrofobik yapıda olup ortam sıcaklık ve basıncında kolaylıkla buharlaşabilen bileşiklerdir (Siddiquee ve ark., 2012). Hücre zarlarını aşarak hava ve toprak ortamına yayılabilmeleri sayesinde mikroorganizmalar ve bitkiler arasında uzun mesafeli kimyasal sinyalleşmede etkili olurlar. *Trichoderma* tarafından üretilen VOC'ler; monoterpenler, seskiterpenler, alkoller, ketonlar, terpenler, aromatik bileşikler, laktonlar, esterler ve aldehitler gibi geniş bir kimyasal sınıf çeşitliliği göstermektedir (Estrada-Rivera ve ark., 2019). Son yıllarda yapılan çalışmalar, *Trichoderma* kaynaklı VOC'lerin yalnızca antifungal etkilere sahip olmadığını, aynı zamanda tohum çimlenmesi ve erken fide gelişimi üzerinde doğrudan düzenleyici etkiler gösterebildiğini ortaya koymuştur (Joo ve Hussein, 2022; Kumar ve ark., 2022). Düşük veya optimum konsantrasyonlarda bazı VOC'lerin, çimlenme oranını artırdığı, çimlenme süresini kısalttığı ve radikula ile hipokotil gelişimini teşvik ettiği bildirilmektedir. Bu olumlu etkilerin, VOC'lerin bitkide hormon benzeri (özellikle oksin ve etilen ilişkili) sinyal yollarını modüle etmesi, hücre bölünmesini ve uzamasını uyarması ya da oksidatif stresin dengelenmesine katkı sağlamasıyla ilişkili olduğu düşünülmektedir. Bununla birlikte, VOC'lerin tohum çimlenmesi üzerindeki etkilerinin doz, maruziyet süresi, bitki türü ve *Trichoderma* suşuna bağlı olarak değişebildiği; yüksek konsantrasyonlarda veya uzun süreli maruziyetlerde çimlenmenin baskılanabildiği de rapor edilmiştir (da Silva ve ark., 2021). Bu durum, *Trichoderma* VOC'lerinin bitki gelişimi üzerindeki etkilerinin çift yönlü ve koşula bağlı olduğunu göstermektedir. *Trichoderma* kaynaklı VOC'lerin biyosentezi, çeşitliliği ve miktarı tür ve hatta suş düzeyinde farklılık göstermekte; sıcaklık, nem, substrat içeriği, ortam pH'sı, ışık ve fungal koloninin yaşı gibi abiyotik ve biyotik faktörlerden önemli ölçüde etkilenmektedir (Hung ve ark., 2013; Lee ve ark., 2015; Guo ve ark., 2019). Canlı bir biyolojik ajan olarak *Trichoderma*'nın çevrede etkinlik gösterebilmesi için ortama adapte olması ve metabolik faaliyetlerinin tam olarak devreye girmesi gerekmektedir. Bu nedenle, hem

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antifungal etki hem de tohum çimlenmesi üzerindeki düzenleyici etkinin, antagonist fungusun çevresel koşullara uyum sağlamasıyla birlikte daha belirgin hâle geldiği kabul edilmektedir. Bu bağlamda, bu çalışmanın amacı, *Trichoderma harzianum* (Th1) tarafından 3 farklı büyüme döneminde yayılan uçucu organik bileşiklerin (VOC'ler) *in vitro* koşullarda *Arabidopsis thaliana* tohumlarının çimlenmesi ve fide gelişim parametreleri üzerindeki etkilerinin belirlenmesidir.

2. DENEYSEL ÇALIŞMALAR

2.1. Materyal

Çalışmada kullanılan *Trichoderma harzianum* izolatı (Th1) Van Yüzüncü Yıl Üniversitesi Ziraat Fakültesi Bitki Koruma Bölümü Mikoloji Laboratuvarı stoklarından temin edilmiş olup toprak orijinli, moleküler teyitli ve yüksek antagonistik özelliklidir. (Demirer Durak, 2018). Fungal izolat patates dekstroz agarda (PDA) 25 ± 2 °C'de 5 gün inkübe edilmiştir. *Arabidopsis thaliana* tohumları (Columbia-7) ticari olarak temin edilmiştir. Fide gelişimi için Murashige ve Skoog (MS) ortamı kullanılmıştır.

2.1. Metot

Tohumlar, 30 saniye boyunca %95 etanolde ve ardından 30 dakika boyunca sürekli karıştırılarak %20 çamaşır suyu çözeltisinde yüzey sterilizasyonuna tabi tutulmuştur (Lee ve ark., 2016). Vitaminler, %3 sakaroz ve %0,03 fitagel içeren Murashige ve Skoog (MS) ortamı (pH 5,7) hazırlanıp 90 × 15 mm iki bölmeli Petri kabının bir tarafına dökülmüştür. *Arabidopsis* bitkilerinin *Trichoderma* VOC'lerine maruz bırakılması, iki bölmeli Petri içinde Petri sistemi kullanılarak gerçekleştirilmiştir. Bu sistemde fiziksel temas olmadan sadece aynı atmosferi paylaşmaları sağlanmıştır. Kısaca, bir bölmeye PDA' da geliştirilen spor oluşturan *Trichoderma* içeren küçük bir Petri kabı (35 × 10 mm) yerleştirilmiş, MS ortamı içeren diğer bölmeye de tohumlar bırakılmıştır. Her petriye 20 adet *A. thaliana* tohumu yerleştirilmiştir. 14 gün boyunca 23 ± 1 °C, % 45 bağıl nem ve 16 saatlik fotoperiyotlu bir büyüme odasında ortak bir atmosferde birlikte yetiştirilmişlerdir. Ayrıca koloni yaşı testlerinde, 0, 48 ve 96 saatlik *T. harzianum* kolonilerinden salınan VOC'lerin çimlenme ve fide gelişimine etkisine de bakılmıştır. Birinci grup; tohum ekimi+*Trichoderma* ekimi aynı anda, ikinci grup; iki günlük *Trichoderma*+tohum ekimi, üçüncü grup; dört günlük *Trichoderma*+tohum ekimi şeklindedir. Kontroller için ise tohumlar sadece PDA içeren petriler ile aynı ortamda bırakılmıştır. Her gün gözlemler yapılarak çimlenen tohumlar kayıt altına alınmıştır. Süre sonunda fideler tek tek

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alınıp yaş ağırlıkları tartılmış ve boyları ölçülmüştür. Her deneme beş tekerrürlü iki tekrardan oluşmuştur. Elde edilen veriler tek yönlü varyans analizi (ANOVA) ile analiz edilmiş ve ortalamalar arasındaki farklar Tukey çoklu karşılaştırma testi ($p < 0.05$) ile belirlenmiştir.

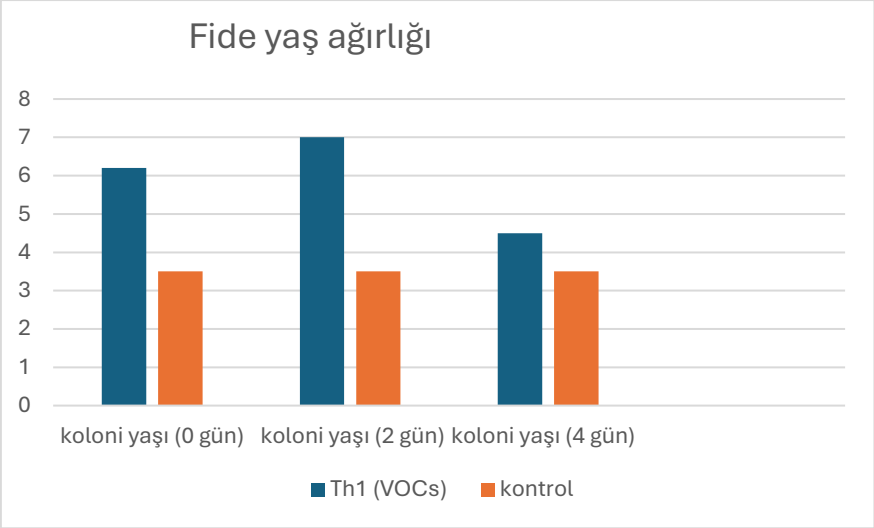
3. SONUÇLAR VE DEĞERLENDİRME

Bitkiler ile mikroorganizmalar arasındaki etkileşimlerin uçucu bileşikler aracılığıyla incelenmesi, uçucu organik bileşiklerin (VOC'lerin) kendine özgü kimyasal özelliklere sahip olması ve bu bileşiklerin; üretici türe, kültürün gelişim evresine, büyüme ortamına ve çeşitli çevresel parametrelere bağlı olarak niceliksel ve niteliksel açıdan dinamik biçimde değişen karmaşık karışımlar hâlinde bulunması nedeniyle metodolojik açıdan önemli güçlükler içermektedir (Lee ve ark., 2015).

Bu çalışmada, doğrudan temas olmaksızın yalnızca aynı atmosferi paylaşan fungal organizma ve *Arabidopsis thaliana* bitkisi arasında kurulan deneysel sistemde, kontrol grubuna kıyasla tohum çimlenmesi ve fide gelişim parametrelerinde VOC'lere maruziyet sonucunda istatistiksel olarak anlamlı farklılıklar tespit edilmiştir. Elde edilen bulgular, bu uçucu maddelere maruz kalan bitkilerin kontrol grubuna kıyasla daha fazla biyokütleye ve daha uzun bitki boyuna sahip olduğunu, çimlenme yanıtının ise VOC maruziyetinin süresine ve yoğunluğuna bağlı olarak değişkenlik gösterdiğini ortaya koymuştur.

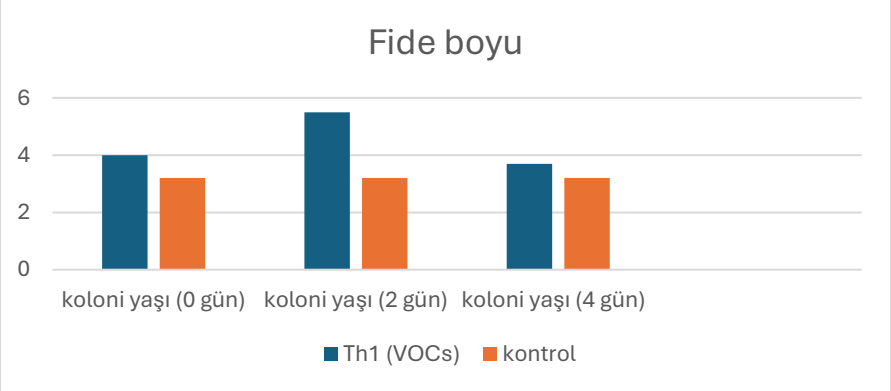
Trichoderma'nın genç ve orta yaşlı kolonilerinden salınan VOC'lerin tohum çimlenmesi üzerinde uyarıcı veya nötr etki gösterdiği, buna karşılık yaşlı kolonilerden salınan yüksek yoğunluklu ve daha sınırlı bileşik profiline sahip VOC'lerin çimlenme süreci üzerinde baskılayıcı etki oluşturabildiği belirlenmiştir. *Arabidopsis* tohumlarının çimlenmesi, *Trichoderma* kaynaklı uçucu organik bileşiklere (VOCs) maruziyet süresine bağlı olarak farklılık göstermiştir. VOC'lere eş zamanlı (0 gün) maruz bırakılan tohumlarda çimlenme oranı ve hızı kontrol grubuna benzer düzeylerde gerçekleşmiştir. İki günlük *Trichoderma* kültürlerinden salınan VOC'lere maruz kalan tohumlarda çimlenme başlangıcında hafif bir gecikme gözlenmiş, ancak nihai çimlenme oranı büyük ölçüde korunmuştur. Buna karşılık, dört günlük *Trichoderma* kültürlerinden kaynaklanan VOC'lere maruziyet, çimlenme sürecinde belirgin bir gecikmeye ve bazı durumlarda nihai çimlenme oranında azalmaya neden olmuştur. Bu bulgular, *Trichoderma* VOC'lerinin tohum çimlenmesi üzerinde yaşa ve doza bağlı bir etki gösterdiğini ortaya koymaktadır.

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Görsel 1. Th1 kolonilerinin farklı yaşlarından (0, 2 ve 4 gün) salınan uçucu organik bileşiklere (VOCs) maruz bırakılan fidelerin 14. gün sonunda ölçülen yaş ağırlıkları

Görsel 1, *Trichoderma harzianum* kaynaklı VOC'lere maruz bırakılan fidelerin yaş ağırlığının, koloni yaşına bağlı olarak kontrole kıyasla nasıl değiştiğini göstermektedir. Buna göre, 0 ve özellikle 2 günlük *Trichoderma* kolonilerinden salınan VOC'lere maruz kalan fidelerin yaş ağırlığı, kontrol grubuna göre daha yüksek bulunmuştur. En yüksek yaş ağırlık artışı 2 günlük koloni uygulamasında gözlenmiştir. Buna karşılık, 4 günlük koloni VOC'lerine maruz kalan fidelerde yaş ağırlık azalmakla birlikte, değerler yine de kontrol grubunun üzerinde veya kontrolle benzer düzeyde seyretmiştir. Bu sonuçlar, *Trichoderma* VOC'lerinin fide biyokütlesi üzerinde koloni yaşına (dolayısıyla VOC profiline ve yoğunluğuna) bağlı bir etki oluşturduğunu göstermektedir.



Görsel 2. Th1 izolatının farklı koloni yaşlarından (0, 2 ve 4 gün) salınan uçucu organik bileşiklere (VOCs) maruz bırakılan fidelerin 14. gün sonunda ölçülen fide boyları.

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Görsel 2, *Trichoderma harzianum* izolatından farklı koloni yaşlarında (0, 2 ve 4 gün) salınan uçucu organik bileşiklere (VOCs) maruz bırakılan fidelerin 14. gün sonunda ölçülen fide boylarını göstermektedir. Buna göre, 0 ve özellikle 2 günlük koloni VOC'lerine maruz kalan fidelerde fide boyu, kontrol grubuna kıyasla belirgin şekilde artmıştır. En yüksek fide boyu artışı 2 günlük koloni uygulamasında gözlenmiştir. Buna karşılık, 4 günlük koloni VOC'lerine maruziyette fide boyunda azalma görülmüş ve değerler kontrol grubuna yaklaşmıştır. Bu bulgular, *Trichoderma* VOC'lerinin fide boyu üzerindeki etkisinin koloni yaşına bağlı olarak değiştiğini ortaya koymaktadır.

Literatürde yer alan çalışmalar da elde edilen bulguları destekler niteliktedir. Bir çalışmada *Trichoderma viride* tarafından salınan izobütil alkol, izopentil alkol ve 3-metilbutanal gibi baskın bileşiklerin, bitkiyle herhangi bir fiziksel temas olmaksızın büyümeyi teşvik edici bir sinyal (infokimyasal) olarak görev yaptığı ve bu bileşiklerin, bitkide oksin ve/veya diğer büyüme hormonu yollarını aktive eden sinyal molekülleri olarak işlev gördüğü bildirilmiştir (Hung ve ark., 2013). Başka bir çalışmada ise VOC'lere maruz kalan fidelerin kök taze ağırlığının kontrol grubunun yaklaşık iki katına çıkabildiği gözlemlenmiş ve bu gelişimin, bitkideki oksin ve diğer büyüme hormonu sinyal yollarının aktivasyonu ile ilişkili olduğu ifade edilmiştir (Contreras-Cornejo ve ark., 2009).

Özetle, literatür bilgileri *Trichoderma* VOC'lerini fidelerin hem toprak üstü hem de toprak altı aksamlarını güçlendiren, fotosentezi artıran ve gelişim sürecini hızlandıran uzun mesafeli bir iletişim aracı olarak tanımlamaktadır. Sonuç olarak bu çalışma, funguslar tarafından salınan VOC'lerin bitki büyümesini uyaran önemli sinyal molekülleri olarak işlev gördüğünü ortaya koymaktadır.

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AGRICULTURAL DROUGHT AND SUSTAINABLE WATER MANAGEMENT

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ABSTRACT

The state of having a resource insufficient to meet demand is called "scarcity," while a low or severe shortage of water is called "drought." Drought is a type of natural disaster, but it differs from earthquakes, floods, and similar disasters in that it spans a long period of time. The imbalance in rainfall (often insufficient) that occurs during drought negatively affects the balance of natural life. Similarly, because it negatively impacts plant and animal production, it has social impacts. Drought can be categorized as "meteorological drought," "agricultural drought," and "hydrological drought."

Drought is a perceptible natural disaster, and different precautions and actions should be implemented before and during its occurrence. Living with drought today, in the face of global warming, requires a series of sustainability actions.

Building on this context, this review examines the types of drought and describes the extent of agricultural drought. Potential precautions and actions against drought are discussed, and recommendations for sustainability are made.

Keywords : Agricultural drought, sustainability, water management

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1. TYPES AND CONSEQUENCES OF DROUGHT

Global climate change is an undeniable reality. One of its most important indicators is the variation observed in spatial and temporal patterns of precipitation and temperature. Changes in precipitation characteristics often manifest as increased seasonality, which becomes evident in certain regions (Rastogi et al., 2024). Precipitation seasonality refers to the deviation of rainfall distribution from an equal (25%) share among the fall, winter, spring, and summer seasons; as this deviation increases, seasonality becomes more pronounced (Adarsh and Janga, 2015; Çeribaşı, 2019). Climate change also leads to reduced precipitation in some areas and increased precipitation intensity in others. The high natural variability of precipitation—both over short distances and from year to year—highlights the need for detailed precipitation analyses. While insufficient precipitation results in problems such as drought and water scarcity, increased precipitation intensity contributes to natural disasters, including floods and overflows (Bölükbaşı Aktaş et al., 2022).

In the Northern Hemisphere, the highest temperature increases occur in the equatorial region during the summer months and in the regions near the poles during the winter months, while rainfall decreases in the south and increases in the north. Increased intensity and frequency of heat waves and floods, as well as changes in the distribution of certain infectious diseases and pollen, can negatively impact human health.

Climate change places additional pressure on ecosystems, causing many plant and animal species to shift northward or to higher altitudes (Seastedt and Oldfather, 2021). While the impacts generally affect sectors such as agriculture, forestry, energy production, tourism, and infrastructure, the majority of the anticipated effects in Europe and Türkiye are negative (IPCC, 2021).

Types of drought emerge from mild to severe as “meteorological drought,” “agricultural drought,” and “hydrological drought.”(Dalezios et al., 2017). Meteorological drought is briefly defined as a decrease in precipitation observed over specific time periods compared to previous years. Agricultural drought occurs when soil moisture is insufficient for plant growth and development, posing a danger to livestock as well. Hydrological drought is the most severe form of drought and refers to long-term precipitation deficiency. As a result, surface and groundwater resources gradually diminish, threatening the lives of all living organisms. Since hydrological drought leads to a reduction in water resources and consequently in vegetation and forest cover, its effects on ecological (environmental) balance are extremely serious (Qiu et al., 2023). These impacts negatively affect urban life, access to clean water resources, food and nutrition, technology and development, and even social stability. Because hydrological drought is long-lasting, its effects are correspondingly profound (MGM, 2022; Kuslu and Barik, 2024).

As a current example, the meteorological drought recently observed in a large part of Türkiye has caused fear and panic among people. Although subsequent rain and snowfall increased

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reservoir occupancy rates to approximately 30%, the water supply problem continues. The occurrence of precipitation should not be interpreted as the end of the drought. Therefore, it is necessary to reconsider our water-use habits. The key is to take precautions before disaster strikes and to adapt our lifestyles accordingly (Yılmaz and Çakır, 2025).

A situation in which a resource is insufficient to meet needs can be defined as "scarcity," while a lack or severe lack of water can be described as "drought." Drought is a type of natural disaster; however, unlike earthquakes, floods, and similar events, it differs in that it occurs over a long period of time and is perceptible (Sivakumar, 2005). The imbalance in precipitation (often a decrease) that accompanies drought negatively affects the balance of natural ecosystems. Similarly, because it adversely impacts plant and animal production, drought also has social consequences. For example, food prices begin to rise due to supply–demand imbalances, dependence on foreign sources for agricultural products increases, and nutrition-related problems emerge, which in turn lead to health issues. In cases of severe drought, mass migration movements may occur, resulting in economic, social, and cultural difficulties (Figure 1).

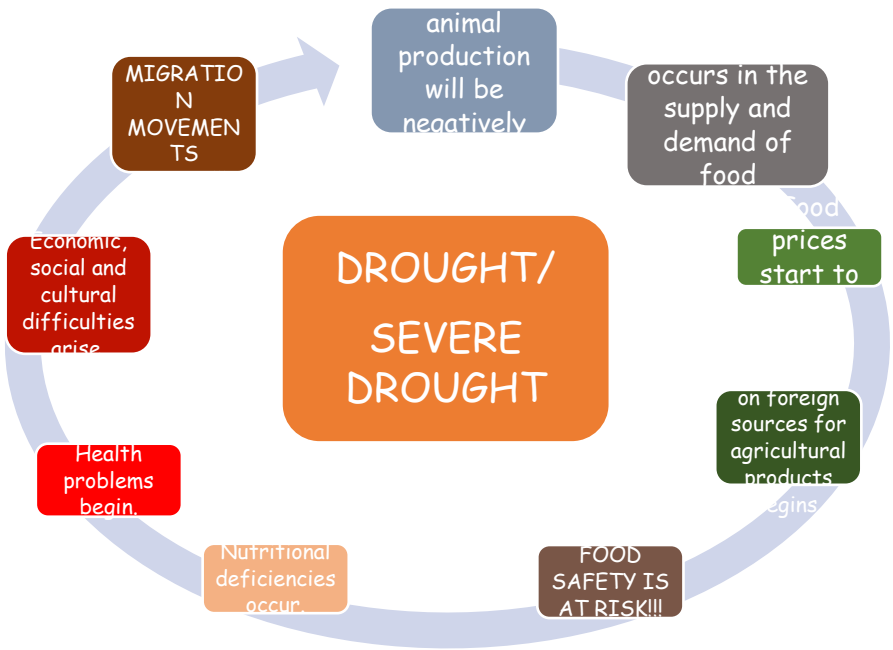


Figure 1. Socioeconomic and Agricultural Impacts of Drought: A Cyclical Consequence Model

2. WHAT SHOULD BE DONE AGAINST DROUGHT?

Drought is a perceptible disaster; therefore, measures must be taken both before and during drought periods.

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Climate change has been acknowledged for many years by institutions ranging from the United Nations to the smallest local administrations. Consequently, sustainable measures must be implemented at global, national, and regional scales. Considering our country as an example, the measures to be taken in the Eastern Black Sea region should differ from those in the Konya Closed Basin or the Western Mediterranean. Each region should be addressed within its own realities, and short-, medium-, and long-term measures—and even sanctions—should be put into practice (Coşkun 2020; Çeribaşı, 2019).

To cope with drought, effective management strategies must be developed. Accordingly, preventive measures before the onset of drought, actions to be taken during drought conditions, and long-term plans for living with drought should be established.

Before Drought:

Water resources must be managed in the most efficient way. Given that more than 70% of freshwater resources worldwide and in our country are used for agricultural purposes, balancing the water budget becomes a priority (Musie and Gonfa, 2023). In an agricultural system, if available water resources are used efficiently and remain sufficient throughout the entire crop production season, the budget is considered to be used economically. If water resources are increased or conserved by the end of the season, the budget can be described as well managed. However, if water resources are depleted midway through the season, the budget is regarded as poorly managed, and measures must be taken to address the resulting deficit. In crop production, if there is not enough water in the soil during the growing period, there is only one way to close this gap: irrigation (Davis et al., 2017).

- Necessary investments should be made to minimize water losses. For example, losses occurring during the conveyance of water from its source to the field, as well as application losses from the field to the plant root zone, should be reduced to a minimum. For this purpose, open canal systems should gradually be converted into closed systems, and irrigation methods that use water most efficiently should be widely adopted.

- Agricultural production planning is indispensable. Institutions and organizations responsible for implementation should work region by region to determine which crops should be grown on which soils and lands. While doing so, alternative plans should be prepared for rainy, semi-arid, and arid periods (Bousbaine, 2018).

- Support and incentives should be provided to promote technologies aimed at the efficient use of water in the plant root zone (Levidow et al., 2014).

- In the water budget, precipitation is the only input. Therefore, methods for storing precipitation should be encouraged. For instance, harvesting rainwater can provide significant advantages for future use (Er and Kuslu, 2024; Tomozeiu et al., 2005)

- In Türkiye, 90% of agricultural enterprises consist of small family farms. Research shows that the primary way for these enterprises to adapt to climate change—and thus to

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drought—is economic production diversity. When diversified production planning is implemented (crop production, livestock, post-harvest food processing, etc.), deficits in one area can be compensated by another, enabling farms to remain viable (Bas and Killi, 2024). Additionally, sharing drought risks and sudden temperature changes with enterprises, properly planning (or reorganizing) planting and harvesting times, focusing on species resistant to temperature and water stress, and adopting conservation (no-till) agriculture techniques have been found to be important for drought adaptation (IPCC, 2021).

During Drought:

- Continuous data and information sharing among all stakeholders (farmers, agricultural institutions, investment organizations, leading enterprises, semi-autonomous institutions, credit institutions, etc.) is essential.

- Production plans that ensure water savings under limited water availability should be implemented. Crop production methods that achieve the highest yield per unit of applied water should be preferred.

- The sustainability of drought management must be ensured. For example, action plans should be prepared to enable the use of groundwater in agricultural production. However, groundwater must be used very sparingly, as it is of strategic importance.

- Investments supporting efficient water management should be accelerated, and legal sanctions should be applied if necessary.

3. CONCLUSION

Overall, global temperature trends show a clear upward tendency, which in turn affects the functioning of the hydrological cycle. Climate change, therefore, leads to noticeable shifts in both temperature and precipitation regimes. Since temperature and precipitation are the fundamental components of the Earth’s climate system, accurate information about these parameters is essential for understanding the nature and magnitude of global climate variations.

Effective use of water resources and the selection of drought-resistant crop varieties are of critical importance under changing climate conditions. In this context, the widespread adoption of pressurized irrigation systems that ensure efficient use of irrigation water should be encouraged, with particular emphasis on drip and subsurface drip irrigation methods. In addition, the integration of digital technologies—such as smart irrigation systems, soil moisture sensors, and data-driven decision support tools—should be considered as part of long-term adaptation strategies for future climate change scenarios.

Furthermore, future research should increasingly focus on the observation and analysis of drought indicators beyond precipitation and temperature alone. Expanding the scope of such studies to include soil moisture, vegetation health, evapotranspiration, and hydrological

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responses would contribute to a more comprehensive understanding of drought processes and improve drought monitoring, management, and mitigation efforts.

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YEM BİTKİLERİ ISLAH AMAÇLARINDA YERALAN BAZI ABİYOTİK VE BİYOTİK STRES FAKTÖRLERİ

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ÖZET

Yem bitkileri ıslah programları ortak bir amaca yöneliktir: Bir türü, üretici ve tüketicilerin istekleri göz önünde bulundurarak belirli bir tarımsal bağlam ve hedef çevre popülasyonu içerisinde, genetik ve sitogenetik esaslardan yararlanarak, kullanılmak üzere iyileştirmek. Birçok ıslah amacı, bir ya da daha fazla belirgin özellik sınırlılığına veya yetersizliğine sahip bir türün seçimiyle önceden belirlenmektedir; örneğin zayıf çimlenme gücü, toksik alkaloid sentezi, kuraklık ve/veya düşük sıcaklık stresine hassasiyet veya bir zararlıya karşı yüksek duyarlılık vb. Bu tür sınırlılıklardan yoksun olan yem bitkilerinde, ıslahçılar daha esnek ve/veya daha az katı ıslah hedefleri tanımlama olanağına sahiptir. Bu durum, ıslahçıların ıslah yöntemlerini ve süreç verimliliğini iyileştirmeye odaklanmalarına, ilave ıslah amaçları ya da seleksiyon kriterleri geliştirmelerine veya ıslah programının kapsamını ve ölçeğini genişletmelerine olanak sağlamaktadır. Tür üzerinde stres oluşturan tarımsal uygulamalar ile abiyotik ve biyotik etmenleri barındıran çevre koşulları, bu stres etmenlerine karşı tolerans veya direnç kazandırmaya yönelik ıslah amaçları ile buna uygun ıslah yöntemlerinin geliştirilmesinde temel belirleyiciler olarak kullanılmaktadır. Bazı durumlarda, karmaşık özelliklerin daha basit bileşen özelliklere ayrıştırılması yoluyla bu hedeflere ulaşmak mümkündür; örneğin, basit bir kuraklık toleransı testi kullanılarak, geliştirilmiş kuraklık toleransı ile tarla koşullarında oluşacak kuraklık stresi altında uzun vadeli verim istikrarına sahip yem bitkilerinin seçimi sağlanabilmektedir. Bu makale, yem bitkileri ıslahına yeni başlayan ve/veya ilgi duyanları ıslah amaçlarında yer alan bazı abiyotik ve biyotik stres faktörleri hakkında bilgilendirmek amacıyla hazırlanmıştır.

Anahtar Kelimeler: Islah, Stres faktörleri, Yem bitkileri

ABSTRACT

Forage crops breeding programs share a common objective: to improve a species for use by leveraging genetic and cytogenetic principles within a specific agricultural context and target environment, while considering the needs of producers and consumers. Many breeding objectives are predetermined by selecting species that exhibit one or more distinct limitations or deficiencies, such as poor germination vigour, synthesis of toxic alkaloids, susceptibility to drought and/or low-temperature stress, or high sensitivity to a pest, etc. In forage crops lacking

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such limitations, breeders have the opportunity to define more flexible and/or less rigid breeding objectives. This enables breeders to focus on improving breeding methods and process efficiency, develop additional breeding objectives or selection criteria, or expand the scope and scale of the breeding program. Agricultural practices that impose stress on the species and environmental conditions encompassing abiotic and biotic factors serve as fundamental determinants in developing breeding aims for tolerance or resistance to these stress factors, as well as in devising appropriate breeding methods. In some cases, achieving these goals is possible by decomposing complex traits into simpler component traits; for example, using a simple drought tolerance test can facilitate the selection of forage crops with improved drought tolerance and long-term yield stability under drought stress conditions in the field. This article has been prepared to inform those new to and/or interested in forage crops breeding about some of the abiotic and biotic stress factors involved in breeding objectives.

Keywords: Breeding, Stress factors, Forage crops

1. GİRİŞ

Hayvancılığın sürdürülebilir biçimde geliştirilebilmesi, düzenli ve kaliteli yem temini olmadan mümkün değildir. Yem bitkilerinin temel işlevi olan hayvanlar için yem üretiminin yanı sıra, bu bitkiler doğaya uygun, dengeli, sürdürülebilir tarım alanları oluşturmak, ekili alanların verimlilik ve fitosaniter durumunun iyileştirilmesinde, toprakların su ve rüzgâr erozyonuna karşı korunmasında, hatta kentlerde elverişli bir yaşam ortamının temeli olarak estetik işlev üstlenmelerinde de önemli rol oynamaktadırlar (Kosolapov ve ark., 2021). Bu bağlamda, yem bitkileri ıslahı büyük bir önem kazanmaktadır.

Islah, insan tarafından yönlendirilen bir evrim süreci olarak tanımlanabilir. Bu süreç, tüm tarımsal öneme sahip bitkilerin ve bunlarla ilişkili türlere ait hatların veya çeşitlerin geliştirilmesinde temel bir rol oynamıştır. İnsanlar binlerce yıldır bitkilerin genetik kaynaklarını başarıyla yönlendirip değiştirmiş olsalar da genetik bilimi ve modern ıslah yöntemleri 20. yüzyılın başlarına kadar tam anlamıyla gelişmemiştir. 20. yüzyılın başlarında, çeşitli yem bitkileri üzerinde ilk sistematik ıslah çalışmaları başlatılmıştır (Wilkins ve Humphreys, 2003; Casler ve Vogel, 2020). Bu ilk çalışmalar, yerleşme yeteneği, kalıcılık, yüksek biyokütle verimi ve zararlılara ve hastalıklara karşı dayanıklılık gibi temel tarımsal özelliklerin iyileştirilmesine odaklanmıştır. Bu özellikler, günümüzde de yem bitkisi ıslahında temel hedefler olarak önemini korumaktadır (Burton, 1986). 1960'lı yıllardan itibaren laboratuvar tekniklerindeki gelişmeler ve yüksek verimli ıslah yaklaşımlarının uygulanabilir hâle gelmesiyle birlikte, ıslah hedefleri genişlemiştir. Bu dönemde, yalnızca verim ve dayanıklılığa değil; aynı zamanda yem kalitesinin artırılması, sindirilebilirliğin iyileştirilmesi ve kaliteyi olumsuz etkileyen bileşenlerin azaltılması veya ortadan kaldırılması gibi niteliksel özelliklere de odaklanılmıştır. Ot üretimi yapılan bir yem bitkileri tarlası ile çayırlar ve meralar, farklı tür ve genetik yapıdaki bitkilerin oluşturduğu bir bitki popülasyonundan meydana gelir. Aynı yem bitkisi türü içerisinde yer alan bireysel bitkiler, özellikle yabancı döllenen türler (örneğin: yonca (*Medicago sativa* L.), çok yıllık çim (*Lolium perenne* L.) vb.) geniş bir genetik varyasyon sergilerler. Buna karşın, kendine döllenen türlerde (örneğin: adi fiğ (*Vicia sativa* L.), yem bezelyesi (*Pisum arvense* L.) vb.), vejetatif olarak çoğaltılan türlerde (örneğin: köpek dişi (*Cynodon dactylon* (L.) Pers.) vb.) ve apomiktik türlerde (örneğin: çayır salkım otu (*Poa pratensis* L.) vb.) genetik çeşitlilik genellikle daha sınırlıdır. Tarla veya bir ıslah parselinde yetiştirilen her bir bitkinin fenotipi, onun belirli bir çevresel koşul altında sergilediği morfolojik ve fizyolojik özelliklerin bütünüdür. Her bir fenotip (P), bitkinin genetik yapısı/genotip (G), çevresel faktörler (E) ve bu ikisin interaksiyonu (G×E) tarafından belirlenir. Bu ilişki şu denklem ile ifade edilir: P=G+E+(G×E). Bu denklem, bitkilerin gözlemlenen özelliklerinin yalnızca genetik

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yapılarından değil, aynı zamanda çevresel koşullar ve genotip-çevre interaksiyonundan da etkilendiğini vurgulamaktadır (Casler ve Vogel, 2020).

Yem bitkilerinin tür, çeşit ve ekotip çeşitliliği- doğal popülasyonlar da dahil olmak üzere- ıslahçılara bu çok yönlü materyalleri kullanma ve yeni çeşitler geliştirme olanağı sunmaktadır. Bu nedenle yem bitkisi genetik kaynaklarının değerlendirilmesine büyük önem verilmektedir. Belli bir hedefe yönelik ıslah programına başlamadan önce genetik varyasyonun artırılması için doğal bitki örtüsünden genotiplerin toplanması, taşınması ve kullanımının yanı sıra, yeni ıslah materyalleri mutagenez, somaklonal varyasyonlar, poliploidi, melezleme ve sentetik hibrit populasyonların oluşturulması yoluyla üretilebilmektedir. Ayrıca, klonal mikro çoğaltım ve somatik hibridizasyon gibi biyoteknolojik yöntemler de yaygın biçimde kullanılmaktadır (Kosolapov ve ark., 2021). Ancak, bireysel bitkiler yüksek genotipik ve fenotipik heterojenlik göstermekte olup, birçok yem bitkisi türünün poliploid olması bu durumu daha da karmaşık hale getirmektedir. Ayrıca, birçok buğdaygilde görülen inbreeding sorunu ve az sayıda tarımsal özelliğin belirgin genlerle ilişkilendirilebilmesi, ıslah çalışmalarını güçleştiren diğer etmenlerdir (Poehlman, 1987; Vogel ve Pedersen, 1993). Bu sorunlar üzerine yapılan araştırmalar, belirli baklagil türleri (Jahufer ve ark., 2002; Riday ve Brummer, 2007; Collins ve ark., 2012; Luo ve ark., 2016) ile buğdaygil türlerinde (de Araüjo ve ark., 2002; Piano ve ark., 2007; Blackmore ve ark., 2016) yoğunlaşmıştır. Ancak bu güçlüklerin varlığına rağmen, özellikle *Medicago* ve *Lolium* cinslerinde olmak üzere yem bitkisi türüne yönelik ıslah çalışmalarında önemli ilerlemeler kaydedilmiştir (Capstaff ve Miller, 2018).

Günümüzde yem bitkileri ıslahçılarının en çok belirledikleri ıslah amaçları; kuru madde veriminin artırılması, bitki dayanıklılığının ve özellikle patojenik mantarlar ile nematodlar gibi zararlılara karşı direncin geliştirilmesi gibi biyotik veya abiyotik stres faktörlerine tolerans ve/veya dayanıklılığın geliştirilmesi, kuru maddenin sindirilebilirliğinin yükseltilmesi ve bitki dokusunun besin içeriğinin iyileştirilmesidir (Capstaff ve Miller, 2018). Bu makale, yem bitkileri ıslahına yeni başlayan veya bu alana ilgi duyan araştırmacıları, ıslah hedefleri arasında yer alan biyotik ve abiyotik stres faktörlerine karşı tolerans ve/veya dayanıklılığın geliştirilmesine ilişkin temel kavramlar ve başlıca stres etmenleri hakkında bilgilendirmek amacıyla hazırlanmıştır.

2. BAZI BİYOTİK VE ABİYOTİK STRESS FAKTÖRLERİ

2.1. Hastalık ve Zararlı Stresi

Birçok yem bitkisi türünün çok yıllık olması, tek tür ekiminin (monokültür) yaygın olması ve bu türlerin farklı ekolojik koşullarda yetiştirilmesi hastalık ve zararlı problemlerini artıran etmenler olarak sayılabilir. Bu hastalık ve zararlıların birçoğu, ot verimini ve/veya kalitesini düşürmekte, hayvan performansını veya sağlığını olumsuz etkileyebilmekte ve yem bitkilerinde büyüme sorunlarına ya da önemli oranda bitkilerin ölümlerine yol açabilmektedir.

Hastalık ve zararlı stresine karşı yürütülecek tolerans ve/veya dayanıklılık ıslahı çalışmaları, yem bitkileri ıslahındaki belki de en yaygın amaçlardan biridir. Hatta, hastalık direnci birincil ıslah amacı olmasa dahi, ıslah parsellerindeki yoğun hastalıklı bitkileri ayıklayarak, tüm yem bitkisi ıslahçılarının bu faaliyete en azından asgari düzeyde de olsa katkı sağladıkları söylenebilir. Yonca ve kırmızı üçgül (*Trifolium incarnatum* L.)'de, hastalık ve zararlı direnci için sağlanan genetik kazanımlar, tarihsel olarak yem bitkileri ıslah çalışmalarındaki en önemli ilerlemeleri temsil etmekte olup; bitki örtüsünün kalıcılığında ve ömür uzunluğunda, ot veriminde ve ekonomik getirilerde belirgin iyileşmeler sağlamıştır (Elgin, 1985, Smith ve Kretschmer ,1989; Casler ve van Santen, 2010).

Fenotipik tekrarlamalı seleksiyon, yem bitkilerinde hastalık ve zararlılara dayanıklılığın artırılmasında en yaygın biçimde uygulanan ıslah yöntemidir. Bu yöntem; tüm bitkilerin eşit

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koşullarda yetiştirilmesini sağlayan standart bir tarama prosedürünün geliştirilmesini ve patojen inokulantının her bir bitkiye homojen bir şekilde uygulanmasını gerektirir. Büyük ölçekli yem bitkisi ıslah programlarının önemli bir bölümü, hastalık ve zararlı direnç düzeylerini belirlemek amacıyla yıllık rutin tarama faaliyetleri kapsamında çok sayıda bitki materyalini test etmektedir. Bu programlarda ve daha küçük ölçekli birçok ıslah programında dolaylı seleksiyon yöntemlerinin kullanılması kaçınılmaz bir gerekliliktir. Dolaylı seleksiyon, doğrudan hedef özellik olmayan ancak hedef özellik ile yüksek derecede pozitif korelasyon gösteren bir fenotip üzerinden seleksiyon yapılmasını ifade eder; böylece farklı bir özelliğe yönelik seleksiyonun doğurabileceği kayıplar, seleksiyon etkinliği ve seleksiyon şiddetindeki artıştan kaynaklanan kazanımlar tarafından fazlasıyla telafi edilir. Örneğin, subtropikal nemli bir ekolojide yetiştirilen serin iklim yem bitkilerinde verimi artırmaya yönelik fenotipik seleksiyon, kaçınılmaz olarak hassas genotiplerin elenmesine yol açmaktadır. Fide materyalinin hâlen juvenil gelişim evresinde (tohum çimlenmesinden sonra başlayıp, tam olgun (yetişkin) morfolojik ve fizyolojik özelliklerine ulaşıncaya kadar devam eden erken dönem büyüme aşaması) bulunması ve sera koşullarında gerçekleştirilen taramaların patojen gelişimi açısından son derece homojen fakat yapay ortamlar yaratması, bu yaklaşımın karakteristik özelliklerindendir. Buna rağmen, çevresel koşullardaki yüksek düzeydeki üniformite ile patojen materyalinin eşit ve kontrollü uygulanması, sahada yapılabilecek taramalara kıyasla çok daha fazla genotipin test edilebilme olanağıyla birleştiğinde, çok sayıda türde birçok patojene karşı kayda değer genetik ilerlemeler elde edilmesini sağlamıştır (Casler ve Pederson, 1996). Başarılı örnekler bulunmakla birlikte, bazı durumlarda sera koşullarındaki fide taramalarının sahadaki seleksiyona kıyasla ya başarısız ya da daha düşük verimlilikte olduğu görülmüştür; bunun temel nedenleri sera ve saha koşulları ile fide ve erişkin bitkiler arasındaki düşük fenotipik korelasyonlardır. Dolayısıyla, en verimli seleksiyon yöntemlerinin belirlenebilmesi ve doğrudan seleksiyon ile dolaylı seleksiyon arasındaki ödünleşimlerin doğru biçimde ortaya konabilmesi için bu ilişkilerin her bir durumda araştırılması gereklidir. Üniform patojen yükleri altında yem verimi veya bitki canlılığı için yapılan dolaylı seleksiyon, yem bitkisi popülasyonlarında virüs veya nematod dayanıklılık düzeylerinin artırılması bakımından son derece etkili bir yöntem olabilmektedir (Casler ve van Santen, 2010).

Fenotipik tekrarlamalı seleksiyon, ıslah edilmesi hedeflenen popülasyonda başlangıçta "dayanıklı" bireylerin bulunmasını gerektirmez. Dayanıklılık genleri çoğu zaman popülasyon içerisinde resesif şekilde ve son derece düşük frekanslarda bulunabilir; bu nedenle dayanıklılık alellerinin frekansının iki ya da üç seleksiyon döngüsü boyunca artmasıyla, ancak daha sonra bu alellere sahip homozigot bireylerin ortaya çıkması sonucu belirgin şekilde dayanıklı bitkiler gözlenebilir. Popülasyonda ilk dayanıklı bireylerin ortaya çıkmasının ardından, her biri daha yüksek düzeyde dayanıklılık aleli taşıyan daha fazla sayıda dayanıklı bitkinin seçilmesi nedeniyle genetik ilerleme hızı artabilir. Birçok patosistem, konukçu–patojen özgüllüğü ile tanımlanır; bu sistemlerde gen-gene etkileşimleri hastalık fenotipini düzenler ve konukçu genotipleri tüm patojen izolatlarına veya ırklarına karşı eşit yanıt vermez. Literatürün kapsamlı bir değerlendirmesi, bu gen-gen ilişkilerinin çok sayıda yem bitkisi patosisteminde bulunduğunu açıkça ortaya koymaktadır; aynı zamanda, çok sayıda başarılı seleksiyon denemesinin gösterdiği üzere, tek bir patojen izolatına veya az sayıda izolattan oluşan basit bir karışıma yönelik seleksiyonun büyük çoğunlukla başarıya ulaştığı da açıktır (Casler ve Pederson, 1996). Çoğu ıslah programında amaç, tarla koşullarında yaygın olarak bulunan ve konukçuya karşı yüksek patojenisite gösteren izolatların kullanılmasıdır; böylece konukçu popülasyonu üzerinde maksimum seleksiyon baskısı oluşturulurken tüm bitkilerin ölümüne yol açılmamış olur. Konukçu dayanıklılığının genetik kontrolü, tek bir majör genden oligo- veya poligenik dirence kadar geniş bir yelpazede değişkenlik gösterebilir. Teorik olarak, çok genli dayanıklılık tek genli dayanıklılığa kıyasla daha kalıcı olmalıdır. Çoğu yem bitkisi türü kendine uyuşmazlık nedeniyle büyük ölçüde yabancı tozlandığından ve çok sayıda heterozigot

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bireylerden oluşan son derece heterojen popülasyonlara sahip olduğu için, birçok çeşitte yüksek oranda genetik çeşitlilik korunmaktadır. Bu durum özellikle poliploid türlerde daha belirgindir. Zararlı ve hastalığa tolerans ve/veya dayanıklılığın artırılması amacıyla yapılan ıslah çalışmaları, arzulanan alellerinin frekansının yükselmesine ve sonuç olarak geliştirilen çeşitlerde toleranslı ve/veya dayanıklı bitkilerin oranının genellikle %30–60 düzeyinde, nadiren %70'in üzerinde olmasına yol açmaktadır. Bu oranlar, patojenler ve diğer stres etmenlerine bağlı olarak ortaya çıkan orta düzeydeki ölüm oranlarını tolere etmek için çoğunlukla yeterlidir; ayrıca dirençli bitkiler, duyarlı bireylerin ölümünün oluşturduğu boşlukları telafi edici büyüme ile doldurabilmektedir. Bu tür bir sistem, konukçu ile patojenin belirli düzeyde birlikte var olmasına olanak tanıyarak, mutasyon veya genetik rekombinasyon sonucu ortaya çıkabilecek aşırı virülan patojen suşları üzerindeki seleksiyon baskısını azaltır ve böylece oldukça kalıcı konukçu dirençlerinin oluşmasına katkı sağlar (Casler ve van Santen, 2010).

2.2. Sıcaklık Stresi

Bitkiler düşük, orta ve yüksek sıcaklıklara toleranslarına göre psikrofilik, mezofilik ve termofilik olarak sınıflandırılmaktadır (Levitt, 1980). Sıcaklık stresinin olumsuzluğu, stresin süresine, şiddetine ve bitkinin gelişim dönemine bağlı olarak değişiklik göstermektedir (Fahad ve ark., 2016). Optimal biyokimyasal, fizyolojik ve morfolojik gelişim için gerekli termal eşiklerin altında veya üzerinde sıcaklığa maruz kalma sonucunda büyüme, metabolizma ve performans potansiyelinin kısıtlanması "termal stres" olarak tanımlanmaktadır (Greaves, 1996).

Ekilebilir alanların yaklaşık %15'inin don stresinden etkilendiği belirtilmektedir (Dudal, 1976). Düşük sıcaklık stresine maruz kalma bitkilerde solgunluk, beyazlama, kararma, nekroz ve ölüme yol açmaktadır (Levitt, 1980). Soğuk veya don, birçok yem bitkisi türünde adaptasyonu ve uzun süre hayatta kalmayı sınırlayan en önemli faktörlerden biridir. Düşük sıcaklık stresi; kar ve neme bağlı hastalıklar, kış kuraklığı ve kurutucu rüzgârlar gibi diğer stres etmenleriyle etkileşime girerek etkili tarama prosedürlerinin geliştirilmesini çoğu zaman güçleştirmektedir. Düşük sıcaklık stresine/soğuğa tolerans, bitkilerin giderek düşen sıcaklıklara karşı yavaş yavaş maruz bırakılmalarını gerektirirken, kış veya erken ilkbahar dönemindeki don sonrası hızlı erimeler bitkilerin soğuğa uyum yeteneklerini azaltarak düşük sıcaklık toleransını düşürebilmektedir. Kar örtüsü ise bitkileri şiddetli soğuktan koruyarak düşük sıcaklık stres toleransı ile etkileşime girer. Üstün düzeyde düşük sıcaklık stres toleransına sahip yem bitkisi genotipleri, genellikle kış sıcaklıklarının çok düşük olduğu iklimlerde bulunabilir; ancak kar örtüsünün sık ve sürekli olduğu bölgelerde bu durum daha sınırlı olabilir (Casler ve van Santen, 2010).

Yem bitkilerinde düşük sıcaklık stres toleransını artıran çeşitli mekanizmalar tanımlanmıştır. Kış dönemi hastalıklarına yönelik gelişmiş direnç, bitkilerin daha sağlıklı kalmasını sağlayarak düşük sıcaklık stresine karşı dayanıklılığı artırmıştır. Suda çözünebilir karbonhidratlardaki artışların, hem ilkbahar döneminde bitkilerin toparlanması üzerinde doğrudan bir etkisi hem de karda görülen mantar hastalıklarına tolerans üzerinde dolaylı bir etkisi yoluyla düşük sıcaklık toleransını artırabildiği bildirilmektedir. Doymamış yağ asitleri ve vejetatif depo proteinleri de çok yıllık yem bitkilerinde düşük sıcaklık stres toleransını artırabilecek potansiyel mekanizmalar arasında gösterilmektedir. Fotoinhibisyon (yani ışığın aşırı yoğun olması nedeniyle fotosentezin baskılanması), PSII'nin topladığı ışık enerjisinin elektron taşıma zincirinin kapasitesini aşmasıyla ortaya çıkar. Yoğun ışığın düşük sıcaklıklarla birleştiği dönemlerde bu durum daha da şiddetlenir ve bitkide doğrudan düşük sıcaklık stresine yol açabilir. Çayır salkım otu (*Festuca pratensis* Huds.) × İtalyan çimi (*L. multiflorum* Lam.) melezlerinden elde edilen androjenik hatlar, düşük sıcaklıklar sırasında fotoinhibisyonun etkilerini azaltan birden fazla genetik yol bulunduğunu ortaya koymuştur (Rapacz ve ark.,

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2004). Stolon ve rizom gibi morfolojik özellikler de bazı çok yıllık yem bitkisi türlerinde düşük sıcaklık stres toleransını artıran mekanizmalar olarak işlev görebilmektedir (Casler ve van Santen, 2010).

Düşük sıcaklık toleransına yönelik seleksiyon, yapay koşullar altında etkin bir şekilde yürütülebilir. Bitkilerin strese maruz bırakılmadan önce sistematik olarak güçlendirilmeleri gereklidir ve bu tür testler, farklı genotiplerin tepkilerindeki varyasyonun doğru şekilde değerlendirilebilmesi için genellikle geniş bir sıcaklık aralığı kullanmayı gerektirir. Seleksiyon çoğunlukla, bir bitkideki sürgün ve kardeş sürgünlerin %50'sinin ölümüne neden olan sıcaklık değeri olarak tanımlanan LT_{50} üzerine kuruludur. Birçok çok yıllık yem bitkisi türünde genç (juvenil) bitkiler soğuk dayanıklılığı geliştiremediği için, ıslahçılar soğuk toleransını değerlendirmek amacıyla taramaları genç bitkiler yerine yetişkin bitkiler üzerinde yapmak zorunda kalmaktadır. Fide düzeyinde yapılan seleksiyonlar fidelerin toleransını artırabilse de yetişkin bitki toleransı üzerinde büyük olasılıkla sınırlı bir etkisi olacaktır (Hides, 1979). Düşük sıcaklık stresine yönelik taramaların yüksek değişkenlik göstermesi nedeniyle genotiplerin tekrarlı taramalar için ve farklı zaman ya da mekânlarda test edilmek üzere vejetatif olarak çoğaltılması veya klonlanması yaygın bir uygulamadır.

Yüksek sıcaklığa toleransın veya dayanıklılığın geliştirilmesinde ise yüksek sıcaklıkların yapraklarda yanıklara ve renk bozulmalarına neden olarak bitki gelişimini azalttığı bilinmektedir (Vollenweider ve Günthardt-Goerg, 2005). Yüksek sıcaklık toleransı gerek saha gerekse sera temelli tarama prosedürleri ile belirlenebilir. Serada yürütülen testlerde, kum yastıklarına yerleştirilmiş ısıtma sistemlerinin kullanılması tekrarlanabilirlik, üniformite ve uygulanabilirliği artırmaktadır (Casler ve van Santen, 2010).

2.3 Nem Stresi

Dünyadaki arazilerin 1990'lı yılların ortalarında yaklaşık yüzde 28'i tarımsal üretimi desteklemek için fazla kurak (Kramer ve Boyer, 1995) iken iklim değişikliğine bağlı olarak ta artan kuraklık eğilimi sonucunda bu alanların oranı hızla artmakta ve bu da bitkilerin fizyolojisi, büyümesi ve üremesinde azalmaya yol açmaktadır (Barnabas ve ark., 2008). Toprak neminin azalması, bitkilerde terlemenin artmasına ve kök bölgesinde suyun azalmasına neden olarak, su dengesinin olumsuz yönde bozulmasına ve bunun sonucunda büyüme, su-besin ilişkileri, fotosentez, asimilasyon süreçleri ve verim üzerinde olumsuz etkilere yol açmaktadır. Bitkilerde nem stresi yanıtı, türlere, gelişim evrelerine ve diğer büyüme faktörlerine bağlı olarak farklılık göstermektedir (Demirevska ve ark., 2010; Anjum ve ark., 2011; Farooq ve ark., 2011; Singh ve Singh Chahal, 2020). Yüksek sıcaklık stresi, bitkilerde enzim aktivitesini ve hücre bölünmesini etkilemekte ve aynı zamanda ürünlerin büyüme dönemi ile dağılımını değiştirmektedir (Smertenko ve ark., 1997; Porter, 2005, Singh ve Singh Chahal, 2020).

Kuraklık toleransı, birçok yem bitkisi türünde belirgin fenotipik varyasyon bulunmadığından seçim yapılacak açık bir özellik sunmayan, yakalanması güç bir özelliktir. En basit ve en açık yöntem gibi görünse de belirli bir süre boyunca serada ya da tarlada suyun tamamen kesilmesi veya azaltılması yaklaşımı; kuraklığın bitkilere eşit uygulanamaması, düşük kalıtım derecesi veya uygun seleksiyon baskısını optimize edecek bir kuraklık rejiminin öngörülememesi nedeniyle çoğu zaman başarısız olmaktadır (Casler ve van Santen, 2010). Kuraklık toleransını artırmaya yönelik birçok çalışma, dolaylı seleksiyon yöntemlerini kullanmıştır. Bu özellikler arasında en umut verici olanlar; yüksek stomatal direnç (daha seyrek stomalar, daha küçük stomalar veya yüzeyde daha sığ epidermal çıkıntılar), düşük yaprak su iletkenliği, düşük ozmotik potansiyel ve düşük karbon izotopu ayırım oranı ($^{13}C/^{12}C$) yer almaktadır (Caster ve ark. 1996; Johnson ve Asay 1993). Bu özelliklere yönelik seleksiyon denemeleri, su kullanım etkinliği veya toprak nem seviyelerindeki artış temelinde potansiyel olarak daha yüksek kuraklık toleransına sahip bitki popülasyonları oluşturmuş olsa da bu

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çabalar henüz ticari olarak kuraklığa dayanıklı çeşitlerin geliştirilmesine yol açmamıştır (Casler ve van Santen, 2010).

Birçok yem bitkisi ıslah programı, tarihsel olarak kuraklığa eğilimli bölgelerden genetik materyal toplamaya yönelmiş ve böylece yüzlerce hatta binlerce nesillik doğal seleksiyon avantajından yararlanmayı hedeflemiştir. Bu bağlamda, Kuzey Afrika'ya ait İngiliz çimi (*Lolium perenne* L.) popülasyonlarının belirli bir potansiyel sunduğu görülmektedir. Yönlendirilmiş doğal seleksiyon da uygulanabilir bir yaklaşım olarak öne çıkmaktadır; bu yöntemde seleksiyon, kuraklığa yatkın topraklarda bitkilerin uzun dönemli hayatta kalma başarısına dayandırılmaktadır. Kuzey-Batı Amerika'nın kuru tarım bölgelerinde kullanılan çim türlerinde yürütülen en başarılı kuraklık toleransı ıslah programlarından biri, sistematik ve doğal seleksiyon yöntemlerinin bir arada kullanılmasına dayanmaktadır. Derin ekimden (5 cm) çimlenme hızına yönelik seleksiyon, birden fazla türde başarılı olmuş ve farklı tarla koşullarında çıkış yüzdesi ile birinci yıl ot veriminde pozitif ilişkili tepkiler elde edilmiştir. Türler arası melezler ve geriye melezleme ile birlikte uygulanan seleksiyon yöntemleriyle karakter aktarımı, bir türdeki kuraklık toleransının agronomik veya besinsel açıdan daha değerli bir türe aktarılmasında etkili bir mekanizma sağlamaktadır. Kafkas üçgülünden (*T. ambiguum* Bay Bieb.) ak üçgüle (*T. repens* L.), çayır salkım otundan çok yıllık çim ile İtalyan çimine kuraklık toleransının aktarılması yoluyla, her iki ebeveynin istenen özelliklerini taşıyan ve kuraklık toleransına sahip popülasyonlar geliştirilmiştir (Abberton ve Marshall 2005; Thomas ve ark. 2003).

2.4 Kimyasal Stres

Bir diğer canlı olmayan faktörlerden kaynaklanan abiyotik stres, toprakta bulunan tuzluluk, ağır metaller, alüminyum toksisitesi, düşük pH (asitlilik), yüksek pH (alkalilik), bor toksisitesi vb. kimyasal faktörleri içeren kimyasal strestir. Yem bitkilerinde toprak kaynaklı kimyasal strese tolerans/dayanıklılık ıslahı çalışmaları halen devam etmektedir.

Yem bitkilerinde; özellikle yonca, ak üçgül, çok yıllık çim ve kanyaş (*Phalaris* spp.) gibi türlerde toprak asitliğine toleransı artırmak için dünyada ıslah çalışmaları yürütülmüştür. Çeşitli seleksiyon çalışmaları olumlu sonuçlar vermiştir; bunlar arasında (a) yüksek asitli topraklarda tarla temelli seleksiyonlar, (b) nispeten yüksek alüminyum (Al) konsantrasyonuna sahip çözelti kültürüne maruz kalan yem bitkisi türlerine ait fidelerin göreceli kök büyümesi, (c) agar ve 8 mm'lik asidik toprak tabakası arasına tohumlar ekilerek yetiştirilen fidelerin nispi kök büyümesi ve (d) bir bakteriyel sitrat sentaz geni ile yoncanın transformasyonu yer almaktadır. Çevre koşulları üzerinde daha fazla kontrol sağlaması, seleksiyon baskısının daha düzgün uygulanması, yüksek tekrarlanabilirlik ve daha güvenilir genotip değerlendirmesi nedeniyle laboratuvar çalışmaları tercih edilmektedir. Ayrıca yoncada, diğer bitki türlerinde bilinen Al-tolerans genleriyle homolog bir dizi aday gen de tanımlanmıştır (Narasimhamoorthy ve ark., 2007; Casler ve van Santen, 2010).

Farklı yem bitkisi türlerinde tuzluluğa tolerans için doğal genetik varyasyon mevcuttur; dolayısıyla tuzluluk toleransı için ıslah genellikle, uygun alellerin ve toleranslı bitkilerin sıklığını artırmak için birkaç seleksiyon döngüsüyle birlikte etkili bir tarama yöntemi geliştirmek gibi nispeten basit bir konudur. En etkili eleme prosedürleri genellikle tuzlu bir çözeltide hızlı çimlenme veya hızlı kök gelişimine dayanmakla birlikte, germplasm koleksiyonları arasında doğrudan yerel çevrenin tuzluluğu ile ilişkili genetik varyasyon örnekleri de bulunmaktadır. Tuzlu çözelti ortamında çimlenme veya kök gelişimi için seçilen bitkiler genellikle tuzluluk toleransı bakımından saflaşır ve tuzlu tarla koşullarında çimlenme, güçlü büyüme ve yem verimi dahil olmak üzere gelişmiş performans sergilerler (Casler ve ark., 1996; Jensen ve ark., 2005). Tuzluluk toleransı genleri, ıslah popülasyonları içinde başlangıçta son derece düşük frekanslarda bulunsa dahi, geniş popülasyon büyüklükleri ile yoğun

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seleksiyon baskıları, toleranslı popülasyonların elde edilmesini sağlayabilir (Casler ve van Santen, 2010).

Ağır metallere karşı gözlenen toleranslar, büyük ölçüde maden artıklarına, eritme tesislerine ve elektrik direklerine bağlı toksik topraklarda hayatta kalabilen çok az sayıdaki yem bitkisinin doğal seçilimi yoluyla ortaya çıkmıştır (Casler ve ark. 1996). Komşu popülasyonlar üzerinde yapılan incelemeler, bazı popülasyonlarda ağır metal toleransına ilişkin allel frekanslarının 0.0001 kadar düşük olabildiğini göstermiştir; bu frekans bile çok az sayıda bitkinin hayatta kalması için yeterli olmaktadır. Çoğu ağır metal toleransı tek bir lokus tarafından basit bir kalıtım şekli gösterir; bu nedenle toleranslı bitkiler genellikle saf olarak ıslah edilebilir ve toleranslı popülasyonlar oluşturmak için kullanılabilir. Bu popülasyonların birçoğu kirlenmiş toprakların iyileştirilmesinde kullanılmıştır. Birçok ağır metalin benzer alım mekanizmalarını paylaşması nedeniyle, ağır metal toleransına ilişkin birçok gen birden fazla elemente özgüllük gösterebilmekte, bu da ağır metal toleranslı popülasyonların potansiyel değerini ve kullanım alanını artırmaktadır (Casler ve van Santen, 2010).

3. SONUÇLAR VE DEĞERLENDİRME

Yem bitkileri ıslahı, sürdürülebilir hayvancılık ve tarım sistemlerinin temelini oluşturmakta olup, verimlilik, kalite ve çevresel dayanıklılık açısından kritik öneme sahiptir. Bu makalede, yem bitkileri ıslah programlarında öne çıkan abiyotik ve biyotik stres faktörleri ele alınmış, bu streslere karşı tolerans ve dayanıklılığın geliştirilmesine yönelik ıslah stratejileri ve yöntemleri değerlendirilmiştir.

Islah programları, genetik varyasyonun korunması ve artırılması temelinde, hedef çevre koşullarına uygun, yüksek verimli ve kaliteli çeşitlerin geliştirilmesini amaçlamaktadır. Biyotik ve abiyotik stres faktörleri bitkilerin gelişimini, verimini ve kalıcılığını doğrudan etkilemekte; bu nedenle ıslahçılar bu streslere karşı dayanıklı genotiplerin seçimine öncelik vermektedir.

Doğal seleksiyon, fenotipik tekrarlamalı seleksiyon, dolaylı seleksiyondan yararlanma, melezleme ve biyoteknolojik yöntemler gibi yaklaşımlar, stres toleransının artırılmasında etkili olmuştur. Özellikle hastalık ve zararlı direnci, kuraklık ve tuzluluk toleransı, düşük sıcaklığa dayanıklılık gibi özellikler üzerinde yoğunlaşan ıslah çalışmaları hem bitki sağkalımını hem de uzun vadeli tarımsal verimliliği desteklemektedir.

Sonuç olarak, yem bitkileri ıslahı dinamik ve çok disiplinli bir alan olup, iklim değişikliği, artan gıda talebi ve çevresel kısıtlar göz önünde bulundurulduğunda önemi giderek artmaktadır. Gelecekte, moleküler ıslah, genomik seleksiyon ve gen düzenleme teknolojilerinin entegrasyonu ile stres toleransı ve verimlilik özelliklerinin daha hızlı ve hedefe yönelik iyileştirilmesi mümkün olacaktır. Bu kapsamda, genetik kaynakların korunması, ıslah programlarının sürdürülebilirliği ve multidisipliner iş birliklerinin güçlendirilmesi büyük önem taşımaktadır.

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TOPRAKTA AĞIR METAL KİRLİLİĞİNİN BELİRLENMESİNDE KİRLİLİK İNDİSLERİNİN KULLANILMASI

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ÖZET

Ağır metaller, çeşitli doğal (tecezzi, erozyon, rüzgarla parçacıkların birikimi, volkanik patlama, orman yangınları, biyojenik kaynaklar) ve antropojenik kaynaklarla (benzin ve kömürün yakılmasından kaynaklanan atmosferik birikim, madenler, elektro kaplama, dökümhaneler, metal içeren cevherlerin eritilmesi, kömür yakıtlı elektrik santralleri, yanma yan ürünleri, araç emisyonları, enerji ve yakıt üretimi, fosfatlı gübre üretimi, hayvan gübresi, atıksu arıtma çamuru, gübreler, pestisit gibi agrokimyasallar) toprağa girmektedir. Doğal kaynaklarla oluşan girdiler ağır metallerin önemli bir yükünü teşkil etmesine rağmen, çoğu element için antropojenik kaynakların katkısı, doğal kaynaklara göre çevresel ve sağlıkla ilgili endişeyi arttıracak kadar çok daha fazladır. Ayrıca antropojenik kaynaklardan gelen ağır metaller daha hareketli olmaya eğilimlidir ve bu nedenle pedojenik ya da litojenik kaynaklara kıyasla biyoyarayışlılığı daha fazladır. Toprakta yukarıda bahsedilen sebeplerle oluşan kirliliğin seviyesinin, çevre ve insan üzerinde oluşturduğu riskin belirlenmesinde kirlilik indislerinden yararlanılmaktadır. Zenginleşme faktörü, kirlilik faktörü, kirlilik derecesi, jeo-birikim indisi, nemerow kirlilik indisi, kirlilik yük indeksi gibi indisler bu amaçla kullanılmaktadır. Bu indislerin yanısıra topraktaki ağır metallerin o toprakta yetişen bitkiye geçişini belirlemede transfer faktörü hesaplanmaktadır. Transfer faktörü gibi bioabsorpsiyon katsayısı, biyokansantrasyon faktörü ve translokasyon faktörü gibi indisler özellikle kirlenmiş topraklarda yetişebilen ve fitoremediasyonda kullanılabilme potansiyeli olan bitkilerin belirlenmesinde kullanılmaktadır. Bu indisler sayesinde hem toprak kirliliğinin düzeyi belirlenebilmekte hem de topraktan bitkiye geçişin ne oranda olduğu saptanabilmektedir. Ayrıca ağır metallerin yoğun olarak biriktiği bölgelerde ağır metale toleranslı bitki türlerinin toprak remediasyonunda kullanılabilirliğinin ortaya çıkması sağlanmaktadır.

Anahtar Kelimeler : Ağır metaller, toprak kirlilik indisi, toprak kirliliği

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THE USE OF POLLUTION INDICES IN DETERMINING HEAVY METAL POLLUTION IN SOIL

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ABSTRACT

Heavy metals originate from various natural sources (weathering, erosion, wind-blown particle accumulation, volcanic eruptions, forest fires, biogenic sources) and anthropogenic sources (atmospheric accumulation from the combustion of gasoline and coal, mines, electroplating, foundries, smelting of metal-containing ores, coal-fired power plants, combustion by-products, vehicle emissions, energy and fuel production, phosphate fertilizer production, animal manure, sewage sludge, fertilizers, agrochemicals such as pesticides) enter the soil. Although inputs from natural sources constitute a significant load of heavy metals, for most elements, the contribution from anthropogenic sources is much greater than that from natural sources, raising environmental and health concerns. Furthermore, heavy metals from anthropogenic sources tend to be more mobile and therefore have greater bioavailability compared to pedogenic or lithogenic sources. Soil contamination indices are used to determine the level of contamination in the soil caused by the reasons mentioned above and the risk it poses to the environment and humans. Indices such as enrichment factor, contamination factor, contamination degree, geo-accumulation index, Nemerow's pollution index, and pollution load index are used for this purpose. In addition to these indices, the transfer factor is calculated to determine the transfer of heavy metals in the soil to the plants growing in that soil. Indices such as the transfer factor, bioabsorption coefficient, bioconcentration factor, and translocation factor are used to identify plants that can grow in contaminated soils and have the potential to be used in phytoremediation. These indices make it possible to determine both the level of soil contamination and the extent of transfer from soil to plant. Furthermore, they reveal the potential for using heavy metal-tolerant plant species in soil remediation in areas where heavy metals accumulate intensively.

Keywords: Heavy metals, soil pollution indices, soil contamination

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TÜRKİYE'DE ENFLASYON ALGISINDAKİ FARKLILIKLAR ÜZERİNE EKONOMETRİK BİR ANALİZ

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ÖZET

Bu çalışmada, Türkiye'de hanehalkı ve reel sektörün enflasyon algıları arasındaki farkın ekonomi politikalarına olan etkilerini araştırmak amaçlanmaktadır. Literatürde enflasyon ile ilgili oldukça geniş kapsamlı çalışmalar olsa da, bu çalışma enflasyon ve beklentiler arasındaki farklılıklara dayanarak enflasyonun ekonomi politikalarını nasıl şekillendirdiği analiz edilmektedir. Bu amaçla, Türkiye ekonomisi 2015Q1-2025Q2 dönemi için güncel zaman serisi teknikleri kullanılarak ekonometrik analiz yapılmaktadır. Ön testler değerlendirildiğinde, TÜFE'deki değişimler hanehalkı enflasyon beklentileri, reel kesim enflasyon beklentileri ve GSYİH tarafından anlamlı olarak açıklanmaktadır. Hanehalkı enflasyon beklentileri ile Tüfe arasında negatif bir ilişki bulunurken; reel kesim enflasyon beklentileri ile Tüfe arasında pozitif ilişki bulunmaktadır. Ayrıca GSYİH ile Tüfe arasında da pozitif bir ilişki görülmektedir. Ekonometrik analiz sonuçlarında reel kesim ve hanehalkı enflasyon beklentileri arasında ortaya çıkan fark, çalışmanın da tam olarak odaklandığı ve aydınlatmaya çalıştığı enflasyon beklentileri arasındaki algısal kopuşun bir kanıtı olarak ifade edilmektedir.

Anahtar Kelimeler : enflasyon, beklentiler, zaman serisi analizi

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1. GİRİŞ

Enflasyon, hem ülke içinde hem de ülkeler arasında makroekonomik istikrarın temel göstergelerinden biridir. Makroekonomik etkilerin yanı sıra, bireylerin tüketim, tasarruf ve yatırım kararlarını doğrudan etkileyen psikolojik bir bileşene de sahiptir. Modern iktisat literatüründe enflasyon, sadece fiyatlar genel düzeyindeki artış olarak değil, aynı zamanda ekonomik birimlerin geleceğe yönelik beklentilerini şekillendiren bir fenomen olarak ele alınmaktadır. Özellikle gelişmekte olan ülkeler kategorisinde yer alan Türkiye ekonomisi için enflasyon, son yıllarda yüksek oynaklık ve yukarı yönlü ivmesiyle hem politika yapıcıların hem de hanehalkının birincil gündem maddesi haline gelmiştir.

Ancak, resmî kurumlar tarafından açıklanan yıllık enflasyon oranları (TÜFE) ile toplumun farklı kesimleri tarafından hissedilen "enflasyon algısı" arasında belirgin bir farklılaşma gözlemlenmektedir. İktisat yazınında "algılanan enflasyon", bireylerin geçmiş fiyat hareketlerini yorumlama biçimleri ve kişisel tüketim sepetlerine göre şekillenirken; bu algının resmi verilerden sistematik olarak sapması, para politikasının etkinliğini ve fiyat istikrarına olan güveni zayıflatabilmektedir. Türkiye özelinde yapılan çalışmaların büyük çoğunluğu makroekonomik belirleyicilere odaklanmış olsa da, enflasyon algısındaki bu heterojen yapının ekonometrik modellerle derinlemesine incelenmesi gerekliliği güncelliğini korumaktadır.

Bu çalışmanın temel amacı, Türkiye'de bireylerin enflasyon algısını etkileyen faktörleri ve bu algının resmi verilerle olan uyumsuzluğunun nedenlerini ekonometrik bir perspektifle analiz etmektir. Araştırma kapsamında, Türkiye Cumhuriyet Merkez Bankası (TCMB) Elektronik Veri Dağıtım Sistemi'nden (EVDS) elde edilen veriler ile ekonometrik zaman serisi analizi yapılmaktadır.

Çalışmanın ilk bölümünde enflasyon ve beklenti yönetimi arasındaki teorik ilişki tartışılacak, ikinci bölümde ise Türkiye'deki enflasyon süreci ve literatür tarihsel perspektifle ele alınacaktır. Üçüncü bölümde, metodoloji ve veri seti ortaya konulacak ve enflasyon algısındaki farklılaşmalar ekonometrik olarak analiz edilecektir. Son bölüm olarak dördüncü bölümde ampirik bulgular sonrasında sonuç ve politika önerilerine değinilmesi hedeflenmektedir.

2. LİTERATÜR TARAMASI

Türkiye'de enflasyon algısındaki farklılıklar ve bu algının resmi verilerle olan asimetrik ilişkisini konu alan bu araştırma kapsamında, mevcut literatür iki ana eksende tasnif edilerek incelenmektedir. Böyle bir ayrım yapılmasının nedeni, konunun hem teorik temellerini hem de ampirik yansımalarını bütüncül bir perspektifle ele almak amaçlanmaktadır.

Literatür taramasının ilk bölümünde, enflasyon algısının kavramsal çerçevesi ve iktisat teorisindeki evrimi üzerinde durulmaktadır. Bu kısımda, geleneksel rasyonel beklentiler hipotezinden sapmalar ve bireylerin fiyat artışlarını yorumlarken başvurduğu bilişsel süreçler; davranışsal iktisat ve sınırlı rasyonalite kuramları ışığında analiz edilmektedir. Uluslararası

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literatürde kabul görmüş temel modeller ve "algı-gerçeklik sapmasına" (inflation gap) dair öncü çalışmalar bu başlık altında incelenmektedir.

Literatür taramasının ikinci bölümünde ise, Türkiye ekonomisinin kendine özgü dinamikleri çerçevesinde yapılmış ampirik çalışmalar ele alınmaktadır. Özellikle yüksek enflasyon deneyimi, döviz kuru geçişkenliği ve hanehalkı tüketim alışkanlıklarının algı üzerindeki etkilerini inceleyen yerel literatür; kullanılan ekonometrik yöntemler ve ulaşılan bulgular bakımından irdelenmektedir. Bu iki aşamalı yaklaşım, çalışmanın ampirik modelinin üzerine inşa edileceği kuramsal ve uygulamalı zemini netleştirmeyi hedeflemektedir.

2.1. Enflasyon Algısının teorik Temelleri ve Uluslararası Yazın

Enflasyon algısı üzerine yapılan teorik tartışmalar, bireylerin makroekonomik sinyalleri nasıl içselleştirdiği sorusu etrafında şekillenmektedir. Geleneksel iktisadi modeller, karar birimlerinin piyasadaki tüm verileri asimetrik bilgi olmaksızın işlediğini varsayan Rasyonel Beklentiler Hipotezi ’ne dayanmaktadır (Muth, 1961). Ancak ampirik gözlemler, bireylerin resmi enflasyon verilerinden ziyade kendi öznel deneyimlerine dayalı bir "hissedilen enflasyon" kurguladığını ortaya koymuştur.

Bu noktada Sınırlı Rasyonalite (Bounded Rationality) kuramı, bireylerin karmaşık ekonomik verileri işlemek yerine bilişsel kısa yollara başvurduğunu savunur. Bryan ve Venkatu (2001) tarafından yapılan öncü çalışmalar, tüketicilerin satın alma frekansı yüksek olan ürünlerdeki (ekmek, yakıt, kira gibi) fiyat artışlarını, seyrek alınan dayanıklı tüketim mallarındaki fiyat düşüşlerinden çok daha baskın algıladığını göstermiştir. Bu durum literatürde "Frekans Önyargısı" (Frequency Bias) olarak tanımlanmakta ve resmi TÜFE ile algılanan enflasyon arasındaki yapısal sapmanın temel nedeni olarak gösterilmektedir.

2.2. Türkiye Ekonomisine Yönelik Ampirik Literatür

Türkiye literatürü incelendiğinde, enflasyon algısının sadece fiyat hareketlerinden değil, aynı zamanda kronik yüksek enflasyon geçmişinden ve döviz kuru oynaklığından beslendiği görülmektedir.

Beklenti Ataleti ve Geçmişe Bakış: Türkiye üzerine yapılan ekonometrik analizlerde, hanehalkı ve reel sektörün enflasyon algısının büyük ölçüde "Uyarlayıcı Beklentiler" çerçevesinde şekillendiği saptanmıştır. Çiçek ve Akar (2013), Türkiye’de bireylerin geleceğe dair enflasyon öngörülerinde geçmiş dönem enflasyonun en belirleyici değişken olduğunu ampirik olarak kanıtlamışlardır.

Döviz Kuru ve Algı İlişkisi: Gelişmekte olan ekonomilere özgü bir dinamik olarak "Kur Geçişkenliği", Türkiye literatüründe merkezi bir yer tutar. Karaman ve diğerleri (2021), döviz kurlarındaki dalgalanmaların, tüketici nezdinde doğrudan bir "maliyet artışı sinyali" olarak algılandığını ve bu durumun resmi enflasyon rakamlarından bağımsız olarak toplumsal enflasyon algısını yukarı çektiğini vurgulamaktadır.

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Sosyo-Ekonomik Heterojenlik: Son dönem çalışmalarında, enflasyon algısının gelir gruplarına göre asimetrik dağıldığına dair bulgular öne çıkmaktadır. Öğünç ve diğerleri (2023), alt gelir gruplarının sepetinde ağırlığı yüksek olan zorunlu harcama kalemlerindeki (gıda ve barınma) artış hızının, bu gruplarda resmi veriye duyulan güveni sarsan bir "algısal ayrışma" yarattığına dikkat çekmektedir.

3. METODOLOJİ VE VERİSETİ

Çalışmada kullanılan tüm veriler, Türkiye Cumhuriyet Merkez Bankası (TCMB) bünyesindeki Elektronik Veri Dağıtım Sistemi (EVDS) üzerinden temin edilmiştir. Analiz, Türkiye ekonomisindeki fiyat hareketlerinin ve algısal değişimlerin en dinamik olduğu 2015Q1-2025Q2 dönemini kapsayan çeyreklik frekanstaki verilerden oluşmaktadır. Araştırmada kullanılan değişkenlere ait bilgiler Çizelge 1'de sunulmaktadır.

Çizelge 1. Değişkenlere Ait Genel Bilgiler

Değişken adı	Değişken tanımı	Kaynak
bekr	Reel sektörün 12 ay sonrası yıllık enflasyon beklentileri (%)-Düzey	Elektronik Veri Dağıtım Sistemi (TCMB)
bekh	Hanehalkının 12 ay sonrası yıllık enflasyon beklentileri (%)-Düzey	Elektronik Veri Dağıtım Sistemi (TCMB)
tufe	GENEL (Tüketici)-Düzey	Elektronik Veri Dağıtım Sistemi (TCMB)
gsyih	Gayrisafi yurtiçi hasıla(Bin TL)-Düzey	Elektronik Veri Dağıtım Sistemi (TCMB)

3.1. Ekonometrik Modelin Spesifikasyonu

Türkiye 'de hanehalkı ve reel sektörün enflasyon algıları arasındaki farkın ekonomi politikalarına olan etkilerinin araştırıldığı bu çalışmada kurulan temel regresyon modeli aşağıdaki gibidir:

$$tufe_t = \beta_o + \beta_1 bekh_t + \beta_2 bekr_t + \beta_3 lngsyih_t + u_t$$

β_o: Sabit Terim
β_1: Eğim katsayısı
u_t: Hata terimi
t: 2015Q1-2025Q2

Bu çalışmada 2015Q1–2025Q2 dönemini kapsayan çeyreklik veriler kullanılmıştır ve toplam 42 gözlem yer almaktadır. Analizde reel sektör enflasyon beklentisi (bekr), hanehalkı enflasyon

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beklentisi (bekh), ve tüketici fiyat endeksi (tüfe) endeks değerler olduğu için normal değerleriyle, gayrisafi yurt içi hasıla (gsyih) değişkeni ise kümülatif değer olduğu için ölçek farklılıklarını azaltmak ve varyansı dengelemek amacıyla doğal logaritmik hali ile kullanılmıştır.

3.2. Ampirik Bulgular

Ekonometrik modelin tahmin sonuçlarından önce, değişkenlerin genel karakteristiğini ortaya koymak ve veri setindeki olası aykırı değerleri/sapmaları gözlemlemek amacıyla betimsel istatistikler hesaplanmıştır. Çizelge 2'de sunulan özet istatistikler, analiz edilen döneme ait ham verilerin dağılım özelliklerini yansıtmaktadır.

Çizelge 2. Değişkenlere Ait Özet İstatistikler

	bekr	*bekh*	*tufe*	*lngsyih*
Ortalama	26.40873	46.10032	854.8946	21.34907
Medyan	15.88333	41.57167	454.3233	20.90641
Maksimum	68.83333	83.31333	3088.380	23.40282
Minimum	8.533333	19.13333	252.6400	20.03359
Standart hata	20.20996	21.64936	809.4592	1.060801
Çarpıklık	0.808965	0.431979	1.491945	0.673723
Basıklık	1.986702	1.780289	3.954411	2.027444
Jarque-Bera	6.377817	3.909709	17.17538	4.832579
prob.(olasılık)	0.041217	0.141585	0.000186	0.089252

Çalışma kapsamında ele alınan değişkenlerin dağılım özelliklerini ve temel istatistiksel karakteristiklerini özetleyen bulgular Çizelge 2'de sunulmuştur. Bu istatistikler, verilerin merkezi eğilimlerini ve volatilite yapılarını anlamak adına kritik önem taşımaktadır. İlgili dönemde enflasyon verilerini temsil eden değişkenlerin ortalama ve medyan değerleri arasında belirgin bir fark olduğu görülmektedir. Özellikle *bekh* değişkeninin ortalaması (46.10), *bekr* değişkeninin ortalamasından (26.40) oldukça yüksektir. Bu durum, bireylerin fiyat artışlarını gerçekleşen rakamlardan çok daha yüksek seviyelerde içselleştirdiğini ampirik olarak göstermektedir. Ayrıca, *tufe* değişkenindeki yüksek standart hata değeri (809.45), fiyatlar genel düzeyinde incelenen dönem boyunca yaşanan yüksek oynaklığın bir göstergesidir.

tufe (1.49) ve *bekr* (0.80) değişkenlerindeki çarpıklık katsayıları, normal dağılımın sağa kuyruklu olduğunu göstermektedir. Bu teknik bulgu, Türkiye ekonomisinde enflasyonun düşük seyrettiği dönemlere kıyasla, aşırı yüksek enflasyonist şokların yaşandığı dönemlerin daha baskın olduğunu ve dağılımın ortalamasını yukarı çektiğine işaret etmektedir. Basıklık değerleri incelendiğinde ise, *tufe* değişkeninin 3.95 değeri ile dik basık bir yapı sergilediği görülmektedir. Bu durum, verilerin merkez etrafında yoğunlaştığını ancak uç değerlerin frekansının yüksek olduğunu işaret etmektedir.

Serilerin normal dağılıp dağılmadığını test eden Jarque-Bera istatistikleri ve bunlara ilişkin olasılık değerleri incelendiğinde; özellikle *tufe* ($p < 0.01$) ve *bekr* ($p < 0.05$) değişkenleri için sıfır hipotezi (Seri normal dağılmaktadır) reddedilmektedir. *bekh* değişkeni ise 0.14 olasılık değeri ile normal dağılıma daha yakın bir seyir izlemektedir. Bu sonuçlar, analizde kullanılacak

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ekonometrik modellerde standart varsayımların ötesine geçilmesi ve dayanıklı tahmincilerin dikkate alınması gerektiğini metodolojik olarak doğrulamaktadır.

3.3. Ampirik Analiz Sonuçlarının Değerlendirilmesi

Bu bölümde, enflasyon algısı ve makroekonomik değişkenler arasındaki ilişkiyi ölçmek amacıyla kurulan regresyon modelinin sonuçları tartışılmaktadır. Ekonometrik modelin spesifikasyonu bölümünde kurulan regresyon EViews 12.0 paket program ile tahmin edilmiş ve sonuçlar Çizelge 3'te raporlanmıştır.

Çizelge 3. Regresyon Sonuçları

Değişken	Katsayı	Standart hata	t istastiği	prob.(olasılık)
c	-20913.77	1098.479	-19.03884	0.0000
bekh	-30.29468	4.558362	-6.645957	0.0000
bekr	11.50001	4.954448	2.321149	0.0257
lngsyih	1070.846	55.44932	19.31215	0.0000
R^2=0.960892				
F-stat= 311.2235				
Prob(F-stat):0.00000				

Elde edilen bulgular, modelin açıklayıcılık gücünün (R2 = 0.96) oldukça yüksek olduğunu ve modelin bir bütün olarak istatistiksel açıdan anlamlı olduğunu (F-istatistiği p-değeri: 0.000) göstermektedir.

Modelden elde edilen katsayılar, bağımsız değişkenlerin bağımlı değişken üzerindeki etkisinin yönünü ve şiddetini ortaya koymaktadır. Hanehalkı enflasyon beklentisi (*bekh*) değişkenin katsayısı $p < 0.01$ seviyesinde istatistiksel olarak anlamlı ve -30.29 olarak bulunmuştur. Bu bulgu, beklentiler ile mevcut enflasyonist süreç arasında karmaşık bir etkileşim olduğuna işaret etmektedir. Reel kesim enflasyon beklentisi (*bekr*) değişkenin katsayısı 11.50 olup, pozitif ve istatistiksel olarak anlamlıdır. Bu, reel kesim enflasyon beklentisindeki artışların enflasyon değerini doğrudan yukarı çektiğini ampirik olarak kanıtlamaktadır. Gayrisafi yurtiçi hasıla (lngsyih) değişkeninin katsayısı ise modeldeki en güçlü pozitif etkiye işaret etmektedir. Gelir seviyesindeki değişimlerin enflasyon algısı üzerinde çok yüksek bir duyarlılığa sahip olduğu görülmektedir.

4. GENEL DEĞERLENDİRME VE SONUÇLAR

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Bu çalışma, Türkiye ekonomisinde enflasyon algısı ve bu algıyı şekillendiren makroekonomik dinamikleri, TCMB EVDS veri seti üzerinden ekonometrik bir perspektifle analiz etmektedir. Elde edilen bulgular, teorik beklentiler ve ampirik literatürle uyumlu olarak, Türkiye'deki enflasyon olgusunun sadece bir fiyat artışı meselesi değil, aynı zamanda karmaşık bir algı ve beklenti yönetimi sorunu olduğunu teyit etmektedir.

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Çalışmanın özet istatistikleri değerlendirildiğinde, analiz döneminde hanehalkı enflasyon beklentisi ortalamasının (46.10), reel kesim enflasyon ortalamasından (26.40) yaklaşık iki kat daha yüksek olduğunu göstermiştir. Bu fark, çalışmanın da tam olarak odaklandığı ve aydınlatmaya çalıştığı hanehalkı enflasyon beklentileri ile reel kesim enflasyon beklentileri arasındaki algısal kopuşun bir kanıtıdır.

Ampirik analiz sonuçlarına göre, gelir seviyesini temsil eden lngsyih değişkeninin enflasyon algısı üzerindeki katsayısı (1070.84) istatistiksel olarak en yüksek etkiye sahiptir. Bu durum, bireylerin enflasyon algısının sadece etiket fiyatlarından değil, doğrudan satın alma gücündeki değişimlerden ve refah seviyesindeki dalgalanmalardan beslendiğini ortaya koymaktadır. Hanehalkı enflasyon beklentileri (bekh) katsayısının negatif ve anlamlı çıkması, Türkiye'de mevcut enflasyonist ortamda beklenti yönetiminin rasyonel zeminden uzaklaştığına ve fiyat istikrarına yönelik güvenin zayıflamasıyla algının daha yüksek seviyelerde çıpalandığına işaret etmektedir.

Elde edilen ampirik sonuçlar ışığında, fiyat istikrarının sağlanması ve enflasyon algısının yönetilmesi için beklenti yönetiminde şeffaflık ve kredibilite önerilebilmektedir. Regresyon modelinde görülen beklenti duyarlılığı, para politikasının sadece faiz araçlarıyla değil, aynı zamanda güçlü bir sözlü yönlendirme ve veri güvenilirliği ile desteklenmesi gerektiğini göstermektedir. Politika yapıcıların hedefleri ile gerçekleşen rakamlar arasındaki tutarlılık, algılanan enflasyonu aşağı çekecek temel unsur olarak görülmektedir. Ayrıca özellikle reel kesim enflasyon beklentileri gerçekleşen enflasyon ile aynı doğrultuda hareket sağladığı için, reel sektör enflassyon beklentilerinin kontrol altında tutulması önerilmektedir. Bunların yanında, enflasyon algısının gelir seviyesine olan yüksek duyarlılığı nedeniyle, para politikasının geniş kitlelerin satın alma gücünü koruyacak maliye politikalarıyla eşgüdümlü yürütülmesi, toplumsal beklentilerin iyileştirilmesi açısından gerekli bir koşul olarak düşünülmektedir.

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DOĞUM SONRASI PSİKOSOSYAL İHTİYAÇLARIN KARŞILANMASINDA ANNE ÜNİTELERİNİN ROLÜ

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ÖZET

Doğum sonrası dönem, anneler için yalnızca fiziksel iyileşmeyi değil; aynı zamanda annelik rolüne uyum, duygusal denge ve sosyal ilişkilerin yeniden yapılandırılmasını da içeren çok boyutlu bir süreçtir. Bu dönemde yeterli psikososyal desteğin sağlanamaması, annelerde stres, kaygı, yalnızlık hissi ve ruhsal uyum sorunlarına yol açabilmektedir. Anne üniteleri ve anne-bebek otelleri, doğum sonrası dönemde annelerin psikososyal ihtiyaçlarını desteklemeyi amaçlayan yapılandırılmış bakım ortamları olarak önemli bir işlev üstlenmektedir.

Anne ünitelerinde sunulan psikososyal destek hizmetleri; emzirme ve bebek bakımı danışmanlığı, anne-bebek etkileşimini güçlendiren uygulamalar, duygusal destek, dinlenme olanakları ve profesyonel sağlık personelinin rehberliğini kapsamaktadır. Bu destekleyici ortam, annelerin annelik yeterliliği algısını güçlendirmekte, öz güvenlerini artırmakta ve doğum sonrası döneme uyumlarını kolaylaştırmaktadır. Ayrıca postpartum depresyon ve anksiyete gibi ruhsal sorunların erken dönemde fark edilmesine ve önleyici müdahalelerin uygulanmasına olanak sağlamaktadır.

Anne üniteleri, koruyucu ruh sağlığı yaklaşımı çerçevesinde değerlendirildiğinde, annelerin psikososyal iyilik hâllerini destekleyen bütüncül bir bakım modeli sunmaktadır. Bu birimlerin yaygınlaştırılması ve multidisipliner ekiplerle güçlendirilmesi, doğum sonrası dönemde anne ruh sağlığının korunmasına, anne-bebek bağlanmasının desteklenmesine ve aile bütünlüğünün güçlendirilmesine önemli katkılar sağlayabilir.

Anahtar Kelimeler: Anne üniteleri, doğum sonrası dönem, psikososyal destek, anne ruh sağlığı, bağlanma, koruyucu ruh sağlığı.

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THE ROLE OF MOTHER UNITS IN MEETING POSTPARTUM PSYCHOSOCIAL NEEDS

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The postpartum period represents a multidimensional transition for mothers, encompassing not only physical recovery but also emotional adjustment, adaptation to the maternal role, and reorganization of social relationships. Insufficient psychosocial support during this period may lead to increased stress, anxiety, feelings of loneliness, and difficulties in maternal adjustment. Mother units and mother-baby hotels have emerged as structured care environments designed to support mothers' psychosocial needs during the postpartum period.

Psychosocial support services provided in mother units include breastfeeding and infant care counseling, interventions aimed at strengthening mother-infant interaction, emotional support, opportunities for rest, and continuous guidance from professional healthcare staff. This supportive environment enhances mothers' self-confidence, strengthens their perceived maternal competence, and facilitates adaptation to the postpartum period. Moreover, mother units contribute to the early identification and prevention of postpartum mental health problems, such as postpartum depression and anxiety.

Within the framework of a preventive mental health approach, mother units offer a holistic care model that promotes maternal psychosocial well-being, supports mother-infant bonding, and strengthens family functioning. Expanding and integrating mother units into multidisciplinary healthcare services may play a crucial role in protecting maternal mental health and improving overall family well-being during the postpartum period.

Keywords: Mother units, postpartum period, psychosocial support, maternal mental health, mother-infant bonding, preventive mental health.

GİRİŞ

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Doğum sonrası dönem, anneler için yalnızca fiziksel iyileşmeyi kapsayan bir süreç değil; aynı zamanda annelik rolüne uyum, duygusal denge, sosyal ilişkilerin yeniden yapılandırılması ve ebeveynlik yeterliliğinin gelişimini içeren çok boyutlu bir yaşam geçişidir. Bu dönemde yaşanan biyopsikososyal değişimler, annelerin ruhsal kırılganlığını artırabilmekte ve postpartum depresyon, anksiyete bozuklukları ve bağlanma sorunları gibi ruhsal sorunların ortaya çıkmasına zemin hazırlayabilmektedir (O'Hara & McCabe, 2013; Stewart & Vigod, 2016).

Postpartum dönemde ortaya çıkan ruhsal sorunların, yalnızca anne sağlığını değil; anne-bebek etkileşimini, bağlanma sürecini ve bebeğin uzun dönemli duygusal gelişimini de olumsuz etkilediği bildirilmektedir (Field, 2010; Moehler ve ark., 2006). Sistematik derlemeler, doğum sonrası depresyonun annelerde işlevsellik kaybına, bebeklerde ise davranışsal ve duygusal sorunlara yol açabildiğini göstermektedir (Slomian ve ark., 2019). Bu nedenle doğum sonrası dönemde erken psikososyal destek sunulması, koruyucu ruh sağlığı yaklaşımının temel bileşenlerinden biri olarak kabul edilmektedir.

Anne-bebek üniteleri, postpartum dönemde ruhsal risk taşıyan annelere yönelik olarak geliştirilmiş, annenin bebeğinden ayrılmadan tedavi ve bakım almasını sağlayan özel yapılandırılmış bakım ortamlarıdır. Literatürde, anne-bebek ünitelerinin annelerin ruhsal belirtilerinde iyileşme sağladığı, annelik yeterliliği algısını güçlendirdiği ve anne-bebek bağlanmasını desteklediği bildirilmektedir (Gillham & Wittkowski, 2015; Adhikary ve ark., 2024). Ayrıca bu ünitelerin, geleneksel psikiyatri servislerine kıyasla anneler ve aileler tarafından daha güvenli ve destekleyici olarak algılandığı belirtilmektedir (Griffiths ve ark., 2019).

Anne-bebek ünitelerinde sunulan psikososyal destek hizmetleri; emzirme ve bebek bakımı danışmanlığı, psiko-eğitim, duygusal destek, dinlenme olanakları ve multidisipliner ekip rehberliğini kapsamaktadır. Bu bütüncül yaklaşım, annelerin stres düzeylerini azaltmakta ve doğum sonrası döneme uyumlarını kolaylaştırmaktadır (Branjerdporn ve ark., 2022). Psikososyal destek ve psikoeğitim temelli müdahalelerin, postpartum depresyon belirtilerini azalttığı ve annelerin öz yeterlilik algılarını güçlendirdiği farklı kültürlerde yürütülen çalışmalarda da gösterilmiştir (Fisher ve ark., 2010; Tessema ve ark., 2024).

Psikiyatri hemşireliği perspektifinden bakıldığında, anne-bebek üniteleri ve yapılandırılmış postpartum destek modelleri; erken ruhsal değerlendirme, psiko-eğitim, danışmanlık ve izlem süreçlerinin etkin biçimde yürütülebileceği önemli uygulama alanları sunmaktadır. Multidisipliner ekip yaklaşımı ile yürütülen bu hizmetlerin, doğum sonrası dönemde anne ruh sağlığının korunması ve güçlendirilmesinde kritik bir role sahip olduğu vurgulanmaktadır (Howard ve ark., 2020; Yadawad ve ark., 2021).

Bu derlemenin amacı, doğum sonrası dönemde anne-bebek üniteleri ve benzeri yapılandırılmış bakım ortamlarında sunulan psikososyal destek hizmetlerini, anne ruh sağlığı, annelik rolüne uyum ve anne-bebek bağlanması bağlamında ele almak ve koruyucu ruh sağlığı perspektifinden değerlendirmektir.

2. YÖNTEM

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Bu çalışma, nitel bir derleme olarak planlanmıştır. Literatür taraması PubMed, Scopus ve Web of Science veri tabanlarında gerçekleştirilmiştir. Tarama sürecinde *"postpartum period", "maternal mental health", "mother-baby units", "postnatal psychosocial support", "mother-infant bonding"* anahtar kelimeleri birlikte kullanılmıştır.
Çalışmaya; 2020-2025 yılları arasında yayımlanmış, İngilizce dilinde, tam metnine erişilebilen, anne ruh sağlığı ve psikososyal destek odaklı nicel, nitel ve derleme çalışmalar dâhil edilmiştir. Sadece obstetrik sonuçlara odaklanan, psikososyal bileşeni olmayan çalışmalar ile vaka sunumları dışlanmıştır. Seçilen çalışmalar, içerik analizi yöntemiyle değerlendirilmiş ve bulgular tematik başlıklar altında sınıflandırılmıştır.

2.2. Doğum Sonrası Dönemde Anne Ruh Sağlığı Sorunları

Doğum sonrası dönem, anneler için biyolojik değişimlerin yanı sıra yoğun psikososyal uyum gerektiren bir süreçtir. Bu dönemde postpartum depresyon ve anksiyete başta olmak üzere çeşitli ruhsal sorunlar sık görülmekte; bu durum annelerin işlevselliğini, bakım verme kapasitesini ve yaşam kalitesini olumsuz etkileyebilmektedir (O'Hara & McCabe, 2013; Stewart & Vigod, 2016). Literatür, doğum sonrası ruhsal sorunların erken dönemde ele alınmaması hâlinde anne ve bebek üzerinde uzun vadeli olumsuz sonuçlar doğurabileceğini göstermektedir (Slomian ve ark., 2019).

2.3. Anne-Bebek Üniteleri: Tanım, Amaç ve Yapısal Özellikler

Anne-bebek üniteleri, doğum sonrası dönemde ruhsal sorun yaşayan annelerin bebeklerinden ayrılmadan bakım ve tedavi almasını sağlayan özel yapılandırılmış birimlerdir. Bu ünitelerin temel amacı, annenin ruhsal iyileşmesini desteklerken anne-bebek ilişkisinin korunması ve güçlendirilmesidir. Literatürde, anne-bebek ünitelerinin bağlanma odaklı ve aile merkezli bakım anlayışıyla geleneksel psikiyatri servislerinden ayrıştığı belirtilmektedir (Gillham & Wittkowski, 2015; Adhikary ve ark., 2024).

2.4. Anne Ruh Sağlığı Üzerine Klinik ve Psikososyal Etkiler

Anne-bebek ünitelerinde sunulan yapılandırılmış psikososyal desteklerin, annelerin depresyon ve anksiyete belirtilerinde anlamlı azalma sağladığı bildirilmektedir (Yadawad ve ark., 2021). Klinik iyileşmenin yalnızca semptom düzeyinde değil, annelik rolüne uyum ve günlük işlevsellik ile birlikte değerlendirilmesi gerektiği vurgulanmaktadır (Branjerdporn ve ark., 2022).

2.5. Anne-Bebek Bağlanması ve Etkileşim

Doğum sonrası dönemde yaşanan ruhsal sorunlar, anne-bebek etkileşimini ve bağlanma sürecini olumsuz etkileyebilmektedir (Field, 2010). Anne-bebek üniteleri, annenin bebeğiyle sürekli temasını sürdürmesine olanak tanıyarak güvenli bağlanmanın desteklenmesini amaçlamaktadır. Erken dönemde desteklenen anne-bebek etkileşiminin, hem annenin ruhsal iyilik hâlini hem de bebeğin duygusal gelişimini olumlu yönde etkilediği gösterilmiştir (Moehler ve ark., 2006; Adhikary ve ark., 2024).

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2.6. Annelik Rolüne Uyum ve Öz Yeterlilik

Annelik rolüne uyum, doğum sonrası ruh sağlığının önemli belirleyicilerinden biridir. Anne-bebek ünitelerinde sunulan rehberlik ve danışmanlık hizmetlerinin, annelerin annelik yeterliliği algısını güçlendirdiği ve öz güvenlerini artırdığı bildirilmektedir (Gillham & Wittkowski, 2015). Bu destekleyici yaklaşım, annelerin bakım verme becerilerini geliştirmelerine katkı sağlamaktadır (Branjerdporn ve ark., 2022).

2.7. Psikososyal Destek ve Psiko-Eğitim Uygulamaları

Psikososyal destek ve psiko-eğitim uygulamaları, doğum sonrası dönemde annelerin bilgi düzeyini artırmayı ve duygusal gereksinimlerini karşılamayı hedeflemektedir. Psiko-eğitim temelli müdahalelerin, stresle baş etme becerilerini güçlendirdiği ve postpartum ruhsal belirtilerin azalmasına katkı sağladığı bildirilmektedir (Fisher ve ark., 2010; Tessema ve ark., 2024).

2.8. Hizmet Kullanıcı Deneyimi ve Bakım Algısı

Anne-bebek ünitelerinde bakım alan annelerin deneyimleri, bu birimlerin güvenli ve destekleyici ortamlar olarak algılandığını göstermektedir. Uzmanlaşmış bakım ortamlarının, annelerin kendilerini anlaşılmış ve desteklenmiş hissetmelerine katkı sağladığı bildirilmektedir (Griffiths ve ark., 2019). Özellikle psikiyatri hemşirelerinin ruhsal değerlendirme, psiko-eğitim ve izlem süreçlerinde kilit bir rol üstlendiği vurgulanmaktadır (Griffiths ve ark., a2019; Branjerdporn ve ark., 2022).

3. SONUÇ VE ÖNERİLER

Bu derleme, doğum sonrası dönemde anne-bebek üniteleri ve benzeri yapılandırılmış bakım ortamlarında sunulan psikososyal destek hizmetlerinin, anne ruh sağlığı üzerinde olumlu etkiler sağladığını ortaya koymaktadır. Literatür bulguları, bu ünitelerde yürütülen bakımın postpartum depresyon ve anksiyete belirtilerinin azalmasına, annelik rolüne uyumun güçlenmesine ve anne-bebek bağlanmasının desteklenmesine katkı sağladığını göstermektedir. Annenin bebeğinden ayrılmadan bakım alabilmesi, ruhsal iyileşmenin bağlanma süreciyle birlikte ilerlemesine olanak tanıyan temel bir unsur olarak öne çıkmaktadır.

Anne-bebek ünitelerinde sunulan psikososyal desteklerin, yalnızca klinik belirtilerin hafifletilmesiyle sınırlı kalmadığı; annelerin öz yeterlilik algısını artırdığı, bakım verme becerilerini güçlendirdiği ve tedaviye uyumu desteklediği görülmektedir. Multidisipliner ekip yaklaşımıyla yürütülen bu hizmetler, doğum sonrası dönemde ruhsal risklerin erken dönemde fark edilmesine ve bütüncül müdahalelerin uygulanmasına imkân tanımaktadır.

Bu doğrultuda, anne-bebek ünitelerinin sağlık sistemleri içerisinde yaygınlaştırılması ve standart bakım modelleri ile desteklenmesi önerilmektedir. Psikososyal destek ve psiko-eğitim bileşenlerinin anne-bebek bakım hizmetlerine sistematik biçimde entegre edilmesi, anne ruh sağlığının korunması açısından önemli bir gereklilik olarak değerlendirilmektedir. Ayrıca psikiyatri hemşirelerinin bu süreçte değerlendirme, eğitim ve izlem rollerinin güçlendirilmesi, bakımın sürekliliği ve etkinliği açısından kritik öneme sahiptir.

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Gelecekte yapılacak araştırmalarda, anne-bebek ünitelerinin uzun dönemli anne ve çocuk ruh sağlığı üzerindeki etkilerinin incelenmesi, kültürel ve sağlık sistemi farklılıklarının bakım sonuçlarına yansımalarının değerlendirilmesi ve yapılandırılmış psikososyal müdahalelerin etkililiğini ortaya koyan karşılaştırmalı çalışmaların artırılması önerilmektedir. Bu tür kanıt temelli verilerin, doğum sonrası ruh sağlığı hizmetlerinin geliştirilmesine ve anne-bebek bakım politikalarının güçlendirilmesine katkı sağlayacağı düşünülmektedir.

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Kapalı Parabolik Hacimlerde Silindir Konumunun Doğal Taşınım Isı Transferi Üzerine Sayısal Etkisi

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ÖZET

Bu çalışmada, parabolik oluk tipi güneş kolektörlerinde alıcı boru ile parabolik yansıtıcı arasındaki hava dolu hacimde doğal taşınımla ısı transferini etkileyen geometrik parametreler sayısal olarak incelenmiştir. Belirli bir yükseklik ve genişliğe sahip parabolik bir kapalı hacim içerisinde konumlandırılan dairesel kesitli alıcı boru, sabit sıcaklıkta bir iç sınır; muhafazanın üst duvarı ise daha düşük sabit sıcaklıkta bir dış sınır olarak modellenmiştir. Kapalı hacim hava ile doldurulmuş, akışkanın hareketi Boussinesq yaklaşımı altında yalnızca kaldırma kuvveti etkisiyle oluşan iki boyutlu, kararlı ve sıkıştırılamaz doğal taşınım akışı olarak ele alınmıştır. Rayleigh (Ra) sayıları 10^5 ve 10^6 için ANSYS-Fluent yazılımında sonlu hacimler yöntemiyle nümerik çözüm yapılmış ve ağ bağımsızlık analizi ile hesaplamalar doğrulanmıştır. Parabolik açıklık genişliği 1,0 m, 2,0 m ve 3,0 m; silindir eksen yüksekliği ise 0,3 m, 0,5 m ve 0,7 m olarak seçilmiş ve toplam dokuz farklı konfigürasyon değerlendirilmiştir. Modellerin ısıl performansını karşılaştırmak için, silindir yüzeyinden muhafazaya aktarılan toplam ısı transferinin muhafaza alanına oranı olarak tanımlanan ısı transfer yoğunluğu performans kriteri olarak kullanılmıştır. Sonuçlar, parabolik açıklığın artmasıyla toplam ısı transferi artsa da, muhafaza alanının da büyümesi nedeniyle ısı transfer yoğunluğunun azaldığını göstermektedir. İncelenen tüm silindir yükseklikleri için en yüksek ısı transfer yoğunluğu, 1,0 m açıklığa sahip parabolik geometri için elde edilmiştir. Elde edilen bulgular, parabolik oluklu kolektör tasarımında alıcı boru konumunun ve parabolik açıklığın yalnızca toplam ısı kazancı açısından değil, birim alan başına ısıl performans bakımından da birlikte optimize edilmesi gerektiğini ortaya koymaktadır.

Anahtar Kelimeler : Parabolik oluklu güneş kolektörü, doğal taşınım, Rayleigh sayısı, ısı transfer yoğunluğu, sayısal analiz.

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A Numerical Analysis of Cylinder Positioning Effects on Natural Convection Heat Transfer within Parabolic Enclosures

ABSTRACT

In this study, the geometric parameters that influence heat transfer by natural convection in the air-filled region between the receiver tube and the parabolic reflector of parabolic trough solar collectors are investigated numerically. The receiver tube with a circular cross-section, positioned inside a parabolic enclosure of specified height and width is modeled as an inner boundary maintained at a constant temperature, while the upper wall of the enclosure is modeled as an outer boundary kept at a lower constant temperature. The enclosure is filled with air and the fluid motion is treated as a two-dimensional, steady, incompressible natural convection flow driven solely by buoyancy forces under the Boussinesq approximation. Numerical solutions were obtained in ANSYS Fluent using the finite volume method for Rayleigh numbers of 10^5 and 10^6 and the computations were verified through a grid-independence analysis. The parabolic aperture width was selected as 1.0 m, 2.0 m, and 3.0 m, while the cylinder axis height was chosen as 0.3 m, 0.5 m, and 0.7 m, resulting in a total of nine different configurations being evaluated. To compare the thermal performance of the models, a heat transfer density defined as the ratio of the total heat transferred from the cylinder surface to the enclosure to the enclosure area, was used as the performance criterion. The results show that although the total heat transfer increases with increasing parabolic aperture, the heat transfer density decreases due to the simultaneous increase in the enclosure area. For all cylinder heights examined, the highest heat transfer density was obtained for the parabolic geometry with an aperture of 1.0 m. The findings indicate that, in the design of parabolic trough collectors, the receiver tube position and the parabolic aperture must be jointly optimized not only in terms of total heat gain but also with respect to thermal performance per unit area.

Keywords: Parabolic trough solar collector, natural convection, Rayleigh number, heat transfer density, numerical analysis

1. GİRİŞ

Parabolik Oluk Tipli Güneş Kolektör (POTGK), güneş enerjisi teknolojileri arasında en yaygın kullanılan sistemlerden biridir. Bu kolektörlerde parabolik geometrili yansıtıcı yüzeyler, güneş ışınlarını tek bir odak hattı üzerinde yoğunlaştırmakta; odak hattı boyunca konumlandırılan alıcı boru içerisinde dolaşan ısı transfer akışkanı, güneşten gelen enerjiyi absorbe ederek yüksek sıcaklıklara ulaşmaktadır. Elde edilen bu ısıl enerji, buhar türbinleri veya Stirling motorları gibi enerji dönüştürücü bileşenler aracılığıyla elektrik enerjisine dönüştürülmektedir.

Literatürde, POTGK ısı transferini iyileştirmeye yönelik çok sayıda çalışma bulunmaktadır. Bu çalışmalar genellikle akış içerisindeki Nusselt sayısını artırmaya odaklanmakta ve böylece kolektör performansını optimize etmek amacıyla ısı transferi ilkelerini uygulamaktadır (Bellos & Tzivanidis, 2017). Yapılan analizler, burulmuş şerit yerleştirmelerinin, helezonik sarmal sarımların ve çukurlu/girintili boruların entegrasyonunun Nusselt sayısını önemli ölçüde artırabildiğini ve bazı konfigürasyonlarda bu iyileşmenin %300'e kadar ulaşabildiğini

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göstermektedir (Bellos & Tzivanidis, 2017). Ayrıca asimetrik dışbükey oluklu boruların ve daralıp genişleyen soğurucu boru geometrilerinin kullanıldığı durumlarda, düz boru kullanımına kıyasla Nusselt sayısında yaklaşık 1,20 ila 1,25 kat arasında iyileşme elde edildiği rapor edilmiştir (Bellos & Tzivanidis, 2017).

Isı transferindeki bu iyileşmeler çoğu zaman, sistem verimliliğinde kritik bir etmen olan basınç düşüşündeki artış ile birlikte görülmektedir (Hamada et al., 2022). Dolayısıyla iyileştirilmiş ısı transferinin artan pompalama gücü gereksinimiyle dengelenebilmesi için kapsamlı bir termo-hidrolik analiz zorunlu hale gelmektedir. Bu amaçla iç elemanların yerleştirilmesi veya akış yollarının değiştirilmesi gibi soğurucu geometrisindeki düzenlemeler incelenmiş; dışarıdan ek bir güç gerektirmeyen, maliyet etkin ve uygulaması görece basit pasif iyileştirme teknikleri yaygın olarak değerlendirilmiştir (Allouhi et al., 2017; Afsharpanah et al., 2020). Bu teknikler, yenilikçi geometrilerin, dalgalı kanalların, saptırıcı elemanların, türbülans artırıcıların, gözenekli ortamların ve faz değiştiren malzemelerin sisteme entegrasyonunu içermektedir (Al-Aloosi et al., 2023).

Nusselt sayısında %2 mertebesinde mütevazı bir artış dahi, POTGK sistemlerinin uzun vadeli sürdürülebilirliğine ve ekonomik uygulanabilirliğine anlamlı katkılar sağlayabilmektedir. Bu nedenle araştırmacılar, bu iyileşmeyi en üst düzeye çıkarmaya yönelik farklı yöntemleri incelemeye devam etmektedir (Bellos & Tzivanidis, 2017). Umut vadeden yaklaşımlardan biri, çukurlu soğurucu boruların kullanımıdır. Çalışmalar, bu tür boruların ısı transferini önemli ölçüde artırdığını ve düzgün ısı akısı koşullarına kıyasla, düzgün olmayan ısı akısı altında daha yüksek Nusselt sayılarının elde edildiğini göstermektedir (Allauddin et al., 2022). Buna ek olarak, basınç düşüşünü sınırlı tutarken verim artışı sağlayabilen ofset şerit türbülanslaştırıcılar gibi elemanların entegrasyonu ve süperkritik CO_2 ile nanoakışkanlar gibi yenilikçi çalışma akışkanlarının kullanımı da araştırılmaktadır (Allouhi et al., 2017). Çukurlu çıkıntılar veya çevresel eğimli kaburgalarla güçlendirilmiş soğurucu yüzeyler, daha iyi ısı çekimi sağlamakta ve soğurucu duvar sıcaklıklarını düşürmektedir (Allauddin et al., 2022). Örneğin delikli kanatçıklı burulmuş şerit türbülanslaştırıcıların kullanılması, düz soğurucu borulara kıyasla Nusselt sayısını %150'ye kadar artırabilmekte; ancak bu durum sürtünme katsayısında kayda değer bir artışla birlikte ortaya çıkmaktadır (Singh & Chandra, 2023). Benzer şekilde, oluklu soğurucu borularda kullanılan yüzey modifikasyonlarının türbülansı artırarak ve ısıl sınır tabakayı bozarak ısı transferini iyileştirdiği, fakat sürtünme katsayılarındaki artış nedeniyle pompalama gücü gereksinimini de yükselttiği bilinmektedir (Allauddin et al., 2022).

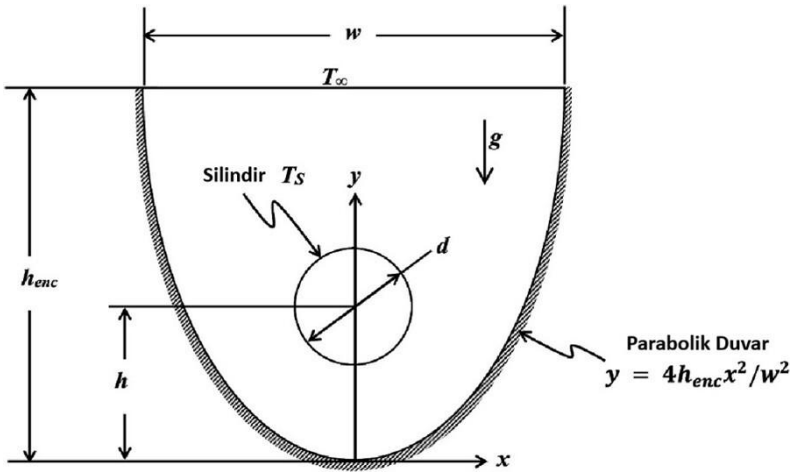
Bu yenilikçi tasarımların ve yüzey modifikasyonlarının ticarileşme aşamasına ilerleyebilmesi için teknik uygulanabilirliklerinin gösterilmesi ve deneysel çalışmalarla doğrulanmaları kritik önem taşımaktadır (Hachicha et al., 2019). Sayısal modellemenin sunduğu olanaklara karşın, özellikle dayanıklılık ve büyük ölçekli uygulamalar açısından ilave deneysel çalışmalar gereksinimi devam etmektedir (Hachicha et al., 2019).

Bu çalışmada, farklı Rayleigh sayılarında parabolik yansıtıcı yüzey açıklığı ile alıcı boru yüksekliği değiştirilerek parabolik yüzey ile alıcı boru arasında kalan hava dolu hacimde doğal taşınımla ısı transfer performansı sayısal olarak analiz edilmiş ve ısı transfer yoğunluğu en yüksek konfigürasyonun belirlenmesi hedeflenmiştir.

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2. PROBLEM TANIMI

Görsel 1'de şematik olarak gösterilen hesap bölgesi, belirli bir yükseklik (h_{enc}) ve genişliğe (w) sahip parabolik bir kapalı hacim ile bu hacim içinde yer alan dairesel kesitli bir silindirden oluşmaktadır. Çapı d olan silindir, parabolik yüzeyin tabanına göre belirli bir yükseklikte ve parabolik yüzeyin merkez ekseni boyunca yatay doğrultuda konumlandırılmıştır. Kapalı hacim hava ile doldurulmuştur; hacim içindeki hava hareketi, silindir sıcak yüzeyi ile muhafazanın soğuk üst duvarı arasındaki sıcaklık farkından kaynaklanan yüzdürme (buoyancy) kuvveti ile oluşan doğal taşınım sonucu gelişmektedir.



Görsel 20 Dairesel borulu parabolik kapalı hacmin şematik gösterimi

Parabolik duvar, $y = 4h_{enc}x^2/w^2$ matematiksel bağıntı ile tanımlanmış ve ısı geçişine kapalı (adiyabatik) sınır koşulu ile modellenmiştir. Boussinesq yaklaşımı altında, bu kapalı hacim içindeki kararlı ve sıkıştırılamaz akış alanı, ANSYS Fluent yazılımı kullanılarak sayısal olarak analiz edilmiştir. Analizlerde iki boyutlu süreklilik, momentum ve enerji denklemleri sonlu hacimler yöntemiyle ayrıklaştırılmış ve artık değerleri belirlenen hedef toleransların altına inene kadar yinelemeli (iteratif) olarak çözülmüştür.

3. SAYISAL YÖNTEM VE AĞDAN BAĞIMSIZLIK TESTİ

Sayısal sonuçların ağ yapısından bağımsızlığını doğrulamak amacıyla, iki farklı Rayleigh sayısı için ayrıntılı bir ağ bağımsızlık çalışması gerçekleştirilmiştir. İlk aşamada ağ topolojisi sabit tutulmuş, yalnızca hücre boyutları sistematik olarak küçültülmüştür. Her bir ağ için silindir yüzeyi ortalama Nusselt sayısı hedef çıktı olarak alınmış ve hücre sayısındaki artışa rağmen bu büyüklükte elde edilen değişim oranları karşılaştırılmıştır. Hedef çıktıdaki farkın ihmal edilebilir düzeye indiği ağ yapısı referans ağ olarak belirlenmiştir.

İkinci aşamada bu referans çözüme bağlı kalınarak, ağ boyutu kontrollü biçimde büyütülmüş ve akış ile ısı transferinin kritik olduğu bölgelerde yerel ağ sıklaştırmaları uygulanmıştır. Böylece benzer doğruluk düzeyi, daha düşük toplam hücre sayısı ile sağlanmaya çalışılmıştır. Çizelge 1'de, Rayleigh sayıları 10^5 ve 10^6 için referans ve detaylandırılmış ağ yapıları karşılaştırılmıştır. Buna göre Ra=10^5 için göreli fark yaklaşık %0,03, Ra=10^6 için ise yaklaşık %0,12 düzeyinde kalmıştır. Bu sonuçlar, ayrıklaştırma hatalarının kabul edilebilir sınırlar

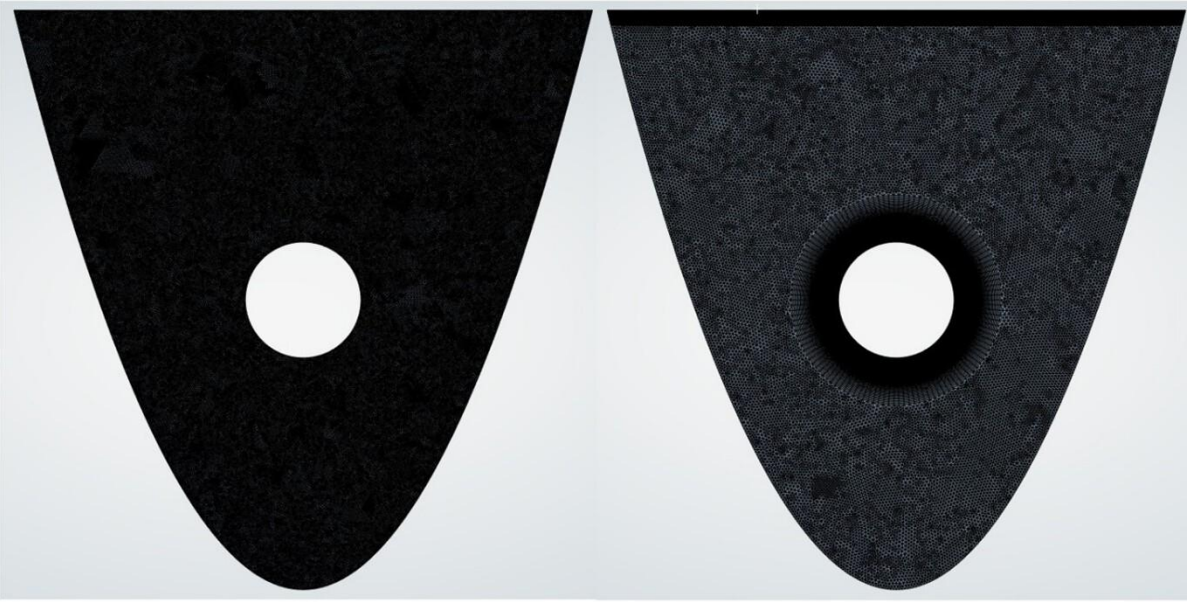
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içinde olduğunu ve nümerik çözümün ağ yapısından anlamlı ölçüde etkilenmediğini göstermektedir.

Çizelge 8. Referans ve detaylandırılmış ağ yapısı karşılaştırma.

Ağ Yapısı	Sınır katmanı sayısı	Büyüme oranı	Sınır katmanı uygulanan yüzey	Ağ boyutu [m]	Hücre sayısı	Yüzey sayısı	Rayleigh sayısı	Nu
(a)	-	-	-	0.003	147246	221527	10^5	5.0767
(b)	100/20	1.02/1.00	Silindir / Çevre	0.005	61014	100231	10^5	5.0753
(a)	-	-	-	0.003	147246	221527	10^6	9.5880
(b)	100/20	1.02/1.00	Silindir / Çevre	0.005	61014	100231	10^6	9.5766

Görsel 2'de referans ve detaylandırılmış ağ yapıları görsel olarak sunulmakta; Çizelge 1 ise sınır katmanı parametreleri, ağ boyutu, hücre ve yüzey sayıları ile birlikte ortalama Nusselt sayılarını özetlemektedir.



Görsel 21 (a) referans ağ yapısı, (b) detaylandırılmış ağ yapısı

3. BULGULAR VE TARTIŞMALAR

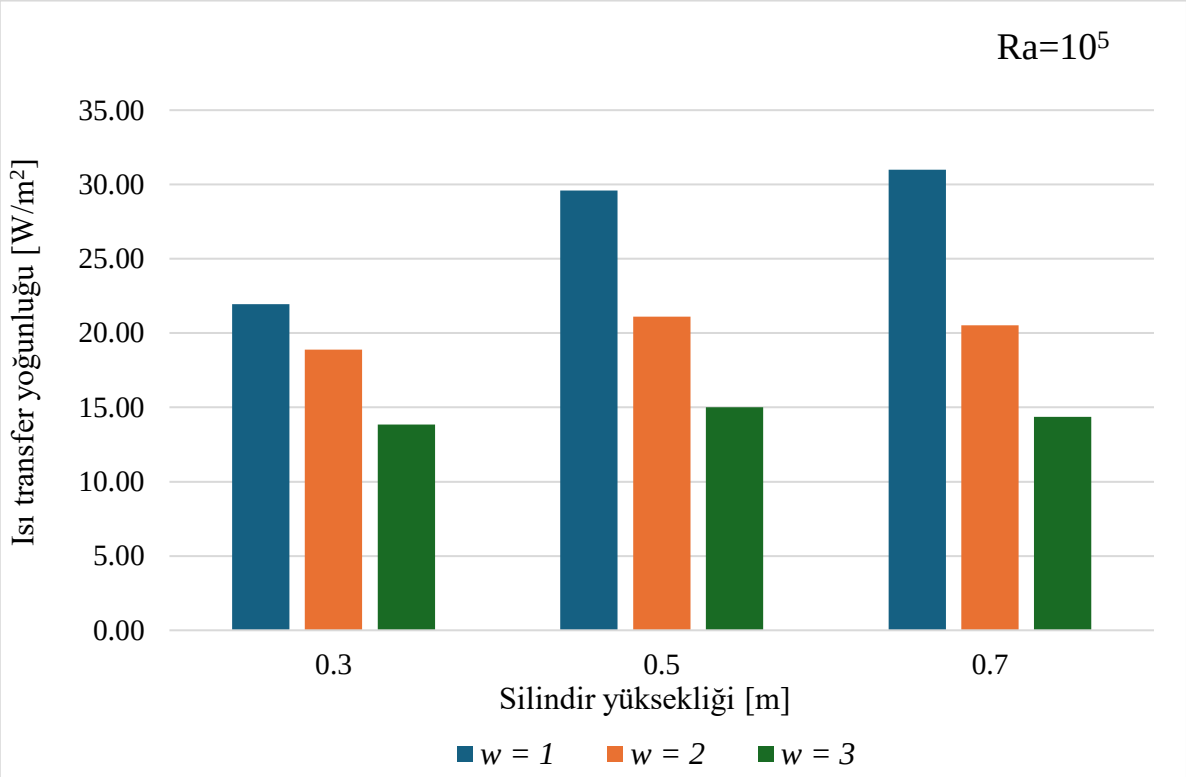
Ağdan bağımsızlık adımı tamamlandıktan sonra, belirlenen ağ özellikleri farklı parabolik açıklıklar ve çeşitli silindir yükseklikleri için tasarlanan geometrilere uygulanarak sayısal analizler gerçekleştirilmiştir. Farklı modellerde muhafaza alanlarının birbirinden farklı olması nedeniyle, yalnızca silindir yüzeyinden muhafazaya aktarılan toplam ısı transfer miktarının karşılaştırılması nesnel ve anlamlı bir kıyaslama yapmaya olanak vermemektedir. Bu sebeple

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modellerin ısıl performanslarının karşılaştırılmasında, Denklem (1)'de verilen ifade kullanılarak muhafaza alanındaki birim yüzeye düşen ısı transfer miktarı hesaplanmış ve "ısı transfer yoğunluğu" olarak tanımlanmıştır.

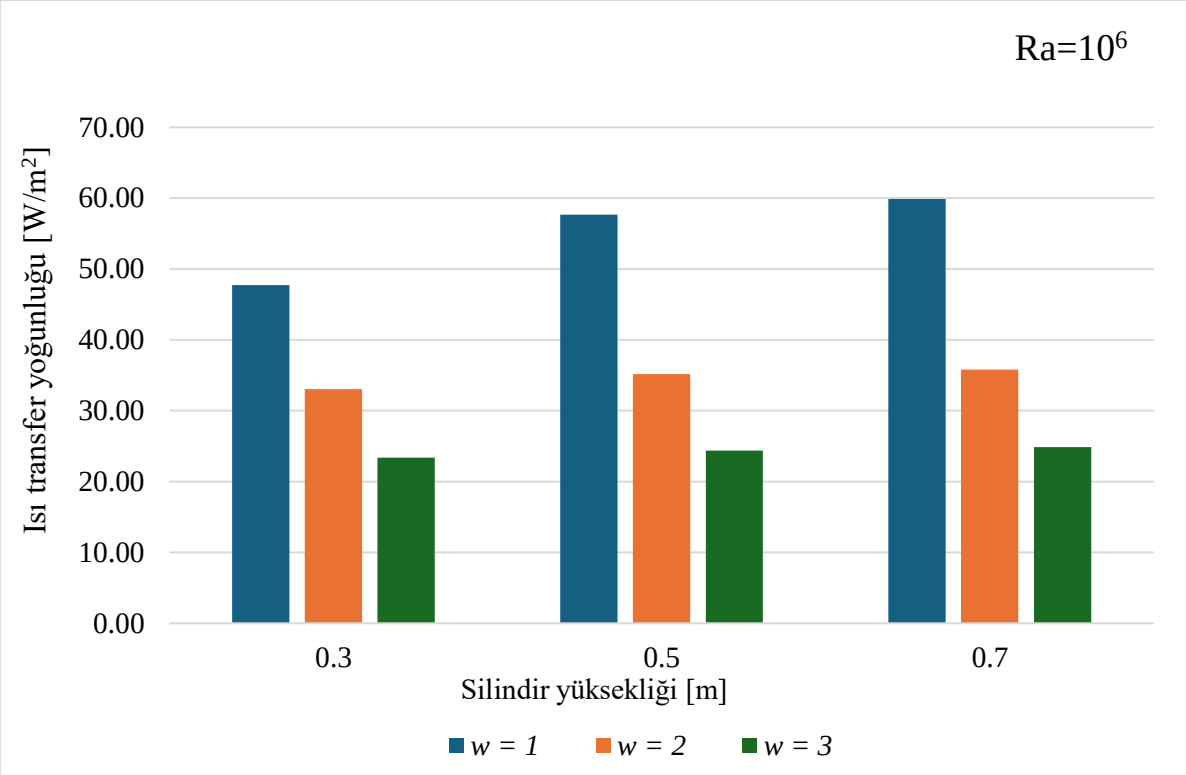
$$\text{Isı transfer yoğunluğu} = \frac{\text{Silindir yüzeyinden muhafaza alanına aktarılan ısı transfer miktarı}}{\text{Muhafaza alanı}} \quad (1)$$

Çalışma kapsamında parabolik açıklık genişliği 1,0 m, 2,0 m ve 3,0 m olan üç farklı geometri için silindir eksen yüksekliği 0,3 m, 0,5 m ve 0,7 m olarak seçilmiş; böylece toplam dokuz konfigürasyon analiz edilmiştir. Modellerin ısıl performanslarının karşılaştırılmasında değerlendirme ölçütü olarak muhafaza ısı transfer yoğunluğu kullanılmış ve bu büyüklük temelinde yürütülen analizler sonucunda en yüksek ısıl performansı sağlayan parabolik açıklık değeri belirlenmiştir.



Görsel 22 Rayleigh sayısı 105 için ısı transfer yoğunluğu sonuçları

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Görsel 23 Rayleigh sayısı 106 için ısı transfer yoğunluğu sonuçları

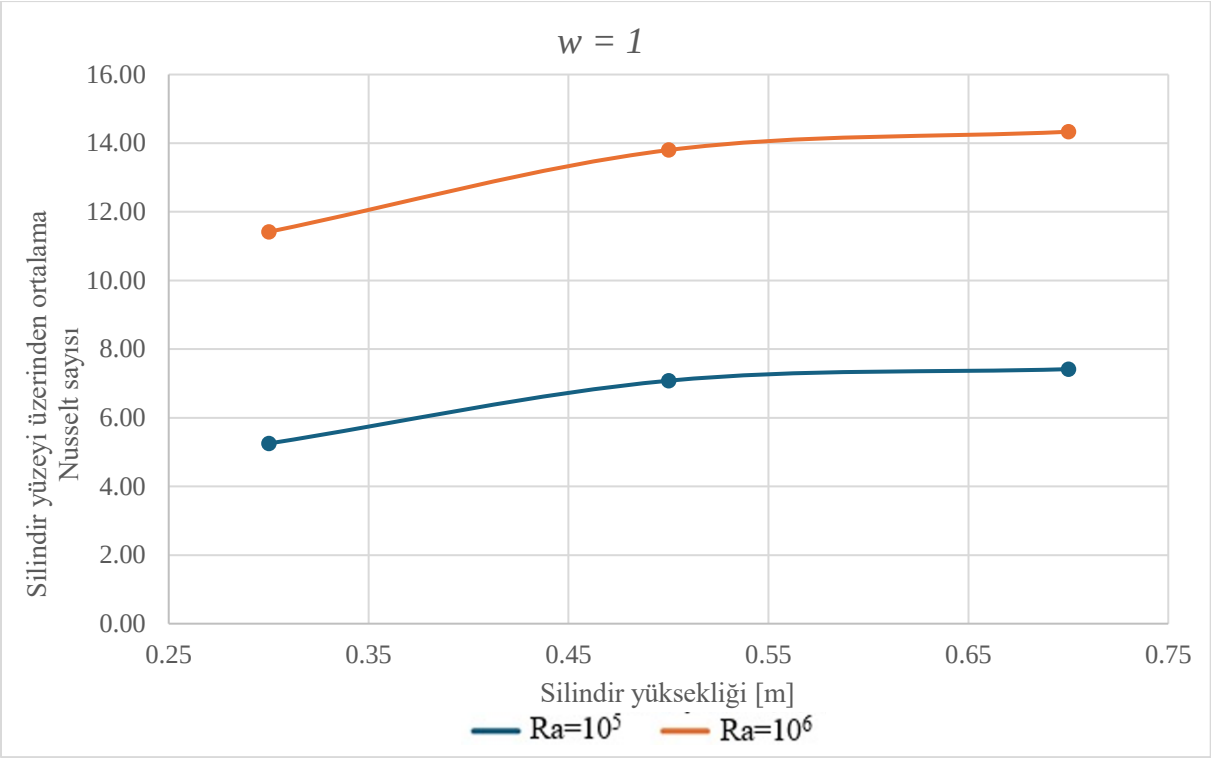
$Ra=10^5$ için ısı transfer yoğunluğu sonuçları Görsel 3'te; $Ra=10^6$ için elde edilen sonuçlar ise Görsel 4'te sunulmaktadır. Parabolik açıklığı 1,0 m olan geometrinin, incelenen üç farklı silindir yüksekliğinin (0,3 m, 0,5 m ve 0,7 m) tamamında daha büyük açıklık değerlerine göre daha yüksek ısı transfer yoğunluğu sağladığı görülmektedir. Bu durum, açıklığın artmasıyla silindirden muhafazaya aktarılan toplam ısının artsa da, muhafaza alanının da büyümesi sonucunda birim alana düşen ısı transferinin azalması ile ilişkilidir.

Görsel 5'te 1,0 m parabolik açıklık için farklı Rayleigh sayılarında silindir yüksekliğine bağlı ortalama Nusselt sayıları verilmiştir. Görsel 6 ve Görsel 7'de $Ra=10^5$ için farklı silindir yüksekliklerinde muhafaza içi sıcaklık konturları ve akım çizgileri; Görsel 8 ve Görsel 9'da ise $Ra=10^6$ için karşılık gelen dağılımlar gösterilmiştir. Bu görseller, silindirin muhafaza içindeki konumunun gelişen termal ve akışkan sınır tabakalarının yapısını ve akış desenlerini etkilediğini göstermektedir.

Görsel 5'te, $w = 1$ sabit genişlik oranı için silindir yüksekliğinin artmasına bağlı olarak silindir yüzeyinden elde edilen ortalama Nusselt sayısının değişimi iki farklı Rayleigh sayısı ($Ra = 10^5$ ve $Ra = 10^6$) için verilmiştir. Her iki Rayleigh sayısında da silindir yüksekliği arttıkça ortalama Nusselt sayısının yükseldiği görülmektedir. Bu durum, silindirin yüksekliği artmasıyla birlikte yüzey boyunca gelişen doğal taşınım hücrelerinin daha güçlü hâle gelmesi ve dolayısıyla ısı transferinin artmasıyla açıklanabilir. Ancak $Ra = 10^6$ değerinde ısı transferi çok daha belirgindir; yüksek Rayleigh sayılarında akışın daha kuvvetli termal kaldırma etkileri nedeniyle ısı transferinin baskın hâle geldiği bilinmektedir. $Ra = 10^6$ için Nusselt sayısı silindir yüksekliği 0.50 m değerine kadar daha yüksek bir artış eğilimine sahiptir, bu noktadan sonra artış eğiliminin azaldığı gözlenmektedir. Bu durum, silindirin daha yükseğe yerleşmesiyle sınır

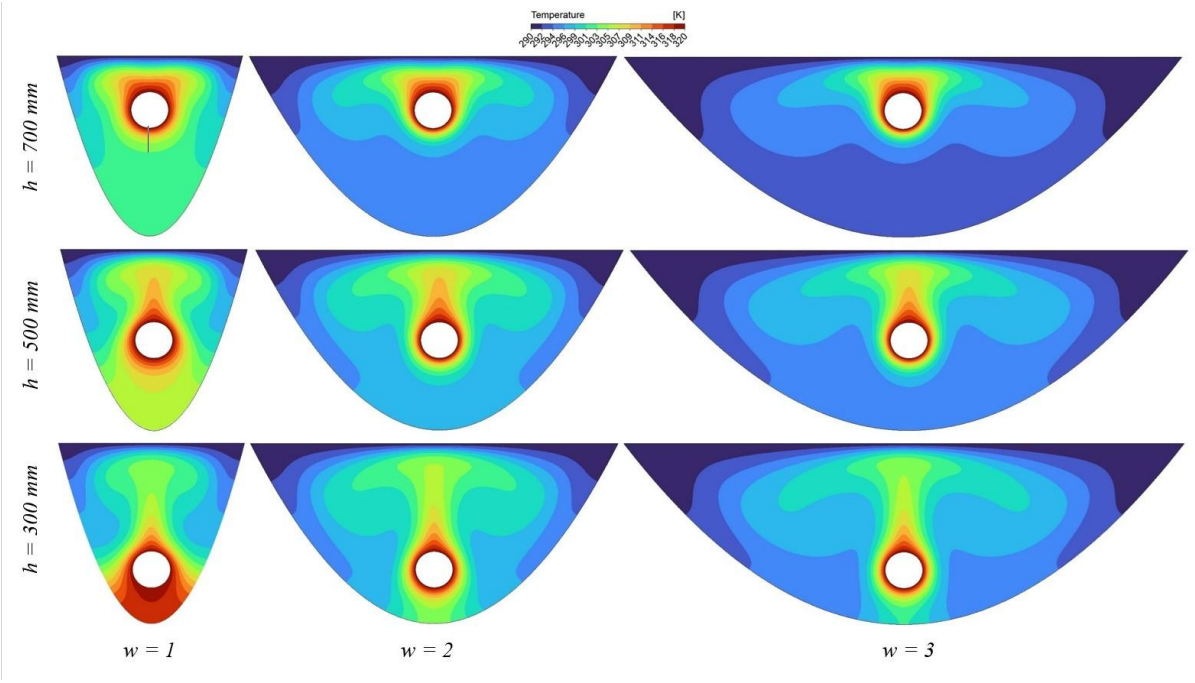
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tabaka kalınlaşması ve akış yapısında meydana gelen dönümsel değişiklikler nedeniyle ısı transferinin optimum bir değere ulaştığını göstermektedir. Ra = 10^5 için benzer görselde yükselme eğilimi mevcuttur; ancak Nusselt sayıları daha düşüktür. Bu, düşük Rayleigh sayılarında doğal taşınımın daha zayıf kalmasıyla ilişkilidir. Sonuç olarak, silindir yüksekliğinin doğal taşınım performansını belirgin şekilde etkilediğini, ancak bu etkinin Rayleigh sayısına bağlı olarak değiştiğini göstermektedir.

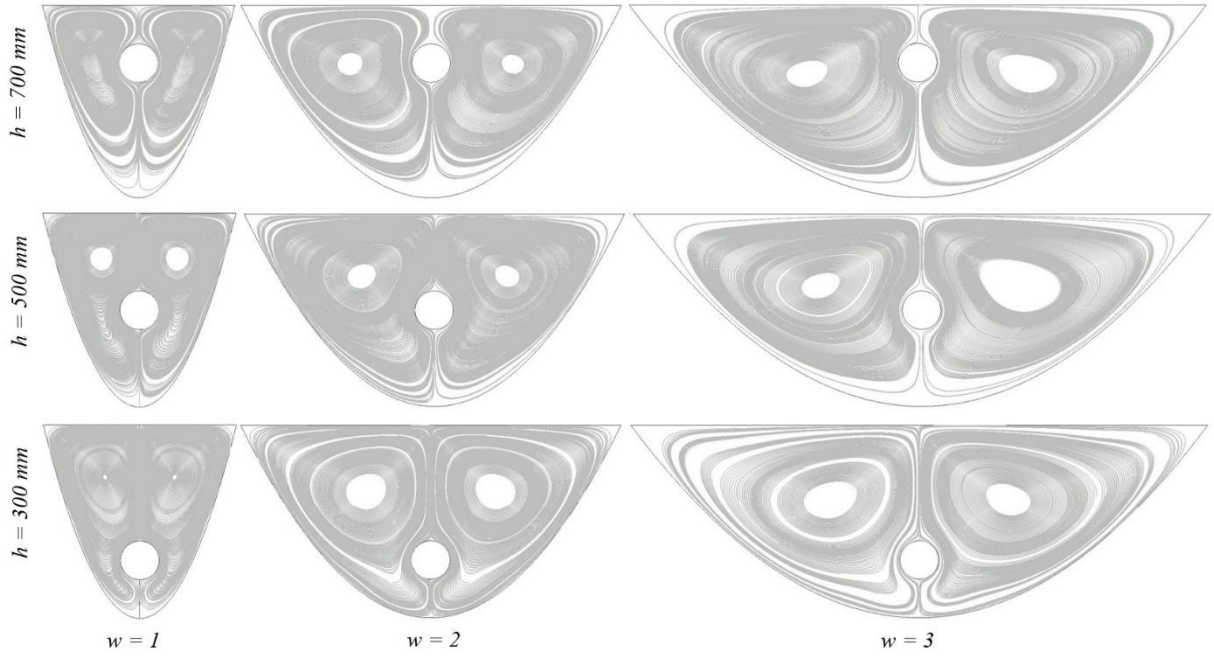


Görsel 24 1 metre parabolik açıklıkta silindir yüksekliğine bağlı farklı Rayleigh sayılarında Nusselt değerleri

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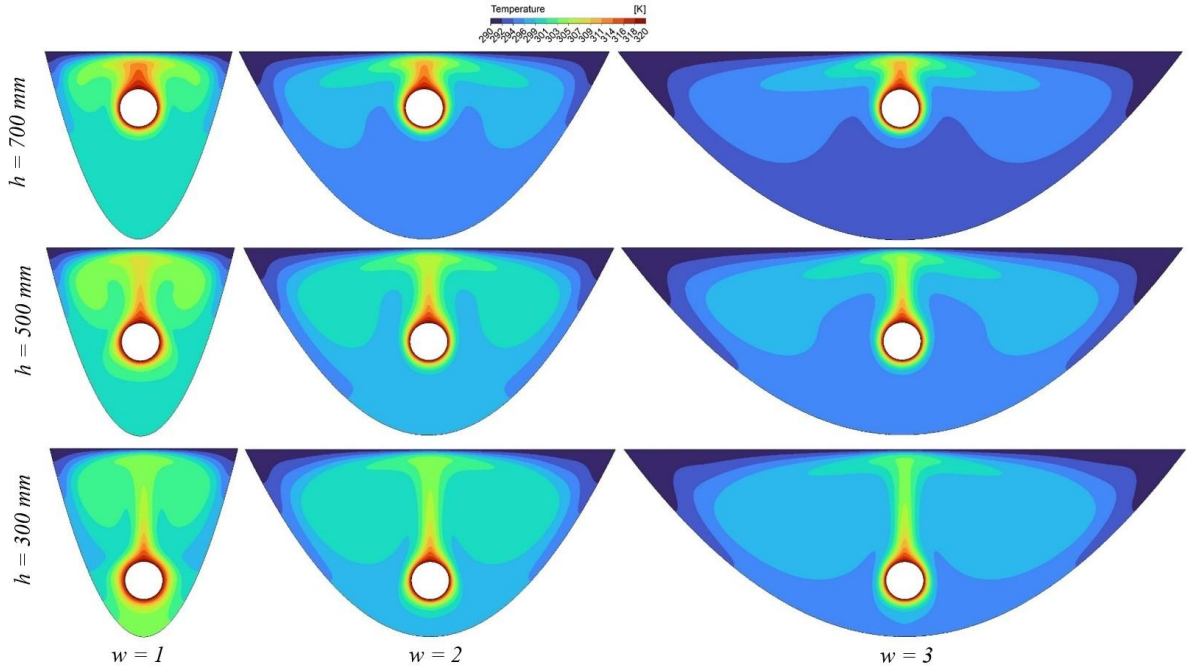


Görsel 25 Ra=10^5 için faklı silindir yüksekliklerinde muhafaza sıcaklık konturları

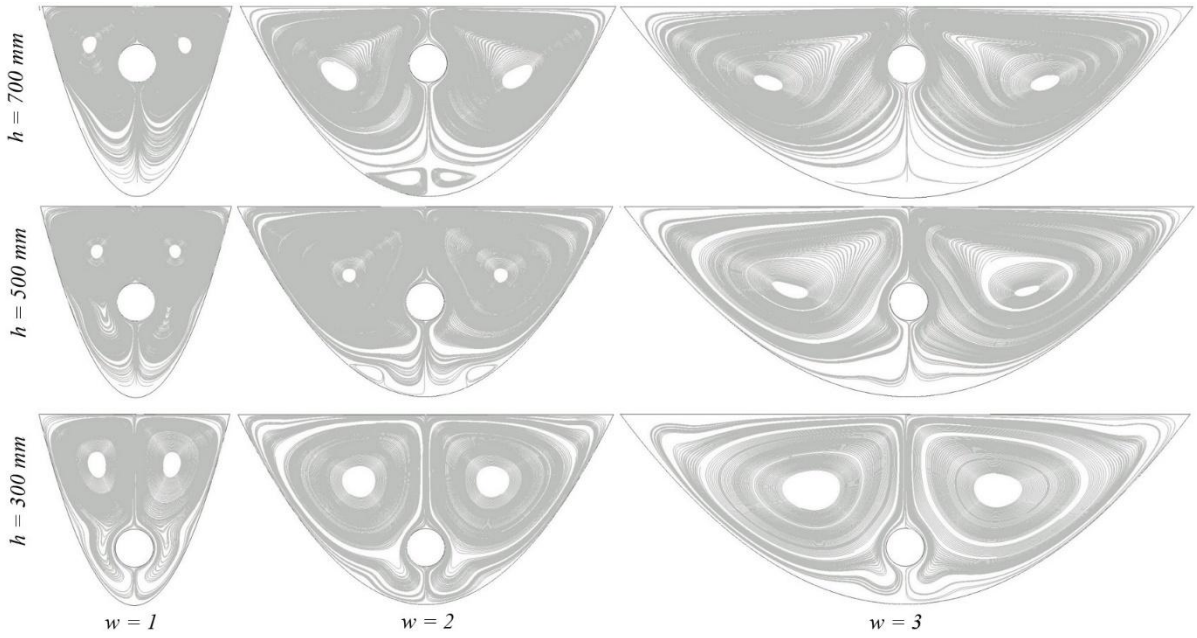


Görsel 26 Ra=10^5 için faklı silindir yüksekliklerinde muhafaza hız akış çizgileri

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Görsel 27 Ra=10^6 için faklı silindir yüksekliklerinde muhafaza sıcaklık konturları



Görsel 28 Ra=10^6 için faklı silindir yüksekliklerinde muhafaza hız akış çizgileri

4. GENEL DEĞERLENDİRME VE SONUÇLAR

Bulgular bölümünde sunulan görsellerden de görülebileceği üzere, parabolik açıklığı 1 m olan geometrinin ısı transfer yoğunluğu, incelenen üç farklı silindir yüksekliğinin (0,3 m, 0,5 m ve 0,7 m) tamamında diğer açıklık değerlerine kıyasla en yüksek seviyede gerçekleşmiştir. Bu nedenle, parabolik açıklığı 1 m olan model, çalışma kapsamında en verimli konfigürasyon olarak tercih edilmiştir. Ayrıca, daha önce ifade edildiği gibi, silindir yüzeyinden muhafaza

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alanına aktarılan toplam ısı transfer miktarı parabolik açıklığın artmasıyla birlikte artsa dahi, muhafaza alanının da büyümesi sonucunda birim alana düşen ısı transferi, diğer bir deyişle ısı transfer yoğunluğu, göreli olarak daha düşük değerlerde kalmaktadır.

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