4. INTERNATIONAL PARIS APPLIED SCIENCES CONGRESS

February 5-9 2025 -Paris

EDITOR
PROF. DR. SONER GÜLER

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4. INTERNATIONAL PARIS CONGRESS ON APPLIED SCIENCES

February 5-9, 2025 – Paris, France

28.02.2025

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CONGRESS ID

CONGRESS TITLE

4. INTERNATIONAL PARIS CONGRESS ON APPLIED SCIENCES

DATE AND PLACE

February 5-9, 2025 – Paris, France

ORGANIZATION

IKSAD INSTITUTE

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Prof. Dr. Soner GÜLER

COORDINATOR

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PARTICIPANTS COUNTRY (21 countries)

TÜRKİYE, MOROCCO, SRI LANKA, ALGERIA, TURKISH REPUBLIC OF NORTHERN CYPRUS, AZERBAIJAN, PORTUGAL, ALBANIA, VIETNAM, MALAYSIA, INDIA, PAKISTAN, GEORGIA, TUNISIA, SAUDI ARABIA, KOSOVO, UKRAINE, SERBIA, UNITED ARAB EMIRATES, IRAQ, ITALY

Total Accepted Article: 86

Total Rejected Papers: 19

Accepted Article (Türkiye): 34

Accepted Article (Other Countries): 52

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4th INTERNATIONAL PARIS CONGRESS ON APPLIED SCIENCES

February 5-9, 2025 / Paris

28.02.2025

REF: Akademik Teşvik

İlgili makama;

4. Uluslararası Paris Uygulamalı Bilimler Kongresi, 5-9 Şubat 2025, tarihleri arasında Paris, Fransa'da 21 farklı ülkenin (Türkiye 34 bildiri- Diğer ülkeler 52 bildiri) akademisyen/araştırmacılarının katılımıyla gerçekleşmiştir

Kongre 16 Ocak 2020 Akademik Teşvik Ödeneği Yönetmeliğine getirilen "Tebliğlerin sunulduğu yurt içinde veya yurt dışındaki etkinliğin uluslararası olarak nitelendirilebilmesi için Türkiye dışında en az beş farklı ülkeden sözlü tebliğ sunan konuşmacının katılım sağlaması ve tebliğlerin yarıdan fazlasının Türkiye dışından katılımcılar tarafından sunulması esastır." değişikliğine uygun düzenlenmiştir.

Bilgilerinize arz edilir,

Saygılarımla

Dr. Germán Martínez Prats
Committee Member

İKSAD ENSTİTÜSÜ
Çankaya – Ankara
06-146-071

Konu : Kongre Düzenlenmesi
Sayı : BSE-2 6 Ağustos 2024

İLGİLİ KURUMA

İçişileri Bakanlığı tarafından tahsis edilen 06-146-071 tescil kodu ile Tüzel Kişiliğe sahip olan İKSAD Enstitüsü 5253 sayılı kanuna uygun olarak "Bilimsel araştırmalar ve akademik çalışmalar" alanında ulusal ve uluslararası düzeyde faaliyetlerini yürütmektedir.

Kurumumuzun Yönetim Kurulu 6 Ağustos 2024 tarihinde saat 10.30'da "Bilimsel Diplomasi Projesi" görüşmeleri ile "Bilimsel Kongreler Düzenlenmesi" gündemleri ile toplanmış ve alınan (2 numaralı) karara istinaden aşağıda detayları yazılı olan bilimsel etkinliğin düzenlenmesine ve etkinliğe ilişkin resmi görevlendirme konusunda karar vermiştir.

Bilgi ve gereğini rica ederim

Dr. Kaldygul ADİLBEKOVA
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Etkinlik Adı: 4. Uluslararası
Uygulamalı Bilimler Kongresi
Etkinlik Tarihi ve Yeri: 5-9 Şubat 2025, Paris

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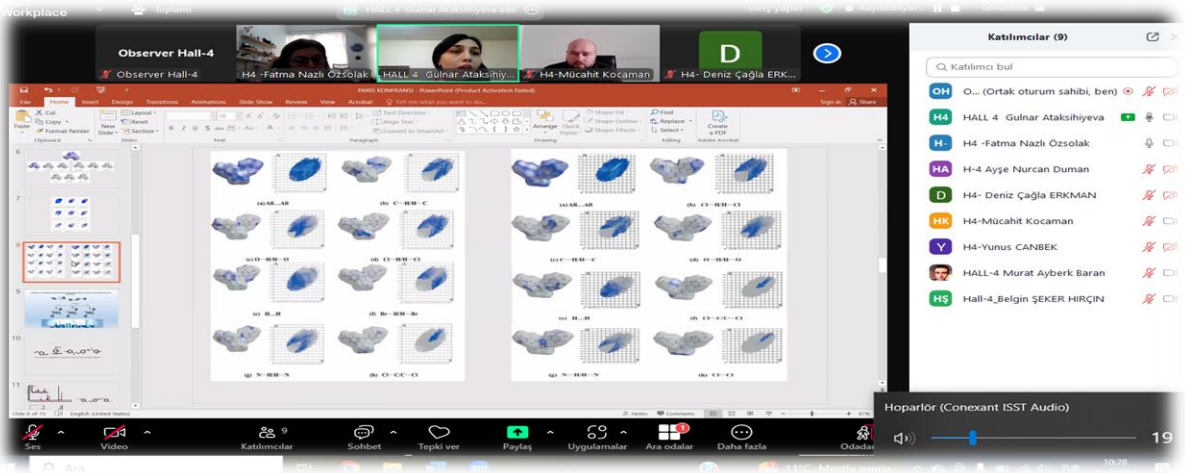

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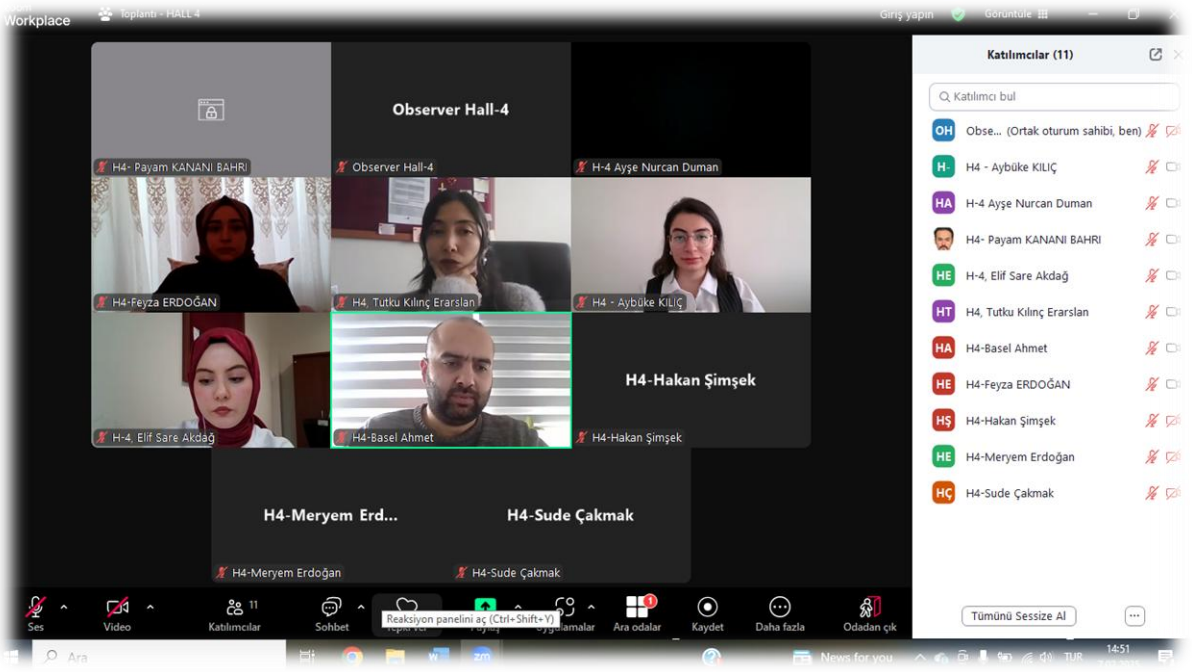

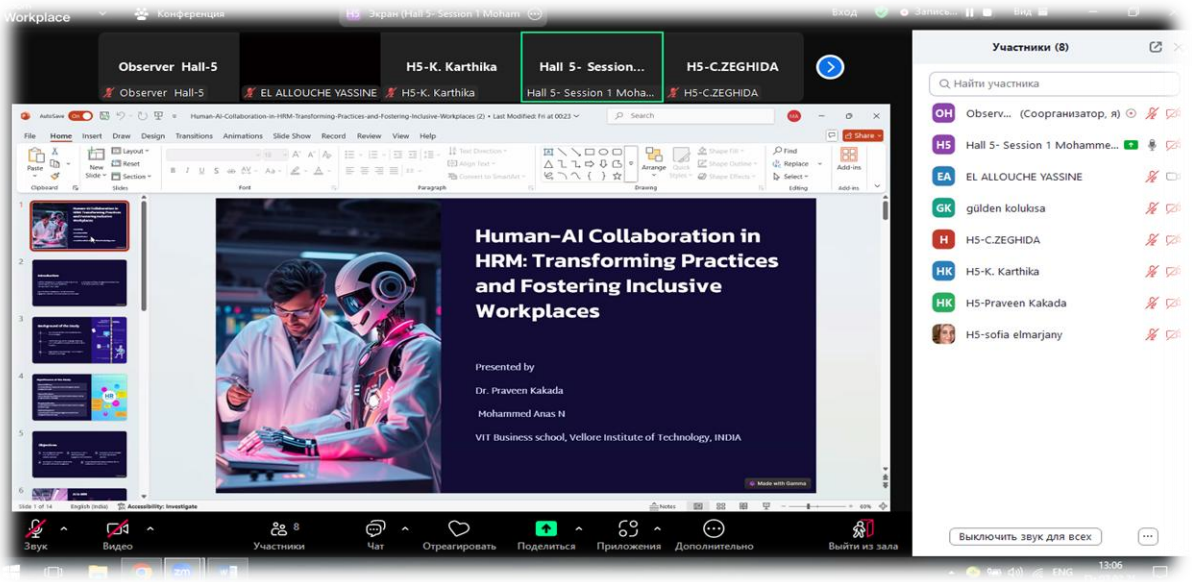

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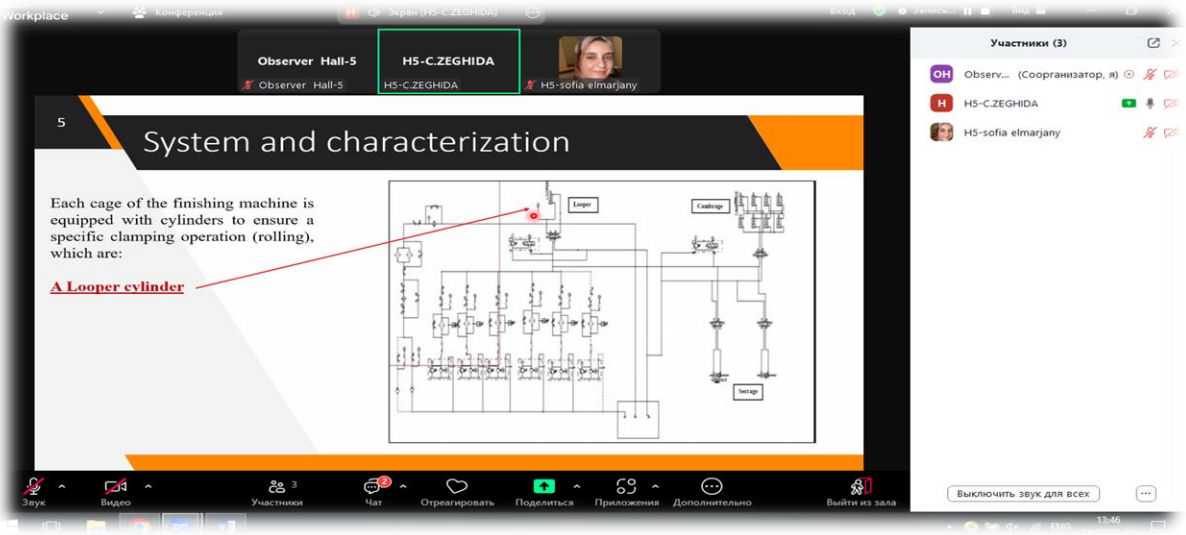

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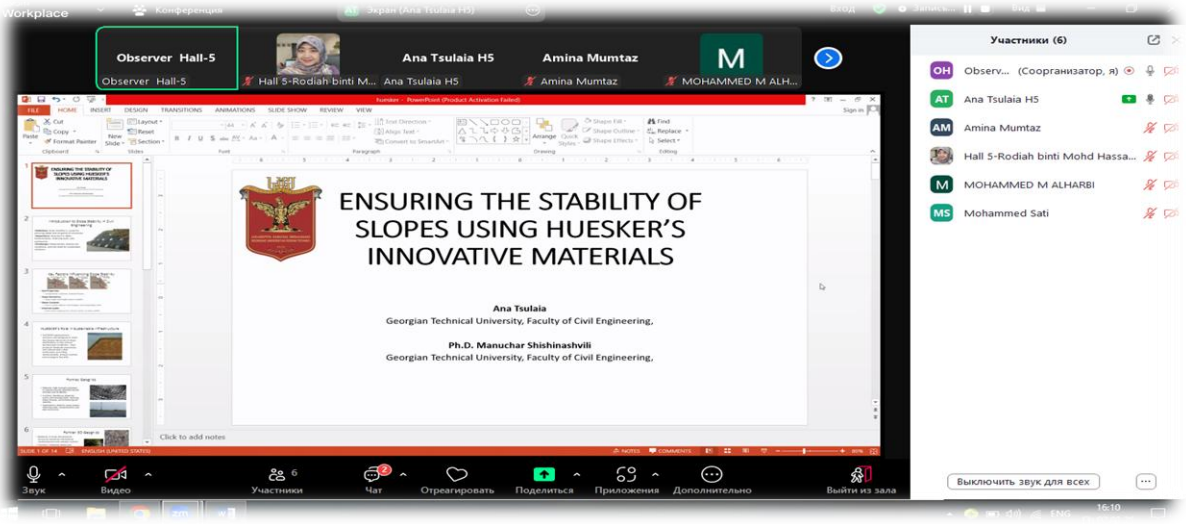

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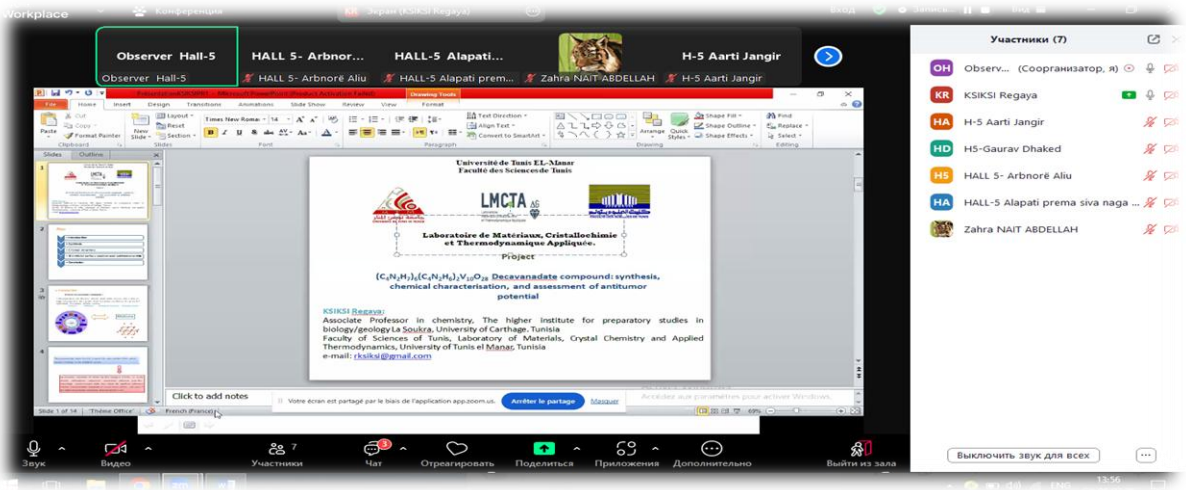

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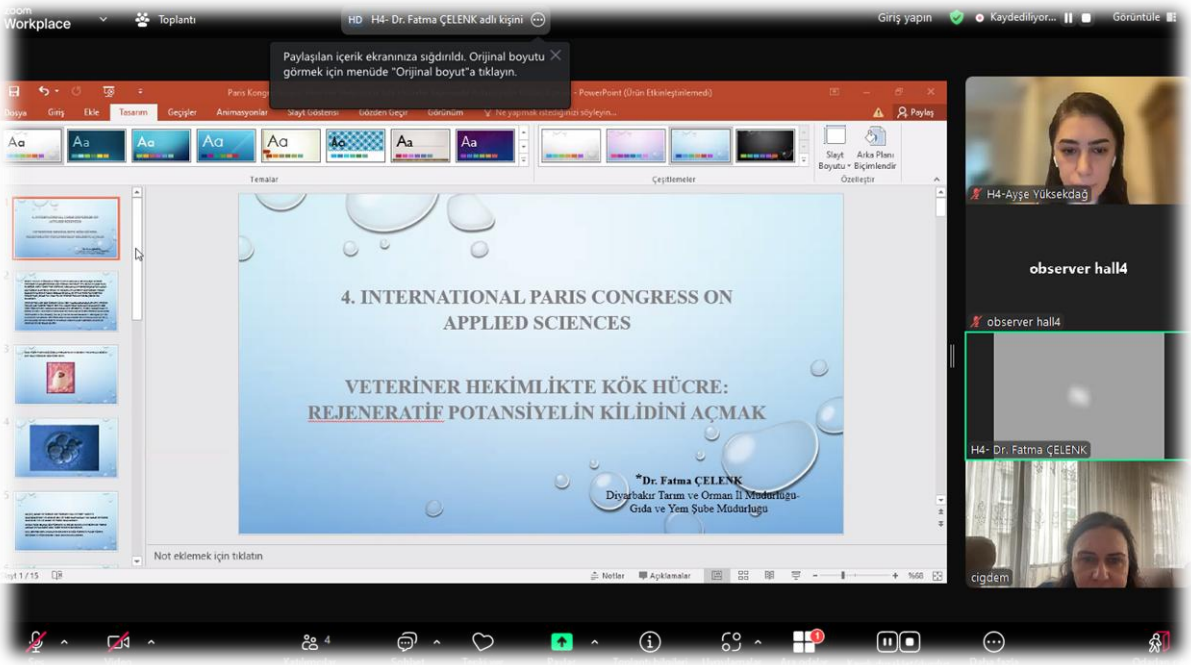

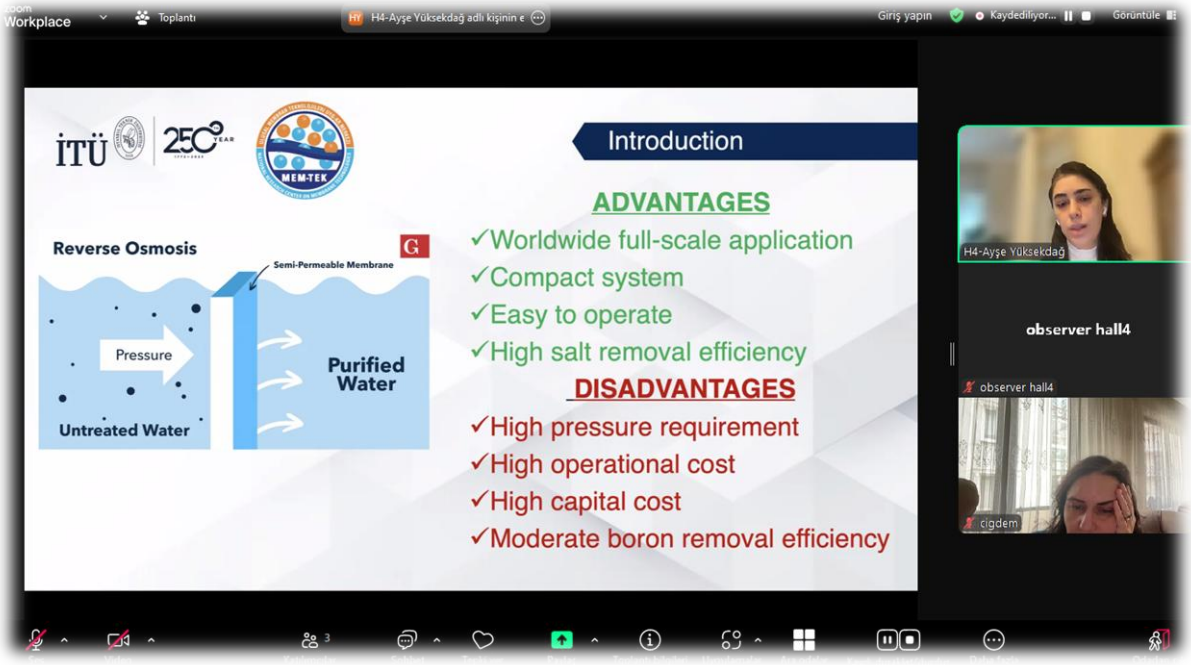

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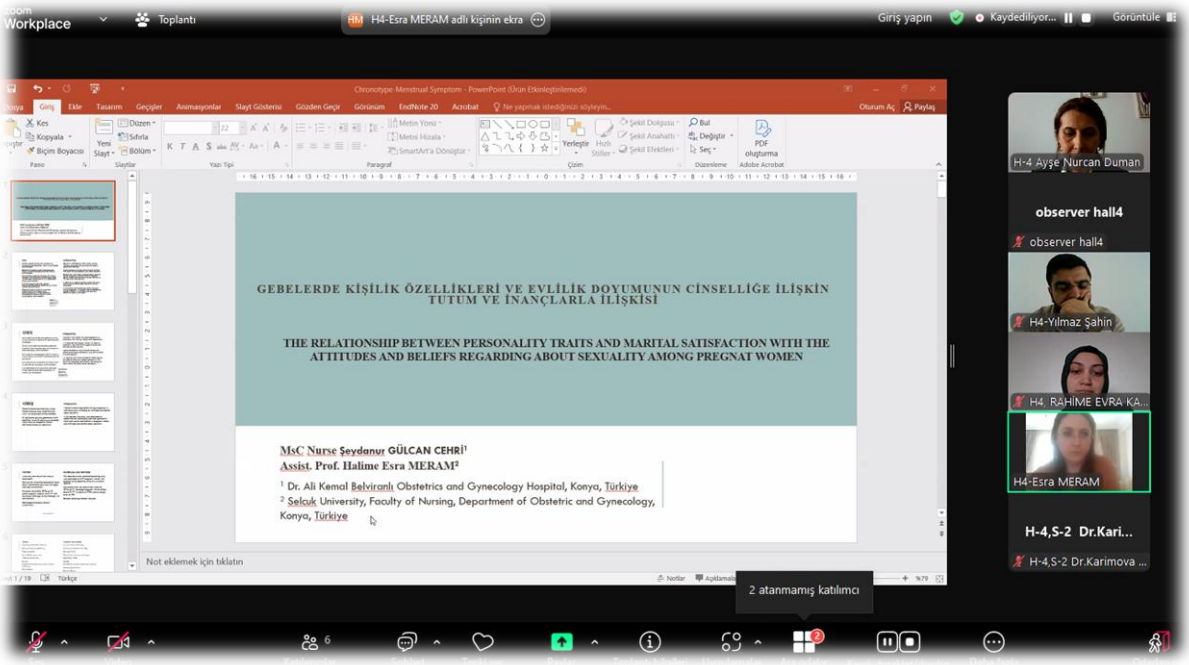

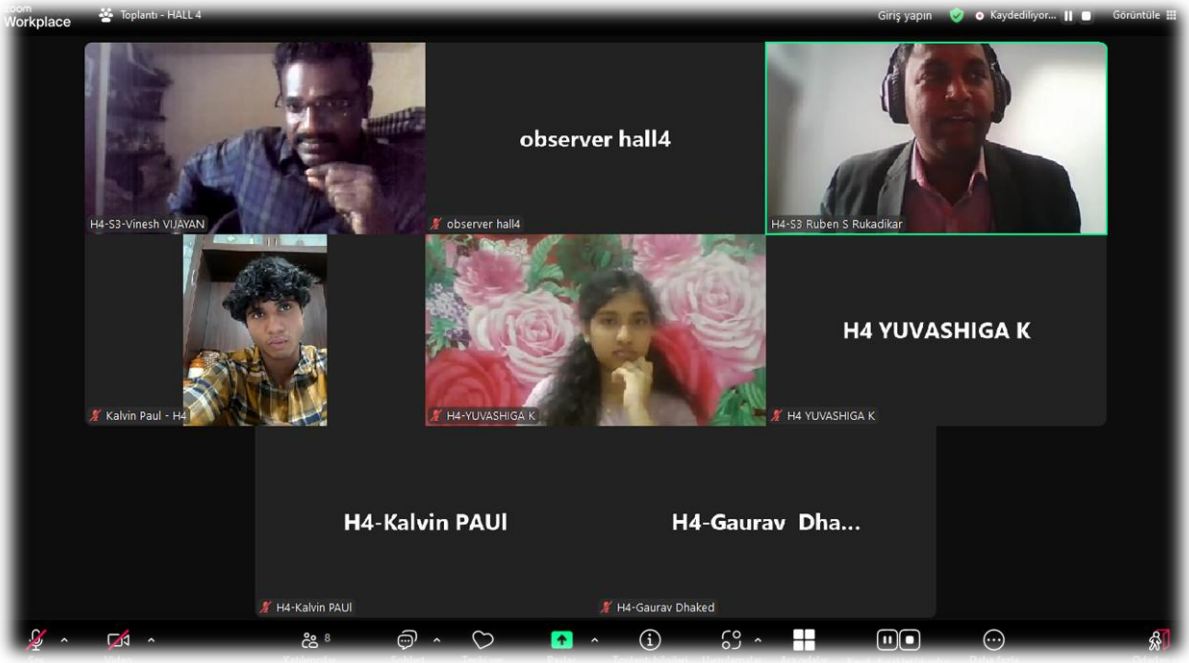

4th INTERNATIONAL PARIS CONGRESS ON APPLIED SCIENCES

February 5-9, 2025 -Paris, FRANCE

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Meeting ID: 829 5595 6031
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- Kongremizde Yazım Kurallarına uygun gönderilmiş ve bilim kurulundan geçen bildiriler için online (video konferans sistemi üzerinden) sunum imkanı sağlanmıştır.
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- Moderatör – oturumdaki sunum ve bilimsel tartışma (soru-cevap) kısmından sorumludur.

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***

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Before you login to Zoom please indicate your hall number, name and surname

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FACE TO FACE PRESENTATIONS

06.02.2025 / SESSION-3

PARIS LOCAL TIME

16 00 : 17 30

HEAD OF SESSION: Prof. Dr. Eti AKYÜZ LEVİ

AUTHORS	AFFILIATION	TOPIC TITLE
Assoc. Prof. Dr. Zehra Funda AKBULUT Prof. Dr. Soner GÜLER	Van Yüzüncü Yıl University TÜRKİYE	SUSTAINABLE CONCRETE SOLUTIONS: ADVANCEMENTS IN ECO-FRIENDLY MATERIALS AND PRACTICES
Res. Assist. Habibe İrem KARAKOÇ	Erciyes University TÜRKİYE	USING MULTI-CRITERIA DECISION MAKING METHODS IN THE SELECTION OF A PANDEMIC HOSPITAL'S LOCATION
Res. Assist. Cemal YÜKSEL	Bandırma Onyedi Eylül University TÜRKİYE	TRANSFORMATION OF DECISION MAKING PROCESSES IN THE DIGITAL AGE: REDEFINING BUSINESS INTELLIGENCE WITH AUTONOMOUS SYSTEMS, EDGE COMPUTING AND GENERATIVE AI
Res. Assist. Cemal YÜKSEL	Bandırma Onyedi Eylül University TÜRKİYE	DECRYPTING GUEST EXPERIENCE WITH TEXT MINING: A CASE STUDY OF ISTANBUL HILTON HOTELS
Assoc. Prof. Dr. Asiye ASLAN Assist. Prof. Dr. Reyhan BAHAR	Bandırma Onyedi Eylül University TÜRKİYE	RENEWABLE ENERGY SOURCES WITHIN THE SCOPE OF SUSTAINABLE ENERGY

ONLINE PRESENTATIONS

07.02.2025 / HALL-4 / SESSION-1

PARIS LOCAL TIME	ANKARA LOCAL TIME
08 00 : 10 00	10 00 : 12 00

HEAD OF SESSION: Assist. Prof. Dr. Fatma Nazlı ÖZSOLAK

AUTHORS	AFFILIATION	TOPIC TITLE
Onur GÜLER Mücahit KOCAMAN	*Karadeniz Technical University TÜRKİYE*	MICROSTRUCTURE, HARDNESS AND THERMAL PROPERTIES OF HOT-PRESSED SILVER-COATED NYLON-BASED COMPOSITES
Deniz Çağla ERKMAN Halime YARAR	*Sakarya University TÜRKİYE*	THEORETICAL INVESTIGATION OF STRUCTURAL, ELASTIC AND ELECTRONIC PROPERTIES OF AuCu 3 TYPE XIn 3 (X= Sc, Pt, and Lu) COMPOUNDS: FIRST-PRINCIPLES CALCULATION
Gulnar Atakishiyeva Nigar Ahmedova Sevinc Mukhtarova Assoc. Prof. Sima Musayeva Assoc. Prof. Ilhama Hamdullayeva Assoc. Prof. Gulnara Babayeva	*Baku State University AZERBAIJAN* *Azerbaijan Technical University AZERBAIJAN* *Azerbaijan State Pedagogical University AZERBAIJAN*	SYNTHESIS OF TEREPHTHALIC BIS-DIHALOGENDIAZABUTADIENES BASED ON CATALYTIC OLEFINATION REACTION CONDITIONS
Gulnar Atakishiyeva Sevinc Mukhtarova Assoc. Prof. Shukufa Eyvazova Assoc. Prof. Naila Veysova Irada Shikhaliyeva Dr Namiq Shikhaliyev	*Baku State University AZERBAIJAN* *Azerbaijan Technical University AZERBAIJAN* *Baku State University AZERBAIJAN* *Baku Engineering University AZERBAIJAN*	NON-COVALENT BONDS IN 1,1-DICHLORODIAZADIENES BASED ON PARA NITROBENZALDEHYDE
Murat Ayberk BARAN Behçet BECERİR	*Bursa Uludağ University TÜRKİYE*	INVESTIGATION OF MORDANT APPLICATION IN DIRECT DYEING OF NYLON FABRICS
Assist. Prof. Dr. Fatma Nazlı ÖZSOLAK Yunus CANBEK	*Erciyes University TÜRKİYE*	CREATIVE INDUSTRIES: AN INDUSTRIAL DESIGN ENGINEERING APPROACH
Assist. Prof. Dr. Belgin ŞEKER HIRÇIN	*Karabük University TÜRKİYE*	CURRENT SITUATION OF THE WOOD PLASTIC COMPOSITE (WPC) SECTOR IN THE WORLD AND IN TURKEY
Assist. Prof. Dr. Belgin ŞEKER HIRÇIN	*Karabük University TÜRKİYE*	PHYSICAL PROPERTIES OF WASTE-CASTING POLYAMIDE 6 (W-PA6G) BASED WOOD PLASTIC COMPOSITES

ONLINE PRESENTATIONS

07.02.2025 / HALL-5 / SESSION-1

PARIS LOCAL TIME	ANKARA LOCAL TIME
08 00 : 10 00	10 00 : 12 00

HEAD OF SESSION: Dr. Praveen Kakada

AUTHORS	AFFILIATION	TOPIC TITLE
Dr. Praveen Kakada Mohammed Anas	*Vellore Institute of Technology INDIA*	HUMAN-AI COLLABORATION IN HRM: TRANSFORMING PRACTICES AND FOSTERING INCLUSIVE WORKPLACES
K. Karthika M. Yamuna	*Vellore Institute of Technology INDIA*	CALCULATING SOMBOR INDEX USING MATLAB
K. Karthika M. Yamuna	*Vellore Institute of Technology INDIA*	DATA ENCRYPTION USING GRAPH THEORY
Azzedine BOUZAOUIT Chouaib ZEGHIDA Mounir GAHGAH	*20 august 1955 Skikda University ALGERIA* *Cherif M'Saadia University ALGERIA*	CONTRIBUTION TO THE ASSESSMENT OF ENERGY LOSSES AT A STEERING VALVE IN A HYDRAULIC SYSTEM
Chhavi M. Kumar	*BITS Pilani, Computer Science, Dubai UNITED ARAB EMIRATES* *Delhi University INDIA*	ENERGY, ENTROPY, AND EFFICIENCY: THERMODYNAMIC PRINCIPLES IN COMPUTER SCIENCE
Sofia El Marjany Fouad Khalil Yassine EL Allouch	*Sidi Mohamed Ben Abdellah University MOROCCO*	IN SILICO APPROACH FOR EVALUATION OF 1-(INDOLIN-1-YL) ÉTHAN-1-ONE DERIVATIVES AS INHIBITORS AGAINST PROSTATE CANCER: 2D-QSAR, ADMET PREDICTION, MOLECULAR DOCKING ANALYSIS
Yassine EL ALLOUCHE Sofia ELMARJANY Said EL RHABORI Hicham ZAITAN Fouad KHALIL	*Sidi Mohamed Ben Abdellah University MOROCCO*	ASSESSING THE THERAPEUTIC POTENTIAL OF 3,5-DISUBSTITUTED INDOLE DERIVATIVES IN TARGETING PIM1 KINASE: IN SILICO ANALYSIS AND DEVELOPMENT OF INNOVATIVE COMPOUNDS FOR HEMATOLOGICAL CANCER TREATMENT
Samer H. K. Al-Jashaami Safaa M. Almudhafar Basim A. Almayahi	*Kufa University IRAQ*	CLIMATE CHANGE AND ITS EFFECTS ON HUMAN HEALTH

ONLINE PRESENTATIONS

07.02.2025 / HALL-4 / SESSION-2

PARIS LOCAL TIME	ANKARA LOCAL TIME
10 30 : 12 30	12 30 : 14 30

HEAD OF SESSION: Assoc. Prof. Dr. Fevzi Çakmak BOLAT

AUTHORS	AFFILIATION	TOPIC TITLE
İrfan TURUNÇ	*Oyak Renault Automobile Factory, Bursa TÜRKİYE*	REVOLUTIONIZING AUTOMOTIVE PRODUCTION AND MAINTENANCE: AN INNOVATIVE AND SUSTAINABLE APPROACH TO GEAR TRANSITION CHALLENGES
Assoc. Prof. Dr. Fevzi Çakmak BOLAT Bartu Çetin TÜRKCAN Prof. Dr. Selim SİVRİOGLU	*Kocaeli University TÜRKİYE* *Piri Reis University TÜRKİYE*	ANALYSIS OF COUNTER-ROTATION DUAL ROTOR WIND TURBINE PERFORMANCE WITH TORQUE CONTROL APPLICATION
Assoc. Prof. Dr. Fevzi Çakmak BOLAT Murat Göksun ÇALTILI	*Kocaeli University TÜRKİYE*	ELECTROMAGNETIC MODAL SHAKER DESIGN AND FINITE ELEMENT ANALYSIS
Assist. Prof. Dr. Kerim Gökhan AKTAŞ	*Karabük University TÜRKİYE*	EVALUATION OF THERMAL FREE VIBRATION RESPONSE OF FUNCTIONALLY GRADED PLATES WITH POWER-LAW, EXPONENTIAL AND SIGMOID MATERIAL GRADIENTS
Assist. Prof. Dr. Berna ARSLAN	*Aydın Adnan Menderes University TÜRKİYE*	A NOTE ON APPROXIMATELY ()-JORDAN BIDERIVATIONS

ONLINE PRESENTATIONS

07.02.2025 / HALL-5 / SESSION-2

PARIS LOCAL TIME	ANKARA LOCAL TIME
$10^{30} : 12^{30}$	$12^{30} : 14^{30}$

HEAD OF SESSION: Assoc. Prof. Dr. Rajeev Kumar

AUTHORS	AFFILIATION	TOPIC TITLE
Nguyen Thi My Duyen Nguyen Phong Vu Le Thi To Quyen Nguyen Thi Hoai Thanh Vo Thi Thao Nguyen	*An Giang University VIETNAM* *An Giang University VIETNAM* *Can Tho Univesity VIETNAM* *Vietnam National University VIETNAM* *Nguyen Tat Thanh University VIETNAM*	DEVELOPING AN GIANG CULINARY TOURISM
EWETOLA, E. A. OWOLABI, O. AYANLEKE, A.	*Ladoke Akintola University of Technology NIGERIA*	DETERMINATION OF SOIL LOSS DUE TO HARVESTING OF TWO YAM CULTIVARS IN THREE SELECTED SOIL SERIES
Rodiah M. H. Norhayati, H. Jamilah B.	*Selangor University MALAYSIA* *Putra University MALAYSIA*	IMPACT OF BORASSUS FLABELLIFER ON THE QUALITY AND NUTRITION OF FIBER-ENRICHED MUFFINS
Dr. Amina Mumtaz Dr. Amjad Nasim Mahnoor Ayesha Naeem	*Pakistan Council of scientific and Industrial Research Laboratories Complex PAKISTAN* *Education University PAKISTAN* *Engineering and Technology University PAKISTAN*	ECO-FRIENDLY MICROWAVE ASSISTED SPECTROPHOTOMETRIC APPROACH TOWARDS THE DETERMINATION OF CEFADROXIL IN PURE AND IN PHARMACEUTICAL FORMULATION
Ana Tsulaia Manuchar Shishinashvili	*Georgian Technical University GEORGIA*	ENSURING THE STABILITY OF SLOPES USING HUESKER'S INNOVATIVE MATERIALS
Assoc. Prof. Dr. Rajeev Kumar	*Manav Rachna International Institute of Research and Studies INDIA*	PLANT WASTE MATERIALS FOR REMOVAL OF HEAVY METALS FROM WATER
V S Angulakshmi S. Kalaiselvan N Anusuya	*P.S.G.R. Krishnammal College for Women INDIA*	ENHANCED CATALYTIC PERFORMANCE THROUGH OXYGEN-FUNCTIONALIZED CARBON NANOTUBES FOR SELECTIVE REDUCTION OF NOX WITH NH_3
Mohammed Sati Alharbi Mohamed Faisal Chevidikunnan Zeiyad Neamatallah	*King Abdulaziz University SAUDI ARABIA*	RELATIONSHIP BETWEEN NECK MUSCLES CROSS SECTIONAL AREA WITH CRANIO-VERTEBRAL ANGLE AND CERVICAL RANGE OF MOTION AMONG THE SUBJECTS WITH CHRONIC NECK PAIN

ONLINE PRESENTATIONS

07.02.2025 / HALL-4 / SESSION-3

PARIS LOCAL TIME	ANKARA LOCAL TIME
13 00 : 15 00	15 00 : 17 00

HEAD OF SESSION: Assoc. Prof. Dr. Hakan ŞİMŞEK

AUTHORS	AFFILIATION	TOPIC TITLE
Aybüke KILIÇ Assist. Prof. Dr. İlker ÖZÇELİK	*Eskişehir Osmangazi University TÜRKİYE*	ENHANCING MINORITY CLASS DETECTION IN INTRUSION DETECTION SYSTEMS USING GAN-BASED DATA AUGMENTATION: A HEURISTIC STUDY
Res. Assist. Feyza ERDOĞAN Assist. Prof. Dr. Vahit TONGUR	*Konya Technical University TÜRKİYE*	EVALUATING THE PERFORMANCE OF CRAYFISH OPTIMIZATION ALGORITHM ON CEC-2022 BENCHMARK PROBLEMS
Res. Assist. Tutku KILINÇ ERARSLAN	*Erciyes University TÜRKİYE*	EVALUATION OF FINANCIAL PERFORMANCE IN TEXTILE FACTORIES WITH MOORA AND COPRAS METHODS
Aleyna ÖZ Assoc. Prof. Dr. Hakan ŞİMŞEK Meryem ERDOĞAN Sündüz Sude ÇAKMAK	*Antalya Science University TÜRKİYE*	ON A MOBILE APPLICATION THAT RECOMMENDS THE MOST SUITABLE CAFÉ-RESTAURANTS FOR THE HEARING IMPAIRED
Hakan KUTUCU Dr. İsa AVCI Basel AHMET	*Karabük University TÜRKİYE*	MODERN APPROACHES TO SOLVING THE 0-1 KNAPSACK PROBLEM WITH METAHEURISTIC METHODS
Dr. İsa AVCI Elif YILDIRIM Elif Sare AKDAĞ	*Karabük University TÜRKİYE*	COMPARATIVE EVALUATION OF OPEN-SOURCE NAC SOLUTIONS FOR ENHANCING NETWORK SECURITY AND POLICY ENFORCEMENT
Payam KANANI BAHRI Prof. Dr. Hüsnü Murat GÜNAYDIN	*İstanbul Technical University TÜRKİYE*	A LITERATURE REVIEW ON THE APPLICATION OF MACHINE LEARNING ALGORITHMS FOR RISK ASSESSMENT IN CONSTRUCTION PROJECTS: A FOCUS ON DELAY MANAGEMENT
Yousif NASSER Prof. Dr. Hüsnü Murat GÜNAYDIN	*İstanbul Technical University TÜRKİYE*	DIGITAL TWIN-DRIVEN BUILDING INFORMATION MODELING (BIM) FOR SUSTAINABLE DESIGN PRACTICES IN ARCHITECTURE AND CONSTRUCTION DESIGN OFFICES

ONLINE PRESENTATIONS

07.02.2025 / HALL-5 / SESSION-3

PARIS LOCAL TIME	ANKARA LOCAL TIME
13 00 : 15 00	15 00 : 17 00

HEAD OF SESSION: Prof. Dr. Ivan PAVLOVIC

AUTHORS	AFFILIATION	TOPIC TITLE
Laila Amjlef Hamid Essabir	*Ibn Zohr University MOROCCO*	INNOVATIVE ECO-FRIENDLY CONCRETE BASED ON AGRICULTURAL WASTE AS NATURAL FILLERS
Elena Sierikova Volodymyr Holota	*National University of Civil Defence UKRAINE*	NEW APPROACHES TO IMPROVE THE ENVIRONMENTAL SAFETY LEVEL OF PETROLEUM PRODUCTS STORAGE AND TRANSPORTATION IN TANKS
Elena Sierikova Elena Strelnikova Kyryl Degtyariov	*National University of Civil Defence UKRAINE* *A.M. Podgorny Institute for Mechanical Engineering Problems NAS UKRAINE*	IMPACT PREDICTION OF TECHNOGENIC SEISMICITY ON THE STORAGE TANKS STABILITY
Asma Amjlef Salaheddine Farsad Aboubakr Ben Hamou Said Et-Taleb Noureddine El Alem	*Ibn Zohr University MOROCCO*	POLYANILINE COATED QUARTZ SAND (QS@PANI) AS AN ADSORBENT COMPOSITE FOR ORANGE G DYE REMOVAL FROM AQUEOUS SOLUTION
Prof. Dr. Ivan PAVLOVIC	*Scientific Institute for Veterinary Medicine SERBIA*	CONTROL MEASURES OF PARASITIC INFECTIONS CAUSED BY NEMATODES ON PHEASANTS IN FARM BREEDING
Anas Hamdani Said Bouda Atman Adiba Rachid Razouk	*National Institute of Agricultural Research (INRA) MOROCCO* *Sultan Moulay Slimane University MOROCCO*	RELATIONSHIP BETWEEN CARBOHYDRATE AND AMINO ACID RESERVES IN TWIGS WITH AGRO-PHENOLOGICAL RESPONSES IN PLUM CULTIVARS OF TWO CONTRASTING GEOGRAPHIC ORIGIN
Muhammad Haseeb Ahmad	*Government College University PAKISTAN*	CHARACTERIZATION AND AUTHENTICATION OF DAIRY PRODUCTS USING FLUORESCENCE SPECTROSCOPY COUPLED WITH CHEMOMETRICS
Noreen Sajjad Aeysha Sultan Muhammad Yasir Arif Nazir	*Lahore University PAKISTAN* *Education University PAKISTAN*	CATALYTICAL SYNTHESIS OF BIODIESEL FROM NON-EDIBLE CASTOR OIL USING BIOGENIC SYNTHESIZED NANOPARTICLES

ONLINE PRESENTATIONS

08.02.2025 / HALL-4 / SESSION-1

PARIS LOCAL TIME	ANKARA LOCAL TIME
08 00 : 10 00	10 00 : 12 00

HEAD OF SESSION: Assist. Prof. Dr. Ayşe YÜKSEKDAĞ

AUTHORS	AFFILIATION	TOPIC TITLE
Assist. Prof. Dr. Ayşe YÜKSEKDAĞ	*İstanbul Technical University TÜRKİYE Prof. Dr. Dincer Topacık National Research Center on Membrane Technologies (MEM-TEK) İstanbul TÜRKİYE*	THE ROLE OF ADVANCED TREATMENT IN BORON REMOVAL: CASE STUDY ON PLANT RESPONSES
Fatma ÇELENK	*Provincial Directorate of Agriculture and Forestry Diyarbakır TÜRKİYE*	STEM CELL
Fatma ÇELENK	*Provincial Directorate of Agriculture and Forestry Diyarbakır TÜRKİYE*	HISTOLOGICAL TECHNIQUES IN VETERINARY MEDICINE
Çiğdem AŞÇIOĞLU Prof. Dr. Ramazan ŞEVİK	*Afyon Kocatepe University TÜRKİYE*	AVALABILITY OF CAROTENOIDS FROM ANIMAL ORIGIN FOODS

ONLINE PRESENTATIONS

08.02.2025 / HALL-5 / SESSION-1

PARIS LOCAL TIME	ANKARA LOCAL TIME
08 00 : 10 00	10 00 : 12 00

HEAD OF SESSION: Prof. Assoc. Dr. Skender DEMAKU

AUTHORS	AFFILIATION	TOPIC TITLE
Prema Siva Naga Teja Alapati Baljeet Singh Saharan Meena Sindhu Ankush Dhanda Tejashree Musini	*Chaudhary Charan Singh Haryana Agricultural University INDIA*	IDENTIFICATION AND ANALYSIS OF PLANT GROWTH-PROMOTING RHIZOBACTERIA FROM SORGHUM PLANTS
Zahra Nait Abdellah	*Mouloud Mammeri University ALGERIA*	THE KINETICS OF GROWTH OF THE FE2B LAYER AND MODELING OF THE MASS GAIN ON AISI D2 STEEL
Prof. Assoc. Dr. Skender DEMAKU Flaka THAQI MSc. Arbnorë ALIU MSc. Donika SYLEJMANI	*Hasan Prishtina University KOSOVO*	STUDY OF THE ENVIRONMENTAL STATE OF THE ARTIFICIAL LAKE IN THE AREA OF TC "KOSOVA A"
Prof. Assoc. Dr. Skender DEMAKU Prof. Dr. Bardha KORÇA MSc. Arbnorë ALIU MSc. Donika SYLEJMANI	*Hasan Prishtina University KOSOVO*	ANALYSIS OF TRACES OF HEAVY METALS IN SAMPLES OF FLOUR DOMESTIC AND IMPORTED
Regaya Ksiksi Saoussen Mlayah-Bellalouna Zaineb Abdelkafi-Koubaa Taissir Aissa Naziha Marrakchi Najet Srairi-Abid Mohamed Faouzi Zid	*Tunis El Manar University TUNUSIA*	(C4N2H7)6(C4N2H6)2V10O28 DECAVANADATE COMPOUND: SYNTHESIS, CHEMICAL CHARACTERISATION, AND ASSESSMENT OF ANTITUMOR POTENTIAL
Olugbenga Babajide SOYEMI Alaba Joseph AROKOOLA	*The Federal Polytechnic NIGERIA*	IMPACT OF REPLACING COARSE AGGREGATE WITH RECYCLED GLASS ON THE FLEXURAL PROPERTIES OF GREEN CONCRETE
Aarti Jangir Gaurav Dhaked Dr. Shalini Rukhaya	*ATS, COCS, CCSHAU, Hisar, Haryana INDIA* *FSN, CCAS, MPUAT, Udaipur, Rajasthan INDIA* *ATS, COCS, CCSHAU, Hisar, Haryana INDIA*	DYEING OF BLEND FABRICS
Aarti Jangir Gaurav Dhaked Dr. Mona Verma	*ATS, COCS, CCSHAU, Hisar, Haryana INDIA* *FSN, CCAS, MPUAT, Udaipur, Rajasthan INDIA* *ATS, COCS, CCSHAU, Hisar, Haryana INDIA*	SUSTAINABLE TEXTILE AUXILIARIES

ONLINE PRESENTATIONS

08.02.2025 / HALL-4 / SESSION-2

PARIS LOCAL TIME	ANKARA LOCAL TIME
10 30 : 12 30	12 30 : 14 30

HEAD OF SESSION: Assist. Prof. Dr. Ayşe Nurcan DUMAN

AUTHORS	AFFILIATION	TOPIC TITLE
Assist. Prof. Dr. Ayşe Nurcan DUMAN	*Gazi University TÜRKİYE*	EFFECT OF THE ADDITION OF BORON-CONTAINING COMPOUNDS ON PROSTHETIC DENTAL MATERIALS
Assist. Prof. Dr. Ayşe Nurcan DUMAN	*Gazi University TÜRKİYE*	THE USE OF BORON-CONTAINING COMPOUNDS IN DENTISTRY
Assist. Prof. Dr. Rahime Evra KARAKAYA	*Ankara Yıldırım Beyazıt University TÜRKİYE*	NON-ALCOHOLIC FATTY LIVER DISEASE (NAFLD) AND GUT MICROBIOTA: UNVEILING THE EFFECTS OF PREBIOTICS, PROBIOTICS, AND SYNBIOTICS
Şeydanur GÜLCAN CEHRİ Assist. Prof. Dr. Halime Esra MERAM	*Dr. Ali Kemal Belviranlı Obstetrics and Gynecology Hospital, Konya TÜRKİYE* *Selçuk University TÜRKİYE*	THE RELATIONSHIP BETWEEN PERSONALITY TRAITS AND MARITAL SATISFACTION WITH THE ATTITUDES AND BELIEFS REGARDING ABOUT SEXUALITY AMONG PREGNAT WOMEN
Lect. Dr. Yılmaz ŞAHİN Prof. Dr. Mevlüt ALBAYRAK Prof. Dr. Ali ŞAHİN Lect. Korkmaz ŞERİFOĞLU	*Atatürk University TÜRKİYE*	CHEMOMETRIC ANALYSIS-ASSISTED RAMAN SPECTROSCOPY IN THYROID CANCER: AN INNOVATIVE APPROACH TO DETERMINING DIAGNOSIS AND TREATMENT EFFICACY
Lect. Dr. Yılmaz ŞAHİN Prof. Dr. Mevlüt ALBAYRAK Prof. Dr. Ali ŞAHİN Lect. Korkmaz ŞERİFOĞLU	*Atatürk University TÜRKİYE*	CHEMOMETRIC ANALYSIS-ASSISTED FOURIER TRANSFORM INFRARED SPECTROSCOPY (FTIR) IN THYROID CANCER: AN INNOVATIVE APPROACH TO DETERMINING DIAGNOSIS AND TREATMENT EFFICACY
Dr. Mehtiyeva Shahla Namig Qasimova Gulnara Nisan Dr. Ismayilova Samira Juma Dr. Huseynzade Kheyransa Rasif Aliyev Fariz Nazim Dr. Karimova Rena Jabbar	*Azerbaijan Medical University AZERBAIJAN*	TREATMENT OF MYASTHENIC SYNDROME AFTER BOTOX AND HYPERTHYROIDISM
Dr. Mehtiyeva Shahla Namig Dr. Huseynzade Kheyransa Rasif Dr. Aliyeva Hokuma Ali Dr. Mammadova Gunel Gulu Abaszade Zumrud Amirgulu Dr. Karimova Rena Jabbar	*Azerbaijan Medical University AZERBAIJAN*	GLUCOSE DURATION IN THE RANGE AND PERIPHERAL NEUROPATHY IN TYPE 2 DIABETES AND CHRONIC KIDNEY DISEASE

ONLINE PRESENTATIONS

08.02.2025 / HALL-5 / SESSION-2

PARIS LOCAL TIME	ANKARA LOCAL TIME
$10^{30} : 12^{30}$	$12^{30} : 14^{30}$

HEAD OF SESSION: Dr. Eda Tabaku

AUTHORS	AFFILIATION	TOPIC TITLE
Amal Bassam Rajaa Bassam Mohammed Hfid Hamid Saufi Said Belaaouad	*Hassan II University of Casablanca MOROCCO* *Mohammed V University of Rabat MOROCCO* *Hassan II University of Casablanca MOROCCO*	PREPARATION OF WASTE RED CLAY-BASED POROUS GEOPOLYMER FOAM AS AN EFFECTIVE ADSORBENT FOR THE REMOVAL OF METHYL ORANGE DYE FROM AQUEOUS SOLUTION
G.K.N. Jayathissa	*Kelaniya University SRI LANKA*	A STUDY OF THE PRACTICAL IMPORTANCE OF TREES, RECOMMENDED TO BE PLANTED IN A HOUSE ACCORDING TO EASTERN ARCHITECTURE
Bochra BOUDJELLAL Assoc. Prof. Dr. Abdelkrim MEBARKI Prof. Dr. Sarra Samra BENHARRATS	*University of Science and Technology of Oran ALGERIA* *Oran University 1 ALGERIA*	VR SCENARIO RULES FOR COGNITION ASSESSMENT APPS
Dr. Mohamed HATIMI Rachid ECHARGHAOUI	*Ibn Tofail University MOROCCO*	A P-LAPLACIAN ELLIPTIC SYSTEM WITH STRONGLY COUPLED CRITICAL TERMS AND CONCAVE-CONVEX NONLINEARITIES
Patrícia Antunes Sandra Ferreira Dário Ferreira	*Beira Interior University PORTUGAL*	OPTIMAL ESTIMATION OF HIGHER-ORDER CUMULANTS IN BI-ADDITIVE STATISTICAL MODELS
Dr. Eda Tabaku Dr. Ejona Duçi Assoc. Prof. Dr. Rinela Kapçiu Assoc. Prof. Dr. Robert Kosova	*Aleksandër Moisiu University ALBANIA*	DEVELOPMENT AND IMPLEMENTATION OF A FRAME-BASED EXPERT SYSTEM FOR ADVANCED ANALYSIS OF RESOURCE CONVERSION PROCESSES
Khalida DERRADJI Leila SMAIL Karima OULBACHIR Mostefa KOUADRIA Abdelkrim HASSANI	*Ibn Khaldoun University of Tiaret MOROCCO*	BIOLOGICAL CONTROL OF GRUB WORMS WHICH ATTACK THE ROOTS OF CROPS
Aminu A. Idris H. Y. Muhammad A. A. Baba A. A. Garba S. Sabo H. M. Kabir H. M. Ladan I. I.	*Bayero University NIGERIA* *Trypanosomiasis Institute NIGERIA*	PHYTOCHEMICAL SCREENING AND ANTI TRYPANOSOMAL ACTIVITY OF Ocimum gratissimum (Scent Leaf)

ONLINE PRESENTATIONS

08.02.2025 / HALL-4 / SESSION-3

PARIS LOCAL TIME	ANKARA LOCAL TIME
13 00 : 15 00	15 00 : 17 00

HEAD OF SESSION: Dr. Elisa MACCARI

AUTHORS	AFFILIATION	TOPIC TITLE
Dr. Elisa MACCARI Dr. Rodolfo REDA Dr. Alessio ZANZA Dr. Dario DI NARDO Dr. Andrea MORGANTE Alessandro AULETTA Giuseppe FERRI Gualtiero GHERARDI Prof. Dr. Luca TESTARELLI	*Sapienza University ITALY*	CLINICAL AND BIOCHEMICAL OUTCOMES IN SOFT TISSUE WITH MACHINED ABUTMENTS VS LASER-MICROGROOVED ONES
Gaurav Dhaked Aarti jangir Dr. Vishakha Singh	*Maharana Pratap University INDIA* *Chaudhary Charan Singh Haryana Agricultural University INDIA* *Maharana Pratap University INDIA*	FORTIFIED FOODS: A PATHWAY TO SUSTAINABLE GLOBAL FOOD SECURITY AND NUTRITION
Ruben S Rukadikar Dr. Firoj A Tamboli	*Bharati Vidhapeeth's College INDIA*	SUSTAINABLE GREEN SYNTHESIS OF NANOPARTICLES: A COMPREHENSIVE OVERVIEW
Dr. Vinesh Vijayan Kalvin Paul K. Yuvashiga Dr. S. Kalaiselvan	*Rathinam Technical Campus INDIA*	AGENT-BASED SWARMING SYSTEMS: THEORETICAL FOUNDATIONS, SIMULATIONS, AND APPLICATIONS IN PATTERN FORMATION AND TURBULENT FLUID DYNAMICS
Kondala Monika Dr. Mona Verma	*Chaudhary Charan Singh Haryana Agricultural University INDIA*	SUSTAINABLE TEXTILE SOLUTIONS: THE EFFICACY OF NATURAL DYES AND ESSENTIAL OILS IN UV PROTECTION
Kondala Monika Dr. Saroj S. Jeet Singh	*Chaudhary Charan Singh Haryana Agricultural University INDIA*	FROM SERICULTURE TO TEXTILES: THE MULTIFACETED APPLICATIONS OF SILK SERICIN
Shivani Malik Dr. Bhumika Sharma Dr. Harish Kumar Verma	*Galgotias University INDIA* *Sharda University INDIA* *ICFAI University INDIA*	IMPACT OF MENSTRUAL PRODUCTS ON ENVIRONMENT: CHALLENGES AND ALTERNATIVES
Mounir GAHGAH Azzedine BOUZAOUIT Haitem SEBBAGH Chouaib ZEGHIDA	*Skikda University ALGERIA* *Cherif M,Saadia University ALGERIA*	STUDY OF THE OPERATIONAL SAFETY OF A SAFETY INSTRUMENTED SYSTEM (SIS) IN AN INDUSTRIAL ENVIRONMENT

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SUSTAINABLE CONCRETE SOLUTIONS: ADVANCEMENTS IN ECO-FRIENDLY MATERIALS AND PRACTICES

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Abstract

The shift from traditional Portland cement (PC) to supplementary cementitious materials (SCMs) is a key strategy for reducing the environmental impact of concrete production. Concrete is the second most widely used material globally, with over 10 billion cubic meters produced annually. The production of PC is a major source of CO2 emissions due to the energy-intensive process of heating raw materials. SCMs like ground granulated blast furnace slag (GBFS), metakaolin (MK), silica fume (SF), and fly ash (FA) offer promising alternatives. These materials not only reduce reliance on PC but also improve concrete's strength, durability, and workability. For example, GBFS enhances concrete's mechanical properties, SF increases density and strength, and FA reduces CO2 emissions while improving mix workability. Using SCMs leads to more durable and sustainable concrete, reducing maintenance costs and supporting circular economy principles by reusing industrial by-products. This transition to SCMs significantly lowers the carbon footprint of concrete production while enhancing its overall performance and longevity.

Keywords: Sustainable Concrete Technologies, Low-Carbon Concrete Innovations, Eco-Friendly Construction Materials

INTRODUCTION

As industrialization progresses, the growing demand for energy has raised significant environmental concerns, particularly due to our reliance on fossil fuels. This dependency has led to a rise in greenhouse gas emissions and the depletion of natural resources. In response, there is an increasing focus on incorporating waste materials into industrial processes to enhance sustainability and minimize environmental impact [1]. Concrete, a vital material in infrastructure and construction, stands as a key area where such changes are urgently needed. Its widespread use in everything from residential buildings to large-scale infrastructure projects makes sustainable practices in concrete production crucial. However, concrete production is a major source of global CO2 emissions, with the manufacturing of Portland cement (PC), a primary ingredient, being a significant contributor [2]. The production of traditional Portland cement is highly energy-intensive, accounting for about 5% of global CO2 emissions [3]. The process involves heating limestone and other raw materials to extreme temperatures, relying heavily on fossil fuels. For every ton of clinker produced, approximately one ton of CO2 is emitted. Given that concrete is the second most consumed material worldwide, the environmental impact of its

production is considerable, highlighting the need for reform in concrete manufacturing [4]. To mitigate these impacts, the construction industry is increasingly turning to alternatives to traditional Portland cement. Supplementary Cementitious Materials (SCMs) such as ground granulated blast furnace slag (GBFS) [5-7], silica fume (SF) [8-10], and fly ash (FA) [11-13] offer promising solutions. These materials not only help reduce the carbon footprint of concrete but also improve its performance, making them essential components in the push for more sustainable construction practices.

Exploring Common Supplementary Cementitious Materials in Modern Construction

Ground Granulated Blast Furnace Slag (GBFS) is a by-product of steel manufacturing, specifically from blast furnaces. It is produced by rapidly cooling molten iron slag with water or steam, resulting in a fine, glassy powder that can be used as an additive in concrete [14]. The inclusion of GBFS in concrete offers both environmental and performance advantages. From an environmental perspective, GBFS reduces the need for Portland cement, thereby lowering CO2 emissions associated with cement production. When combined with calcium hydroxide in concrete, GBFS undergoes a pozzolanic reaction, producing additional calcium silicate hydrate, which improves the strength and durability of the concrete. This process enhances the material's mechanical properties and boosts its resistance to environmental challenges such as sulfate attack and chloride-induced corrosion. In addition to these benefits, GBFS also improves the workability of concrete and reduces the heat generated during the curing process, which is especially beneficial in large-scale construction projects where temperature control is critical. The incorporation of GBFS not only contributes to more sustainable concrete production but also enhances the long-term performance of concrete structures [15]. Silica fume (SF), also referred to as microsilica, is a by-product of the production of silicon metal and ferrosilicon alloys [16]. It consists of ultra-fine particles that can fill the gaps between cement particles in concrete, leading to significant improvements in its properties. When incorporated into concrete, silica fume enhances its density and compressive strength. The very fine particles facilitate a more efficient hydration process by providing additional nucleation sites for the formation of calcium silicate hydrate (C-S-H), the key compound responsible for binding the components of concrete [17]. This results in a denser, stronger, and more durable concrete structure. SF also improves the concrete's resistance to chemical deterioration, including attacks from acids and sulfates, making it ideal for use in aggressive or chemically challenging environments. Moreover, its addition reduces the permeability of the concrete, which helps prevent issues related to water infiltration, such as corrosion of reinforcement or freeze-thaw damage. Overall, the inclusion of SF not only strengthens the concrete but also significantly enhances its durability, making it a valuable material for projects where long-term performance and resilience are essential. Fly ash (FA) is a by-product from coal combustion in power plants, collected from flue gases [18]. When used in concrete, it partially replaces Portland cement, offering both performance and environmental benefits. Fly ash reacts with calcium hydroxide in the mix to form additional calcium silicate hydrate (C-S-H), enhancing concrete's strength and density. It also improves the workability of fresh concrete, making it easier to handle and finish. Moreover, fly ash reduces the heat generated during curing, which is especially useful for large concrete pours [19].

Using fly ash in place of Portland cement lowers CO2 emissions from concrete production, helping to reduce the carbon footprint. Overall, fly ash not only strengthens and improves the workability of concrete but also supports more sustainable construction practices [20].

Enhancing Concrete Sustainability: Environmental and Performance Gains with SCMs

The use of Supplementary Cementitious Materials (SCMs) in concrete offers both environmental and performance advantages. Environmentally, SCMs reduce the need for Portland cement,

lowering CO2 emissions and decreasing the carbon footprint of concrete production. They also contribute to sustainability by repurposing industrial by-products, such as fly ash or slag, that would otherwise end up as waste. From a performance perspective, concrete with SCMs typically exhibits improved strength, durability, and resistance to environmental stresses. For example, SCM-enhanced concrete is more resistant to sulfate attacks, acid corrosion, and chloride penetration, leading to longer-lasting structures. These improvements result in reduced maintenance requirements, supporting sustainable construction practices. Additionally, SCMs enhance the workability and reduce the permeability of concrete, making it ideal for applications that demand high durability, such as large infrastructure projects. Economically, the use of SCMs can lead to cost savings by extending the lifespan of structures and reducing the need for repairs and maintenance over time. This combination of environmental, performance, and economic benefits makes SCMs a key element in advancing more sustainable and resilient concrete construction.

Figure 1: Visual Properties of Waste Materials Used in the Concrete Mix Design [21].

Integrating Sustainable Materials and Methods in Construction

The use of Supplementary Cementitious Materials (SCMs) in concrete production marks a crucial step toward more sustainable construction practices. By incorporating materials like Ground Granulated Blast Furnace Slag (GBFS), Silica Fume (SF), and Fly Ash (FA), the industry can reduce its reliance on Portland cement, thereby lowering the environmental impact of concrete production. This shift aligns with broader sustainability objectives and contributes to global efforts to mitigate climate change.

SCMs also support the principles of a circular economy by repurposing industrial by-products that would otherwise be wasted, reducing landfill use and conserving natural resources. This approach not only addresses immediate environmental concerns but also promotes long-term sustainability by minimizing raw material depletion and reducing the overall carbon footprint of construction activities.

For stakeholders in the construction sector, recognizing and adopting SCMs is essential for fostering environmentally responsible building practices. By making informed choices about the

materials used in concrete, we can contribute to a sustainable future and help advance climate-conscious construction.

In summary, the transition from traditional Portland cement to SCMs such as GBFS, SF, and FA represents a major opportunity to reduce CO2 emissions, improve concrete performance, and support a circular economy. Embracing these materials helps create a greener, more resilient built environment, addressing the urgent challenges of climate change while promoting sustainability in the construction industry.

CONCLUSION

Concrete is a fundamental material in modern construction, known for its durability and versatility. However, its heavy reliance on Portland cement (PC) presents both environmental and economic challenges. The production of Portland cement is a major contributor to carbon dioxide (CO2) emissions, which accelerates global warming and raises construction costs. In response, there is an increasing shift toward using alternative materials that provide both environmental and economic benefits.

Supplementary Cementitious Materials (SCMs), such as Ground Granulated Blast Furnace Slag (GBFS), Fly Ash (FA), and Silica Fume (SF), are becoming popular substitutes for Portland cement. These materials not only help lower CO2 emissions but also enhance the sustainability of concrete production. GBFS, a by-product of steel manufacturing, improves concrete's strength, workability, and reduces the heat generated during curing, making it particularly useful in large-scale constructions. Fly ash, which comes from coal combustion, diverts waste from landfills and enhances concrete's durability by improving its resistance to sulfate attack and alkali-silica reactions. Silica fume, a by-product of silicon metal production, is made up of extremely fine particles that fill voids between cement particles, resulting in denser, more durable concrete with improved resistance to chemical attacks.

The use of SCMs not only helps reduce the carbon footprint of concrete but also improves the material's overall performance and extends the lifespan of structures, reducing the frequency of maintenance. This shift supports global sustainability efforts by encouraging the responsible use of resources and reducing waste.

As research continues to uncover new benefits of SCMs, collaboration between industry experts, researchers, and policymakers will be essential in scaling their use. The widespread adoption of SCMs in concrete production represents a significant step toward more sustainable building practices and a greener future for the construction industry.

Acknowledgment

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USING MULTI-CRITERIA DECISION MAKING METHODS IN THE SELECTION OF A PANDEMIC HOSPITAL'S LOCATION

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ABSTRACT

Introduction and Purpose: In order to prevent problems such as the inability to find hospital beds for patients and the epidemic getting out of control due to the increasing epidemics in recent years, the establishment of pandemic hospitals and the location of the place where they will be established are also of great importance. In the problem of selecting an establishment location where so many criteria come together, multi-criteria decision-making methods were used. In the study, it was aimed to find the region where the pandemic hospital could be used in the most effective and efficient way.

Materials and Methods: In order to determine in which region among the 7 regions of Turkey it would be more advantageous to establish a pandemic hospital, multi-criteria decision-making methods AHP and MULTIMOORA, AHP and TOPSIS methods were used together. The AHP method will be used to determine the weights in the problem. 7 basic criteria and 24 sub-criteria were determined in the problem. The basic criteria here are resources, transportation, geological situation, manpower resource, demographic structure, fixed assets and cost. Multi-criteria decision-making methods were compared with each other and it was revealed which region was the most advantageous in terms of which criteria.

Results: The Marmara region was found to be the most advantageous region for both methods used to solve the problem.

Discussion and Conclusion: Since the Marmara region is of great strategic importance, has a low average altitude and is the region with the highest population density, it is envisaged that a pandemic hospital to be opened here will provide many advantages to the region and the hospital will be used effectively.

Key Words: AHP, TOPSIS, MULTIMOORA

TRANSFORMATION OF DECISION MAKING PROCESSES IN THE DIGITAL AGE: REDEFINING BUSINESS INTELLIGENCE WITH AUTONOMOUS SYSTEMS, EDGE COMPUTING AND GENERATIVE AI

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ABSTRACT

Introduction and Purpose: The digital age has transformed data-driven decision-making, rendering traditional Business Intelligence (BI) systems insufficient to address the growing complexity of data. Technologies such as autonomous systems, edge computing, and Generative AI are reshaping BI by enabling faster and more adaptive processes. This study explores the transformative potential of these technologies and provides a roadmap for integrating them into organizational frameworks to enhance strategic decision-making.

Materials and Methods: The study evaluates the roles of autonomous systems, Generative AI, and edge computing in advancing BI capabilities. Autonomous systems reduce human intervention, fostering agility and efficiency. Generative AI, powered by natural language processing and deep learning, enhances BI with dynamic reporting, intuitive interfaces, and customized visualizations. Edge computing decentralizes data processing, ensuring real-time analytics and operational efficiency, particularly in IoT applications where low latency is essential.

An integrated analysis assesses the collective potential of these technologies to address challenges such as data security, scalability, and responsiveness. The study highlights their role in improving decision-making speed and reliability..

Results: Autonomous systems significantly enhance decision-making speed and accuracy, allowing businesses to adapt to dynamic environments. Generative AI improves user interactions and actionable insights, while edge computing ensures real-time data analysis and operational efficiency. These technologies collectively redefine BI, offering scalability and a competitive edge for organizations that adopt them..

Discussion and Conclusion: Integrating advanced technologies into BI systems enables organizations to meet the demands of the digital age. Combining autonomous systems, Generative AI, and edge computing creates a paradigm shift, characterized by faster, more accurate, and interactive decision-making. This transformation fosters sustainable growth and resilience, providing organizations with a clear competitive advantage in a data-driven environment.

Keywords: Business Intelligence, Digital Transformation, Generative AI, Autonomous Systems, Edge Computing, IoT, Strategic Decision Support

DECRYPTING GUEST EXPERIENCE WITH TEXT MINING: A CASE STUDY OF ISTANBUL HILTON HOTELS

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ABSTRACT

Introduction and Purpose: Customer satisfaction and experience play a critical role in the hospitality industry, and online reviews provide valuable insights into the quality of services offered. In this study, we aimed to analyze customer feedback from Tripadvisor reviews of Istanbul Hilton Hotels using advanced text mining techniques. The main objective was to identify key factors influencing customer satisfaction and dissatisfaction by employing sentiment analysis and topic modeling techniques. Specifically, the study explored recurring themes in positive and negative feedback and evaluated the effectiveness of hotel services based on these insights.

Materials and Methods: The dataset comprised 27,113 Tripadvisor reviews. Sentiment analysis utilized the DistilBERT-base-uncased-finetuned-sst-2-english model with 92.7% accuracy. Topic modeling employed Latent Dirichlet Allocation to extract themes. Analyses included: Overall sentiment classification (positive/negative), general topic modeling to identify key themes and separate topic modeling for positive and negative reviews at each hotel branch.

Results: Sentiment analysis revealed that 86% of reviews were positive (23,329), while 14% were negative (3,517). Positive comments praised buffet variety, personalized omelets, scenic views, and staff attentiveness. Negative feedback highlighted breakfast overcrowding and parking issues. Keywords like "rooms" and "reception" showed variability; some reviews lauded room quality and staff professionalism, while others criticized delayed check-ins and extended stay management. Recurring mentions of staff names in both positive and negative contexts provided actionable insights.

Discussion and Conclusion: The findings demonstrate that sentiment analysis and topic modeling are effective tools for evaluating customer feedback. Addressing recurring complaints, such as breakfast and reception issues, could enhance customer satisfaction. Advanced text mining techniques enable hotel management to identify key concerns and develop targeted strategies to improve service quality and customer loyalty.

Keywords: Text mining, sentiment analysis, topic modelling, customer satisfaction, hotel management, Tripadvisor, Hilton hotels

RENEWABLE ENERGY SOURCES WITHIN THE SCOPE OF SUSTAINABLE ENERGY

SÜRDÜRÜLEBİLİR ENERJİ KAPSAMINDA YENİLENEBİLİR ENERJİ KAYNAKLARI

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ÖZET

Yenilenebilir enerji, zaman içinde doğal olarak yenilenebilen kaynaklardan enerji üretimidir. Sürdürülebilir enerji ise tüketildiğinden daha hızlı kendini yenileyebilen kaynaklardan enerji üretimidir. Fosil yakıtlarının doğayı tehdit etmesi ve sınırlı olması, doğayı koruyan ve sürdürülebilir olan yenilenebilir enerji kaynaklarının önemini her geçen gün artırmaktadır. Bu çalışmada sürdürülebilirliğin sağlanmasında yenilenebilir enerji kaynaklarının önemi araştırılmıştır. Güneş enerjisi, güneşin çekirdeğinde meydana gelen hidrojeni helyum gazına dönüştürücü füzyon reaksiyonu sonucunda ortaya çıkan bir enerji türüdür. Rüzgar enerjisi, kaynağının güneş olması sebebiyle doğal olaylar neticesinde kendiliğinden meydana gelen ve yenilenebilen bir enerji türüdür. Jeotermal enerji, yerkabuğunun derinliklerindeki ısının yer altı sularını ısıtması sonucunda ısınan suyun yeryüzüne çıkmasıyla oluşan bir enerji türüdür. Hidrolik enerji, pek çok enerji kaynağında olduğu gibi güneş kaynaklı bir enerji olup doğal su çevrimi sonucunda oluşmaktadır. Bitki ve hayvan atıkları biyokütle enerjisinin kaynağıdır. Odun, tarımsal ürünler, tarımsal yan ürünlerin atıkları, hayvan atıkları, belediye katı atıkları, atıksu arıtma tesislerinden çıkan arıtma çamurları, gıda işlemeden kaynaklanan atıklar, su bitkileri ve algler biyokütlenin en önemli kaynaklarıdır. Güneş, rüzgar, hidroelektrik ve jeotermal enerji hem yenilenebilir hem de sürdürülebilirken, biyokütlenin sürdürülebilirliği, üretim ve kullanım süreçlerinde uygulanan yöntemlere bağlıdır. İklim değişikliğinin sonuçlarının hafifletilmesinde en etkili yöntemlerden birisi rüzgar, güneş gibi yenilenebilir enerji kaynaklarına yatırımı arttırmaktır. Ayrıca yenilenebilir enerji kaynakları, enerji temininde dışa bağımlığı büyük oranda ortadan kaldırma potansiyeline de sahiptir. Sonuç olarak yaşamın sürdürülebilirliğinin sağlanması ve ekonomik kayıpların ortadan kaldırılması için iklim değişikliliğinin önlenmesi ve etkilerinin azaltılması bu kaynakların etkin ve verimli kullanımı kritik önem taşımaktadır.

Anahtar Kelimeler: Yenilenebilir enerji; Sürdürülebilirlik; Küresel ısınma; İklim değişikliği

ABSTRACT

Renewable energy is the generation of energy from resources that are naturally replenished over time. Sustainable energy, on the other hand, refers to the production of energy from sources that can regenerate themselves faster than they are consumed. The threats posed by fossil fuels to the environment and their limited nature have increasingly highlighted the importance of renewable energy sources, which are both environmentally friendly and sustainable. This study

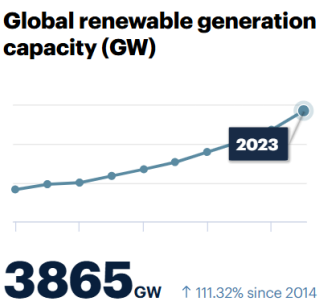
examines the significance of renewable energy sources in ensuring sustainability. Solar energy: It is a form of energy generated through fusion reactions in the sun's core, which convert hydrogen into helium gas. Wind energy: Since its source is the sun, it is a renewable energy type that occurs naturally as a result of atmospheric events. Geothermal energy: It is produced when heat from the Earth's crust warms underground water, causing it to rise to the surface. Hydraulic energy: Like many other energy sources, it is solar-based and arises from the natural water cycle. Biomass energy: Its sources include plant and animal waste. Key biomass sources are wood, agricultural products, agricultural residues, animal waste, municipal solid waste, sludge from wastewater treatment plants, food processing waste, aquatic plants, and algae. While solar, wind, hydroelectric and geothermal energy are both renewable and sustainable, the sustainability of biomass depends on the methods applied in its production and use processes. One of the most effective strategies for mitigating the impacts of climate change is increasing investments in renewable energy sources such as wind and solar. Additionally, renewable energy sources have significant potential to reduce dependency on external energy supply. In conclusion, preventing climate change and mitigating its effects through the efficient and effective use of these resources is critical for ensuring the sustainability of life and eliminating economic losses.

Key Words: Renewable energy; Sustainability; Global warming; Climate change

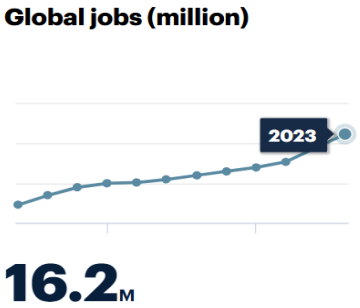
GİRİŞ

Artan enerji talebi, küresel olarak meydana gelen önemli nüfus ve ekonomik büyümenin bir sonucudur. Herhangi bir ulusun sanayi devrimi büyük ölçüde güç üretimine bağlıdır. Fosil yakıtlar uzun zamandır birincil enerji kaynağı olmuştur, ancak bunlar sonludur ve sonunda tükenecektir. Bu, geleneksel kaynakların gelecekte artan enerji talebini karşılama yeteneği konusunda ciddi endişeler yaratmaktadır. Bu geleneksel kaynakları (fosil yakıtlar) kullanmanın başlıca olumsuz etkisi, küresel ısınma ve CO_2 emisyonlarındaki artıştır (Çıtak ve Pala 2016, Çevik vd. 2017). Artan sayıda çevresel sorun göz önüne alındığında, yenilenebilir enerji kaynakları bu geleneksel kaynakların yerini almaya en olası adaylardır. Artan sera gazı emisyonları, çevresel sorunlar ve artan sıcaklıklar nedeniyle, dünyanın enerji yapısı geleneksel enerjiden yenilenebilir enerjiye geçmelidir. Fosil yakıtların yerini alacak en umut verici yenilenebilir enerji kaynakları arasında biyokütle, jeotermal, hidro, güneş ve rüzgar enerjisi yer almaktadır (Şenpınar ve Gençoğlu 2006).

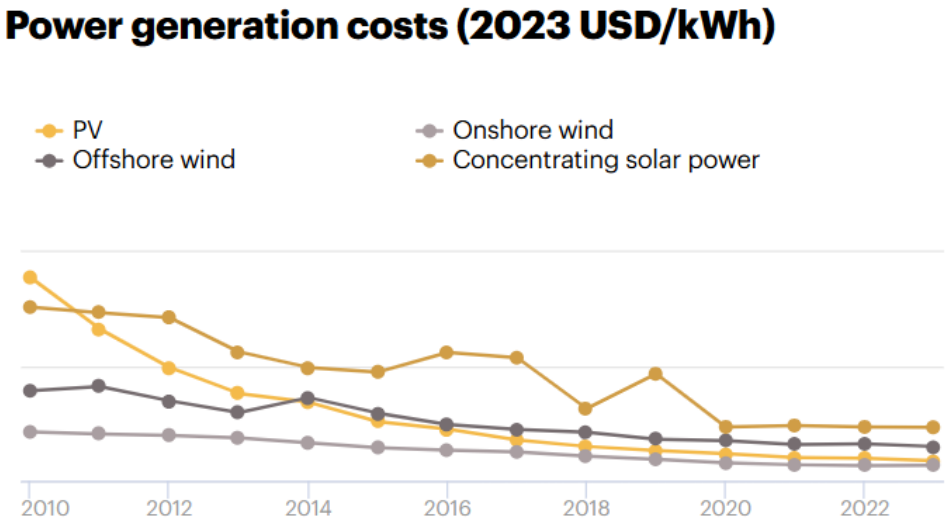
Şekil 1'de Dünya'da yenilenebilir enerji kapasite, istidam ve enerji maliyetlerinin yıllara göre değişimleri verilmiştir (IRENA, 2024). 2014 yılında 1829 GW olan yenilenebilir enerji üretim kapasitesi 2023 yılında 3865 GW'a ulaşmıştır. 2012 yılında yenilenebilir enerji sektöründe 7.3 Milyon kişi istihdam edilirken, 2023 yılında 16.2 Milyona ulaşmıştır. PV maliyetleri; 2010 yılında 0.445 USD/kWh iken 2023 yılında 0.044 USD/kWh olmuştur. Onshore rüzgar maliyetleri; 2010 yılında 0.107 USD/kWh iken 2023 yılında 0.034 USD/kWh olmuştur. Offshore rüzgar maliyetleri; 2010 yılında 0.197 USD/kWh iken 2023 yılında 0.075 USD/kWh olmuştur. Yoğunlaştırılmış güneş enerji sistemleri maliyetleri; 2010 yılında 0.38 USD/kWh iken 2023 yılında 0.117 USD/kWh olmuştur. Şekil 2'de ise Yenilenebilir elektrik üretimi değerleri Dünya ve Türkiye için verilmiştir (Internet, 2024).



(a) 2014-2023 yılları arası küresel yenilenebilir enerji kapasitesi (GW)

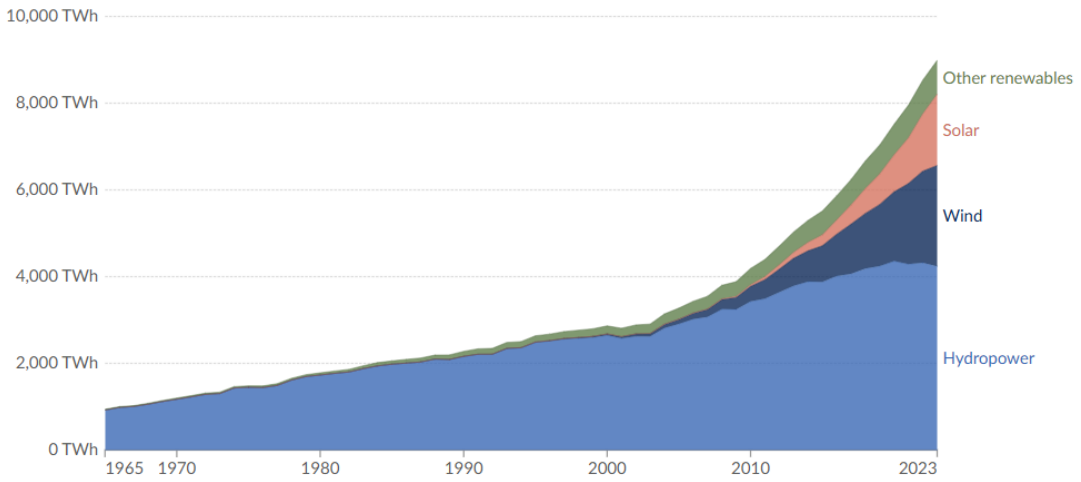


(b) 2012-2023 yılları arası küresel istihdam sayısı (milyon)

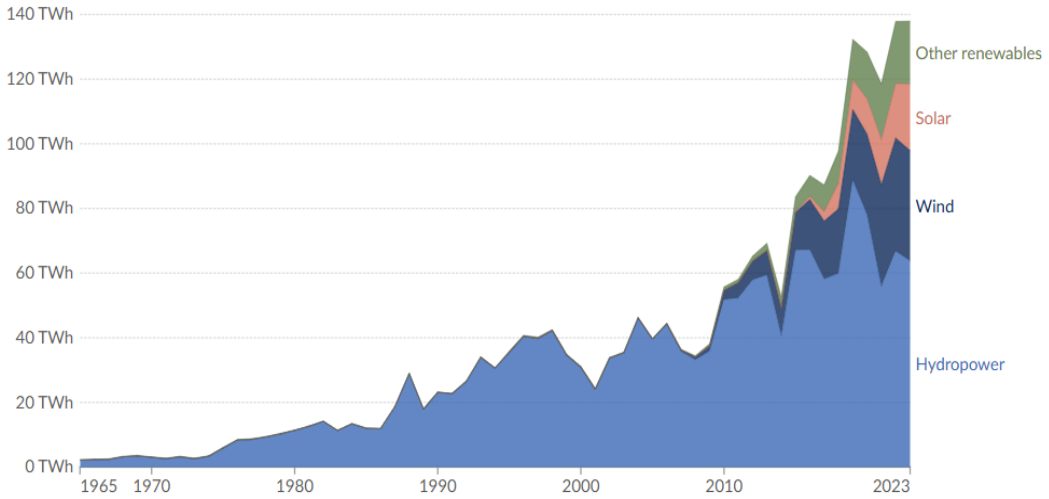


(c) 2010- 2023 yılları arası enerji maliyetleri (2023 USD/kWh)

Şekil 1. Dünyada yenilenebilir enerji kapasite (a), istihdam (b) ve enerji maliyetleri (c) değişimi.



(a) Yenilenebilir elektrik üretimi, Dünya



(b) Yenilenebilir elektrik üretimi, Türkiye

Şekil 2. Yenilenebilir enerjiden elektrik üretimi.

YENİLENEBİLİR ENERJİ KAYNAKLARI VE SÜRDÜRÜLEBİLİRLİK

Sürdürülebilir enerji kullanımı, bugünkü ihtiyaçları karşılamakla birlikte, gelecek nesillerin kendi gereksinimlerini karşılama olanaklarını riske atmadan bu dengeyi sağlamayı hedeflemektedir. Yenilenebilir ve sürdürülebilir enerji kaynakları, fosil yakıtlara bir alternatif olarak küresel iklim değişikliğiyle mücadelede önemli bir rol oynamaktadır. Bu enerji kaynakları, sera gazı emisyonlarını azaltmaya katkıda bulunarak çevresel etkileri en aza indirmektedir. Ancak, yenilenebilir enerjinin sürdürülebilir olması, kaynağın doğal yenilenme hızının üzerinde bir tüketim gerçekleşmemesine bağlıdır. Eğer enerji kaynakları, yenilenme hızlarının ötesinde kullanılmaya başlanırsa, bu kaynakların sürdürülebilirliği tehlikeye girmektedir. Özetle, yenilenebilir enerji kaynaklarının sunduğu enerji miktarı belirli bir zaman diliminde sınırlıdır. Bu kaynakların hasat oranı, doğal yenileme hızını aşmadığı sürece sürdürülebilirliği devam eder (Öymen 2020).

GÜNEŞ ENERJİSİ

Güneş enerjisi, en önemli sürdürülebilir enerji kaynaklarından biri olarak kabul edilir (Emeksiz ve Fındık 2021). Bunun nedeni, güneşin Dünya'ya sağladığı enerjinin tükenmez, temiz ve uzun vadeli bir kaynak olmasıdır. Ancak sürdürülebilirlik, güneş enerjisi sistemlerinin üretim, kullanım ve geri dönüşüm süreçleri dahil olmak üzere tüm yaşam döngüsü boyunca değerlendirilmelidir.

Güneş Enerjisinin Sürdürülebilirliği

Yenilenebilirlik: Güneş enerjisi, güneşin varlığına bağlıdır ve pratikte tükenmez bir kaynaktır. Bilimsel tahminlere göre güneş, en az 5 milyar yıl daha enerji yaymaya devam edecektir. Güneş enerjisinin yenilenebilir olması, onu sürdürülebilir bir enerji kaynağı yapar.

Karbon Ayak İzi ve Çevresel Etki: Güneş panelleri elektrik üretirken hiçbir karbon emisyonu veya zararlı gaz salınımı yapmaz. Ancak, güneş panellerinin üretim süreçleri sırasında enerji tüketimi ve sera gazı salınımı gerçekleşebilir. Bu etkiler, yenilenebilir enerjiye geçiş sürecindeki genel kazançlarla kıyaslandığında oldukça düşüktür.

Enerji Verimliliği ve Teknolojik Gelişmeler: Güneş panellerinin verimliliği sürekli olarak artmaktadır. Bu, daha az malzeme ve alan kullanılarak daha fazla enerji üretilebileceği anlamına gelir. Teknolojik gelişmeler, daha çevre dostu üretim yöntemlerini ve uzun ömürlü güneş panellerini mümkün kılmaktadır.

Atık Yönetimi ve Geri Dönüşüm: Güneş panellerinin ömrü genellikle 20-30 yıl arasındadır. Bu süre sonunda panellerin geri dönüşümü sürdürülebilirlik için kritik bir öneme sahiptir. Panel üretiminde kullanılan malzemelerin (örneğin, silikon ve metaller) geri dönüştürülmesi üzerinde çalışmalar devam etmektedir. Daha etkili geri dönüşüm yöntemleri, gelecekte güneş enerjisini daha sürdürülebilir hale getirecektir.

Yerel ve Küresel Kullanım: Güneş enerjisi, bölgesel bağımsızlık sağlar. Güneş potansiyeli olan her yerde kullanılabilir ve enerji güvenliğini artırır. Fosil yakıtların taşınması ve işlenmesi sırasında oluşan çevresel zararlar, güneş enerjisinde ortadan kalkar.

RÜZGAR ENERJİSİ

Rüzgar enerjisi, sürdürülebilir enerji kaynakları arasında yer alır çünkü tükenmez, çevre dostu ve uzun vadede enerji üretimi için ideal bir kaynaktır (Emeksiz ve Fındık 2021). Ancak, sürdürülebilirlik değerlendirilirken rüzgar türbinlerinin üretimi, işletimi ve ömrü sonundaki geri dönüşüm süreçleri de dikkate alınmalıdır.

Rüzgar Enerjisinin Sürdürülebilirliği

Yenilenebilirlik: Rüzgar, doğal hava hareketlerinden kaynaklanır ve sürekli yenilenir. Atmosferdeki hava akışları durmadığı sürece rüzgar enerjisi tükenmez bir enerji kaynağıdır. Bu özelliği, rüzgar enerjisini uzun vadeli bir enerji çözümü haline getirir.

Karbon Emisyonu ve Çevresel Etki: Rüzgar enerjisi, elektrik üretimi sırasında hiçbir karbon emisyonu yapmaz. Rüzgar türbinlerinin üretim ve kurulum süreçlerinde karbon ayak izi oluşabilir; ancak türbinlerin enerji üretimi sırasında sağladığı düşük emisyonlarla bu etki hızlıca

dengelenir. Araştırmalar, rüzgar türbinlerinin kurulum sırasında harcanan enerjiyi birkaç ay içinde telafi ettiğini ve ömürleri boyunca net bir karbon azaltımı sağladığını göstermektedir.

Enerji Verimliliği ve Süreklilik: Rüzgar türbinleri, enerji verimliliği yüksek olan teknolojiler arasındadır. Modern türbinler düşük rüzgar hızlarında bile enerji üretebilir. Ancak, rüzgar hızı düzensiz olduğundan enerji üretimi yerel hava koşullarına bağlıdır. Bu durum, enerji depolama teknolojilerinin önemini artırır.

Kaynak Yönetimi ve Alan Kullanımı: Rüzgar türbinleri geniş alanlara kurulabilir, ancak aynı alanlar tarım ve hayvancılık gibi diğer faaliyetlerle paylaşılabilir. Türbinlerin kurulumunun bazı doğal habitatları etkileyebileceği göz önünde bulundurulmalıdır. Bu nedenle, çevresel etkilerin değerlendirilmesi ve doğru alan seçimi önemlidir.

Atık Yönetimi ve Geri Dönüşüm: Türbinlerin ömrü genellikle 20-25 yıl arasındadır. Kullanım ömrü sonunda türbin kanatlarının ve diğer bileşenlerin geri dönüşümü sürdürülebilirlik açısından bir zorluktur. Kanatların geri dönüşümü halen teknolojik ve ekonomik zorluklar içeriyor olsa da, bu alanda geri dönüşüm yöntemleri hızla gelişmektedir.

JEOTERMAL ENERJİ

Jeotermal enerji, sürdürülebilir enerji kaynakları arasında kabul edilir çünkü doğru yönetildiğinde çevre dostu ve uzun vadeli bir enerji kaynağıdır (Emeksiz ve Fındık 2021). Bununla birlikte, sürdürülebilirliğini belirleyen birkaç faktör vardır.

Jeotermal Enerjinin Sürdürülebilirliği

Yenilenebilirlik: Jeotermal enerji, Dünya'nın doğal ısısını kullanır. Bu ısı, yer kabuğundaki radyoaktif elementlerin sürekli bozunumu sayesinde sürekli olarak yenilenir. Doğru yönetildiği takdirde, jeotermal rezervuarların enerji üretim kapasitesi uzun yıllar korunabilir.

Karbon Emisyonu: Jeotermal enerji, diğer fosil yakıtlara kıyasla oldukça düşük karbon salınımına sahiptir. Bu, onu çevre açısından sürdürülebilir kılar. Ancak bazı durumlarda, jeotermal kuyularından çıkan karbondioksit ve metan gibi gazlar çevreye salınabilir. Bu salınımlar, genellikle kontrol edilebilir seviyededir.

Doğal Kaynakların Yönetimi: Jeotermal rezervuarlar aşırı tüketilirse, su ve ısı kaybı yaşanabilir. Bu nedenle, sürdürülebilir yönetim stratejileri uygulanmalıdır (örneğin, üretim sonrası suyun rezervuara yeniden enjekte edilmesi).

Çevresel Etkiler: Jeotermal tesislerin kurulumu sırasında, habitat değişiklikleri ve çevresel etkiler görülebilir. Ancak bu etkiler genellikle diğer enerji kaynaklarına kıyasla daha azdır. Su kullanımı ve yer altı sularının kirlenme riski de dikkatle yönetilmelidir.

Uzun Ömür: İyi planlanan jeotermal projeler, yüzlerce yıl enerji sağlayabilir. Bunun için, rezervuarların sürdürülebilir kullanımı önemlidir.

HİDROLİK ENERJİ

Hidrolik enerji (hidroelektrik enerji), dünyanın en eski ve en yaygın kullanılan yenilenebilir enerji kaynaklarından biridir (Emeksiz ve Fındık 2021). Su döngüsüne dayandığı için teorik olarak tükenmez bir enerji kaynağıdır ve sürdürülebilir olarak kabul edilir. Ancak, hidrolik

enerjinin sürdürülebilirliği, enerji üretiminde kullanılan yöntemlerin çevresel, sosyal ve ekonomik etkilerine bağlıdır.

Hidrolik Enerjinin Sürdürülebilirliği

Yenilenebilirlik: Hidrolik enerji, su döngüsüne dayalı olduğu için yenilenebilir bir enerji kaynağıdır. Güneşin etkisiyle okyanuslar, göller ve nehirlerdeki su buharlaşır, yağmur olarak tekrar yeryüzüne düşer ve su döngüsü devam eder. Bu, enerji üretimi için kullanılan suyun sürekli olarak yenilenmesini sağlar.

Karbon Emisyonu ve Çevresel Etki: Hidrolik enerji, enerji üretim sürecinde karbon emisyonu yapmaz, bu da onu çevre dostu bir enerji kaynağı yapar. Ancak, büyük barajların inşası sırasında fosil yakıt kullanımı nedeniyle karbon emisyonu oluşabilir. Ayrıca, baraj gölleri, organik maddelerin su altında kalması sonucu metan gazı salınımına neden olabilir. Bu çevresel etkiler, barajların tasarımı ve yönetimi ile minimize edilebilir.

Ekolojik Etkiler: Büyük barajlar, suyun doğal akışını keserek nehir ekosistemlerini etkileyebilir. Bu, balık göçleri, biyolojik çeşitlilik ve su kalitesi üzerinde olumsuz etkiler yaratabilir. Çevreye duyarlı hidroelektrik projeler ve balık geçitleri gibi çözümler, bu etkileri azaltabilir.

Enerji Sürekliliği ve Güvenilirlik: Hidrolik enerji, diğer yenilenebilir kaynaklara göre daha güvenilir ve sürekli bir enerji kaynağıdır. Nehirlerin debisi sabit olduğu sürece enerji üretimi süreklidir. Ancak, iklim değişikliği ve su kaynaklarının azalması, bazı bölgelerde hidroelektrik üretimi için risk oluşturabilir.

Sosyal ve Ekonomik Etkiler: Büyük baraj projeleri, yerel toplulukların taşınmasına ve yaşam alanlarının kaybına neden olabilir. Bu durum, sosyal ve ekonomik sorunlara yol açabilir. Öte yandan, hidroelektrik projelerinin uzun ömürlü olması, bölgesel kalkınmaya ve istihdama katkıda bulunabilir.

Geri Dönüşüm ve Uzun Ömür: Hidrolik enerji tesisleri, genellikle 50-100 yıl gibi uzun ömürlüdür. Bu süre boyunca düşük bakım maliyetleri ile enerji üretimi sağlar. Barajların bakım ve yenileme süreçleri, sürdürülebilirlik açısından önemlidir.

BİYOKÜTLE ENERJİSİ

Biyokütle enerjisi, sürdürülebilir enerji kaynakları arasında yer alabilir, ancak sürdürülebilirliği biyokütlenin üretimi, işlenmesi ve kullanımı süreçlerinde uygulanan yöntemlere bağlıdır (Emeksiz ve Fındık 2021). Biyokütle enerjisi, organik maddelerin (bitkiler, tarımsal atıklar, hayvansal atıklar ve odun gibi) yakılması, gazlaştırılması veya başka yollarla enerjiye dönüştürülmesiyle elde edilir.

Biyokütle Enerjisinin Sürdürülebilirliği

Yenilenebilirlik: Biyokütle, doğal süreçlerle sürekli yenilenebilir bir enerji kaynağıdır. Örneğin, tarımsal ürünlerin artıkları veya odun, tekrar üretilebilir. Ancak, biyokütlenin aşırı tüketimi ya da yenilenme hızını aşan bir kullanım, kaynakların tükenmesine veya ekosistemlerin zarar görmesine yol açabilir.

Karbon Ayak İzi: Biyokütlenin yanması sırasında karbon emisyonu oluşur. Ancak, bu süreçte salınan karbon, bitkilerin büyümesi sırasında atmosferden emdikleri karbonla dengelenebilir

(karbon döngüsü). Fosil yakıtlarla karşılaştırıldığında biyokütlenin karbon ayak izi genellikle daha düşüktür, ancak sürdürülebilir tarım ve orman yönetimi kritik öneme sahiptir.

Enerji Verimliliği: Biyokütle enerji sistemlerinin verimliliği, kullanılan teknolojiye ve yakıt türüne bağlıdır. Modern biyokütle enerji tesisleri, enerji üretiminde oldukça verimlidir. Ancak, biyokütlenin düşük enerji yoğunluğu, taşınması ve depolanmasında zorluklar yaratabilir.

Ekolojik ve Çevresel Etkiler: Aşırı biyokütle hasadı, toprak erozyonuna, ormansızlaşmaya ve biyolojik çeşitliliğin azalmasına yol açabilir. Tarımsal biyokütle üretimi, su tüketimi ve gübre kullanımı gibi faktörlerle çevresel sorunlara katkıda bulunabilir. Biyokütle atıklarının enerjiye dönüştürülmesi (örneğin, gübre veya tarımsal atıklar) çevresel faydalar sağlayabilir, çünkü bu atıkların kontrolsüz bırakılması metan gazı gibi güçlü sera gazlarının salınımına neden olabilir.

Sosyal ve Ekonomik Etkiler: Biyokütle enerji projeleri, kırsal alanlarda istihdam yaratabilir ve yerel ekonomiyi destekleyebilir. Ancak, biyokütle üretimi için ayrılan tarım arazileri, gıda üretimine rakip hale gelebilir ve gıda güvenliği sorunlarına yol açabilir (örneğin, biyoyakıt üretimi için mısır veya şeker kamışı yetiştirilmesi).

Atık Yönetimi ve Döngüsellik: Biyokütle enerjisi, atık yönetimi için etkili bir çözüm sunar. Organik atıkların enerjiye dönüştürülmesi, bu atıkların çevresel zararını azaltabilir. Döngüsel ekonomi ilkelerine uygun bir şekilde kullanıldığında, biyokütle enerji sistemleri sürdürülebilirliği artırır.

SONUÇLAR VE TARTIŞMA

Güneş enerjisi, yenilenebilir, temiz ve uzun vadeli bir enerji kaynağı olduğundan sürdürülebilir enerji kategorisinde yer alır. Ancak, sistemlerin üretimi, kullanımı ve geri dönüşüm süreçlerinde sürdürülebilirlik prensiplerine uygun hareket edilmesi, çevresel etkilerin minimuma indirilmesi açısından önemlidir. Teknolojik gelişmeler bu alandaki zorlukları aşmaya devam etmektedir.

Rüzgar enerjisi, düşük karbon emisyonları, yenilenebilir doğası ve uzun vadeli enerji üretimi potansiyeliyle sürdürülebilir bir enerji kaynağıdır. Ancak, türbinlerin çevresel etkileri, geri dönüşüm süreçleri ve enerji depolama sistemleri gibi konulara dikkat edilmesi gerekir. Teknolojik gelişmeler bu zorlukları aşmaya devam ederken, rüzgar enerjisi iklim değişikliğiyle mücadelede ve enerji geçişinde önemli bir rol oynamaktadır.

Jeotermal enerji sürdürülebilir bir enerji kaynağıdır, ancak çevresel etkilerinin azaltılması ve kaynakların dikkatli yönetimi önemlidir. Bu, sürdürülebilirlik açısından etkili ve uzun ömürlü bir enerji çözümü olmasını sağlar.

Hidrolik enerji, yenilenebilir, düşük karbon emisyonlu ve uzun vadeli enerji üretimi sağlayabilen sürdürülebilir bir enerji kaynağıdır. Ancak, çevresel ve sosyal etkilerinin yönetilmesi, projelerin sürdürülebilirliği açısından kritik öneme sahiptir. Daha küçük ölçekli ve çevre dostu hidroelektrik projeleri, bu sorunları azaltmak için bir çözüm olabilir. Teknolojik yenilikler ve daha iyi yönetim stratejileri, hidrolik enerjinin sürdürülebilirliğini artırmaya devam etmektedir.

Biyokütle enerjisi, doğru yönetildiği takdirde sürdürülebilir bir enerji kaynağıdır. Aksi halde değildir. Karbon nötr olma potansiyeli, atık yönetimindeki faydaları ve yenilenebilirliği gibi özellikleri nedeniyle sürdürülebilir enerji sistemlerinde önemli bir rol oynayabilir. Ancak, çevresel etkilerin minimize edilmesi, gıda üretimine olan etkilerin dikkatle değerlendirilmesi ve kaynakların dikkatli bir şekilde yönetilmesi gereklidir. Bu nedenle biyokütlenin sürdürülebilirliği, üretim ve kullanım süreçlerinde uygulanan yöntemlere bağlıdır.

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ENERGY, ENTROPY, AND EFFICIENCY: THERMODYNAMIC PRINCIPLES IN COMPUTER SCIENCE

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Abstract

A fundamental tenet of Physics is Thermodynamics, which governs energy transformations and entropy. This principle applies to all physical systems. Within the field of Computer Science, these fundamental concepts serve as the foundation for the design, operation, and optimization of computational systems. The purpose of this work is to investigate the meaning of energy, entropy, and efficiency in the field of computer science, with a particular emphasis on the implications these concepts have for the design of hardware, algorithmic efficiency, and sustainable computing. We want to bring attention to the rising significance of energy-aware computing in this day and age of large-scale data processing and artificial intelligence by bridging the gap between the principles of thermodynamics and contemporary computational theory.

Keywords: Energy, Entropy, Computation, Energy loss.

STUDY OF THE ENVIRONMENTAL STATE OF THE ARTIFICIAL LAKE IN THE AREA OF TC "KOSOVA A"

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Abstract

The Kosovo Energy Corporation is one of the most valuable and important manufacturing plants for the economy of the state of Kosovo, but it also has its negative side with an impact on environmental pollution and human health.

The Kosovo Energy Corporation (KEK) is a company that produces electricity by burning coal, leaving behind a large amount of ash, where the two thermal power plants "Kosova A and B", deposit the ash in the ash landfill in Mirash.

A lake has been created from the waters flowing from the ash residues of coal combustion that are deposited through the hydraulic system, which has taken on a blue color due to the basic content and the presence of various chemicals that come from the composition of the ash. Ash in its composition, in addition to other components, also contains heavy metals (Cr, Zn, Pb, Co, Fe, Ni) in the form of inorganic compounds.

The level of concentration of heavy metals is a major concern, because it creates the possibility of penetration into surface and groundwater, which endangers drinking water. Another problem is the contamination of the land surface around the landfill location. Therefore, this fact arouses curiosity and the will to research and assess the environmental situation in the area of the artificial lake, using water and silt as experimental tools.

To assess this, we analyzed the levels of potentially toxic elements (PTEs) in the samples (water and sediment) using Atomic Absorption Spectroscopy, (Atomic Absorber- AA, Spectrometer- S SERIES). The elements examined included; As, Zn, Fe, Al, Cu, Cd, Cr, Mn, Ni, and Pb.

Key Words: Artificial Lake, potentially toxic metals, TC "Kosova A", water, sediment, SAA Methode.

ANALYSIS OF TRACES OF HEAVY METALS IN SAMPLES OF FLOUR DOMESTIC AND IMPORTED

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ABSTRACT

The subject of this research study, have been analyzed and the concentration of heavy metals, such as: Cd, Cu, Fe, Ni, Cr, As, Co, Mn and Hg, in local and imported flour in Kosovo, which citizens use as basic food, in everyday life, also obtaining knowledge about the processes that are performed in local factories and import of flour, ranging from abroad. For the determination of heavy metals in samples of flour, we use the standard method for analysis - ICP-OES, as contemporary method. Samples of flour were taken in three site-sampling, such as: S1-Finesa-Devolli-Kososvo, which was acquired in Emona market, S2-Divella -Farina-Italia, which was acquired in Maxi market in Ulpian and S3-Riviera-Serbia, which is Interex buy in Pristine. All flour samples were taken according to the rules provided for sampling of powder samples, (flour milled-schist).

Keywords: Flour, heavy metals, Finesa, Divella, Riviera.

A LITERATURE REVIEW ON THE APPLICATION OF ACHINE LEARNING ALGORITHMS FOR RISK ASSESSMENT IN CONSTRUCTION PROJECTS: A FOCUS ON DELAY MANAGEMENT

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ABSTRACT

Introduction and Purpose: The increasing complexity of construction projects highlights the critical need for effective risk management methods to ensure project success. Among these risks, delays are particularly significant, often leading to substantial financial losses, disputes, and diminished outcomes. This paper reviews the application of machine learning (ML) algorithms in assessing risks in construction projects, with a particular focus on delay risks, to provide insights for improving delay risk management.

Materials and Methods: This paper reviews existing studies that apply ML algorithms to assess risks in construction projects, particularly delay risks. It focuses on the specific methods and algorithms used in these studies and evaluates their effectiveness in predicting risk levels. The paper also outlines approaches to improving the accuracy and efficiency of delay risk prediction using ML.

Results: This review identifies key findings on the application of ML in construction risk assessment and delay prediction: 1-ML enhances risk assessment by processing large datasets and identifying complex patterns. Techniques like Random Forest (RF), Artificial Neural Networks (ANN), and Gradient Boosting (GB) demonstrate high predictive accuracy; 2-ML models effectively predict delays caused by various factors within the construction industry. Integration with real-time data from Internet of Things (IoT) sensors and Building Information Modeling (BIM) further enhances accuracy; 3-Challenges such as data standardization, model interpretability, and scalability hinder ML adoption. Addressing these through hybrid models, Explainable Artificial Intelligence, and improved data integration can facilitate wider implementation.

Discussion and Conclusion: The debate highlights the advantages of integrating ML algorithms into construction project management strategies. This integration has the potential to significantly increase project success rates by delivering projects with greater efficiency, cost-effectiveness, and reliability. The paper also emphasizes further exploring hybrid ML models and real-time project data to improve delay risk management.

Key Words: Machine Learning, Delay Risk Management, Construction Projects, Predictive Analytics, Project Risk Assessment

INTRODUCTION

Importance of risk management in construction projects

The construction industry faces many risks that can significantly impact project success.[1] These risks stem from diverse factors, including unforeseen site conditions, design errors, material price fluctuations, contractor performance issues, and regulatory changes.[1] Construction risks can result in schedule delays, cost overruns, and quality defects, ultimately undermining the overall project performance.[1] Also, large-scale and complex construction projects are highly susceptible to various technical, sociopolitical, and business risks, making risk management a significant challenge for industry practitioners.[2] So, effective risk management has become a crucial aspect of project management in the construction industry.[3]

Risk Management Approaches

Researchers have proposed various approaches to address the risk management challenges in construction projects. The existing body of literature has emphasized the importance of a comprehensive risk management framework that encompasses identifying potential risks, assessing their likelihood and impact, and developing appropriate mitigation strategies to address these risks.[3,1] Therefore, the risk management process consists of four key stages: First, potential risks are identified based on project conditions and historical data. Next, both qualitative and quantitative analyses assess the likelihood and impact of these risks. Once assessed, mitigation strategies are developed and integrated into project planning. Finally, continuous monitoring ensures that risks are managed proactively throughout the project lifecycle.[4] This process typically includes the following stages: risk identification, qualitative and quantitative risk analysis, risk response planning, and risk monitoring and control.[5]

Overview of traditional risk management methods and their limitations

Conventional approaches to risk management in construction have often relied on a combination of expert judgment, historical data analysis, and qualitative assessment techniques, such as risk matrices, failure mode and effects analysis, and Monte Carlo simulation.[6] While these methods have been widely adopted, they have inherent limitations in their ability to effectively cope with the increasing complexity and uncertainty associated with modern construction projects.[6] A core problem is their inability to capture the dynamic and interrelated nature of construction risks fully, and they may fail to provide a comprehensive and data-driven assessment of risk probabilities and impacts.

Traditional risk assessment techniques struggle to address the complexity of modern construction projects due to three key limitations:

1. Subjectivity: They tend to depend heavily on the subjective perceptions and experiences of project managers and subject matter experts, which can introduce biases and inconsistencies in the risk assessment process.
2. Limited adaptability: Traditional methods often struggle to account for construction risks' dynamic and interconnected nature, which can evolve throughout a project.
3. Dependence on historical data: The reliance on historical data may limit the ability to anticipate and respond to emerging risks that have not been previously encountered.[6]

On the other hand, the growing complexity and multifaceted nature of contemporary construction projects have underscored the need for more advanced risk assessment techniques that can harness the power of data-driven analytics and cutting-edge analytical tools. Therefore, researchers and industry practitioners have increasingly focused on the potential of advanced analytical methods to enhance construction risk management.

Emerging Technologies in Risk Management

The limitations of traditional risk management approaches have led researchers to explore the potential of advanced analytical techniques to improve risk prediction in construction projects. Therefore, the construction industry has witnessed the emergence of various technologies that have the potential to enhance the effectiveness of risk management practices.[7] For instance, integrating BIM can help visualize and simulate construction processes, enabling the identification and assessment of potential risks at an early stage.[8] Similarly, sensor-based monitoring systems and real-time data analytics can provide project managers with valuable insights into site conditions, equipment performance, and worker safety, allowing for proactive risk mitigation.[9] Furthermore, the increasing adoption of artificial intelligence and ML algorithms can enable more accurate risk prediction and decision-making by analyzing historical project data and identifying patterns or correlations that may not be readily apparent to human decision-makers.[1]

ML is a subfield of artificial intelligence that enables computers to learn from data and make informed decisions without being explicitly programmed.[10] This approach has gained significant traction in the construction industry due to its ability to process large volumes of data, identify complex patterns, and make accurate predictions.[11] Compared to traditional risk assessment methods, ML offers several advantages:

1- Improved Accuracy: ML algorithms can analyze vast amounts of historical data, identify complex relationships, and make more accurate risk probabilities and impact predictions.

2- Enhance Adaptability: ML models adapt to new data over time, which enables projects to assess risks in real time. This approach ensures a flexible and proactive response to risks as the project evolves.

3- Reduced Subjectivity: ML models rely on data-driven analysis and reduce the influence of subjective biases and inconsistencies found in traditional expert-based approaches.

4- Scalability: ML techniques can be applied to large-scale construction projects, where the volume and complexity of data would be overwhelming for traditional risk management methods.

Objectives and research gap

While the adoption of ML in construction risk management is gaining prominence, the current research has largely concentrated on the development and application of ML models for various aspects of construction management, such as cost estimation,[12,13] and safety management.[14] Nevertheless, the specific application of ML for construction delay risk prediction and mitigation remains an area that needs further exploration.

Accordingly, this paper aims to provide a comprehensive review of the existing literature on the application of ML algorithms for risk assessment and delay management in construction projects. Specifically, this review seeks to: 1- explore the potential of ML techniques to enhance the accuracy and dynamism of construction risk assessment; 2- examine the existing research on the application of ML in construction delay prediction and mitigation; 3- identify the key challenges and opportunities associated with the implementation of ML-based risk management approaches in the construction industry.

This paper provides a structured review of ML applications in delay risk assessment, identifying key opportunities and challenges. By synthesizing current research, it aims to bridge the gap between theoretical advancements and practical implementation, guiding both academics and industry practitioners in leveraging ML for improved risk management.

METHODOLOGY

This literature review was conducted by systematically searching for relevant academic publications on the application of ML in construction risk management and delay prediction. The online databases used to identify the relevant sources are Web of Science, Scopus, and Google Scholar. The keywords used in the search included: “machine learning”, “construction”, “risk management”, “delay prediction”, “delay mitigation”, and “construction 4.0”. To ensure the relevance and currency of the information, the search results were filtered to include only peer-reviewed journal articles and conference papers published in recent years.

The study selection process involved a three-stage screening procedure. In the first stage, the titles and abstracts of the identified articles were reviewed to assess their relevance to the research objectives. The articles that met the initial criteria were then subjected to a full-text review in the second stage to further evaluate their content and ensure they addressed the application of ML in construction risk management and delay prediction. In the final stage, the relevant information from the selected articles was extracted and synthesized, including the ML techniques employed, the types of construction risks and delays examined, the data sources and characteristics, and the key findings and limitations of the studies.

The analysis of the collected literature used a comparative approach to identify similarities and differences in ML techniques, data sources, and research findings across the selected studies. The review presents a narrative synthesis of the identified literature, discussing the overall trends, common themes, and notable insights regarding the application of ML in construction risk management and delay prediction.

As noted in the introduction, the comprehensive literature review highlighted the importance of effective risk management in the construction industry, which faces a wide range of risks that can significantly impact project performance. The paper then provided an overview of traditional risk management methods and their inherent limitations in addressing the increasing complexity and dynamism of modern construction projects.

Further, the review explores the potential of advanced techniques, specifically ML techniques, to enhance the accuracy and dynamism of construction risk assessment, examining the existing research on the application of ML in construction delay prediction and mitigation. Finally, the paper concludes by identifying the main challenges and opportunities of using ML for risk management in the construction industry and provides insights for future research and practical applications.

LITERATURE REVIEW

Traditional construction risk management approaches have largely relied on subjective, expert-based techniques, such as risk matrices, Failure Mode and Effects Analysis, and Monte Carlo simulation.[6,15] While these methods have been widely adopted, they often have limitations that undermine their effectiveness in accurately assessing and managing construction project risks.

Purpose of the literature review and significance of using ML

Several studies have explored the application of ML techniques in various aspects of construction risk management, including cost estimation,[12,13] safety monitoring,[14] and supply chain optimization.[6,15] This literature review examines recent research on the application of ML algorithms in construction risk management, with a specific focus on the prediction and management of project delays. The primary objective of this review is to explore the application of ML techniques to enhance the construction industry's ability to anticipate and address the persistent challenge of schedule delays, which can have significant implications for project performance, profitability, and overall industry competitiveness.

The use of ML in construction risk management represents a promising avenue for improving project outcomes. Compared to traditional statistical models, ML algorithms can uncover complex patterns and relationships in large, heterogeneous datasets, enabling more accurate and dynamic risk assessment and mitigation strategies.[6,16] This is particularly relevant for the construction industry, given its unique characteristics, such as the complexity of construction projects, the diversity of stakeholders, and the fragmentation of information, which often hinder the effective management of risks and uncertainties.

ML algorithms can significantly improve the accuracy and efficiency of construction risk predictions by leveraging the power of data analysis and pattern recognition. [14,17] These advanced techniques can process extensive construction project data, including historical performance records, site conditions, weather patterns, and market trends, to identify the key factors that contribute to project delays and other risk events.[6]

Unlike traditional statistical models, which often rely on predefined assumptions and linear relationships, ML algorithms can uncover complex, nonlinear dependencies and subtle, interdependent risk factors that may not be readily apparent to human analysts.[6] By training these models on comprehensive datasets, researchers and practitioners can develop predictive models that accurately forecast the likelihood and potential impact of various risk events, such as cost overruns, schedule delays, and safety incidents.[14,15] Moreover, the adaptive nature of ML allows these models to continuously improve their performances as new data becomes available, enabling project managers to stay ahead of emerging risks and adapt their mitigation strategies accordingly.

ML Algorithms for Delay Risk Assessment in Construction

Several studies have explored the application of various ML algorithms to address the persistent challenges of construction project delays. These studies have employed a range of ML techniques to develop predictive models that can estimate the likelihood and severity of delay events in construction projects.

For example, a study conducted by Muizz et al. (2022) used K-Nearest Neighbors (KNN), Artificial Neural Networks (ANN), Support Vector Machines (SVM), and Ensemble methods to assess delay risk in tall building projects. Their results showed that the ANN model achieved the highest accuracy (93.75%), identifying key contributors such as slow decision-making and subcontractor delays, which can support risk management in construction projects.[18]

Similarly, another study utilized Decision Tree and naïve Bayesian classification models to analyze and predict delay risks based on multivariate datasets of project time performance and delay-inducing factors. While both models performed well, the naïve Bayesian model showed better predictive accuracy through cross-validation tests, demonstrating its potential to support proactive risk management strategies in complex and interdependent construction systems.[6]

Another study applied the Bayesian Belief Network (BBN) to quantify the probability of project delays in Vietnam. Sixteen delay factors were identified, and 18 cause-effect relationships were established to develop the model. Key delay causes included financial difficulties, contractors' inadequate experience, and material shortages. The model was validated using case studies, demonstrating its usefulness for proactive delay risk management.[19]

In a study conducted by Liben et al.,[20] compares some of the most used ML algorithms for predicting construction duration in Addis Ababa’s public sector. It evaluates models including Random Forest (RF), SVM, KNN, ANN, and Classification and Regression Trees (CART). The results show that RF and KNN achieved the highest accuracy, while ANN performed poorly due to data limitations.

Furthermore, a study by Zhang and Li [21] evaluates four ML algorithms, KNN, Support Vector Regression (SVR), Gradient Boosting Trees (GBT), and ANN, to predict the construction duration of work areas within a project. The models are compared based on prediction accuracy and efficiency. The findings indicate that while each model has its strengths, the selection of an appropriate algorithm depends on the specific context and requirements of the construction project.

Furthermore, the other study used techniques like Multi Linear Regression, KNN, ANN, SVM, and Ensemble methods to mitigate construction delays, focusing on cost estimation, duration estimation, and delay risk assessment.[15]

Therefore, different ML algorithms have been explored for construction delay risk prediction, each with its own unique advantages that project managers should carefully consider when selecting the most appropriate model for their specific project requirements and constraints.

Comparative Discussion of ML Techniques

The reviewed studies demonstrate the potential of ML techniques to enhance construction risk management and delay prediction. Compared to traditional statistical models, ML algorithms have shown superior performance in terms of accuracy, flexibility, and adaptability when analyzing complex, interdependent construction data. The reviewed studies employed a variety of ML techniques, each with its own strengths and weaknesses.

Table 1 provides a comprehensive overview of the advantages and limitations of each ML algorithm applied to delay risk assessment.

Table 1. Comparison of ML Algorithms: Advantages and Limitations

Algorithm	Advantages	Limitations	Source
Random Forest (RF)	- High accuracy in complex predictive modeling. - Handles high-dimensional data well. - Robust against overfitting.	- Requires significant computational resources. - Can be less interpretable due to its ensemble nature.	Liben et al.[20]
Support Vector Machine (SVM)	- Effective in handling high-dimensional data. - Performs well with nonlinear relationships using kernel tricks.	- Computationally expensive for large datasets. - Requires careful hyperparameter tuning.	Liben et al.[20]
K-Nearest Neighbors (KNN)	- Simple and easy to implement. - Effective for small datasets with well-structured patterns.	- Computationally expensive as dataset size increases. - Sensitive to irrelevant or redundant features.	Liben et al.[20]
Artificial Neural Networks (ANN)	- Can model complex and nonlinear relationships. - Suitable for deep learning tasks.	- Requires large datasets for effective training. - Prone to overfitting and difficult to interpret.	Liben et al.[20]
Decision Tree (DT)	- Easy to interpret and visualize. - Works well with small datasets.	- Prone to overfitting. - Can be unstable with small variations in data.	Gondia et al.[6]
Naïve Bayes (NB)	- Fast and efficient for classification tasks. - Performs well with small datasets.	- Assumes feature independence, which may not always be valid. - Less accurate for complex dependencies.	Gondia et al.[6]
Gradient Boosting Trees (GBT)	- High predictive accuracy. - Handles various data types well. - Reduces overfitting through boosting.	- Prone to overfitting if not properly tuned. - Longer training times due to sequential model training.	Zhang and Li[21]

FINDINGS

Key Delay Factors in Construction Projects

A literature review reveals that construction projects are susceptible to various delay factors, each with the potential to disrupt project schedules and impact overall performance.[6,15,18,22–25] These delay factors can be broadly categorized into the following groups:

- Financing-related factors: These include contractors' financial difficulties, clients' cash flow problems, and market fluctuations, all of which can disrupt project funding and delay payments for materials and labor.
- Project-related factors: This category covers design changes, scope modifications, poor planning and scheduling, material shortages, equipment breakdowns, and inefficient

labor productivity. Such issues can lead to work stoppages, rework, and extended project durations.

- Stakeholder-related factors: Delays can arise from poor communication and coordination among project stakeholders, slow decision-making processes, and underperformance of subcontractors, all of which contribute to inefficiencies in project execution.
- External factors: Uncontrollable elements such as adverse weather conditions, regulatory changes, and economic or political instability can significantly impact construction timelines by causing unexpected work stoppages and compliance-related delays.

Identifying and carefully selecting these delay factors are critical for developing effective ML models for predicting construction delay risk. By carefully selecting the most relevant and influential delay factors, project managers can enhance the accuracy and reliability of these predictive models, ensuring that they can effectively anticipate and address the complex challenges posed by construction delays.[26]

In addition to the careful selection of delay factors, the availability and quality of historical project data and real-time monitoring information also play crucial roles in the development of an accurate and reliable ML model for predicting construction delay risk.[27] Researchers and practitioners should strive to collect and curate comprehensive datasets that capture the diverse factors contributing to construction delays, including project-specific information, environmental conditions, and stakeholder interactions.

Challenges and Limitations of Using ML for Risk Management

Despite ML's promising potential for construction risk management, several challenges and limitations must be addressed.

- Data Quality and Availability

One major challenge is the lack of high-quality and structured datasets which are necessary for developing and training these predictive models effectively.[28] Many construction organizations still rely on fragmented, unstructured data sources, which can hinder the development of robust and reliable ML models.[6]

- Complexity and Interpretability of ML Models

Another significant challenge is the inherent complexity of the ML algorithms themselves, which often require specialized knowledge, advanced computational resources, and considerable time and effort to deploy and maintain effectively.[29] Project managers and construction professionals may face difficulties in understanding the intricacies of these algorithms and interpreting their outputs, which can limit the practical adoption and implementation of these technologies in the industry.

- Scalability and Real-Time Application

Additionally, the scalability and real-time applicability of ML models for construction risk management may be constrained by the dynamic and complex nature of construction projects. The complex site environment not only limits algorithm performance but also significantly impacts the quality of the data that these models depend on.[28]

To address the challenges related to data quality and availability, construction organizations should focus on developing and implementing standardized data collection and management practices. This includes the adoption of digital technologies, such as BIM, IoT sensors, and project management software, to capture and integrate real-time project data from various sources.

To overcome the challenges associated with the complexity and interpretability of ML algorithms, researchers have proposed the development of hybrid models that combine the predictive capabilities of ML with expert-driven insights from conventional methods like Monte Carlo simulation and fuzzy logic.

Furthermore, the construction industry can benefit from the development of Explainable AI techniques, which aim to make ML models more transparent and interpretable for end-users.[30] These approaches can help construction professionals better understand the underlying logic and decision-making processes of the ML models, thereby increasing their trust and confidence in the technology and facilitating its widespread adoption in the industry.

In summary, the successful application of ML for construction risk management requires a multi-faceted approach that addresses the challenges of data quality, algorithm complexity, and real-time applicability. To overcome these challenges, the construction industry should prioritize the implementation of strategies that focus on enhancing data standardization, integrating hybrid models that combine ML with traditional risk analysis techniques, and developing Explainable AI systems to improve the transparency and interpretability of these advanced technologies.

CONCLUSION

This research paper has provided a comprehensive overview of the current state of ML applications in the domain of construction delay risk management. The review has highlighted the potential of ML models to accurately predict and mitigate construction delays, as well as the key challenges and limitations that must be addressed to ensure the successful implementation of these technologies in the industry. Based on the objectives set at the beginning of this study, the key findings are summarized as follows:

1. Exploring the potential of ML techniques to enhance the accuracy and dynamism of construction risk assessment:

This review found that ML significantly improves the accuracy and adaptability of risk assessment compared to traditional methods. Unlike conventional models that rely on expert judgment and historical data, ML can process large-scale datasets, identify complex patterns, and refine predictions in real time. Techniques such as RF, ANN, and GB have demonstrated high predictive accuracy, making them valuable tools for proactive risk management.

2. Examining the existing research on the application of ML in construction delay prediction and mitigation:

The literature revealed that ML models have been increasingly applied in predicting and mitigating delays in construction projects. These models, particularly Neural Networks and Gradient Boosting algorithms, have proven effective in identifying key risk factors such as contractor inefficiencies, material shortages, and scheduling conflicts. Moreover, integrating ML with real-time project data from IoT sensors and BIM enhances predictive accuracy and enables project managers to take proactive measures, ultimately reducing project delays and cost overruns.

3. Identifying the key challenges and opportunities associated with the implementation of ML-based risk management approaches in the construction industry:

Despite its potential, several challenges hinder the widespread adoption of ML in construction risk management. Key obstacles include the lack of high-quality, standardized datasets, the complexity and interpretability of ML models, and scalability limitations in real-time applications. Addressing these challenges through hybrid ML models, Explainable AI, and improved data standardization will facilitate broader adoption in the industry.

Moving forward, the integration of advanced ML techniques with emerging digital tools and robust data management strategies holds immense potential to transform the construction industry's approach to managing delay risks. Therefore, data quality, model interpretability, and scalability challenges must be addressed in the construction sector to unlock the full benefits of ML-powered risk management solutions.

The successful application of ML algorithms to assess delay risks in the construction industry can yield several significant benefits. For one, the ability to accurately forecast and mitigate delay risks can enable project managers to make more informed and timely decisions, allowing them to optimize the allocation of resources and proactively address potential issues before they escalate, ultimately leading to improved project outcomes and reduced costs.

Potential and Future Directions for ML in Delay Risk Management

Researchers have explored the potential of combining multiple ML algorithms or using ML in conjunction with other quantitative techniques to create hybrid models that can leverage the strengths of different approaches and improve the overall accuracy and reliability of delay risk prediction.[15]

Also, the increasing availability and integration of real-time data from various sources, such as sensors, BIM systems, and project management software, can significantly enhance the capability of ML models for construction delay risk assessment. By incorporating real-time data, these models can provide more accurate and timely insights, enabling project managers to proactively address emerging risks and mitigate delays throughout the project lifecycle.

Furthermore, the integration of ML with other emerging technologies, such as the IoT and BIM, can further enhance the effectiveness of construction risk management systems. By leveraging the synergies between these technologies, project teams can develop more comprehensive and integrated solutions that can more effectively identify, assess, and manage construction delays and other project risks.

Overall, the adoption of ML in construction delay risk management has the potential to transform the industry by enabling more accurate prediction, proactive risk mitigation, and improved project performance.

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ON A MOBILE APPLICATION THAT RECOMMENDS THE MOST SUITABLE CAFÉ-RESTAURANTS FOR THE HEARING IMPAIRED

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ABSTRACT

Hearing-impaired individuals often face challenges in social environments due to communication barriers. These obstacles not only hinder their ability to engage fully but also lead to feelings of isolation. Recognizing this, the aim of the study is to address these issues by developing a mobile application tailored to the needs of hearing-impaired individuals in selecting accessible cafes and restaurants. The communication needs of hearing-impaired users are catered to through the application, which evaluates 45 venues in Antalya's Beach Park region. These venues are categorized based on criteria such as accessibility features, menu options (e.g., vegan, gluten-free), and the availability of hearing-impaired-friendly services like sign language support. A fuzzy logic-based decision-making system is utilized to generate personalized venue recommendations, ensuring an inclusive dining and social experience. A comprehensive survey and evaluation process involving venue operators and hearing-impaired individuals was conducted as part of the methodology. Features like Wi-Fi availability, visual menu clarity, and event offerings were analyzed, alongside accessibility metrics, to rank venues effectively. The application was developed using modern prototyping tools such as Canva and InVision, and an intuitive interface for users to filter and select venues based on their preferences was provided. In addition, developed by .Net. The study's outcomes demonstrate that the social participation of hearing-impaired users is significantly improved, while awareness among venue operators is raised. By streamlining venue selection processes and promoting inclusion, a more equitable social environment is fostered through the app. In future iterations, the app's reach is planned to be expanded to other regions, and advanced features such as real-time sign language translation and community feedback systems are intended to be integrated.

Keywords: Hearing-impaired individuals; Restaurant; Accessibility; Mobile application; Fuzzy logic.

IMPACT OF REPLACING COARSE AGGREGATE WITH RECYCLED GLASS ON THE FLEXURAL PROPERTIES OF GREEN CONCRETE

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Abstract

The construction sector's continuous progress has led to a permanent transition from natural aggregate use toward recycled glass materials. The construction sector requires this transformation because it strives to discover better and more sustainable building material techniques. This research explores how glass aggregates affect concrete rheological properties and strength measurements and flexural characteristics. Tests on workability and compressive strength and flexural strength were carried out following previously established criteria. Concrete mixtures with glass aggregates achieved their best performance at a 2.5% glass aggregate volume ratio as they reached 16MPa compressive strength compared to 17.1MPa for the control mix. The compressive strength dropped substantially from this threshold point while the control mix consistently demonstrated superior performance compared to each modified mixture. The addition of glass aggregates results in changes to concrete workability. Additions of glass aggregate at 2.5% or 5% improved mixture workability though higher percentages decreased workability showing the requirement for water content adjustment and mixture structure amendments. Matches with 2.5% of glass aggregates for concrete exhibit superior effects based on the experimental analysis yet fail to perform well beyond this specific percentage threshold.

Introduction

The volume composition of concrete consists largely of aggregate which constitutes 80 percent while aggregate characteristics determine both price effectiveness along with behavior of fresh concrete and its hardened state (Hudson, 2019). The construction industry strives to develop modern approaches that build better sustainable materials with enhanced performance outcomes. Today's construction relies heavily on concrete which requires specific properties from its components to function properly. Recent research indicates glass aggregates find increased market demand as sustainable materials since they offer environmental benefits over conventional sand and gravel aggregate materials (Shayan & Xu, 2004). Abrasion-tested glass debris from recycled materials allow builders to adopt environmentally-friendly construction practices and decrease product discharge (Gupta, 2020). The properties of shape texture and grading affect fresh concrete bleeding and workability and segregation during production and determine strength and stiffness along with shrinkage creep density and permeability and durability in hardened concrete. Reports by Lafrenz (2017) show deteriorating construction quality and reduced durability when constructors use incorrect mixture ratios or allow material grade variations.

Flexural performance, strength, and rheology can be affected by glass particles in concrete. Concrete needs workability, slump, and viscosity to mix, transport, and place (Ferrara *et. al.*, 2007). The shape and surface roughness of glass aggregates might affect these properties, hence

more study is needed (Topçu & Canbaz, 2004). Compressive, tensile, and flexural strength indicate concrete's ability to withstand loads and stresses. Early research on glass aggregates and these properties has found mixed results, with some showing downsides and others showing improvements (Taha & Nounu, 2008). These variations must be understood to optimise mix designs and assure concrete reliability in structural applications. Concrete using glass aggregates must be ductile and fracture-resistant. Concrete's flexural strength determines beam and slab load-bearing capacity (Ismail & Al-Hashmi, 2009). Flexural qualities of glass-particle concrete reveal its architectural versatility.

Sand, gravel, crushed stone, crushed concrete, and recovered asphalt pavement are aggregates. These components are the main constituent in concrete, mortar, and asphalt mixes for bulk, strength, and durability (Shayan & Xu, 2004; Topçu & Canbaz, 2004). Concrete is made from inert aggregate, cement, water, and other additions. In sustainable building, recycled and waste aggregates are prioritised. Aggregates are recycled from crushed concrete, asphalt, and other building debris. Recycling these materials minimises natural resource use and landfill space while giving a sustainable building option. Industrial wastes are elements or materials originating from various human industrial and non-domestic activities that have to be dumped as waste (Adeala & Soyemi, 2021). Concrete is mostly aggregates, 60–80% of its volume. Concrete's qualities and performance depend on its aggregates, which make up most of its volume. Workability, strength, and durability of concrete depend on aggregate choices (Neville, 2011).

Recycled glass aggregate (RGA) is crushed post-consumer glass trash that is shaped for concrete application. Recycled glass replaces sand and gravel in concrete (Shayan & Xu, 2004; Topçu & Canbaz, 2004). This method tackles glass trash disposal's environmental issues and may improve sustainability and resource conservation (Gupta et al., 2020). Recycled glass aggregates represent a sustainable material alternative to natural aggregates used in concrete production. According to Shayan and Xu (2004) and Topçu and Canbaz (2004) the processing steps used in combination with glass composition influence the features of glass aggregates. The range of tiny powers to coarse particles present in these aggregates affects how concrete mixes perform. Glass aggregate properties depend on glass manufacturing conditions and particle embodiment methods as well as dimensional composition variations which restrict specific concrete applications (Ferrara et. al., 2007; Ismail & Al-Hashmi, 2009). The understanding of variability must exist for effective concrete mix design optimization and structural element performance guarantee (Taha & Nounu, 2008; Gupta et. al, 2020).

Projects studying sustainable environmental aggregate substitutes have remained active for several years. The use of recycled waste glass, rubber and plastic reduces both building debris generation and consumption of natural aggregates. Studies show glass aggregates become widely used because they enhance concrete resistant qualities alongside its overall appearance (Shayan & Xu, 2004). Cement concrete containing glass exhibits lower water uptake and enhanced strength properties which results in decreased workability according to Gjorv (2017). Higher glass aggregate contents in concrete result in mixtures that become difficult to handle during construction activities.

This paper conducted an empirical research study to investigate the mechanical performance of recycled concrete aggregates (Topçu and Canbaz, 2004). This study methodically studied the impact of recycled aggregate ratio levels on concrete's three main performance areas including strength and durability together with workability properties. Researchers performed exhaustive trials as well as studies in order to achieve optimal concrete mix designs resulting in desired performance outcomes. Topçu and Canbaz's empirical review studied recycled aggregates' impacts on concrete's compressive, flexural, and durability properties such freeze-thaw cycles and chloride penetration. They examined how aggregate quality, particle size distribution, and

replacement ratios affected mechanical qualities. They found both pros and cons of employing recycled aggregates in concrete. Slump test measures concrete workability. It is the most common and oldest concrete workability test. Freshly mixed concrete is used. ASTM C 143 is a slump test standard. Topcu, *et. al.,* (2004) found that waste glass in concrete mixtures reduced slump by 0.2%. Inefficient waste glass geometry caused this drop. In their 2017 experiment, Andrić, *et. al.,* employed 0.45 water cement ratio and discarded glass as aggregate in concrete. A 1.5% drop in concrete mixture workability was noted. Concrete's compressive strength is its highest resistance to axial compression loading. Per pound per inch square (psi) or Kilo-newton per millimetre square. One of the most essential concrete mechanical tests is compressive strength. It easily illustrates the impact of concrete additives and concrete constituents. As previously done, compressive strength tests show the impact of extra wasted glass. As waste glass rises, compressive strength falls in most experiments (de Castro & de Brito, 2013). Topcu, *et. al.,* (2004) cured concrete samples with varying waste glass percentages for 28 days. Concrete without waste glass compressed 2.04-23.50 MPa. As waste glass grew, compressive strength decreased. Compressive strength decreased 8% for 15% waste glass and 15% for 30%. It dropped 31% for 45% waste glass. Due to poor waste glass-cement paste adhesion.

Ling, *et. al.,* (2011) tested concrete developing strength using ceramic tiles as coarse aggregate. Concrete with 0.5 water-cement ratio has 20MPa strength. Both compressive and split tensile strengths increased by 4.84% and 13.30% at 20% replacement. Flexure strength is highest at 10% replacement, 4.84% higher than standard concrete. Ahmed, *et. al.,* (2012) found that fragile ceramic materials waste a lot when manufacturing, shipping, and fixing. Crushed waste ceramic tiles replaced natural coarse aggregates in concrete at 10%, 20%, 30%, 40%, and 50%. The study found that ceramic tile aggregate improves concrete's compression and flexural strength.

Some research found that waste glass aggregate size affects concrete compressive strength. Due to waste glass's pozzolanic characteristics. Ildir et al. 2010 discovered that 80 um aggregate enhanced concrete compressive strength from 30-35 MPa. Concrete specimens are tested for split tensile strength. Because concrete is fragile, tensile forces break it. The tensile strength test indicates the concrete cracking load. Tensile strength varies when discarded glass is used as concrete aggregate. Tensile strength increased or decreased in various trials. Topcu et al. 2004 found a 10% drop in concrete tensile strength. Concrete absorbs energy in an impact test. Impact tests measure toughness, fracture resistance, and impact strength (Rehacek et al., 2015). Impact tests are usually done on fiber-added or regular concrete specimens. Concrete studies using discarded glass as aggregate do not test for impact. This thesis will use the impact test to enhance concrete's mechanical qualities. Water absorption capacity is a key concrete durability test. It predicts permeability and sulphate attack resistance (Zhang & Zong, 2014). ASTM C 642-13 defines water absorption as the weight increase of oven-dry concrete after a given duration in water. Waste glass as aggregate in concrete may decrease its absorption capacity. Glass' impermeability should alter concrete's permeability. Taha & Nounu (2008) found that discarded glass decreased concrete water absorption and micro-cracks and moisture migration.

ASTM C1293-08 defines alkali-silica deterioration as expansion higher than 0.04% per year. Almesfer (2013) found that waste glass samples expand more owing to expansion gel. 20 They saw 0.802% growth for 12% waste glass, 0.777% for 24%, and 0.583% for 0%. Shi, (2019) found that recycled waste glass aggregate increased alkali-silica reactivity in concrete. Fly ash also boosts alkali-silica reactivity. Aruna et al. (2015) in their investigation, they replaced coarse aggregates with 20mm tile waste, partial cement with fly-ash, and 0%, 5%, 10%, 15%, 20%, and 30% tile waste. Maximum compressive strength is achieved after 25% replacement. Compressive strength drops 15–20% with 25% tile aggregate substitution. At 0%, 15%, 20%, 25%, and 30%; Meyer, & Baxter, (2003) reuses coarse aggregate by waste glasses. M20 concrete is used. The article recommends replacing waste tile aggregate with 5-30% and using it in M10, M15, etc.

mixtures. Subramani & Ravi, (2015). This research should provide appealing ways to utilise hard-plastic trash as coarse aggregate. Based on this analysis, plastic waste is used as coarse aggregate rather than fine aggregate. Whatever the plastic content, quality decreased over 20%.

Patil et al. (2010).This study proposes replacing coarse aggregate in concrete with plastic recycled aggregate. Six beams/cylinders and 48 specimens were cast from varied plastic percentages (0, 10, 20, 30, 40, and 50%) utilised to substitute coarse aggregate in concrete mixtures. Many experiments have shown that replacing aggregate with recycled plastic concrete reduces concrete density. With increasing coarse aggregate substitution with recycled plastic aggregate, compressive strength decreased for 7 and 28 days. They suggest replacing 20% to meet strength requirements. Again, these researchers only studied compressive strength and no other essential concrete qualities. Their study does not employ concrete admixtures to compensate for strength loss.

This research aims to systematically examine the influence of aggregate factors on the flexural performance, strength properties, and rheological features of concrete including glass aggregates. This project is to promote the advancement of environmentally friendly construction techniques and contribute to the knowledge base on sustainable concrete materials via comprehensive testing and analysis of recycled glass as a substitute for coarse aggregate. This study examines how aggregate strength and flexural performance affect concrete containing glass aggregates. It tests concrete mix designs with varying recycled glass aggregate proportions, workability, flow, viscosity, and compressive, tensile, and flexural strengths.

Materials and Method

All concrete mixes in this experiment used ASTM C150-compliant Ordinary Portland Cement (OPC). Fine and Coarse Aggregates are natural sand (particle size < 4.75 mm) and crushed granite (particle size ½ inch (12.5mm)), whereas Glass Aggregates are recycled glass cullet treated to comparable particle sizes. Multiple tests were performed on the materials in this study to assure quality for concrete manufacturing. Sieve analysis, specific gravity, water absorption, and workability were tested. Standards were followed for each test to ensure accuracy and dependability.

Fine and coarse aggregate representative samples were sieved. Sun-drying all samples eliminated surface moisture, which might distort weight readings and reduce accuracy. The dried samples were put on a stack of sieves in diminishing mesh sizes, from biggest to smallest. Each sample was agitated for 10 minutes with a manual sieve shaker to ensure particle separation across sieve sizes. After that, each filter was carefully dismantled and its retained material weight was recorded. To determine the particle size distribution for each coarse aggregate size and ensure concrete manufacturing requirements, this procedure was essential. By weighing the retained material on each filter, the samples' particle size fraction percentages were calculated. The cumulative data was tabulated to show particle size distribution. To verify aggregate size appropriateness in concrete mix design, grading results were compared to industry norms. Based on these results, concrete mix proportions and water-cement ratios were adjusted to optimise performance.

Concrete mixes will be designed with varying proportions of glass aggregates replacing natural coarse aggregates at 0%, 2.5%, 5%, 7.5%, 10%, 12.5% and 15% by volume. A control mix with 100% natural aggregates will be included for comparison. The water-cement ratio will be kept constant across all mixes to isolate the effect of aggregate type on concrete properties. Concrete Sample will be prepared by thoroughly mixing the ingredients in a laboratory mixer. The fresh concrete will be cast into molds to form standard test specimens, including cubes (for compressive strength tests), cylinders (for splitting tensile strength tests), and beams (for flexural

strength tests). The specimens will be cured in water at 23°C for specified periods before testing. All other materials are typically available from local store with reputable cement suppliers. Ensuring the aggregates meet the required specifications for the project. A total of concrete cubes were prepared. These hardened samples were subjected to compressive strength testing at 7, 14, and 28 days using a compression testing machine to evaluate their performance over time. A mix ratio of 1:2:4 was used, with precise weighing of the concrete batching constituents. For the aggregate component, glass aggregates were employed, with a blend of crushed glass and natural aggregates. The study began with control groups consisting of 100% crushed glass and 100% natural aggregates. Subsequently, various blends were tested: 90% crushed glass with 10% natural aggregates, 80% crushed glass with 20% natural aggregates, 70% crushed glass with 30% natural aggregates, 60% crushed glass with 40% natural aggregates, and 50% crushed glass with 50% natural aggregates. Each blend was prepared according to these specified ratios.

The aggregates were thoroughly mixed before the addition of water, maintaining a water-to-cement ratio of 0.5. Once all ingredients were combined to form the concrete mixture, it was poured into molds in approximately 50 mm layers. Each layer was compacted using a tamping rod with 25 uniform blows. The surface of the mortar was leveled with a trowel, and the molds were covered with moist bags to ensure proper curing. The samples were kept in this environment for 24 hours before being de-molded and stored in the laboratory for further curing. We measured the weights of each component in the concrete. 13.4 kilogram of cement was measured after 21.0 kg of glass. Spades were used to combine these two until a homogenous mixture was achieved. Next, measured 44.7 kg of aggregates were added, then 6.7 kg of water. After mixing for five minutes, the slump test was conducted.

Figure 1: Slump Test using Inverted Cone

Compressive strength tests will be conducted on cube specimens at 7, 14, and 28 days of curing using a universal testing machine (ASTM C39). Flexural strength tests was carried out on beam specimens at 28 days of curing using the third-point loading method (ASTM C78). Additional tests, such as water absorption (ASTM C642), was conducted to evaluate the durability of concrete with glass aggregates.

Figure 3: Concrete Placed in Moulds

Figure 4: Curing of Concrete Samples

After a 24-hour hardening period, the cast cubes were taken out of the molds. Then, for the appropriate length of days, they will be immersed in a tough that contains water to determine their compressive strength. This will be carried out in order to maintain the concrete's low, consistent temperature.

The specimens will be removed from the water and cleaned to remove any remaining moisture after curing. Weight will be recorded for each cube. Clean the testing apparatus's bearing surface and insert the specimen to load the cube cast's opposing sides. The specimen will be centre on the machine's base plate. The movable component will be manually turned to touch the specimen's top. The weight will be given gradually without shock until the specimen fails. The failure type's anomalies and maximum load-to-weight ratio were noted.

Figure 5: Compressive Strength Test

Results and Discussion

The results derived from the experimental investigations of concrete samples incorporating varying percentages of glass aggregates are discussed. The primary aim of this research is to evaluate how the substitution of traditional aggregates with glass aggregates impacts the flexural properties and durability of concrete. To analyze the compressive strength of concrete at different curing ages (7, 14, and 28 days) with varying percentages of glass aggregates. Likewise, the workability of concrete mixtures were assessed using the slump test. Also, to evaluate the durability characteristics of concrete with glass aggregates through water absorption and finally, the flexural test was carried out using a 150 x 150 x 600 mm beam placed under a three point loading system.

Workability Assessment

Workability is a critical factor in concrete mix design, as it affects the ease of handling, placing, and finishing. The workability of the concrete mixtures was assessed through slump tests, with results indicating varying degrees of consistency based on the glass aggregate proportions (Table 1). From Table 2, it can be seen that as the amount of glass in the concrete matrix increases, the slump decreases. The slump test results showed that concrete mixtures with lower percentages of glass aggregates (specifically 2.5% and 5%) exhibited higher slump values, indicative of better workability.

Table 1: Result of the Slump Test

% Glass Aggregate	Slump Value (mm)
0.0%	90
2.5%	110
5.0%	100
7.5%	80
10.0%	70
12.5%	60
15%	50

An increase in glass aggregate content above 5% resulted in concrete mix stiffness through reduced slump performances. The manipulative properties of concrete decrease as glass aggregates demonstrate inherent tendencies to absorb water and modify the mix fluidity. The findings demonstrate that proper optimization between water content and aggregates proportions leads to proper workability maintenance while maintaining concrete mechanical qualities.

Compressive Strength

The data presented in Table 4.2 displays clear proof of how concrete cube compressive strength responds to different recycled glass percentage concentrations during 7, 14, and 28-day curing periods. The structural performance and durability of concrete heavily depend on its compressive strength because it determines both strength under load and material lifetime. The 0% mix demonstrated an increase from 11.04 MPa at 7 days to 17.148 MPa at 28 days, indicating the positive effect of extended curing on strength development as cement hydration continues.

Table 2: Compressive Strength Results

	7 days (MPa)	14 days (MPa)	28 days (MPa)
0%	11.040	15.434	17.148
2.5%	14.174	14.405	16.056
5,0%	10.866	13.984	15.538
7.5%	11.673	13.952	15.502
10.0%	9.489	10.293	11.437
12.5%	6.007	9.388	10.431
15.0%	12.736	12.533	13.926

For the 2.5%, the initial compressive strength was 14.174 MPa at 7 days, slightly reduced from the 0%, implying that no recycled glass may contribute favorably to early strength. However, by 28 days, the strength reached only 16.056 MPa, indicating that the rate of strength gain decreases over time for increased percentage of glass. The 5% exhibited a lower early strength of 10.866 MPa but increased significantly to 15.538 MPa at 28 days, suggesting that this percentage benefits from extended curing, as hydration enhances strength. The 7.5% had another increase to 11.673 MPa at 7 days, with a slower increase to 15.502 MPa at 28 days, suggesting that this percentage can result in more void, potentially weakening the bond strength. However, the 10%

showed a bad performance with a strength of 9.489 MPa at 7 days, increasing to 11.437 MPa by 28 days, indicating that while higher percentages may initially limit early strength, they do not contribute effectively to the concrete's long-term performance. In summary, smaller percentages yield higher early strength, but larger percentages have a bad performance over time. Achieving the optimal recycled glass percentage is essential for balancing workability and compressive strength, which is vital for structural applications. The findings underscore the role of proper curing and mix design in achieving the required mechanical properties, with potential for future studies to examine the impact of factors like water-cement ratio and admixtures on concrete performance with different recycled glass percentages.

Flexural Strength

The flexural strength results presented in Table 3 indicate the performance of concrete beams with various recycled glass percentages after 7, and 28 days of curing. Overall, the flexural strength increased with time, beginning at 4.408 MPa at 7 days and reaching 12.175 MPa at 28 days. This upward trend underscores the importance of adequate curing to allow the concrete to develop its strength over time. Focusing on the 0%, the flexural strength at 7 days was slightly higher than the overall average at 9.175 MPa, but it increased to only 12.175 MPa by 28 days. This modest growth suggests that while smaller percentages may contribute positively to early performance, they significantly enhance long-term flexural strength.

Table 3: Flexural Strength Results

	Strength	
(%)	28days	7days
0.0	12.175	9.175
2.5	11.380	8.380
5.0	11.032	8.000
7.5	11.006	8.012
10.0	8.120	5.134
12.5	7.406	4.408
15.0	9.887	6.848

These findings, which outlines the testing and assessment of flexural strength in concrete. The observed trends emphasize the need for careful selection of recycled glass percentages to optimize both workability and mechanical properties. Smaller percentages appear to enhance early strength, while the long-term performance may depend more on proper curing and the overall mix composition. Future research could delve deeper into how varying types of cement and supplementary materials influence these mechanical properties, providing further insights into the best practices for concrete mix design.

Conclusion

Concrete mixes incorporating glass aggregates exhibited varying compressive strengths, with the optimal performance recorded at 2.5% glass aggregate substitution. Compressive strength decreased significantly as the percentage of glass aggregates increased beyond this point, with the control mix outperforming all modified mixes. The addition of glass aggregates affected the workability of concrete. Lower percentages (2.5% and 5%) resulted in improved workability, while higher percentages led to reduced workability, indicating a need for adjustments in water content and mix design.

The study concludes that incorporating glass aggregates into concrete can be advantageous if done judiciously. Specifically, a substitution of up to 2.5% can enhance the mechanical properties of concrete without significantly compromising its durability. However, as the percentage of glass aggregates increases, there is a clear trend of decreasing strength, workability, and

durability. Therefore, while glass aggregates present a sustainable alternative for concrete production, careful consideration must be given to their proportions in order to maintain the desired performance characteristics.

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THE RELATIONSHIP BETWEEN PERSONALITY TRAITS AND MARITAL SATISFACTION WITH THE ATTITUDES AND BELIEFS REGARDING ABOUT SEXUALITY AMONG PREGNAT WOMEN

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ABSTRACT

Introduction and Purpose: Sexuality during pregnancy is affected by many physiological and psychological factors. This study was conducted to determine the relationship between personality traits and marital satisfaction in pregnant women, with attitudes and beliefs about sexuality.

Materials and Methods: This descriptive and relationship-seeking study was conducted on 447 pregnant women who applied to the obstetrics clinic of a university hospital. The data were collected with the "Introductory Information Form", "Attitudes and Beliefs Scale about Sexuality during Pregnancy (ABSSP)", "The Marital Life Scale (MLS)" and the "International Personality Inventory Short Form (IPISV)". In the analysis of data; t test, analysis of variance, pearson correlation analysis and multiple regression analysis were used.

Results: The mean ABSSP score of the pregnant women was 59.23±17.83. The total score of the ABSSP of pregnant women and the total scores of the sub-dimensions of the IPISV showing positive personality traits were negatively correlated ($p<0.05$). There was a negative and low-level correlation between the total score of the pregnant women's ABSSP and the total score of the MLS ($p<0.05$). In the multiple regression analysis, the pregnant woman's age, employment status, education level, family structure, parity, abortion and miscarriage status, marriage type, spouse's employment status, frequency of sexual intercourse during pregnancy, source of information about sexuality, satisfaction with sexual life, total score of IPISV's "introversion", "agreeableness" and "emotional stability/instability" sub-dimensions explained 47.1% of the change in the ABSSP score.

Discussion and Conclusion: It is observed that pregnant women have many sexual myths during pregnancy. Believing in sexual myths during pregnancy is affected by many characteristics related to socio-demographic, obstetric, marriage, spouse and sexuality. As the level of believing in sexual myths during pregnancy increases, the harmony of pregnant women in their marriages decreases. Pregnant women generally have decreased sexual myths in positive personality traits. In this context, it is important for health professionals to provide consultancy services to pregnant women on sexual health.

Key Words: Sexuality; Pregnancy; Personality.

DIGITAL TWIN-DRIVEN BUILDING INFORMATION MODELING (BIM) FOR SUSTAINABLE DESIGN PRACTICES IN ARCHITECTURE AND CONSTRUCTION DESIGN OFFICES

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ABSTRACT

Introduction and Purpose: The integration of Digital Twin technology with Building Information Modeling (BIM) is widely regarded as a transformative innovation in sustainable design practices. However, its adoption faces challenges such as lack of awareness, complexity in implementation, and resource constraints. This study investigates the benefits, challenges, and potential problem areas associated with the adoption of these technologies in sustainable design practices, with the aim of providing actionable insights for their broader implementation.

Materials and Methods: A thorough literature review was conducted to define the study objectives and goals, focusing on the intersection of BIM, Digital Twin, and sustainable design practices. Based on these findings, a structured questionnaire survey was developed to measure professionals' awareness, perceived benefits, challenges, and strategies related to these technologies. The survey was administered to 50 experts in the architecture and construction sectors, including architects, engineers, and project managers. Quantitative metrics such as mean values and standard deviations were calculated from the survey data, and case studies were reviewed to compare Digital Twin-driven BIM with traditional methods in addressing sustainability metrics.

Results: Awareness of BIM was significantly higher than Digital Twin technologies. Perceived benefits such as real-time performance monitoring (68%) and greater lifecycle assessment (51%) were widely acknowledged among participants. Key challenges identified for Digital Twin adoption included complexity and cost (64%), data integration and interoperability (57%), and the learning curve (40%). In comparison, projects using BIM were rated as highly effective or effective in achieving sustainability objectives by 94% of respondents. When asked about preferred technologies, 43% favored a hybrid approach combining BIM and Digital Twin for sustainable design projects.

Discussion and Conclusion: The findings highlight the substantial potential of Digital Twin-driven BIM in enhancing sustainable design outcomes while addressing significant challenges. Strategies such as phased implementation, targeted training programs, and resource optimization are essential for broader adoption. This study provides a foundational understanding of how these technologies can be leveraged to enhance sustainability outcomes, paving the way for innovative and sustainable practices in the architecture and construction industry.

Key Words: Digital Twin; Building Information Modeling; Sustainable Design; Architecture; Construction; Framework.

A STUDY OF THE PRACTICAL IMPORTANCE OF TREES, RECOMMENDED TO BE PLANTED IN A HOUSE ACCORDING TO EASTERN ARCHITECTURE

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According to eastern architecture, a study on the practical importance of the trees recommended for planting in a house is the background for this study. Therefore, this research was conducted with the aim of completing that research vacuum. It is expected that the application of a comprehensive study on the practicality of the trees recommended for planting in a house or a domestic garden and among them, which are the most suitable and useful types of trees to plant when setting up domestic gardens, will be able to provide an experimentally proven answer or knowledge. The importance of conducting this research can be described as follows. For this research, it is expected to include the facts about Vrukshayurveda mentioned in the book Vastu vidyawa or architecture and the book Vasturajawallabha. These books discuss the importance of planting trees, trees to be planted in a garden, suitable time frames for planting trees and the procedures to be followed when transporting a tree to another location, how to plant trees, how to water the planted tree, how far to plant trees, how to know the diseases of trees, how to treat those diseases, what to do when a tree does not bear fruit. But no information is given about the practical effects of those trees on humans. Therefore, this research has focused on that sector. Here, 10 types of trees are expected to be used as research samples. Azadirachta indica, Ficus benghalensis, Tamarindus indica, Limonia acidissima, Phyllanthus emblica, Mangifera indica, Saraca asoca, Syzygium cumini, Punica granatum, Jasminum officinale are selected. At the end of this research, to clearly distinguish the types of trees that should be planted in a home garden and the types of trees that should not be planted. This research is carried forward based on a hypothetical conclusion that modern people will be able to choose plants for their home garden in a more effective way and plant them in the home garden.

Key words: Home garden, Vrukshayurveda, Architecture, Trees, Rituals.

A P-LAPLACIAN ELLIPTIC SYSTEM WITH STRONGLY COUPLED CRITICAL TERMS AND CONCAVE-CONVEX NONLINEARITIES

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ABSTRACT

Introduction and Purpose: The study of elliptic systems with strongly coupled critical terms dates back several decades within the partial differential equations (PDEs) framework. These concepts stem from mathematical developments in various fields such as differential geometry, the theory of nonlinear differential equations, and theoretical physics. This work aims to study the existence and multiplicity of positive solutions of an elliptic system with strongly coupled critical terms and concave-convex nonlinearities on a regular bounded domain $\Omega \subset \mathbb{R}^N$ involving the p-Laplacian operator, under appropriate conditions.

Materials and Methods: In studying the critical problem, several mathematical techniques can be employed to establish the existence and multiplicity of solutions, among which variational methods play a central role. Especially by the Nehari manifold method and Palais Smale condition, we prove the existence and multiplicity results of positive solutions for our problem.

Results: Using the Nehari Manifold method, under appropriate conditions for an elliptic system with strongly coupled critical terms and concave-convex nonlinearities, we prove that there are at least two positive solutions for our problem.

Discussion and Conclusion: By exploring new functional frameworks, incorporating richer nonlinear terms, or studying domains with complex geometries, this work paves the way for a deeper understanding of critical systems involving non-local operators, both in their theoretical and applied dimensions.

Key Words: p-Laplacian; positive solutions; elliptic system; strongly coupled critical terms; Nehari manifold; variational method

SUSTAINABLE GREEN SYNTHESIS OF NANOPARTICLES: A COMPREHENSIVE OVERVIEW

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Abstract:

Nanotechnology is regarded as one of science's most significant recent advances. Because of its numerous uses and quickly rising demand, innovative techniques for the synthesis of higher-quality nanomaterials have been made possible. Due of the pollution produced by traditional synthesis processes, there is a need for environmentally friendlier synthesis approaches. The creation of green nanoparticles has several potential applications in the environmental and biological sciences. Green synthesis's primary objective is to utilise less dangerous chemicals. Plant extracts, fungus, bacteria, and enzymes are some of the resources available for the environmentally friendly creation of nanoparticles. We provide an overview of the principles of plant-mediated nanoparticle synthesis in this review.

Keywords: Nanoparticles, Green Synthesis, biohybrid, plant-mediated

STUDY OF THE OPERATIONAL SAFETY OF A SAFETY INSTRUMENTED SYSTEM (SIS) IN AN INDUSTRIAL ENVIRONMENT

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ABSTRACT

Industrial installations are likely to generate dangerous phenomena (fire, explosion, release of hazardous materials, etc.) that can reach vulnerable targets such as people, property and the environment. The objective of any industrial manager is not the complete elimination of the risks associated with them, because this is an impossible task, but rather the assurance that these risks are maintained at acceptable levels.

Safety Instrumented Systems (SIS) is essential to address the risks associated with technical systems and processes. Their main function is to detect dangerous deviations from the process and to trigger the necessary actions to avoid potential accidents. The IEC 61508 standard provides a structured approach based on hazard identification for establishing SIS safety requirements. This standard aims to design and operate SIS with a level of reliability that meets these requirements. we focus on the application of the approach recommended by IEC 61508 to evaluate the safety barriers implemented on a butane storage tank, in particular safety barriers against overpressure.

Keywords: HAZOP method, operational safety, reliability, Safety Instrumented Systems (SIS).

CATALYTICAL SYNTHESIS OF BIODIESEL FROM NON-EDIBLE CASTOR OIL USING BIOGENIC SYNTHESIZED NANOPARTICLES

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Abstract

The depletion of conventional fossil fuel resources is a threat to human. Depletion, exhaustion and catastrophic effects of fossil fuel urges exploration of alternates and clean sources of energy. Biofuels produced from biomass are sustainable, eco-friendly and green fuels. In this work, Citrullus colocynthis extract as a stabilizing and reducing agent to synthesize copper (Cu) and nickel (Ni) nanoparticles. To evaluate synthesized nanoparticles were characterized by techniques such as UV-VIS, FTIR, SEM, and EDX. Furthermore, transesterification of non-edible castor oil was done by utilizing bimetallic copper and nickel nanocatalysts to evaluate the catalytic effectiveness of these nanoparticles. To optimize transesterification was performed by using Cu/Ni bimetallic nanocatalysts and sodium hydroxide. Synthesized biodiesel was further characterized using GC-MS and FTIR techniques. The major fuel properties of Ricinus communis methyl esters formed were found to be within defined limits of ASTM D6751 standards for biodiesel, suggesting that it could be used as a potential petro-diesel substitute.

Keywords: Citrullus colocynthis, nanocatalysts, transesterification, green synthesis, bimetallic nanoparticle

INNOVATIVE ECO-FRIENDLY CONCRETE BASED ON AGRICULTURAL WASTE AS NATURAL FILLERS

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Abstract

The building materials construction industry plays a crucial role in economic development, however, it can also have considerable environmental impacts, particularly in terms of energy consumption, depletion of natural resources and degradation of ecosystems. Faced with these challenges, this work aimed implementation and characterization of sustainable and green building construction materials based on natural fillers, by promoting natural by-products as substitutes for conventional micrometric fillers in eco-efficient materials. This substitution showed an improvement on the mechanical, thermal and acoustic properties of materials, while optimizing their compatibility with various matrices through the control of particle size, the treatment of natural fillers, the use of advanced manufacturing processes and the use of predictive modeling, as well as an environmental and energy assessment, to ensure that the solutions developed meet the project's sustainability and energy efficiency objectives.

Key words: Construction materials, natural fillers, mechanical properties, thermal properties, acoustic properties.

SUSTAINABLE TEXTILE SOLUTIONS: THE EFFICACY OF NATURAL DYES AND ESSENTIAL OILS IN UV PROTECTION

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Abstract

The depletion of the ozone layer and the resulting increase in ultraviolet radiation (UVR) exposure have heightened health concerns, including skin cancer, cataracts, and photoaging, making effective protective measures essential. This study focuses on enhancing the ultraviolet protection factor (UPF) and multifunctional properties of cotton textiles through the application of natural dyes—indigo, banana sap, annatto, and madder—and essential oils such as orange, lemon, and grapeseed. Natural dyes are valued for their eco-friendly, non-toxic nature and inherent UV resistance, while essential oils contribute antibacterial properties, pleasant fragrances, and additional UV-blocking capabilities. Using standardized techniques, the research optimizes dyeing processes and microencapsulation methods for essential oils. The dyeing process is fine-tuned by adjusting variables such as dye concentration, temperature, pH, and material-to-liquor ratio to achieve optimal coloration and UV protection. Essential oils are encapsulated to improve their durability and controlled release, ensuring sustained functionality even after exposure to environmental factors and repeated washing. The treated fabrics are evaluated for their physical and functional properties, including tensile strength, air permeability, bending length, UV protection efficiency, and fragrance retention. This study highlights the synergistic benefits of combining natural dyes and essential oils to create textiles that address both health and environmental concerns. By offering enhanced UV protection, antimicrobial effects, and aromatic properties, these textiles align with industry demands for sustainable, multifunctional materials. This innovative approach promotes eco-friendly practices in textile production while providing significant health and environmental benefits, contributing to the advancement of sustainable and value-added fabric technologies.

Keywords: Ultraviolet Protection Factor (UPF), Natural Dyes, Essential Oils, Cotton Textiles, Eco-Friendly Textiles, Microencapsulation, Sustainable Materials, Textile Dyeing, Functional Finishes

ENHANCED CATALYTIC PERFORMANCE THROUGH OXYGEN-FUNCTIONALIZED CARBON NANOTUBES FOR SELECTIVE REDUCTION OF NOX WITH NH

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Abstract

This study highlights the effective use of oxygen-functionalized carbon nanotubes (CNTs) as supports for catalytic materials to enhance their dispersion and performance. The surface acid treatment, employing sulfuric and hydrochloric acids, successfully introduced oxygen functional groups onto CNTs, creating anchoring sites for catalytic nanoparticles. Key points include:

- **CNT Properties**: High specific surface area (460–820 m^2/g) and chemical stability make CNTs ideal for supporting active materials.
- **Challenges**: Lack of intrinsic surface functionality in pristine CNTs limits the dispersion of catalytic materials.
- **Functionalization Process**: Acid treatments controlled by reaction time allowed tuning of the oxygen functional group density.
- **Catalytic Materials**: Vanadium, tungsten, and nickel oxides were impregnated onto the functionalized CNTs, showing improved nanoparticle dispersion and size reduction.
- **Performance**: The functionalized CNT-supported catalysts achieved over 82% NOx removal efficiency at 440–490 °C, aligning with operational temperatures in power plants.

This demonstrates that surface functionalization significantly enhances the interaction between CNTs and catalytic nanoparticles, leading to superior performance in applications like selective catalytic reduction.

Keywords: Selective Catalytic Reduction, Oxygen functionalized carbon nanotubes, Surface Functionality, Impregnation method, Pollution Abatement, Power Plants

THE KINETICS OF GROWTH OF THE FE_2B LAYER AND MODELING OF THE MASS GAIN ON AISI D2 STEEL

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Abstract

The work consists of simulating the boriding kinetics of AISI D2 steel using the integral diffusion model. The boriding parameters for the powder method were 1123 K, 1173 K, 1223 K and 1273 K with variable treatment times 2, 4, 6 and 8 h.

The value of the boron activation energy in the Fe_2B layer was calculated on the basis of experimental data from the literature. This value of energy was estimated as 207.22 kJ mol^{-1} for the AISI D2 steel and compared with the literature results. The mass gain associated with the formation of Fe2B layer was also simulated.

This diffusion model was then validated experimentally using an additional boriding condition which corresponds to the temperature of 1253 K for 5 h.

Keywords: Boriding, Kinetic, Mass gain, Integral model, Activation energy.

RELATIONSHIP BETWEEN CARBOHYDRATE AND AMINO ACID RESERVES IN TWIGS WITH AGRO-PHENOLOGICAL RESPONSES IN PLUM CULTIVARS OF TWO CONTRASTING GEOGRAPHIC ORIGIN

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Abstract

This study assessed the effect of climatic conditions on the production and phenological traits of four plum cultivars (Prunus salicina L. and Prunus domestica L.) grafted on 'Myrobolan' rootstock planted in two contrasting experimental zones at INRA Meknes, namely 'Ain Taoujdate' in the Saïs plain and 'Annoceur' in the foothills of the Middle Atlas, during two consecutive years, 2019-2020 and 2020-2021. Observations were made of production and phenological traits, including flowering and bud burst rates and twigs reserves (total soluble solids 'TSS', soluble sugars content 'SSC' and amino acids content 'AAC') during the dormancy and budburst phases. The results showed that the effect of the climate factor varies according to cultivar and site. Yields expressed by tree fruit load and fruit weight were reduced as a result of the climate, with overall averages of 34% and 23%, respectively. Similarly, budburst and flowering rates were reduced on both sites, with overall averages of 10% and 6%, respectively. The earliest cultivar was 'Methley' while the latest was 'Stanley' which had significant decreases in 'TSS' and 'SSC' in twigs against an increase in 'AAC' moving from the dormancy and budburst phases. The aim of this study is to gain an idea of the areas likely to be favorable for plum cultivation, taking climatic conditions into account, and to contribute to the understanding of adaptation mechanisms under conditions resulting from global warming.

Key words: Prunus domestica L., Prunus salicina L., climate, production, phenology, twigs reserves.

DYEING OF BLEND FABRICS

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ABSTRACT

Dyeing blended fabrics presents a unique set of challenges due to the diverse nature of fibers involved. Blended textiles, such as cotton-polyester, wool-nylon, and silk-spandex, combine fibers with different dyeing affinities, making it difficult to achieve uniform coloration and durability. Each fiber type has its own specific requirements in terms of dye absorption, fixation, and processing conditions. For instance, while cotton readily absorbs water-based dyes, polyester requires high temperatures and pressure for proper dye penetration. Various dyeing techniques have been developed to address these complexities. Conventional methods often involve multiple dye baths and chemical treatments to ensure consistent coloration across the different fibers. However, these traditional techniques are not without their drawbacks. They can be resource-intensive, requiring significant amounts of water, energy, and chemicals, which can lead to environmental pollution. To mitigate these environmental concerns, the textile industry is increasingly turning towards sustainable dyeing alternatives. Waterless dyeing techniques, such as supercritical CO2 dyeing, have gained popularity for their ability to dye synthetic fibers without the need for water. This method not only reduces water consumption but also eliminates the need for harmful effluents. Eco-friendly dyes, derived from natural sources like plants and insects, offer a less toxic alternative to synthetic dyes. Additionally, digital printing technology has revolutionized the industry by allowing precise application of dyes with minimal waste and reduced chemical usage. These innovations are reshaping the dyeing process, ensuring improved color consistency, quality, and reduced environmental impact. As the industry continues to evolve, the adoption of these sustainable practices will play a crucial role in addressing the challenges associated with dyeing blended fabrics, ultimately leading to a more eco-friendly and efficient textile production process.

Keywords: Blended Fabric, Dyeing, Fibers, Sustainable, Environmental friendly

SUSTAINABLE TEXTILE AUXILIARIES

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ABSTRACT

Sustainability has become a central focus in the textile industry, driving innovation in textile auxiliaries—those chemical agents essential for processes like dyeing, printing, and finishing. This shift is fueled by the pressing need to reduce environmental impact while maintaining high performance. Traditional textile auxiliaries often contribute to significant environmental issues, including water pollution and chemical toxicity. In response, the industry is reengineering these agents to develop biodegradable, non-toxic, and renewable-resource-based alternatives. Innovations in this area are particularly noteworthy. Enzyme-based auxiliaries, for instance, offer a biodegradable option that can replace harsher chemicals, facilitating more eco-friendly processing. These enzymes, derived from natural sources, are effective at lower temperatures and pH levels, reducing the energy and water needed in textile treatments. Waterless processing agents, another groundbreaking development, enable dyeing and finishing operations without using water, addressing one of the industry's major environmental concerns. This method not only conserves water but also eliminates wastewater generation, thereby reducing the overall environmental footprint. Low-temperature reactive chemicals are also gaining traction. These chemicals enable effective dyeing and finishing processes at lower temperatures, which cuts down on energy consumption and associated carbon emissions. Such advancements not only enhance the sustainability of textile production but also help manufacturers meet increasingly stringent environmental regulations and consumer demands for eco-friendly products. Despite these promising developments, the large-scale implementation of sustainable textile auxiliaries faces several challenges. The primary hurdle is the high cost associated with developing and adopting new technologies. Additionally, there is a need for extensive research and development to ensure that these sustainable alternatives can meet the performance standards of their conventional counterparts. Moreover, there is a learning curve for manufacturers to adapt to new processes and equipment. As the textile industry continues to evolve, the adoption of sustainable textile auxiliaries will play a crucial role in reducing environmental impact. By addressing both environmental concerns and performance requirements, these innovations are paving the way for a more sustainable future in textile production.

Keywords: Textile auxiliaries, Eco-friendly, Renewable resources, Environmental impact

POLYANILINE COATED QUARTZ SAND (QS@PANI) AS AN ADSORBENT COMPOSITE FOR ORANGE G DYE REMOVAL FROM AQUEOUS SOLUTION

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Abstract

In this study, a composite adsorbent QS@PANI was synthesized as an efficient, low cost, environmentally friendly adsorbent for Orange G dye removal from aqueous solution. The surface properties of materials were characterized using X-Ray diffraction analysis (XRD), Fourier Transform Infrared spectroscopy (FTIR), Scanning Electron Microscopy (SEM) - Energy Dispersive X-Ray Analysis (EDX), and the point of zero charge analysis. The influences of adsorbent dose, pH, adsorption kinetics, isotherm, and thermodynamics on OG removal were studied. The kinetic and isotherm studies indicate that OG adsorption on QS@PANI was well fitted by the pseudo-second-order, and Langmuir models. The adsorbent exhibit a high monolayer adsorption capacity of 85.49 mg/g for Orange G dye at 298K and pH 6. Thermodynamic investigations confirmed that OG adsorption was spontaneous and endothermic. Furthermore, the QS@PANI can be regenerated, and used more than six times, which demonstrate that it is qualified for practical applications.

Keywords: Quartz sand (QS), Polyaniline, Composite, Orange G, Adsorption.

ASSESSING THE THERAPEUTIC POTENTIAL OF 3,5-DISUBSTITUTED INDOLE DERIVATIVES IN TARGETING PIM1 KINASE: IN SILICO ANALYSIS AND DEVELOPMENT OF INNOVATIVE COMPOUNDS FOR HEMATOLOGICAL CANCER TREATMENT

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ABSTRACT

The World Health Organization (WHO) has recognized cancer as one of the most lethal diseases of our era, with an alarming increase in mortality rates. In response to this urgent challenge, researchers are actively investigating new therapeutic molecules. Among the promising targets for the treatment of hematological cancers, proviral integration moloney (Pim) kinases have garnered significant attention. This study focuses on a series of thirty-four 3,5-disubstituted indole derivatives, which were systematically evaluated as potential inhibitors of Pim1 kinase using advanced methodologies, including two-dimensional quantitative structure-activity relationship (2D-QSAR) analysis and molecular docking techniques.

The thorough investigation of these compounds produced promising results, highlighted by a Q^2 value of 0.71, an R^2 value of 0.82, and an $rtest^2$ value of 0.96. The modeling process utilized 28 compounds as a training set and 6 compounds as a test set. Additionally, leveraging computational simulations, four novel compounds were designed in silico, indicating potential for further investigation. To assess the stability of the newly designed compound X1 and the most active compound (compound 28), molecular docking studies were performed. The results indicated that compound X1 demonstrated superior stability compared to compound 28.

Furthermore, the newly designed compounds were evaluated for their in silico toxicity profiles, ensuring compliance with the five Lipinski rules, which evaluate specific molecular characteristics related to drug-likeness and oral bioavailability, thereby confirming the feasibility of these compounds for subsequent experimental validation. In conclusion, this study explored the potential of 3,5-disubstituted indole derivatives as Pim1 kinase inhibitors, aiming to develop effective treatments for hematological cancers. The findings revealed promising activity, with the newly designed compound X1 exhibiting enhanced stability relative to the most active compound in the series. Further experimental validation in laboratory settings is essential to establish the therapeutic efficacy of these compounds in practical applications.

Keywords: 3,5-disubstituted indole derivatives, QSAR, Cancer, Molecular docking, Pim kinases.

IMPACT OF MENSTRUAL PRODUCTS ON ENVIRONMENT: CHALLENGES AND ALTERNATIVES

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ABSTRACT

Menstruation is often linked only with women and girls. On the contrary, non-binary people also menstruate. Menstruation is not an issue limited to health, hygiene. It touches society, environment, religion and more. Period poverty is common in developing and under-developed world. Simultaneously, we need to look at the interplay of how periods are tackled with their impact on the environment. Menstrual products often used in present times are entangled to environmental issues. The impact of menstrual products on environment has captured interest in recent years as non-recyclable and non-biodegradable like sanitary pads, tampons and panty liners harm the environment by polluting water body and landfills. These products are made from non-biodegradable substances like plastics, synthetic fibers and bleached paper which take hundred of years to decompose. The incineration of menstrual waste also affect environment adversely by releasing harmful gases. Alternatives like menstrual cups, organic cotton pads are reusable and eco-friendly. This paper analyses environmental consequences of sustainable menstrual products and challenges surrounding their broader adoption in society. It calls for increase in public awareness and policy interference to alleviate environmental impacts related with menstrual products. Scientific developments coupled with social and political willingness are a solution.

Keywords: Menstruation, Environment, SDG, India, Health.

REVOLUTIONIZING AUTOMOTIVE PRODUCTION AND MAINTENANCE: AN INNOVATIVE AND SUSTAINABLE APPROACH TO GEAR TRANSITION CHALLENGES

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ABSTRACT

The automotive industry is at the forefront of technological innovation, facing challenges that demand smarter and more efficient solutions in both manufacturing and maintenance. The **Shift Unlock Mechanism** represents a paradigm shift, providing a robust and adaptable approach to ensuring smooth gear transitions when vehicles are unpowered. This function is especially critical for modern assembly lines and aftersales services, where power system dependency often hinders operational efficiency.

The mechanism is built on principles of simplicity and sustainability, integrating seamlessly with compact cockpit designs, and reducing material usage without compromising functionality. Unlike traditional energy-dependent systems or other complex solutions, it offers an independent, mechanical alternative that simplifies production workflows, minimizes costs, and supports eco-friendly practices. By enabling easy transitions between gear states, it enhances production flexibility and addresses maintenance challenges effectively.

This article explores the mechanism's engineering foundations, its role in redefining industry benchmarks, and its broader implications for sustainable and efficient vehicle production. The Shift Unlock Mechanism demonstrates how targeted innovation, rooted in smart simplicity, can address modern automotive challenges while setting new standards for adaptability, efficiency, and sustainability.

Keywords: Automotive engineering, gear transition systems, production efficiency, sustainability in manufacturing.

OPTIMAL ESTIMATION OF HIGHER-ORDER CUMULANTS IN BI-ADDITIVE STATISTICAL MODELS

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ABSTRACT

Cumulants are powerful statistical measures that go beyond traditional moments to provide nuanced descriptions of probability distributions, including skewness and kurtosis. This talk presents advanced estimators for cumulants in bi-additive models, leveraging the cumulant-generating function and least-squares estimators. These models, comprising fixed and independent random terms, enable precise estimation of fourth-order cumulants using independent and identically distributed data. We also examine how distributions with parameters of location, dispersion, and shape can be analyzed, highlighting the theoretical and practical significance of cumulants.

Key Words: Ovary Transplantation; Hydrocortisone; Inflammation; Necrosis; Histopathology

IMPACT PREDICTION OF TECHNOGENIC SEISMICITY ON THE STORAGE TANKS STABILITY

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Seismic loads are serious threat to the integrity of storage tanks with liquid hydrocarbons. Earthquakes could cause deformations and damage to tank structures, which leads to the leakage of hazardous substances, environmental pollution and significant economic losses. The abstract investigates the seismic loads impact on the structural integrity of storage tanks and analyzes methods to prevent and minimize negative consequences.
Modern approaches to increase the seismic resistance of tanks have been considered, such as floating membranes installation, internal partitions and damping systems application to reduce fluid vibrations.

A comprehensive method to increase the environmental safety of reservoir operation in conditions of increased seismicity has been proposed, which includes engineering solutions, regular monitoring, and improvement of the regulatory framework. The implementation of these measures will help to reduce the risks of emergency situations, ensure environmental protection, and increase the operation reliability of oil and gas storage facilities in seismically hazardous regions.

Reports of damage caused by past earthquakes show that liquid storage tanks exhibit complex dynamic behavior under seismic conditions. The occurrence of certain failures depends on factors such as the presence of anchors, slenderness factor, roof type, filling rate, etc. Experience shows that based on the height to diameter ratio, the dynamic behavior of the tank could be completely change. Typically, under seismic conditions, a thin tank behaves like a cantilever, with high stress concentrations at the base and a significant overturning moment due to the high center of mass. The most likely failures are uplift and buckling of the foot, rupture of the bottom-bottom shell joint, buckling of the bottom shell, failure of the inlet/outlet piping system, failure of anchors, buckling of the shell in the central part of the shell. Damage to the top and roof is not typical for tall tanks. In contrast, very squat tanks suffer more damage to the top due to fluctuations in the contents inside, including warping at the top of the body and roof, failure of the wall-roof junction, and failure of the column supporting the roof [1-3].

According to the research results, the free surface elevation in tanks of various shapes has been calculated under the action of seismic loads of different frequencies, magnitudes and at different distances from the earthquake epicenter. The free surface elevation in tanks has also been calculated using damping devices [4-5]. The forecast data for the change in the free surface elevation in tanks have been presented in Table 1.

Table 1 – Forecasting the impact of technogenic seismicity on the tanks stability

Seismic load frequency, Hz	Magnitude	Distance to the epicenter of the earthquake, m	Free surface elevation in the tank, m	Tank filling level, m	Tank type	Damping devices
2	3	300	0,32	1	prismatic	немає
2	3	300	0,17	1	prismatic	немає
2	6	300	0,25	1	cylindrical	немає
2	6	200	0,4	1	cylindrical	немає
4	8	800	0,3	2	cylindrical	немає
4	4	200	0,011	2	cylindrical	немає
2	4	500	0,05 (0,25)	1	cylindrical	membrane
2	6	200	0,2 (0,63)	1	cylindrical	membrane
2	6	200	0,03 (0,55)	1	cylindrical	ring partition at height 0,8 m, R_{hole}=0,5 m
2	5	500	0,2 (0,45)	1	cylindrical	ring partition at height 0,8 m, R_{hole}=0,5 m
2	3	500	0,02 (0,1)	1	cylindrical	ring partition at height 0,6 m, R_{hole}=0,5 m

Using damping devices, it is possible to reduce the fluctuations of the liquid in the tank by 20-30%, which will allow for the safe operation of liquid hydrocarbon tanks under seismic loads of up to 5 points, prevent spills and release of liquid hydrocarbons into the environment, and reduce the technogenic impact on the environment.

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NEW APPROACHES TO IMPROVE THE ENVIRONMENTAL SAFETY LEVEL OF PETROLEUM PRODUCTS STORAGE AND TRANSPORTATION IN TANKS

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ABSTRACT

The issue of environmentally safe transportation of petroleum products is urgently important. The experience of past environmental disasters and accidents during the petroleum products transportation proves the possibility of large-scale consequences, which manifest themselves not only in the form of significant economic losses, but also in the destruction of ecosystems and threats to human health.

According to the study, traditional methods of petroleum products storage and transportation do not meet modern environmental requirements and the introduction of innovative technologies is critically important to minimize the negative impact on the environment. It is necessary to assess the impact of petroleum products on the environment under different transportation conditions. As practice shows, the use of modern tank condition monitoring systems and automated storage parameter control systems allows for timely detection of deviations and prevention of emergency situations, which helps reduce the environmental pollution risks [1-2].

It should be noted that the use of new materials with increased corrosion resistance and hermetic tank structures reduces the likelihood of petroleum product leaks and their entry into soil and water resources.

At the same time, it is necessary to emphasize that the implementation of technologies for the utilization and processing of petroleum product waste is also important, which also allows to reduce the volume of hazardous waste and use them as secondary resources [3-4].

Increasing the environmental safety level of storage and transportation of petroleum products in tanks is a complex task that requires an integrated approach. The combination of modern technological solutions will minimize the negative impact on the environment, ensure the sustainable functioning of the oil industry and increase the level of environmental responsibility of enterprises. The implementation of the proposed measures will contribute not only to the preservation of natural resources and public health, but also to increase the economic efficiency of enterprises, strengthening their reputation in the international market and fulfilling Ukraine's international environmental obligations.

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ECO-FRIENDLY MICROWAVE ASSISTED SPECTROPHOTOMETRIC APPROACH TOWARDS THE DETERMINATION OF CEFADROXIL IN PURE AND IN PHARMACEUTICAL FORMULATION

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Abstract:

Analysis of drugs utilizes organic chemicals and solvents which not only pollute the environment but also have toxic effects on health. A simple eco-friendly method has been developed for estimation of anti-bacterial drug (cefadroxil) in pure and in pharmaceutical formulations using microwave-assisted spectrophotometry. The absorption maxima of the resultant blue complex was determined to be 700nm. All the reaction condition and different statistics parameters for the proposed methods have been studied. Hence the proposed method is useful for routine determination of cefadroxil. The developed method was successfully applied to the determination of cefadroxil in pharmaceutical formulations, including capsules and tablets.The results showed a good agreement with the labeled claims, indicating the suitability of the method for routine analysis.

A NOTE ON APPROXIMATELY (α, β)-JORDAN BIDERIVATIONS

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ABSTRACT

Introduction and Purpose: The stability of functional equations was first introduced by S.M. Ulam in 1940. Over the decades, mathematicians have explored stability problems for functional equations with various domains and ranges. In this context, we introduced (α, β)-Jordan biderivations in Banach algebras and investigated their stability in the sense of Hyers-Ulam-Rassias.

Materials and Methods: The stability problem of functional equations originated from a question of Ulam concerning the stability of group homomorphisms: Let $(G_1,*)$ be a group and $(G_2,\diamond, d)$ a metric group with metric d. For $\varepsilon > 0$, does there exist $\delta(\varepsilon) > 0$ such that if a mapping $h: G_1 \to G_2$ satisfies $d\big(h(x * y), h(x) \diamond h(y)\big) < \delta$ for all $x, y \in G_1$, then there exists a homomorphism $H: G_1 \to G_2$ such that $d\big(h(x), H(x)\big) < \varepsilon$ for all $x \in G_1$? When such a solution exists, the homomorphisms are called stable. D.H. Hyers partially solved Ulam's problem in 1941 for approximate additive mappings in Banach spaces. In 1978, Th. M. Rassias extended Hyers' theorem to cases involving unbounded Cauchy differences. This led to many results on Hyers-Ulam-Rassias stability, applied to various functional equations and mappings. In this talk, we used the fixed point method to prove the stability and superstability of (α, β)-Jordan biderivations on Banach algebras under the biadditive s-functional inequality: $\|f(x + y, z + w) + f(x + y, z - w) + f(x - y, z + w) + f(x - y, z - w) - 4f(x, z)\| \leq \big\|s\big(2f(x + y, z - w) + 2f(x - y, z + w) - 4f(x, z) + 4f(y, w)\big)\big\|$, where s is a fixed nonzero complex number with $|s| < 1$.

Results: For a Banach algebra A with automorphisms α, β, we say that a $\mathbb{C}$-bilinear mapping $D: A \times A \to A$ is a (α, β)-Jordan biderivation if $D(x^2, y^2) = D(x, y)\alpha(y)\alpha(x) + \beta(y)D(x, y)\alpha(x) + \beta(x)D(x, y)\alpha(y) + \beta(x)\beta(y)D(x, y)$ for all $x, y \in A$. We proved the stability of such mappings on Banach algebras, associated to biadditive s-functional inequalities.

Discussion and Conclusion: The current findings suggest that these results can be extended to a broader class of spaces where analogous structures exist. In conclusion, this generalization offers promising opportunities for further exploration and development in this field of research.

Key Words: Hyers-Ulam-Rassias stability; (α, β)-Jordan biderivation; Banach algebra; biadditive s-functional inequality.

CONTRIBUTION TO THE ASSESSMENT OF ENERGY LOSSES AT A STEERING VALVE IN A HYDRAULIC SYSTEM

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Abstract

In this work we present the results of an experimental study carried out on the analysis of the influence of pressure drops on the quality of energy transmitted by a hydraulic system. The hydraulic system studied is used in a rolling mill at a steel complex in Algeria. The system has a operating pressure of around 210 bar, with a variable oil flow rate of up to 120 l/min.

The study focused mainly on assessing pressure losses at the steering valve (4/3 Hydraulic distributor) installed on the working line (high pressure), and the tests were carried out in two stages. The first stage using a closed-centre valve (R), while the second stage experiments were carried out using an open-centre valve (H), see figure below.

The pressure drop ΔP at each valve was measured in both working directions (P-A and P-B), respectively during the extension and return of the rod of the double-acting hydraulic cylinder installed at the finisher of the steel rolling system.

In this context, we have exploited the results (differential pressure values ΔP) collected. The influence of the flow rate Q (mainly the flow velocity of the fluid), which passes through the hydraulic components in question on the singular energy loss ΔP of the valve was characterised. A statistical analysis was carried out on the sample collected of ΔP followed by statistical tests of fit. The statistical analysis clearly shows that the evolution of local (singular) pressure losses at the steering valves (4/3 Hydraulic distributor) studied follows a Beta law.

In conclusion, knowing the distribution law of the pressure losses ΔP, we can improve the efficiency of the hydraulic system studied, by choosing the right component to install (the H or R centre valve), and consequently improving the quality of the hydraulic energy transmitted.

Key words : hydral energy, pressure losses, hydraulic distibutor, statistical analysis

IN SILICO APPROACH FOR EVALUATION OF 1-(INDOLIN-1-YL) ÉTHAN-1-ONE DERIVATIVES AS INHIBITORS AGAINST PROSTATE CANCER: 2D-QSAR, ADMET PREDICTION, MOLECULAR DOCKING ANALYSIS

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Abstract – Prostate cancer is a vital global health concern, it is among the most prevalent cancers affecting men. While various therapeutic options are available to manage this disease, the development of resistance to existing pharmaceutical treatments highlights the critical need for new anti-prostate cancer drugs.

This research seeks to evaluate the potential bioactivity of newly designed 1-(indolin-1-yl) éthan-1-one derivatives through in-silico approaches, with an emphasis on investigating their inhibitory interactions with TRIM24 PHD-bromodomain.

For that purpose, combined computational approaches were employed, including 2D-QSAR, molecular docking. The multiple linear regression (MLR) method were utilized to conduct a quantitative structure-activity relationship analysis on a collection of 37 1-(indolin-1-yl) éthan-1-one derivatives. The analysis of 2D-QSAR results demonstrated that the inhibitory activity could be predicted with high precision with coefficients of determination (R^2) of 0.82 and 0.78 for the training and test datasets, respectively. The developed models underwent rigorous validation through internal and external procedures.

Furthermore, the assessment of ADMET properties established the likelihood of these newly designed ligands being suitable as drug candidates. Four of the selected ligands were submitted to the molecular docking study to evaluate their affinity to the TRIM24 PHD-bromodomain receptor.

Amongst the newly proposed molecules, the ligands P4 and P5 have demonstrated potential as promising candidates for inhibiting prostate cancer. To assess the binding stability of the chosen ligands with the enzyme under study, a Molecular dynamics simulations study is currently underway.

Keywords: Prostate cancer. 2D-QSAR. ADMET. Molecular Docking. TRIM24 PHD-bromodomain. 1-(indolin-1-yl) éthan-1-one

$(C_4N_2H_7)_6(C_4N_2H_6)_2V_{10}O_{28}$ DECAVANADATE COMPOUND: SYNTHESIS, CHEMICAL CHARACTERISATION, AND ASSESSMENT OF ANTITUMOR POTENTIAL

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Abstract

Numerous investigations, conducted over the last decade, highlighted the antitumor properties of decavanadate compounds. In this study, we synthesized and characterized a novel decavanadate compound of a formula unit $(C_4N_2H_7)_6(C_4N_2H_6)_2V_{10}O_{28}$. Its structural characterisation, performed by X-ray diffraction on a single-crystal, revealed that the compound crystallized in the monoclinic system space group $P2_1/c$ with lattice parameters a=11.937(8) Å, b=13.399(6) Å, c=17.941(3) Å, β=105.35(3), Z=4 and V=2767.4(9) $Å^3$. In the crystal, the centrosymetric decavanadate groups $[V_{10}O_{28}]^{6-}$ and the organic cations 2-methylimidazolium participated in O-H···N hydrogen-bonding interactions. The Hirshfeld surface analysis of the crystal structure indicated that the most important contributions for the crystal packing were from H···H (30.3%),

O…H/H…O (23.1%), V...O/O...V (8.7%), H…C/C…H (8.4%), N…C/C…N (7.8%) and O…O (4.1%) interactions.

Interestingly, this compound showed highly anti proliferative effect on the IGR39 melanoma cell line with an IC_{50} value of 7 µM , without being cytotoxic. However, this compound displayed cytotoxic effect on triple negative breast cancer cells (MDA-MB-231) with IC_{50} values of 18.7 µM and 6 µM, after 24h and 72h treatments, respectively. These results contributed to better understand the structure-function relationship of the decavanadate compounds, in order to develop the next generation antitumor drugs, targeting specific cancer cells.

Keywords: Decavanadate, X-ray diffraction, Hirshfeld surface analysis, Anti-proliferative activity, Melanoma, Breast cancer.

AGENT-BASED SWARMING SYSTEMS: THEORETICAL FOUNDATIONS, SIMULATIONS, AND APPLICATIONS IN PATTERN FORMATION AND TURBULENT FLUID DYNAMICS

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Abstract

This paper explores the theoretical and computational framework of agent-based swarming systems, emphasizing their potential to model and simulate complex behaviors observed in natural and engineered systems. By leveraging multi-agent interactions, we investigate the emergence of self-organized patterns and their parallels to phenomena in turbulent fluid dynamics. Central to this study is the integration of swarm intelligence with principles of nonlinear dynamics and statistical mechanics, enabling the development of robust simulation tools. These tools elucidate how localized interactions can drive global pattern formation and transitionary states akin to turbulence. Applications span diverse domains, including ecological modeling, adaptive robotics, and the study of coherent structures in fluid systems. Through comparative analyses and simulations, we demonstrate the utility of agent-based approaches in bridging the gap between micro-level agent dynamics and macro-level emergent phenomena. The insights garnered underscore the relevance of swarm-based methodologies in advancing the understanding of pattern formation and turbulence across interdisciplinary boundaries.

Keywords: Agent-based Modeling, Swarm Intelligence, Nonlinear Dynamics, Statistical Mechanics, Computational Simulation & Ecological Modeling

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CREATIVE INDUSTRIES: AN INDUSTRIAL DESIGN ENGINEERING APPROACH

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ABSTRACT

Introduction and Purpose: Integrating engineering and design disciplines is crucial for fostering innovation and gaining competitive advantage in creative industries. This study aims to examine the effects of an Industrial Design Engineering approach utilizing artificial intelligence-based generative design technology on motorcycle brake calipers. Specifically, the research seeks to develop three distinct designs suitable for three different manufacturing methods—CNC machining, casting, and 3D printing—by applying an AI-based generative design approach to the design of motorcycle brake caliper brackets. Considering the unique geometric and material constraints of each manufacturing method, optimized design solutions will be presented based on functionality, aesthetics, and production efficiency criteria. In this context, advanced technologies such as 3D modeling, 3D printing, generative design, and rapid prototyping enable the rapid development of innovative and versatile product concepts.

Materials and Methods: In the research process, the structural loads and geometric constraints to which the motorcycle brake caliper bracket is subjected were first identified. This data was input into generative design tools, along with manufacturing method constraints (CNC machining, casting, 3D printing). Using generative design software, three optimized bracket designs were genereted for each manufacturing method. Design for CNC machining featured simpler geometries suitable for cutting/drilling processes, design for casting ensured appropriate material distribution and ease of molding, and 3D-printed bracket design incorporated complex internal structures and lightweighting techniques. The designs obtained were detailed using 3D modeling software and transformed into physical prototypes using rapid prototyping techniques (e.g., 3D printing). Each design was evaluated based on criteria such as functionality, aesthetics, production cost, and time.

Results: The generative designs developed for the three different manufacturing methods reflect the unique advantages and limitations of each method. Designs developed for CNC machining were optimized for ease of production and minimal material waste. Casted designs were optimized with moldability in mind. Brackets designed for 3D printing achieved weight optimization through complex internal structures and lightweighting techniques, while also offering more innovative aesthetic solutions. Each design was validated for suitability with its respective manufacturing method, and production costs and times were analyzed comparatively.

Discussion and Conclusion: The results demonstrate the contribution of the Industrial Design Engineering approach to creative industries through a specific example, showing that the generative design approach can be adapted to different manufacturing methods to develop high-performance and production-efficient brake caliper brackets. Designs optimized separately for CNC machining, casting, and 3D printing maximized the technical and cost advantages of each method. This approach enhances flexibility and innovation potential in the design process while providing solutions tailored to the requirements of manufacturing processes. Future studies can expand into areas such as the integration of these three manufacturing methods and the use of sustainable materials, thereby enabling more environmentally friendly and user-focused product designs.

Key Words: Industrial Design Engineering; Motorcycle Brake Caliper Bracket; Generative Design; CNC Machining; Casting; 3D Printing; Rapid Prototyping; 3D Modeling; Artificial Intelligence; Creative Industries

PREPARATION OF WASTE RED CLAY-BASED POROUS GEOPOLYMER FOAM AS AN EFFECTIVE ADSORBENT FOR THE REMOVAL OF METHYL ORANGE DYE FROM AQUEOUS SOLUTION

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ABSTRACT

Introduction and Purpose: Discharges of various micropollutants (organic and inorganic) into the environment are on the increase. These pollutants are generally toxic, poorly biodegradable, and cause numerous adverse health effects. In this context, this work focuses on the development of a geopolymer based on red clay waste, with a view to its application as an adsorbent in the treatment of an aqueous medium contaminated by Methyl Orange.

Materials and Methods: The synthesized geopolymer was characterized by various analytical techniques. The raw material and the synthesized geopolymers were characterized by various physico-chemical methods. The results of XRF, XRD, and FTIR confirmed the successful synthesis of geopolymer beads, while the SEM/EDX findings revealed the homogeneous surface of the adsorbents. Adsorption tests were carried out by varying various parameters likely to affect adsorption performance, including adsorbent dose, solution pH, contact time, initial Methyl Orange concentration, and solution temperature.

Results: The kinetic study revealed that the geopolymer eliminates Methyl Orange relatively quickly. The pseudo-second-order model is the most suitable for presenting the adsorption

mechanism. The isotherm for Methyl Orange retention on geopolymer is in perfect agreement with the Langmuir model. Evaluation of the thermodynamic quantities showed that the Methyl Orange adsorption process is favorable, spontaneous, and endothermic. The results we have found allow us to predict that the use of these new generations of geopolymers offers great potential for the retention of cationic textile dyes.

Discussion and Conclusion: The main factors controlling the affinity of the geopolymer beads for the dye is ion exchange capacity. In general, according to the results obtained, methyl orange be haves in a similar way to the geopolymer beads studied.

Key Words: Adsorption; red clay waste; Geopolymer Beads; Methyl Orange; Characterization.

PHYTOCHEMICAL SCREENING AND ANTI TRYPANOSOMAL ACTIVITY OF Ocimum gratissimum (Scent Leaf)

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ABSTRACT

Trypanosomiasis is a disease which is caused by trypanosomes that are single-celled parasitic protozoa belonging to the family Trypanosomatidae, being flagellated organisms which are commonly found in various vertebrate hosts, including humans and animals, the organism caused various degree of infection serious economic losses in livestock from anemia, loss of condition and effects on reproduction. Losses in cattle are especially prominent as well as economy in general, this made the management to be costly, which in turn lead us to the determination of management of drugs from natural plant, Collection of Plant Material were collected from the private garden along Bayero University Kano road and taking to the department of plant sciences and biotechnology for authentication, Extraction of Ocimum gratissimum was done using standard method as described by Atawodi (1993) and Namadina et. al., (2006), with slight modification from Aminu et. al., (2023), standard method of Phytochemical Screening of Ocimum gratissimum was des as describe by Sofowora (2006), Fourier Transformed Infrared Spectroscopy (FTIR) Analysis was conducted using standard method with spectrophotometer,

Acute toxicity and lethality of plant samples was determined using the modified method of (Lorke 1983), T. brucei brucei were obtained from the Department of Trypanosomiasis Research Kano State liaison office. The parasites were maintained in the laboratory by continuous passage in rats intraperitoneally, for the in vivo Anti-Trypanosomal Activity of the extracts. from the results of the study it was determined that percentage yield of the plants extracts were found to be 5.0 and 8.2 of both ethanol and aqueous respectively, alkaloids, saponins and tannins were among the phytochemicals compounds presents while anthraquinones and tryterpenes were absents in the plants extracts, about 10 different peak position were detected in the interatomic bond position from the isolated compound of the plants extracts by FTIR, the LD 50 of the Ocimum gratissimum **(**Scent Leaf**)** shows that no death were recorded at all the doses of the plants extracts which shows that the plants sample is safe for consumption the effects of Occimum gratissimum on the Parasitaemia of Wistar Rats Infected with Trypanosoma brucei brucei shows that extracts at 250mg/kg body weight prolong the lives of the experimental animals thus in conclusion the plants could be used in sustaining the management of trypanosomiases It is recommended that further phytochemical assessment should be done to determine the functional group of the compounds of Ocimum gratissimum so as to ascertain the full therapeutic potential of the plant sample.

Key words: Phytochemical, Trypanosomisis, Ocimum gratissimum

Introduction

Trypanosomes are single-celled parasitic protozoa that belong to the family Trypanosomatidae, They are flagellated organisms that are commonly found in various vertebrate hosts, including humans and animals (WHO, 2021). Trypanosomes are transmitted to their hosts through the bites of infected insects, such as tsetse flies, and can cause a group of infectious diseases collectively known as trypanosomiasis (WHO, 2021). Previous reports have shown that Ocimum gratissimum has a wide range of bioactive compounds such as flavonoids and polyphenols (Venuprasad et al., 2014; Irondi et al., 2016) and essential oils with several beneficial effects (Benitez et al., 2009; Melo et al., 2019).

Problem

Trypanosomiasis is of immense economic importance with a recent estimate of 4.5 billion U.S. Dollars as annual losses to agricultural production in Africa alone (PAAT, 2000). Furthermore, most of the drugs used for treatment are either scarce or costly when available, while the parasite is rapidly developing resistance to the available drugs. In addition, no new anti-trypanosomal drug for treatment of animals have been introduced in the last fifty years, thus underlying the need for the exploration of new drugs in the treatment of this disease. Consequently, several attempts have been made to scientifically evaluate plants that are traditionally said to have anti-trypanosomal effects (Asuzu and Chineme 1990; Mbaya et al., 2007). In an earlier study the water extract of the leaf of this plant was observed to be potentially toxic to rats with an intra-peritoneal LD50 of 120mg/kg body weight (Adamu et al., 2008). However, the plant is yet to be scientifically evaluated for efficacy against trypanosomes. This study reports the therapeutic activity of the water extract of Ocimum gratissimum in experimental Trypanosoma brucei brucei infection.

Justification

Phytochemicals are biologically active compounds found in plants in small amount which are currently having medicinal properties under study for a variety of diseases. These

phytochemicals seems to contribute significantly for protection against degenerative diseases. Some phytochemicals might be poisonous to animals and others might be used as traditional medicine. The absence of some phytochemical components of the plant sample in adding nutritional value to the animal might cause some effects to the animals.

Objectives

The aim of the research is to evaluate the phytochemical components, acute toxicity and Anti Tryanosomal Activity of Ocimum gratissimum (Scent leaf).

The objectives are:

1. To determine the phytochemical composition of Ocimum gratissimum (Scent leaf) leaves using aqueous and ethanolic extraction methods.

2. To determine the Acute Toxicity of O. gratissimum (Scent leaf)

3. To evaluate the in vivo Anti-trypanosomal activities of O. gratissimum (scent leaf).

Material and methods

Collection of Plant Material were collected from the private garden along bayero university kano road and taking to the depertment of plant sciennces and biotechnology for authentication, Extraction of Ocimum gratissimum was done using standard method as described by Atawodi (1993) and Namadina et. al., (2006), with slight modification from Aminu et. al., (2023), standard method of Phytochemical Screening of Ocimum gratissimum was des as describe by Sofowora (2006), Fourier Transformed Infrared Spectroscopy (FTIR) Analysis was conducted using standard method with spectrophotometer, Acute toxicity and lethality of plant samples was determined using the modified method of (Lorke 1983), T. brucei brucei were obtained from the Department of Trypanosomiasis Research Kano State liaison office. The parasites were maintained in the laboratory by continuous passage in rats intraperitoneally, for the in vivo Anti-Trypanosomal Activity of the extracts.

Results and discussion

Table one below show the result of the percentage yield of ethanol and aqueous extract of the leave of Ocimum gratissimu the aqueous has the highest percentage value followed by the ethanol this is as a result of high polarity of the aqueous than the ethanol.

Table 1: Percentage Yield of the Ethanol and Aqueous Extracts of the Leaves of Ocimum gratissimum

Extract (50g)	Percentage (%)
Ethanol	5.0
Aqueous	8.2

The table two below shows the phytochemical constituents of the two solvents shows that anthraquinones and triterpenes were both absent in the two solvent extract and alkaloids saponins, flavonoids and carbohydrates were all present in the sample. It was found that the presence of alkaloids and flavonoids in both ethanol and aqueous extracts (Table 2) revealed the efficacy of the plant against the diseases that they are used for. The presence of flavonoids in the extracts also confirms the assertion of Ingrid and Mathias (2006) who said that O. gratissimum

is a highly antiparasitic plant, the activity of this plant is probably due to the ability of flavonoids to inhibit α-amylase activity which regulates the amount of glucose in the blood. The presence of saponins and glycosides in reasonable quantities also justified the traditional use of the plant in the treatment of tuberculosis and diabetes (Abdullahi et al., 2003). Dapar et al. (2007) reported that tannins form complexes with proteins through hydrogen and covalent bonds as well as other hydrophobic effects which inhibit cell protein synthesis. The presence of these phytochemicals therefore has been adduced for the significant antibacterial activity of the extracts.

Table 2: Phytochemical Constituents in Ethanolic and Aqueous Extracts of O. gratissimum

Phytochemical	Ethanol Extract	Aqueous Extracts
Alkaloids	+	+
Saponins	+	+
Carbohydrates	+	+
Tannins	+	+
Anthraquinones	-	-
Steroids	+	+
Triterpenes	_	-
Terpenoids	+	+
Flavonoids	+	+
Cardiac glycosides	+	+

The results of the FTIR analysis confirmed the presence of alcohol, aldehyde, alkenes, amines, ketones, esters, alkyl, carboxylic acid and phenol. The absorbance band analysis in bioreduction process are observed in the region between 400-4000cm^{-1} are 3321.1, 2926.0, 1602.8, 1654.9, 1446.2, 1353.0, 1304.6, 1062.3 and 1013.8cm^{-1}. Major peak was 3321.1cm^{-1} that could be assigned to the –OH stretching (Vibration of O-H alcohol and phenols). Presence of –OH functional group indicates the presence of different secondary metabolites (Steroid, terpenoids, alkaloid, saponins, flavonoid, phenols and carbohydrates). 2926 cm^{-1} is indicating the presence of C-H stetching, C=O stretching of carboxylic acid and ketone (hydrogen bonded). 1654 cm^{-1} and 1602.8 cm^{-1} indicating the presence of C=C stretching, N-H bending of amines and C=O stretching of amide respectively (steroid, terpenoid, saponins, fatty acids, glycosides and coumarin). 1446.2 cm^{-1} is indicating the presence of C-N stretching of primary amines and C-H bending, the presence of C-N and C-H functional group indicated alkaloid.1353 and 1304.6 cm^{-1} is indicating the presence of -CH (CH3) isobutyl/ prophyl group and -CH3 alkyl/CH deformation respectively. 1200.2 cm^{-1} and 1062.3 cm^{-1} is indicating C-O stretching of aryl ether and phenol (Anthraquinones present) and C-H stretching of aromatic hydrcarbons (Terpenoids, steroid, saponins, glycoside and carbohydrate present). 1013 cm^{-1} is indicating the presence of C-O stretching (Anthraquinones present).

Table 3: Peak Positions and Probable Inter-atomic bond of Isolated Compounds from leaves Ocimum gratissimum extract fraction by FTIR

IR-absorption (cm^{-1})	Functional group	Remark
3321.1	O-H Stretching vibration of alcohol and phenols	Steroid, terpenoids, saponins, phenols, carbohydrates
2926.0	C-H (Stretching), C=O Stretching of Carboxylic acid and ketone	Flavonoids, terpenoids, steroid, saponins
1654.9	C=C Stretching, N-H bending of primary amines	Steroid, terpenoids, saponins, fatty acid
1602.8	C=O Stretching of amide	Glycosides , coumarin
1446.2	C-N stretching of aromatic amines,C-H bending	Alkaloids,
1353.0	$CH(CH_3)$ isobutyl and isopropyl, CH deformation, -NH	Alkaloid
1304.6	-CH3 alkyl, N-H	Alkaloid
1200.2	C-O stretching of aryl-ether and phenols	Anthraquinones
1062.3	C-H stretching of aromatic hydrocarbon	Terpenoid, steroid , saponins, glycosides, carbohydrate
1013.0	C-O Stretching	Anthraquinones

No death was recorded in the first phase of the study in rats. In the second phase, doses of 250, 150, 75mg/kg and control were used and no death was also recorded. The oral median lethal dose (LD50) for the ethanol extract of **Ocimum gratissimum** was therefore estimated to be greater than 250SSmg/kg and no sign of behavioural changes were also observed.

Table 4: Acute Toxicity Studies (LD50) of the Ethanolic Extract of Ocimum gratissimum

Dose (mg/kg) Administration	No. of Animals before Administration	No. of Death After Administration
250	3	0
150	3	0
75	3	0
Control	3	0

The result in the table 5 below show that the group of rats treated with higher dose of 200mg shows higher survival days in the animals than those with lower dose although all the concentration of the animal shows that the extracts of the animals have supress the growth of the parasite, however all the concentration of the extracts were not as effective as the control group

Table 5: Effects of Occimum gratissimum on the Parasitaemia of Wistar Rats Infected with Trypanosoma brucei brucei

Group (Dose mg/kg)	Pre-Treatment Parasitaemia ($\times 10^6$)	Post-Treatment Parasitaemia ($\times 10^6$)	Survival Days
100	0.56 ± 0.05^b	227.02 ± 23.2^a	8 - 10
150	0.59 ± 0.7^b	188.55 ± 62.7^a	8 - 12
200	0.57 ± 0.1^b	114.81 ± 7.9^a	10 - 13
Control(D A)	0.57±0.2		

D. A (Diminazine aceturate)

Conclusion

It can be concluded that the phytochemical analysis revealed the presence of bioactive compounds including Alkaloids, Flavonoids, Quinones, Saponins and Tannins. Treatment of T. brucei brucei infected rats with Ocimum gratissimum extracts at 250mg/kg body weight prolonged the lives of the experimental animals, thus substantiating the fact that scent leaf could be used in the management of Trypanosomiasis.

Recommendations

It is recommended that further phytochemical assessment should be conducted to determine the functional group of the lead compounds of Ocimum gratissimum in order to ascertain the full therapeutic potential of the plant.

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ENHANCING MINORITY CLASS DETECTION IN INTRUSION DETECTION SYSTEMS USING GAN-BASED DATA AUGMENTATION: A HEURISTIC STUDY

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ABSTRACT

When classifying imbalanced datasets, the classification performance of minority classes is often low. In this study, the effect of the Generative Adversarial Network (GAN) data augmentation method on the minority classes, which exhibit poor performance in intrusion detection systems (IDS), a significant problem in the field of cybersecurity, has been investigated. The inability to detect minority class attacks can lead to serious security vulnerabilities. The main objective of the study is to examine the change in the performance of machine learning (ML) methods, which are affected at varying levels by imbalanced datasets, after the use of GAN. In this study, data augmentation was performed using the GAN method on the UNSW-NB15 dataset, and the classification performance of Random Forest Classifier and AdaBoost methods was compared before and after data augmentation. The success of the process was analyzed using metrics such as accuracy, precision, recall, and F1-score. Following GAN-based data augmentation, significant improvements in metrics such as accuracy, recall, and F1-score were observed in the Random Forest Classifier model, which is particularly effective in high-dimensional datasets. The accuracy of the Random Forest Classifier model increased from 83.57% to 98.43%, corresponding to an improvement of approximately 15%. AdaBoost, which generally performs better on imbalanced datasets, showed limited improvement (8% increase) in accuracy, increasing from 86.50% to 94.67 % when the imbalance was eliminated. This study is expected to provide a useful reference for understanding the impact of GAN-based data augmentation techniques on improving the detection performance of IDSs in minority classes.

Key Words: Imbalanced Datasets, Generative Adversarial Networks (GAN), Intrusion Detection Systems (IDS), Machine Learning, Data Augmentation

INTRODUCTION

Intrusion Detection Systems (IDS) frequently face challenges in identifying minority attack classes, primarily due to imbalanced datasets. Traditional models trained on such datasets tend to prioritize majority classes, resulting in significant security vulnerabilities. To mitigate this issue, researchers have proposed data augmentation techniques in the literature. Imbalanced data refers to datasets where the disparities between classes are substantial, leading to inadequate classification performance by traditional models. The underrepresentation of minority classes often results in their neglect.(Gong & Kim, 2017)

This study explores the impact of GAN-based data augmentation on balancing class distributions and enhancing detection accuracy. The UNSW-NB15 dataset (Moustafa & Slay, 2015) was employed in the experiments. The research investigates the effects of a GAN-based data augmentation method on improving the performance of IDS, particularly for minority classes, within the cybersecurity domain. By utilizing the UNSW-NB15 dataset, data augmentation was conducted, and the performance of machine learning models was compared before and after augmentation. The analysis revealed that data balancing positively influences the performance of machine learning models, consistent with findings from prior studies. However, this study further examines how the impact of data augmentation may vary across different ensemble learning methods.

The rest of the paper is organized as follows: Section 2 reviews related work on imbalanced learning and anomaly detection. Section 3 provides the theoretical background of ensemble machine learning techniques, specifically AdaBoost and Random Forest, along with the GAN-based data augmentation approach. Section 4 details the dataset, preprocessing techniques, and machine learning models utilized in the study. Section 5 presents the results and performance analysis of the machine learning models before and after data augmentation. Finally, Section 6 concludes the paper by discussing key findings, study limitations, and potential directions for future research.

RELATED WORKS

Imbalanced datasets are commonly encountered in real-world problems, where the majority of samples consist of "normal" examples, while "abnormal" examples constitute only a small portion. Misclassifying a minority class example as normal tends to result in more significant consequences compared to the reverse error (Chawla et al., 2002). To address this issue, various methods have been proposed in the literature to balance imbalanced datasets. Oversampling methods increase the number of minority class examples, while under sampling methods reduce the number of majority class examples to achieve balance. Additionally, hybrid methods that combine both approaches have been developed (Japkowicz & Stephen, 2002). Among oversampling techniques, the Synthetic Minority Over-sampling Technique (SMOTE) is widely used. Proposed by Chawla et al. (2002), SMOTE generates synthetic examples from minority class samples to create a balanced dataset. However, this method may lead to class overlapping or noise formation, as it does not account for the overall data distribution around the minority class (Nguyen et al., 2009). Recent advancements, such as the random walk-based oversampling method, have demonstrated the ability to generate synthetic examples more efficiently than SMOTE(Pir, 2022). Furthermore, cost-sensitive learning and ensemble methods have shown promise in handling imbalanced datasets. Cost-sensitive learning increases the weight of errors associated with minority classes, while ensemble methods combine multiple models to improve performance. These approaches are particularly effective in high-stakes applications, such as banking, where the cost of errors is substantial and the detection of even the smallest classes is critical.

BACKGROUND

This section provides the necessary background information on used ensemble learning methods, AdaBoost and Random Forest, as well as an overview of the Generative Adversarial Network (GAN) approach.

AdaBoost, developed by Freund and Schapire (1997), is one of the earliest boosting techniques designed to construct a robust and stable model through the integration of weak classifiers. The process initiates by assigning equal weights to all observations. Following the training of the initial model, higher weights are allocated to misclassified observations. Consequently,

subsequent learners prioritize these misclassified examples, enhancing the model's classification accuracy. This iterative procedure continues until a predefined iteration limit, denoted as t, is achieved.

Random Forests constitute an ensemble learning method that integrates multiple decision trees, each constructed using independent and identically distributed random vectors. Each tree within the forest is trained independently, and the final prediction is derived by aggregating the outputs of the individual trees. As the number of trees in the forest increases, the generalization error of the model converges to a specific limit (Breiman, 2001).

The generalization performance of a random forest is influenced by two key factors: the accuracy of the individual trees and the degree of correlation among them. The random selection of features during the node-splitting process reduces the model's error rates to levels comparable to those achieved by the AdaBoost algorithm, while simultaneously enhancing its robustness to noise (Breiman, 2001).

The model incorporates an internal estimation mechanism to monitor critical metrics, including the error rate, the strength of individual trees, and the correlation among the trees. This mechanism also evaluates the impact of the number of features used during the splitting process on the model's performance. Furthermore, internal estimates are employed to assess the importance of variables within the model. This approach is applicable not only to classification tasks but also to regression problems.

A Generative Adversarial Network (GAN) comprises two primary components: a generator and a discriminator. The generator is designed to create synthetic data that closely mimics real data, while the discriminator aims to accurately distinguish between the artificially generated data and the real data. Through this adversarial process, the continuous competition between the two networks enhances their overall performance (Goodfellow et al., 2014).

After the introduction of Generative Adversarial Networks (GANs), numerous variations derived from the classical GAN model have emerged. GAN models are broadly categorized into two primary groups: advancements based on architectural optimization and advancements based on objective function optimization.

Architectural optimization-based developments are further divided into convolutional models (e.g., DCGAN), conditional models (e.g., CGAN, infoGAN, ACGAN, and SGAN), and autoencoder-based models (e.g., AAE, BiGAN, ALI, AGE, and VAE-GAN). Conversely, advancements based on objective function optimization include models such as Unrolled GAN, f-GAN, Mode-Regularized GAN, Least-Square GAN, EBGAN, WGAN, WGAN-GP, and WGAN-LP.(Salehi et al., 2020)

EXPERIMENT

This study investigates the impact of GAN-based data augmentation on the performance of machine learning models. Machine learning models were evaluated using accuracy, precision, recall, and F1-score metrics both before and after the generation of synthetic data using GANs. The experiments were conducted within a controlled software and hardware environment. The hardware configuration included an AMD Ryzen 5 5600X MPK processor with six cores operating at speeds between 3.7 GHz and 4.6 GHz, 16 GB of DDR4 RAM, and an NVIDIA RTX 3060 Ti OC graphics processor with 8 GB of memory. The operating system was Windows 10. The software environment comprised Visual Studio Code version 1.96.2, Python version 3.10.4, and deep learning frameworks such as PyTorch version 2.2.2+cpu and Scikit-learn version 1.3.2. Additionally, libraries including NumPy (1.25.2), Pandas (1.4.2), and Matplotlib (3.7.3) were employed for data processing and visualization. This setup was carefully selected to ensure the reliability of the model training and evaluation processes.

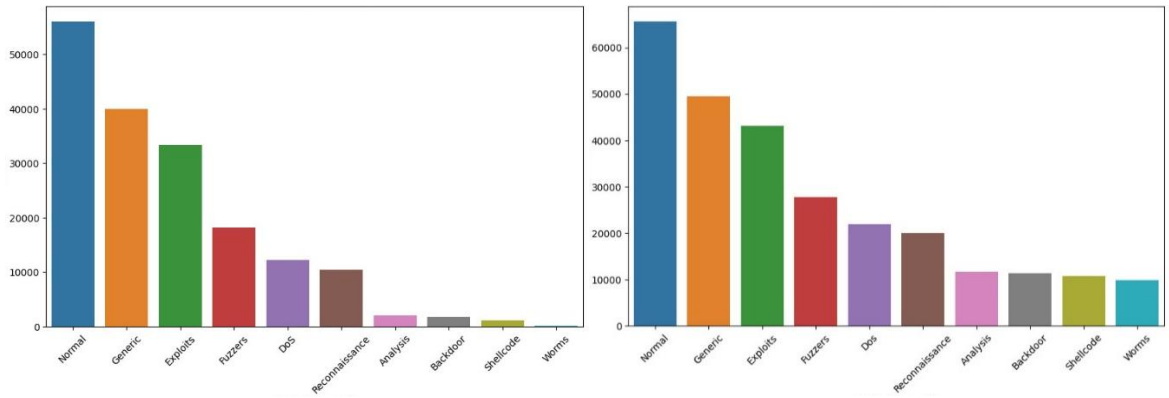
The UNSW-NB15 dataset was utilized in this study, which encompasses a wide range of attack types. Denial-of-Service (DoS) attacks aim to disrupt services, while User-to-Root (U2R) and Remote-to-Local (R2L) attacks seek unauthorized access. Probing and port scanning attacks are designed for information gathering, whereas brute force attacks focus on password cracking. Phishing attacks target the acquisition of sensitive information, and SQL injection attacks provide unauthorized access to databases. Additionally, malware and backdoor attacks pose significant threats by compromising system security. These attack types exploit system vulnerabilities, thereby jeopardizing the integrity and confidentiality of systems.

Data preprocessing is a critical step to ensure the data is appropriate for machine learning and data augmentation. In this study, nominal data were transformed into ordinal integers to facilitate processing by GAN and machine learning models. The data samples were normalized to unit norm, and each feature was scaled using StandardScaler, resulting in all variables being standardized with a mean of 0 and a standard deviation of 1. Variables exhibiting high correlation or predominantly constant values were eliminated. Based on correlation analysis, columns demonstrating more than 95% dependency or containing over 99% constant values—specifically 'ct_srv_dst', 'ct_srv_src', 'dloss', 'dpkts', 'is_ftp_login', 'sloss', 'spkts', and 'swin'—were excluded from the dataset.

In the training process of the GAN model and machine learning, hyperparameters are utilized for optimization. The latent dimension, which refers to the size of the random noise vector input to the generator, is set to 100, serving as a critical component for synthetic data generation. The label size is assigned to the value of 10, corresponding to the number of class labels. The output size is configured as 36, incorporating the attack_cat feature, which is employed as a label during data preprocessing. This ensures that the generated synthetic data aligns with the feature space of real samples. As illustrated in Figure 1, the dataset achieves greater balance following data augmentation using GAN.

Figure 1

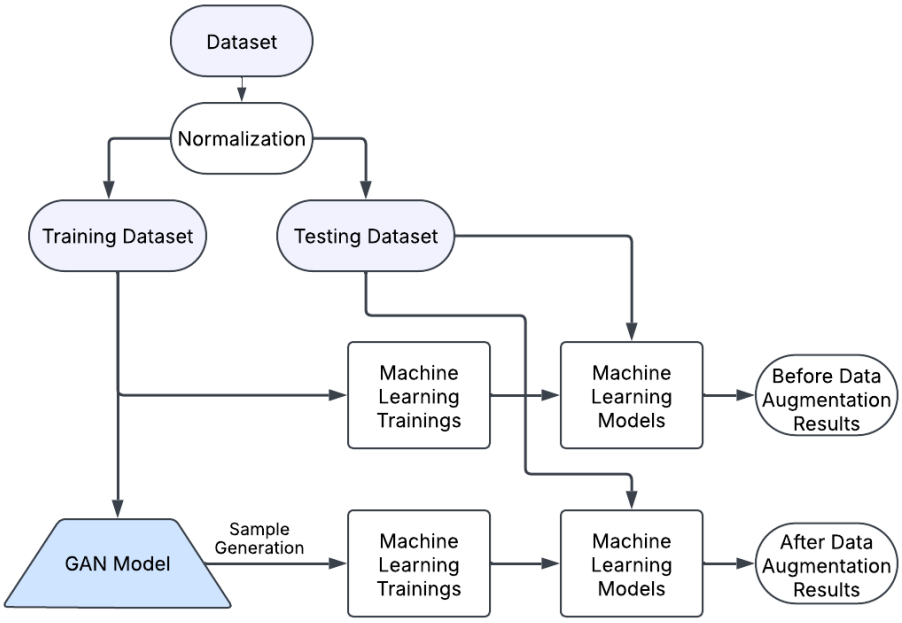
Comparison of Class Distributions Before and After GAN-Based Data Augmentation



The learning rate was established at 0.0002 to regulate the step size of model weight updates, thereby ensuring convergence and stability. A mini-batch size of 64 was employed, determining the number of samples processed in each training iteration and balancing computational efficiency with model accuracy. The training process was conducted over 100 epochs, enabling the dataset to be processed multiple times by the model to enhance predictive performance.

Figure 2

Integration of GAN-Based Data Augmentation into Ensemble Machine Learning Models



To maintain a balanced training dynamic and mitigate risks such as overfitting or mode collapse, the discriminator loss threshold was set to 1. Furthermore, the number of generated data samples was fixed at 10,000 for each class, representing the volume of synthetic data created to augment the dataset. This strategy enhances the model's generalization capability and improves classification accuracy.

The overall structure of data processing and model training is illustrated in Figure 2. Initially, raw data undergoes a normalization process, maintaining the division into training and test sets as provided by the dataset sources. The training data is utilized directly for training machine learning models and is also processed for synthetic data generation through the GAN model. The synthetic data produced by the GAN is incorporated into the training dataset, enhancing the balance of the data distribution for machine learning algorithms. The test data is employed directly for the final evaluation of the machine learning models. Consequently, the performance of ensemble machine learning models, trained with both the original and GAN-augmented data, is analyzed to assess the influence of synthetic data generation on model performance.

Model evaluation is based on several key performance metrics. True Positives (TP) represent correctly classified positive examples, meaning actual attacks are successfully detected. True Negatives (TN) are correctly classified negative examples, indicating that normal network traffic is accurately identified. False Positives (FP) or Type I errors occur when normal examples are mistakenly flagged as attacks, leading to unnecessary security alerts and operational inefficiencies. False Negatives (FN) or Type II errors occur when actual attacks are misclassified as normal traffic, posing serious security risks.

To quantitatively assess classification performance, various statistical measures are employed. Among these, accuracy is a critical metric, representing the proportion of correctly classified instances relative to the total number of instances. It is calculated as follows:

- $\text{Accuracy} = \frac{\text{TP+TN}}{\text{TP+TN+FP+FN}}$

Precision measures the proportion of accurately identified positive instances relative to the total number of instances predicted as positive, and it is calculated as follows:

- $\text{Precision} = \frac{TP}{TP+FP}$

Recall measures the model's capability to accurately detect and classify true positive instances:

- $\text{Recall} = \frac{TP}{TP+FN}$

The F1-score, which serves as a balanced metric for evaluating model performance, is defined as the harmonic mean of precision and recall. It is calculated as follows:

- $\text{F1 Score} = 2 * \frac{\text{Precision} * \text{Recall}}{\text{Precision} + \text{Recall}}$

These evaluation metrics provide a comprehensive understanding of the model's effectiveness, helping to optimize classification performance and reduce security vulnerabilities. The adoption of these measurements enables a detailed analysis of the GAN-based attack detection system, allowing for more informed decision-making in cybersecurity applications.

RESULTS

Table 1

Performance Comparison of Machine Learning Models Before and After GAN-Based Augmentation

Model	Data Status	Accuracy	Precision	Recall	F1-Score
AdaBoost	Before	0.8650	0.7652	0.8650	0.8077
	After	0.9457	0.9452	0.9467	0.9368
RandomForestClassifier	Before	0.8357	0.8766	0.8357	0.8182
	After	0.9843	0.9853	0.9843	0.9840

The performance results of Accuracy, Precision, Recall, and F1-Score for the two ensemble learning methods, both before and after GAN-based data augmentation, are presented in Table 1. The results demonstrate significant improvements in both detection techniques following the application of GAN-based augmentation. Notably, the Random Forest Classifier, which is particularly effective in handling high-dimensional datasets, exhibited substantial gains in accuracy, recall, and F1-score. Specifically, its accuracy increased from 83.57% to 98.43%, reflecting an improvement of approximately 15%. In contrast, AdaBoost showed a more modest enhancement, with its accuracy rising from 86.50% to 94.67%, representing an 8% increase after data balancing. It is important to emphasize that the disparity in performance improvement between Random Forest and AdaBoost is considerable, a finding that constitutes a central focus of this study.

DISCUSSION AND CONCLUSION

This study, consistent with prior research, establishes that GAN-based data augmentation is an effective approach to mitigating class imbalance issues in cybersecurity datasets. Specifically, the findings reveal that the Random Forest model exhibits significant performance improvements, indicating that models adept at handling high-dimensional datasets derive greater benefits from augmented data. In contrast, AdaBoost demonstrates only marginal performance gains, suggesting that not all learning methods are equally capable of leveraging data augmentation effectively. This underscores the necessity for additional optimizations tailored to the operational principles of specific algorithms. For example, the BW-AdaBoost (Bias Weighted AdaBoost) method, as proposed by Jiang et al. (2022), addresses the neglect of minority classes by adjusting error weights. Future research could explore the integration of the BW-AdaBoost method to compare the performance of various ensemble learning techniques, particularly those sensitive to minority classes, on both balanced and imbalanced datasets.

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CURRENT SITUATION OF THE WOOD PLASTIC COMPOSITE (WPC) SECTOR IN THE WORLD AND TURKEY

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ABSTRACT

Introduction and Purpose: The products produced by mixing lignocellulosic materials (wood, agricultural waste, microcrystalline cellulose, etc.) and thermoplastic polymers (HDPE, LDPE, PET, PVC, etc.) using many methods (extruder, injection molding method, etc.) are called in wood-plastic composite (WPC). The objective of this research is to present literature insights regarding the overall condition of the wood-plastic composite industry both wold and in Turkey.

Materials and Methods: WPC's are widely utilized in numerous industries, including construction, furniture production, transportation, technology, and additional fields. In this paper, the general situation of the WPC sector in the world and in Turkey was evaluated on literature and the results obtained were aimed to provide information to researchers and implementers.

Results: In this paper, the current situation of WPC in the world and in Turkey is examined and analyzed. The results showed that WPC industry has made significant progress in recent years; along with technology developments, market dynamics are also changing. North America is the leader, with Europe also holding a significant WPC market share. The Asia-Pacific region is one of the fastest growing regions, particularly driven by China's high demand. The composite material sector in Turkey is growing at a rate above the European and world growth rates. The WPC industry in Turkey is expanding and diversifying and adopting increasingly higher technologies.

Discussion and Conclusion: WPC sector continues its growth trend and it is anticipated that it will continue to rapidly increase its usage area and market share, especially in the furniture sector, with the constantly developed new products.

Key Words: Wood Plastic Composite; World; Turkey; Market Share; Growth Rate.

INTRODUCTION

Composites are solid materials obtained by combining filler and matrix with complementary properties. The filler forms the skeleton or, in other words, the framework of the composite. Its function is to carry most of the mechanical stress applied to the composite material. The matrix allows the reinforcements to be bonded together, to protect the external environment and to distribute the mechanical load within the material (Bourai, 2010; Chanhoun et al., 2018).

Wood-plastic composites (WPCs) are materials created by combining natural wood fibers as filler and plastic polymers as matrix. The word "wood" here does not have a narrow meaning such as a piece of wood, but includes all agricultural waste and woody materials with a fibrous structure (Dönmez Çavdar, 2011; Kaçamer, et al., 2019). On the other hand, the word "plastic" includes plastic types such as polypropylene, polyethylene (high density polyethylene (HDPE), low density polyethylene (LDPE), polyvinylchloride, polystyrene and polycarbonate (Şerker Hırçın, 2021). The advantages of WPCs over plastic materials are; low cost, high heat stability,

ease of supply of raw materials, environmental friendliness as it deteriorates relatively more quickly in nature (Leu et al., 2012; Kaçamer et al., 2019). Their advantages over wood materials are; they can be produced in different colors and textures, have low maintenance and renewal costs, have high dimensional stability, desired shape, are more resistant to physical impacts, fungal and insect damage, lower density per weight of raw material, and can be produced from recyclable (waste) materials (Rowell, 2006; Şeker Hırçın, 2024). Disadvantages of WPCs are; high initial installation cost, low thermal resistance (Çavuş and Mengeloğlu, 2019), low energy efficiency and production volume (Özdemir, 2020).

WPCs can be used both outdoors and indoors, and some common applications include household goods, building materials, automotive applications (indoor and engine), garden and patio products, packaging, and consumer goods. However, construction and automotive applications are the most common worldwide (Schwarzkopf and Burnard, 2016). Due to the diversity of these application areas, the WPC sector is developing and growing day by day. The aim of this study is to examine the current status of the WPC industry in the world and in Turkey.

CURRENT STATUS OF WPC INDUSTRY IN THE WORLD AND TURKEY

Trees are being cut down to obtain wood all over the world. This situation is causing rapid deforestation. Additionally, the current reliance on plastics derived from fossil sources is expected to increase as emerging economies continue to grow (Schwarzkopf and Bernard, 2016). Therefore, researchers are trying to find new ideas to create wood-based alternatives to meet the demand for these resources. One of the alternative solutions developed to overcome the disadvantages of tree cutting is WPCs. The market demand for WPCs is increasing rapidly every year and was 1728.9 kilotons worldwide in 2019 (Hassanin et al., 2021). Polyethylene-based WPCs accounted for 65.9% of the global revenue in 2023. Low cost, high stiffness, and biodegradability offered by polyethylene-based WPC products have been instrumental in driving the market growth. The building and construction segment led the WPC market and accounted for 71.3% of the global revenue share by 2023. Increasing infrastructure development activities in emerging economies such as China, India, Thailand, and Brazil, and rising interest in aesthetically appealing furniture and flooring solutions across the globe have fueled the demand for WPC products in the construction sector (Research and Markets, 2025). The WPC market size is assessed at USD 5.09 billion in 2024 (Market Research Future, 2025). The world, the WPC market is expected to reach USD 15.41 billion by 2030, with a compound annual growth rate (CAGR) of 11.6% from 2024 to 2030 (Research and Markets, 2025). The growth of this market has been driven by increasing applications in areas such as kitchen accessories, home furniture, vehicle interiors, and vehicle speakers (Çolak Bayram, 2024).

North America holds the largest market share of the WPC market due to the growing residential and commercial projects in the region (Mordor Intelligence, 2025). Europe's WPC market accounts for the second-largest market share. China’s WPC market held the largest market share Asia-Pacific region (Market Research Future, 2025). China has shown rapid growth in the WPC market through 2023 due to developments in the construction and building industries (Grand View Research, 2025).

The composite material sector in Turkey is growing at a rate above the European and World growth rates. The Turkish composite material sector is developing rapidly and in the long term, as in other sectors, in parallel with global economic developments in the world (Yılmaz, 2018). In Turkey, the WPC sector within the composite sector is experiencing significant growth in parallel with global trends. While the current installed production capacity exceeds 20 thousand tons, the sales volume has also approached 10 thousand tons. This positive trend has caused the number of WPC manufacturing companies to increase each year, reaching 12. Despite economic difficulties, the sector continues its growth trend and it is anticipated that it will continue to

rapidly increase its usage area and market share, especially in the furniture sector, with constantly developed new products. While the majority of the approximately 10 thousand tons of WPC in Turkey is flooring, the remaining 15% is mainly used in applications such as pergolas. In this context, the future of WPC both in the world and in Turkey seems bright and it is expected to continue to grow in line with the ever-increasing demand in construction projects (Çolak Bayram, 2024).

CONCLUSIONS

In this study, the production amount of WPC and the market situation in the world and in Turkey were examined in detail. WPC is increasingly used in line with the growing demands in construction and other industries both worldwide and in Turkey. The advantages offered by this material, the variety of areas of use and its environmentally friendly features are expected to make its use even more widespread in the future. In this direction, the WPC sector is developing rapidly both world and in Turkey due to increasing environmental awareness and technological developments.

WPCs provide significant advantages with features such as high strength, suitability for end-use and low cost, in addition to raw material savings. In this respect, it is important to increase studies on new composite materials to be produced and especially to expand studies that enable the use of lignocellulosic and agricultural waste as substitutes for solid wood; and to evaluate pure and waste plastic materials.

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PHYSICAL PROPERTIES OF WASTE-CASTING POLYAMIDE 6 (W-PA6G) BASED WOOD PLASTIC COMPOSITES

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ABSTRACT

Introduction and Purpose: The composite material is a macroscopic combination of two or more materials with different chemical or physical properties, resulting in a third material with improved superior properties. The wood plastic composites are materials that use organic plastic as the matrix component and fiber as the reinforcing element. The objectives this research was determined the effects of microcrystalline cellulose (MCC) filler on physical properties (density, thickness swelling (TS) and water absorption (WA)) of PA6G composites.

Materials and Methods: In this paper, wood plastic composites were produced using microcrystalline cellulose (10-20-30%) as lignocellulosic filler, w-PA6G (66-76-86%) as plastic. In addition, lithium chloride salt (LiCI) (2%) and N-butyl benzene sulfonamide (N-BBSA) (2%) were used as melting temperature-lowering material and plasticizer, respectively. The densities, TS and WA of PA6G composites were determined.

Results: The results showed that density, thickness swelling and water absorption increased with the increase in the amount of microcrystalline cellulose. It was observed that thickness swelling and water absorption were raised due to the increase in the water retention time (2-6-12-24-48-72-96-168-336 hours).

Discussion and Conclusion: In this study, the use of industrial PA6G wastes in wood plastic composite production will reduce environmental pollution, and the recycling processes of wood plastic composite materials will be facilitated by the use of microcrystalline cellulose containing natural fibers.

Key Words: Waste-Casting Polyamide 6; Microcrystalline Cellulose; Density; Thickness Swelling; Water Absorption.

INTRUDUCTION

Wood plastic composites (WPC) are environmentally friendly and sustainable materials created by mixing natural wood fibers with thermoplastic polymers. These composites are widely used in various industrial applications such as construction, automotive (dashboards, seat parts, armrests, car, cabin trims, etc.) and packaging (Miléo et al., 2015, Chanhoun et al., 2018; Effah et al., 2018; Mital'ová et al., 2024). The main advantages of WPC's are high durability, acceptable strength and stiffness, lower price, good insulation, thermal and acoustic properties, less maintenance compared to other materials (Dönmez Çavdar et al., 2021; Mital'ová et al., 2024). Microcrystalline cellulose (MCC) is used as an additive, filler and reinforcer in the production of wood-plastic composites (Boudjellal et al., 2022). Cellulose consists of both amorphous and crystalline parts (Rehman et al., 2019). Crystalline cellulose is stronger and more rigid than either amorphous or native cellulose. MCC is derived from crystalline cellulose by eliminating the amorphous regions via acid hydrolysis (Raharjoa et al., 2023). Raharjo et al.

(2023) were used MCC (1-2-3-4%) as a adding in cantala fiber-recycled high density polyethylene (r-HDPE) composites. They investigated the effect of adding MCC on the mechanical and physical properties of cantala fiber/r-HDPE composites and found that the addition of 4 wt% MCC resulted in a important development in mechanical properties and increased density. Şeker Hirçin et al. (2021) produced w-PA6G based composites filled with Uludağ fir wood flour and rice husk determined the mechanical, thermal and morphological properties of these composites. Contrast with rice husk filled composites, Uludağ fir wood flour filled composites had better flexural and tensile properties at 30% and 20% filler contents, in the morphological study; it was determined that the fillers showed inhomogeneous distribution in the polymeric matrix, in the thermal study; filler reduced the crystallinity and melting temperature of w-PA6G based composites. Bhasney et al. (2020) produced HDPE-poly (lactic acid) (PLA) composites and microcrystalline cellulose composites and found that the hardness of HDPE increased by approximately 7% and 10% after incorporating PLA and then MCC fibers. Many studies have been examined in the literature. It has been determined that the studies on the use of PAG6 plastics and MCC in wood plastic composites are limited. The purpose of this study is to determine the physical properties (densities, thickness swelling and weight absorption) of microcrystalline cellulose-PA6G composites.

MATERIAL AND METHODS

Material

Microcrystalline cellulose (MCC) was used as filler. The MCC (density of 0.26 gr/ml; size of 15 µm) was provided by JRS Pharma GmbH & Co. KG (Germany, Rosenberg). Waste cast polyamide 6 (w-PA6G) was generously provided by Plamek Plastic Industry and Commerce Plant located in Bursa, Turkey. Lithium chloride (LiCl), which has a density of 2.068 g/cm³ at 20 °C and a purity of 99% with a molecular weight of 42.39 g/mol, was utilized to reduce the melting temperature of w-PA6G and was sourced from Carlo Erba Company in Val de Reuil, France. N-butyl benzene sulfonamide (N-BBSA), purchased from Sigma Aldrich in St. Louis, MO, USA, served as a plasticizer with a molecular weight of 213.30 g/mol and a density of 1.15 g/mL at 25 °C. 31% boron nitride (BN) was used as mold release agent and it was procured from Alfa Aesar GmbH & Co. KG (Germany, Karlsruhe).

Methods

In this study, w-PA6G was dried in an oven for 24 hours at a temperature of 103 ± 2 °C. Then, w-PA6G-based composites were produced following the manufacturing prescription outlined in Table 1. All components were thoroughly blended in a high speed mixer at speeds of 900 to 1000 rpm for 2 minutes. The mixtures were fed into a single screw extruder (Turkey, Istanbul, TTB 30, Teknomatik), which featured five heating zones. The extruder's screw speed was adjusted to 50 rpm, while the temperatures ranged between 230 and 250 °C from the barrel to the die.

Table 1. The manufacturing prescription of w-PA6G based composites with microcrystalline cellulose additives (%).

ID	MCC	LiCI	N-BBSA	PA6G
Control	-	2	2	96
PA6G-10M	10	2	2	86
PA6G-20M	20	2	2	76
PA6G-30M	30	2	2	66

The extruded materials were first cooled in a water bath maintained at 23 ± 2 °C, and subsequently processed into pellets with a Wiley mill. The pellets were subjected to drying in an

oven set at 103 ± 2 °C for 24 hours to reduce the moisture level to under 1% before being injection molded with a HAIDA HDX-88 (China, Ningbo, Haida Plastic Machinery Co., Ltd.). The injection pressure and temperature parameters (spanning from the feed area to the die area) were adjusted to between 5 and 6 MPa and from 190 to 220 °C, respectively. Prior to testing, the specimens were conditioned in a climatic chamber maintained at 23 ± 2 °C and relative humidity of 65 ± 2%. The density and TS, WA tests were determined based on the procedures of ASTM D 1505-03 (2003) and ASTM D 570-98 (1998), respectively, and five specimens from each composition were tested.

$d = m/V, \quad (1)$

Where d is the density of the specimen (g/cm³) and M is the mass of the specimens (g) and V is the volume of the specimens (5 x 13 x 30 mm).

TS and WA tests were performed on specimens that were soaked in water at room temperature. The retention time of the specimens in water is 2 h, 6 h, 12 h, 24 h, 48 h, 72 h, 96 h, 168 h and 336 h. TS can be calculated through the following equation:

$TS = (T_A - T_B)/T_B \times 100, \quad (2)$

Where; T_A is the thickness of the specimens after immersion (mm), and T_B is the thickness of the specimens before immersion (mm). The WA can be calculated according to the following equation:

$WA = (M_A - M_B)/M_B \times 100, \quad (3)$

Where; M_A is the mass of the specimens after immersion (g), and M_B is the mass of the specimens before immersion (g).

RESULTS AND DISCUSSION

The density results of MCC-PA6G composites are shown in Table 2. The results revealed that there was an increase in the density of the composites due to the increase in MCC addition.

Table 2. The density values of MCC added PA6G based composites.

ID	Density (gr/cm³)
Control	1.08 (0.02)
PA6G-10M	1.10 (0.02)
PA6G-20M	1.12 (0.01)
PA6G-30M	1.16 (0.01)

*Values in parentheses are standard deviation.

While the lowest value was determined from the control specimens, the highest value was obtained from the composites with 30% MCC additive. This is due to the fact that the filler material has a higher density than the plastic matrix (Çavuş, 2017). In addition, the added MCC fills the voids in the plastic matrix, causing an increase in density (Raharjo et al., 2023).

TS and WA properties of MCC-PA6G composites are presented in Table 3. It was observed that the addition of MCC to the PA6G plastic matrix increased the swelling and water uptake amounts in thickness. The maximum increase occurred at 30% MCC addition. This situation is due to the hydrophilic properties of MCC (Yadav and Yusoh, 2015; Mubarak and Abdulsamad, 2019).

Table 3. The thickness swelling and water absorption values of MCC added PA6G composites.

		2 h	6 h	12 h	24 h	48 h	72 h	96 h	168 h	336 h
Control	**TS**	0,29 (0,14)	0,31 (0,14)	0,70 (0,44)	1,29 (0,36)	1,50 (0,44)	1,84 (0,45)	2,64 (0,59)	3,10 (0,63)	3,93 (0,52)
	WA	1,12 (0,34)	1,35 (0,26)	2,07 (0,44)	2,51 (0,39)	3,16 (0,50)	3,62 (0,42)	4,33 (0,61)	4,88 (0,60)	7,92 (0,85)
PA6G-10M	**TS**	0,31 (0,19)	0,58 (0,20)	1,11 (0,35)	1,57 (0,47)	1,84 (0,92)	1,91 (0,95)	2,78 (1,26)	3,34 (1,26)	3,87 (1,30)
	WA	1,51 (0,69)	1,99 (0,45)	2,02 (0,55)	2,73 (0,43)	3,14 (0,28)	3,71 (0,51)	4,25 (0,36)	5,96 (0,69)	6,35 (1,30)
PA6G-20M	**TS**	0,50 (0,17)	0,84 (0,23)	1,41 (0,18)	1,80 (0,35)	2,71 (0,44)	3,36 (0,59)	4,02 (0,28)	5,70 (0,90)	6,50 (0,98)
	WA	1,48 (0,08)	1,88 (0,12)	2,50 (0,08)	3,48 (0,20)	4,60 (0,28)	5,43 (0,25)	6,43 (0,19)	8,77 (0,34)	10,67 (0,36)
PA6G-30M	**TS**	0,80 (0,34)	1,67 (0,21)	2,00 (0,23)	2,48 (0,21)	3,74 (0,57)	4,48 (0,26)	4,97 (0,24)	6,67 (0,64)	8,27 (1,06)
	WA	1,74 (0,17)	2,76 (0,19)	3,10 (0,24)	4,18 (0,35)	5,76 (0,48)	6,43 (0,55)	7,32 (0,62)	10,40 (0,99)	12,59 (1,26)

As the immersion time in water increased, thickness swelling and water absorption increased. Chaharmahali (2010) produced WPC panels from high density polyethylene, particleboard and MDF wastes with 60-70-80% fiber ratios using the dry mix/hot press method. They discovered that the water absorption rates of WPC panels rose as the fiber content was increased from 60% to 80%, which was attributed to the hydrophilic nature of natural fibers.

CONCLUSIONS

In this study, MCC added PA6G based composites were successfully produced. The physical properties (density, TS and WA) of these composites were defined. The results are as follows;

The density values increased with the addition of MCC used as filler to the plastic matrix. The highest density value was obtained from PA6G composites using 30% MCC (1.16 g/cm³), while the lowest value was determined in the control group (1.08 g/cm³).

While the lowest TS and WA values were determined in the control groups, the highest value was obtained from PA6G composites with 30% MCC additive. A linear increase occurred in TS and WA values due to the increase in MCC filler.

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CLINICAL AND BIOCHEMICAL OUTCOMES IN SOFT TISSUE WITH MACHINED ABUTMENTS VS LASER-MICROGROOVED ONES

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Abstract

The aim of this study is to evaluate peri-implant soft tissue behaviour around machined vs laser-microgrooved implants/healing/prosthetic abutments during 1 year of function by assessing IL-6, IL-1b and MMP-8 levels in peri-implant crevicular fluid (PICF). Twenty-four patients were selected. Each patient received 2 one-stage implants in the same jaw with a split mouth design. One implant, one immediate healing, and one prosthetic abutment with a machined surface (M group), and one implant, one immediate healing abutment and one prosthetic abutment with a laser-microgrooved surface (LMS group) were used. PICF sampling, pocket probing depths (PPD) and bleeding on probing (BOP) were assessed at 1, 3, and 12 months. IL-6, IL-1b and MMP-8 levels were determined by specific enzyme-linked immunosorbent assay systems (ELISA). Repeated measure ANOVA was used to compare the two groups at 1, 3, and 12 months. At 3 and 12 months, the LMS group showed significantly lower PD, BOP and IL-6, IL-1β and MMP-8 levels than the M group ($P<0.05$). This study suggests the presence of more remodeling and/or inflammatory phenomena around implants/abutments with a machined surface than around implants/abutments with a laser-microgrooved surface.

Keyword: dental implant, machined surface abutment, micro-grooved surface abutment

CONTROL MEASURES OF PARASITIC INFECTIONS CAUSED BY NEMATODES ON PHEASANTS IN FARM BREEDING

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ABSTRACT

Introduction and Purpose: Parasitoses caused by helminths produce health problems in wild-raised and farm-raised pheasants. Nematode infection is the most frequent infection transmitted throughout intermediate host to pheasants. Worldwide researches have shown that helminths normally occur in farm-raised pheasants and have an important place in the pathology of these birds. The aim of the work was to establish the types of nematodes in pheasants and the measures of their control

Materials and Methods: The investigation was carried out two years in 2 pheasantries near Belgrade. A total of 172 samples of faeces from birds above 14 weeks of age and 116 samples of faeces from birds 4-14 weeks of age were examined using sedimentation and flotation concentration technique. A total of 212 pheasants up to 14 weeks of age and 146 pheasants above 14 weeks of age were examined by parasitological necropsy. Parasites were determined based on their morphological characteristics

Results: Infection with nematodes was found in 31.72% of the pheasants up to 14 weeks of age old and in 34.420% of pheasants above 14 weeks. Polyparasitism involving two species was detected in 28.01% pheasants up to 14 weeks of age and in 29.25% of birds above 14 weeks. The following nematode species were found: Syngamus trachea, Ascaridia galli, Ascaridia columbae, Heterakis isolonche, Heterakis gallinarum, Capillaria gallinae, Capillaria columbae and Capillaria phasianina. The therapeutic efficacy of the anthelmintic drugs was examined by coprological examination and necropsy.

Discussion and Conclusion: After a diagnosis, one of the following anthelmintic was mixed with food: mebendazole, fenbendazole, cambendazole, levamizole, pyranteltartarat and tetramizolchloride. Therapy with medicated food is the only efficient method to control the presence of these nematode parasite species in farm-reared pheasants.This was confirmed here by examination of the infected flocks after treatment. In addition, the application of biosecurity measures and control parasitological examinations are necessary

Key Words: Phasianus colchicus, nematodes, control

ANALYSIS OF COUNTER-ROTATION DUAL ROTOR WIND TURBINE PERFORMANCE WITH TORQUE CONTROL APPLICATION

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ABSTRACT

Blade angle control in wind turbines is important for turbine efficiency and performance. With the instantaneously changing blade angle, the interaction between the wind and the blade surface can be continuously controlled. This has a direct effect on the torque to be produced by the wind turbine. With blade angle control, maximum torque output can be achieved by creating instantaneous responses to variable wind speed. With the provision of this situation, it will increase the energy gain to be obtained from the turbines and will reveal efficient working conditions. In this study, a mathematical model based on the MATLAB/Simulink model has been created for a small scale wind turbine. Different control methods are applied to this model and their responses are compared. By analysing the time-based control responses, the performance evaluations of the applied controllers are carried out. The interaction of pitch angle change with torque change is analysed and torque control is also provided. By applying different wind speed profiles, the effects and time responses of the controllers against these inputs are analysed.

Key Words: wind turbine, blade angle, active pitch control

INTRODUCTION

Wind turbines are essential for achieving a sustainable energy future. They provide a clean, renewable source of power that is increasingly cost-effective and technologically advanced. The increasing global demand for sustainable energy has driven substantial advancements in wind turbine technology [1-3]. Among these innovations, Counter-Rotation Dual Rotor Wind Turbines (CRDRWTs) have emerged as a promising solution for enhancing energy capture efficiency. By increasing the relative rotational speed between the rotor and the stator of the generator, CRDRWTs significantly improve the amount of power harvested.

Dual Rotor Wind Turbines (DRWTs) have been demonstrated to achieve a substantial enhancement in the power coefficient when compared to conventional Single Rotor Wind Turbines (SRWTs). Extensive studies in this area have reported that the implementation of a dual-rotor configuration can lead to an increase in power output, with improvements varying between 12% and 60% [4-7].

The use of airfoil profiles with a high lift-to-drag coefficient ratio, along with optimized rotor geometrical spacing designs, can improve the net increase in power generation about 4.6% [8].

For a drawback of the dual rotor wind turbine, while at the operating conditions increase the Tip-Speed Ratio (TSR, λ) can lead to Negative-Torque generation resulting in the reduction of the Power Coefficient (C_p) by up to 13.1%.

Negative-Torque phenomenon can be eliminated by designing different types of DRWT design .The redesigned system addresses this issue by refining the operating range of the inner rotor, removing negative torque, improving the performance of the outer rotor, and reducing the wake length by 16.7%, which is essential for optimizing wind farm efficiency [6].

An optimised design and placement of a flat plate deflector can reduce Negative-Torque phenomenon and directs the wind to the turbine blades to improve the maximum power coefficient (C_p) by 42% [9].

The purpose of this study is to design and compare different types of controller systems to increase power and prevent the Negative-Torque phenomenon by controlling the pitch angle of the turbine blades connected to the rotor. This ensures that the torque generated by the rotor matches the torque generated by the stator.

2.Mathematical Model for Aerodynamic Power

Since the wind turbines blades converts the some of the the linear kinetic energy of the income wind, to the rotational motion for the rotor of the wind turbine, the equations for this conversation can be represented as following steps,

2.1 Wind Flow Power

The power of moving air ($\mathbf{P_v}$), assuming the wind speed ($\mathbf{v_w}$) is constant,

$$P_v = 0.5\dot{m}\, v_w{}^2 \quad (1)$$

Where $\dot{m}$ the mass flow rate of air per second, and as the air moves through an area (A), considering the air density (ρ), the mass flow rate can be described as:

$$\dot{m} = \rho A v_w \quad (2)$$

For the modeling of the wind turbine, the flow area can be assumed to be the swept area of the blades of the turbine. Where r is the radius of the turbine.

$$A = \pi r^2 \quad (3)$$

Using the equations (1), (2) and (3) combined, the flow power of the wind can be represented as:

$$P_v = 0.5\rho\pi r^2 v^3{}_{wind} \quad (4)$$

2.2 Turbine Aerodynamic Power

There is no 100% efficient aerodynamic-mechanical energy conversion due to adherence to the continuity equations. According to Betz's Law, the efficiency of aerodynamic-mechanical energy conversion for a wind turbine can reach approximately 59%. [10-12]

Since the main reason for this reduction in power is the geometric properties and response of the blades to the different wind speed rotor speed ratios, there is a variable function component for aerodynamic-mechanical energy conversion that is needed and this function can be calculated by empirical studies.

According to this acknowledgement the power harnessed by the wind turbine (P_m) can be represented as:

$$P_m = 0.5\rho\pi R^2 {v_w}^3 C_p(\lambda, \beta) \quad (5)$$

Where $C_p(\lambda, \beta)$ is the power coefficient for the wind turbine model and Cp is an empirical defined function that contains pitch angle (β) and Tip-Speed Ratio (λ) as independent variables.

$$C_p = C_1(C_2/\lambda_i - C_3\beta - C_4)e^{-C_v/\lambda_i} + C_6\lambda \quad (6)$$

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{1+\beta^3} \quad (7)$$

Where Tip-Speed Ratio (λ) is the ratio between wind speed and linear speed at the tip of the turbine blade.

$$\lambda = \frac{wR}{v_w} \quad (8)$$

Where as the results of the empirical investigations, the constants for the power coefficient for the wind turbine model [13-17]:

C_1=0.5176, C_2= 116,C_3=0.4, C_4= 5, C_5=21, C_6=0.0068

Since the power coefficient (C_p) contains two independent parameters pitch angle pitch angle (β) and Tip-Speed Ratio (λ), the change of C_p with both parameters represented with Figure X. But remembering the TSR is also a function that contains two independent variables wind speed (v_w) and rotor speed (w).

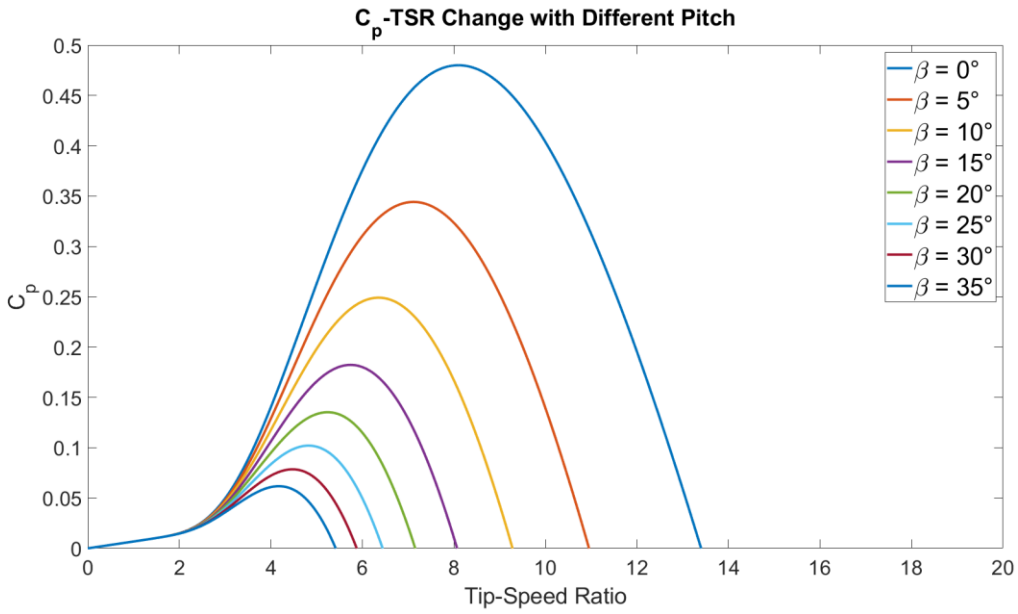


Figure 1- C_p - TSR Change with Different Pitch Angles

2.3 Turbine Aerodynamic Torque

Since the Power is the applied force times velocity caused by this force

$$P_m = T * w \ [W] \quad (9)$$

Torque can be calculated as,

$$T_m = \frac{P_m}{w} \ [Nm] \quad (10)$$

As represented as equation number (5) and (10)

$$T_m = \frac{P_m}{w} = 0.5\rho\pi R^2 v_w{}^3 \frac{C_p(\lambda,\beta)}{w} \quad (11)$$

For parameter reduction purposes, using definition of TSR (λ) the Aerodynamic torque acquired can be represented as:

$$T_m = 0.5\rho\pi R^3 v_w{}^2 \frac{C_p(\lambda,\beta)}{\lambda} \quad (12)$$

2.4 Turbine Dynamic Equations and Rotor Speed

Assuming the mechanical model of the wind turbine reduced and simplified as basic rotational mechanical system as in Figure 2, where total mass moment of inertia of the turbine rotor system (J_r), and overall damping ratio of the system (B), aerodynamic torque (T_m), and the rotor rotational speed (w), with the use of Newton's 2nd Law of Motion the simplified equation of motion of the system becomes,

$$T_s = J_s \dot{w}_s + B w_s \quad (13)$$

$$T_r = J_r \dot{w}_r + B w_r \quad (14)$$

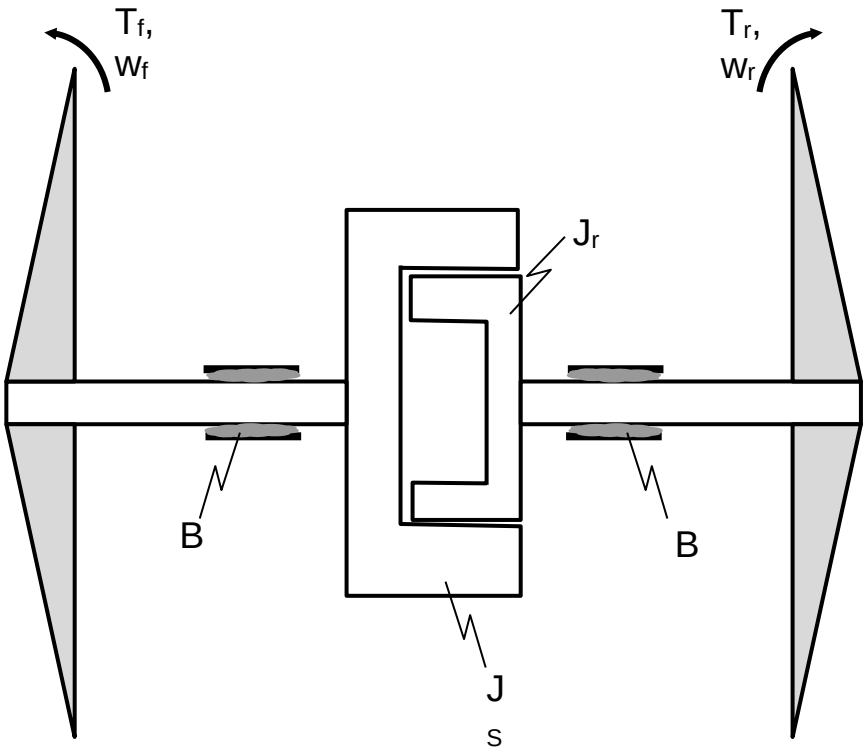


Figure 2- Turbine Simplified Mechanical Model

3.Matlab SIMULINK Model

A MATLAB Simulink model of the dual-rotor wind turbine has been developed based on the mathematical formulations provided in Equations (12) and (13). In the model, the changeable wind input to the rear rotor is assumed to experience a 30% reduction in velocity relative to the wind speed acting on the front rotor, reflecting aerodynamic interaction effects. The electromechanical torque connection between the rotors has been neglected to simplify the analysis. While the front rotor operates with a fixed pitch angle, the pitch angle of the rear rotor is actively controlled to align its torque with that of the front rotor, thereby optimizing the overall torque output of the system.

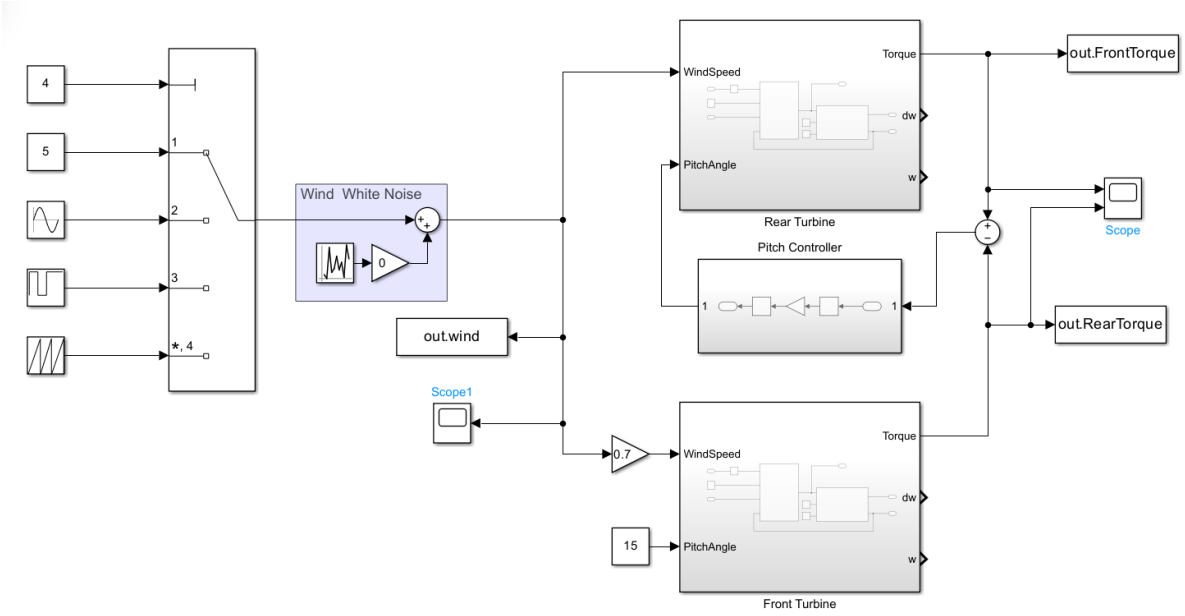


Figure 3- Dual-Rotor Wind Turbine Matlab Simulink Model

4.Analysis

4.1 Different Inputs

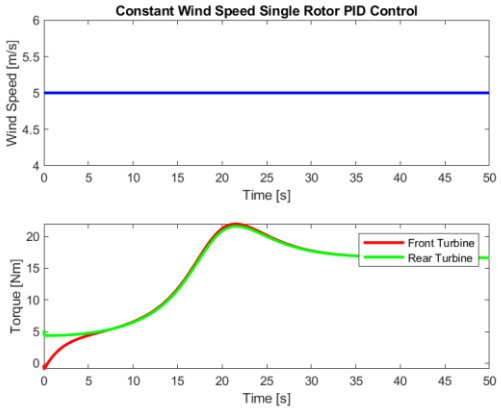
Five different wind inputs have been selected for the comparison of the control algorithms, constant, white noise, sine wave, square and sawtooth wind speeds have been implemented with all of the control algorithms.

4.1 PI Controller

Same PI controller used for each wind speed profile and torque following properties have been investigated with the Matlab/Simulink model. The Proportional P

arameter (P) is 10 and the Integral Parameter (I) is 5 in the PI parameter.

A)



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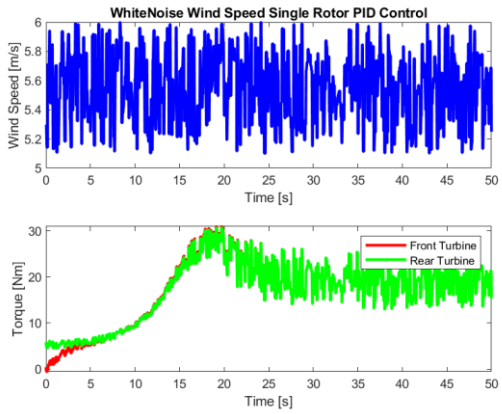
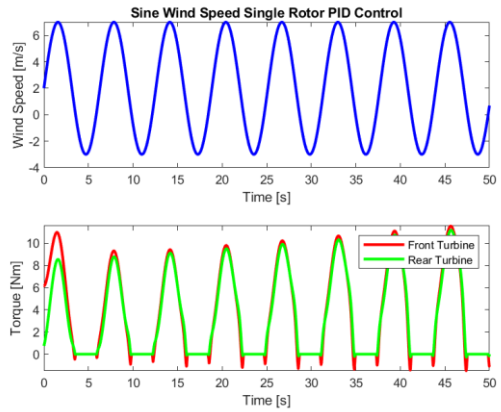


C)



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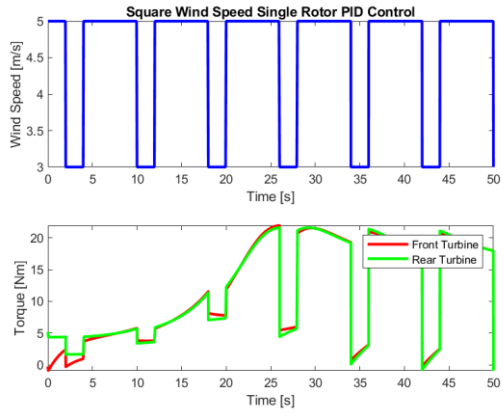

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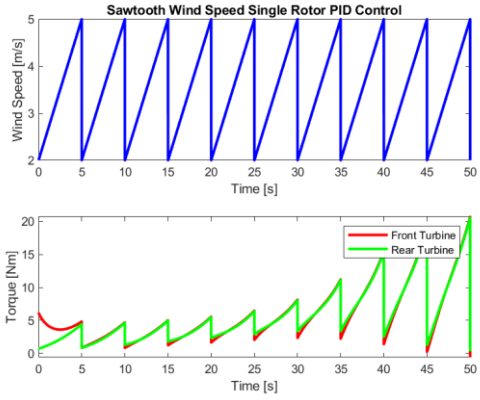
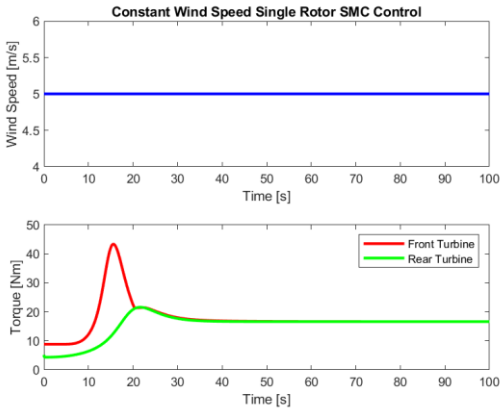


Figure 4- Torque Following Operation using PI Controlled Pitch Angle Under a)Constant b)White Noise c)Sine d)Square e) Sawtooth wind profiles.

4.2 On/Off Controller

A)



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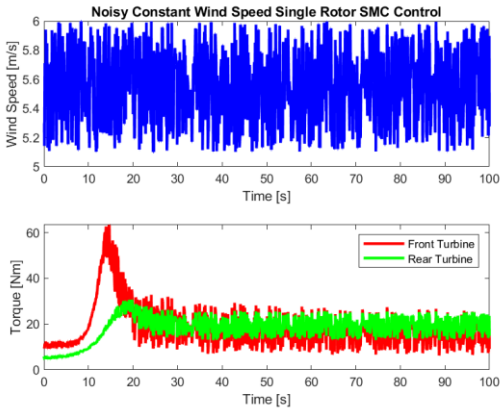

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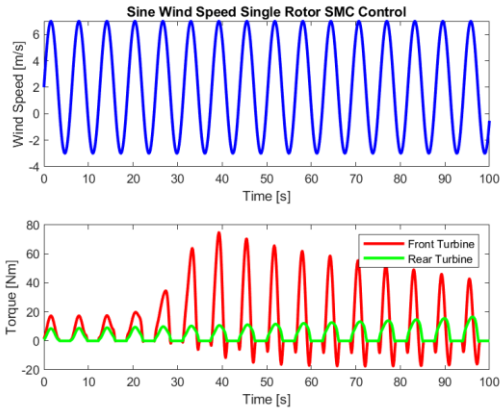

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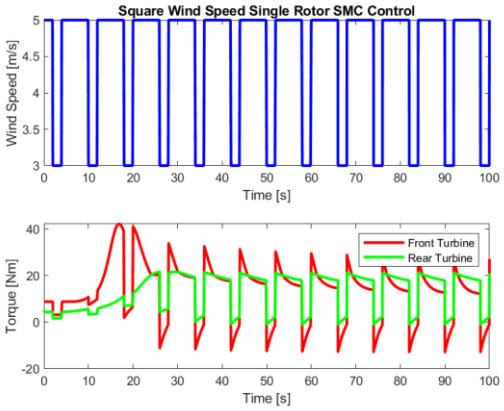
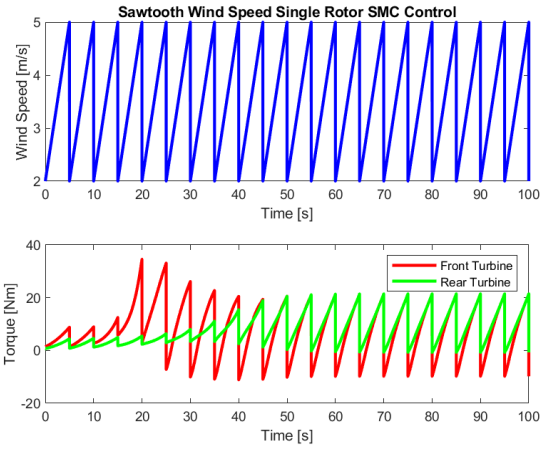




E)

Figure 5- Torque Following Operation using On/Off Controlled Pitch Angle Under a)Constant b)White Noise c)Sine d)Square e) Sawtooth wind profiles.

4.3 Model Free Sliding Mode Controller

General Sliding Mode Control contains two main elements, “Equivalent Control” and “Switching Control”.

$$u = u_{eq} + u_{sw} \qquad (15)$$

Where, sliding surface defined by linear approach by x1 is Torque error and x2 is differential of torque error.

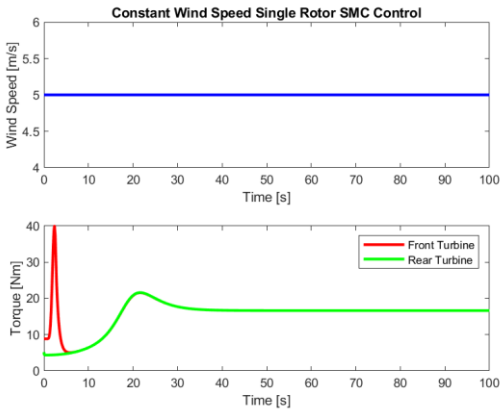
$$s = ax_1 + x_2 \qquad (16)$$

$$u_{sw} = -K\,\mathrm{sgn}(s(x)) \qquad (17)$$

For the model-free approach application, the equivalent control (u_{eq}) is neglected, and the equivalent control parameter is defined as given in Equation (19). The saturation function is used instead of the signum function to eliminate the chattering problem.

$$u_{sw} = 15\,\mathrm{sat}(s) \qquad (18)$$

A)



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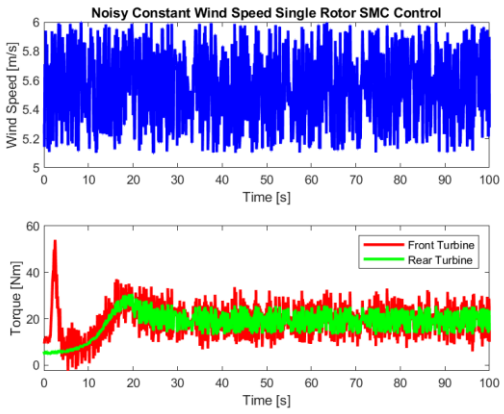

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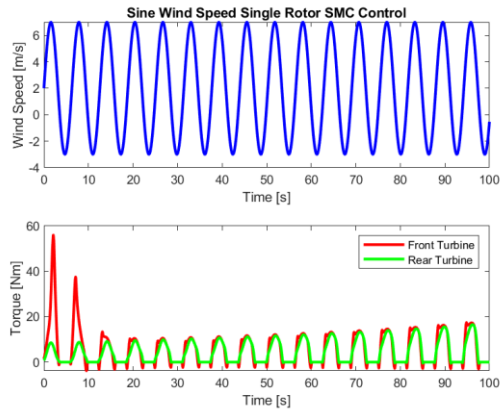

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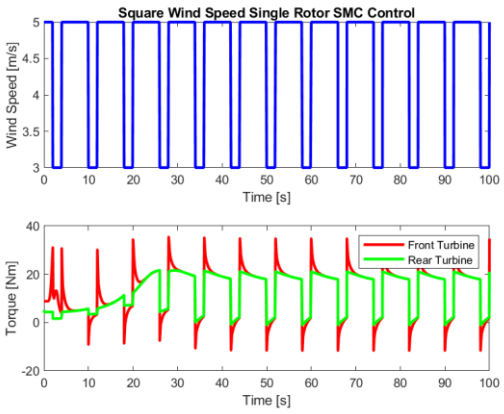

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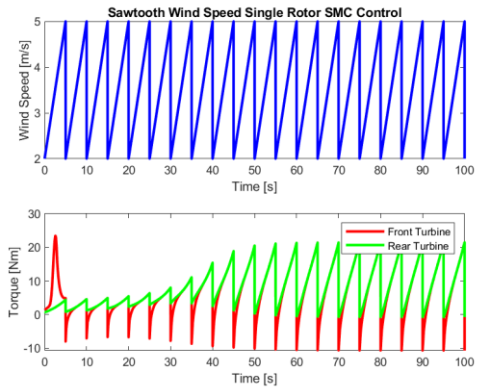
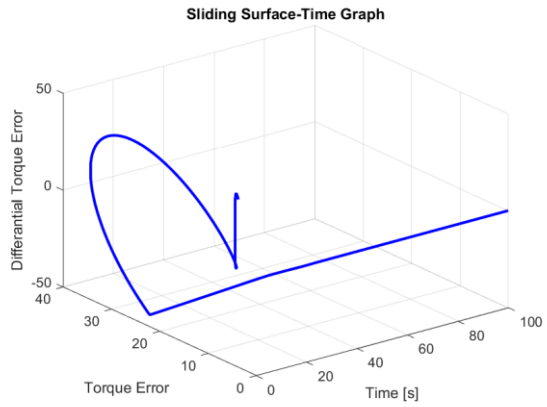
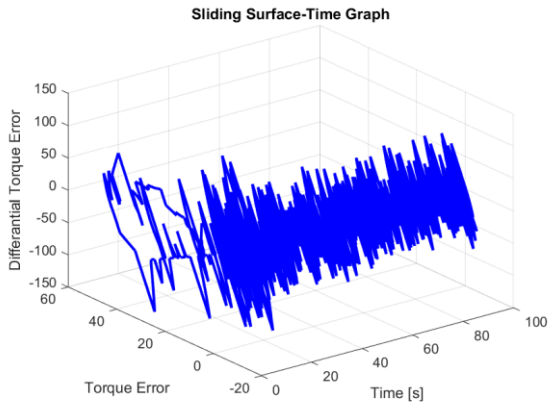


Figure 6- Torque Following Operation using SM Controlled Pitch Angle Under a)Constant b)White Noise c)Sine d)Square e) Sawtooth wind profiles.

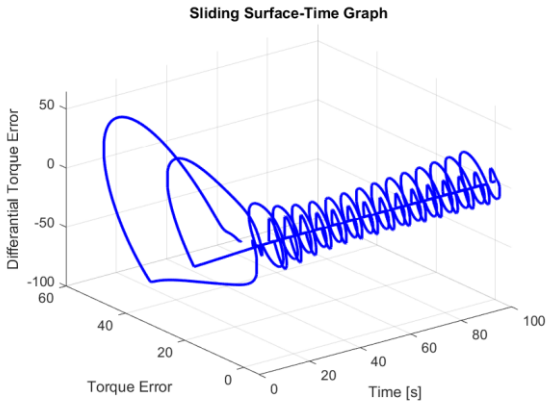
A)



B)



C)



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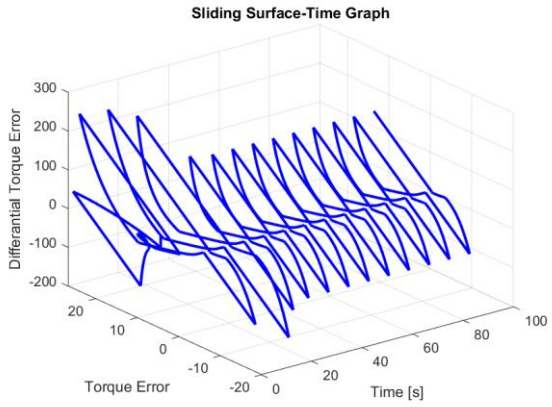

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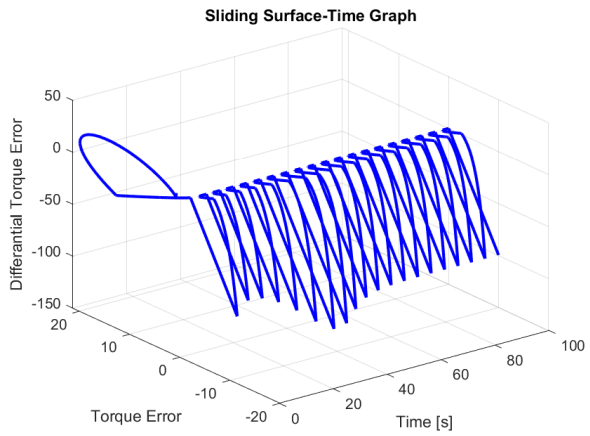

Figure 7- Torque Following Operation using SM Controlled Pitch Angle Sliding Surface Graphs Under a)Constant b)White Noise c)Sine d)Square e) Sawtooth wind profiles.

5. Comparison of controllers

5.1 Constant Wind Speed Responses

A) B) C)

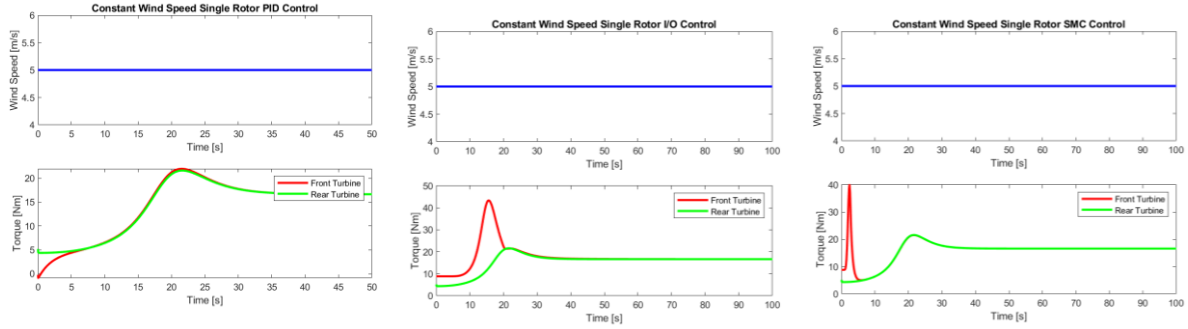

Figure 8- A) PI B) I/O C) SMC controller responses to Constant Wind Speed Input

Table 1- Controller Responses to Constant Wind

	PI	**On/Off**	**SMC**
Max.Overshoot	1.71 %	247.31%	800%
Settle Time	10 s	20 s	7s
State Error	0.003	0.0004	0.000001

As seen in Table 1, SMC control offers the best accuracy and fastest response but suffers from excessive overshoot, risking mechanical stress. PI control provides a stable balance with minimal overshoot and moderate settling time, making it a safer choice. On/Off control is highly unstable due to extreme overshoot and slow settling, making it unsuitable.

5.2 White Noise Wind Speed Responses

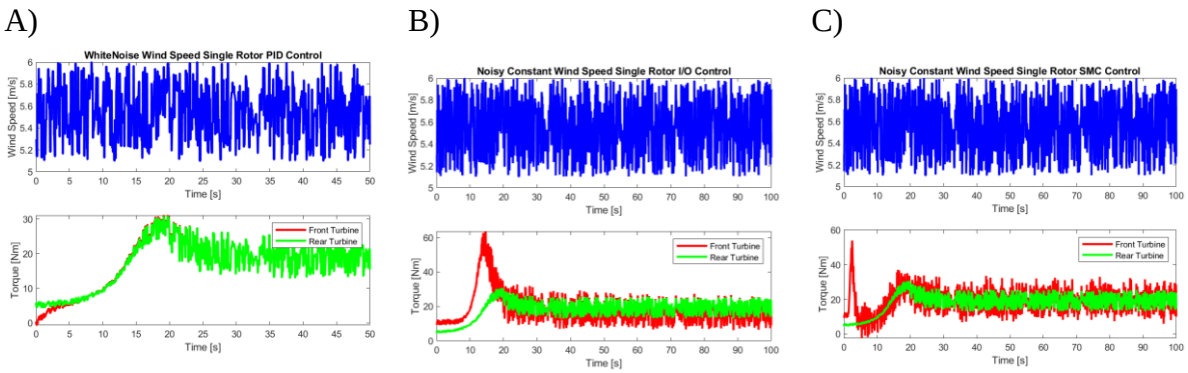

Figure 9- A) PI B) I/O C) SMC controller responses to White Noise Wind Speed Input

Table 2- Controller Responses to White Noise Wind

	PI	**On/Off**	**SMC**
Max.Overshoot	1.1 %	189%	770%
Settle Time	5.77 s	21 s	10 s
State Error	1.3%	5.32%	3.4%

PI control offers the most stable performance with minimal overshoot (1.1%), the shortest settling time (5.77s), and the lowest steady-state error (1.3%), making it the safest choice. SMC control provides a faster response than On/Off (10s settling time) but has extreme overshoot (770%) and a slightly higher steady-state error (3.4%). On/Off control is the least stable, with high overshoot (189%), the longest settling time (21s), and the highest steady-state error (5.32%), making it the least suitable option.

5.3 Sine Wind Speed Responses

A) B) C)

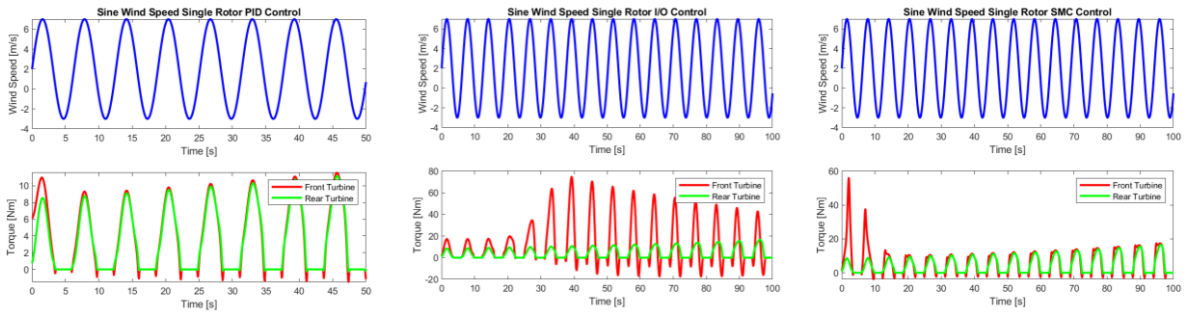

Figure 10- A) PI B) I/O C) SMC controller responses to Sine Wind Speed Input

Table 3- Controller Responses to Sine Wind

	PI	**On/Off**	**SMC**
Max.Overshoot	27.5%	266.5 %	743%
Settle Time	3.6 s	-	16 s
State Error	3.2%	-	0.3%

SMC control achieves the lowest steady-state error (0.3%) but suffers from extreme overshoot (743%) and a long settling time (16s), which may cause instability and mechanical stress. PI control provides a more balanced performance with moderate overshoot (27.5%), fast settling time (3.6s), and a manageable steady-state error (3.2%), making it a stable choice. On/Off control remains highly unstable due to excessive overshoot (266.5%) and undefined settling time, making it unsuitable for reliable applications.

4 Square Wind Speed Responses

A) B) C)

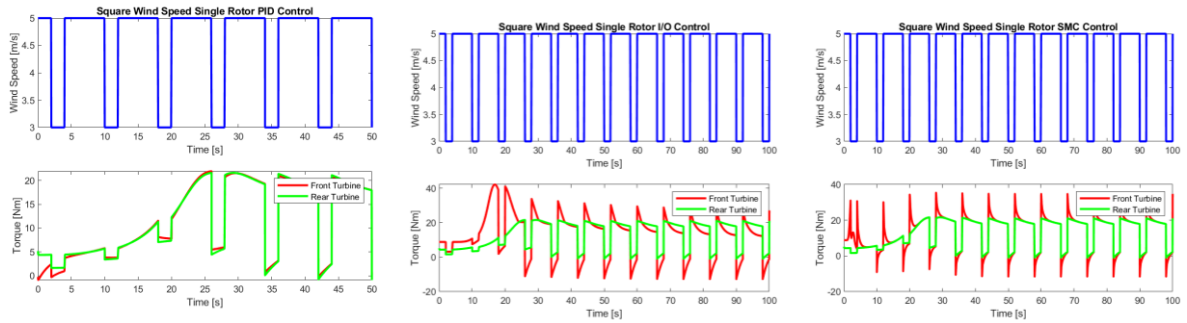

Figure 11- A) PI B) I/O C) SMC controller responses to Square Wind Speed Input

Table 4- Controller Responses to Square Wind

	PI	On/Off	SMC
Max.Overshoot	1.5%	336%	530%
Settle Time	5.8 s	-	3
State Error	7.5%	-	1%

SMC control delivers fast response and low steady-state error (1%) but suffers from excessive overshoot (530%), which may cause mechanical stress. PI control offers a balanced approach with minimal overshoot (1.5%), moderate settling time (5.8s), and a steady-state error of 7.5%, making it a stable option. On/Off control is highly unstable, with extreme overshoot (336%) and undefined settling time, making it impractical for reliable control.

5.5 Sawtooth Wind Speed Responses

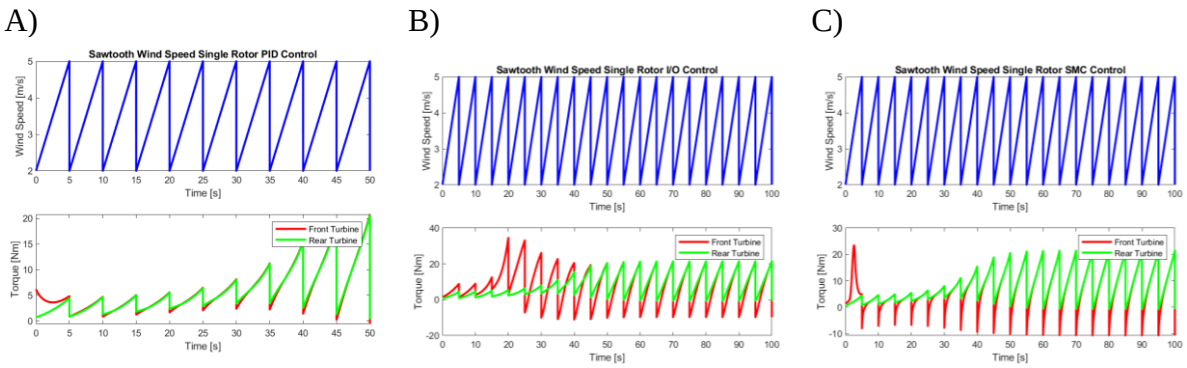

Figure 12- A) PI B) I/O C) SMC controller responses to Square Wind Speed Input

Table 5- Controller Responses to Sawtooth Wind

	PI	On/Off	SMC
Max.Overshoot	54%	538%	840%
Settle Time	5 s	-	2 s
State Error	5.2%	-	1%

SMC control provides the fastest response with a 2s settling time and the lowest steady-state error (1%), but suffers from extremely high overshoot (840%), which may cause instability and mechanical stress. PI control offers a more balanced approach with moderate overshoot (54%), a reasonable settling time (5s), and a steady-state error of 5.2%, making it a safer and more stable option. On/Off control remains highly unstable, with excessive overshoot (538%) and an undefined settling time, making it impractical for reliable applications.

Conclusions

In this study, different types of controllers were designed for the control of the blade angle of a twin rotor wind turbine. PI, On/Off and SMC control methods were selected as controllers. The performances of these controllers were compared against different wind load inputs. The criteria determining the controller performances such as time responses, maximum overshoot, and settling time were presented as a table. After the study, it was determined that the torque values of both rotor elements would converge after the active torque control to be applied to the twin rotor turbines. It was shown that these turbines could be operated in the opposite direction with the achievement of torque equality..

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FROM SERICULTURE TO TEXTILES: THE MULTIFACETED APPLICATIONS OF SILK SERICIN

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Abstract

India, the second-largest global producer of raw silk, is uniquely positioned as the only country manufacturing five types of silk: Mulberry, Tasar, Eri, Muga, and Tropical Tasar. Silk, known as the "queen of textiles," primarily consists of two proteins: fibroin and sericin, with Mulberry silk (Bombyx mori) being the most commercially significant variety. Silk sericin, a byproduct of silk production, has garnered significant attention for its unique properties, including biocompatibility, biodegradability, moisture retention, and antimicrobial, antioxidant, and anti-inflammatory effects. These attributes make sericin a versatile material for applications in textiles, cosmetics, pharmaceuticals, and biomedicine. This review delves into sericin's molecular structure, extraction methods (chemical, enzymatic, autoclave, and membrane-based), and its transformative applications in areas such as textile finishing, UV protection, antimicrobial treatments, and wound healing. It highlights innovations like eco-friendly enzymatic and infrared heating techniques, addressing environmental challenges posed by conventional alkaline extraction processes. The applications of sericin span diverse fields. In textiles, sericin is used as a finishing agent to impart UV protection, antimicrobial activity, and enhanced moisture management. It also improves dyeability, mechanical strength, and thermal regulation. In the biomedical domain, sericin plays a significant role in wound healing, drug delivery systems, and the creation of bio-nanocomposites. Additionally, sericin's integration with both synthetic and natural fibers is enabling the development of biodegradable and high-performance materials. Advances in sericin integration with synthetic and natural fibers for biodegradable and high-performance materials, as well as its application in wearable sensors, skincare textiles, and sustainable dyeing solutions, underscore its potential. With projected market growth exceeding 10.65% CAGR by 2032, particularly in the Asia-Pacific region, silk sericin emerges as a promising material for sustainable and multifunctional innovations across industries.

Keywords: Silk sericin, Biocompatibility, Biodegradability, Textile applications, Sustainable innovations, Biomedical advancements, Eco-friendly materials

Introduction

India holds a prominent position in the global silk industry, being the second-largest producer of raw silk in the world, following China. Silk is the most beautiful of all fibres, known as the queen of textiles. India is recognized as the second-largest producer of silk globally, producing approximately 16,700 metric tons (mt) of silk annually. The country is uniquely distinguished as the only nation producing five different types of silk: Mulberry, Eri, Muga, Tasar, and Oak Tasar. This diversity in silk production is complemented by India's rich cultural heritage and consumer demand for silk products, particularly in traditional garments like saris. The current market prices for reeled silk range from Rs 900 to Rs 1,300 per kilogram, while pierced cocoons and waste silk can be sold for Rs 80 to Rs 100 per kilogram. Notably, waste silk constitutes nearly 30% of total cocoon production, highlighting a significant area for potential economic recovery and sustainability efforts (Babu, 2019; Datta and Nanavaty,2005).

Silk production primarily involves two families of insects, Saturnidae and Bombycidae, with the domesticated silkworm, Bombyx mori, being a key member of the Bombycidae family. Bombyx mori commonly known as mulberry silkworm, produce a delicate creamise white silk fibre which is the main commercial silk in the world. Silk derived from silkworm Bombyx mori is a natural protein that is mainly made of silk sericin and fibroin proteins.This species produces a delicate twin thread of silk fibroin, which is coated with a protective layer of silk sericin. Silk proteins, including fibroin and silk sericin, are essential constituents of the cocoon filament, synthesized by silk gland cells and stored in the lumen of the silk glands. During the spinning process, silkworms secrete liquid silk that passes through the anterior gland and is expelled through the spinneret opening, hardening upon exposure to air to form continuous filaments (Astudillo et al. 2014). The quantity and nature of silk sericin are crucial in conferring distinctive traits to the cocoon, as it cements the fibroin filaments together, enhancing structural integrity. Silk sericin constitutes 25–30% of silk protein and it envelops the fibroin fibre with successive sticky layers that help in the formation of a cocoon. Silk fibers are primarily composed of two proteins: silk fibroin and silk sericin. Silk sericin is a high molecular weight protein produced by the Bombyx mori silkworm, constituting about 20-30% of silk proteins (Rajput and Singh, 2015). It is insoluble in cold water but can be easily hydrolyzed into smaller fractions that dissolve in hot water, making it versatile for various applications. Silk production generates wastewater with high organic content, primarily due to the degumming process, where silk sericin, or "silk gum," is removed from silk fibres and silk sericin is obtained. As silk sericin is a major component of raw silk, it has been estimated that out of 4.0 lakh tons of dry cocoons produced worldwide, around 50,000 tons of silk sericin are usually discarded as waste in sewage, representing an environmental hazard (Gimenes et al. 2014 and Rassent,1967).

But Silk sericin exhibits several beneficial properties, including resistance to oxidation, antibacterial activity, UV protection, and the ability to absorb and release moisture effectively. During silk production, silk sericin is typically removed from fibroin to enhance the silk's luster, leading to significant waste generation; approximately 50,000 tons of silk sericin are discarded annually from the global production of silk cocoons. However, there is a growing trend towards utilizing silk sericin waste and byproducts as value-added products in industries such as textiles and biomedicine (Wu et al. 2007). After the degumming process, the remaining fibroin is used for various applications due to its desirable characteristics, including being thin, long, light, and soft. Silk fibers are known for their water absorbency, dyeing affinity, thermal tolerance, insulation properties, and luster. Recent advancements suggest that incorporating ionic liquids in silk processing could further enhance the mechanical and optical properties of silk fibers, opening new avenues for their application in producing high-performance materials like artificial blood vessels and surgical sutures (Wang et al.2019). Silk sericin is useful as finishing agent, mainly in textile industry because of its special characteristics such as antibacterial properties, resistance to oxidation, and light. The commercial value of silk sericin is high, as evidenced from the price of about EUR 80–90 per its gram in the market. It is reported that, if this silk sericin protein is recovered and recycled, it would be a significant economic and social benefit can be achieved while also reducing environmental impact (Capar et al. 2008 and Yuan et al. 2024).

Composition and Structure

Silk filament, primarily produced by the Bombyx mori silkworm, is a protein fiber composed of two main proteins: fibroin and sericin. Sericin is deposited in **three distinct layers** around the fibroin core:

1. **Sericin A (Innermost layer)**: Closely adheres to fibroin.
2. **Sericin B (Middle layer)**: The primary cementing layer.
3. **Sericin C (Outermost layer)**: Acts as a protective barrier.

These layers are secreted sequentially from the **posterior, middle, and anterior silk glands**, forming a sheath that protects fibroin and adds mechanical strength to the silk thread.The composition of raw silk includes various natural impurities in addition to these proteins, as outlined in the following table (Jo et al. 2020 and Mondal et al. 2007):

Constituents	**Percent**
Fibroin	70-80
Silk sericin	20-30
Wax matter	0.4-0.8
Carbohydrates	1.2-1.6
Inorganic matter	0.7
Pigment	0.02

Sericin is composed of **18 amino acids**, predominantly those with polar side chains. Among them, **serine (37.3%)** is the most abundant, followed by **glycine (14.7%)** and **aspartic acid (14.8%)**. These amino acids provide the adhesive properties required to hold fibroin fibers together. The remaining amino acids include **threonine, alanine, glutamic acid, and lysine** in smaller proportions (Borgohain , 2015).

Amino acids	Percent (%)
Lysine	20-30
Serine	16-20
Glycine	8-10
Aspartic acid	8-12
Threonine	4-6
Histidine	4-6

Table : Different amino acids present in silk sericin.

Sericin is a complex protein that forms a protective coating around the silk fibroin fibers. Its molecular weight can range from 24 kDa to 400 kDa, depending on the specific type and method of extraction. The high content of polar amino acids, particularly serine, contributes to sericin's hydrophilic nature, allowing it to absorb moisture and interact with water-soluble substances effectively.Sericin predominantly exhibits a random coil structure but can adopt β-sheet conformations under certain conditions. This structural flexibility is crucial for its functional properties (Aad et al. 2024).The presence of hydroxyl, carboxyl, and amino groups in its structure enables sericin to form hydrogen bonds, making it an effective adhesive and enhancing its compatibility with other materials. Sericin can be classified into two types based on its location in the cocoon: α-sericin, which is found in the outer layer and has higher solubility in hot water, and β-sericin, located in the inner layer (Züge et al. 2017 and Kamili and Masoodi ,2000).

Role of **Amino Acids in Silk Sericin:**

1. **Serine (37.3%)**:The most abundant amino acid in sericin.It has a hydroxyl group that makes sericin hydrophilic, aiding water retention and moisture absorption. It plays a significant role in **adhesion** and **hydration**, enhancing sericin's utility in cosmetics and skin-care applications (Nayak and Kundu, 2016).
2. **Glycine (14.7%)**:Glycine is another major component, contributing significantly to the structural integrity and flexibility of sericin. It plays a crucial role in maintaining the biochemical properties reof sericin, including its solubility and ability to form hydrogels. It contributes to the **compact structure** of sericin. It provides flexibility and reduces steric hindrance in the protein chain (Silva et al. 2022).
3. **Aspartic Acid (14.8%) and Glutamic Acid (3.4%)**:Aspartic acid is important for its role in cellular metabolism and as a precursor for other amino acids. These amino acids have carboxyl groups that provide **ionic properties**, making sericin bioactive .It helps maintain the biochemical balance within sericin, contributing to its functional properties. Contribute to **antioxidant and anti-inflammatory properties**, beneficial in medical and cosmetic applications (Kunz et al. 2016).
4. **Threonine (8.6%)**:It contains hydroxyl groups, enhancing sericin’s hydrophilic nature. It promotes **protein stability** and adhesion.
5. **Alanine (4.3%)**:Alanine supports energy production and is involved in metabolic processes. Its presence in sericin enhances the protein's stability and functionality. It helps maintain **structural integrity** and contributes to sericin’s crystalline properties.
6. **Lysine (2.4%)**:Provides amino groups for **cross-linking** and binding activities, aiding in sericin’s adhesive properties.
7. **Valine (3.5%) and Arginine (3.5%)**:Contribute to sericin's **structural stability** and flexibility (Sheng et al. 2013).

Chronology of Silk Sericin

➢ Ancient Era (2700 BCE – 1st Millennium)

Silk production, or sericulture, began in ancient China around 2700 BCE. Initially, sericin—the protein coating silk fibers—was considered a waste product. Early Chinese silk production focused on the luxurious silk fibroin, discarding sericin during the reeling process. Archaeological evidence from the Neolithic Age shows that silk reeling and weaving were well-established practices in regions like Henan and Zhejiang.

According to legend, Empress Luozhu introduced the domestication of silkworms and the techniques for processing silk cocoons. During this period, silk production techniques spread along the Silk Road, connecting China to regions like India, Persia, and Europe. While sericin was not utilized, the trade routes facilitated the exchange of knowledge about silk production (Xia, 2024).

➢ Tang and Song Dynasties (7th–13th Centuries)

By the Tang and Song dynasties, sericin began to be recognized for its unique properties, such as its moisturizing effects. This marked an early shift in its perception from waste to a resource with potential applications in cosmetics and medicine. These centuries witnessed advancements in sericulture techniques, although the primary focus remained on the production of silk fibroin for textiles (Savithri et al.2013).

➢ 18th and 19th Centuries

The 18th century brought significant advancements in the understanding of silk's composition. In the early 1700s, Italian scientist Antonio Vallisneri identified sericin as a "gum-like" substance that binds fibroin filaments in the cocoon. This discovery highlighted its adhesive properties and set the stage for further research.

In 1823, Braconnot separated sericin and fibroin as distinct components. This paved the way for studies revealing sericin's antioxidant activity, which includes inhibiting lipid peroxidation and neutralizing free radicals. Despite these findings, sericin continued to be discarded during silk production due to limited applications (Ma et al. 2004).

➢ 20th Century

The early 20th century saw renewed interest in sericin for its potential as a finishing agent in textiles, thanks to its dye-binding properties. However, its application remained limited, as the removal of sericin during silk reeling was prioritized to enhance silk's luster and softness.

By the mid-1900s, researchers began to recognize sericin's hydrophilicity, antioxidant activity, and biodegradability. These properties led to its exploration in cosmetics and biomedical fields. During the 1980s and 1990s, studies revealed its antibacterial and wound-healing properties. Sericin was found to stimulate collagen production, aiding in skin regeneration and tissue repair. Despite these advancements, most sericin was still discarded as a byproduct.

- **21st Century**

In the early 2000s, sericin gained significant attention in the cosmetics industry for its moisturizing and antioxidant properties. It was incorporated into skincare products, shampoos, and other personal care items. Concurrently, biomedical applications expanded, with sericin being used in wound dressings, tissue engineering scaffolds, and drug delivery systems. Improved extraction methods allowed sericin to be refined for advanced uses.

Recent research has further highlighted sericin's versatility. Its biocompatibility has made it valuable in regenerative medicine, while its biodegradable nature has led to its application in sustainable packaging materials. These developments represent a major shift in how sericin is perceived, transforming it from a waste product into a valuable, multifunctional material.

Extraction Methods for Silk Sericin

Silk sericin, a protein derived from the silk cocoon, has gained attention for its wide range of applications due to its antioxidant, biocompatible, and biodegradable properties. The extraction process of silk sericin significantly influences its molecular weight, purity, and functional properties. Various methods have been developed over time, with molecular weights reported to range from **10 kDa to 310 kDa**. Each extraction method offers distinct advantages and limitations, influencing the quality, yield, and application of silk sericin. While traditional methods like boiling are simple and cost-effective, modern techniques such as enzymatic treatments and polymeric membrane filtration enable higher precision and purity. The choice of method depends on the intended application of sericin, whether it is for cosmetics, biomedical products, or sustainable materials (Aramwit et al. 2010a).

1. Conventional method
2. Chemical method - i. Alkaline , ii. Acidic and iii. Urea and salt
3. Enzymatic method
4. Autoclave method
5. Infrared rays
6. Polymeric membranes- i. Ultrafiltration and ii. Nanofiltration

1. Conventional Method

This involves boiling silk cocoons or degumming the silk fibers in water at elevated temperatures. The sericin dissolves into the water during the process. While simple and cost-effective, this method may lead to a broad range of molecular weights and loss of some functional properties. It is often used as a baseline method for sericin extraction in research (Chaudhary et al. 2015).

- **Boiling in Water**

One of the earliest and most straightforward methods involves boiling silk cocoons in water. This process, also known as degumming, allows the sericin to dissolve into the water. While effective, this method often results in a wide range of molecular weights and requires subsequent processing for sericin recovery (Aramwit et al. 2010b).

- **Use of Alkaline Solutions**

The extraction of silk sericin using alkaline solutions is a more advanced conventional approach. It employs detergents and alkaline compounds that aid in the removal of sericin by inducing protein denaturation and partial hydrolysis of the silk filament chains.

- **Common Alkaline Agents**:

- **Sodium Carbonate (Na_2CO_3)**: Widely used for its effectiveness in breaking down sericin bonds (Aramwit et al. 2010b).
- **Calcium Hydroxide ($Ca(OH)_2$)**: Provides mild alkaline conditions suitable for controlled extraction(Zhao et al. 2018),.
- **Non-Ionic Detergents**: Facilitate the degumming process by breaking down sericin layers while minimizing fibroin damage (Mahmoodiet al. 2010)

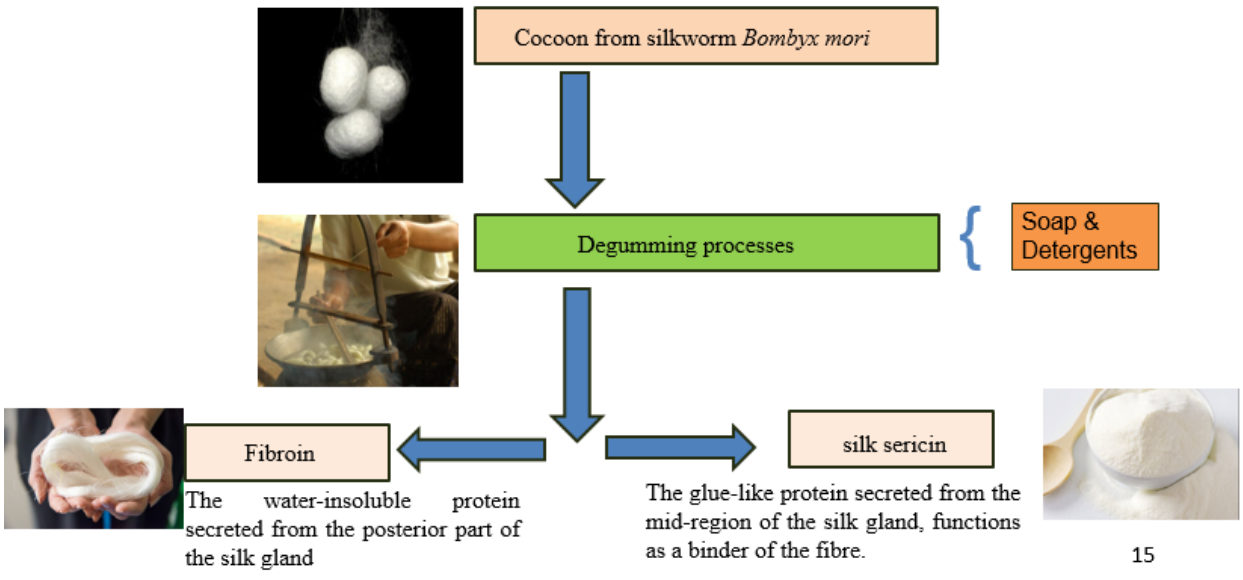
➢ **Detergent-Assisted Degumming**

This method integrates detergents and soaps into the alkaline solution, enhancing the efficiency of sericin removal. The detergents aid in protein denaturation and improve the solubility of sericin. However, this technique poses challenges:

- **Complex Isolation**: Separating the extracted sericin from detergents involves intricate purification steps, often leading to reduced yields.
- **Environmental Concerns**: The presence of alkaline residues and detergents in wastewater raises ecological issues, requiring proper treatment systems (Yang et al. 2013).

➢ **Quality Implications**

While conventional methods are effective in extracting sericin, they often compromise its quality. High temperatures and alkaline conditions can degrade sericin, resulting in lower molecular weights and reduced functionality. Additionally, the process can inadvertently affect the properties of silk fibroin.



Advantages:

- **Effectiveness:** The use of detergents and alkaline compounds, such as sodium bicarbonate, is effective in removing silk sericin from silk fibres, facilitating the degumming process.
- **Simplicity:** This method is relatively simple and widely adopted in the silk processing industry due to its straightforward application and established protocols.

- **High Yield:** It can achieve a high yield of silk sericin extraction, making it a practical choice for industrial applications (Wang et al. 2015).

Disadvantages:

- **Degradation of silk sericin:** The extraction process often leads to significant degradation of silk sericin, resulting in a loss of its functional properties and molecular weight, which can affect its applications in various industries.
- **Environmental Impact:** The residual alkaline compounds and detergents contribute to pollution, creating effluent problems that pose risks to aquatic ecosystems and complicate wastewater treatment processes.
- **Recovery Challenges:** Isolating silk sericin from the detergent solutions is complex and inefficient, often leading to reduced purity and increased costs associated with additional purification steps.
- **Non-Sustainable:** This method is not environmentally friendly, prompting a need for more sustainable alternatives that minimize chemical usage and environmental impact (Yun et al. 2013 and Dash et al.2007).

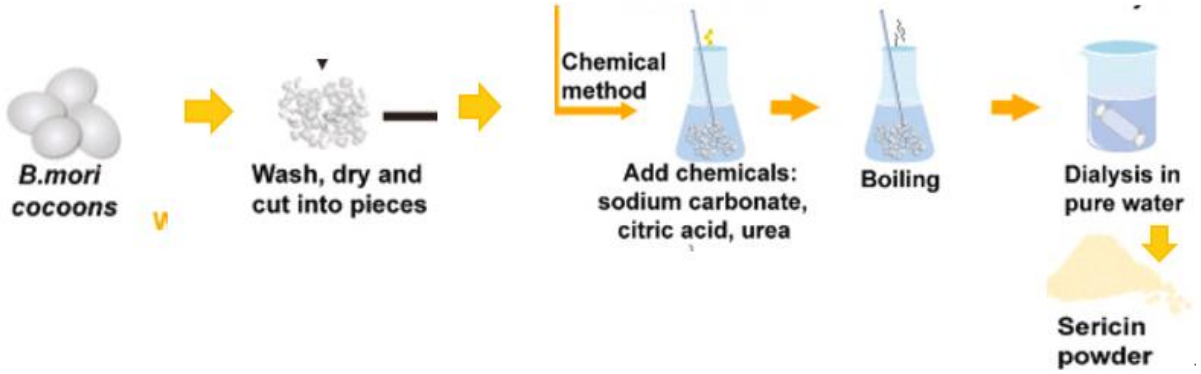
Yunet al. (2013); **Ohet al.** (2011) mentioned that the traditional soap-alkaline method, using sodium bicarbonate (Na_2CO_3) and Marseille soap, effectively isolates fibroin but is costly and leaves soap residues that complicate SS recovery.

Dashet al. (2007); **Aramwitet al.** (2012) Alternatives using Na_2CO_3, urea, and sodium chloride reduce costs but also require extensive purification to obtain high-quality SS.

Wang et al. (2015) introduced a **silk protein surfactant (SPS),** synthesized from silk fibroin amino acids and lauroyl chloride, as a novel, eco-friendly degumming agent for silk. In experiments comparing SPS to traditional agents like sodium carbonate (Na_2CO_3) and neutral soap (NS), SPS proved highly effective. When applied in a 0.2% aqueous solution at a bath ratio of 1:80 (g/mL) and boiled three times for 30 minutes each, SPS completely removed silk sericin from silk fibres. The study showed that SPS not only matched the effectiveness of NS but also outperformed Na_2CO_3 in terms of degumming rate, thermal stability, and mechanical properties. The findings suggest SPS as a superior, environmentally sustainable degumming alternative for silk processing, with applications extending to the manufacture of silk textiles and floss quilts.

2. Chemical Methods

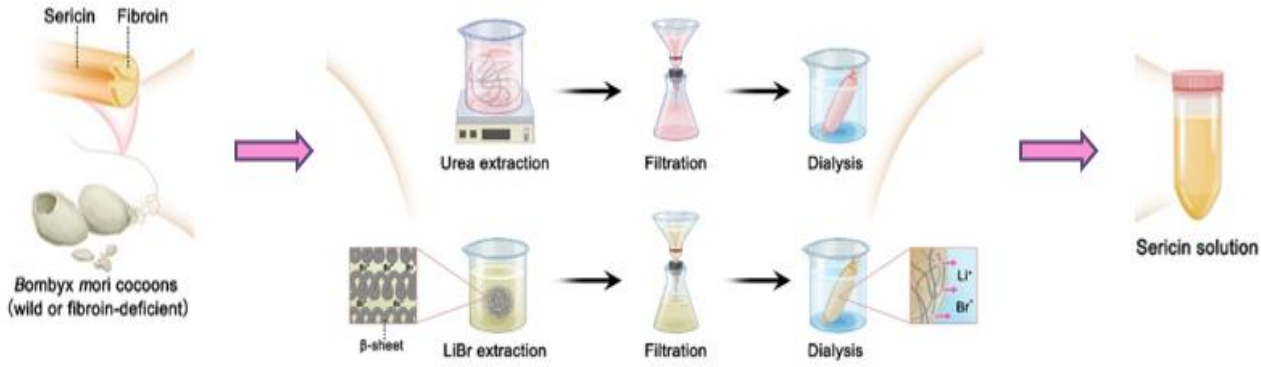
Chemical treatments involve the use of acids, alkalis, or other chemical agents to extract sericin. These methods allow for greater control over the protein's molecular weight and properties but may introduce impurities or alter the biochemical composition (Liu et al. 2022).



1. Alkaline Method: Uses alkaline solutions, such as sodium carbonate or sodium hydroxide, to solubilize sericin. It is effective in breaking down the sericin layer but may degrade fibroin if not carefully controlled. This method is efficient but may lead to high molecular weight variations.

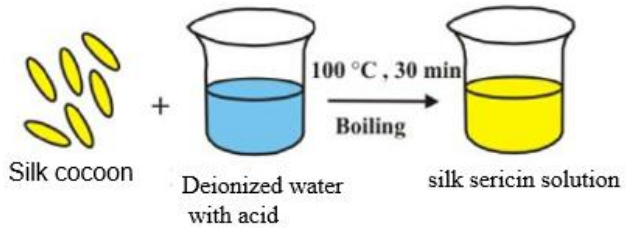
Advantages: This method is widely used for its high yield and relatively mild impact on silk sericin structure, which retains its bioactive properties (Miguel and Álvarez-López, 2020).

2. Acidic Method: Employs acidic solutions, such as citric acid or acetic acid, to dissolve sericin. Acidic treatments are milder compared to alkaline methods and preserve certain functional properties, but the extraction efficiency is often lower. This method is often chosen when the



extracted silk sericin is intended for applications requiring minimal structural modification (**Zhao et al. (2018)**.

Advantages: Acid hydrolysis can yield silk sericin with fewer by-products and preserves



functional groups better than other methods, making it suitable for biomedical applications (Wang et al. 2019).

3. Urea and Salt Treatment: Involves using urea and salts to extract sericin under controlled conditions. Solutions of urea (in varying concentrations) and salts (e.g., magnesium sulfate) can solubilize silk sericin by disrupting hydrogen bonds and electrostatic interactions. Urea acts as a denaturing agent, allowing for the release of silk sericin without significant degradation. This method helps to retain the protein's bioactivity and structure while ensuring better solubility (Aramwit et al. 2010a).

Advantages: The silk sericin extracted by this method tends to have intact bioactive properties, which is ideal for pharmaceutical and cosmetic applications (Wang et al. 2024)..

Advantages:

- **High Efficiency:** Chemical extraction methods, such as those using sodium carbonate, urea, and other alkaline agents, can effectively remove silk sericin from silk fibres, leading to higher yields compared to some physical methods .
- **Controlled Process:** The use of chemicals allows for better control over the extraction conditions, such as pH and temperature, which can be optimized to enhance silk sericin recovery and tailor its properties for specific applications .

- **Versatility:** Various chemical agents can be employed in the extraction process, allowing for flexibility in method selection based on desired silk sericin characteristics and applications (Wang et al. 2024)..
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Disadvantages:

- **Degradation of Silk sericin:** The extraction process often results in significant degradation of silk sericin, affecting its molecular weight and functional properties, which can limit its applications in food, cosmetics, and biomedical fields.
- **Environmental Impact:** The use of chemical agents raises environmental concerns due to the generation of hazardous waste and residual chemicals in wastewater, complicating treatment processes and posing risks to aquatic ecosystems.
- **Purification Challenges:** After extraction, additional steps are typically required to purify silk sericin from residual chemicals, which can be complex and costly, reducing the overall efficiency of the method.
- **Lower Purity:** Chemical extraction methods may yield silk sericin with lower purity compared to alternative methods like enzymatic extraction or high-temperature processes that do not rely on harsh chemicals.

Aramwit et al. (2010) This study examines silk sericin (SS) extracted from three Thai silk cocoon strains (Chul 1/1, Chul 3/2, and Chul 4/2) using different extraction methods, focusing on yield, pigment removal, and biological properties. The urea and high-temperature/high-pressure extraction methods resulted in higher SS yields compared to citric acid and sodium carbonate, with protein structure largely preserved. The urea extraction yielded the highest SS, with clear protein bands across a broad molecular mass range (10-225 kDa) and notable antityrosinase activity .Ethanol was effective in removing carotenoid and flavonoid pigments without affecting SS yield, as shown in reduced color intensity (b* values) for Chul 3/2 and Chul 4/2 strains. Additionally, the SS extracted maintained structural integrity and displayed antityrosinase activity, indicating potential for biomedical and cosmetic applications.

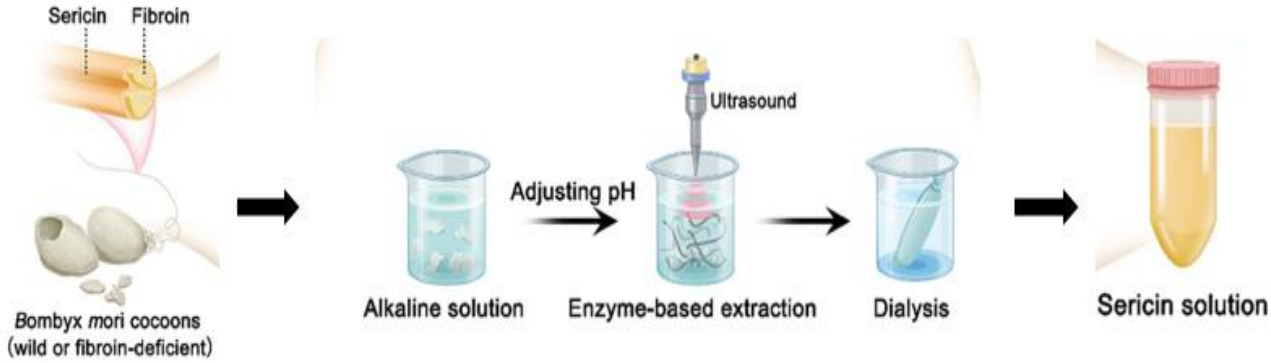
Zhao et al. (2018) explored the use of hydrated lime water (calcium hydroxide solution) as a sustainable and economical degumming agent for silk processing. This method effectively removed silk sericin from silkworm cocoon shells, raw silk, silk pieces, and spun silk products by boiling the fibres in a 0.025% calcium hydroxide solution for two 20-minute cycles, achieving about a 28% degumming ratio. After the degumming process, the wastewater was neutralized with sulfuric or phosphoric acid, leading to the precipitation of silk sericin protein (20 kDa) and calcium salt. This precipitate could then be recycled, presenting a green solution that minimizes environmental impact by reducing wastewater pollution and conserving biological resources. This study highlights a novel, eco-friendly approach for silk refinement and silk sericin recycling.

3. Enzymatic Method

This method uses enzymes such as proteases or serine-specific enzymes to selectively degrade sericin from silk fibroin. The enzymatic method for extracting silk sericin utilizes proteolytic enzymes such as bromelain, pancreatin, alcalase, savinase, degummase, papain, and trypsin. This technique relies on the action of enzymes to selectively hydrolyze and remove the silk sericin layer from silk fibers while preserving the core fibroin structure. The enzymatic process ensures high specificity, preserving sericin's bioactivity and molecular structure. However, it can be time-consuming and costly. It is highly regarded for biomedical and cosmetic applications due to the minimal introduction of contaminants (Freddi et al. (2003).

Process Overview

1. **Degumming with Proteolytic Enzymes**:
   - Proteolytic enzymes facilitate the breakdown of silk sericin into soluble peptides.
   - Alkaline and neutral proteases are particularly effective in achieving efficient degumming.
2. **Recovery and Drying**:
   - After enzymatic action, the dissolved silk sericin is separated and recovered by drying.
3. **Molecular Composition**:
   - The resulting silk sericin peptides typically fall within the molecular weight range of **5 to 20 kDa**.
   - These peptides are free from alkali and fatty acid residues, ensuring high purity (Suwannaphan et al. 2017).



Influencing Factors

1. **Enzyme Dosage:** The amount of enzyme used significantly impacts the rate and efficiency of sericin removal.
2. **Treatment Time:** The duration of enzymatic treatment affects the yield and molecular characteristics of the extracted sericin.
3. **Enzyme Type:** The choice of protease determines the chemical properties and solubility of the resulting sericin peptides.
4. **Treatment pH:** The pH of enzymatic treatment affects the yield and molecular characteristics of the extracted sericin (Arami et al. 2007**)**.

Advantages

- **Purity**: This method yields silk sericin peptides devoid of chemical residues, ensuring better quality for applications.
- **Energy Efficiency**: Compared to conventional techniques, enzymatic extraction requires less energy, making it more sustainable.
- **Biocompatibility**: The extracted sericin maintains its natural bioactive properties, enhancing its potential for biomedical and cosmetic applications (Yakul et al. 2019)

Limitations

- **Cost**: The use of specialized enzymes makes this method slightly more expensive than conventional techniques.
- **Process Optimization**: Precise control of enzyme concentration and treatment duration is critical for achieving consistent results (Pandya and Shetty,2021).

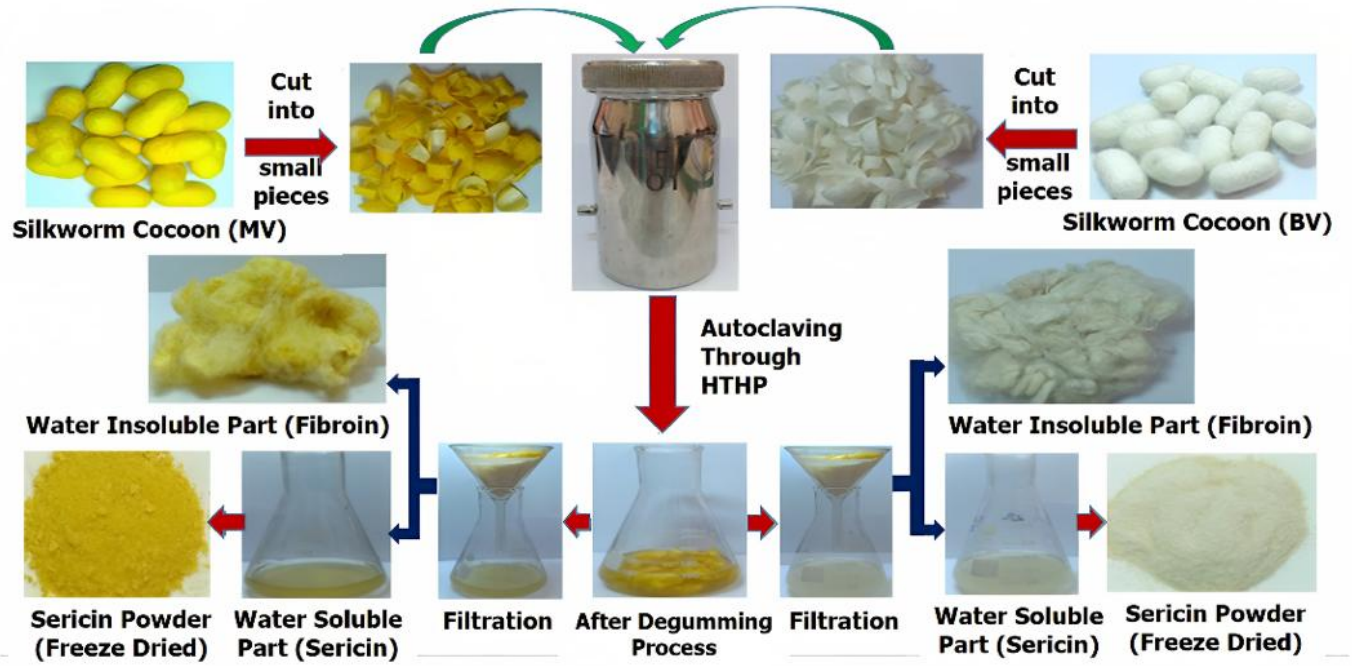
Suwannaphan et al. (2017) investigated a newly isolated Bacillus sp. C4, which produced a highly effective extracellular serine protease with a unique specificity to silk sericin. This enzyme, with an optimal pH of 8 and temperature of 50°C, achieved complete silk sericin removal without harming silk fibroin fibres, making it advantageous for silk textile processing. Its degumming performance, tested on silk yarn, showed comparable or superior results to sodium carbonate, with minimal fibroin destruction as observed via SEM. Furthermore, the enzyme displayed multifunctional capabilities, including silk sericin degradation and color bleaching, making it a potential resource for the silk, cosmetic, and detergent industries. Ongoing research aims to enhance enzyme potential through cloning and expression.

Freddi et al. (2003) studied the effectiveness of various proteases in degumming crêpe silk fabric. Different alkaline, neutral, and acid proteases were tested under optimal pH and temperature conditions, with varying enzyme dosages (0.05–2 U/g fabric) and treatment times (5–240 min) to evaluate their efficiency in removing silk sericin. Results indicated that alkaline and neutral proteases significantly outperformed traditional chemical methods, achieving silk sericin removal rates of 17.6 wt.% for 3374-L, 24 wt.% for GC 897-H, and 19 wt.% for 3273-C, with a maximum degumming loss of 27 wt.% using soap and alkali. The analysis revealed that silk sericin was completely removed from the warp yarns, while residues remained in the twisted weft yarns. A mixture of soluble silk sericin peptides was produced, with molecular weights ranging from 5 to 20 kDa, averaging around 12 kDa, suggesting potential for recovery and reuse in cosmetic applications. The study highlights the need for further optimization of degumming conditions, particularly regarding mechanical agitation to enhance enzyme penetration, which is crucial for improving the quality of silk goods. Ongoing pilot plant tests aim to scale up this enzymatic process for industrial application.

4. Autoclave Method

An autoclave system operates at high temperatures and pressures to extract sericin. This method is efficient and results in uniform molecular weights, making it suitable for industrial applications. The high-pressure environment enhances solubility and allows for rapid extraction, but it may denature sensitive proteins. The high-temperature and pressure method for extracting silk sericin leverages steam or autoclaving to destabilize hydrogen bonds within the silk sericin structure. This allows water to interact with polar amino acids, facilitating the separation of sericin from the silk fiber (Silva et al. 2012).

The systematic diagram of a degumming process to isolate fibroin and silk sericin from silk worm cocoons by using heat method (Hossainet al. 2023)



Process Overview

1. **Heat and Pressure Application**:
   - Silk fibers are subjected to high-temperature steam or autoclaving.
   - The elevated heat destabilizes hydrogen bonds between hydroxyl groups, enabling water to penetrate and interact with silk sericin's polar amino acids (**Castrillón et al. 2017, Saha et al.2019)**.
2. **Molecular Weight Range**:
   - The extracted silk sericin typically has molecular weights ranging from **20 to 400 kDa**.
   - The molecular weight is influenced by factors such as temperature and duration of the extraction process (Rocha et al. 2017).

3. Recovery and Quality:

- The method yields a clean and good-quality sericin product, although the yield is lower compared to alkaline-based methods (e.g., calcium carbonate extractions) (Wang et al.2018).

Advantages

- **Simplicity**: The method is straightforward and does not require complex chemical treatments.
- **Environmental Sustainability**:No chemical compounds are involved, minimizing potential chemical waste.Water consumption is significantly reduced, contributing to its eco-friendly nature(Chirila et al. (2013).

Limitations

- **Degradation Risk**:High temperatures may degrade silk sericin proteins, reducing their bioactivity and structural integrity.

- **Yield**: The amount of silk sericin extracted using this method is lower compared to chemical extraction methods.
- **Molecular Weight Variability**: Variations in temperature and extraction duration can lead to inconsistent molecular weights in the final product (Srinivas et al. (2014).

Rocha et al. (2017) explored the extraction of crude silk sericin from Bombyx mori silk cocoons using two methods: high-temperature autoclaving followed by either lyophilization or freezing-thawing precipitation. The study characterized the extracted silk sericin's physicochemical and biological properties, finding that it exhibited significant antioxidant and antimicrobial activities without any cytotoxic, genotoxic, or mutagenic effects. The extraction methods preserved the silk sericin's chemical characteristics, resulting in a wide molecular weight range (37 kDa to 200 kDa) and a protein concentration of approximately 30%. The research indicated that silk sericin could be valuable for food, textiles and biopharmaceutical applications due to its ability to scavenge free radicals and its overall safety profile.

Castrillón et al. (2017) investigated silk sericin(SS), a byproduct of silk production that is often regarded as waste in Colombia. They characterized silk sericin extracted from both cocoons (SSC) and silk yarns (SSY) to explore its potential value in various industries, given its notable biological properties, such as corrosion resistance, antimicrobial activity, and moisture management. The researchers used high-pressure water extraction in an autoclave (121 °C for 30 minutes, liquor ratio of 1:30) followed by freeze-drying to obtain silk sericin. Characterization techniques like Scanning Electron Microscopy (SEM), Attenuated Total Reflectance-Fourier Transform Infrared (ATR-FTIR), and Thermogravimetric Analysis (TGA) revealed that the extraction method and the type of raw material significantly influence the properties of the resulting silk sericin. The study highlights the potential for developing value-added products from silk sericin in biomedical, textiles, pharmaceutical, cosmetic, and food applications.

5. Infrared Ray Method

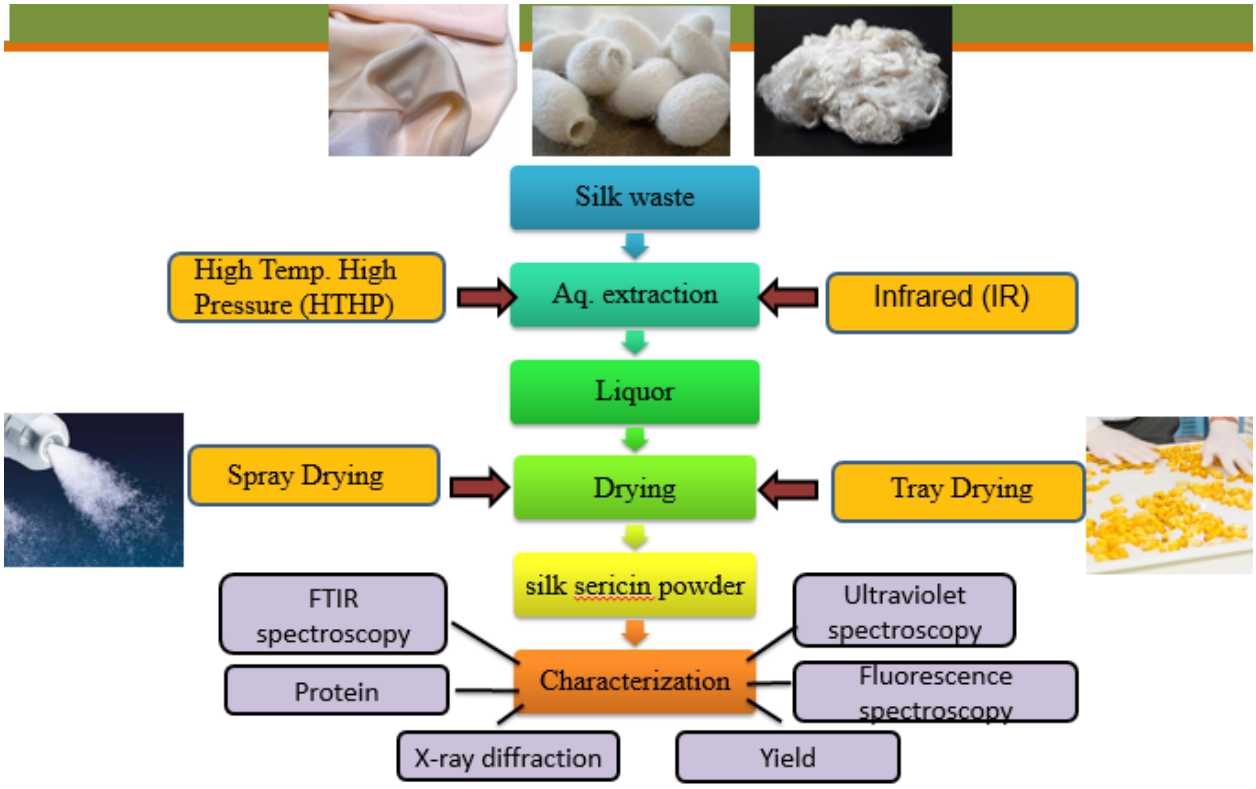
Infrared rays are used to heat the silk fibers, promoting the breakdown of sericin. The extraction and drying parameters of silk sericin, including the heating method, extraction time, temperature, and liquor ratio, play a critical role in influencing both the yield and quality of the recovered protein (Aramwitet al. 2012). Traditional methods like high-temperature, high-pressure (HTHP) extraction and tray drying often degrade sericin due to prolonged heat exposure, whereas innovative methods like infrared (IR) heating and spray drying have emerged as promising alternatives. This technique is emerging as a greener alternative, as it reduces the need for chemicals and water. It preserves sericin's functional properties but requires sophisticated equipment, making it less common in large-scale production (Sakai and Hanzawa, 1994 and Liet al. 2012).

Innovative Extraction Process

1. **Infrared (IR) Heating**:
   - **Mechanism**: IR heating eliminates the need for chemical agents, relying on thermal radiation to extract sericin efficiently.
   - **Environmental Impact**: This method is a "green" alternative, significantly reducing water usage and environmental pollution compared to traditional soap or alkali-based methods.
   - **Yield and Quality**: Sericin extraction via IR heating achieves complete protein recovery under milder conditions with lower temperature, reduced time, and minimal water consumption. The yield is reported to be **13 times higher** than conventional HTHP methods (**Gupta et al. (2013)**.

2. **Spray Drying**:

- **Simplified Recovery**: The liquor containing extracted silk sericin can be directly spray-dried, simplifying the recovery process and yielding approximately **28% sericin**.
- **Protein Integrity**: Spray drying preserves the protein's structural integrity, ensuring high-quality sericin suitable for applications in biomedical and cosmetic industries (Gencet al.2009).



Advantages of IR Heating and Spray Drying

- **Eco-Friendly**: The absence of chemicals and minimal water use make these methods highly sustainable.
- **Enhanced Quality**: These techniques prevent protein degradation, maintaining the biochemical properties of silk sericin.
- **Efficiency**: IR heating extracts sericin with significantly lower energy and time requirements (Gupta et al., 2014 and Panthonget al.2015)

Assessment and Monitoring of Quality

- **UV and Fluorescence Spectroscopy**:
  - UV spectra provide a reliable measure of sericin quality.
  - Fluorescence spectroscopy is more sensitive and effective in detecting protein degradation, making it a valuable tool for quality assurance during the extraction process (Gupta et al.2013).

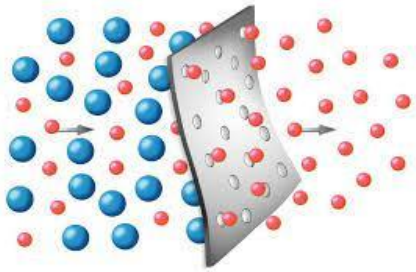
Gupta et al. (2013) explored that a cleaner process for silk sericin extraction, shifting from conventional methods such as soap and alkali treatments or high-temperature high-pressure (HTHP) processes to a more sustainable infrared (IR) heating approach. Traditional methods generate significant chemical waste and lower yields, whereas the IR method enables complete silk sericin extraction at lower temperatures (100-110°C) and shorter durations (60-120 minutes), achieving yields of up to 26%. This technique minimizes water and chemical usage, substantially

reducing environmental pollution. Furthermore, characterization of silk sericin extracted via IR heating demonstrates superior protein quality, with UV and fluorescence spectroscopy revealing fewer conformational changes compared to HTHP methods. Overall, IR heating represents a cleaner, more efficient technique for silk sericin extraction, meriting further investigation for commercial applications.

6. Polymeric Membrane Filtration

The membrane process is a technique that permits concentration and separation without the use of heat and today has emerged as one of the fastest growing processes in the recovery of valuable materials from industrial wastewater. The membrane process represents a modern and efficient technique for concentrating and separating valuable materials without the application of heat. This process has gained significant traction in the industrial recovery of proteins such as silk sericin, particularly from silk cocoon degumming wastewater. By leveraging selective filtration techniques like ultrafiltration and nanofiltration, this method enables the recovery of silk sericin while preserving its functional properties (Capar et al. 2008 and Sonjui et al.2009) .

Polysulfone (PSF) Membranes



Polysulfone (PSF) membranes are widely used in membrane processes due to their advantageous structural and performance characteristics. These membranes are typically prepared through a phase inversion process, incorporating additives like polyethylene glycol (PEG) and poly(1,3-dioxolane) (PDXL) to enhance their separation capabilities (**Sonjui et al. 2009)**.

- **Recovery Efficiency**: PSF membranes allow for the recovery of silk sericin with molecular weights ranging from **10 to 250 kDa**, accommodating a diverse range of applications.
- **Sustainability**: By treating and recycling wastewater from silk degumming, the process significantly reduces environmental impact while enabling resource recovery (Sonjuiet al. 2009).

The method can vary depending on the desired properties of the extracted silk sericin. It have two methods.This method involves ultrafiltration or nanofiltration techniques to separate sericin from the silk solution (Nasrollahiet al. 2019).

- **Ultrafiltration**: Retains sericin molecules of specific molecular weights while removing impurities. It is an efficient method for obtaining high-purity sericin.
- **Nanofiltration**: Provides finer separation, producing sericin with more controlled molecular weight ranges and higher purity. It is particularly useful in advanced biomedical and cosmetic applications (Li et al. 2015)

1. Ultrafiltration for Silk Sericin Recovery

Ultrafiltration (UF) is a membrane filtration technology that is gaining attention for the recovery and purification of silk sericin, a valuable protein extracted from silk cocoons. It offers a sustainable, efficient, and eco-friendly method for concentrating sericin from aqueous solutions.

i. Principle of Ultrafiltration

Ultrafiltration is a pressure-driven filtration process where water and small molecules pass through a membrane with a specific molecular weight cut-off (MWCO). The larger silk sericin molecules, which have a relatively high molecular weight, are retained on the membrane, allowing for the purification and concentration of sericin (Khosa et al.2014b).

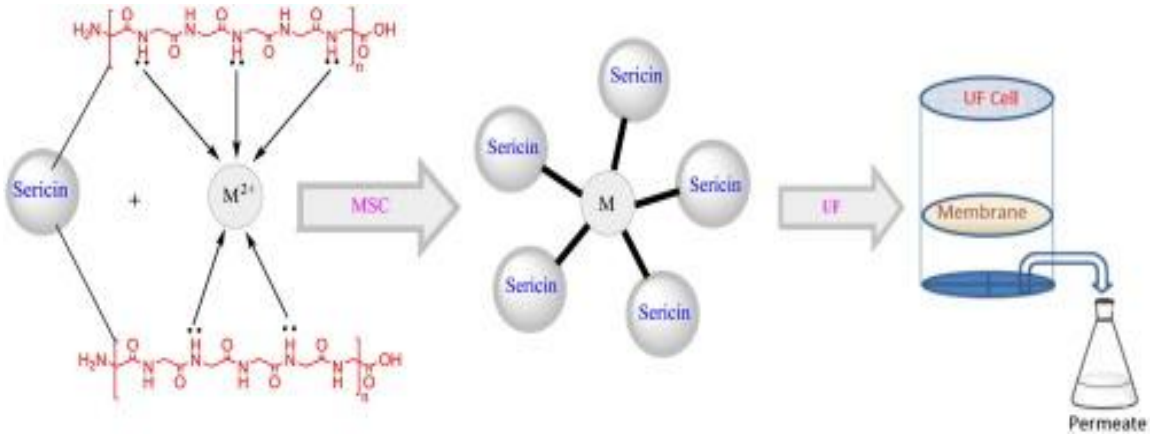
2. **Key Features of Ultrafiltration for Silk Sericin Recovery**

1. **Molecular Weight Cut-off (MWCO)**:

- UF membranes are designed with a specific MWCO range, typically between 1 to 100 kDa, which allows smaller molecules like water and low-molecular-weight impurities to pass through, while retaining the larger sericin molecules.
- This ensures the recovery of sericin with high purity, maintaining its bioactive properties like antioxidant activity and biocompatibility.
-

2. **Efficiency**:

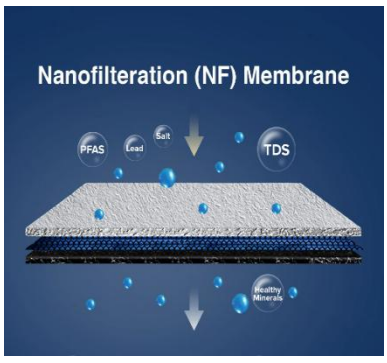
- **High Yields**: Ultrafiltration enables high recovery rates of silk sericin with minimal degradation of the protein, maintaining its functional properties.
- **Temperature Control**: Unlike traditional methods that often require heat, UF operates at lower temperatures, preventing the thermal degradation of sericin, and preserving its properties.
- **Energy Efficiency**: UF requires less energy compared to other extraction methods such as solvent extraction or centrifugation, making it a more sustainable and cost-effective option (Khosa et al. 2014a ; Gimenes et al. 2014 and Silva et al. 2012).



2. Nanofiltration for Silk Sericin Recovery

Nanofiltration (NF) is a filtration process that operates at a finer scale than ultrafiltration (UF), typically used for separating smaller solutes from larger ones. This process falls between ultrafiltration and reverse osmosis (RO) in terms of pore size and pressure requirements, offering a unique blend of advantages for extracting and concentrating silk sericin (Huan et l.,2009)

Principle of Nanofiltration



Nanofiltration membranes are designed to selectively separate particles based on size and charge. Typically, NF membranes have a pore size in the range of 1–10 nanometers, which allows them to retain larger organic compounds like silk sericin while allowing smaller solutes, such as salts and low-molecular-weight molecules, to pass through. This selective separation ensures a high concentration of the targeted protein with minimal loss of quality (Wuet al.2014 ; Wanget al. 2006).

Key Features of Nanofiltration for Silk Sericin Recovery

1. **Selective Separation**:
   Nanofiltration offers a high degree of selectivity, allowing silk sericin to be effectively separated from smaller solutes, including salts, sugars, and other low molecular weight contaminants. This selectivity leads to higher purity in the recovered sericin, which is crucial for its functional properties.
2. **Lower Energy Requirement**:
   Unlike reverse osmosis, which operates at very high pressures, nanofiltration typically requires lower operating pressures, making it a more energy-efficient alternative for recovering silk sericin. This results in reduced operational costs and a more sustainable process.

3. **Quality of Extracted Sericin**:
   The nanofiltration process is gentle enough to preserve the structural integrity and bioactive properties of silk sericin. This is essential because the functional properties of sericin, such as its antioxidant, moisturizing, and skin-repairing abilities, must remain intact for its application in cosmetics, pharmaceuticals, and food industries (Li et al. 2015).

Advantages and Disadvantages of Polymeric Membrane Filtration

Advantages:

- **Selective Separation:** Designed to selectively extract silk sericin, enhancing purity.
- **Environmentally Friendly:** Requires less water and fewer chemicals, promoting sustainability.
- **Efficiency:** Faster and more energy-efficient than traditional extraction methods.
- **Low Temperature Processing:** Preserves silk sericin's functional properties by operating at lower temperatures.
- **Continuous Operation:** Allows for large-scale production without the need for batch processing(Silva et al. 2012; Gimenes et al. 2014)

Disadvantages

- **Membrane Fouling:** One significant challenge with polymeric membranes is fouling, where impurities from the silk or other materials accumulate on the membrane surface, reducing efficiency and requiring frequent cleaning or replacement.
- **Limited Chemical Resistance:** Polymeric membranes may not be resistant to all chemicals used in extraction processes, which can limit their effectiveness or lead to degradation over time, affecting their longevity and performance.
- **Initial Cost:** The initial investment in membrane technology and equipment can be high, which may deter some industries from adopting this method, especially small-scale operations.
- **Lower Yield in Some Cases:** Depending on the membrane design and operating conditions, the yield of silk sericin extracted using polymeric membranes may be lower compared to more aggressive chemical or thermal methods.
- **Complexity of Process Design:** Designing an effective membrane system for silk sericin extraction can be complex, requiring careful optimization of parameters such as pressure, flow rate, and membrane characteristics to achieve desired outcomes (Caparet al. 2008 ; Li et al. 2015 and Sonjuiet al. 2009) .

Sonjui et al. (2009) investigated the preparation and performance of flat sheet polysulfone (PSF) membranes with polyethylene glycol (PEG) and polydioxolane (PDXL) as additives for recovering silk sericin from silk cocoon degumming wastewater. The study varied the

concentration and molecular weight of these additives and examined the effects on membrane morphology, permeate flux (PF), protein retention, and molecular weight cut-off (MWCO). Results indicated that increasing the concentration and molecular weight of PEG and PDXL enhanced pore size, porosity, and PF but reduced protein retention. Higher transmembrane pressures also boosted PF but lowered protein retention, with SEM analysis revealing that membranes had asymmetric structures with finger-like cavities in the sub-layer. The PSF membranes demonstrated potential for silk sericin recovery across various molecular weight ranges, making them suitable for different applications.

Silva et al. (2012) investigated the extraction of high molecular weight silk sericin from Bombyx mori cocoons using high-temperature extraction and ultrafiltration. They found that extraction yields between 22.5% and 24.5% were achieved at temperatures of 120°C and 127°C, respectively, with molecular weight distribution of extracted silk sericin ranging between 100-200 kDa. Ultrafiltration, using a 50 kDa polysulfone membrane, showed that transmembrane pressure significantly impacted permeate flux, with higher pressures reducing permeability due to increased resistance. The study highlights the effectiveness of high-temperature and ultrafiltration methods for obtaining high molecular weight silk sericin.

Li et al. (2015) The study focuses on optimizing a process for recovering high-purity silk sericin protein from silk reeling wastewater, which often leads to environmental pollution. Researchers developed an inner-side hollow fibre nanofiltration (NF) membrane using interfacial polymerization and integrated it with ultrafiltration (UF) and acidulation precipitation treatments. The optimal UF (6000 MWCO)–NF process achieved a silk sericin protein recovery rate of over 86% from various silk wastewaters, with a protein loss rate of 34.1% and salinity reduction of 29.1%. Diluting the concentrated solution four times improved overall efficiency, while cleaning the NF membrane with 0.2 mol/L hydrochloric acid successfully mitigated protein fouling, allowing for a flux recovery rate above 80%.

Charactertics of Silk Sericin

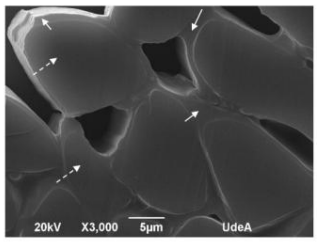
Silk sericin is a unique protein due to its non-conventional properties which are summarized as follows;

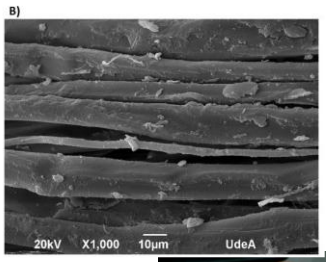
1. Molecular Weight- Molecular weight of silk sericin depends on the method of extraction as shown in Table. When silk sericin is extracted with 1% sodium deoxycholate solution, Mw is 17100-18460. When it is extracted by hot water it shows molecular wt. of 24000 by gel electrophoresis. When it is extracted by enzyme action mol. wt. is 3000-10000 and when it is extracted with aqueous urea mol.wt. is around 50000 (Rassent, 1967).

S.NO	Method Of Extraction	Molecular Weight
1.	1% Sodium Deoxycholate Solution	17,100-18,460
2.	Gel Electrophoresis	24,000
3.	Aqueous Urea	50,000
4.	Enzyme Extraction	3000-10,000

Sericin Molecular Weight by Different Techniques

2. Morphology-The surface morphology of the spray dried silk sericin powder was reported to be like wrinkled particles which can be due to the collapse of hollow spherical structures when rapidly evaporated. Silk sericin by virtue of its hydrophilic nature gets agglomerated by immediate picking of moisture when exposed to atmosphere (Kimet al.2009)





3. Property of gelling- It consists of random coil and β-sheet structure. Random coil structure is soluble in hot water and as the temperature lowers, the random coil structure convert to β-sheet structure, this results in gel formation. Silk sericin has sol-gel property as it easily dissolves into water at 50-600C and again retuns to gel on cooling (Zhuet al. 1995).

4. Isoelectric Ph: In silk sericin there are more acidic than basic amino acid residues, hence the isoelectric point of silk sericin is around 4.0(Voegeliet al.1993).

5. Solubility: Solubility of silk sericin in water decreases when the silk sericin molecules are transformed from random coil into β-sheet structure. Solubility of silk sericin may be increased by addition of poly Sodium acrylate and it may be decreased by the addition of formaldehyde, polyacrylamide or resin based finishes (Kataoka,1977).

6. Other characteristics of silk sericin like moisture content ,nitrogen content, ash content, color and solubility are reported in given in Table.

Parameters	**Percent**
Moisture content	10-17
Nitrogen Content	9-16
Ash content	0.8-6
Color	Cream to light yellow
Solubility	soluble in hot water

Various characteristics of silk sericin. (Padamwar and Pawar, 2004).

Properties of Silk Sericin

Silk sericin, a natural protein derived from silkworm cocoons, possesses several advantageous properties that make it suitable for various biomedical applications. Below are the key characteristics of silk sericin:

1. Biocompatibility

Silk sericin is recognized for its biocompatibility, allowing it to interact safely with biological tissues without provoking adverse reactions. This is crucial for its use in medical textiles such as wound dressings and sutures, where it supports cell attachment, proliferation, and differentiation. Although some studies have indicated potential immunogenic responses, these are generally mild, and the overall safety profile remains favorable for clinical applications (Nguyenet al.2019).

2. Biodegradability

As a natural polymer, silk sericin is biodegradable, which means it can decompose naturally in the environment. This property aligns with sustainable manufacturing practices, reducing environmental impact compared to synthetic materials. The ability to break down without leaving harmful residues enhances its appeal in biomedical applications (Aramwit et al. 2010a)..

3. Non-toxicity

Silk sericin is considered non-toxic, making it safe for consumer products that come into contact with skin. Its safety profile is particularly beneficial in applications involving personal care items and clothing. This non-toxicity is a significant advantage in developing products intended for sensitive skin (Gencet al.2009)..

4. Moisture Absorption

The hydrophilic nature of silk sericin allows it to absorb moisture effectively. This characteristic improves the comfort of textiles by enhancing moisture retention, making them ideal for activewear and intimate apparel56. The ability to maintain skin hydration is particularly valuable in wound healing applications **Li et al. (2015)**.

5. Anti-Inflammatory Properties

Silk sericin exhibits anti-inflammatory effects, which can help reduce skin irritation when used in textile applications. This property makes it suitable for products designed for sensitive skin or conditions prone to inflammation. Its use in creams and dressings can promote healing and comfort (Silva et al. 2022)..

6. Immuno-compatibility

Silk sericin exhibits immuno-compatibility, ensuring that textiles made from or treated with this protein do not provoke immune responses. This quality is essential for medical textiles, as it minimizes the risk of adverse reactions when in contact with biological tissues (Aramwit et al. 2009).

7. Anti-oxidation

Silk sericin possesses antioxidant properties that protect fabrics from oxidative damage, which can lead to deterioration over time. This characteristic not only enhances the longevity of textiles but also contributes to maintaining their appearance and functionality (Kunz et al. 2016).

8. Photo-Protective Properties

The ability of silk sericin to provide UV protection makes it valuable for outdoor textiles and clothing. This property helps shield the skin from harmful UV rays, making it suitable for sun-protective apparel and outdoor gear.

9. Gelling/Sol-Gel Property

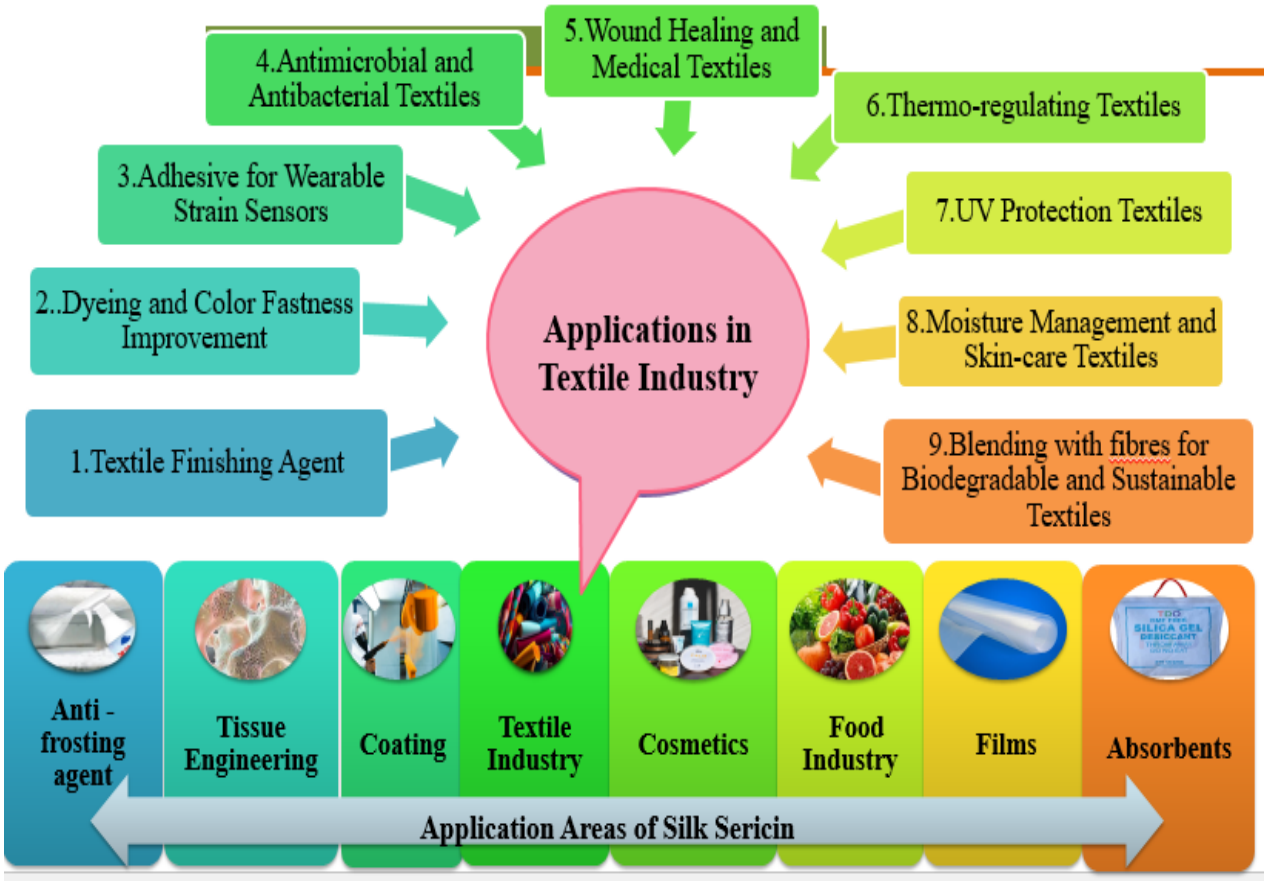
Silk sericin can form gels, which can be utilized in various textile treatments to enhance fabric properties or create coatings that improve functionality. This gelling ability is beneficial for applications such as drug delivery systems and tissue engineering scaffolds (Zhuet al. 1995).

10. Anti-bacterial and Anti-microbial Activity

Silk sericin demonstrates significant anti-bacterial and anti-microbial properties, making it effective against a range of pathogens. This quality is particularly useful in medical textiles and activewear, as it helps reduce odor and maintain hygiene by preventing microbial growth (Fatahianet al. 2022).

Application of Silk Sericin In Textile Industry

Silk sericin, a natural protein extracted from silkworm cocoons, has gained significant attention in the textile industry due to its beneficial properties. Below are the primary



applications of silk sericin in textiles:

1. Textile Finishing Agent

Silk sericin, with its unique properties, is increasingly being used as a finishing agent in the textile industry to improve the performance and feel of fabrics. Its ability to interact with both natural and synthetic fibers enhances the texture, durability, and overall quality of textiles. Silk sericin enhances fabrics by improving their texture and durability through its strong binding affinity with both natural (e.g., cotton, wool) and synthetic fibers (e.g., polyester, nylon) (Dash, and Patra, 2008 and Saleemet al.2024). Acting as a protective coating, sericin shields fabrics from environmental damage, such as sunlight, moisture, and pollutants, while reducing the effects of repeated washing, thus maintaining their integrity over time.In addition to durability, sericin significantly enhances fabric softness and smoothness. It gives textiles a silky, smooth hand-feel, making them more comfortable for clothing and intimate apparel. By reducing surface roughness, sericin also creates a refined and polished appearance, improving the tactile and visual appeal of fabrics (Kunduet al.2010).

The application of silk sericin imparts a subtle shine or lustre to fabrics, giving them a luxurious, high-end look. The smooth, glossy finish mimics the natural feel of silk, making it ideal for enhancing the aesthetic quality of premium textiles(Kabiret al.,2024) .Sericin's ability to retain moisture provides comfort and prevents skin dryness, making it especially beneficial for fabrics that come into direct contact with the skin, such as clothing and bedding (Yang et al.

2024). This moisturizing effect makes sericin-treated textiles ideal for sensitive skin and medical applications, offering soothing and hydrating benefits (Xu, 2015).

1. **Nylon and Polyester**: Silk sericin can be coated onto synthetic fibers like **nylon** and **polyester**. This ability to bond with these commonly used synthetic fabrics makes sericin a versatile finishing agent. It enhances the **feel**, **durability**, and **comfort** of synthetic textiles, which are often criticized for being stiff or uncomfortable and reducing static build up.

2. **Indoor Air Filtration**: In addition to its use in clothing and bedding, sericin-coated fabrics have potential applications in **indoor air filters**. These filters can help reduce the presence of **toxic free radicals**, fungi, and bacteria (such as **micrococcus**). This functionality provides an eco-friendly solution for improving air quality.

Mondal et.al (2024) investigated the use of silk sericin and chitosan to enhance cotton fabric's antimicrobial, UV-protective, and antioxidant properties, achieved through an eco-friendly finishing process. silk sericin, derived from silkworm cocoons, is valued for its biodegradable, non-toxic, and moisture-absorbing properties. Its high hydroxyl and amine content improves cotton's moisture absorption, radical scavenging activity, and UV protection. The study found that silk sericin-treated fabrics demonstrated significant antioxidant activity, with a radical scavenging rate of up to 53%, while combined silk sericin-chitosan treatments further improved UV protection, achieving a UPF of 16.8. This research underscores silk sericin's potential in developing sustainable, multifunctional textiles and silk sericin can be an alternative to petroleum-based finishing agents, which are toxic.

Yang et al. (2024) focuses on the development and properties of silk sericin protein/nano-titanium dioxide (TiO_2) composites for textile applications. Researchers modified citric acid-pretreated cotton fabrics using a two-dipping and two-padding process with a blend finishing solution of silk sericin protein and nano-TiO_2. The results demonstrated that the modified fabrics achieved multifunctional properties, including deodorization, UV protection, and enhanced thermal and mechanical performance. The silk sericin/TiO_2 composite formed a uniform coating, contributing to smoother fibre surfaces, increased tensile strength, and improved functional attributes. This research highlights the potential of combining organic (silk sericin) and inorganic (nano-TiO_2) materials to produce advanced textiles with practical applications in protective and functional clothing

Lee et.al (2004) investigated the use of silk sericin as an antistatic agent when applied to synthetic fabrics, such as polyester (PET) and polypropylene (PP). By grafting N-vinylformamide (NVF) onto these fabrics using electron-beam irradiation and then crosslinking with silk sericin, the research demonstrated improved moisture absorption and antistatic properties. Silk sericin, a hydrophilic silk protein, mitigates static charge build-up, which is a common issue with hydrophobic synthetic fibres. The treated fabrics showed increased water retention and reduced static charge without compromising their tactile qualities. This approach not only enhances fabric comfort and usability but also offers an eco-friendly alternative to conventional antistatic finishes.

2. Silk Sericin in Dyeing and Color Fastness Improvement

Silk sericin's unique chemical properties make it an excellent agent for improving the **dyeing process** and enhancing the **color fastness** of textiles. By interacting with dyes, silk sericin can improve the **uptake**, **retention**, and **vibrancy** of colors on fibers, as well as enhance their resistance to fading and washing. Silk sericin significantly enhances the dyeing process of textiles, improving both the aesthetic and functional properties of dyed fabrics. It interacts with dyes through hydrogen bonding and electrostatic interactions, enabling better dye uptake and deeper, richer colors (Bhandariet al. 2017). This interaction also enhances the fiber's affinity for dyes, resulting in brighter and more vibrant colors compared to untreated fabrics (Chaudharyet al. 2017).

Beyond improving dye uptake, silk sericin enhances color fastness by securing dye molecules to fiber surfaces. This reduces dye run-off during washing or exposure to sunlight, ensuring longer-lasting, durable colors. Fabrics treated with sericin exhibit reduced fading, maintaining their vibrancy and aesthetic quality over time (Eser and Yavas, 2021)..

Silk sericin serves as both a pre-treatment and finishing agent. As a pre-treatment, it prepares fibers for dyeing by increasing dye affinity, leading to enhanced color intensity and uniformity. As a finishing agent, it reinforces color retention and washing resistance, stabilizing the dye for prolonged vibrancy (Bhandariet al. 2017).Additionally, sericin reduces dye run-off, preventing color bleeding and minimizing dye loss during washing. This not only enhances color fastness but also has eco-friendly benefits. By reducing excessive dyeing and dye pollution, sericin promotes a more sustainable and environmentally responsible textile dyeing process (Zhou et al. 2012)..

Benefits for Synthetic and Natural Fibers

1. **Versatility**: Silk sericin can be used to treat both **natural fibers** (such as cotton, wool, and silk) and **synthetic fibers** (like polyester and nylon), improving their dyeability and color fastness across a range of fabric types. This versatility makes silk sericin a valuable tool in the textile industry for achieving high-quality, long-lasting colors on various textile materials (Zhou et al. 2012).

2. **Synergy with Synthetic Dyes**: When used in combination with synthetic dyes, silk sericin can improve the uptake and stability of dyes, ensuring that synthetic fibers retain their color without compromising the fabric's feel or durability (Chaudharyet al. 2017).

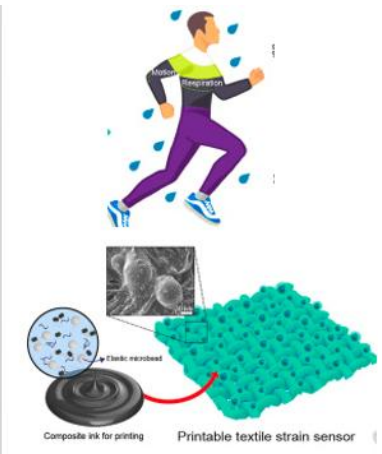
Chaudhary et.al (2017) investigated the enhancement of polyester fabrics through the application of silk sericin and basic dyes. The research demonstrates that pre-irradiation of polyester significantly improves dye uptake, with optimal dyeing conditions established at 100 °C for 60 minutes. The application of silk sericin further enhances dye absorption due to its hydroxyl groups facilitating ionic interactions with basic dyes, resulting in a noticeable increase in color intensity and a yellowish tint. The silk sericin-treated samples exhibited improved moisture regain and radical scavenging activity, indicating better moisture management and antioxidant properties. Additionally, the treated fabrics showed good wash fastness ratings and antimicrobial activity against Staphylococcus aureus, with increased zones of inhibition observed as dye concentration rose. Overall, silk sericin not only enhances the dyeability of polyester but also imparts multifunctional properties, making it a valuable addition to textile treatments.

Bhandari et al. (2017) investigated the impact of sericin treatment on the dyeability of cotton fabric using manjistha, a natural dye, and optimized treatment conditions for maximum dye absorption and washing fastness. The findings revealed that treating cotton with 0.5% (w/v)

sericin, combined with 4% citric acid as a crosslinking agent and 1% sodium hypophosphite as a catalyst, under specific conditions—70°C for 45 minutes, followed by drying at 70°C for 4 minutes and curing at 160°C for 2 minutes—significantly enhanced the fabric's affinity for the dye. The dye uptake of sericin-treated cotton increased substantially from 19.5% to 31.7%, while color strength (K/S value) improved from 3.2 to 5.7. This improvement was attributed to the functional groups in sericin (-NH2, -COOH, and -OH), which interacted with the hydroxyl groups in cotton and the natural dye, forming strong bonds that enhanced dye absorption and retention. Additionally, the study highlighted the importance of controlled parameters, such as sericin concentration, treatment temperature, pH, and curing conditions, in achieving uniform application and avoiding adverse effects like uneven deposition or fiber damage. The optimized process not only improved the visual and functional qualities of the dyed fabric but also eliminated the need for harmful metallic mordants, promoting eco-friendly and sustainable textile dyeing practices.

Pattanaik et al. (2024) demonstrated that chemically modified silk sericin by cyanuric chloride , applied during the dyeing process, significantly enhanced textile properties. The modified silk sericin improved the dye depth (K/S values), with silk and wool showing excellent dye absorption due to increased amine group availability, while polyester benefited from enhanced affinity through the introduced chlorine groups. The fabrics exhibited strong wash and light fastness, retaining color even after 10 washes. Additionally, antimicrobial activity was observed, with silk showing a 1 mm inhibition zone for both gram-positive and gram-negative bacteria, while wool and polyester inhibited gram-negative bacteria effectively. The treated fabrics also displayed increased Ultra Violet Protection Factor (UPF) as silk sericin concentration and shade depth rose. Structural analysis revealed a slight increase in crystallinity, as confirmed by XRD, and surface morphology changes, as SEM images showed silk sericin coating fibres even after multiple washes. This study highlights modified silk sericin's multifunctional potential in dyeing, antimicrobial protection, and UV shielding for textiles.

3. An Adhesive for Wearable Strain Sensors



Silk sericin's unique properties make it an ideal candidate for use as an **adhesive** in **wearable strain sensors**, offering a sustainable and effective solution for integrating **conductive materials** into textiles. These sensors are designed to monitor physical movements, making them valuable in **healthcare**, **sports**, and **fitness applications**. Below is an overview of the role of silk sericin in enhancing the functionality of wearable strain sensors (Song et at.,2024).

Silk sericin, a natural and biodegradable protein, is an eco-friendly alternative to synthetic adhesives, particularly in wearable technology. Its sustainable nature eliminates the need for harmful chemical adhesives, supporting the development of environmentally conscious wearable devices. The flexibility and softness of sericin ensure that wearable strain sensors do not compromise comfort or mobility, making it ideal for applications requiring extended use, such as medical monitoring or sportswear. Moreover, sericin's non-toxic and biocompatible properties make it safe for prolonged skin contact without causing irritation (Seyedinet al.2019).

In addition to its adhesive qualities, silk sericin facilitates the integration of conductive materials like conductive polymers, carbon nanotubes, or silver inks. These materials are essential for wearable strain sensors to effectively track strain and electrical signals. Sericin provides a stable adhesive base, ensuring secure bonding of conductive layers to textiles or skin surfaces. Its strong adhesive properties also preserve the integrity of the conductive materials, preventing

detachment or loss of functionality during regular use. This reliability is critical for accurate strain measurement and consistent sensor performance **(**Duan and Lu, 2021).

Applications of Wearable Strain Sensors with Silk Sericin

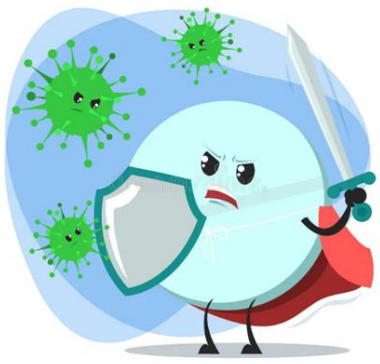
1. **Healthcare**: Wearable strain sensors with silk sericin can be used in **medical monitoring devices**, such as those tracking **muscle movement**, **joint strain**, or **posture correction**. The sensors can provide real-time data for **physiotherapy** or **rehabilitation**, helping patients and doctors monitor progress.

2. **Sports and Fitness**: In **sportswear**, wearable strain sensors with silk sericin can be used to track the wearer's **biomechanics**, including movements like **bending**, **stretching**, or **jumping**. The data gathered can assist athletes in improving performance, preventing injury, and optimizing training regimens.

3. **Smart Textiles**: Silk sericin-based sensors can be integrated into **smart textiles** for **wearable electronics**, such as **health-monitoring garments** and **fitness trackers**. These garments can monitor movement, temperature, or even posture, providing valuable feedback to the user or healthcare providers (Seyedinet al.2019)..

Duan and Lu (2021) investigated that a novel, cost-effective, and environmentally friendly approach for creating multifunctional conductive textiles by nickel-plating acetate fabrics coated with carbon nanotubes (CNTs), with silk silk sericin. The use of silk sericinas a green adhesive to enhance the dispersion and adhesion of carbon nanotubes (CNTs) on acetate fabrics. silk sericin, a natural protein derived from silk, serves as an eco-friendly binder, promoting better interaction between the CNTs and the fabric substrate. This not only improves the uniformity and stability of the CNT coating but also contributes to the overall functionality of the textile, including its enhanced conductivity and electromagnetic interference (EMI) shielding effectiveness. The use of silk sericin, a biodegradable material, aligns with the study's focus on sustainable and environmentally friendly textile innovation. As the integration of CNTs and nickel layers provides high tensile strength, good flexibility, and the ability to detect strain via negative resistance changes, which could be useful for human-machine interaction, such as finger and wrist movement monitoring. Additionally, the textile sensors show good durability and reproducibility over 150 cycles of strain, highlighting their potential for use in advanced wearable devices and EMI shielding applications.

4 . Antimicrobial and Antibacterial Textiles



Silk sericin's inherent **antibacterial properties** and its ability to enhance the effectiveness of antimicrobial agents make it an excellent addition to **hygiene-focused textiles**. These properties allow silk sericin to improve fabric cleanliness and prevent microbial growth, making it ideal for various applications, especially in settings where **hygiene** and **antimicrobial resistance** are crucial (Jassim and Saree, 2012).

Silk sericin exhibits antibacterial action through several mechanisms. It disrupts bacterial cell membranes, which inhibits the growth and reproduction of bacteria. Additionally, silk sericin reduces microbial adhesion to textile surfaces, creating a less favorable environment for bacterial colonization. When combined with antibacterial agents like silver nanoparticles, silk sericin enhances its antimicrobial effects by improving the retention and binding of these agents to the textile, further disrupting bacterial metabolism.The effectiveness of silk sericin-treated fabrics has been demonstrated against common bacteria, such as E. coli and Staphylococcus aureus, both of which are associated with infections and skin conditions.

Silk sericin also shows broad-spectrum antimicrobial activity, making it effective against a wide range of bacteria and fungi (Sarovaret al. 2003).

Silk sericin-treated textiles have numerous applications in various industries. In medical textiles, such as hospital gowns and surgical drapes, it helps reduce the risk of hospital-acquired infections. In sportswear, silk sericin inhibits odor-causing bacteria and reduces moisture that supports bacterial growth. Its antibacterial properties are also beneficial for intimate apparel and household textiles, enhancing hygiene and preventing skin irritation. Additionally, silk sericin's biocompatibility and antibacterial action make it suitable for healthcare products like sanitary napkins, diapers, and face masks (Rajendran et al. 2012).

The advantages of silk sericin in antimicrobial textiles include its biodegradability, non-toxicity, durability, and moisture-absorbing properties. It provides a sustainable, eco-friendly option compared to synthetic agents, and its antimicrobial properties remain effective through multiple washes. To further enhance its antibacterial efficacy, silk sericin can be combined with nanoparticles, crosslinking agents, or applied as a layered coating to improve adhesion, stability, and overall performance (Gokceet al. 2020).

Gokce et,al (2020) explores the application of silk sericin, a protein typically discarded in silk production, as an antimicrobial finishing agent for cotton fabrics. This study repurposed waste silk sericin from silk degumming processes to create a silk sericin-silver nanocomposite, which was then applied to cotton. The nanocomposite exhibited substantial antibacterial properties, effectively inhibiting Escherichia coli and Staphylococcus aureus even after 20 wash cycles. The antimicrobial effect is due to silk sericin's inherent bacterial growth inhibition and the bactericidal properties of silver nanoparticles. Additionally, the treated fabrics showed improved mechanical properties, such as tensile strength, enhanced by cross-linkers used during nanocomposite synthesis. The study suggests silk sericin as a sustainable, eco-friendly alternative to conventional synthetic antimicrobials, aligning with circular economy goals by reducing industrial waste and pollution.

5. Wound Healing and Medical Textiles

Silk sericin's **bioactive properties** make it an exceptional component for medical textiles, particularly for applications in **wound care** and **tissue regeneration**. Its ability to stimulate **collagen production**, maintain a **moist healing environment**, and offer **antibacterial protection** enhances its effectiveness in promoting faster healing and reducing the risk of infection (Guptaet al. 2015).

Silk sericin supports wound healing through several mechanisms that promote tissue repair and minimize complications. It stimulates collagen production, which is vital for skin regeneration and repair. Enhanced collagen synthesis accelerates wound closure, improves skin elasticity, and facilitates tissue remodeling for quicker healing (Aramwitet al.2012). Additionally, silk sericin maintains a moist healing environment, which is essential for cellular activity and tissue growth, reducing scabbing and dehydration that can slow the healing process. The antibacterial properties of silk sericin further protect wounds by inhibiting bacterial growth, reducing the risk of infection and ensuring better outcomes for both chronic and acute wounds(Liu et al. 2022).

Applications in Medical Textiles

Silk sericin is used in various medical textiles to enhance patient care. For wound dressings, sericin-coated bandages provide a protective barrier against microbial invasion while promoting faster healing. Moist-retentive dressings, which maintain optimal moisture levels, minimize pain during dressing changes and reduce tissue trauma. Sericin-infused compression garments are beneficial in burn injuries and post-surgical recovery, aiding healing while preventing infections. In surgical textiles, sericin-coated drapes and sutures reduce infection risk and improve biocompatibility, enhancing the safety and efficacy of medical procedures (Gokarneshan, 2023).

Silk sericin's antibacterial action is crucial in wound care, reducing the adhesion of harmful microbes like Staphylococcus aureus and E. coli, thus minimizing infection risks. When combined with silver nanoparticles, silk sericin-treated medical textiles exhibit enhanced antimicrobial properties, offering additional protection, particularly for patients with weakened immune systems. This combination improves patient outcomes by ensuring both effective healing and reduced infection rates (Siritientong et al. 2014 and Borgeset al.2024).

Future Innovations

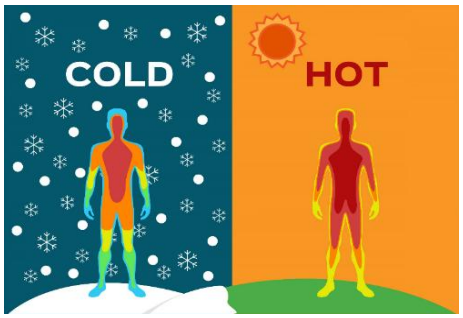
The integration of silk sericin into **advanced wound care solutions** and **smart medical textiles** is an area of active research:

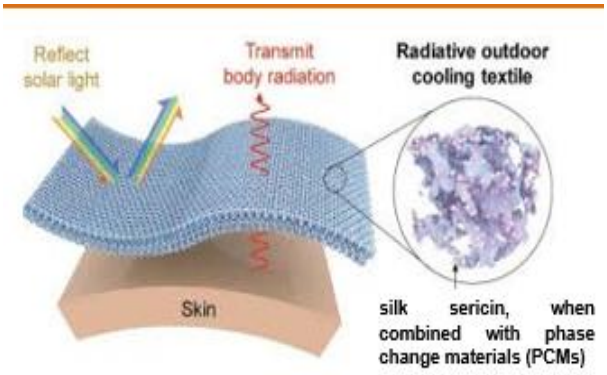
- **Nanofiber Dressings**: Combining silk sericin with nanofiber scaffolds for controlled **drug delivery** and **growth factor release**.
- **3D Bioprinted Textiles**: Developing silk sericin-based bioinks for creating customizable, biodegradable wound dressings.
- **Hybrid Materials**: Merging sericin with other bioactive agents or polymers to improve wound care outcomes.

Gupta et al. (2015) demonstrated the effective application of a durable silk sericin-based finish on UV-modified polyester using glutaraldehyde as a cross-linking agent. Optimal conditions were achieved with 10 g/L of silk sericin and 10 mL/L of glutaraldehyde, cured at 130°C for 2 minutes. The UV excimer treatment increased surface polarity, enabling silk sericin attachment and enhancing the fabric's properties, including moisture regain (2.36%), vertical wicking (64% higher), and antistatic performance. Treated polyester showed significantly improved UV protection (UPF 125 ± 6.37), free radical scavenging, and hydrophilicity, although antimicrobial activity was not observed. These properties make silk sericin-coated fabrics suitable for medical applications, particularly in wound healing, skin moisturizing, and anti-aging products, benefiting patients with skin conditions such as atopic dermatitis and pressure ulcers.

6. Thermo-Regulating Textiles with Silk Sericin

Silk sericin's unique properties make it a valuable component in the creation of **thermo-regulating textiles**, which are designed to maintain a stable body temperature in response to environmental changes. By acting as a **binder** for **phase change materials (PCMs)**, silk sericin enhances the integration and performance of these materials in textiles (Lianget al. 2022).





Phase Change Materials (PCMs) are substances that absorb, store, and release heat as they transition between solid and liquid states. In warmer conditions, PCMs absorb excess body heat, keeping the wearer cool. In contrast, when temperatures drop, PCMs release the stored heat, providing warmth (Pielichowskaet al. 2024). Silk sericin plays an essential role by acting as a binding agent, ensuring that the PCMs remain securely attached to the textile fibers and preventing material loss during use and washing. Additionally, sericin's natural compatibility with textiles helps to distribute the PCMs evenly, maximizing the efficiency of the heat regulation process (Vinuthaet al.2021).

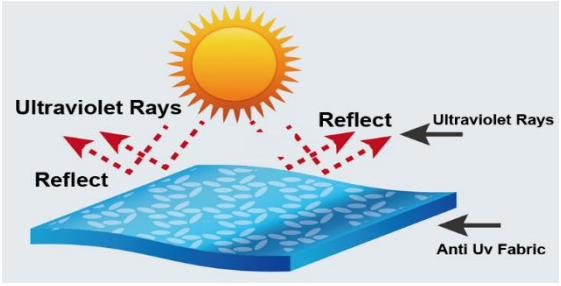
Advantages of Silk Sericin in Thermo-Regulating Textiles

Silk sericin offers several advantages in the development of thermo-regulating textiles. First, its softening properties improve the texture of the fabric, making it more comfortable to wear. The moisture absorption capability of silk sericin also contributes to enhanced comfort by effectively managing sweat, keeping the wearer dry and at ease (Jianget al. 2024). Furthermore, silk sericin is a natural, biodegradable material, aligning with eco-friendly manufacturing practices and contributing to the sustainability of textile products. The strong adhesion it provides ensures that PCMs remain effective over time, even after multiple washes, increasing the durability of thermo-regulating textiles. Additionally, the versatility of these textiles makes them suitable for various weather conditions, offering flexibility for use in diverse applications (Li et al.2021 and Wanget al.2022).

Thermo-regulating textiles, incorporating silk sericin and Phase Change Materials (PCMs), have a wide range of applications. In **sportswear and activewear**, they help maintain optimal body temperature, enhancing performance and comfort. For **outdoor gear**, such as jackets and sleeping bags, these textiles provide thermal comfort in extreme conditions while minimizing the need for bulky layers. **Casual clothing** offers year-round comfort, especially in climates with temperature fluctuations. In **medical applications**, these textiles support patient care, particularly for those with temperature sensitivity or recovering from surgeries (Vinuthaet al.2021).

Liang et.al (2022) explored that a novel humidity-responsive material that combines graphene with silk sericin(GS) to create a flexible, tunable heat-conducting textile. The composite exhibits an unprecedented switching ratio of up to 14 times in thermal conductance in response to humidity variations, driven by the hydration and dehydration of silk sericin. As the material absorbs moisture, the graphene-silk sericin interface changes, modifying the overall thermal conductance. This process is reversible, making the material adaptable to fluctuating environmental conditions. The GS composite can be easily applied to everyday textiles through dyeing, enabling the development of smart, responsive fabrics for applications in clothing and building materials aimed at optimizing comfort and energy efficiency.

7. UV-Protective Textiles with Silk Sericin



Silk sericin's inherent ability to absorb ultraviolet (UV) radiation makes it an excellent choice for creating **UV-protective textiles**. This property arises from its amino acid composition, particularly **tyrosine** and **tryptophan**, which can effectively mitigate the harmful effects of UV exposureand convert it into harmless heat (Zhouet al.2023). When applied to textiles, it forms a protective layer that reduces UV transmittance, enhancing the UV-blocking ability of both natural and synthetic fibers, making them more effective against **UV-A** and **UV-B** rays (Dashet al.2008).

This makes silk sericin-treated fabrics ideal for a range of applications, including outdoor clothing, home furnishings, automotive materials, and medical textiles, offering protection from UV exposure. The advantages of using silk sericin include its natural, biocompatible nature, durability (maintaining UV protection even after multiple washes), moisture retention, and the ability to combine with other functionalities such as antimicrobial properties, making it a versatile and eco-friendly choice for UV-protective textiles (Chitichotpanya and Chitichotpanya,2017 and Chitichotpanyaet al. 2017).

Chitichotpanya et al. (2019) focused on the development of silk sericin(SS)–copper nanoparticle (CuNP) bio-nanocomposites for improving UV protection in silk fabrics. Using response surface methodology (RSM), optimal conditions of 9500 ppm SS and 2380 ppm $CuSO_4$ were identified, achieving enhanced UV protection with a high ultraviolet protection factor (UPF) of 56.8. The SS matrix ensured uniform CuNP distribution and strong adhesion to the silk fibres, contributing to effective UV shielding. Functionalized fabrics demonstrated enhanced UV protection and excellent antibacterial activity against S. aureus and E. coli, with durability sustained over 20 washing cycles. Mechanical properties also improved, with increased tensile strength and reduced elongation. The SS matrix provided uniform CuNP distribution, contributing to enhanced functional properties and strong adhesion, making it effective for durable textile applications.

Chitichotpanya et al. (2017) demonstrated the successful functionalization of silk fabrics using silk sericin-silver nanocomposites (SS-AgNP) to enhance UV protection and antibacterial properties. Untreated silk exhibited poor UV protection with a UPF of 5.14, while SS-AgNP-treated silk achieved UPF values exceeding 40, categorized as "excellent UV protection." This enhancement results from the strong UV-absorption properties of uniformly distributed silver nanoparticles (AgNPs) in the 9–40 nm size range. Additionally, the treatment imparts long-lasting antibacterial effects against E. coli and S. aureus due to sustained silver ion release. The study highlights an eco-friendly, value-added use of silk sericin, a silk industry byproduct, to create multifunctional textiles.

8. Moisture Management and Skin-Care Textiles with Silk Sericin

Silk sericin’s ability to form a thin, protective film on the skin makes it an excellent choice for textiles aimed at **moisture management** and **skin care**. Its natural properties provide a dual benefit of enhancing fabric performance and promoting skin health, making it highly suitable for **cosmetic** and **wellness-oriented textiles** (Kirikawaet al.2000)**.**

Silk sericin plays a key role in moisture management due to its hydrophilic nature, with amino acids that attract and retain moisture, preventing skin dehydration. Its film-forming ability creates a protective barrier, reducing transepidermal water loss and shielding the skin from irritants. Additionally, silk sericin’s composition closely mirrors natural skin proteins,

enhancing skin health. In skin-care textiles, silk sericin is used in products like innerwear, sleepwear, beauty masks, body wraps, and therapeutic clothing. These textiles help to hydrate and rejuvenate the skin, making them ideal for individuals with dry or sensitive skin, promoting healing and providing enhanced comfort and relaxation (Wang and Zhou,2020).

Singh and Mukhopadhyay (2023), explored the synthesis and application of silk sericin/β-cyclodextrin materials for skincare textiles, with potential uses in beauty masks, body wraps, and anti-aging garments. silk sericin, a biopolymer derived from silk, was isolated and characterized for its molecular weight distribution, with SDS-PAGE revealing two silk sericin samples (S1 and S2) having molecular weight ranges of 63-245 kDa and 20-245 kDa, respectively. The silk sericin/β-cyclodextrin complex, synthesized using citric acid, was characterized through SEM, FTIR, and TGA, confirming its formation and thermal stability. When applied to cotton fabric, the treated textiles exhibited excellent antioxidant properties, with scavenging activity ranging from 62-70% after 20 washes, and demonstrated UV protection (UPF 18-26), making them effective at shielding the skin from harmful UV radiation. Additionally, the fabrics showed enhanced moisture transport, wicking properties, and film-forming capabilities, enabling the slow release of α-tocopherol (vitamin E), which helps moisturize and protect the skin. These silk sericin-treated textiles are ideal for use in beauty masks, body wraps, and anti-aging garments, offering long-lasting skincare benefits such as skin hydration, antioxidant protection, and UV shielding, even after multiple washes. The slow release of active compounds makes these textiles particularly valuable for skincare and anti-aging applications, promoting healthier, more youthful skin.

9. Blending with fibres for Biodegradable and Sustainable Textiles

Silk sericin acts as a biocompatible binder in fibre blends, improving moisture absorption, dyeing properties, and softness. Textiles made with silk sericin-fibre blends are biodegradable and sustainable, aligning with the growing trend toward environmentally friendly textile production (Barnthipet al. 2022).

- Silk sericin can be blended with natural and synthetic fibres to produce biodegradable textiles.
- This is of particular interest in the development of eco-friendly fabrics.
- When used in combination with fibres such as cotton, rayon, or synthetic polymers, silk sericin enhances the mechanical and aesthetic properties of textiles while maintaining their biodegradability.
- Additionally, it strengthens the fabric by increasing tear and abrasion resistance, making textiles more durable and suitable for high-wear applications like outdoor gear and workwear. It also imparts flexibility to fibers, contributing to the overall comfort of garments (Zhang, 2002).

Silk sericin-fiber blends are used in a variety of applications. In eco-friendly apparel, they create soft, breathable, and moisture-retaining garments. These blends are also found in home textiles like bedsheets, pillowcases, and curtains, offering comfort and eco-friendly disposal options. In technical textiles, such as medical fabrics and geotextiles, they are valued for their biocompatibility and degradability, reducing environmental impact. Luxury fabrics that combine silk sericin with other fibers like rayon or modal provide a high-end, sustainable option with improved tactile properties (Rangi and Jajpura,2015 and Rajalakshmiet al.2022).

Barnthip et al. (2022) highlighted that the potential of polycaprolactone/cellulose acetate (PCL/CA) nanofibre mats containing silk sericin (SS) and fibroin (SF) for advanced textile applications, particularly in biomedical textiles. The incorporation of SS and SF enhances the functionality of textile fibres by improving mechanical properties, elasticity, and

biocompatibility. These fibres exhibit super hydrophilicity, slow biodegradation, and enhanced cell adhesion, making them suitable for functional textiles used in medical applications such as wound dressings, scaffolds, and wearable health monitors. The study also demonstrates the feasibility of using SS and SF, which are byproducts of the silk industry, to create sustainable and high-performance textiles. The optimized blend (SS:SF ratio of 2.5:2.5) offers an excellent balance of strength, flexibility, and biodegradability, paving the way for textiles that integrate health-monitoring capabilities with environmental sustainability.

Valuation and CAGR of the Silk Sericin Market

- **Global Silk Sericin Market Growth**

The global silk sericin market has seen substantial growth, valued at approximately USD 1.49 billion in 2022, with projections reaching USD 1.65 billion in 2023. The market is expected to continue growing, reaching an estimated USD 4.1 billion by 2032, reflecting a strong compound annual growth rate (CAGR) of 10.65% from 2024 to 2032. Despite differing market analyses, all trends indicate significant market expansion driven by the increasing demand for silk sericin in industries like cosmetics, pharmaceuticals, and textiles due to its versatile and sustainable properties (Market Research Intellect, 2024).

- **Regional Dynamics of the Silk Sericin Market**

Asia Pacific is a dominant player in the global silk sericin market, holding around 23% of global revenue. The region is expected to maintain a strong position, with a projected market size of USD 94.81 million in 2024 and a CAGR of 8.0% from 2024 to 2031. The growth is fueled by the established silk industries in China and India, leading both in silk production and sericin extraction, which supports the availability of raw materials for diverse applications in textiles, cosmetics, and pharmaceuticals (Market Research Future, 2024).

- **Indian Silk Sericin Market**

India’s silk sericin market is poised for steady growth, with a projected CAGR of 6.0% from 2024 to 2031. By 2024, the market is expected to reach USD 412.2 million, driven by increasing demand across textile finishing, cosmetics, and biomedical sectors. India’s silk-producing regions, such as Karnataka, Andhra Pradesh, and West Bengal, are key contributors to this growth, supported by government initiatives aimed at boosting the silk industry and its value-added products (Phagare, 2024).

Key Players of Silk Sericin

The silk sericin Market Report provides a comprehensive analysis of both well-established and emerging players in the market. It offers an extensive list of leading companies, organized by the types of products they manufacture and other market-related factors. The report not only profiles these companies but also includes the year of entry into the market for each player, offering valuable insights for market research and analysis conducted by the report's analysts.

1. Seide Group (Germany):

Seide Group is a leader in the silk industry, recognized for its high-quality silk sericin products. The company has diversified its operations into various applications, including textiles and cosmetics, leveraging sericin's biocompatibility and sustainability.

2. Thai Silk Sericin Co. Ltd. (Thailand)

Located in Thailand, Thai Silk Sericin Co. Ltd. is known for producing silk sericin for use in personal care products, cosmetics, and textiles. The company focuses on sustainable production methods, emphasizing sericin's natural properties for skin health.

3. Jilin Province Silkworm Cocoon Development Co. Ltd. (China)

Based in Jilin Province, China, this company is involved in sericin extraction from silkworms. Their products are utilized in the textile industry, as well as in high-end cosmetics and biomedical applications due to the functional properties of sericin.

4. Anhui Qiangwang Flavouring Food Co. Ltd. (China)

Operating from Anhui Province, China, Anhui Qiangwang is involved in the extraction of silk proteins, including sericin, which is used in food additives, supplements, and cosmetic products.

5. Tianjin Shengao Cosmetics Co. Ltd. (China)

Tianjin Shengao focuses on utilizing silk sericin in the formulation of cosmetics and skincare products. They have developed a range of products targeting skin hydration, anti-aging, and nourishment.

6. CFS Biologicals (China)

CFS Biologicals is a prominent player in the Chinese market specializing in biological extracts, including silk sericin. Their products find applications in textiles, cosmetics, and pharmaceuticals.

7. Xinxiang City Ruifeng Bio-Technology Co. Ltd. (China)

Xinxiang Ruifeng is involved in the production and application of silk sericin for various industries, particularly in the fields of healthcare, cosmetics, and textiles. They are known for their sustainable extraction processes.

8. Fuji Spinning Co. Ltd. (Japan)

A leading manufacturer in Japan, Fuji Spinning specializes in the production of high-quality silk fibers and sericin-based products. They are actively exploring innovative applications of sericin in textiles and biomedical products.

9. Sasmira Silks and Fabrics (P) Ltd. (India)

This Indian company focuses on producing silk fabrics and sericin-based products for the textile industry. They are known for their sustainable practices and commitment to producing high-quality silk sericin for diverse applications.

10. Hangzhou Ruijiang Chemical Co. Ltd. (China)

Located in Hangzhou, China, Ruijiang Chemical produces a variety of silk-based chemicals, including silk sericin, which are utilized in cosmetics, textiles, and healthcare.

11. Nakaumra Co. Ltd. (Japan)

A well-known player in Japan, Nakaumra Co. Ltd. specializes in the extraction of silk sericin and its incorporation into various high-end textiles and skincare products.

12. Central Silk Board (CSB), Bengaluru (India)

The Central Silk Board is an Indian government organization that plays a pivotal role in the promotion of silk production in India. They are involved in the research and development of sericin extraction techniques and its applications in textiles, cosmetics, and biomedical fields.

13. Karnataka Silk Industries Corporation (KSIC), Mysore (India)

Located in Mysore, India, KSIC is a state-run organization involved in silk production and sericin extraction. They are well-known for producing premium silk products and exploring innovative uses of silk sericin in textiles and medical textiles.

14. Vanyleela Silks Pvt. Ltd. (Bengaluru, India)

Vanyleela Silks is a prominent manufacturer and processor of silk products in Bengaluru, India. The company is known for its silk sericin extraction and production, which is used in various industries such as textiles, cosmetics, and pharmaceuticals. They focus on sustainable practices and high-quality silk-based products.

15. Bangalore Silk Manufacturers (Karnataka, India)

Located in Karnataka, Bangalore Silk Manufacturers specializes in silk production and value-added products, including silk sericin. Their sericin extraction is utilized in the textile and cosmetic industries for its functional properties like moisturizing and anti-aging effects.

16. Sree Arumuga Silk Mills Pvt. Ltd. (Tamil Nadu, India)

Based in Tamil Nadu, Sree Arumuga Silk Mills Pvt. Ltd. is a well-established player in the silk industry. The company contributes to the extraction and production of silk sericin, which is used for textile applications and cosmetic formulations, ensuring high product quality.

17. Sambandam Spinning Mills Ltd. (Tamil Nadu, India)

Sambandam Spinning Mills Ltd. is one of the key players in Tamil Nadu, dealing with the production of silk yarn and silk sericin. Their expertise lies in the extraction and value addition of sericin, enhancing the functionality of textiles and personal care products.

18. The Indian Silk Export Promotion Council (ISEPC)

Although not directly involved in the production of silk sericin, ISEPC plays a vital role in supporting silk-related businesses in India. They promote Indian silk products, including sericin, and provide resources to businesses involved in the silk industry. ISEPC supports market expansion and export opportunities for Indian silk manufacturers.

19. Mysore Silk Factory (Karnataka, India)

Mysore Silk Factory is a major producer of premium silk in Karnataka. Known for its rich heritage in silk manufacturing, the factory also contributes to the sericin extraction process, making it available for use in textiles and medical textiles, benefiting from the sericin's biocompatible and functional properties.

20. Rajmahal Silks (Tamil Nadu, India)

Rajmahal Silks is involved in both silk production and the extraction of silk sericin, which is used in various applications like high-end textiles, cosmetics, and pharmaceuticals. They are recognized for their quality and innovative use of sericin in fabric treatments and skincare formulations.(Phagare, 2024).

Conclusion

Silk sericin, a byproduct of silk processing, has emerged as a multifunctional, sustainable material with transformative potential across various industries. Its natural properties, including biocompatibility, biodegradability, and antimicrobial efficacy, position it as a key player in advancing eco-friendly and high-performance solutions. This versatile protein demonstrates exceptional value in textiles, cosmetics, healthcare, and environmental applications, offering a sustainable alternative to synthetic and chemically intensive materials.

In the textile sector, silk sericin has proven to enhance fabric properties such as durability, softness, and dyeability while contributing to moisture retention, thermal regulation, and UV protection. It enables the development of advanced textiles, such as antimicrobial fabrics for medical use, moisture-wicking sportswear, thermo-regulating outdoor gear, and odor-resistant intimate apparel. Its ability to securely bind with fibers ensures the durability and longevity of treated fabrics, even after multiple washes. Furthermore, silk sericin plays a critical role in sustainable dyeing processes by increasing dye uptake, reducing dye runoff, and eliminating the need for harmful mordants, significantly reducing environmental pollution.

In healthcare, silk sericin's wound-healing properties, driven by its ability to stimulate collagen production and maintain a moist healing environment, make it an invaluable component in wound dressings, compression garments, and surgical textiles. Its antibacterial activity further enhances its suitability for medical applications, offering protection against infections and promoting faster recovery. The integration of sericin with nanoparticles has amplified its antimicrobial capabilities, making it a powerful material for healthcare and hygiene products, including face masks, diapers, and sanitary napkins.Silk sericin also contributes to technological advancements, particularly in wearable technology. As an eco-friendly adhesive for wearable strain sensors, it provides a stable, biocompatible base for conductive materials, ensuring reliable performance and comfort. Its natural flexibility and skin-friendly properties make it ideal for applications in medical monitoring, sports performance tracking, and fitness wear.

Beyond these industries, silk sericin supports broader environmental goals. Its biodegradable nature aligns with the principles of circular economy practices, offering a sustainable solution to reducing silk waste while minimizing reliance on synthetic polymers. Its applications in air filtration, antimicrobial coatings, and sustainable manufacturing further highlight its potential to address pressing environmental challenges.

In conclusion, silk sericin represents a paradigm shift toward sustainable, multifunctional materials that enhance product performance while addressing environmental and societal needs. Its integration across various industries underscores its potential to drive innovation, reduce waste, and create eco-conscious solutions, making it a cornerstone of sustainable development in material science. As research and technological advancements continue, silk sericin is poised to play a pivotal role in shaping a greener, more resource-efficient future for generations to come.

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DETERMINATION OF SOIL LOSS DUE TO HARVESTING OF TWO YAM CULTIVARS IN THREE SELECTED SOIL SERIES

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Abstract

Variation of soils in time and space can have marked effect root crop performance and consequently on soil loss due to crop harvesting. Therefore, a pot experiment was conducted to evaluate soil loss due to yam harvesting as influenced by three soil series (Gambari, Itagunmodi and Majeroku) and two yam cultivars (Asiedu and Kpmayo. Treatments were arranged as a split plot in a completely randomized design with four replications. Data were recorded on number of leaves, length of vine at 1 month interval to 6 months and soil loss was estimated per pot after 6 months of planting. Data were subjected to analysis of variance and means were separated using least significant difference at 5% probability level. Soil series significantly influenced the growth of yam cultivars. Itagunmodi series produced the longest vines, at 4 months after planting (MAP) (220 cm) whereas the shortest vines were recorded from plants grown in Gambari series (36 cm). Cultivar Kpamyo produced the highest yam yield parameters. The highest quantity of soil loss (236 g) was recorded in Itagunmodi series while the lowest soil loss occurred in Majeroku series (38 g). Cultivar Kpamyo resulted in the highest quantity of soil loss (236 g) while cultivar Asiedu resulted in the lowest quantity of soil loss. In conclusion, yam growth and soil loss varied with soil series.

Keywords: Soil series, Yam cultivar, Growth, Soil loss, Nutrient loss

EFFECT OF THE ADDITION OF BORON-CONTAINING COMPOUNDS ON PROSTHETIC DENTAL MATERIALS

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ABSTRACT

Introduction and Purpose: In recent years, nanomaterials have been widely used in dentistry. Boron element is a mineral with metal and nonmetal properties, the highest reserves in the world are in our country. However; there are few studies in which boron compounds are incorporated into prosthetic dental materials for reinforcement. Therefore, the objective of the present study was to draw attention to the contribution of improving the properties and preference of boron-containing materials in prosthodontics to the country's economy.

Discussion and Conclusion: Boron derivatives such as borax, boric acid, and colemanite are widely used as inorganic binders in the ceramic industry. It has been reported that boron-derived compounds can increase the mechanical properties of some dental materials and show important antimicrobial properties against various bacteria, yeasts, and fungi. Boron compounds have reduced the viscosity and surface tension of ceramic materials, which resist cracking and discoloration of the surface. Boron-containing coatings have also improved the mechanical and antimicrobial properties of translucent zirconia. Boron nitride nanotubes have been proposed as a suitable material for strengthening dental ceramic materials due to their white color and biocompatibility. Adding borax and colemanite has been reported to increase the mechanical properties of polymethyl methacrylate denture base material. Pathogenic microorganisms can not adhere to the surface of prostheses made with boron addition. Since boron mineral is not a toxic substance, it is not irritating when in contact with the oral tissue and gingival mucosa. Further studies are required to develop and use boron-containing prosthetic materials that are biocompatible and have increased mechanical and physical properties.

Key Words: Boron Compounds, Dental Materials, Prostheses

INTRODUCTION

Nowadays, many nanomaterials, especially metal, metal oxide and organic nanoparticles, are included in dental polymers to improve polymer properties due to their nanosize, large contact surfaces, smooth bonding and mixing with the resin matrix of the polymer (Gad et al., 2020).

Nanocomposite structures combine the best properties of each component.The properties of nanocomposite materials depend not only on the properties of the substances in the composition but also on their morphology and interfacial properties. (Camargo et al., 2009). Nanoparticles improve material properties by increasing the interfacial interaction. (Camargo et al., 2009).

The development of polymer nanocomposites with superior properties depends on the good interfacial interaction between the nanoparticle and the polymer. The selection of nanoparticles compatible with the matrix and the use of techniques that will provide homogeneous distribution within the matrix (Hussain, 2018). With an advanced production process and controlled nano-

sized second-phase dispersion, mechanical properties such as thermal stability, adhesion resistance, flexural strength, toughness, and hardness of polymer structures can be improved (Okpala, 2013).

Ceramic restorations are frequently preferred in fixed prosthetic applications due to their aesthetic superiority and superior hygienic properties. However; ceramics have a fragile structure due to their low tensile strength. Their resistance to shear and tensile forces that occur during chewing may decrease over time. Therefore, the ceramic structure needs to be reinforced (Lee et a, 2020).

Polymethylmethacrylate (PMMA) acrylic resins have been used in the production of full and partial dentures for a long time. Although aesthetics, low water absorption and surface smoothness are advantages of acrylic resins as denture base materials, their low mechanical properties are their main disadvantages. Due to insufficient mechanical properties, patients using removable prostheses often complain of prosthesis breakage (Craig& Powers, 2002; Ozdemir et al., 2021).

Many materials and methods have been developed to overcome these problems and improve the restoration. The denture base has been tried to be strengthened by using aluminum and steel plates, stainless steel wire and mesh, adding nanometallic powder and particles to acrylic resin, using various amounts and forms of fiber polyethylene, glass, carbon or graphite, adding cross-linked binders and copolymers to the resin (Ozdemir et al., 2021).

It has been reported that boron derivative compounds can increase the mechanical properties of some prosthetic materials and can exhibit significant antimicrobial properties against various bacteria, yeasts, and fungi (Alqahtani, 2020; Ozdemir et .al,2021; Kıvanç et al., 2018).

The aim of this study is to draw attention to the contribution of improving the mechanical and biological properties of prosthetic materials to which boron compounds are added and preferring them in prosthesis production to the country's economy.

DISCUSSION

The boron element, shown with the symbol B in the periodic table, is a natural mineral with atomic number 5, atomic weight of 10.81, density of 2.84 gr/cm3, melting point of 2300°C and boiling point of 2550°C, showing both metal and non-metal properties, semi-metal, semi-conductor properties. Crystallized boron is similar to diamond in terms of appearance and optical properties and is almost as hard as diamond. It can be easily cleaned thanks to its water repellency. This element, which is almost never found in pure nature, is mostly obtained from its compounds (borate minerals). There are approximately 250 types of boron minerals in nature. The largest boron reserves are found in our country (73.8%) (Nanobor, 2019; Yakıncı& Kök,2016; Yünlü, 2016).

Boron ores (concentrated boron) are subjected to physical processes and enriched, then refined and converted into different boron chemicals. In general, all of these products are called "Boron" (Aslan, 2021).

Boron is the element that is most similar to carbon and silicon and has a very high affinity for oxygen. It is the hardest element after the diamond. It does not lose electrons easily and, therefore, does not become an ion. Therefore, boron makes covalent bonds and is similar to non-metal compounds such as silica.There are many different boron-oxygen compounds due to its tendency to bond with oxygen. The general name of boron-oxygen compounds is borate (Nanobor, 2019).

Boron minerals are usually found in compounds with metals such as Mg, Na, and Ca (Yakıncı& Kök,2016). Boron minerals of Na origin are called "tincal" (borax), those of Ca origin are called "colemanite" and those of Na-Ca origin are called "ulexite" (Aslan, 2021). Tincal, colemanite

and ulexite, which contain boron oxide (B_2O_3) in different proportions in their structures, are important boron minerals (Yakıncı& Kök,2016).

The most widely used boron compound is boric acid (H_3BO_3). Boric acid is a white solid. Its molecular weight is 61.83 g/mol, density is 2.6 g/cm3, melting point is 300-400 °C, boiling point is 1860 °C. It has been reported that the addition of boric acid to dental ceramic structures is effective in the formation of a glassy phase during sintering and in the decrease of the viscosity of the glassy phase. In addition, boron oxides reduce the surface tension and thermal expansion coefficient of the ceramic paste. They increase the mechanical strength and scratch resistance of the ceramic structure, and provide resistance to chemicals.

When ceramic restorations are prepared, they are subjected to firing in the laboratory. During the cooling of the fired ceramic material to room temperature, micro cracks form on the surface of the porcelain due to the dimensional change and volumetric shrinkage in the material. These micro cracks spread even deeper.

In addition, the leveling process performed during the final shape of the restoration negatively affects the mechanical properties of the ceramic material by advancing the micro cracks. It has been reported that boron phosphate added to the ceramic structure regulates the dimensional change behaviors, provides resistance to thermal shocks, and improves electrical and mechanical properties, in addition to the effect of reducing the furnace temperature appropriately.

Alumina is a very commonly used ceramic type as a structural ceramic, but its fragility limits its use in practice. Boron nitride nanotubes (BNNP) have been suggested as a suitable material to reinforce dental ceramic materials due to their white color and biocompatibility, and it has been stated that their addition to alumina ceramics increases the mechanical properties of the structure (Wang et al., 2011; Lee et al., 2020).

Hexagonal boron nitride has a graphite-type structure known as white graphite. It is prepared by the following methods:

- 1. High temperature and high pressure synthesis method
- 2. Chemical vapor synthesis method
- 3. Hydrothermal synthesis method
- 4. Benzene thermal synthesis method.

Traditionally, hBN has been prepared by the classical high-temperature synthesis routes and the direct combination of boron with nitrogen (Shi et al, 2008).

Studies on BN-reinforced oxide-based ceramic composite materials have reported that BN reacts with oxygen in the matrix materials and that the homogeneous distribution of BN improves the flexural strength, fracture toughness, and wear resistance (Lee et al., 2020).

It has been found that the addition of of 1–1.5 vol % BNNPs increases the mechanical strength and fracture toughness of translucent zirconium without any cytotoxic effect and improves its antimicrobial properties (Lee et al., 2020; Sabino et al.2024).

When boron minerals (colemanite, ulexite-tincal) and their products (borax, boric acid) are added to the ceramic glazes (glaze) in the final stage of ceramic restoration, they both improve the glassy appearance of the glaze with their melting and binding properties and create resistance against scratches, cracks, spalling and color changes that may occur on the surface by reducing viscosity and surface tension (Sezzi, 2001).

Zhang et al. (2012) added 1-20% silanized aluminum borate to PMMA powder and crushed it by ball milling at 180 rpm for 10 minutes, then dry-milled the mixture powder by a rotating ball mill for 120 minutes and mixed it with MMA monomer at a powder-liquid ratio of 2:1. They examined the mechanical and thermal properties of the composite materials obtained after these

processes and reported that the addition of 5% silanized aluminum borate increased the flexural strength, surface hardness and thermal stability of PMMA and strengthened the PMMA prosthesis (Zhang et al., 2012).

Alqahtani (2020a) added hexagonal BN nanoparticles at concentrations of 0.5, 1.0, 3.0 and 5.0% by weight to self-curing PMMA-based dental materials and examined the structural and mechanical properties of the samples prepared by manual and ultrasonic mixing methods. It was reported that, regardless of the mixing method used, boron nitride nanoparticles added to acrylic resin increased the hardness and flexibility values of the material, and the addition of boron nitride nanopowder with ultrasonic mixing method increased the hardness of the material to 300% and the flexibility values to 550% (Alqahtani, 2020a).

In another study (2020b), Alqahtani prepared samples from self-hardening acrylic PMMA material using manual and ultrasonic mixing methods to which hexagonal BNNP with 99.98% purity and concentrations of 0.5, 1.0, 3.0 and 5.0 wt% and 20 nm and 800 nm stabilized zirconia (8Y ZrO_2) nanoparticles with 99.95% purity were added at concentrations of 1, 2, 3, 5, 7 and 10% and investigated the mechanical properties of the samples such as hardness, flexural strength and elastic modulus. It was observed that there was a significant increase in the values with the increase in nanoparticle concentration. Ultrasonic mixing of PMMA with 5 wt% BN increased the flexural strength and elastic modulus (Young's modulus) by approximately 550% and 240%, respectively. He stated that a similar zirconia concentration increased the hardness value to approximately 400% and that PMMA prepared with the combination of boron nitride and zirconia nanopowders could lead to nanocomposites with outstanding mechanical performance. (Alqahtani, 2020b).

Ozdemir et al. (2021) investigated the effects of different boron types (borax, boric acid and colemanite) at 1, 2 and 3% on the mechanical properties of PMMA used as denture base material, and reported that the addition of borax increased the surface hardness of the base material, the addition of 1% colemanite increased the impact resistance of PMMA used as denture base material; the addition of 3% borax increased the bending strength of PMMA more than 1% colemanite, therefore, when high-strength acrylic resins are needed, boron-reinforced resins may be a preferred material (Ozdemir et al., 2021).

In scientific studies conducted with boron compounds, it has been found that boron compounds exhibit remarkable antimicrobial properties against a wide variety of bacteria, yeasts and fungi (Dembitsky et al., 2011; Demirci et al., 2015; Kıvanç et al., 2018). It has been reported that boron compounds have bactericidal activity, antibiofilm properties and antifungal activity against gram-positive and gram-negative bacteria (Aral et al., 2020; Dembitsky et al., 2011; Kıvanç et al., 2018; Sayin et al., 2016).

It has been observed that pathogenic microorganisms do not adhere to the surface of prostheses made with boron addition; since boron mineral is not a toxic substance, it does not irritate the oral tissue and gingival mucosa when it comes into contact with them.

In the study conducted with boron nitride nanoplates and silver nanoparticles (h-BNNs/AgNPs) containing 0.2, 0.6, 1.0, 1.4, 1.8% by weight, it was reported that 1% by weight boron nitride nanoplates and silver nanoparticles content increased the compression and bending strength of PMMA, and when the nanocomposite concentration in PMMA resin was 1.4% by weight, the antibacterial rate increased significantly (92%) (Li et al.2022).

CONCLUSION

The results obtained from the limited number of studies on the improvement of mechanical and biological properties of prosthetic materials by the addition of boron compounds have been quite encouraging for future research.

Boron-containing dental prosthesis materials have the potential to become a new generation biomaterial class. More studies are needed to develop and use biocompatible and boron-containing prosthetic materials with increased mechanical and physical properties.

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ELECTROMAGNETIC MODAL SHAKER DESIGN AND FINITE ELEMENT ANALYSIS

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ABSTRACT

Electromagnetic modal shaker is a device used for various vibration tests. Electromagnetic shakers have an important role in vibration and shock tests. In this study, a small-scale modal shaker design was realized and two-dimensional electromagnetic analyses were performed. Here, the effects of the gap and other features between the coil and the core that affect the electromagnetic field on the design were investigated parametrically. The changes in these parameters were analysed using the Finite Element Method Magnetic (FEMM) program. Comparisons were made using the material library in the FEMM program. For this purpose, many analyses were performed for the distance between the coil and the core, the applied electric current, and different copper wire diameters, and the results were compared. These design comparisons provided us with results about what will provide the force that can be obtained and what will change the magnetic field. Steel material, copper coil types with 0.5, 1, 1.6, 2 mm wire diameter, pure copper material and magnets were used for the core in the design. The parameters that these materials affect according to the distances between them or material types were analysed and supported with images.

Keywords: Electromagnetic modal shaker, magnetic field, vibration

ÖZET

Elektromanyetik modal sarsıcı, çeşitli titreşim testleri için kullanılan bir cihazdır. Elektromanyetik sarsıcıların titreşim ve şok testlerinde önemli bir rolü vardır. Bu çalışmada, küçük ölçekli bir modal sarsıcı tasarımı gerçekleştirilmiş ve iki boyutlu olarak elektromanyetik analizleri gerçekleştirilmiştir. Burada, elektromanyetik alanı etkileyen bobbin ve nüve arasındaki boşluk ve diğer özelliklerin tasarım üzerindeki etkileri parametrik olarak incelenmiştir. Bu parametrelerin değişimi Sonlu Elemanlar Yöntemi Manyetik (FEMM) programı kullanılarak analiz edilmiştir. Karşılaştırmalar FEMM programındaki malzeme kütüphanesi kullanılarak yapılmıştır. Bu amaçla bobin ile çekirdek arasındaki mesafe, uygulanan elektrik akımı, farklı bakır tel çapları için çok sayıda analiz gerçekleştirilmiş sonuçlar karşılaştırılmıştır. Bu tasarım karşılaştırmaları bize hangi elde edilebilinecek kuvvet ve manyetik alanine değişimini nelerin sağlayacağı hakkında sonuçlar sağlamıştır. Tasarımda nüve için çelik malzeme, 0,5, 1, 1,6, 2mm tel çapında bakır bobbin tipleri, saf bakır malzeme ve mıknatıslar kullanılmıştır. Bu malzemelerin aralarındaki mesafelere veya malzeme türlerine göre etkilediği parametreler analiz edilmiş ve görsellerle desteklenmiştir.

Keywords: Elektromanyetik modal sarsıcı, manyetik alan, titreşim

GİRİŞ

Literatürde, elektromanyetik modal sarsıcı kullanımı ve kontrol ünitesi için yazılar bulunsa da kontrol yüzeyinin içerisindeki parametre değişimlerinin belli farklılıklar ile bulunan sonuçlarının kıyaslamasına sık rastlanmamaktadır. Bu amaçtaki bir çalışmanın literatüre olumlu yönde etkisi olması beklenmektedir. Beraberinde bulunan sonuçların inceleyen kişiler için de fayda sağlayacağı düşünülmektedir. Elektromanyetik modal sarsıcının ne olduğunu ve hangi şartlarda çalıştırıldığı ve ne koşullarda çalıştığı literatürden çekilmiş olup yazının belli yerlerinde referans olarak gösterilmiştir.

Mühendislikte geçmişten günümüze belli başlı tasarım üretimleri gerçekleştirilmiştir. Bu tasarımların her birinin belli koşullarda titreştiği gözlemlenmiştir. Bu titreşim malzemelere zarar vermekte hatta kırılmalarına yol açabilmektedir [1,2]. Mekanik yapıların belli bir duruma karşı gösterdikleri tepki zamana bağlı olarak bozulmalar yaratır [2]. Bu gibi sorunların önüne geçme amacıyla sarsıcılar üretilmiştir. Sarsıcılar malzemelerin doğal frekansını tespit etmeye yarayacak olup o frekansta titrediğinde rezonansa gireceğini bize gösterir. Rezonans ise parçada olumsuzluklara yol açacağından istenmeyen bir durumdur. Elektromıknatısın doğrudan sensör ve/veya aktüatör olarak nerelerde görev yaptığı derinlemesine [3]'de inceleniyor. Sarsıcıların geçmişten günümüze gelişiminde son yıllarda elektromanyetik modal sarsıcı kullanılmaktadır. Z. Hadas and F. Kšica, yaptıkları çalışmalarda elektromanyetik modal sarsıcı tasarımı yapmışlardır [4]. Elektromanyetik modal sarsıcı prensibi, esnek bir yapının, tam olarak demir plakanın elektromanyetik uyarılmasına dayanmaktadır [4,5]. Özellikle kablosuz bir şekilde güç üretme kabiliyeti olduğundan, son yıllarda büyük ilgi duyulmaktadır [6]. Modal sarsıcı; kontrol yüzeyi dış iskelet ve titreşimi iletecek parçalardan oluşmaktadır. Bu titreşim elektromanyetik kuvvet ile sürtünmesiz bir şekilde sağlanabilir [7]. Bu yazı; kontrol yüzeyi tasarımına ve hangi koşullarda en verimli sonuçlara ulaşılabilir, analizlerle ve kıyaslamalarla inceler.

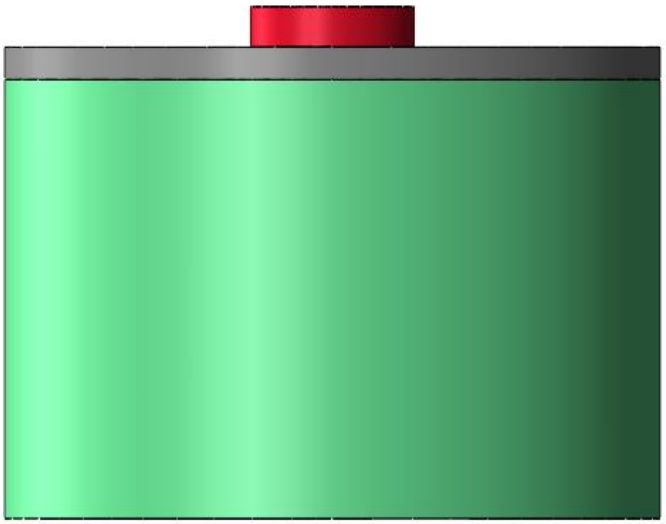
Tasarımda Alüminyum 1100, saf demir plaka, saf bakır plaka, bakır bobin, bobin sarılacak 0.5,1,1.6,2mm kalınlığında bakır teller kullanılmıştır. Kıyaslamalar; bobin ile bakır plaka arasındaki mesafe, bobin sarılacak tellerin kalınlığı, bobinin uzunluğu ve uygulanan akım değiştirilecektir. Test öncesi belirlenen parametreler eşliğinde her bir parametre kıyas adına denenecek olup sonuçları detaylandırılacaktır. Akım, bobin sarılacak olan bakır telden geçirilecek olup belli mesafedeki kontrol yüzeyini titreştirmesi hedeflenecektir. Manyetik alan büyüklükleri ve manyetik alan kuvvetleri sayesinde titreşen kontrol yüzeyinin tepkileri kıyaslanacak olup en verimli kontrol yüzeyi ve bobin tasarımı belirlenecektir.

VERİ SETİ VE YÖNTEM

Bahsedilen analizler Finite Element Method Magnetics (FEMM) programı kullanılarak hazırlanmıştır. Yapılan tasarım neticesinde modal sarsıcının geometrik kısıtlar ve malzemeleri belirlenmiştir. Kıyaslamalar FEMM programının kütüphanesinden malzemeler seçilerek tasarım analize hazır hale getirilmiştir. FEMM programında noktalar belirlenerek çizgiler yardımıyla tasarım birleştirilir. Ardından birleştirilen tasarıma 'materials' kısmından malzemeler eklenir. Eklenen malzemelerin atamaları yapılır. Bu aşamadan sonra işlemin sonlanacağı sınırlar belirlenerek akımın yolunun biteceği konumlar hazırlanır. Geomtrik çizim bittikten sonra sarsıcıyı çevreleyen birer sınır çizgileri belirlenir. Boundry sekmesinden A=0 şeklinde hazırlanan sınır koşulu bu sınır çizgilerine atanır. Bu sayede akım verilerek üretilen manyetik alan elbet bir noktada sonlanır. Bu noktalar manyetik alan etkisinin sonlanacağı yeri ifade eder. Ardından Circuits kısmından bobin sarılan bakır tele verilecek olan akım ve bu akımın kaç çevrim doğrultusunda verileceği belirlenir. Bu tasarımda devre koşulları 2,4,6,8,10 amper, 80 çevrim olacak şekilde hazırlanmıştır. Bu koşullar bobine atanır. Tasarım tamamlanmış olup MESH atılabilir duruma gelmiştir. Bölge bölge manyetik alan büyüklüğünü görebilmek için mesh atmak önemlidir. Ardından analiz alınır.

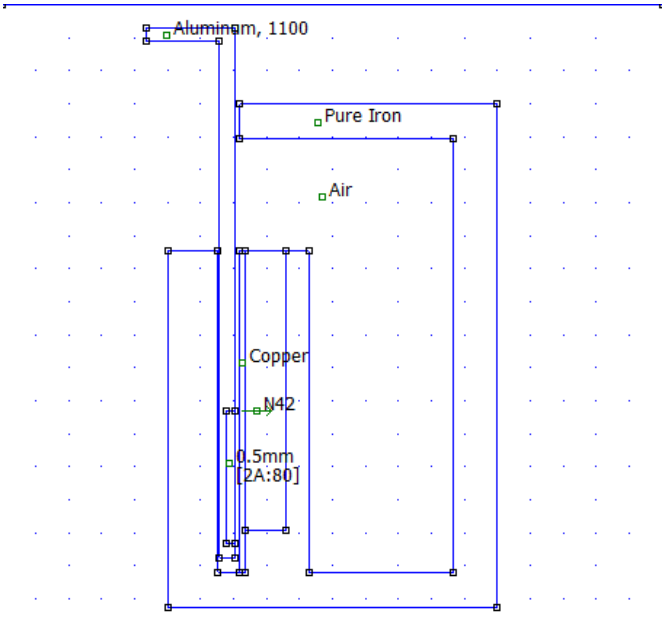
TASARIM VE ANALİZLER

Şekil 1'de tasarımı yapılan elektromanyetik modal sarsıcının ait bir görsel verilmiştir. Verilen akım doğrultusunda orta bölümdeki kırmızı parça eksenel olarak hareket edecek şekilde tasarlanmıştır. Bu hareketin farklı frekanslarda uygulanabiliyor olması cihaz üzerine bağlanılacak numunenin doğal frekanslarını bulmamızı sağlayacaktır.



Şekil.1 Elektromanyetik Modal Sarsıcı

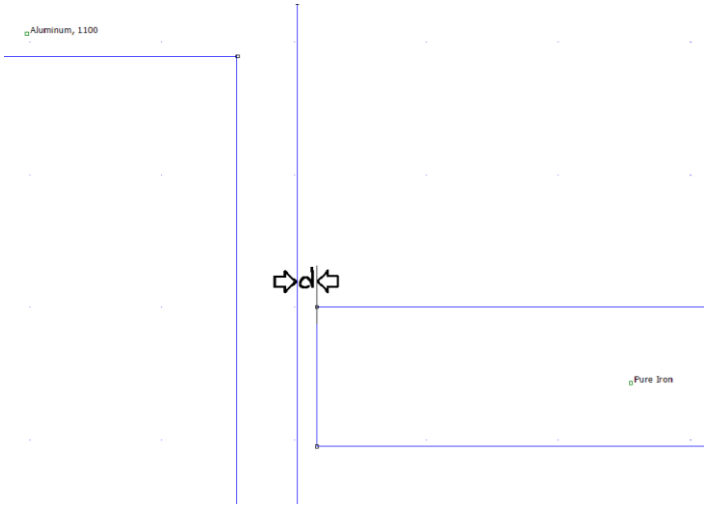
Elektromanyetik sonlu elamanlar analizleri FEMM programı ile gerçekleştirilmiştir.



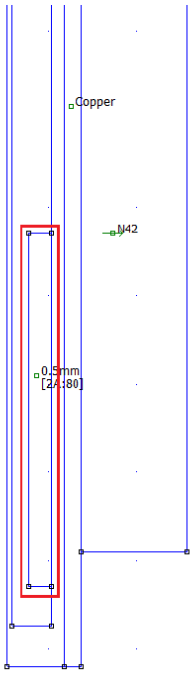
Şekil.2 Elektromanyetik modal sarsıcı FEMM modelinin hazırlanması

Tasarımın iki boyutlu çizimi aşağıdaki Şekil 2 de verilmiştir. Alüminyum plaka ile bakır plaka arasındaki mesafe değiştirilerek kıyaslanacaktır. Şekil 3'te demir plakayla arasındaki mesafe değiştirilmiş gibi gözükse de alüminyum plaka aşağı doğru uzandığından asıl değişimin yapılma sebebi bakır plaka ile arasını açmaktır. En kolay anlaşılması için bu şekilde gösterim tercih edilmiştir. Öte yandan şekil 4'te kırmızıyla gösterilen bobin boyu değiştirilecek olup bobin sarılacak tellerin kalınlığı değiştirilecektir. Her biri için ayrı ayrı 2, 4, 6, 8, 10 amper uygulanacak olup sonuçlar incelenecektir.

Şekil 2'de de görüldüğü üzere 0.5mm tel ile sarılmış olan bobine 2 amper 80 çevrim şeklinde verilmiştir. Bu devre değeri plakayı titretecek manyetik kuvveti oluşturacak olup aradığımız istatistiği bize sağlamaktadır.



Şekil.3 Değiştirilecek olan mesafe parametre görüntüsü



Şekil.4 Bobin uzunluğunu ifade eden görsel

Tablo 1: 0.5mm Aralık İçin

	40mm Bobin için kuvvet (N)					60mm Bobin için kuvvet (N)					80mm Bobin için Kuvvet (N)				
Tel kalınlığı (mm)	2A	4A	6A	8A	10A	2A	4A	6A	8A	10A	2A	4A	6A	8A	10A
0.5	7,28875	7,38966	7,49711	7,61077	7,73033	8,33626	8,4141	8,49983	8,59314	8,69373	7,50431	7,57228	7,64895	7,73404	7,82726
1	7,28875	7,38966	7,49711	7,61077	7,73033	8,33626	8,4141	8,49983	8,59314	8,69373	7,50431	7,57228	7,64895	7,73404	7,82726
1.6	7,28875	7,38966	7,49711	7,61077	7,73033	8,33626	8,4141	8,49983	8,59314	8,69373	7,50431	7,57228	7,64895	7,73404	7,82726
2	7,28875	7,38966	7,49711	7,61077	7,73033	8,33626	8,4141	8,49983	8,59314	8,69373	7,50431	7,57228	7,64895	7,73404	7,82726

Tablo 2: 1mm Aralık İçin

	40mm Bobin için kuvvet (N)					60mm Bobin için kuvvet (N)					80mm Bobin için Kuvvet (N)				
Tel kalınlığı (mm)	2A	4A	6A	8A	10A	2A	4A	6A	8A	10A	2A	4A	6A	8A	10A
0.5	7,07644	7,1762	7,28238	7,3946	7,51257	8,7436	8,81875	8,90178	8,9924	9,09027	7,44585	7,51025	7,58338	7,66496	7,75473
1	7,07644	7,1762	7,28238	7,3946	7,51257	8,7436	8,81875	8,90178	8,9924	9,09027	7,44585	7,51025	7,58338	7,66496	7,75473
1.6	7,07644	7,1762	7,28238	7,3946	7,51257	8,7436	8,81875	8,90178	8,9924	9,09027	7,44585	7,51025	7,58338	7,66496	7,75473
2	7,07644	7,1762	7,28238	7,3946	7,51257	8,7436	8,81875	8,90178	8,9924	9,09027	7,44585	7,51025	7,58338	7,66496	7,75473

Tablo 3: 1.5mm Aralık İçin

	40mm Bobin için kuvvet (N)					60mm Bobin için kuvvet (N)					80mm Bobin için Kuvvet (N)				
Tel kalınlığı (mm)	2A	4A	6A	8A	10A	2A	4A	6A	8A	10A	2A	4A	6A	8A	10A
0.5	7,32738	7,4232	7,52536	7,63348	7,74727	7,10897	7,18351	7,26585	7,35566	7,45264	7,78782	7,84805	7,9169	7,99411	8,0794
1	7,32738	7,4232	7,52536	7,63348	7,74727	7,10897	7,18351	7,26585	7,35566	7,45264	7,78782	7,84805	7,9169	7,99411	8,0794
1.6	7,32738	7,4232	7,52536	7,63348	7,74727	7,10897	7,18351	7,26585	7,35566	7,45264	7,78782	7,84805	7,9169	7,99411	8,0794
2	7,32738	7,4232	7,52536	7,63348	7,74727	7,10897	7,18351	7,26585	7,35566	7,45264	7,78782	7,84805	7,9169	7,99411	8,0794

Tablo 4: 2mm Aralık İçin

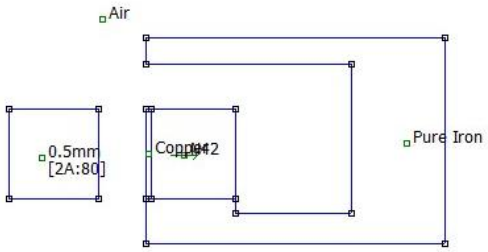
	40mm Bobin için kuvvet (N)					60mm Bobin için kuvvet (N)					80mm Bobin için Kuvvet (N)				
Tel kalınlığı (mm)	2A	4A	6A	8A	10A	2A	4A	6A	8A	10A	2A	4A	6A	8A	10A
0.5	7,96347	8,06685	8,17628	8,29144	8,41202	8,31347	8,38439	8,46305	8,54914	8,64231	8,30779	8,36811	8,43689	8,51387	8,59876
1	7,96347	8,06685	8,17628	8,29144	8,41202	8,31347	8,38439	8,46305	8,54914	8,64231	8,30779	8,36811	8,43689	8,51387	8,59876
1.6	7,96347	8,06685	8,17628	8,29144	8,41202	8,31347	8,38439	8,46305	8,54914	8,64231	8,30779	8,36811	8,43689	8,51387	8,59876
2	7,96347	8,06685	8,17628	8,29144	8,41202	8,31347	8,38439	8,46305	8,54914	8,64231	8,30779	8,36811	8,43689	8,51387	8,59876

Tablo 5: 2.5mm Aralık İçin

	40mm Bobin için kuvvet (N)					60mm Bobin için kuvvet (N)					80mm Bobin için Kuvvet (N)				
Tel kalınlığı (mm)	2A	4A	6A	8A	10A	2A	4A	6A	8A	10A	2A	4A	6A	8A	10A
0.5	6,41811	6,51647	6,62079	6,73074	6,84602	7,94869	8,02078	8,10056	8,18775	8,28202	7,82442	7,87804	7,94031	8,01089	8,08957
1	6,41811	6,51647	6,62079	6,73074	6,84602	7,94869	8,02078	8,10056	8,18775	8,28202	7,82442	7,87804	7,94031	8,01089	8,08957
1.6	6,41811	6,51647	6,62079	6,73074	6,84602	7,94869	8,02078	8,10056	8,18775	8,28202	7,82442	7,87804	7,94031	8,01089	8,08957
2	6,41811	6,51647	6,62079	6,73074	6,84602	7,94869	8,02078	8,10056	8,18775	8,28202	7,82442	7,87804	7,94031	8,01089	8,08957

Tablo 6: 3mm Aralık İçin

	40mm Bobin için kuvvet (N)					60mm Bobin için kuvvet (N)					80mm Bobin için Kuvvet (N)				
Tel kalınlığı (mm)	2A	4A	6A	8A	10A	2A	4A	6A	8A	10A	2A	4A	6A	8A	10A
0.5	6,07986	6,18559	6,29701	6,41375	6,53555	6,72858	6,81548	6,9097	7,01086	7,11869	8,32794	8.37750	8,43562	8,502	8,57639
1	6,07986	6,18559	6,29701	6,41375	6,53555	6,72858	6,81548	6,9097	7,01086	7,11869	8,32794	8,32794	8,43562	8,502	8,57639
1.6	6,07986	6,18559	6,29701	6,41375	6,53555	6,72858	6,81548	6,9097	7,01086	7,11869	8,32794	8,32794	8,43562	8,502	8,57639
2	6,07986	6,18559	6,29701	6,41375	6,53555	6,72858	6,81548	6,9097	7,01086	7,11869	8,32794	8,32794	8,43562	8,502	8,57639



Şekil.5 Aradaki mesafeyi ifade eden temsili çizim

Benzer ama daha basit bir tasarım ile aradaki deplasmanın artmasının sonuçları incelemeye alındı. Aradaki deplasmanın 1mm, 5mm, 10mm ve 15mm olacağı şekilde kıyaslaması yapılmaktadır. Bu denemenin sonuçları ise şu şekildedir.

Tablo 7 Boşluk etkisi detay analizi sonuçları

Aradaki boşluk [mm]	Oluşan Kuvvet [N]
1	128.875
5	126.73
10	126.704
15	126.68

Aradaki mesafe arttıkça etki eden kuvvet de azalmaktadır. Yapılan tasarımda da benzer sonuçlar mevcuttur.

SONUÇLAR

Bu çalışmada bir elektromanyetik modal sarsıcı tasarlanarak FEMM programı ile nümerik analizi gerçekleştirilmiştir. Nümerik analizlerde farklı bakır tel çapları, uygulanan farklı akım değerleri,

mesafe ve bobin yüksekliği gibi farklı parametreleri içeren çok sayıda analiz gerçekleştirilerek tablolar ile sunulmuştur. Yapılan analizlerde bobin ile nüve arasındaki boşluk değişiminin manyetik alan değişimine etkisi, uygulanan farklı elektrik akımlarının kuvvet ve manyetik alan üzerine etkisi detaylı olarak çok sayıda analiz yapılarak araştırılmıştır. Elde edilen sonuçlar bobin yüksekliğinin, uygulanan elektrik akım değerinin ve nüve ile bobin arasındaki boşluğun ortaya çıkacak olan manyetik alan şiddetini ve kuvveti değiştirdiğini göstermiştir. Tasarımı yapılan cihazda istenilen parametrelerin dikkate alınarak bu analizlerin gerçekleştirilmesinin yapılacak tasarımın doğru çalışması açısından önemli olduğunu ortaya çıkarmıştır.

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DATA EN CRYPTION USING GRAPH THEORY

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Abstract

Data encryption is a casual and secure method to protect any kind of data. Various methods and algorithms are publicly available to protect the data, but hackers are still stealing the data from the users. This data may be personal or private data, but there is a possibility that this may give a lead to using the data for criminal purposes like identity theft or financial fraud. The biggest challenge nowadays is to protect data from hackers. For that reason, it is required to find some strong techniques and will not give any chance to steal the data. Graph theory plays a major role in data encryption. In this article, we provide a new method to encrypt any data into a graphical structure using a complete graph along with a few algebraic properties. This proposed method will lead for safe communication.

Keywords. Encryption, Graph theory, Complete graph.

EVALUATING THE PERFORMANCE OF CRAYFISH OPTIMIZATION ALGORITHM ON CEC-2022 BENCHMARK PROBLEMS

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ABSTRACT

The Crayfish Optimization Algorithm (COA) is a recently developed metaheuristic optimization algorithm introduced in the literature. COA models the optimization process based on the social behaviors of crayfish, which serve as its inspiration. Evaluating the success of optimization algorithms and comparing their advantages over one another requires testing them on diverse benchmark functions and problem sets. In this context, the CEC-2022 benchmark test functions, known for their challenging and complex structures, serve as a standard tool for assessing the performance of such algorithms. In this study, the performance of COA was analyzed using 12 different CEC-2022 benchmark test functions. During the experimental evaluations, the results of COA were compared with those of 10 different optimization algorithms. The performance analysis utilized metrics such as mean fitness values, standard deviation, and ranking. The findings demonstrated that COA exhibited competitive and robust performance across many functions. In particular, COA achieved the best results among all algorithms in terms of average ranking. However, it was also observed that COA's performance needs improvement for solving complex hybrid functions. This study contributes to the literature by presenting the results of COA on CEC-2022 test functions and providing a comprehensive evaluation of the algorithm's effectiveness. The research aims to establish COA as a valuable reference for comparative studies with other metaheuristic algorithms.

Keywords: Crayfish Optimization Algorithm, Metaheuristic Algorithm, Optimization, CEC-2022 Benchmark Test Functions.

INTRODUCTION

Optimization is emerging as an increasingly popular field of study in many disciplines including engineering, science and economics (Erdoğan, Karakoyun, & Gülcü, 2024). The primary reason for this prominence is its ability to offer effective and efficient solutions to complex and challenging problems, thereby enhancing the utilization of resources and improving processes (Wang et al., 2024). Throughout history, numerous methods have been proposed for solving optimization problems (Akay & Karaboga, 2009). While traditional optimization methods have been effective for simple problems, they often fall short in handling complex and multi-dimensional issues. Metaheuristic algorithms have been suggested for problems where traditional methods are inadequate, and they have been successfully employed in the literature (Tongur & Ülker, 2019). Particularly, there is growing interest in swarm intelligence-based metaheuristic

optimization algorithms, which are being tested on a variety of different problems (Erdoğan et al., 2024; Ervural & Hakli, 2023; Wang et al., 2024).

The Crayfish Optimization Algorithm (COA) is a swarm intelligence-based metaheuristic optimization algorithm that simulates the summer resort, competitive, and feeding behaviors of crayfish (Jia, Rao, Wen, & Mirjalili, 2023). Since its introduction into the literature, COA has been successfully used in various studies. Jia et al. (2024) have developed the Modified Crayfish Optimization Algorithm (MCOA) by adding an environmental renewal mechanism and a learning strategy based on ghost antagonism to COA. Tests conducted on IEEE CEC2020 test functions, four constrained engineering problems, and feature selection problem have shown significant performance improvements of MCOA over COA. Shikoun, Al-Eraqi, and Fathi (2024) have proposed the Binary Crayfish Optimization Algorithm (BinCOA) aimed at eliminating unnecessary features for big data problems. By adding a refracted opposition-based learning strategy and a crisscross strategy to COA, the exploitation capacity and convergence accuracy of the algorithm have been enhanced. Tests on 30 different datasets have demonstrated that BinCOA outperforms seven other methods in terms of classification accuracy and selected feature count. Chaib et al. (2024) have developed the Improved Crayfish Optimization Algorithm (ICOA) by combining COA with fractional-order chaos maps (FC-maps) to provide adaptive tuning adjustments. Moreover, a dimension learning-hunting (DLH) search mechanism has been added to COA, enhancing its local and global search capabilities. ICOA, combined with the Newton-Raphson method, has been used for estimating circuit parameters in photovoltaic (PV) models; experimental results have shown that ICOA achieves more precise and consistent results compared to other metaheuristic methods.

Testing optimization algorithms on various benchmark test functions and problems is crucial for interpreting their successes and comparative advantages. The performance analysis of the Crayfish Optimization Algorithm (COA) in its original article was conducted on 23 CEC-2014 benchmark test functions and 5 different engineering problems. In this study, COA's performance is tested on 12 known challenging and complex CEC-2022 benchmark test functions. This approach systematically evaluates COA's performance, providing significant insights into the strengths and weaknesses of the algorithm in handling complex optimization problems.

The remainder of the study is organized as follows: Section 2 introduces the Crayfish Optimization Algorithm and the CEC-2022 benchmark test functions used in the performance analysis. Section 3 discusses the parameter settings used during the experiments on the CEC-2022 benchmark test functions and the experimental results obtained. Finally, Section 4 discusses the overall results of the study and provides recommendations for future research.

MATERIALS AND METHODS

Crayfish Optimization Algorithm (COA)

COA is a swarm intelligence-based metaheuristic optimization algorithm introduced to the literature by Jia et al. in 2023. Inspired by the social behavior of crayfish in nature, COA consists of three main stages: Summer Resort Stage, Competition Stage, and Foraging Stage, which correspond to the three fundamental life habits of crayfish. Each stage employs different optimization strategies to enhance the algorithm's global and local search capabilities, thereby driving the optimization process (Jia et al., 2023).

In COA, each crayfish is defined as a 1×d matrix in a d-dimensional optimization problem, with its position confined within the upper (ub) and lower (lb) bounds of the search space. The algorithm identifies the optimal solution at each evaluation and stores it as the global optimum

for the problem. The initial positions of the population are determined using a random distribution based on Equation (1).

$$X_{i,j} = lb_j + (ub_j - lb_j) \times rand \quad (1)$$

where $X_{i,j}$ represents the value of the i-th crayfish in the j-th dimension, ub_j denotes the upper boundary value of the j-th dimension, lb_j represents the lower boundary value of the j-th dimension, and $rand$ is a randomly determined number in the range [0,1].

The Summer Resort Stage simulates the behavior of crayfish seeking cool caves to protect themselves from high temperatures. This behavior represents the exploration phase of the algorithm. During this stage, if the temperature exceeds 30 °C, crayfish search for caves and update their positions based on randomness. The positions of the caves are determined using Equation (2).

$$X_{shade} = (X_G + X_L)/2 \quad (2)$$

where X_G represents the best position obtained so far during the iterations, while X_L denotes the best position of the current population.

Cave competition among crayfish is modeled as a random behavior. If $rand < 0.5$, it is assumed that there is no competition, and the position update is performed using Equation (3).

$$C_2 = 2 - (t/T)$$

$$X_{new} = X_{i,j} + C_2 \times rand \times (X_{shade} - X_{i,j}) \quad (3)$$

where X_{new} represents the new position value of the i-th crayfish, t denotes the current iteration number, T is the maximum number of iterations, and C_2 represents a decreasing curve value.

During the Summer Resort Stage, crayfish move closer to the cave, which represents the optimal solution. This enhances COA's exploitation capability and accelerates the convergence of the algorithm.

In the Competition Stage, when the temperature exceeds 30 °C and the condition $rand \geq 0.5$ is met, crayfish compete with other individuals for caves. In this case, two crayfish struggle for a cave, and the position of X_i is adjusted based on the position of a randomly selected individual (X_z). The position update is performed using Equation (4).

$$z = round\big(rand \times (N - 1)\big) + 1$$

$$X_{new} = X_{i,j} - X_{z,j} + X_{shade} \quad (4)$$

where N represents the total number of crayfish in the population.

The Competition Stage enhances information sharing among individuals within the population, facilitating the discovery of better solutions. Additionally, it strengthens the local search capability, contributing to the improvement of solutions.

The Foraging Stage simulates the process of crayfish leaving their caves to search for food when the temperature is 30 °C or lower. Crayfish determine the location of the food based on the best position obtained in the current evaluation round and update their positions accordingly. The food position is calculated using Equation (5).

$$X_{food} = X_G \quad (5)$$

The food intake of crayfish depends on the temperature and the size of the food. When the temperature is between 20 °C and 30 °C, their foraging behavior is strong, with the maximum

amount of food found at 25 °C. During this process, food intake is modeled using a normal distribution. The normal distribution for food intake is calculated using Equation (6).

$$p = C_1 \times \frac{1}{\sqrt{2\times\pi}\times\sigma} \times \exp\left(\frac{(temp-\mu)^2}{2\sigma^2}\right) \quad (6)$$

where μ represents the most suitable temperature for crayfish feeding, while σ and C_1 are parameters used to control the variation in food intake of crayfish at different temperatures.

The amount of food obtained by crayfish depends not only on food intake but also on the size of the food. The size of the food is calculated using Equation (7).

$$Q = C_3 \times rand \times (fitness_i/fitness_{food}) \quad (7)$$

where C_3 is a food factor representing the maximum food size, with a value of 3. $fitness_i$ denotes the fitness value of the i-th crayfish, while $fitness_{food}$ represents the fitness value of the food's location.

Crayfish decide their feeding method by evaluating the amount and size of the food. If the food is too large $\left(Q > \frac{C_3+1}{2}\right)$, they shred the food and consume it alternately. The shredding process is performed using Equation (8).

$$X_{food} = \exp\left(-\frac{1}{Q}\right) \times X_{food} \quad (8)$$

After the food is reduced to a consumable size, the crayfish uses its second and third claws to alternately transfer the food to its mouth. This alternating feeding process is represented by mathematical models to simulate bipedal movement. These models, based on sine and cosine functions, depict the crayfish's alternating feeding behavior. The simulation of crayfish alternating feeding is performed using Equation (9).

$$X_{new} = X_{i,j} + X_{food} \times p \times \left(\cos(2 \times \pi \times rand) - \sin(2 \times \pi \times rand)\right) \quad (9)$$

This process is crucial for the effective consumption of food and the modeling of feeding behavior.

If the size of the food is appropriate $\left(Q \leq \frac{C_3+1}{2}\right)$, the crayfish directly moves to the food location and feeds. This behavior of the crayfish is calculated using Equation (10).

$$X_{new} = \left(X_{i,j} - X_{food}\right) \times p + p \times rand \times X_{i,j} \quad (10)$$

The foraging stage enables crayfish to optimize their search and exploitation processes using different strategies based on temperature and food size.

The flowchart of COA is presented in Figure 1.

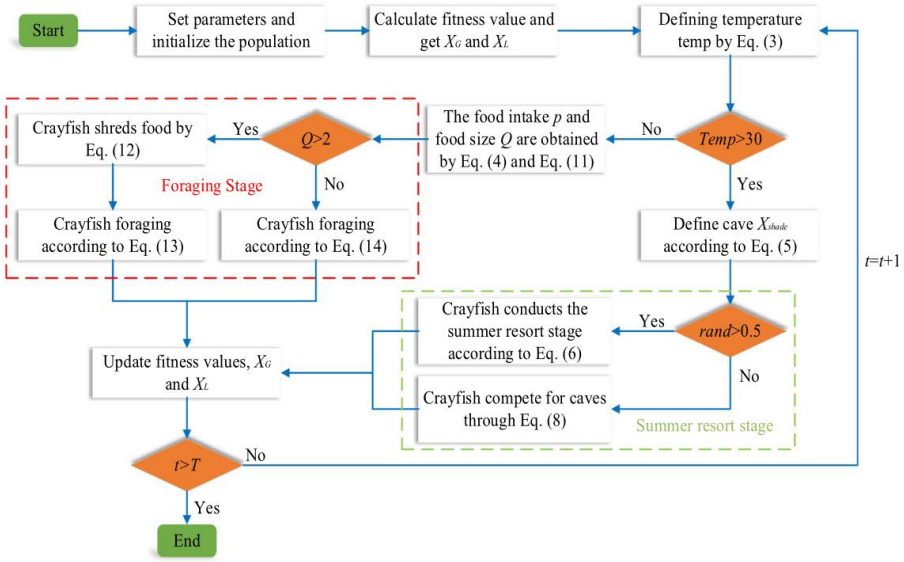

Figure 1. Flowchart of COA (Jia et al., 2023)

CEC-2022 Benchmark Test Dataset

CEC-2022 benchmark test functions are widely used to evaluate the performance of optimization algorithms. These functions exhibit diverse complexities and characteristics. They are designed to test the exploration and exploitation capabilities of algorithms. The functions include unimodal, multimodal, hybrid, and composition types (Kumar, Price, Mohamed, Hadi, & Suganthan, 2021).

The benchmark test functions incorporate features such as shifted, rotated, and discontinuous surfaces. These features provide a challenging platform to assess the robustness and adaptability of algorithms (Bujok & Kolenovsky, 2022; Wang et al., 2024).

Detailed information about the CEC-2022 benchmark test functions used in the experiments is presented in Table 1.

Table 1. CEC-2022 Benchmark Test Dataset (Bujok & Kolenovsky, 2022; Wang et al., 2024)

Function Type	Function ID	Function Name	Search Range	F_{min}
Unimodal Function	F1	Shifted and Full Rotated Zakharov Function	$[-100,100]^{dim}$	300
Multimodal Functions	F2	Shifted and Full Rotated Rosenbrock's Function	$[-100,100]^{dim}$	400
	F3	Shifted and Full Rotated Expanded Schaffer's F6 Function	$[-100,100]^{dim}$	600
	F4	Shifted and Full Rotated Non-Continuous Rastrigin's Function	$[-100,100]^{dim}$	800
	F5	Shifted and Full Rotated Levy Function	$[-100,100]^{dim}$	900
Hybrid Functions	F6	Hybrid Function 1 (N = 3)	$[-100,100]^{dim}$	1800
	F7	Hybrid Function 2 (N = 6)	$[-100,100]^{dim}$	2000
	F8	Hybrid Function 3 (N = 5)	$[-100,100]^{dim}$	2200
Composition Functions	F9	Composition Function 1 (N = 5)	$[-100,100]^{dim}$	2300
	F10	Composition Function 2 (N = 4)	$[-100,100]^{dim}$	2400
	F11	Composition Function 3 (N = 5)	$[-100,100]^{dim}$	2600
	F12	Composition Function 4 (N = 6)	$[-100,100]^{dim}$	2700

EXPERIMENTAL RESULTS

In this study, the Crayfish Optimization Algorithm (COA) was comprehensively evaluated on CEC-2022 benchmark test functions. The experiments were conducted on a computer with Windows 10 operating system, an Intel (R) Core (TM) i7-7500U CPU @ 2.70GHz processor, 12 GB of RAM, and a 64-bit configuration. All coding tasks were performed using the MATLAB 2022b platform.

All parameter settings used in the experiments were based on the study referenced as (Wang et al., 2024) in the literature. In this context, the population size (ps) was set to 100, the dimension of the functions (dim) was set to 20, and the maximum number of iterations (MaxFEs) was set to 10,000 (MaxFEs=1,000,000). The performance of COA was compared with the results of 10 different optimization algorithms, namely the Arithmetic Optimization Algorithm (AOA) (Abualigah, Diabat, Mirjalili, Abd Elaziz, & Gandomi, 2021), Genetic Algorithm (GA) (Holland, 1992), Gravitational Search Algorithm (GSA) (Rashedi, Nezamabadi-Pour, & Saryazdi, 2009), Grey Wolf Optimizer (GWO) (Mirjalili, Mirjalili, & Lewis, 2014), Jaya Algorithm (Jaya) (R. Rao, 2016), Particle Swarm Optimization (PSO) (Kennedy & Eberhart, 1995), Sine Cosine Algorithm (SCA) (Mirjalili, 2016), Stochastic Paint Optimizer (SPO) (Kaveh, Talatahari, & Khodadadi, 2022), Teaching–Learning-Based Optimization (TLBO) (R. V. Rao, Savsani, & Vakharia, 2011), and Whale Optimization Algorithm (WOA) (Mirjalili & Lewis, 2016). The data for these algorithms were directly obtained from the study referenced as (Wang et al., 2024) and included in the analyses.

As part of the experimental studies, the performance of COA and the other algorithms was analyzed on 12 CEC-2022 test functions. For each test function, the mean fitness values (Mean) obtained by the algorithms and their corresponding standard deviation values (Std) were calculated and presented in Table 2. Additionally, the ranking values (Rank) of each algorithm, based on their mean fitness values for the respective test functions, were also provided.

In Table 2, the best Mean, Std and Rank values for each function are highlighted in bold. The Mean values in the table represent the average fitness performance of the algorithms for each function. COA demonstrated highly competitive performance across many functions. In the F1 function, COA ranked second with a value of 4.2296E-04, following closely behind PSO. This highlights COA's strong performance in unimodal functions. In the F9 function, COA achieved the best result with a value of 1.8078E+02, making it the algorithm with the lowest Mean value for this function. However, in the F8 function, COA ranked 10th with a Mean value of 2.5047E+02, indicating that the algorithm is less effective for complex hybrid functions. Overall, COA stands out in terms of Mean values across many functions, although it requires performance improvements for certain complex functions.

The Std values reflect the consistency and reliability of the algorithms. Lower Std values indicate less variability in the results and more reliable outcomes. COA had a very low Std value of 3.2924E-04 in the F1 function, demonstrating consistent performance. Although COA had a relatively high Std value of 5.3582E+02 in the F5 function, it still achieved one of the top rankings. In the F9 function, COA had a low Std value of 1.3829E-05, outperforming other algorithms in terms of consistency. Overall, COA's standard deviation values are generally low across many functions, indicating reliable results.

The Rank values represent the position of each algorithm for each function. Lower Rank values indicate better performance. In the F9 function, COA secured first place, demonstrating clear superiority. In the F1 and F2 functions, COA ranked second, highlighting its competitiveness. However, in complex functions such as F8 and F12, COA's Rank values were higher, indicating reduced performance. Overall, COA stood out with low Rank values in many functions, though its ranking in some functions suggests areas for performance improvement.

The Average Rank value in Table 2 indicates the average ranking of each algorithm across all functions. COA's Average Rank value of 3.67 represents the best result among all algorithms. This establishes COA as a leading algorithm in overall performance. COA exhibited superior and consistent performance in many functions, particularly in terms of Mean and Std values. By achieving the lowest Average Rank, COA solidified its overall success. However, improving its performance in complex hybrid and composition functions (e.g., F8 and F12) could further enhance its overall superiority.

Table 2. Experimental results of COA and 10 comparative algorithms on CEC-2022

Function	Index	COA	AOA	GA	GSA	GWO	Jaya	PSO	SCA	SPO	TLBO	WOA
F1	Mean	4.2296E-04	3.0441E+04	1.7863E+03	9.7105E+03	4.9282E+03	7.4929E+03	**3.2043E-06**	4.7965E+03	8.584 3E+04	1.5334E+03	1.9456E+01
	Std	3.2924E-04	8.9421E+03	3.1889E+02	1.8891E+03	3.0532E+03	1.4638E+03	**2.6646E-06**	1.4039E+03	3.750 5E+04	1.1835E+03	1.9551E+01
	Rank	2	10	5	9	7	8	**1**	6	11	4	3
F2	Mean	4.3750E+01	2.0569E+03	7.3987E+01	4.9279E+01	7.2824E+01	8.9697E+01	**2.8567E+01**	1.8378E+02	1.191 3E+03	4.6685E+01	6.1174E+01
	Std	2.4418E+01	7.1438E+02	3.9499E+00	**1.0647E+00**	2.7904E+01	1.8721E+01	2.1522E+01	2.5970E+01	5.319 2E+02	3.5117E+00	2.3629E+01
	Rank	2	11	7	4	6	8	**1**	9	10	3	5
F3	Mean	9.4091E+00	5.2497E+01	5.3975E+00	3.3315E+01	**9.7599E-01**	1.3499E+01	3.1822E+01	2.9503E+01	4.291 2E+01	3.0344E+01	5.2128E+01
	Std	7.8815E+00	4.4944E+00	**6.0488E-01**	7.9191E+00	8.2626E-01	1.6195E+00	7.4213E+00	3.6768E+00	1.793 9E+01	7.1651E+00	1.4155E+01
	Rank	3	11	2	8	**1**	4	7	5	9	6	10
F4	Mean	7.8133E+01	1.0365E+02	8.9475E+01	7.3925E+01	**4.0720E+01**	1.1365E+02	5.9100E+01	1.1753E+02	1.605 9E+02	8.2900E+01	1.0739E+02
	Std	1.7354E+01	1.1227E+01	**5.5059E+00**	8.2633E+00	2.0575E+01	9.0888E+00	1.2083E+01	9.5302E+00	3.592 3E+01	1.9485E+01	2.5710E+01
	Rank	4	7	6	3	**1**	10	2	9	11	5	8
F5	Mean	4.5521E+02	1.5253E+03	5.4604E+01	**0.0000E+00**	6.4314E+01	3.8385E+02	3.9023E+02	6.3936E+02	2.967 1E+03	1.4380E+03	2.2903E+03
	Std	5.3582E+02	7.1773E+01	1.4024E+01	**0.0000E+00**	5.6484E+01	1.1786E+02	3.0567E+02	1.9671E+02	2.052 4E+03	6.0650E+02	1.1784E+03
	Rank	6	8	2	**1**	3	4	5	7	11	9	10
F6	Mean	3.0271E+03	1.1610E+05	1.6627E+03	1.1456E+03	5.4369E+04	2.8479E+07	**4.1429E+02**	4.7086E+07	5.407 3E+08	6.2156E+04	5.6291E+03
	Std	4.5953E+03	6.2465E+05	9.9000E+02	**6.6349E+02**	1.6863E+05	1.4237E+07	7.8275E+02	2.9946E+07	8.247 0E+08	1.6875E+05	5.8590E+03
	Rank	4	8	3	2	6	9	**1**	10	11	7	5
F7	Mean	4.3336E+01	1.7715E+02	**3.8782E+01**	3.1833E+02	4.8326E+01	9.4879E+01	8.9918E+01	9.7681E+01	1.737 8E+02	8.4191E+01	1.4679E+02
	Std	2.5291E+01	7.1756E+01	**8.9573E+00**	5.8689E+01	2.5962E+01	9.4474E+00	4.2943E+01	1.3681E+01	6.039 0E+01	1.5755E+01	4.7372E+01
	Rank	2	10	**1**	11	3	6	5	7	9	4	8
F8	Mean	2.5047E+02	1.2427E+02	**2.6203E+01**	2.4136E+02	3.8631E+01	3.5182E+01	5.9918E+01	4.1606E+01	9.750 9E+02	3.4974E+01	4.1587E+01
	Std	7.3186E+01	7.6430E+01	**8.5478E-01**	5.4998E+01	3.5733E+01	3.0255E+00	5.5722E+01	3.3712E+00	4.268 7E+03	3.0702E+00	1.1228E+01
	Rank	10	8	**1**	9	4	3	7	6	11	2	5
F9	Mean	**1.8078E+02**	6.3915E+02	1.8933E+02	**1.8078E+02**	1.9164E+02	1.8977E+02	1.8934E+02	2.2497E+02	5.108 2E+02	1.8089E+02	1.8119E+02
	Std	1.3829E-05	1.3441E+02	1.2939E+00	**1.2820E-13**	1.5930E+01	2.3377E+00	1.9528E+01	1.4006E+01	1.615 7E+02	6.8565E-02	4.3189E-01
	Rank	**1**	10	4	**1**	7	6	5	8	9	2	3
F10	Mean	2.2361E+02	1.5317E+03	1.2860E+02	2.4475E+03	6.8868E+02	1.3753E+03	1.0626E+03	**1.1273E+02**	2.677 0E+03	1.3511E+02	1.5229E+03
	Std	1.6966E+02	5.4484E+02	**7.1964E+01**	5.6397E+02	5.4130E+02	1.3769E+03	9.4515E+02	3.4417E+00	1.232 8E+03	1.5561E+02	1.0673E+03
	Rank	4	9	2	10	5	7	6	**1**	11	3	8
F11	Mean	3.2335E+02	5.8495E+03	6.8170E+02	3.5000E+02	6.5005E+02	1.0729E+03	3.5370E+02	1.4128E+03	4.512 3E+03	**3.0510E+02**	5.2810E+02
	Std	7.6077E+01	8.6153E+02	**3.4694E+01**	5.0855E+01	1.9816E+02	2.1041E+02	1.6778E+02	3.4108E+02	1.403 0E+03	1.5024E+02	1.0462E+03
	Rank	2	11	7	3	6	8	4	9	10	**1**	5
F12	Mean	2.7460E+02	7.4006E+02	2.7515E+02	5.0753E+02	2.5356E+02	**2.4847E+02**	3.8741E+02	2.9651E+02	5.129 7E+02	2.6070E+02	3.2229E+02
	Std	2.2934E+01	1.3497E+02	6.4562E+00	1.2039E+02	1.3748E+01	**2.6293E+00**	1.3224E+02	1.0365E+01	1.277 5E+02	1.7575E+01	6.9277E+01
	Rank	4	11	5	9	2	**1**	8	6	10	3	7
Average Rank		**3.67**	9.50	3.75	5.83	4.25	6.17	4.33	6.92	10.25	4.08	6.42

CONCLUSION AND DISCUSSION

In this study, the performance of the Crayfish Optimization Algorithm (COA) was evaluated on 12 CEC-2022 benchmark functions. Unlike the original paper proposing the algorithm, the CEC-2022 test suite was not previously used, which includes challenging and complex functions designed to rigorously test the robustness and adaptability of optimization algorithms. By employing this benchmark, the aim was to assess COA's performance in handling both unimodal and multimodal problems, as well as hybrid and composition functions.

The results obtained from the experiments were compared with 10 other state-of-the-art optimization algorithms, including well-established methods such as Genetic Algorithm (GA) and Particle Swarm Optimization (PSO), as well as recently proposed methods like Arithmetic Optimization Algorithm (AOA) and Sine Cosine Algorithm (SCA). The comparison was based on the Mean, Std and Rank metrics for each function.

COA demonstrated superior performance in several functions, consistently outperforming well-known methods like GA and PSO. For example, COA achieved the best or near-best results in F1, F7, F9 and F11 functions, showcasing its capability to handle unimodal and multimodal optimization problems effectively. Moreover, COA surpassed recently proposed algorithms like AOA and SCA across multiple functions, indicating its competitiveness against newer approaches.

The Mean values revealed that COA provided optimal or near-optimal solutions in a majority of the test functions. Notably, in F9, COA achieved the best Mean value and exhibited the lowest Std, reflecting both accuracy and consistency. While COA excelled in several functions, its performance in complex hybrid functions such as F8 and F12 was comparatively less competitive, indicating potential areas for improvement.

In terms of the Rank metric, COA had an average rank of 3.67, which was the best among all tested algorithms. This demonstrates its overall dominance across the test functions. Despite its strong performance, the results suggest that fine-tuning COA's parameters or introducing adaptive mechanisms might further enhance its capability in handling more complex functions.

In conclusion, COA proved to be a robust and reliable optimization algorithm, outperforming many well-known and contemporary algorithms in the majority of the CEC-2022 functions. These results highlight its potential as an effective optimization method, while also identifying opportunities for further refinement to improve its versatility in addressing more complex optimization challenges.

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DEVELOPING AN GIANG CULINARY TOURISM

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Abstract:

An Giang's cuisine presents a rich and diverse culinary tapestry shaped by the convergence of various ethnic cultures. These culinary creations are not merely products of human labor but cultural artifacts that reflect the ingenuity and adaptability of local communities. By harnessing the tourism potential of An Giang's cuisine, we can preserve and promote its invaluable cultural heritage and cultivate innovative tourism experiences that attract visitors and invigorate local economies. This paper aims to (1) explore the theoretical underpinnings of culinary tourism, with a particular focus on the role of cultural heritage; (2) examine the potentials and challenges inherent in leveraging cultural values for tourism development in An Giang Province, including the preservation of traditional knowledge and skills; and (3) propose strategies for preserving and enhancing the region's culinary heritage to stimulate the growth of its tourism industry, such as developing culinary tours, cooking classes, and food festivals.

Keywords: culinary tourism, An Giang cuisine, An Giang tourism.

Introduction

Culinary tourism has emerged as a promising segment within the global tourism industry, offering significant economic advantages and playing a crucial role in preserving and promoting local culture. It facilitates the creation of memorable experiences for tourists, enhancing their engagement with the destination. In the context of the Mekong Delta, An Giang stands out as a notable destination, renowned for its stunning natural landscapes, characterized by rivers and streams, and its vibrant culinary scene. Historically, the region has been celebrated as “the land of rice on the top and fish on the bottom” a testament to its agricultural richness. Furthermore, An Giang’s unique cultural tapestry, woven from the interactions of the Kinh, Khmer, Cham, and Hoa ethnic groups, contributes to a rich and diverse culinary heritage, making it an ideal location for culinary tourism.

When discussing culinary tourism in An Giang, it is impossible to overlook its renowned dishes, each representing the region's rich gastronomic heritage. One of the most famous is Chau Doc fish noodle soup, a dish distinguished by its flavorful broth made from snakehead fish, complemented by Dien Dien flowers and fresh vegetables. Another iconic dish is Chau Doc fish sauce, often considered the "soul" of An Giang cuisine, which comes in various types and is integral to many local recipes. The Sau Dau salad, featuring the slightly bitter taste of Sau Dau leaves, pork belly, shrimp, dried fish, and a tangy tamarind fish sauce, is another delicacy that stands out. Additionally, fish sauce hotpot, a flavorful blend of fish sauce and fresh ingredients like fish, shrimp, and vegetables, epitomizes the unique hotpot traditions of the Mekong Delta.

Furthermore, An Giang's culinary appeal extends to other dishes associated with specific locations, each with a unique charm. Vinh Trung rice noodle soup (from Tinh Bien district) is made from soc rice, lending the noodles a soft, chewy texture, distinctive aroma, and natural elasticity. The Seven-course beef from Sam Mountain (Chau Doc city) is a highly praised dish that offers a diverse array of preparations, including boiled beef offal, beef stew with rice vermicelli, beef porridge, beef stewed with bread, beef stir-fried with giang leaves, beef shaken, and beef steak. The beef is renowned for its tenderness and sweetness. Puffed sticky rice from Cho Moi district, served with roast chicken, is another dish widely recognized for its ability to delight tourists.

Meanwhile, Tan Chau mountain climbing beef (from Tan Chau town) captivates diners with its name and preparation method and the dish's remarkable softness and sweetness. Lastly, Banh xeo Nui Cam (from Tinh Bien district) stands out, offering over 20 wild vegetables, creating a unique and flavorful experience when paired with the pancakes. Combining these vegetables and distinct flavors contributes to a particularly memorable dining experience. Each dish encapsulates the essence of An Giang's culinary landscape, drawing tourists to experience the region's diverse and rich food culture.

Culinary tourism encompasses more than merely savoring local dishes; it also involves engaging with destinations intrinsically linked to their culinary traditions. For example, the Long Xuyen floating market captivates tourists by offering a unique opportunity to enjoy breakfast infused with intense regional flavors, such as noodles and stir-fried pork vermicelli, all served on the floating river, creating an immersive culinary experience. Similarly, Da Phuoc Cham village excites visitors as they savor traditional Cham dishes, including goat curry, ni rice, and tung lo mo (beef sausage), while observing Cham women in their vibrant traditional costumes. The scenic palmyra palm fields, particularly at sunset, offer tourists a picturesque setting to capture beautiful photographs while providing a tranquil atmosphere enhanced by a refreshing glass of palm honey.

Moreover, visiting An Giang during the flood season presents an exceptional opportunity for tourists to immerse themselves in the region's natural beauty fully. As the waters submerge the fields, visitors can take boat rides to pick Dien Dien flowers and enjoy them alongside young Linh fish, allowing them to experience the close connection between local food culture and the surrounding environment. This harmonious blend of nature, culture, and cuisine makes culinary tourism in An Giang a distinctive and enriching experience.

An Giang's culinary tourism represents a harmonious fusion of savoring exquisite local dishes and embarking on a journey to explore the rich cultural heritage and the warmth of its people. This combination offers tourists unique and distinctive experiences, thereby enhancing the overall brand value of the An Giang destination. Notably, this form of tourism aligns with the emerging trend of sustainable tourism, which emphasizes the preservation of cultural traditions and intangible heritage. Moreover, it contributes to the local economy by fostering the development of community-based initiatives and supporting sustainable practices within the tourism industry. This approach ensures the long-term viability of the region's cultural resources and creates opportunities for economic growth in An Giang.

Overview of culinary tourism

Culinary tourism has emerged as a significant segment within the tourism industry as contemporary travelers increasingly seek more than just traditional sightseeing experiences. Instead, they desire unique and immersive encounters that provide deeper insights into the destinations they visit. Local cuisine plays a pivotal role in this, serving as a powerful medium through which travelers can engage with a region's culture, history, and people. By exploring a destination's culinary traditions, tourists can form more meaningful connections and better understand its identity and heritage.

According to Hall and Mitchell (2001), culinary tourism is defined as a form of tourism in which travelers engage in activities centered around food and drink, thereby crafting an experience intrinsically linked to the culture and local traditions of the destination. This definition underscores the integral role of cuisine in shaping the overall tourist experience, highlighting how food-related activities contribute to a deeper connection with a place's cultural and geographical identity.

According to Kivela and Crotts (2006), culinary tourism represents a harmonious integration of travel experiences and gastronomic activities, where tourists are drawn to a destination's distinctive dishes and culinary traditions. This concept emphasizes the allure of local cuisine as a key motivator for travel, illustrating how food culture can serve as a powerful catalyst for tourism, offering visitors an immersive and authentic encounter with the culinary heritage of a region.

Similarly, the UNWTO (2012) defines culinary tourism as exploring local food and beverages within the broader context of culture, history, and community. This definition highlights the role of culinary tourism in fostering cultural connections between tourists and destinations, thereby enhancing the overall travel experience. Additionally, numerous other perspectives on culinary tourism emphasize the intrinsic link between cuisine and the three foundational pillars of tourism: culture, heritage, and experiential engagement. These viewpoints collectively underscore the importance of food as a medium for promoting cultural exchange and enriching the tourist experience.

Culinary tourism offers visitors a unique opportunity to gain a deeper understanding of a locality's culture by enjoying traditional cuisine. As Bessière (1998) suggests, cuisine can be regarded as a form of intangible cultural heritage, encapsulating local communities' values, skills, and traditions across generations. Through culinary experiences, tourists can connect with the local community, trace the origins and evolution of local diets, and observe how food practices shape people's daily lives. In the case of An Giang, experiencing its cuisine provides insight into the region's gastronomic traditions, the riverine character, and the open, welcoming nature of its people, further enhancing the cultural experience.

The role of cultural heritage in culinary tourism is paramount, as it encompasses not only traditional dishes but also preparation techniques, recipes, and distinctive eating habits. These heritage elements are often passed down through generations, serving as key identifiers of a community's culture. According to the UNWTO (2012), traditional cuisine is a vital component of intangible cultural heritage, and the growth of culinary tourism plays a crucial role in preserving and promoting these cultural values. By fostering an appreciation for local culinary traditions, culinary tourism helps to safeguard the cultural identity of regions while providing economic and social benefits.

In addition, culinary tourism extends beyond merely enjoying food; it is an integral aspect of the broader tourism experience. Kivela and Crotts (2006) emphasized that cuisine plays a pivotal role in shaping the tourism experience, creating profound and unique impressions for visitors. Specifically, in An Giang, culinary tourism encompasses a variety of activities, such as participating in culinary festivals, exploring traditional cooking methods, visiting local markets,

and engaging in cooking classes. These immersive experiences provide tourists with valuable insights into the local way of life, fostering a deeper connection to the community and leaving them with lasting, memorable impressions of their visit.

Potential and Challenges of Culinary Tourism in An Giang

An Giang, with its rich and diverse cultural heritage, is home to four distinct ethnic groups - Kinh, Khmer, Cham, and Hoa - which contribute to the region's unique customs, practices, festivals, and cuisine. This cultural diversity creates a compelling and attractive destination for tourists exploring varied cultural experiences. Notably, the cuisine of the Cham ethnic group in An Giang is heavily influenced by Islam, with strict dietary regulations that believers must observe throughout their lives. For instance, the Cham people follow several taboos regarding food and drink, consuming only their dishes. When slaughtering animals, they read the Quran and pray towards Mecca, adhering strictly to Halal standards.

This distinct culinary tradition is a significant feature of Cham culture in An Giang, setting it apart from other ethnic groups in the region. The unique nature of this culinary culture is of considerable interest to tourists, particularly those eager to experience the customs of different ethnic communities. Moreover, it presents An Giang with a distinct opportunity to develop Halal culinary tourism, a niche offering many other destinations may not be able to provide. This specialized form of tourism could serve as a valuable addition to the region's tourism portfolio, attracting a specific demographic of visitors while preserving and promoting the cultural heritage of the Cham people.

Noteworthy festivals such as the Ba Chua Xu Festival at Sam Mountain, the Bay Nui Bull Racing Festival, and the religious ceremonies of the Khmer and Cham communities attract millions of visitors each year. According to data from the Department of Culture, Sports, and Tourism of An Giang, the province welcomed nearly 9 million tourists in 2024 and aims to reach 10 million visitors in 2025. This tourism growth provides a solid foundation for the expansion of culinary tourism in An Giang, offering significant potential for developing food-related experiences that align with the region's cultural and festival-driven attractions.

Abundant food resources play a pivotal role in fostering the potential for culinary tourism development in An Giang. The region’s environmental and soil conditions, characterized by a vast network of rivers, streams, ponds, lakes, and canals, have created a diverse and bountiful range of food products, supporting a prosperous and vibrant way of life for its inhabitants. In addition to rice, the primary staple food for the people of An Giang, the local diet is enriched by a wide variety of aquatic species, including fish, shrimp, crabs, snails, frogs, eels, snakes, and rats, as well as an assortment of wild vegetables. These natural resources contribute to the creation of numerous delicious and distinctive dishes. Furthermore, the Mekong Delta is renowned for its unique flood season cuisine. An Giang, the first locality to receive floodwaters and one with an extended flood season, is particularly famous for this culinary tradition. This gives An Giang a competitive edge in culinary tourism development, attracting tourists eager to experience the region’s distinctive flood season dishes.

Although An Giang holds significant potential for culinary tourism, considerable infrastructure and service challenges must be addressed. As a specialized product, culinary tourism demands rigorous standards of food safety and hygiene. However, in An Giang, many popular tourist destinations still lack standardized restaurant facilities, and the quality of service is often unprofessional. These issues undermine the overall appeal and dining experience for tourists, hindering the region's full development of culinary tourism. Addressing these challenges by improving service standards and ensuring consistent food safety practices would enhance the attractiveness and competitiveness of An Giang as a culinary tourism destination.

On the other hand, despite its rich culinary culture, An Giang's culinary heritage has not been effectively promoted domestically or internationally. Local dishes are seldom presented as professional tourism products, meaning only those familiar with the region know their exceptional quality, such as sticky rice and mountain beef. In contrast, other provinces in the Mekong Delta, including Can Tho, Dong Thap, and Tien Giang, which possess similar culinary resources, are making significant strides in developing culinary tourism. This highlights the need for An Giang to distinguish itself by emphasizing its unique culinary offerings and strategically promoting them to attract tourists within this growing market segment.

In particular, the rapid pace of modernization poses a significant threat to preserving traditional dishes, as the influence of contemporary lifestyles increasingly overshadows traditional culinary practices. The younger generation, both nationally and in An Giang, demonstrates a growing reluctance to adopt and preserve traditional recipes, which creates substantial challenges in safeguarding the long-term sustainability of the region's culinary heritage. This shift in attitudes risks the erosion of local food traditions and hinders efforts to maintain the cultural identity embedded in these culinary practices.

Strategy for Preserving and Promoting Culinary Tourism in An Giang

In light of the growing threat to local culinary traditions, it is crucial to prioritize preserving and promoting An Giang's culinary heritage. Developing comprehensive strategies is essential to stimulate the growth of culinary tourism in the region. First and foremost, creating culinary tours that elevate the food experience is necessary, transforming the concept from "eating because you are here" to "eating because you want to be here." One viable approach is to design tours that focus on exploring rural markets, where visitors can engage in activities such as visiting traditional markets to learn about local ingredients and discover how these elements are used in signature dishes.

Additionally, culinary tours could include visits to renowned local eateries, such as traditional restaurants, family-run establishments, or food craft villages, allowing tourists to immerse themselves in authentic dining experiences. To further enhance the appeal of An Giang's culinary tourism, it is important to develop unique seasonal menus that reflect the region's natural environment and changing landscapes, offering visitors a deeper connection to the local culture and ecology. Specialty products, such as fish sauce, cakes, and traditional candies, should be emphasized as integral components of the culinary tourism experience. These items can be packaged attractively for tourists to purchase as souvenirs while ensuring strict hygiene standards and supporting local production. This approach will preserve An Giang's culinary traditions and contribute to the region's economic development through sustainable tourism practices.

In particular, it is highly beneficial to regularly organize culinary-related events, such as cooking workshops and food festivals, to promote An Giang’s rich culinary heritage further. Specifically, cooking classes could invite local artisans to teach visitors how to prepare traditional and iconic dishes, such as Linh fish sauce, banh xeo, or tung lo mo. These classes should not only focus on the cooking process but also incorporate storytelling elements, providing insights into the origins of these dishes, their cultural significance, and their connections to local life.

In addition to cooking classes, it is essential to continue hosting established culinary festivals, such as the Chau Doc Fish Sauce Festival and the Thot Not Festival, while also introducing new culinary-themed festivals. These events could feature a combination of art performances, folk games, culinary booths, and cooking competitions, creating an engaging and dynamic atmosphere for visitors. By integrating cultural, artistic, and culinary elements, these festivals would showcase the region’s food culture and provide memorable and immersive experiences for tourists, fostering a deeper connection with An Giang’s culinary traditions.

It is essential to strengthen the preservation of culinary heritage by systematically documenting recipes, preparation methods, and the stories behind local dishes to ensure their long-term preservation and facilitate their transmission to future generations. Additionally, providing both material and human resources to support the continued operation of traditional craft villages, such as those involved in fish sauce production, palm sugar making, and other specialty processed products, is crucial for safeguarding traditional skills.

Furthermore, it is important to regularly recognize and celebrate the contributions of artisans in the culinary sector through awards or honors, which will acknowledge their dedication to preserving and promoting culinary heritage and inspire continued passion for their craft. To ensure the longevity of these traditions, community education programs should be developed to teach the younger generation traditional cultural skills and knowledge, fostering an appreciation for local culinary practices and ensuring their transmission to future custodians of the region's rich food heritage.

It is crucial to prioritize upgrading infrastructure and tourism services, ensuring that dining establishments, ranging from restaurants to small eateries, meet standardized requirements for cleanliness, food hygiene, and safety. Additionally, it is essential to invest in training human resources within the tourism sector, equipping them with the skills necessary to provide high-quality, professional service. This will improve the overall visitor experience and ensure that the service standards align with international expectations, fostering greater tourist satisfaction and enhancing the region's competitiveness as a culinary tourism destination.

Maximizing information technology and social media platforms is essential to promoting and establishing local culinary brands, incorporating visually appealing and memorable logos or slogans. Collaborating with online travel agencies to introduce culinary tours and cooking classes to international tourists will further expand the reach of An Giang's culinary offerings. Additionally, active participation in international events dedicated to food and culture can serve as a platform to showcase local cuisine on a global stage. Strengthening partnerships with international organizations will also play a pivotal role in promoting the region's cultural values and culinary heritage, thus enhancing its visibility in the global tourism market.

The increasing integration of science and technology into the culinary sector significantly enhances the value of traditional specialties. In An Giang, with its rich natural resources, products such as fish sauce and palm sugar are being transformed into distinctive souvenirs. Thoughtful packaging design, incorporating environmentally friendly materials, comprehensive information on the product's origin, production process, and ideal ways to enjoy it can significantly elevate these items' aesthetic appeal and perceived value.

Moreover, applying virtual reality (VR) and augmented reality (AR) technologies offers exciting opportunities to engage visitors. By scanning QR codes on product packaging, tourists can virtually explore the traditional fish sauce-making process, learn about the ancient palm trees, or participate in interactive games related to the culinary cultures of the Khmer and Cham communities. However, while incorporating such technologies, it is crucial to ensure that the preservation and promotion of traditional culinary values remain central. A balanced integration of modern technology with cultural identity will not only enhance the marketability of these products but also contribute to the broader goal of promoting An Giang's tourism image on the global stage.

It is essential to prioritize using local ingredients, such as floating rice, Linh fish, wild vegetables, bamboo fruit, and palmyra palm, to craft authentic dishes that appeal to tourists. Efforts should be made to preserve and promote traditional preparation techniques and spices characteristic of each ethnic group, thereby ensuring that the distinctive flavors of these dishes are maintained. Creating culinary spaces that reflect the cultural essence of each ethnic group will offer visitors an immersive experience, making them feel as though they are partaking in a traditional family meal. Building on these traditional dishes, innovative recipes can be developed by skillfully

blending time-honored flavors with modern elements, thus catering to diverse customer preferences. However, it is crucial to avoid imposing foreign culinary influences on local cuisine, as doing so risks diluting the unique identity of each ethnic group's culinary heritage.

It is essential to develop a sustainable strategy for culinary tourism that ensures the exploitation of culinary cultural values is balanced with conservation efforts, avoiding over-commercialization. Local initiatives should be organized to raise awareness among the community regarding the significance of traditional cuisine and its potential in tourism. These programs will help foster a deeper understanding of how culinary heritage can sustainably integrate into tourism. Moreover, strengthening community-based tourism models is crucial, where residents take an active role in delivering tourism services and directly benefit from the growth of culinary tourism. This approach not only preserves cultural heritage but also empowers local communities, ensuring that the benefits of tourism are distributed equitably.

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FORTIFIED FOODS: A PATHWAY TO SUSTAINABLE GLOBAL FOOD SECURITY AND NUTRITION

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ABSTRACT

Fortified food and fortification is new approach in dealing with micronutrient deficiency emerges as a strategic approach toward food security and progress toward achieving the set goals under SDG 2 regarding ending hunger, achieving food security, and improved nutrition, and promoting sustainable agriculture. This article elaborates on the role of food fortification in nutritional outcomes, which have been endorsed particularly by populations with poor dietary diversity and limited access to micronutrient-rich foods. Fortification, the process of adding essential vitamins and minerals to commonly consumed foods such as salt, flour, and oil, provides an affordable way of addressing micronutrient deficiencies that help reverse the perceived relationships between economic development and health outcomes. Evidence is already emerging from different countries where a well-planned fortification program has been able to reduce the prevalence of deficits in iron, iodine, vitamin A, and folic acid. Moreover, fortification contributes to the overall goals of SDG 2 by making food more available, nutritious, and at its root cause an end to hunger. The paper discusses global experience in fortification programs, assesses the challenges this face, and outlines policy frameworks that could best maximize the effectiveness of fortification. Although it is not a cure-all, it is a fundamental complementary measure for food security and equal access to nutrients. Fortification can thus contribute to a more sustainable and healthy future by strengthening public health systems and involving stakeholders from both the private and public sectors.

Keywords: fortification, food security, SDG 2, micronutrient deficiencies, nutrition, sustainable development.

Introduction

Global food security, therefore, faces the challenge brought about by the climate change crisis, population explosion, and unequal socio-economic states. The FAO reports estimate that in 2020, an estimated 690 million people worldwide were undernourished, meaning the number can only have increased even further with the COVID-19 pandemic (FAO, 2021). Fortified foods promise to close the gap with regard to a micronutrient gap while developing sustainable agriculture. Increasingly, food fortification is recognized as an important intervention in ensuring global food security and nutrition. Micronutrient deficiencies that today affect billions of people are addressed by adding essential vitamins and minerals to commonly consumed foods. This article explores the international experience of fortification programs, discusses

challenges faced, and outlines policy frameworks to maximize the effectiveness of these initiatives.

Addressing Nutritional Deficiencies

- Fortified foods are enriched with essential vitamins and minerals, such as iron, vitamin A, and folic acid, which are critical for preventing deficiencies that can lead to serious health issues.
- By providing these nutrients, fortified foods help improve the nutritional status of populations, particularly children and pregnant women, who are most at risk.

The role of Fortified Foods

Fortified foods are enhanced with vitamins and minerals so as to improve the nutritional value. Micronutrient deficiencies, commonly known as "hidden hunger," have been believed to affect billions of people, thereby causing serious health problems like anemia, stunted growth, and impaired cognitive development (World Health Organization, 2023). Fortified foods in particular play a pertinent role in achieving SDG 2 by helping eradicate malnutrition and food insecurity. They prevent nutritional deficiencies that affect vulnerable groups, thus contributing to better health, food security, and general well-being.

Key Benefits of Fortified Foods

Since fortification essentially eliminates the end results of dietary deficiencies, it is most important for deficiencies related to an insufficient supply of iron, iodine, vitamin A, and folic acid-situations that occur widely among different populations (Bhutta et al., 2018).

This is a cost-effective and scalable solution where public health can improve at negligible behavioural changes by the consumer in the consumption of micronutrient-fortified foods (Horton et al., 2019).

Promoting Sustainable Practices: Fortification can be introduced with local agricultural systems, and therefore, the food system is made sustainable through the promotion of local products and food products.

Some of the global food fortification programs are given below:

- **Universal Salt Iodization (USI):** This is an effort to eradicate iodine deficiency disorders (IDD) by making sure that all salt consumed is iodized. Iodine is necessary for thyroid function and cognitive development.
- **Flour Fortification Initiative (FFI):** This is an effort to promote the fortification of wheat flour with essential nutrients such as iron, folic acid, and B vitamins to combat anemia and neural tube defects.
- **Global Alliance for Improved Nutrition (GAIN):** This focuses on improving the nutritional quality of food and increasing access to fortified foods, especially in low- and middle-income countries, to combat malnutrition.
- **Vitamin A Supplementation and Fortification Program:** This focuses on reducing vitamin A deficiency, which causes blindness and increased mortality, by fortifying staple foods such as cooking oil and margarine with vitamin A.
- **The Micronutrient Initiative (MI):** This target alleviating micronutrient deficiency through food fortification and supplementation programmes among the poor, particularly targeting women and children.
- **The World Food Programme (WFP) Fortification Programs:** Enhance the nutrition value of the food provided under emergency and development situations, address malnutrition for vulnerable populations through fortification of staple foods distributed.

- **The Food Fortification Initiative (FFI):** This is an effort to promote and support the fortification of staple foods worldwide, focusing on the implementation of effective fortification strategies to combat micronutrient deficiencies.
- **The Global Fortification Data Exchange (GFDx):** This is an effort to provide a platform for sharing data and best practices related to food fortification, facilitating collaboration among stakeholders to improve fortification efforts worldwide.
- **The Scaling Up Nutrition (SUN) Movement:** An effort to collaborate governments, civil society, and the private sector in efforts to improve nutrition, including through fortification of foods as a major strategy in the effort to reduce malnutrition.
- **The International Fortification Alliance:** It aims at promoting fortification of foods worldwide with its focus on creating policy advocacy, technical assistance, and capacity building in order to enhance effectiveness in the fortification programs.

Challenges Faced in Fortification

Although the positive impacts are numerous, several challenges for implementing food fortification programs exist.

•**Lack of Specific Guidelines and Standardization:** At times, there are no specific policies and regulations regarding the fortification process, causing inconsistencies in formulations among products (Gernand et al., 2016).

•**Public Awareness:** Since many customers are not aware of the benefits of fortified foods, their consumption should be facilitated by education.

• **Quality Control:** Production of quality and effective fortified products requires there to be very efficient monitoring and review processes in place; this is not the case in all areas (Ruel et al., 2019).

•**Economic Constraints:** Low-income countries face the problem of implementing and maintaining fortification programs because of scarce resources and infrastructure.

Global Experience in Fortification Programs

•**Successful Case Studies:** Countries like India and Mexico have initiated large-scale fortification programs that have significantly reduced deficiencies in iron and vitamin A.

•**WHO Guidelines:** Fortification of foods is supported by the WHO as a cost-effective public health measure that has guidelines for implementation and evaluation.

•**Regional Variations:** Various regions have adapted their fortification policies according to regional diets and nutritional requirements, for example, iodized salt in coastal areas to fight against iodine deficiency.

Policy Frameworks for Effective Fortification

•**Multi-Sectoral Collaboration:** Involving all stakeholders from government, industry, and civil society can strengthen the design and implementation of fortification programs.

•**Monitoring and Evaluation:** It is also important to have effective systems for monitoring the impact of fortification initiatives to improve and be accountable.

• **Motivations for Industry:** Financial incentives to food manufacturers may attract more industry players to participate in product fortification to maximize the impact of fortification.

•**Integration with Other Nutrition Programs:** Fortification might be more potent when combined with other public health initiatives, including nutrition education and supplementation.

Conclusion

Fortified foods are an essential element in the fight against global food insecurity and nutritional deficiencies. With proper facilitation of the challenges in their implementation, fortified foods will significantly contribute to the development of sustainable food systems and better public health outcomes across the globe. There is a need for further investment in research, policy, and community engagement to fully tap the potential of food fortification.

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HUMAN-AI COLLABORATION IN HRM: TRANSFORMING PRACTICES AND FOSTERING INCLUSIVE WORKPLACES

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Abstract:

The use of Artificial Intelligence (AI) in Human Resource Management (HRM) is transforming traditional practices, offering new ways to enhance efficiency and support strategic decision-making. This study delves into the significant impact of AI across various HR functions, including recruitment, performance evaluation, employee engagement, and workforce analytics. By employing technologies such as machine learning, natural language processing, and predictive analytics, AI is automating repetitive tasks while allowing HR professionals to dedicate more time to strategic priorities. Despite these advantages, the integration of AI also brings challenges. Issues such as ethical dilemmas, data privacy concerns, potential biases in algorithms, and the need to upskill HR teams are becoming increasingly relevant. This research takes a closer look at these complexities through real-world case studies from various industries, identifying key strategies for smooth AI adoption. Additionally, the paper highlights the importance of collaboration between humans and AI in creating inclusive workplaces, minimizing disruptions, and ensuring transparency and ethical use of AI systems. The findings aim to provide practical insights for HR professionals, researchers, and policymakers, offering a guide to navigating the rapidly evolving relationship between AI and HRM in today's technology-driven world.

Keywords: AI in HRM, Recruitment and selection, Performance management, Employee Engagement, Retention & Reward system

Introduction

The incorporation of Artificial Intelligence (AI) into Human Resource Management (HRM) has revolutionized traditional HR practices by introducing innovative technologies that enhance efficiency, improve decision-making, and optimize organizational performance. Historically, HRM has been a people-oriented discipline, heavily reliant on human judgment to carry out tasks such as engagement. However, the advent of AI has transformed these processes into more automated and data-driven systems (Achchab & Khallouk, 2023) Technologies such as machine learning, natural language processing (NLP), and predictive analytics now allow HR professionals to automate repetitive and time-intensive tasks like resume screening, interview scheduling, and payroll processing (Meijerink et al., 2020). This automation frees up HR managers to focus on strategic priorities, such as cultivating a positive organizational culture and advancing employee development.

Despite its advantages, the growing presence of AI in HRM brings forth critical considerations regarding the interplay between human judgment and AI systems in managing core HR functions. While AI excels in efficiency and data analysis, the human touch remains vital for addressing complex issues like conflict resolution, understanding employee sentiments, and aligning decisions with organizational values and culture (Tuffaha & Perello-Marin, 2023). Thus, collaboration between AI and human professionals is imperative to leverage AI's computational strengths alongside human creativity, empathy, and ethical reasoning. For instance, while AI can process large datasets to generate insights on employee performance and satisfaction (Aydin et al., 2024) AI in HR practitioners to interpret and apply these insights in a fair and empathetic manner that aligns with organizational goals (Dastin, 2018; Navaei & Pahlevanzadeh,2024).

Furthermore, the integration of AI into HRM poses significant challenges. Concerns have been raised about biases in algorithmic decision-making, as poorly designed AI systems may unintentionally reinforce existing inequalities in recruitment and performance evaluation (Tambe et al., 2019; Chowdhury et al.,2023). This study aims to investigate how AI is reshaping HR functions such as recruitment, performance management, and employee engagement, while also addressing the ethical challenges it presents. Key issues such as algorithmic bias, data privacy, and transparency will be explored, offering actionable recommendations for HR professionals to integrate AI responsibly and equitably into their workflows (Raisch & Krakowski, 2023; Azeem et al.,2023). Ultimately, this research seeks to provide HR leaders with a strategic framework for navigating AI adoption, ensuring that it enhances efficiency while upholding fairness, inclusivity, and human-centric values.

Literature Review

The Role of AI in Recruitment and Selection

AI has significantly influenced recruitment and talent acquisition by automating resume screening and analyzing extensive candidate datasets, enabling HR professionals to identify top candidates more efficiently (Jain & Kaur, 2020). For example, machine learning algorithms can utilize historical hiring data to predict a candidate's potential success in specific roles, improving the precision of hiring decisions (Tambe et al., 2019). Moreover, AI-powered tools like chatbots and virtual assistants are being utilized to enhance the candidate experience by automating tasks such as scheduling interviews and addressing frequently asked questions (Upadhyay & Khandelwal, 2021). Despite the potential to enhance efficiency and minimize bias, there are concerns about algorithmic bias in AI recruitment tools. If the data used to train these systems lack diversity or fail to represent real-world demographics, the systems may inadvertently reinforce biases present in traditional hiring processes (Scherer et al., 2019). This underscores the need for greater transparency in AI decision-making and the implementation of oversight measures to ensure fairness in recruitment (Dastin, 2018).

Performance Management and Employee Engagement

AI has become an integral part of improving performance management by providing data-driven insights. Unlike traditional performance reviews that can be subjective, AI systems analyze diverse employee data, such as work output and peer feedback, to identify performance trends and suggest actionable improvements (Strohmeier & Piazza, 2015). These systems also reduce managerial workload by automating tasks like goal-setting and progress tracking (Jain et al., 2020). Despite these benefits, challenges remain. Employees may have privacy concerns about continuous monitoring or the use of personal data in evaluations. Additionally, AI systems risk perpetuating biases if they are not carefully designed or audited (Raisch & Krakowski, 2021). Ensuring transparency and fairness in AI-powered evaluations is critical for maintaining employee trust (Strohmeier & Piazza, 2015).

Reward and Retention with AI

AI has proven valuable in enhancing employee engagement and retention by equipping HR teams with tools to analyze employee sentiment. Through sentiment analysis, AI processes large datasets, such as employee surveys and communications, to gauge job satisfaction and engagement levels (Azeem et al., 2021). Predictive analytics further supports HR by identifying employees at risk of leaving, using indicators such as declining productivity or negative sentiment. These insights enable HR professionals to implement targeted strategies to improve retention (Hameed & Khan, 2021). Additionally, AI-driven platforms deliver personalized recommendations for professional development, training, and work-life balance initiatives, contributing to overall satisfaction (Zheng et al., 2021). However, these systems must be regularly updated to align with organizational goals, and challenges related to data privacy and ethical considerations must be addressed to safeguard employee trust (Azeem et al., 2021).

AI in Human Resource Management

AI Technologies in HRM

AI technologies are transforming HR functions by enhancing efficiency, decision-making, and predictive capabilities. Key technologies include machine learning (ML), natural language processing (NLP), and predictive analytics (Chien, 2020). Machine learning detects patterns in large datasets, enabling predictions about employee performance and turnover. NLP allows AI systems to process and understand human language, making it useful for recruitment, engagement, and performance evaluations (Cascio & Montealegre, 2016). It also analyzes unstructured data, such as resumes and feedback, to derive insights about candidates and employees. Predictive analytics combines ML and statistical methods to forecast trends like turnover risks and skill gaps, enabling proactive HR decisions (Upadhyay & Khandelwal, 2021). These tools not only streamline processes but also empower HR professionals to make data-informed decisions, enhancing the effectiveness of HRM practices.

.2 Benefits of AI in HR Functions

Integrating AI into HR functions provides numerous benefits, including reducing the time spent on repetitive tasks. Processes such as resume screening, payroll processing, and scheduling are automated, allowing HR professionals to focus on strategic activities (Meijerink et al., 2020). AI also enables more informed decisions by analyzing real-time and historical data to identify trends and provide actionable insights for workforce planning, promotions, and evaluations (Tambe et al., 2019). Furthermore, AI can help reduce hiring biases when algorithms are properly trained to evaluate candidates based on objective criteria, promoting diversity and inclusivity (Scherer et al., 2019). Additionally, AI enhances employee engagement by providing insights into satisfaction levels and enabling targeted interventions. Predictive capabilities allow HR to identify at-risk employees early, improving retention efforts (Zheng et al., 2021).

Challenges of AI implementation in HRM

Challenges in AI Adoption

While AI offers numerous advantages, its adoption and implementation in HRM are not without challenges. One of the primary concerns is the potential resistance from HR professionals and employees. The introduction of AI into HR practices may be met with skepticism, particularly from those who view AI as a threat to their job security (Raisch & Krakowski, 2021). Furthermore, HR teams may lack the necessary technical skills to effectively use AI tools, necessitating ongoing training and upskilling. Another significant challenge is the issue of data

privacy. AI systems require large volumes of data to function effectively, and the collection and processing of employee data can raise concerns about privacy and compliance with data protection regulations, such as the GDPR (General Data Protection Regulation) (Strohmeier & Piazza, 2015). Moreover, the quality of data used to train AI models is crucial. If the data is incomplete, inaccurate, or biased, the outcomes generated by AI systems can lead to flawed decisions that negatively impact employees or organizations (Scherer et al., 2019). Ethical concerns, such as algorithmic bias, are also a major challenge in AI implementation. Even though AI systems can help reduce human biases, they are not immune to perpetuating or amplifying them if not properly designed and tested (Tambe et al., 2019).

Thus, organizations must take deliberate steps to ensure fairness, transparency, and accountability in their AI applications. Integrating artificial intelligence (AI) into human resource management (HRM) practices offers numerous advantages, but achieving successful implementation involves navigating significant challenges. One of the foremost concerns is resistance to change among HR professionals and employees. AI technologies are often perceived as a threat to job security, fueling fears that automation will replace human roles (Raisch & Krakowski, 2021). Specifically, HR professionals may feel apprehensive about AI systems assuming control over core decision-making functions, such as recruitment and performance evaluations. This apprehension stems from concerns about job displacement, as well as a lack of understanding regarding how AI tools can complement rather than replace human expertise. Addressing these challenges requires organizations to adopt strategies that emphasize the role of AI as an augmentation tool, designed to assist HR professionals in their responsibilities rather than eliminate their positions (Meijerink et al., 2020). By fostering a collaborative mindset, organizations can alleviate fears and create a more conducive environment for AI integration.

Another major challenge lies in the data requirements and quality that underpin AI systems. These technologies rely heavily on vast datasets to make accurate predictions and informed decisions. However, the effectiveness of AI is contingent on the accuracy, representativeness, and bias-free nature of the data used. If historical data is skewed or incomplete, the resulting AI-driven recommendations may perpetuate flawed or discriminatory practices (Tambe et al., 2019). For example, recruitment algorithms trained on biased historical hiring data could unintentionally reinforce gender or racial biases, further embedding inequities into the hiring process (Scherer et al., 2019).

Another critical challenge is ensuring that AI technologies are ethical, transparent, and accountable. Ethical concerns related to algorithmic bias, data privacy, and the opaque nature of AI decision-making processes often serve as barriers to adoption (Dastin, 2018). For instance, AI systems that are not carefully designed or monitored may unintentionally replicate biases associated with race, gender, or socioeconomic background, particularly in sensitive areas like hiring decisions. To mitigate these risks, organizations must prioritize the development of fair and unbiased algorithms, conduct regular audits to ensure adherence to ethical standards, and align AI tools with organizational values (Raisch & Krakowski, 2021). Transparency is equally vital; organizations must ensure that both HR professionals and employees understand how AI systems operate and how decisions are made. Such measures are critical for building trust and fostering widespread acceptance of AI in HRM.

Findings

The integration of artificial intelligence (AI) into Human Resource Management (HRM) practices has demonstrated transformative potential, enhancing efficiency, streamlining processes, and supporting strategic decision-making. AI offers significant benefits in areas such

as recruitment, performance evaluation, employee engagement, and workforce analytics, where its ability to process large datasets and generate predictive insights is particularly impactful (Brynjolfsson & McAfee, 2014). By automating routine tasks, AI enables HR professionals to dedicate more time to strategic initiatives, ultimately improving organizational performance. Nevertheless, the adoption of AI in HRM comes with notable challenges. Key concerns include ethical considerations, such as algorithmic bias, transparency, and data privacy. AI systems risk perpetuating biases from historical data, which could result in unfair hiring and evaluation practices (Binns, 2020). Transparency in AI-driven decision-making and clear communication with employees are vital for addressing mistrust and fostering a positive workplace culture. Additionally, the data used to train AI systems must be accurate, representative, and securely managed to minimize the risks of misuse and ensure employee trust (Strohmeier & Piazza, 2015).

Despite these challenges, AI's future role in HRM is poised to drive significant advancements. From enhancing employee engagement and personalizing work experiences to predicting workforce trends, AI's potential to transform HR functions is immense (Tambe et al., 2019). Importantly, its success depends on its ability to function as a collaborative tool that complements human expertise, preserving the value of human judgment and empathy in critical decision-making processes (Raisch & Krakowski, 2021).

Practical Implications and Future direction

For HR professionals, effectively integrating AI into HRM necessitates a shift in both mindset and skillset. Rather than perceiving AI as a threat, HR professionals should view it as a powerful tool to enhance decision-making and improve operational efficiency (Meijerink et al., 2020). Leveraging AI technologies enables HR teams to make data-informed decisions that align with organizational objectives while also enhancing the overall employee experience. Understanding the ethical implications of AI is essential for HR professionals. This includes ensuring fairness, transparency, and accountability in AI applications, with regular audits to identify and mitigate biases (Scherer et al., 2019). Upskilling HR teams is another crucial component of successful AI adoption. Training programs should focus on AI literacy to help HR professionals understand AI systems' capabilities and limitations while equipping them to interpret AI-generated insights effectively (Tambe et al., 2019).

Ongoing professional development is essential to keep HR teams updated on advancements in AI technologies (Brynjolfsson & McAfee, 2014). Position AI as a partner that supports HR professionals rather than a replacement for human expertise. Encourage the use of AI for routine tasks, allowing HR teams to focus on strategic initiatives requiring human judgment and empathy (Raisch & Krakowski, 2021). Transparency will help address employee concerns about bias and discrimination while fostering a positive perception of AI adoption (Liu et al., 2020). Regularly assess the performance of AI systems to ensure they are operating as intended. Feedback mechanisms and audits can help identify biases or ethical concerns, enabling timely corrective actions (Strohmeier & Piazza, 2015).

Future of AI in HRM

The future of AI in HRM is poised to bring transformative changes, with several emerging trends set to redefine HR functions. One of the most notable trends is the growing adoption of AI-driven employee experience platforms. These platforms utilize AI to provide personalized learning opportunities, tailored career development pathways, and well-being initiatives aligned with individual employee needs (Zheng et al., 2021). By analyzing vast amounts of employee data,

AI enables HR professionals to implement dynamic and personalized engagement strategies, thereby improving employee satisfaction and retention. As organizations increasingly rely on AI to anticipate workforce needs, forecast talent shortages, and optimize organizational structures, predictive analytics will become a cornerstone of HR decision-making (Tambe et al., 2019; Upadhyay & Khandelwal, 2021). By leveraging AI's strengths in data analysis and pattern recognition, HR professionals can make more informed decisions while retaining the human judgment and empathy that remain essential in HR practices. This collaborative approach is anticipated to empower HR teams and foster a more balanced integration of technology and human expertise.

Conclusion

Integrating AI into HRM has the potential to revolutionize workforce management, driving efficiency, inclusivity, and innovation. However, ethical, transparent, and employee-centric implementation is critical for realizing these benefits. By addressing challenges such as bias, data privacy, and transparency, organizations can build more inclusive and effective workplaces. The recommendations outlined in this paper provide HR professionals and organizations with a roadmap to navigate AI adoption responsibly, ensuring it serves as a powerful tool for organizational success.

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ENSURING THE STABILITY OF SLOPES USING HUESKER'S INNOVATIVE MATERIALS

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ABSTRACT

Slope stability is vital in civil engineering to ensure the safety and durability of structures like dams, embankments, and retaining walls. HUESKER, a leader in geosynthetics, provides innovative solutions such as geogrid-reinforced slopes and SoilTain geotextile containers, combining reinforcement, cost-efficiency, and environmental sustainability.

These technologies address challenges in steep terrains and diverse soil conditions, offering durable and adaptable alternatives to traditional methods. Successful applications, like the Kalwakurthy Lift Irrigation Scheme in India, demonstrate their effectiveness in balancing safety, cost, and ecological preservation.

With a focus on sustainability, smart materials, and digital tools, HUESKER continues to drive advancements in slope stabilization for resilient and eco-friendly infrastructure.

Key Words: Slope stability, geosynthetics, HUESKER, geogrid-reinforced slopes, SoilTain geotextile containers, civil engineering, sustainable infrastructure, steep terrain, erosion control, dam construction, environmental sustainability, cost-efficiency, smart materials.

INTRODUCTION

Slope stability is a fundamental consideration in civil engineering, essential for ensuring the safety and longevity of structures such as dams, embankments, retaining walls, and earthworks. As global infrastructure demands grow, engineers face increasingly complex challenges, including steep terrain, diverse soil conditions, and the need for environmentally sustainable solutions.

HUESKER, a pioneer in geosynthetics, offers cutting-edge materials and technologies that address these challenges while prioritizing sustainability, cost-efficiency, and durability. Among these technologies, geogrid-reinforced slopes stand out as a versatile solution, particularly for steep and problematic terrains in dam construction. This article explores HUESKER's innovative

geosynthetic products, their applications in civil engineering, and their transformative role in shaping the future of slope stability.

Slope stability refers to a slope's ability to resist failure under the influence of natural and human-induced forces. When a slope fails, it can lead to landslides, erosion, or structural collapses, posing serious risks to human safety, infrastructure, and the environment.

Key factors influencing slope stability include: Soil Properties-Variations in soil composition, cohesion, and internal friction affect the slope's capacity to bear loads. Slope Geometry-The angle and height of a slope directly impact its stability, with steeper slopes being more prone to failure. Water Content-Excessive water from rainfall, seepage, or reservoir fluctuations reduces soil strength and increases the likelihood of slope failure. External Loads- Construction activities, seismic forces, or heavy traffic can impose additional stress on slopes.

Traditional stabilization techniques often involve extensive excavation, concrete retaining walls, or other heavy infrastructure. These methods, while effective, are often expensive, time-consuming, and environmentally disruptive. HUESKER's geosynthetic technologies offer a modern alternative, combining engineering efficiency with environmental sensitivity.

MAINTEXT

HUESKER's geosynthetic solutions are designed to meet the diverse demands of slope stabilization across various terrains and conditions. Their products integrate seamlessly into natural and urban landscapes, providing reinforcement, erosion control, and ecological benefits.

Fortrac Geogrids:

- Material: High-strength polyester or aramid ensures excellent tensile strength and durability;
- Function: Reinforces slopes by evenly distributing loads, reducing shear stresses, and enhancing soil stability;
- Applications: Ideal for steep slopes, retaining walls, embankments, and dam structures;

HUESKER - Fortrac Geogrids

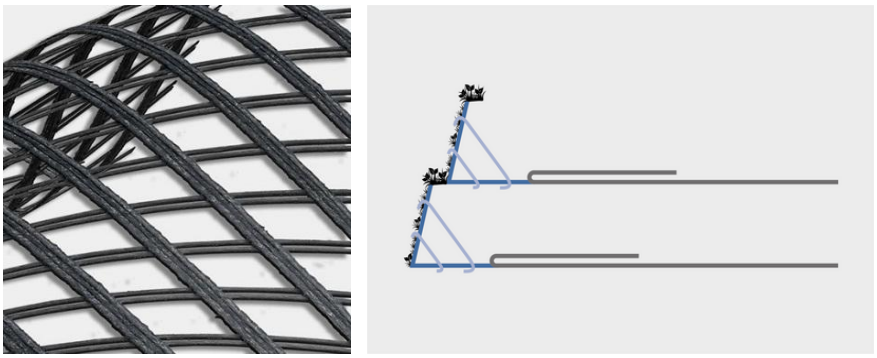
Fortran 3D Geogrids:

- Material: A three-dimensional structure combines mechanical reinforcement with erosion control;
- Function: Stabilizes steep and vegetated slopes, integrating engineering with ecological restoration;
- Applications: Suitable for naturalized slopes in urban parks, roadsides, and environmentally sensitive areas;

HUESKER - Fortran 3D Geogrids

Fortrac Nature:

- Material: Engineered to blend with natural surroundings while supporting vegetation growth.
- Function: Allows for steep inclinations of up to 110° while maintaining aesthetic and ecological value.
- Applications: Perfect for eco-sensitive projects, green walls, and natural embankments.



HUESKER - Fortran nature

SoilTain Geotextile Containers:

- Material: High-strength geotextiles designed for soil stabilization and erosion control.
- Function: Enables the construction of stable slopes in challenging environments, including coastal zones and riverbanks.
- Applications: Used in dams, levees, and marine applications to stabilize soil and prevent erosion.

HUESKER - SoilTain Geotextile Containers

High Geogrid-Reinforced Slopes in Dam Construction - Steep terrains often present significant challenges in dam construction, requiring innovative approaches to ensure slope stability, safety, and environmental harmony. HUESKER's high geogrid-reinforced slopes provide a flexible and effective solution for stabilizing steep and problematic areas.

Applications in Dam Projects: Reservoir Slopes: Stabilizing slopes around reservoirs to withstand water pressure fluctuations and prevent landslides.

Spillways and Embankments: Reinforcing spillways to protect against erosion caused by heavy rainfall and water discharge.

Tailings Dams: Stabilizing steep embankments in mining operations to ensure safety and minimize environmental impact.

Access Roads: Providing stable foundations for roads in steep terrains, ensuring safe and durable access to dam sites.

Case Study: Kalwakurthy Lift Irrigation Scheme, India. In this project, HUESKER's geogrids were employed to stabilize steep embankments, reducing construction costs and ensuring long-term durability. By incorporating geosynthetics, the project achieved a balance between safety, cost-efficiency, and environmental preservation.

Advantages of Geosynthetic Solutions for Steep Terrain - Cost-Effectiveness: Lightweight materials reduce transportation and installation costs; Faster construction compared to traditional methods.

Environmental Benefits: Promotes vegetation growth for natural erosion control; Minimizes excavation and material use, reducing the ecological footprint.

Flexibility and Adaptability: Suitable for complex and irregular terrains; Compatible with both natural and urban landscapes. Enhanced Durability: Resistant to chemical, biological, and UV degradation; Performs reliably under extreme weather and seismic conditions.

Future of HUESKER's Geosynthetics - As infrastructure demands evolve, HUESKER continues to innovate, paving the way for more advanced, sustainable, and efficient solutions in slope stabilization.

Key Trends and Innovations - Sustainability: Development of biodegradable geosynthetics to further reduce environmental impact; Increased use of recycled materials in geosynthetic production. Smart Materials: Integration of sensors for real-time monitoring of slope performance and structural health. Digital Integration: Leveraging tools like Building Information Modeling (BIM) to optimize design and construction processes. Global Applications: Expanding use in climate-resilient infrastructure, flood control systems, and urban green spaces.

CONCLUSION

HUESKER's innovative geosynthetic solutions have redefined slope stabilization, merging engineering precision with environmental stewardship. High geogrid-reinforced slopes exemplify the adaptability and efficiency of these technologies, particularly in challenging projects like dam construction.

By adopting HUESKER's advanced materials, engineers can tackle steep terrains with confidence, ensuring safer, more sustainable infrastructure. As the industry moves toward a future defined by resilience and sustainability, HUESKER's contributions will remain at the forefront, empowering engineers to meet the challenges of tomorrow with innovative and reliable solutions.

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VR SCENARIO RULES FOR COGNITION ASSESSMENT APPS

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ABSTRACT

The integration of Virtual Reality (VR) technology has revolutionized cognitive assessments by providing unparalleled capabilities for simulating real-world tasks and environments. However, the efficacy of assessments hinges on the implementation of well-defined scenario rules. This paper explores these essential rules, outlining their role in ensuring VR cognitive assessments are clear, engaging, and effective for a broad range of users. The cornerstone of this framework is meticulously crafted instructions, focusing on clarity, accessibility, and adaptability. Task design is equally crucial, promoting user engagement through variety, personalization, and meaningful context within the VR scenario. Furthermore, effective pacing and breaks are essential to prevent user fatigue and optimize performance. The provision of timely, actionable, and culturally sensitive feedback is paramount for user motivation and accurate assessment. Finally, safety considerations and user settings tailored to diverse needs ensure an inclusive and secure VR assessment experience. By adhering to these comprehensive scenario rules, VR cognitive assessments can become reliable and user-friendly tools with vast potential for applications in both clinical and educational settings.

Keywords: Virtual Reality, Cognition Assessment, Design Rules, Model Driven Engineering

INTRODUCTION

The evaluation of cognitive function has traditionally relied on standardized pen-and-paper tests or clinical interviews. While these methods have provided valuable insights, they often lack ecological validity, meaning they may not accurately reflect how people use their cognitive skills in real-world settings [1]. Virtual Reality (VR) technology offers a revolutionary approach to cognitive assessment, creating immersive environments that simulate real-world tasks and situations [2]. This immersive nature of VR holds great promise for overcoming the limitations of traditional methods and providing a more ecologically valid assessment of cognitive function. However, unlocking the full potential of VR cognitive assessments hinges on the development and implementation of well-defined scenario rules. These rules serve as a blueprint for constructing VR assessment environments that are not only engaging and interactive but also scientifically sound and reliable [3]. Just as standardized testing procedures ensure consistency and fairness in traditional assessments, VR scenario rules establish a framework for creating VR

experiences that produce accurate and meaningful cognitive data [4]. This paper delves into the key components of VR cognitive assessment scenario rules. We explore how these rules govern various aspects of the VR experience, from the clarity and accessibility of instructions to the design of tasks, pacing, and the feedback provided to users. We will examine the importance of cultural considerations and user settings in ensuring inclusivity and a positive assessment experience for all. Finally, we will discuss safety considerations to guarantee the well-being of users during VR assessments. By outlining these essential VR scenario rules, this paper aims to equip researchers and practitioners with the knowledge necessary to create effective and reliable VR cognitive assessments. As VR technology continues to evolve, adhering to these guidelines will be instrumental in harnessing its potential to revolutionize the field of cognitive assessment and open doors for broader applications in clinical, educational, and research settings.

STATE OF THE ART

The field of virtual reality (VR) for cognitive assessment is rich with diverse applications and studies. Recent studies have used VR to assist stroke survivors in their recovery. By using headsets like the Oculus Rift, patients can engage in virtual activities of daily living, which aids in their rehabilitation [5]. This approach not only helps in regaining lost skills but also provides a safe and controlled setting for patients to practice and improve their cognitive functions.

The development of specialized VR tools for cognitive assessment has also been a focus of research. For instance, the CAVIR system offers an interactive VR kitchen scenario where users can perform tasks that measure various cognitive abilities such as memory, attention, and problem-solving [6]. This immersive tool provides a more engaging and accurate assessment of cognitive functions compared to traditional methods.

Comparative studies indicate that VR is generally preferred over technologies like social robots for cognitive training across diverse demographics [7]. Additionally, VR has been integrated with other technologies such as EEG recording to create comprehensive systems for spatial cognitive training. These systems not only train users on specific tasks but also evaluate their progress over time, offering insights into the effectiveness of VR-based cognitive training [8].

The adaptability of VR is further highlighted in its application across various domains. From aiding children with autism spectrum disorder (ASD) in learning and identifying objects, colors, and animals [9], to helping individuals with schizophrenia practice everyday tasks [10], VR has shown significant potential in improving symptoms and functional capacities. Moreover, VR has been used to assess cognitive impairment in cancer patients [11] and has been well-received by older adults participating in cognitive training programs [12].

Adding to the breadth of VR's applications, [13] introduced a machine learning-based assessment method in a VR supermarket setting using the HTC Vive headset to evaluate early-stage neurocognitive impairment. [14] investigated the effects of an immersive VR nature-trail tour on participants' science learning and cognitive functions, showing positive outcomes compared to traditional walking tours. [15] evaluated the feasibility and acceptance of the DiSCoVR protocol for social cognition training in individuals with Autism Spectrum Disorder (ASD). [16] used EEG signals and game performance data to study cognitive abilities in different VR game modes over time. Lastly, [17] examined cognitive processing abilities in a VR driving system, noting the influence of display type on performance.

These studies collectively illustrate the expanding role of VR in cognitive research, offering innovative ways to assess and train cognitive functions across various populations and conditions. As VR technology continues to evolve, its role in cognitive assessment and rehabilitation is expected to grow, offering new possibilities for patient care and cognitive research.

METHODOLOGY

A structured review was conducted to analyze the design of applications in VR-based cognitive assessment. Our approach involved identifying relevant studies through searches in academic databases such as IEEE Xplore, PubMed, and Google Scholar, using keywords such as “Virtual Reality,” “Cognition,” and “VR Task Design.” We focused on peer-reviewed research from the last decade, selecting studies that examined VR for cognitive assessment or training, provided insights into scenario design and usability, and included empirical findings on task construction. We synthesized the extracted data into a structured framework of key VR scenario rules, ensuring a standardized, user-friendly, and scientifically grounded approach to cognitive assessment. The identified rules are presented in the next section.

VR COGNITION ASSESSMENT SCENARIO RULES

VR scenario rules are guidelines that standardize and optimize virtual environments for cognitive assessment. These rules cover all aspects of the VR experience, including user instructions, task design, feedback mechanisms, and session management. By implementing these rules, researchers and practitioners can create immersive, interactive, and scientifically valid VR-based cognitive assessments.

These rules also enable the automation of virtual cognition evaluation models, with constraints defined using Object Constraint Language (OCL) or other constraint languages to ensure consistency and conceptual model verification.

INSTRUCTION DESIGN

Instruction design rules define how information is communicated to users. Since users may be novices or have cognitive difficulties, interfaces should be adapted to ensure clarity and accessibility. Key principles include:

- **Clarity:** Instructions should be concise and straightforward, avoiding technical jargon. Everyday language and illustrative examples enhance comprehension and ensure accessibility for all users.
- **Accessibility:** Instructions should be available at all times via virtual assistants, on-screen prompts, or subtitles, providing users with immediate guidance as needed.
- **Adaptability:** A "Help" button should offer explanations in multiple formats, such as text, audio, or animations, catering to different learning preferences. Users should also be able to revisit instructions at any time.
- **Timing:** Instructions should be provided just before users need to apply them, ensuring they are retained effectively. Tiered explanations—starting with a brief overview and expanding if needed—help users grasp concepts efficiently.

TASK DESIGN

Tasks in VR-based cognitive assessments evaluate specific cognitive functions. Effective task design follows these principles:

- **Diversity:** A variety of tasks should assess different cognitive domains, such as problem-solving, spatial reasoning, and memory, ensuring a well-rounded assessment of cognitive abilities.
- **Personalization:** Tasks should dynamically adjust in difficulty based on user background and cognitive abilities, ensuring an optimal challenge level.

- **Meaningful Context:** Tasks should be embedded within coherent narratives to enhance engagement and relevance, making assessments feel purposeful rather than arbitrary.
- **Practice Mode:** Before the main assessment, users should have access to a practice mode featuring simplified versions of tasks. This helps them acclimate to the VR interface and controls.

TIMING AND DURATION

Effective scheduling of tasks within VR assessments ensures user engagement and minimizes fatigue.

- **Task Duration:** Individual task durations should align with attention spans (typically 20–25 minutes) to balance challenge and engagement. Visual cues like timers or progress bars help users manage time effectively.
- **Fatigue Prevention:** Real-time monitoring of indicators like gaze time and response time can detect signs of cognitive fatigue. If fatigue is detected, tasks should be shortened, or users should be prompted to take a break.
- **Rest Periods:** Breaks should be scheduled every 15 to 20 minutes to prevent cognitive overload. These intervals should incorporate calming visuals and ambient sounds to aid recovery.

FEEDBACK MECHANISM

Feedback is crucial for guiding users and reinforcing learning. Effective feedback should be:

- **Timely:** Provided immediately after task completion to reinforce learning and allow users to reflect on performance.
- **Actionable:** Focused on practical advice users can apply to improve in subsequent tasks.
- **Multimodal:** Delivered through audio, visuals, and text to accommodate different learning styles.
- **Aligned:** Feedback should correspond to the specific cognitive function being assessed, ensuring relevance.
- **Encouraging:** Language should be positive and constructive to maintain motivation. For example, instead of "You failed to recall the sequence," use "With a bit more practice, you'll master these sequences in no time!"

CULTURAL CONSIDERATIONS

Cultural sensitivity is essential for inclusivity in VR-based cognitive assessments. Considerations include:

- **Language:** Instructions and feedback should be available in multiple languages, ensuring accessibility while respecting cultural nuances.
- **Visuals:** Graphics and symbols should be culturally neutral and inclusive, avoiding imagery that may be offensive or unfamiliar to certain groups.
- **Accessibility:** Features like text-to-speech, alternative visual representations, and closed captions should be available to accommodate diverse user needs.

SETTINGS

Allowing users to customize their VR experience enhances comfort and usability. Key settings include:

- **Customization:** Users should be able to adjust difficulty levels, session durations, and text size to suit their needs.
- **Accessibility Settings:** Options like color contrast adjustments and audio descriptions should be provided to support users with visual or auditory impairments.
- **Privacy:** Clear data collection policies and secure encryption protocols should protect user information, fostering trust and confidence.

SAFETY MEASURES

Ensuring users' physical and emotional well-being in VR environments is critical, especially for cognitive assessments.

- **Physical Safety:** VR scenarios should avoid elements that may cause discomfort, such as simulations of heights or rapid movement, which can lead to disorientation or motion sickness.
- **Emotional Safety:** VR content should be designed to avoid inducing stress or fear. Users should have clear options to exit the experience at any time, and supportive messages should be integrated to maintain a positive emotional state.

To visually represent the framework of VR cognitive assessment scenario rules, the following graph outlines the key components. This diagram provides an easy-to-understand overview of the core rules and their integration into VR-based cognitive assessments.

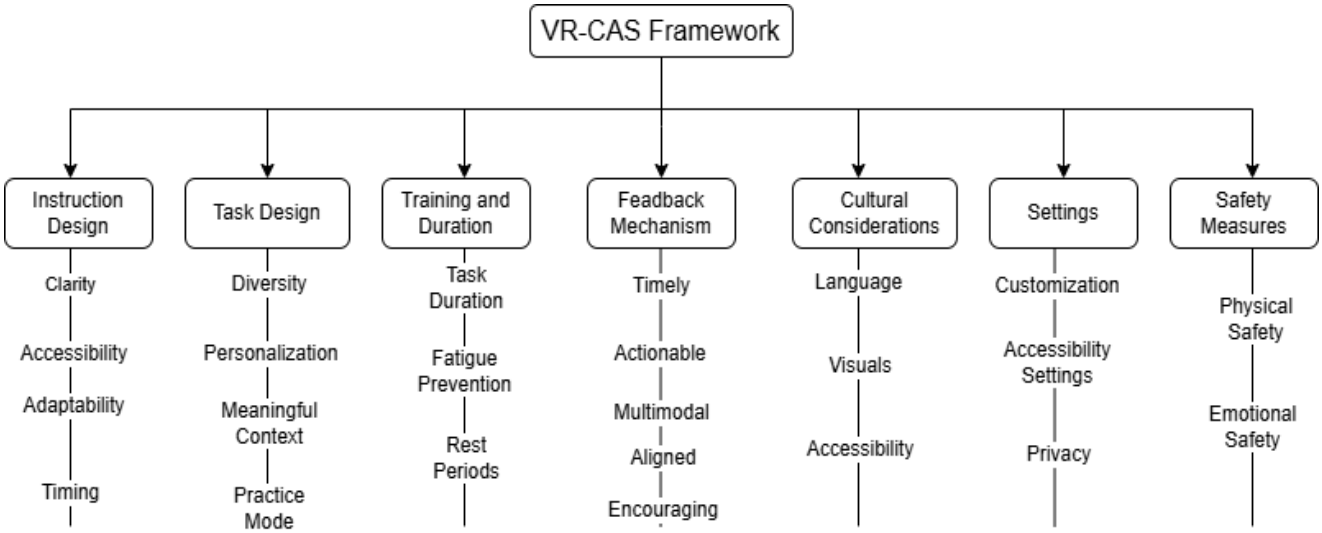

FIGURE 1 VR-CAS FRAMEWORK (VR-COGNITION ASSESSMENT FRAMEWORK)

ADHERENCE OF VR COGNITIVE ASSESSMENT APPS TO SCENARIO RULES

The following table provides an overview of VR applications that align with the proposed scenario rules. Each entry presents a specific rule alongside an example of an application that integrates its principles. These examples highlight how VR is used in cognitive assessment, ensuring clarity, engagement, and accessibility.

Rule Title	Example Application
Instruction Design	The CAVIR system [1] integrates step-by-step virtual guidance, ensuring clarity and accessibility in VR cognitive tasks.
Task Design	A VR-based supermarket scenario [2] incorporates diverse tasks within a meaningful context and a guide session for practice.
Timing and Duration	A study on VR cognitive training [3] implemented fatigue monitoring through response time analysis, ensuring optimal session lengths.
Feedback Mechanism	A VR-based table tennis scenario [4] provided real-time multimodal feedback (audio, visual, and haptic) to enhance user engagement and performance during gameplay.
Cultural Considerations	A VR training system for older adults [12] included localized content and multilingual instructions to enhance accessibility.
Settings	The DiSCoVR protocol for social cognition training in individuals with Autism Spectrum Disorder (ASD) [5] explored user experience factors, including customization aspects. A VR-based learning system for children with ASD [6] provided an adaptive environment tailored to user needs. Another study [7] investigated usability considerations for older adults, emphasizing the importance of user-friendly settings.
Safety Measures	A VR-based therapy for schizophrenia [8] emphasized stress-free environments, reducing anxiety triggers in virtual settings.

FIGURE 2 EXAMPLES OF APPLICATIONS RESPECTING RULES

These examples demonstrate how existing VR applications integrate key scenario rules, reinforcing the importance of a structured framework for VR-based cognitive assessments. By standardizing these principles, future applications can ensure improved usability, reliability, and effectiveness in evaluating cognitive functions.

CONCLUSION

The development and application of scenario rules in VR cognitive assessments are essential for their success. These rules not only enhance the user experience but also ensure the reliability and validity of the assessments. As VR technology continues to evolve, these guidelines will serve as a critical foundation for creating engaging, effective, and respectful cognitive assessment tools. Future research should focus on refining these rules, evaluating their impact on diverse populations, and expanding their application across various cognitive domains. Additionally, ongoing efforts should aim to adapt the framework to emerging VR technologies, ensuring it remains relevant and scientifically robust in the years to come.

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NON-ALCOHOLIC FATTY LIVER DISEASE (NAFLD) AND GUT MICROBIOTA: UNVEILING THE EFFECTS OF PREBIOTICS, PROBIOTICS, AND SYNBIOTICS

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ABSTRACT

Non-Alcoholic Fatty Liver Disease (NAFLD) is a growing public health concern, as it is one of the leading causes of chronic liver disease. NAFLD is defined as the presence of liver fat exceeding 5% of its weight, and it can progress from simple steatosis to non-alcoholic steatohepatitis (NASH), a condition characterized by inflammation, fibrosis, and hepatocyte damage. This progressive condition can potentially lead to cirrhosis or hepatocellular carcinoma. The prevalence of NAFLD is increasing over time, and the development of this disease is shaped by the interaction of dietary habits, environmental factors, and genetic influences. In the pathophysiology of NAFLD, insulin resistance, oxidative stress, and the inflammatory response, which lead to fat accumulation in hepatocytes, are thought to play an important role. However, the exact pathogenesis of NAFLD has not yet been fully elucidated. The gut microbiota plays a significant role in the production of short-chain fatty acids, bile acid metabolism, and maintaining intestinal barrier integrity. However, in the case of dysbiosis, microbiota-derived metabolites and endotoxins can enter the bloodstream, triggering inflammation and oxidative stress in the liver. Recent studies have shown that this mechanism contributes to the development of NAFLD by inducing insulin resistance, hepatic steatosis, necroinflammation, and fibrosis. Although lifestyle changes and dietary interventions are commonly used in the treatment of NAFLD, these approaches generally have limited effects, and there is currently no specific treatment for the disease. A number of studies have indicated that prebiotics, probiotics, and synbiotics may have a positive effect on the treatment of NAFLD. These components may offer benefits in the treatment of NAFLD by improving liver tests, inflammatory markers, insulin resistance, and lipid profiles through the regulation of gut microbiota. The objective of this review is to assess the clinical effectiveness of prebiotics, probiotics, and synbiotics in the treatment of NAFLD.

Keywords: Non-Alcoholic Fatty Liver Disease, Prebiotics, Probiotics, Inflammation, Microbiota

INTRODUCTION

Non-alcoholic fatty liver disease (NAFLD) is recognized as one of the most prevalent chronic liver diseases worldwide. Among its subtypes, non-alcoholic steatohepatitis (NASH) poses a significant risk for progression to severe liver conditions, such as cirrhosis and hepatocellular carcinoma (Anstee et al., 2013). NAFLD is diagnosed based on excessive fat accumulation in hepatocytes, defined as “lipid infiltration in more than 5% of liver cells or constituting over 5% of total liver weight”. The global prevalence of NAFLD has been rising steadily, reaching an estimated 32.4% (Riazi et al., 2022). The condition is widespread across various regions, with the highest prevalence observed in South America (31%) and the Middle East (32%), while

Africa has a relatively lower prevalence of 14% (Younossi, 2016). The development of NAFLD is influenced by genetic predisposition, demographic factors, and environmental and clinical conditions. Lifestyle factors such as poor dietary habits, physical inactivity, inadequate sleep, male gender, obesity, insulin resistance, and type 2 diabetes significantly contribute to NAFLD and liver fibrosis through multiple biological pathways (Huh et al., 2022). Despite its invasive nature, liver biopsy remains the definitive method for diagnosing NAFLD. Currently, no approved pharmacological treatment specifically targets NAFLD. However, therapeutic strategies aimed at improving glucose and lipid metabolism, liver protection, and inflammation reduction, alongside lifestyle and dietary interventions, are key components of NAFLD management (Rong et al., 2023).

Insulin resistance, inflammation, and oxidative stress play critical roles in the progression of NAFLD. Insulin resistance occurs when cells fail to respond effectively to insulin signaling, leading to disturbances in glucose metabolism and lipid homeostasis. Disruptions in the communication between adipose tissue and the liver cause an influx of free fatty acids (FFAs) into the liver, promoting hepatic fat accumulation and NAFLD development. Elevated circulating FFAs, cholesterol levels, and insulin resistance contribute to increased lipolysis, further raising the hepatic FFA load. This excess fat leads to mitochondrial dysfunction, oxidative damage, and lipotoxicity. During the beta-oxidation of FFAs, reactive oxygen species (ROS) are generated, which induce oxidative stress and stimulate the release of inflammatory cytokines such as Tumor Necrosis Factor-α (TNF-α) and Interleukins (IL-6, and IL-1β). This inflammatory response worsens insulin resistance and facilitates the progression from simple steatosis to steatohepatitis (Palma et al., 2022; Marušić et al., 2021).Recent studies emphasize the significant influence of gut microbiota on NAFLD development, with microbial imbalance (dysbiosis) being linked to liver damage. Dietary habits are key in maintaining gut microbiota equilibrium and managing NAFLD. The use of probiotics, prebiotics, and synbiotics has been shown to help restore microbial balance and may contribute to slowing disease progression (Hrncir, 2021; Pan et al., 2024). This research aims to investigate the effects of prebiotics, probiotics, and synbiotics on gut microbiota composition and assess their potential role in NAFLD management.

NAFDL AND GUT MICROBIOTA

Microbiota refers to the diverse community of microorganisms that inhabit a particular environment, including bacteria, fungi, archaea, viruses, and protozoa (Sekirov, 2010). The human gut microbiota is composed of approximately 10^{13} to 10^{14} microbes, with a collective genome (microbiome) containing at least 100 times more genes than the human genome (Gil et al., 2006). The majority of these microorganisms are obligate anaerobes, primarily classified within the phyla Bacteroidetes, Firmicutes, and Proteobacteria. Additionally, certain bacteria present in very low abundance (typically less than 1%) belong to phyla such as Actinobacteria, Verrucomicrobia, Acidobacteria, and Fusobacteria (Dieterich et al., 2018). The composition of gut microbiota is influenced by both host-related and environmental factors. Host-related determinants include immune function, the intestinal barrier (comprising epithelial cells, mucus layers, enzymes, and immune components), and genetic predisposition. Environmental influences encompass dietary patterns, nutrition, mode of delivery at birth, infant feeding practices (breastfeeding or formula feeding), medication and antibiotic exposure, hygiene standards, and lifestyle habits (Thursby and Juge, 2017).The gut microbiota plays a vital role in numerous physiological functions, including nutrient metabolism, drug and foreign substance processing, maintaining the integrity of the intestinal mucosal barrier, immune system regulation, and defense against harmful microorganisms (Jandhyala et al., 2015). However, an imbalance in microbial composition, known as dysbiosis, can disrupt these essential processes. Gut dysbiosis has been linked to various intestinal conditions as well as systemic conditions like allergies, asthma, metabolic syndrome, cardiovascular diseases, and obesity (Carding et al., 2015). In recent years, increasing research has focused on the connection between dysbiosis and NAFLD

(Fukui, 2019).The gut-liver axis regulates communication between the gut and liver. Dysbiosis, or disrupted gut microbiota, increases gut permeability, allowing harmful metabolites to enter the liver, triggering inflammation and contributing to NAFLD progression (Song and Zhang, 2022). In individuals with NAFLD, a reduction in beneficial, anti-inflammatory bacteria such as Ruminococcaceae and Coprococcus is observed, while pro-inflammatory bacteria like Fusobacterium and Escherichia tend to be more abundant (Su et al., 2024).

Gut microbiota metabolites also play a key role in NAFLD progression. Short-chain fatty acids (SCFAs) like butyrate and propionate support gut health, decrease inflammation, and enhance insulin sensitivity. Bile acids regulate lipid and glucose metabolism preventing liver fat accumulation. Trimethylamine N-oxide from choline metabolism contributes to hepatic fat storage and inflammation, while bacterial ethanol weakens the intestinal barrier and promotes inflammation. These metabolites influence liver health through the gut-liver axis (Carpi et al., 2022).

EFFECTS OF PREBIOTICS, PROBIOTICS, AND SYNBIOTICS ON NAFLD

Diet plays a vital role in maintaining gut microbiota balance. NAFLD management emphasizes energy restriction, reducing simple sugars, and ensuring sufficient omega-3 and fiber intake. Given the strong association between gut dysbiosis and NAFLD progression, dietary interventions targeting microbiota restoration hold promise. Research suggests that probiotics, prebiotics, and synbiotics can help rebalance gut microbiota and provide benefits for NAFLD patients (Moszak et al., 2021).

Probiotics are defined as “live microorganisms that provide health benefits when consumed in sufficient amounts” (FAO/WHO, 2001). Common probiotics include Lactobacilli, Streptococci, and Bifidobacteria, which naturally reside in the human gut. Their benefits stem from three key mechanisms: they compete with pathogens to maintain microbiota balance, produce antimicrobial compounds like organic acids and SCFAs to inhibit harmful microbes, and regulate immune function by activating T-cells and cytokine production. These effects contribute to managing conditions such as hypertension, allergies, diabetes, irritable bowel syndrome, liver diseases, and immune disorders (Abatenh et al., 2018; Das et al., 2022).

In the context of NAFLD, probiotics have shown promise in modifying the gut microbiota, providing protective benefits through mechanisms such as pathogen exclusion, production of antimicrobial substances, and enhancing gut barrier integrity (Iacono et al., 2011). Several studies have explored the therapeutic potential of probiotics for NAFLD patients. Probiotic supplementation has been linked to better liver enzyme activity, enhanced lipid metabolism, improved insulin sensitivity, and lower levels of inflammation (Arellano-García et al., 2022). For instance, a placebo-controlled trial investigating the effects of VSL#3 probiotics over three months found significant reductions in triglycerides, high-sensitivity C-reactive protein (Hs-CRP), transaminases, and γ-glutamyl transferase (γ-GT), despite no notable changes in body mass index (BMI), waist circumference, fasting plasma glucose, or lipid profiles. Additionally, hepatic parameters improved, as evidenced by a reduction in the aspartate aminotransferase (AST)/Alanine aminotransferase (ALT) ratio and hepatic steatosis (Derosa et al., 2022).

However, results from other trials have been more variable. In a randomized controlled trial, 12 weeks of probiotic therapy led to improvements in ALT, AST, and BMI, but no significant effects were observed on the NAFLD fibrosis score (Abd El Hamid et al., 2024). In contrast, an 8-week trial involving kefir consumption (500 cc/day) showed no significant changes in liver aminotransferases or metabolic markers, except for increases in high-density lipoprotein cholesterol (HDL-C) and fat-free mass (Mohammadi et al., 2025).

Recent systematic review and meta-analyses study indicated that probiotics may offer benefits such as enhanced insulin sensitivity and improved ALT levels in NAFLD patients (Mozaffari et al., 2024). Furthermore, research comparing traditional probiotics with next-generation probiotics (NGPs) suggests that while traditional probiotics can help improve gut microbiota and reduce liver fat accumulation and inflammation, NGPs may offer enhanced therapeutic effects. These newer probiotics have been shown to reduce oxidative stress and increase SCFA production (Zhu et al., 2024). Overall, while probiotics show promise as part of a holistic approach to managing NAFLD, further research is needed to better understand the mechanisms and optimize treatment strategies.

Prebiotics, as defined by Gibson and Roberfroid (1995), are “non-digestible food components that selectively stimulate the growth and/or activity of beneficial bacteria in the colon, thereby improving host health”. Among various substances evaluated for their prebiotic potential, four have well-established effects: inulin, fructo-oligosaccharides (FOS), galacto-oligosaccharides (GOS), and lactulose. These compounds can naturally be found in foods such as chicory, onions, artichokes, asparagus, bananas, garlic, and soybeans (Thammarutwasik et al., 2009). These prebiotics have been associated with various positive effects, including supporting the growth of helpful gut microbiota, particularly Bifidobacterium and Lactobacillus species. They also contribute to the production of beneficial metabolites, enhance mineral absorption, and help reduce pathogen populations in the gut. Moreover, prebiotics play a key role in improving immune function, regulating lipid metabolism, and lowering the risk of certain cancers. They also show promise in managing inflammation and obesity (Ferreira et al., 2023).

Prebiotics may also alleviate liver fat accumulation by modulating the gut microbiota, promoting SCFA production, and regulating lipid metabolism while lowering ammonia levels. Additionally, they could serve as adjunctive treatment for NAFLD by improving insulin sensitivity and addressing metabolic dysfunctions (Iacono et al., 2011). In a recent placebo controlled trial, participants were given 16 g/day of inulin-type fructans for 12 weeks. The study observed a significant increase in Bifidobacterium levels in the prebiotic group, but no substantial changes were noted in liver fat content, liver enzyme levels, or inflammatory markers. Additionally, body weight didn’t change in both groups (Reshef et al., 2024). Supporting evidence from a systematic review indicated that a 10-12 week supplementation regimen with 10-16 g daily doses of psyllium, Ocimum basilicum, inulin, or oligofructose powders resulted in notable improvements in several metabolic and liver-related biomarkers, including BMI, AST, fasting insulin levels, and insulin resistance (HOMA-IR) in NAFLD patients. These findings suggest that fiber supplementation, particularly prebiotics, may lead to beneficial modifications in both metabolic and liver function parameters in individuals with NAFLD (Stachowska et al., 2020).

Synbiotics, which combine probiotics and prebiotics, exert a synergistic effect by enhancing the survival and function of probiotics while offering targeted health benefits (Sekhon and Jairath, 2010). In an early-stage NAFLD model, a study involving synbiotic yogurt containing Streptococcus Bifidobacterium, Streptococcus thermophilus, and the prebiotic inulin demonstrated positive changes in key biochemical markers, including cholesterol, triglycerides, low-density lipoprotein cholesterol (LDL-C), HDL-C, and insulin resistance. This synbiotic intervention improved lipid metabolism, mitigated inflammation and addressed gut barrier dysfunction induced by a high-fat diet. Additionally, it led to significant alterations in the gut microbiota, particularly influencing the Firmicutes/Bacteroidetes ratio (Zhang et al., 2024). Moreover, Musazadeh et al. (2024) observed that synbiotic supplementation led to significant improvements in liver enzymes (AST, ALT, gamma-glutamyl transferase (GGT)), lipid profiles (total cholesterol), obesity-related indices (body weight, waist circumference), systolic blood pressure, and inflammatory markers (CRP, TNF-α). Notably, among NAFLD patients, synbiotics resulted in the most substantial reductions in AST, waist circumference, total cholesterol, LDL-C, and fasting plasma glucose compared to a placebo. On the other hand, probiotics were more effective in reducing ALT and triglycerides. However, no treatment significantly impacted BMI, HDL-C, or HOMA-IR (Kanchanasurakit et al., 2022). These findings collectively underscore the potential of synbiotics as a beneficial adjunctive treatment in managing NAFLD and its associated metabolic disturbances.

Supporting these findings, a meta-analysis by Song et al. (2025) confirmed that both probiotics and synbiotics significantly reduced ALT, AST, BMI, HOMA-IR, and liver stiffness, indicating their therapeutic potential in NAFLD. Similarly, a systematic review by Pan et al. (2024) highlighted the improvements in liver enzymes, lipid profiles, and inflammatory markers with the supplementation of probiotics, prebiotics, and synbiotics. Further, Ding et al. (2024) noted that prebiotics, probiotics and synbiotics could help regulate glucose homeostasis in individuals with NAFLD. Synbiotic therapy has also been shown to effectively lower liver enzymes (ALT and AST), improve lipid profiles, and regulate glucose levels, while simultaneously reducing pro-inflammatory cytokines such as TNF-α (Fadhilah et al., 2024).

CONCLUSION

In conclusion, emerging evidence strongly supports the beneficial role of probiotics, prebiotics, and synbiotics in managing NAFLD. These interventions have demonstrated significant improvements in liver function markers, lipid profiles, insulin sensitivity, and inflammatory parameters. Probiotics and synbiotics, in particular, have shown promising effects in reducing liver enzymes, triglycerides, and inflammatory cytokines, while also improving glucose metabolism. Prebiotics, though beneficial for gut microbiota modulation, may require further exploration to confirm their efficacy in improving liver fat content and metabolic outcomes in NAFLD. Synbiotics, combining both probiotics and prebiotics, appear to offer the most comprehensive therapeutic potential by restoring gut microbiota balance, enhancing lipid metabolism, and alleviating inflammation. These findings highlight the importance of gut health in NAFLD management, suggesting that diet-based strategies aimed at restoring microbial balance could be a promising adjunct to conventional treatments for NAFLD. However, more extensive and long-term studies are necessary to establish the optimal formulations and treatment durations for these interventions in NAFLD patients.

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CHEMOMETRIC ANALYSIS-ASSISTED FOURIER TRANSFORM INFRARED SPECTROSCOPY (FTIR) IN THYROID CANCER: AN INNOVATIVE APPROACH TO DETERMINING DIAGNOSIS AND TREATMENT EFFICACY

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ABSTRACT

Thyroid cancer is a common type of cancer worldwide and is asymptomatic in the early stages. This necessitates the development of effective methods for accurate and early diagnosis. Although traditional diagnostic methods such as biopsy and ultrasound are effective, they need improvement due to their invasiveness and limited accuracy. Fourier Transform Infrared Spectroscopy (FTIR) is a promising method for detailed analysis of chemical components in biological tissues. FTIR measures molecular vibrations by examining the interaction of biological samples with infrared light, providing detailed information on the samples' chemical composition. The FTIR data obtained were processed using chemometric analyses to determine the differences between cancerous and healthy tissues. These data were also used to monitor responses during the treatment process. Methods used in Thyroid Cancer Diagnosis are: Tissue Analysis: FTIR can be used to analyze thyroid tissue samples to determine spectral differences between healthy and malignant tissues. Biomarker Identification: Specific spectral features can be associated with cancerous changes and may help identify biomarkers for thyroid cancer. Chemometric Analysis; Data Interpretation: Chemometric techniques such as principal component analysis (PCA) and partial least squares regression (PLSR) are used to interpret complex spectral data and increase diagnostic accuracy. Analysis with FTIR spectroscopy has revealed that tissue samples from thyroid cancer patients exhibit chemical compositions that are significantly different from healthy tissues. In particular, the density of lipid and protein components differs between cancerous and healthy tissues. Furthermore, while monitoring the treatment process, FTIR data successfully reflected patients' responses to treatment. Supported by chemometric analysis, FTIR was able to distinguish between cancerous and healthy tissues with high accuracy. This study shows that FTIR spectroscopy can be an important method in thyroid cancer diagnosis and treatment monitoring process. As a non-invasive method, FTIR provides fast and reliable results compared to biopsy and other conventional techniques. It also offers significant advantages in monitoring responses to treatment and personalizing patients' treatment processes.

Key Words: Thyroid cancer, FT-IR Spectroscopy; Chemometric Analysis, Diagnosis, Treatment Efficacy

INTRODUCTION

Thyroid cancer is a type of cancer that can often be confused with benign diseases and is usually asymptomatic at an early stage. Early diagnosis increases the treatability of the disease while monitoring treatment efficacy can improve the long-term survival of patients. Traditional diagnostic methods are usually invasive, time-consuming, and expensive. At this point, non-invasive techniques such as FTIR spectroscopy can contribute to clinical practice. FTIR analyses the vibrational motion of molecules due to the interaction of samples with infrared rays 1. These analyses provide information on the structure of organic compounds, especially proteins, lipids, and nucleic acids. Since the biochemical components of cancer cells differ from those of normal cells, FTIR has the potential to reveal these differences[2]

FTIR and Chemometric Analyses: FTIR spectra often generate complex data sets. Chemometric methods are used to interpret these data correctly. Chemometrics allows the data to be analyzed using mathematical and statistical methods. Techniques such as PCA (Principal Component Analysis) and PLS (Partial Least Squares) are frequently used to classify and model FTIR data. These techniques are powerful tools for identifying biochemical differences between cancerous and healthy cells [3]

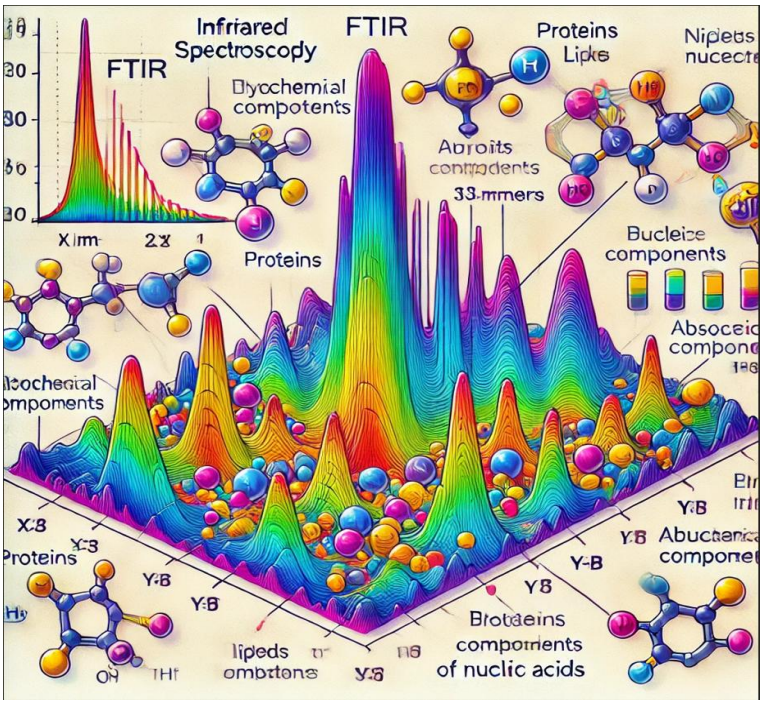

Figure 1. Image showing the main features of FTIR spectra.

Role in Diagnosis: FTIR can be used as an alternative method to biopsy and histopathological examinations to diagnose thyroid cancer. Analyses at the molecular level can determine the presence and type of cancer. In particular, changes in cancerous cells' lipid and protein components of cancerous cells can be detected through FTIR spectra. Chemometric analyses enhance disease diagnosis by accurately classifying these spectra. [1]

Monitoring Treatment Efficacy: After treatment, biochemical changes in cancer cells can be monitored by FTIR and chemometric analyses. For example, after chemotherapy or radiotherapy, analyzing cells that respond and do not respond to treatment can be used to determine the effectiveness of treatment protocols. FTIR data can be helpful in detecting improvement or progression in the treatment process [2,4]

METHODOLOGY

Schmitt M. et al. 2022 reviewed the applications of Fourier Transform Infrared Spectroscopy (FTIR) and chemometric analyses in cancer diagnosis. FTIR can rapidly and non-invasively analyze the molecular level changes of biological samples. Differences in the biochemical components of cancerous tissues can be detected through FTIR spectra. Chemometric techniques have great potential in determining cancer's presence, type, and stage by analyzing these spectra. The article discusses the essential advantages and limitations of FTIR in cancer diagnosis.[3] Zhang, X. et al. 2019, examine the classification of thyroid cancer tissues by Fourier Transform Infrared Spectroscopy (FTIR) and chemometric analyses. In the study, FTIR spectra of healthy and cancerous thyroid tissues were compared, and an accurate classification was made using chemometric methods. Chemometric analyses include Principal Component Analysis (PCA) and Partial Least Squares (PLS). These techniques extract meaningful information from FTIR data and provide an effective means to confirm the diagnosis of thyroid cancer[4]. Miljkovic, M., et al. In their study in 2020, This review article examines the latest developments and applications of FTIR spectroscopy in cancer diagnosis. It is emphasized that FTIR offers an effective method to analyze changes in the biochemical composition of cancer cells[5]. In recent years, the sensitivity of FTIR technology has increased and its combination with chemometric analyses has enabled more accurate and rapid identification of cancer [6]. In this paper, we discuss how FTIR has been applied to different types of cancer, especially skin, breast, and thyroid cancer. This study shows that FTIR has a high potential to detect early stages of cancer diagnosis. Thanks to technological advances, FTIR's accuracy has increased. Dutta, S., et al. examine the role of FTIR spectroscopy in "precision oncology" (personalised cancer treatment) in a study they conducted in 2023. FTIR stands out as a fast, accurate, and non-invasive method to detect cancer cells' genetic and biochemical profile. It is emphasized that FTIR can be used to develop more personalized approaches for cancer treatment. Furthermore, this paper also addresses the potential of FTIR in the early detection of cancer. According to the results obtained in this article, FTIR plays an essential role in implementing personalized cancer therapy. FTIR is a rapid and non-invasive method for genetic and biochemical profiling. FTIR can detect biochemical changes even in the early stages of cancer [7]

CONCLUSION AND DISCUSSION

FTIR and chemometric analyses are essential in determining the effectiveness of thyroid cancer diagnosis and treatment. These technologies may enable faster, more reliable, and non-invasive cancer detection. It may also contribute to developing individualized approaches in the treatment process. However, the clinical use of these methods requires further research and validation.

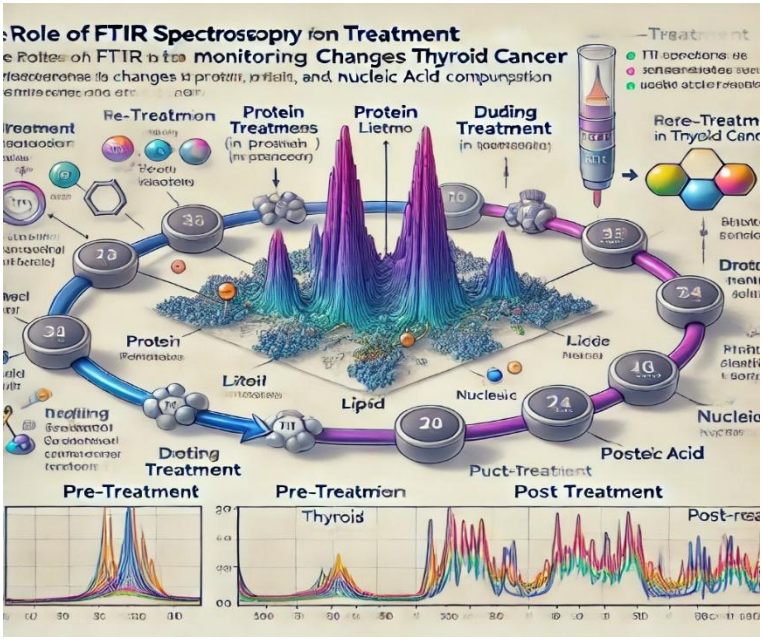

Figure 2. A graph or chart highlighting the process of monitoring response to treatment.

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CHEMOMETRIC ANALYSIS-ASSISTED RAMAN SPECTROSCOPY IN THYROID CANCER: AN INNOVATIVE APPROACH TO DETERMINING DIAGNOSIS AND TREATMENT EFFICACY

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ABSTRACT

Thyroid cancer is one of the most common types of endocrine cancer worldwide. The fact that it is asymptomatic in the early stages and is often discovered incidentally makes the diagnosis of this disease. Traditional diagnostic methods include biopsy, ultrasonography, and fine needle aspiration biopsy (FNAB), but the limitations of these methods require developing innovative strategies for accurate and early diagnosis. Raman spectroscopy combined with chemometric analysis shows promise as a potential method for diagnosing thyroid cancer and evaluating treatment efficacy. This study used Raman spectroscopy and chemometric analysis methods to investigate thyroid cancer patients' biological changes in thyroid tissues. Raman spectroscopy reveals the differences between cancerous and healthy tissues by determining the chemical components of biological samples. Statistical and mathematical methods were used to analyze the spectroscopic data obtained. Chemometric analysis plays a vital role in classifying the data and improving the accuracy of tumor characteristics. In the diagnosis of thyroid cancer, the Raman Spectroscopy technique allows the identification of molecular vibrations in tissue samples. This technique analyzes Raman spectra to distinguish cancerous and non-cancerous tissues according to their molecular composition. Chemometric analysis-assisted Raman spectroscopy has achieved higher accuracy rates in thyroid cancer diagnosis than conventional methods. Chemical differences between cancerous and healthy tissues were clearly identified, and these differences were associated with characteristics specific to cancerous tissue. The treatment responses of patients in the treatment process were monitored with spectroscopic data and valuable information on treatment efficacy was obtained. When combined with chemometric methods, Raman spectroscopy achieves high sensitivity and specificity in the detection of cancerous changes. This study demonstrates that chemometric analysis-assisted Raman spectroscopy has significant potential in early thyroid cancer diagnosis and treatment efficacy monitoring. This technique, which offers a less invasive approach than conventional biopsy and imaging methods, may increase its usability in clinical practice. In addition, it contributes to the personalization of treatment processes, allowing a more precise evaluation of patients' responses to treatment.

Key Words: Thyroid cancer, Raman Spectroscopy; Chemometric Analysis, Diagnosis, Treatment Efficacy

INTRODUCTION

Thyroid cancer is a type of cancer that is common worldwide, and the treatment process can be quite complex. Early diagnosis and monitoring of treatment efficacy are critical to improve the prognosis of patients. Conventional methods offer limited accuracy and sensitivity in diagnosing thyroid cancer and monitoring treatment responses [1]. Traditional methods offer limited accuracy and sensitivity in diagnosing thyroid cancer and monitoring treatment responses [2]. Raman spectroscopy has the potential to revolutionise diagnosis and treatment processes by analysing the chemical components of biological samples at the molecular level [3]. Integration of chemometric analysis techniques with Raman data provides more accurate and reliable results [4].

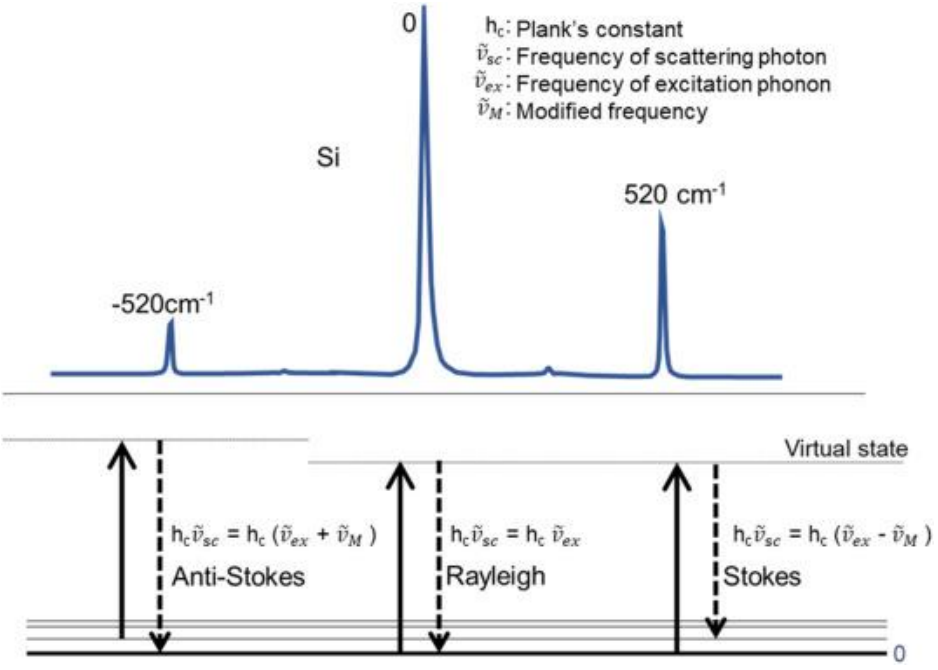

Figure 1. Schematic representation of Raman shift

Raman Spectroscopy: Basic Principles and Applications

Raman spectroscopy is a method of analysis in which, when a laser light strikes a sample, the light is reflected chiefly, but some of it undergoes a frequency change[5]. This frequency change reflects the chemical structure and components of the sample [6]. In diagnosing diseases such as thyroid cancer, this technique is very effective for determining the biochemical profiles of cells and metabolic changes associated with cancer [7]. This method is notable for its ability to detect changes at the cellular level in a non-invasive and rapid manner [8]

A wide variety of methods are used in Raman spectroscopy to compare spectroscopically obtained data with tissue types for diagnostic evaluation. Raman bands, statistical models or classification algorithms are widely used to distinguish tissue types [9]. Figure 2 shows the Raman spectra of the surgically removed brain tissue in the 400-1800 cm-1 spectral region. In this spectrum, tissues evaluated as normal (gray matter and white matter), tumor (GBM), infiltrating tumor and necrosis according to histopathology are seen.

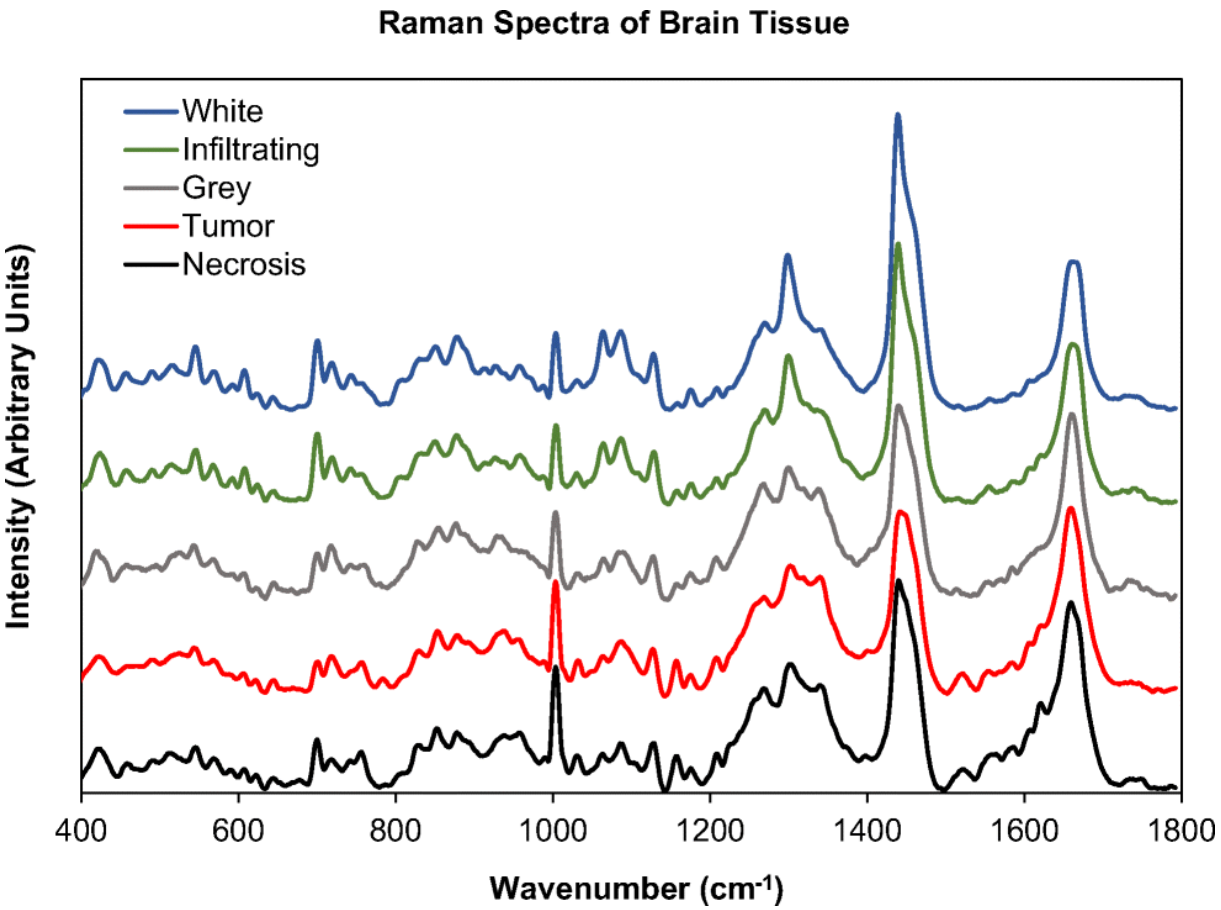

Figure 2. Brain tissue samples in the spectral range of 400-1800 cm-1 [9].

Chemometric Analysis: Processing of Raman Data

Raman spectroscopy produces large amounts of data. However, these data are complex and multidimensional. Chemometric analysis plays a vital role in processing and interpreting these data [10]. Chemometric techniques analyze data using mathematical and statistical methods, allowing, for example, cancerous cells to be distinguished from healthy cells [5]. In particular, methods such as principal component analysis (PCA), discriminant analysis, and support vector machines (SVM) enable accurate classification and interpretation of Raman data [11].

Raman Spectroscopy and Chemometric Analysis in the Diagnosis of Thyroid Cancer

Raman spectroscopy in diagnosing thyroid cancer offers the opportunity to distinguish cancerous cells from healthy cells by analyzing the chemical components of cells or tissue samples[12]. Integration of chemometric analysis techniques further enhances this discrimination. For example, specific biomolecular changes in thyroid cancer cells appear as distinct peaks in Raman spectra [13]. Analysis of these peaks may be effective in identifying early stages of cancer [6].

CONCLUSION AND DISCUSSION

Chemometric analysis-assisted Raman spectroscopy in thyroid cancer has great potential for early diagnosis and monitoring treatment efficacy [14]. This innovative approach can increase the accuracy of cancer diagnosis, speed up treatment processes, and improve patients' quality of life [11]. Integrating these technologies into clinical practice and future studies could provide revolutionary developments in thyroid and other types of cancer [15].

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METASEZGİSEL YÖNTEMLERLE 0-1 KNAPSACK PROBLEMİNİN ÇÖZÜMÜNDE MODERN YAKLAŞIMLAR

MODERN APPROACHES TO SOLVING THE 0-1 KNAPSACK PROBLEM WITH METAHEURISTIC METHODS

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ÖZET

0-1 Knapsack problemi, kombinatorik optimizasyon alanında önemli bir yer tutmakta ve lojistik planlama, kaynak tahsisi ve portföy optimizasyonu gibi çeşitli pratik uygulama alanlarında karşımıza çıkmaktadır. Bu çalışmanın ana amacı, tabu arama algoritması gibi bir metasezgisel yaklaşımın, bu problemi çözmede etkili bir alternatif sunduğunu ortaya koymaktır. Çalışma, tabu arama algoritmasının temel prensiplerini, yerel arama mekanizmalarını ve tabu listesi yapısını detaylı bir şekilde incelemekte ve algoritmanın performansını farklı veri setleri üzerinde test etmektedir. 50 eşyalık bir veri seti üzerinde yapılan testlerde, optimal çözüm %98 doğruluk oranı ile elde edilirken, hesaplama süresi 10 saniyenin altında kalmıştır. Ayrıca, daha büyük veri setlerinde (100-200 eşya) tabu arama algoritması, literatürdeki diğer yöntemlerle benzer performans sergileyerek başarılı sonuçlar elde etmiştir. Elde edilen bulgular, tabu arama algoritmasının hem çözüm kalitesi hem de hesaplama süresi açısından literatürdeki diğer yöntemlerle rekabet edebileceğini göstermektedir. Örneğin, genetik algoritmalara kıyasla daha düşük hesaplama süresi sağlarken, parçacık sürü optimizasyonu ile benzer çözüm kalitesi elde edilmiştir. Tabu arama algoritması, özellikle büyük veri setlerinde yerel arama yöntemlerine göre daha kararlı bir performans sergilemiştir. Bu çalışma, metasezgisel yöntemlerin optimizasyon problemlerindeki çözüm potansiyelini vurgulamakta ve tabu arama algoritmasının belirli problem türlerinde sağladığı avantajları ön plana çıkarmaktadır. Özellikle lojistik planlama ve kaynak tahsisi gibi uygulamalarda maliyetlerin optimize edilmesi ve verimli rota belirleme konularında etkili sonuçlar elde edilmiştir. Bu bulgular, gelecekteki çalışmalara yön verebilecek önemli bir katkı sağlamaktadır.

Anahtar Kelimeler: 0-1 Knapsack Problemi, Metasezgisel Yöntemler, Yerel Arama, Tabu Search

ABSTRACT

The 0-1 Knapsack problem holds a significant place in combinatorial optimization and appears in various practical application areas such as logistics planning, resource allocation, and portfolio optimization. The main goal of this study is to demonstrate that a metaheuristic approach, such as the Tabu Search algorithm, provides an effective alternative for solving this problem. The study thoroughly examines the basic principles of the Tabu Search algorithm, local search mechanisms, and the structure of the tabu list, while testing the algorithm's performance on different datasets. In tests conducted on a dataset with 50 items, the optimal solution was achieved with 98% accuracy, and the computation time remained under 10 seconds. Additionally, on larger datasets (100-200 items), the Tabu Search algorithm showed similar performance to other methods in the literature, yielding successful results. The findings indicate that the Tabu Search algorithm is competitive with other methods in terms of both solution quality and computation time. For example, it provided a lower computation time compared to genetic algorithms, while achieving similar solution quality as particle swarm optimization. Furthermore, the Tabu Search algorithm exhibited more stable performance than local search methods, especially on larger datasets. This study highlights the solution potential of metaheuristic methods in optimization problems and emphasizes the advantages offered by the Tabu Search algorithm for specific problem types. Particularly, in applications like logistics planning and resource allocation, it has shown effective results in cost optimization and efficient route planning. These findings provide a significant contribution that could inspire future research.

Key Words: 0-1 Knapsack Problem, Metaheuristic Methods, Local Search, Tabu Search

GİRİŞ

0-1 Knapsack Problemi (KP), belirli kapasiteli bir çanta ve bu çantaya yerleştirilecek n adet eşya ile ilgili bir NP-zor optimizasyon problemidir. Bu problemde, her bir eşya ya bütün olarak çantaya alınır ya da hiç alınmaz; bu, ismindeki "0-1" terimini açıklar. Matematiksel olarak, n eşyanın her biri için w_i ağırlık ve v_i değerleri tanımlanmıştır. Eşyaların çantaya koyulub koyulmadığı durumunu belirten x_i (0 veya 1) karar değişkeni problemi ifade eder. Amaç, çantanın kapasitesini aşmayacak şekilde bu eşyalardan bir alt küme seçerek toplam karı maksimize etmektir [1]. Daha resmi bir ifadeyle, 0-1 Knapsack problemi aşağıdaki ile tanımlanabilir:

Maximize $\sum_{i=1}^{n} v_i x_i$ (1)

Kısıt $\sum_{i=1}^{n} w_i x_i \leq C$ (2)

$x_i \in \{0,1\}$, $\forall_i \in \{0,1,\ldots\ldots,n\}$ (3)

Burada, x_1 , x_2 , … , x_n ikili değişkenler karar değişkenleri olarak işlev görür ve bir eşyanın çantaya konulup konulmayacağını belirler. Problem parametreleri C , n , w_1, w_2, … , w_n ve v_1 , v_2 , … , v_n, girdi olarak verilir. Bu çalışmanın devamında, tüm problem parametrelerinin kesinlikle pozitif tam sayılar olduğunu, ağırlıkların azalmayan sıra ile düzenlendiğini (yani, $w\ 1 \geq w\ 2 \geq \cdots \geq w\ n$), çantanın aynı anda tüm eşyaları alamayacağını (yani, $\sum i = n$ $w_i > c$) ve her bir eşyanın tek başına çantaya konabileceğini (yani, $w_i \leq c$, $\forall\ i : 1 \leq i \leq n$) varsayıyoruz [2].

0-1 Knapsack problemi, birkaç önemli optimizasyon problemiyle yakından ilişkili önemli bir optimizasyon problemidir. Örneğin, sınırlı knapsack problemi, sınırsız knapsack problemi ve ikili tam sayılı programlama gibi problem örnekleri, 0-1 knapsack problemine eşdeğer bir problem örneği çözülerek çözülebilir [3]. 0-1 Knapsack problemi ayrıca kesim stok problemi için bir sütun oluşturma alt problemi olarak ortaya çıkar [4] ve geniş bir problem çeşitliliğinin özel bir durumudur (örneğin, seyahat eden hırsız problemi, çatışmalı knapsack problemi ve çok boyutlu knapsack problemi [5].

Zor optimizasyon problemleri, doğru yöntemlerle makul bir zaman diliminde optimal çözüme ulaşılamayan problemler olarak ifade edilebilir. Bu tür karmaşık problemler için uygun çözümler bulmak amacıyla meta sezgisel yöntemler kullanılabilir. Çeşitli zorlu optimizasyon sorunları, özel bir problem adaptasyonu gerektirmeden genellikle bir meta sezgisel algoritma ile yaklaşık olarak çözülür. Belirli problemleri çözmek için etkin tekniklerin bulunmadığı durumlarda, meta sezgiseller bu tür sorunları çözmek için sıkça tercih edilir. Finans ve mühendislik gibi alanlarda karmaşık sorunları çözmek için geniş bir kullanım alanına sahiptirler. Meta sezgiseller, biyoloji, fizik ve etoloji gibi disiplinlerden ilham alarak doğa bazlı yaklaşımlar benimserler ve soruna uygun çeşitli kontrol parametreleri ile bağımsız değişkenler kullanırlar [6]. Meta sezgiseller, keşif ve sömürü olmak üzere iki aşamadan oluşur. Belirli bir optimizasyon problemi için başarılı bir meta-sezgisel algoritma, keşif ve sömürü arasında dengeli bir yapı sağlayabilir. Keşif, arama alanının bölümlerinde yüksek kaliteli çözümler belirlerken, sömürü artan arama uzmanlığının çeşitli bölgelerinde aramayı yoğunlaştırır. Bu dengenin sağlanması, mevcut meta sezgiseller arasındaki ana farkı oluşturur. Son yirmi yılda, meta sezgisellere büyük bir ilgi gösterilmiştir [7].

LİTERATÜR ÇALIŞMASI

Literatürde KP01 problemi için çeşitli algoritmalar önerilmiştir. Bu algoritmaların çoğu kesin yaklaşımlarla ilgilenir. Bu bölümde, KP problemi çözmek için kullanılan çeşitli yaklaşımları sunuyoruz.

Önerilen Dinamik Strateji Tabu Arama Operatörü Tabanlı Kuantum Genetik Algoritması (DTS-QGA), 0-1 sırt çantası sorununu etkin bir şekilde ele almak için tabu aramasını bir kuantum genetik algoritma ile birleştirir. Yapılan deneyler, algoritmanın farklı boyutlardaki on set 0-1 sırt çantası test verisi üzerinde küresel arama yetenekleri, yerel optimumlardan kaçınma becerisi ve hızlı yakınsama gibi özellikleri başarıyla sergilediğini göstermiştir. Bu, DTS-QGA'nın zorlu optimizasyon problemlerinde etkili bir çözüm sunabileceğini kanıtlar [8].

Yapılan çalışmada [9], beş metasezistik algoritmayı araştırıldı: At sürüsü optimizasyon algoritması (HOA), Gradyan Tabanlı Optimize edici (GBO), Kızıl tilki arama optimize edici (RFSO), Altın Kartal Optimize edici (GEO) ve Bonobo Optimize edici (BO), bu algoritmalar yüksek boyutlu 0-1 sırt çantası örneklerini etkili bir şekilde ele almak için V şeklindeki ve S-şekilli transfer fonksiyonları kullanılarak ikili varyantlara dönüştürüldü. Yapılan çalışmada [10], 0-1 knapsack problemlerini çözmek için üç farklı meta-sezgisel algoritma olan QTS, ACO ve GA'nın performanslarını karşılaştırılmıştır. GA, optimal çözümlere daha hızlı yaklaşma eğilimi göstermesine rağmen, her yineleme için daha yüksek hesaplama süresi gerektirmiştir. ACO, küçük problem boyutlarında daha üstün performans sergilerken, QTS daha büyük giriş boyutları için daha verimli olmuştur.Deneysel sonuçlar, GA'nın daha hızlı yakınsama gösterdiğini ve optimal çözümleri bulmada daha kararlı olduğunu göstermiştir. Öte yandan, ACO daha az dalgalanma ile daha uygun çözümler bularak, QTS'ye göre daha iyi bir stabilite sergilemiştir. Sorun boyutu arttıkça, QTS'nin daha düşük zaman karmaşıklığına sahip olduğu

gözlemlenmiştir.Genel olarak, GA optimal çözümler üretmede daha etkili olurken, ACO küçük problem boyutları için daha iyi performans göstermiş ve QTS ise daha büyük giriş boyutları için mükemmel bir seçenek olmuştur.

Yapılan çalışmada [11], problemi çözmek için doğadan ilham alınarak tasarlanmış çeşitli meta sezgisel algoritmalara odaklanılmaktadır. Bunlardan bazıları, genetik varyasyon ile zenginleştirilmiş Yarasa Algoritması (BA), Rüzgâr Güdümlü Optimizasyon ve Yusufçuk Algoritması'na (DA) açı modülasyon mekanizması eklenmiş şekilleridir. 0-1 knapsack problemlerinin çözümünde kullanılan altı farklı kodlama yöntemi vardır: gerçek, ikili, karmaşık değerli, kuantum, ayrık ve diğer kodlama yöntemleri. Bu çeşitlilik, farklı yaklaşımların problemin çözümüne katkısını ortaya koymaktadır. Deneysel çalışmalar, IAMDA gibi bazı algoritmaların yakınsama hızı ve çözüm kalitesi açısından diğerlerinden daha üstün olduğunu göstermektedir. Bu sonuçlar, çeşitli senaryolarda algoritmaların pratik uygulama ve optimizasyon potansiyelini de sergilemektedir. Yapılan çalışmada [12], problem çözümü için özel olarak tasarlanmış bir yenilikçi yaklaşım olarak Hibrit Açgözlü Onarım ve Optimizasyon Operatörü içeren Liste Tabanlı Simüle Edilmiş Tavlama (LBSA) algoritması tanıtılmaktadır. Bu çalışma, liste tabanlı soğutma şemasının etkinliğini ve parametre sağlamlığını değerlendirmek amacıyla yapılmıştır. Ayrıca, hibrit açgözlü onarım ve optimizasyon operatörünün faydalarını belirlemek için küçük, orta ve büyük ölçekli 0-1 KP örnekleri üzerinde geniş çaplı deneyler gerçekleştirilmiştir. Bu deneyler, algoritmanın farklı boyutlardaki problemler üzerindeki performansını ve uygulanabilirliğini gözler önüne sermektedir.

Yapılan çalışmada [13], negatif olmayan alt-modüler fonksiyonları maksimize etmek amacıyla tasarlanmış GREEDY+SINGLETON algoritması sunulmaktadır. Bu algoritma, sırt çantası kısıtlaması altında çalışarak, tamamen açgözlü çözümle en iyi tek elemanlı çözüm arasından daha iyi bir seçim yapmaktadır. Monoton fonksiyonlar için yaklaşık oran 0,273 iken, monoton olmayan alt-modüler fonksiyonlar için bu oran 0,219 olarak belirlenmiştir. Ayrıca, makalede sınırlamalar olmaksızın farklı maksimizasyon problemleri için çeşitli algoritmaların yaklaşım oranları incelenmiştir. GREEDY2, GREEDY8, MULTIEXT ve STREAM gibi algoritmalar karşılaştırılmış ve GREEDY+SINGLETON algoritması 0,273 oranıyla dikkat çekmiştir. Bu oran, algoritmanın etkinliğini ve farklı senaryolarda uygulanabilirliğini göstermektedir.

Yapılan çalışmada [14] , 0/1 Knapsack problemi için tasarlanmış bir Genetik Algoritmanın (GA) farklı seçim ve çapraz işlevlerle davranışını derinlemesine analiz etmeyi amaçlanmaktadır. Ampirik sonuçlar, tek noktalı çaprazlama ve ters mutasyon (GaOi) kombinasyonuna sahip GA'nın, problem boyutu ne olursa olsun, neredeyse her denemede ilk 10 nesil içinde %100 değer verimliliği sağladığını göstermektedir. Bu sonuçlar, GA'nın bu özel konfigürasyonunun yüksek verimlilikte sonuçlar üretme kapasitesini ortaya koymaktadır. Ayrıca, düzgün çaprazlama ve ters mutasyonun birleşimi, 0/1 Knapsack problemi için GA kullanımında en etkili yöntem olarak belirlenmiş ve bu yaklaşım optimal sonuçlar sağlamıştır. Bu bulgular, Genetik Algoritmanın problem çözme kapasitesini ve çeşitli çaprazlama ve mutasyon stratejilerinin etkinliğini vurgulamaktadır. Yapılan çalışmada [15], Çok Boyutlu Sırt Çantası Problemleri (MKP) için geliştirilen EOCG (Edge-Oriented Chromatic Graph) algoritmasının, yüksek boyutlu problemlerin boyutunu başarıyla azaltma yeteneğine odaklanılmaktadır. EOCG, 5 ve 10 boyutlu MKP örneklerini kısa zaman dilimlerinde etkin bir şekilde çözmektedir.

Yapılan çalışmada [16], 0-1 sırt çantası problem örneklerinin çözülmesini zorlaştıran özellikleri incelemeye odaklanılmaktadır. Yazarlar, en son teknoloji çözücüler için zorluk yaratan özellikleri belirlemek amacıyla, maksimum çözümlere (Inclusion Maximum Solutions - IMS)

dayalı 14 özellik önermişlerdir. Bu özelliklerin verimli bir şekilde hesaplanması için algoritmalar geliştirilmiştir. Yapılan çalışmada [17], klasik 0-1 sırt çantası problemine yeni bir bakış açısı getiren İndirimli 0-1 Sırt Çantası Problemi'ne (DKP) odaklanılmaktadır. DKP, öğelerin üçlü olarak gruplandığı ve çözümde her grup içinden yalnızca bir öğenin seçilebildiği bir problem uzantısı olarak tanımlanmaktadır. DKP'yi ele almak için iki farklı sabitleme tekniği önerilmiştir. İlk teknik, sezgisel bir yaklaşım olup, LP-baskınlık kurallarına dayanarak değişkenleri atar. İkinci teknik ise, optimal çözümlere zarar vermeden grupları çıkararak, problemi daha yönetilebilir hale getirir. Her iki teknik de dinamik programlama işlemine başlamadan önce problemi ön işleme aşamasında basitleştirmeye yardımcı olur. Bu tekniklerin uygulanması, DKP'nin daha etkili ve verimli bir şekilde çözülmesine olanak tanır ve problemle ilgili daha derinlemesine anlayış sağlar.

Yapılan çalışmada [18], özel bir sırt çantası paketleme problemi için deterministik bir sezgisel algoritma önermekte ve bu algoritmayla parça konumlarını ve dönme açılarını belirleyerek iyi çözümler elde edilmektedir. Ayrıca, çözüm kalitesi açısından daha üstün olan geliştirilmiş bir özyinelemeli arama sezgisel (RSH) algoritması geliştirilmiştir, bu algoritma daha karmaşık problemleri daha etkin çözebilmektedir. Yeni geliştirilen bir meta-sezgisel algoritma, kızıl tilkinin çeşitli doğal davranışlarını simüle ederek matematiksel optimizasyon problemlerini çözmeye yöneliktir. Bu algoritma, Red Fox Search Optimizer (RFSO) adıyla bilinir ve yiyecek bulma, nüfus geliştirme, avlanma ve avcılardan kaçma gibi davranışları modellemektedir. RFSO'nun matematiksel modeli, algoritmanın temel işleyişini ve bu davranışların nasıl optimizasyon sürecine entegre edildiğini açıklayan orijinal makalede detaylı olarak sunulmuştur [19]. Bu yaklaşım, geleneksel optimizasyon tekniklerine alternatif olarak gelişmiş ve etkili çözümler sunma potansiyeline sahiptir.

Yapılan çalışmada [20], çakışmalarla sırt çantası problemine yönelik çözümler sunmak için kapsamlı bir yaklaşım geliştirilmektedir. Bu yaklaşım içinde, problemi çözmek için üç aşamalı bir algoritma, bir Branch-and-Bound (BB) algoritması ve bir Branch-and-Cut (BC) algoritması önerilmektedir. Bu algoritmalar, kararlı küme problemini, özellikle çakışmaları dikkate alarak ele almaktadır. Ayrıca, makale problem için önemli olan kesme düzlemlerini tanımlayan çokyüzlü yönleri ve fasetleri detaylı bir şekilde tartışmaktadır. Bu, çözüm sürecinde kullanılan geometrik ve matematiksel yapıların daha iyi anlaşılmasını sağlar ve algoritmaların etkinliğini artırarak daha doğru ve optimize edilmiş çözümler üretmelerine olanak tanımaktadır. Yapılan çalışmada [21], 0/1 Sırt Çantası Problemini çözmek için basit bir evrimsel algoritma ile çalışan bir hiper sezgisel modeli geliştiriyor ve bu modeli geleneksel buluşsal yöntemlerle karşılaştırılmaktadır. Testlerde, 20 öğe ve 50 birim kapasiteli 100 farklı sırt çantası örneği kullanılıyor ve bulgular, tek bir buluşsal yöntemin her durum için en iyi olmadığını gösteriyor. Model, sekiz mutasyon operatörü kullanarak evrim geçiriyor ve hiper sezgisel yaklaşım, bireysel buluşsal yöntemlerden daha üstün performans sergiliyor. Özellikle, model en umut verici buluşsal yöntem olan MaxPW'nin performansını geçiyor ve çeşitli senaryolarda etkili olduğunu kanıtlıyor.

Yapılan çalışmada [22], 0-1 Sırt Çantası problemi için önerilen bulanık tabanlı seçim hiper-sezgisel modeli, geleneksel seçim hiper-sezgisel modellerine kıyasla daha iyi performans sergilenmiştir. Bu bulanık model, dört, altı ve sekiz kural kullanarak düşük seviyeli buluşsal yöntemler ve geleneksel hiper buluşsal yöntemlerden daha iyi ortalama sonuçlar elde etmiştir. Ayrıca, model hem eğitim hem de test setlerinde daha düşük standart sapma değerleri ile yüksek stabilite göstermiş ve karşılaştırılan diğer yöntemler arasında en düşük standart sapma değerleri ile en iyi kararlılık sonuçlarını vermiştir. Bulanık model, dinamik programlama ile elde edilen

sonuçlara ulaşamamış olsa da, 0-1 Sırt Çantası gibi optimizasyon problemlerinin çözümünde umut vaat eden sonuçlar ve kararlılık sağlamıştır.

Yapılan çalışmada [23], 0-1 sırt çantası problemi için çeşitli algoritmaları karşılaştırılmaktadır. Simüle edilmiş tavlama ile hibrit genetik algoritma ve dinamik programlama gibi yöntemler hesaplama süresi ve çözüm kalitesi açısından diğer algoritmalardan daha üstün performans göstermiştir. Özellikle, dinamik programlama ve dal ve bağlanma yöntemleri, bu problemin çözümü için en etkili yaklaşımlar olarak belirlenmiştir. Simüle edilmiş tavlama algoritması ise düşük performansı nedeniyle olumsuz sonuçlar üreterek dikkat çekmiştir. DiABC algoritması, ABC algoritmasına kıyasla altı standart fonksiyon optimizasyon problemi üzerinde daha hızlı yakınsama ve daha iyi performans sergileyerek üstün sonuçlar elde etmiştir. Rosenbrock işlevi hariç diğer algoritmalarla yapılan karşılaştırmalarda iABC daha iyi performans göstermiştir. Ayrıca, 0-1 sırt çantası problemleri üzerinde test edildiğinde, DiABC algoritması, yerel minimum tuzaklarından kaçınarak ve evrim süreçlerini iyileştirerek, NP-zor problemler için etkili bir çözüm olduğunu kanıtlamıştır. Genel olarak, DiABC, çeşitli senaryolarda diğer algoritmaların önüne geçmiştir [24].

Yapılan çalışmada [25], Önerilen Uyarlanabilir Optimizasyon Spiking Neural P Sistemi (AOSNPS), 0/1 sırt çantası problemini çözmek için farklı algoritmalara karşı test edilmiştir ve bu algoritmalardan birçoğunu geçerek etkinliğini kanıtlanmıştır. AOSNPS, Genetik Kuantum Algoritması (GQA), Yeni Kuantum Evrimsel Algoritması (NQEA) ve Optimizasyon Spiking Neural P Sistemi (OSNPS) gibi yöntemlerle karşılaştırıldığında, on senaryodan dokuzunda en iyi performansı göstermiştir. Sadece madde sayısının az olduğu senaryolarda NQEA, AOSNPS'den biraz daha iyi sonuçlar elde etmiştir. Ayrıca, AOSNPS içindeki Evrimsel Kılavuz Algoritması, OSNPS'de kullanılana göre sürekli daha iyi performans göstermiş, bu da önerilen memetik algoritmanın üstünlüğünü göstermiştir. Holm-Bonferroni prosedürü ile yapılan istatistiksel analiz, AOSNPS'nin diğer tüm test edilen algoritmalardan önemli ölçüde daha iyi performans gösterdiğini doğrulamıştır.

Yapılan çalışmada [26], boyutları küçük olmasına rağmen önceki örneklerden daha zor olan yeni bir 0-1 sırt çantası problemi örnekleri sınıfı önerilmiştir. Bu yeni sınıf için 3240 zor problem örneğinden oluşan bir veri kümesi, 810 CPU saati kullanarak bir süper bilgisayarda çözülmüştür. Çalışma ayrıca, problem örneklerini iki boyutlu bir alanda görselleştirmek için Örnek Uzay Analizi metodolojisini kullanmış ve bu yöntemle algoritma performansı ile problem özellikleri arasındaki ilişkiler incelenmiştir. Sonuçlar, bu yeni problem sınıfının, küçük arama alanlarına rağmen, diğer veri kümelerindeki örneklerden daha zor çözüldüğünü göstermiştir. Yapılan çalışmada [27], Kuadratik Çoklu Sırt Çantası Problemi (QMKP) için bir matematiksel yaklaşım önermektedir ve bu yöntem kısa sürelerde yüksek kaliteli çözümler sunmaktadır. Yaklaşım, Lagrange gevşemesi, sezgisel çözümler ve yerel arama prosedürleriyle birleştirilmiştir. Önerilen algoritma, Fleszar algoritmasına kıyasla bazı durumlarda daha düşük sonuçlar elde etse de, birden fazla çalıştırma ile sonuçlar iyileştirilebilir ve genel olarak olumlu karşılaştırmalar sunar. Algoritmanın performansı, veri kümesi boyutlarına bağlı olarak değişiklik gösterir.

Sırt çantası problemi, kârı maksimize etmek için ağırlık kısıtlamaları dahilinde çeşitli eşyaların seçilmesini içerir. Bu problemi çözmek için kullanılan yaygın yöntemler arasında kaba kuvvet, açgözlü,

dinamik programlama ve dal ve bağlama algoritmaları bulunur. Dinamik programlama, genellikle optimum sonuçlar sunar ve en iyi çözüm olarak kabul edilir, ancak açgözlü yönteme

göre daha yavaş çalışır. Açgözlü algoritmalar daha hızlıdır ancak her zaman en doğru çözümleri sağlamayabilir. Bir çalışma, Python kullanarak 0-1 sırt çantası problemleri için bu algoritmaları test etmiş ve dinamik programlamanın etkili sonuçlar verdiğini belirtmiştir; ancak algoritmaların avantajları ve dezavantajları üzerine daha fazla araştırmaya ihtiyaç duyulmaktadır [28]. Önerilen küme tabanlı Parçacık Sürü Optimizasyonu (PSO) algoritması, çoklu enerji koruma kısıtlamaları olan problemleri çözmek için kullanılmış ve bu problemlerde minimum boyutlar için %100, daha büyük boyutlarda ise %85'in üzerinde doğruluk sağlamıştır. Algoritmanın performansı, hesaplama süresi, yakınsama oranı ve hata oranı gibi çeşitli kriterlerle değerlendirilmiş ve Simüle Edilmiş Tavlama (SA) ile Genetik Algoritma (GA) gibi diğer yöntemlere göre daha iyi sonuçlar verdiği belirlenmiştir. Algoritmanın sağlamlığı ve doğruluğu, en iyi senaryolarda sıfır hata ile %100 optimum değer elde edilm [9] [29]esiyle kanıtlanmıştır [30].

ÖNERİLEN YÖNTEM

Bu çalışmada, 0-1 knapsack probleminin çözümü için tabu search algoritması kullanılmıştır. Tabu search, yerel arama teknikleri ile global en iyi çözüme ulaşmayı hedefleyen bir metasezgisel algoritmadır. Algoritmanın temel bileşenleri keşif stratejisi, sömürü stratejisi ve tabu listesi gibi operatörlerden oluşmaktadır.

Algoritmanın Bileşenleri:

1. Keşif Stratejisi (Exploration Strategy): Tabu search algoritması, çözüm uzayını geniş bir şekilde araştırmak için komşu çözümleri değerlendirir. Rastgele seçilen başlangıç çözümü, iterasyonlar boyunca komşu çözümlerle iyileştirilir.
2. Sömürü Stratejisi (Exploitation Strategy): Yerel maksimumlardan kaçınmak için, en iyi komşu çözüm seçilir ve bu çözüm tabu listesine eklenir. Bu sayede, daha önce ziyaret edilen çözümler tekrar ziyaret edilmez ve çözüm uzayında daha derinlemesine bir arama yapılabilir.
3. Tabu Listesi (Tabu List): Tabu listesi, belirli bir süre boyunca (tabu süresi) tekrar ziyaret edilmemesi gereken çözümleri içerir. Bu liste, algoritmanın daha önce ziyaret edilen çözümlerden kaçınmasını sağlar.

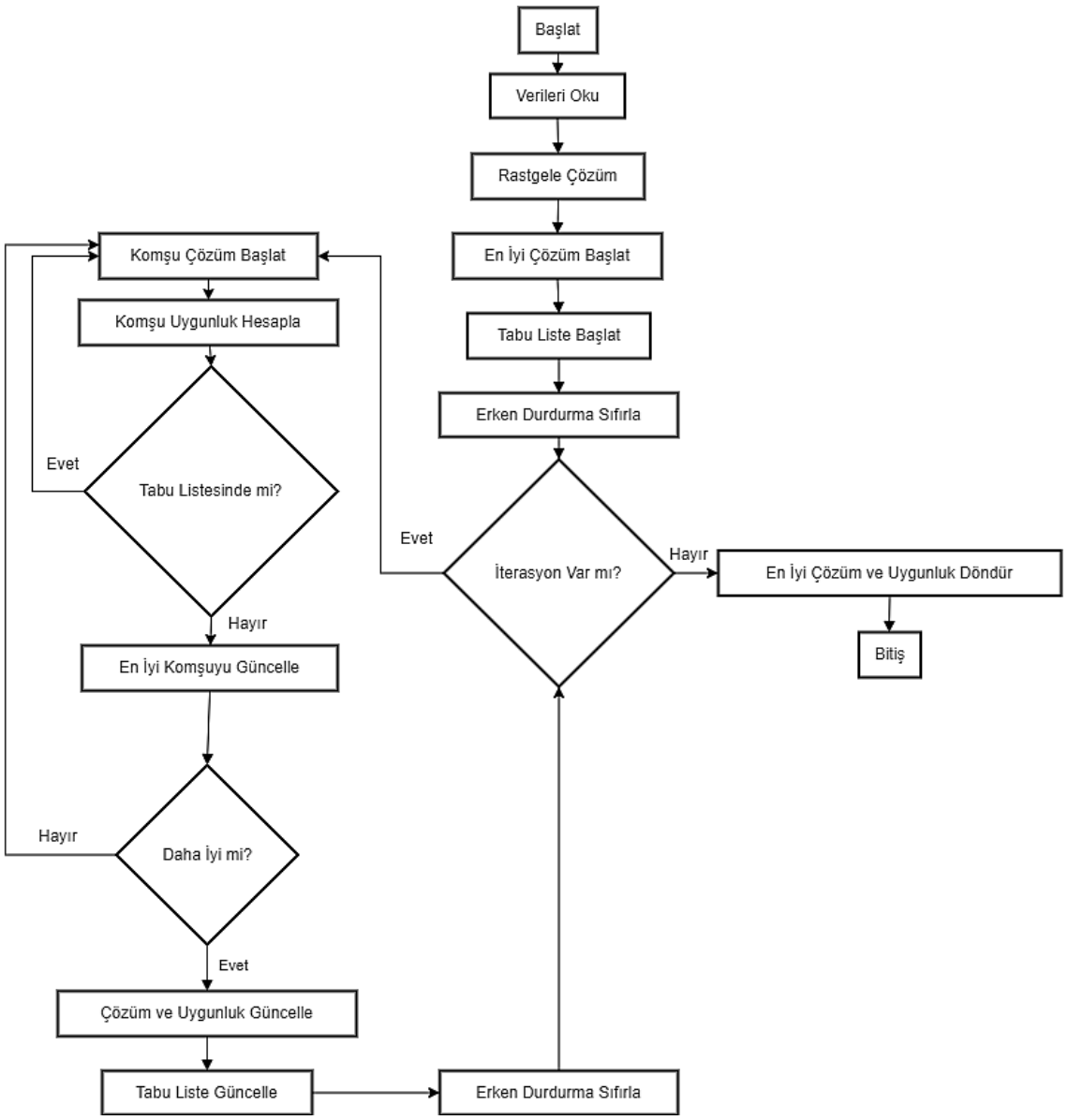
Operatörler:

1. Başlangıç Çözümü (Initialization):Algoritma, rastgele seçilen bir başlangıç çözümü ile başlar. Bu çözüm, knapsack kapasitesini aşmayan rastgele seçilmiş öğelerden oluşur.
2. Komşu Çözüm (Neighborhood Solution): Mevcut çözümün komşu çözümleri, çözümdeki bir öğenin seçilip seçilmemesi durumuna göre oluşturulur. Her komşu çözüm, mevcut çözümün küçük bir değişikliğe uğramış halidir.

3. Uygunluk Değeri (Fitness Calculation): Her komşu çözümün uygunluk değeri, toplam kar ve toplam ağırlık dikkate alınarak hesaplanır. Eğer toplam ağırlık kapasiteyi aşıyorsa, uygunluk değeri 0 olarak belirlenir.
4. En İyi Komşu Seçimi (Best Neighbor Selection): Tabu listesinde olmayan ve en yüksek uygunluk değerine sahip komşu çözüm, yeni geçerli çözüm olarak seçilir.
5. Tabu Listesi Güncelleme (Tabu List Update): Yapılan değişiklikler tabu listesine eklenir ve belirli bir tabu süresi boyunca listede tutulur. Tabu süresi dolan hareketler listeden çıkarılır.

Sözde Kod:

```
Başlat
Verileri Oku (ağırlıklar, değerler, kapasite)
Rastgele bir başlangıç çözümü oluştur (current_solution)
 En iyi çözümü başlat (best_solution = current_solution)
 Tabu listesini ve sürelerini sıfırla (tabu_list)
 Erken durdurma sayacını sıfırla (no_improvement_counter)
Döngü (max_iterations kadar)
  En iyi komşu çözümü başlat (best_neighbor_solution = None)
  En iyi komşu uygunluk değerini başlat (best_neighbor_fitness = -1)
  Döngü (tüm genler için i)
 Eğer tabu_list[i] > 0 ise
  Devam et (continue)
  Komşu çözümü oluştur (neighbor_solution = current_solution)
Bir geni ters çevir (neighbor_solution[i] = !current_solution[i])
  Komşu çözümün uygunluk değerini hesapla (neighbor_fitness)
  Eğer (neighbor_fitness > best_neighbor_fitness) veya (best_neighbor_solution == None) ise
    En iyi komşu çözümü güncelle (best_neighbor_solution = neighbor_solution)
    En iyi komşu uygunluk değerini güncelle (best_neighbor_fitness = neighbor_fitness)
Eğer (best_neighbor_solution == None) ise
Devam et (continue)
Geçerli çözümü güncelle (current_solution = best_neighbor_solution)
Geçerli uygunluk değerini güncelle (current_fitness = best_neighbor_fitness)
Tabu listesini güncelle:
Döngü (tüm genler için i)
Eğer (current_solution[i] != best_solution[i]) ise tabu_list[i] = tabu_tenure
Aksi halde Eğer (tabu_list[i] > 0) ise tabu_list[i] -= 1
Eğer (current_fitness > best_fitness) ise
En iyi çözümü güncelle (best_solution = current_solution)
En iyi uygunluk değerini güncelle (best_fitness = current_fitness)
Erken durdurma sayacını sıfırla (no_improvement_counter = 0)
Aksi halde Erken durdurma sayacını artır (no_improvement_counter += 1)
Eğer (no_improvement_counter >= early_stopping) ise
Durdur ve çık (break)
Döngü sonu
En iyi çözümü ve uygunluk değerini döndür (best_solution, best_fitness)
Son
```



Şekil 1. 1 Tabu Araması ile knapsack probleminin akış diyagram

Deneysel Sonuçlar

Bu bölümde, tabu search algoritması ile elde edilen sonuçlar sunulmaktadır. Deneyler, çeşitli 0-1 knapsack problem örnekleri üzerinde gerçekleştirilmiş ve algoritmanın performansı analiz edilmiştir.

Deney Ortamı :

Deneyler, aşağıdaki donanım ve yazılım ortamında gerçekleştirilmiştir:

- **İşletim Sistemi**: Windows 11
- **CPU**: Intel(R) Core(TM) i7-9750H CPU @ 2.60GHz 2.59 GHz
- **RAM**: 16.0 GB
- **Yazılım ve Kütüphaneler**: Python 3.9, NumPy 1.21.0, Matplotlib 3.4.2, Pandas 1.2.4

Deney Prosedürü:

Her bir problem örneği, 30 kez çalıştırılmış ve elde edilen sonuçlar kaydedilmiştir. Deneylerde, tabu search algoritmasının performansı analiz edilmiştir. Algoritmanın yakınsama hızı ve en iyi çözümleri elde etme süresi değerlendirilmiştir.

Sonuçların Sunumu:

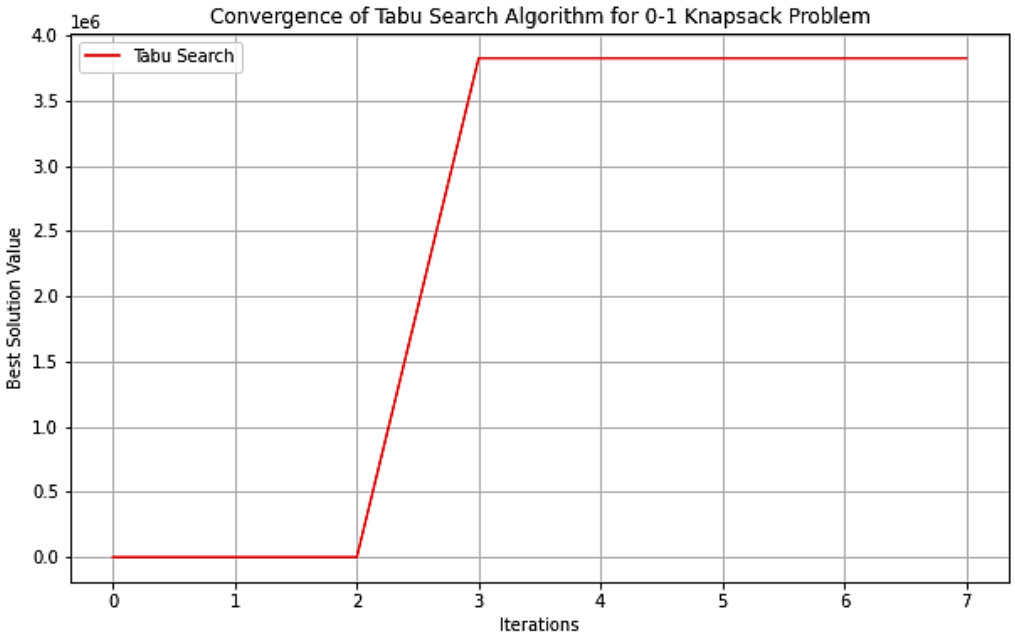
Sonuçlar, tabu search algoritmasının 30 çalıştırma sonucunda elde edilen ortalama en iyi çözüm değerleri ve standart sapmalarıyla sunulmuştur. Ayrıca, yakınsama grafikleri ile algoritmanın performansı görselleştirilmiştir.

Tablo 1. Tabu Search Algoritmasının Performansı

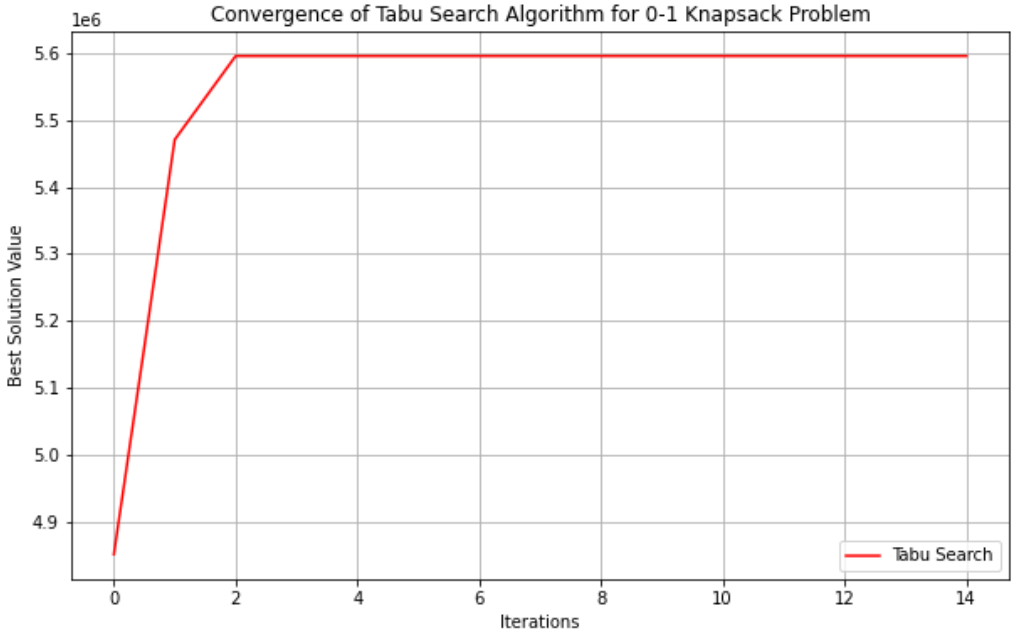
Problem	**Optimum**	**En İyi**	**Ortalama**	**En Kötü**	**Orta Değer**	**Std. Sapma**	**Zaman (sn.)**
ks_8a	3924400	3924400	3713268.4	2907099	3739475.5	215490.3	0.1072
ks_8b	3813669	3813669	3690810.73	3411728	3710218	95136.85	0.1067
ks_8c	3347452	3347452	3187802.33	3054418	3167639	96802.42	0.1071
ks_8d	4187707	4187707	4091745.5	3842405	4127370	99880.97	0.108
ks_8e	4955555	4955555	4799501.17	4463520	4856657	123847.71	0.1069
ks_12a	5688887	5688887	5550255.3	5023535	5591808	118830.61	0.1477
ks_12b	6498597	6498597	6274980.7	5887653	6324767	137858.43	0.1474
ks_12c	5170626	5170626	4939712.13	4640525	4920316	125612.36	0.1492
ks_12d	6992404	6992404	6748466.03	6368893	6843382	180485.8	0.1475
ks_12e	5337472	5337472	5144427.57	5016501	5130234	70850.83	0.1497
ks_16a	7850983	7759789	7588818.43	7381728	7592267	103789.74	0.1904
ks_16b	9352998	9267143	9032329.47	8774289	9001907	122112.02	0.1913
ks_16c	9151147	9100116	8793238.4	8511135	8779303	162966.57	0.1905
ks_16d	9348889	9336691	9065705.03	8837254	9094646	122869.54	0.1914
ks_16e	7769117	7655263	7510309.7	7238854	7537076	114147.26	0.1916
ks_20a	10727049	10678523	10389098.8	10036629	10403003	157456.91	0.2346
ks_20b	9818261	9581415	9439130.6	9278461	9445236	81976.6	0.2321
ks_20c	10714023	10566522	10315569.4	10059114	10356762	137684.59	0.2325
ks_20d	8929156	8895152	8655496.97	8496875	8649982	106592.53	0.2324
ks_20e	9357969	9316553	9131463.97	8940741	9113920	93343.07	0.2336
ks_24a	13549094	13410720	13205304.87	12883268	13225154	131342.64	0.2758
ks_24b	12233713	12126544	11891714.8	11708792	11880935	107762.37	0.2792
ks_24c	12448780	12363636	12099782.17	11836511	12099375	138914.6	0.2796
ks_24d	11815315	11793333	11467929.2	11208003	11478911	133888.03	0.2779
ks_24e	13940099	13788791	13632948.47	13430781	13663014	86214.11	0.2781

Yakınsama Grafikleri

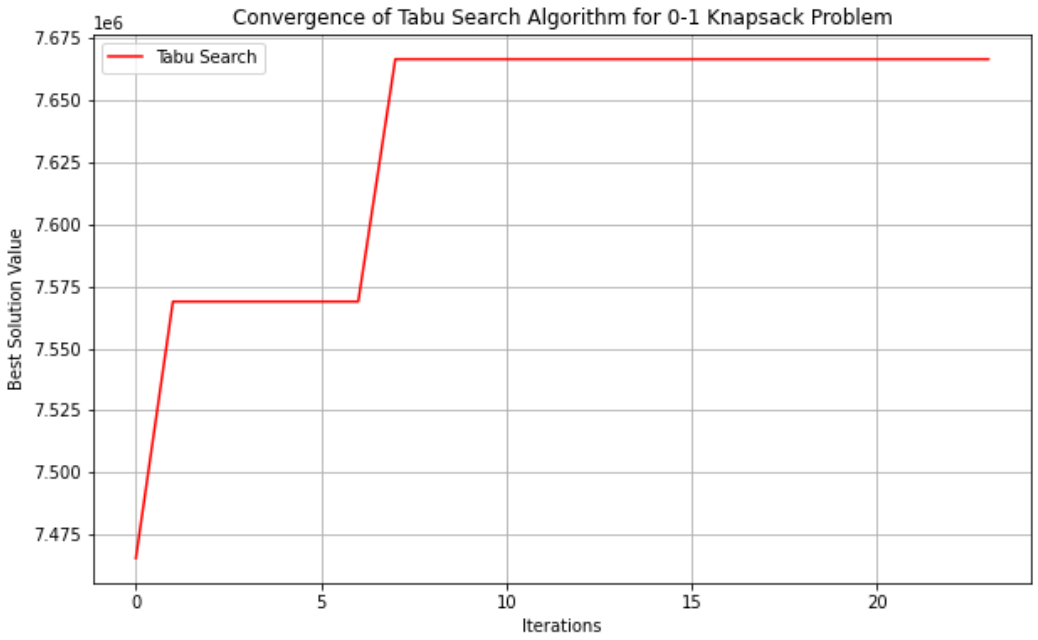
Tabu search algoritmasının yakınsama hızı, her bir iterasyonda elde edilen en iyi çözüm değerlerinin zaman içinde nasıl geliştiğini gösterir. Aşağıdaki grafik, tabu search algoritmasının 0-1 knapsack problemine çözüm bulma sürecini göstermektedir.



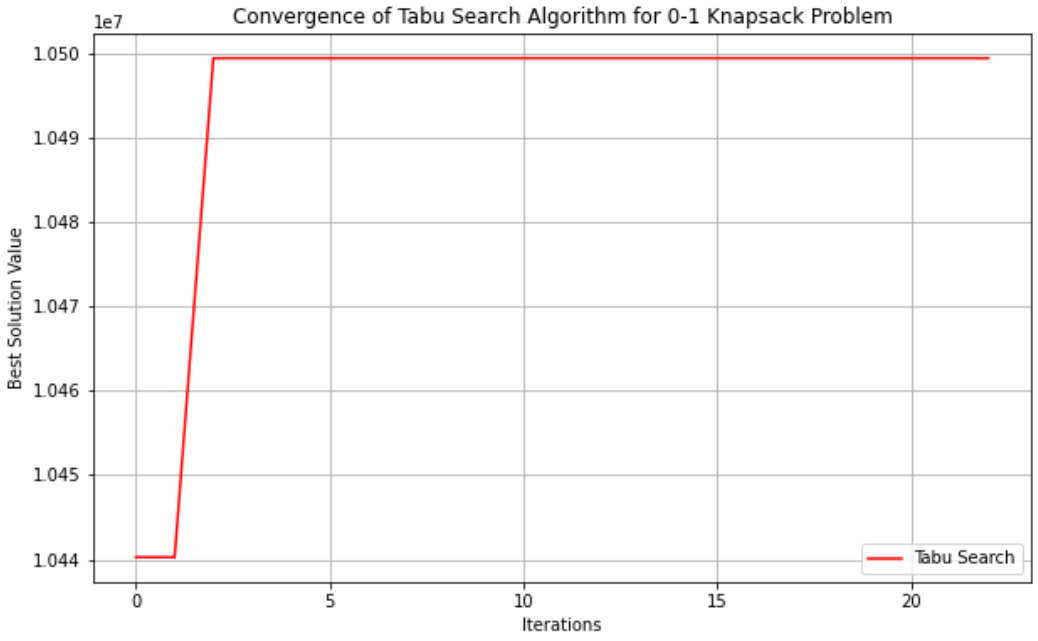
Şekil 2. 1 ka_8a ilk çalıştırmanın yakınsama grafiği



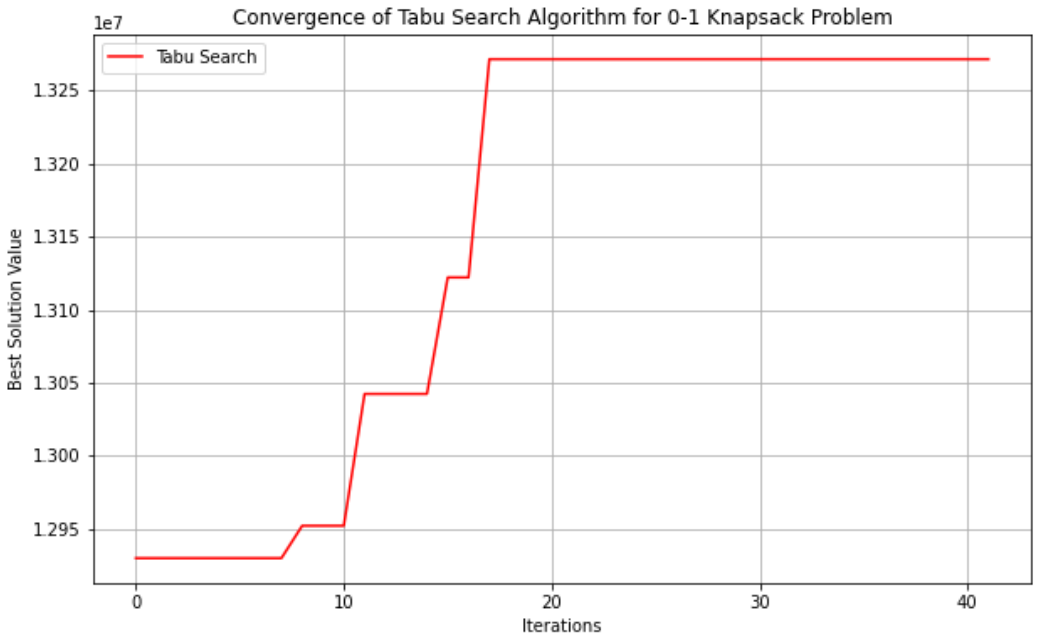
Şekil 3. ks_12a ilk çalıştırmanın yakınsama grafiği



Şekil 4. ks_16a ilk çalıştırmanın yakınsama grafiği



Şekil 5. ks_20a ilk çalıştırmanın yakınsama grafiği



Şekil 6. ks_24a ilk çalıştırmanın yakınsama grafiği

Sonuçların Analizi:

- **Yakınsama Hızı**: Tabu search algoritması, hızlı bir şekilde optimum çözüme yaklaşmaktadır. Yakınsama grafiği, algoritmanın iterasyonlar boyunca en iyi çözüm değerinde nasıl iyileşme sağladığını göstermektedir.
- **Çözüm Kalitesi**: Tabu search algoritması, 30 çalıştırmada yüksek performans göstermiş ve tutarlı çözümler üretmiştir. Ortalama en iyi çözüm değerleri ve düşük standart sapma, algoritmanın güvenilirliğini ortaya koymaktadır.
- **Hesaplama Süresi**: Tabu search algoritması, kısa sürede etkili çözümler üretmiştir. Ortalama hesaplama süreleri, algoritmanın hızlı bir şekilde çözümler üretebildiğini göstermektedir.

Bu deneysel sonuçlar, tabu search algoritmasının 0-1 knapsack probleminin çözümünde etkili bir metasezgisel yöntem olduğunu göstermektedir. Algoritma hem çözüm kalitesi hem de hesaplama süresi açısından üstün performans sergilemiştir.

SONUÇ

Bu çalışma, 0-1 knapsack probleminin çözümüne yönelik modern yaklaşımlar arasında tabu search algoritmasının etkinliğini incelemiştir. Tabu search algoritması, yerel maksimumlardan kaçınmak ve daha geniş bir çözüm alanını keşfetmek için güçlü bir yöntem olarak öne çıkmıştır. Deneysel sonuçlar, tabu search algoritmasının hızlı ve etkili çözümler ürettiğini göstermiştir. 30 farklı çalıştırma sonucunda elde edilen veriler, algoritmanın tutarlı bir şekilde yüksek performans sergilediğini ortaya koymuştur. Ortalama en iyi çözüm değerleri ve düşük standart sapma, algoritmanın güvenilirliğini ve istikrarını göstermektedir. Yakınsama grafikleri, tabu search algoritmasının iterasyonlar boyunca hızlı bir şekilde optimum çözüme yaklaştığını ve çözüm kalitesinde önemli iyileşmeler sağladığını göstermiştir. Hesaplama süreleri açısından da algoritma, kısa sürede etkili çözümler üreterek zaman açısından verimliliğini kanıtlamıştır.

Bu bulgular, tabu search algoritmasının 0-1 knapsack probleminin çözümünde etkili bir meta sezgisel yöntem olduğunu doğrulamaktadır. Tabu search algoritmasının keşif ve sömürü stratejileri, çözüm uzayında daha derinlemesine ve geniş kapsamlı bir arama yapmayı mümkün kılmaktadır. Bu sayede, yerel arama tekniklerinin sınırlamalarını aşarak daha iyi çözümler elde

edilebilmektedir. Sonuç olarak, tabu search algoritması, optimizasyon problemlerinde kullanılabilecek güçlü ve esnek bir yöntem olarak değerlendirilebilir. Gelecekteki çalışmalar, algoritmanın farklı parametrelerle ve daha büyük veri setleriyle performansını inceleyerek, yöntem üzerinde daha fazla iyileştirme yapılmasına olanak sağlayabilir. Ayrıca, tabu search algoritmasının diğer meta sezgisel yöntemlerle hibritleştirilmesi, çözüm kalitesini ve yakınsama hızını daha da artırabilir. Bu çalışmanın bulguları, tabu search algoritmasının optimizasyon problemlerinin çözümünde etkili bir araç olarak kullanılabileceğini göstermekte ve bu alanda yapılan araştırmalara önemli katkılar sunmaktadır.

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DEVELOPMENT AND IMPLEMENTATION OF A FRAME-BASED EXPERT SYSTEM FOR ADVANCED ANALYSIS OF RESOURCE CONVERSION PROCESSES

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ABSTRACT

This paper explores resource conversion processes, including production, logistics, and business-related activities, with the primary goal of developing an expert system for enhanced decision-making. The proposed system utilizes frames and a production model for effective knowledge representation, facilitating structured decision support.

Developed within the Bpsim.MSN platform, the expert system employs a frame-based approach and an object-oriented inference mechanism, incorporating advanced UML sequence diagrams to structure system logic and behavior.

The system was successfully applied to the problem of network communication equipment replacement, where it generated and evaluated alternative solutions. The results demonstrated that the system efficiently supported decision-making by providing optimized alternatives and streamlining the resource conversion process.

By leveraging a frame-based structure, the expert system enhances decision-making in complex processes, offering a scalable and adaptable solution. Future work may focus on refining system capabilities and extending its application to diverse industry sectors.

Keywords: Expert System, Frame-based Approach, Resource Conversion, Decision Support, Network Communication Equipment

INTRODUCTION

In the modern business landscape, the rapid advancement of technology plays a crucial role in shaping organizational success and long-term sustainability. To remain competitive, companies must continuously adapt to emerging technologies that redefine business operations, financial management, and decision-making processes. Among these innovations, artificial intelligence (AI), expert systems, and high-availability infrastructures have become indispensable tools in industries such as finance, healthcare, resource management, and digital services.

One specialized AI approach, frame-based expert systems, utilizes structured data frameworks to represent knowledge and derive informed conclusions (Nazaruks, 2017). Frames, hierarchical structures containing attributes and values, enable systematic data organization and structured decision-making. These systems compare new information with existing frames and apply predefined rules to generate insights (Roth et al., 2018). Their ability to handle complex structured data makes them valuable across multiple fields, including medicine, engineering, finance, logistics, and accounting (Lytvynov & Lytvynov, 2023).

One of the key applications of frame-based expert systems is in medical diagnostics, where they model patients, symptoms, diseases, and treatments. For example, a medical expert system can analyze patient data, match symptoms with a knowledge base of diseases, and suggest possible diagnoses and treatments (Roth et al., 2018).This improves decision-making in healthcare, enhances diagnostic accuracy, and streamlines patient care.

Beyond medicine, these systems play a pivotal role in finance and business applications, particularly in corporate finance and accounting. The rapid evolution of financial technology has significantly transformed these fields, shifting from traditional accounting methods to AI-driven automation. Frame-based expert systems can automate financial analysis, detect anomalies in transactions, and optimize investment strategies. By leveraging AI, businesses can enhance financial decision-making, improve compliance with regulatory frameworks, and mitigate risks associated with market fluctuations. However, challenges such as data privacy concerns, cybersecurity risks, and regulatory compliance must be addressed to maximize the benefits of AI-driven financial systems.

A critical application of these systems is in resource conversion processes, where they assist in transforming input resources into outputs under predefined execution mechanisms (Ledentsov, 2023). This is particularly useful in industries such as manufacturing, logistics, and energy management. By integrating multi-agent modeling techniques, expert systems can analyze various factors influencing resource transformation and optimize operational efficiency (Nolan & McCarthy, 1986). Multi-agent systems facilitate intelligent interactions between different agents, simulating different scenarios and enabling data-driven decision-making(HAYES, 1981).

One of the key advantages of using AI-driven expert systems in resource management is their ability to incorporate human factors into decision-making and optimize complex processes (Yang & Zhu, 2024). Multi-agent modeling techniques have already been widely adopted to analyze and improve operational efficiency (Yang & Zhu, 2024b). By leveraging these technologies, industries can enhance productivity, minimize waste, and ensure sustainable resource utilization.

AI is increasingly transforming the banking sector, revolutionizing customer service, fraud detection, and financial decision-making. Research highlights the potential of AI to automate financial transactions, detect fraudulent activities, and personalize banking services. However, implementing AI-driven solutions also presents challenges such as regulatory constraints, cybersecurity threats, and ethical considerations(’Tabaku, ’Duçi, ’Kapçiu, ’Kosova, et al., 2025).

Despite these challenges, AI-based expert systems offer significant opportunities for optimizing banking operations. They can enhance customer experiences by providing real-time financial insights, streamline loan approval processes, and improve risk assessment methodologies.

Additionally, AI-powered chatbots and virtual assistants are becoming standard features in online banking, reducing the burden on human customer service agents while improving response times and efficiency(’Tabaku, ’Duçi, ’Kapçiu, & ’Kosova, 2025).

In the digital era, critical infrastructure sectors such as banking, internet service providers (ISPs), and cloud-based services rely on AI and high-availability (HA) systems to ensure uninterrupted service. Key operations, including financial transactions, online banking, and digital customer support, require high system uptime to maintain business continuity and customer trust. Network and server administrators play a crucial role in ensuring HA for systems such as file servers, web servers, database servers, backup systems, and enterprise applications.

HA infrastructures typically consist of redundant servers working collaboratively to maintain continuous service. If a server fails, another takes over seamlessly, preventing service disruptions. Virtualization technology further enhances HA systems by enabling services to run on virtual machines (VMs) that can migrate between physical nodes in a cluster (Tabaku, 2025). This ensures uninterrupted service availability even in cases of hardware failure.

By integrating frame-based expert systems into HA management, organizations can leverage AI-driven automation for predictive maintenance, fault detection, and proactive diagnostics. These expert systems can analyze network conditions, detect vulnerabilities, optimize server workloads, and recommend corrective actions to prevent service outages. In industries such as finance, telecommunications, and cloud computing, the combination of AI-based decision-making and HA infrastructure is crucial for ensuring resilient and efficient digital operations.

As businesses continue to evolve in the face of rapid technological advancements, AI-driven solutions are becoming integral to corporate sustainability and long-term success. Technological innovation has significantly influenced accounting and corporate finance, transitioning from manual bookkeeping to automated financial reporting and AI-powered analytics. This transformation has improved efficiency, accuracy, and fraud detection while enabling businesses to make data-driven financial decisions.

Despite these advancements, organizations must address challenges such as cybersecurity risks, regulatory compliance, and ethical considerations when implementing AI-driven financial systems. Proper governance frameworks and strategic AI adoption can help businesses leverage technological innovation while maintaining transparency and security.

Frame-based expert systems offer a powerful AI-driven approach to structured knowledge representation and intelligent decision-making. Their versatility enables their application in medicine, finance, engineering, and resource management, making them valuable tools for optimizing complex processes. Moreover, their integration into high-availability infrastructures enhances service reliability and operational efficiency in critical digital services.

The banking sector stands out as a key industry where AI-driven expert systems are transforming customer service, fraud detection, and financial decision-making. Despite challenges such as data privacy concerns and regulatory requirements, AI offers significant opportunities for enhancing banking efficiency and improving customer experiences(’Tabaku, ’Duçi, ’Kapçiu, & ’Kosova, 2025).

Finally, the use of expert systems in resource conversion analysis, high-availability infrastructures, and corporate finance demonstrates their broader impact across industries. As businesses continue to navigate the rapidly evolving technological landscape, the combination of AI, multi-agent modeling, and HA infrastructure will play a vital role in driving innovation, efficiency, and resilience in the digital age.

ANALYSİS OF KNOWLEDGE REPRESENTATİON MODELS FOR RESOURCE CONVERSİON PROCESSES

The main objects of the multi-agent resource conversion process model are as follows:

1. Operations
2. Resources (RES)
3. Mechanisms (MECH)
4. Control
5. Commands (U)
6. Processes
7. Resource senders and receivers
8. Crossings
9. Parameters
10. Goals (G)
11. Messages and agents

The description of cause-and-effect relationships between the elements of the model is provided by the Relation object (Wang et al., 2009). The production system apparatus has been used for building the dynamic modeling of the system core. The structure of the multi-agent production system (PS) is defined as follows:

PS={RPS∪BPS∪IPS}P S = \{RP_S \cup BP_S \cup IP_S\}

BPSBP_S represents the set of rules for resource conversion and agent actions (basic knowledge). IPSIP_S is the inference engine, which consists of a logical inference mechanism based on the agents' knowledge base. RPSRP_S represents the current state of resources, mechanisms, control commands, and objectives (working memory).

RPS={RES(t)∪MECH(t)∪U(t)∪G(t)}RP_S = \{RES(t) \cup MECH(t) \cup U(t) \cup G(t)\}

The simulation algorithm consists of the following basic steps:

The simulation process begins with determining the current time by identifying the minimum activation time among the transformation rules, where each rule has a specific activation time, and the set of rules governs resource conversion. Next, the system processes agent actions, followed by the formation of a queue for transformation rules. These rules are then applied sequentially to update the system state. As a result, the working memory is modified accordingly. Throughout this process, the simulator interacts with the expert system module to diagnose situations and generate appropriate control commands.

BASİC REQUİREMENTS FOR THE EXPERT SYSTEM OF MULTİ-AGENT RESOURCE CONVERSİON PROCESSES

The proposed approach to resource conversion processes is guided by several key principles:

1. Orientation towards hierarchical resource transformation processes.
2. Solving the techno-economic design problem of the organization and technical systems.
3. Presence of intelligent agent communities that control the process.
4. Consideration of decision-making scenarios based on knowledge.
5. Support for an object-oriented approach.
6. Visual tools for working with the knowledge base and a visual inference engine designer (UML language can be used as the basis for visual representation).

For knowledge representation in resource conversion processes, an integrated approach based on frame and production models has been chosen (García Coria et al., 2014). The frame-based approach of A. N. Shvetsov, combined with the conceptual graph structures of J. F. Sowa, has been used to construct a conceptual domain model and solve problems while reducing software development costs.

ANALYSİS OF THE APPLİCABİLİTY OF CONTEMPORARY INDUSTRY RELATİONAL DATABASES FOR CREATİNG A FRAME-BASED EXPERT SYSTEM

When developing a frame-based expert system, one of the main challenges is transforming frame structures into a tabular format. The application of relational databases for implementing frames is not extensively covered in the literature. In its basic form, the frame model resembles a hierarchical tree structure, meaning that the implementation challenge is essentially selecting an appropriate method for storing such a structure. The most straightforward approach involves a tree model with "abstract-to-specific" hierarchical relationships. In each node, there are several object instances, forming the simplest tree structures. Such a structure has specific functions, is rarely used, but is relatively simple to implement (Leo Kumar, 2019).

With a static frame structure, this organization is easily managed: a separate table is created for each template to store the data (each table row corresponds to an object instance). In this case, there is no need to create additional tables, monitor the uniqueness of table names, or deal with errors related to the integrity of the tree structure.

Applying system constraints ensures the uniqueness of all records. Stored procedures allow for data encapsulation. However, the set of functions available for such a tree will be very limited. Often, more complex tree models are required. If the structure of the tree model needs to be dynamically changed, it is necessary to use a tabular framework for its description. For this purpose, a slot description table has been proposed, with the following columns: The key elements include Location Name, Inheritance Indicator, Attribute Indicator, Slot Value, and Daemon. H. Ueno and M. Ishizuka propose creating a similar table for each object model. This method is appropriate when the frame system is developed on a platform specifically designed for such tasks.

1) Slot values must be predefined and monotonic, and they should not correspond to the attribute indicator.

2) An attribute indicator is not needed, as information about it can be obtained from the system tables.

3) Storing the daemon in a table is impossible.

4) Creating a new table for each object is impractical.

5) A lot of data in the tables is duplicated.

For implementing a frame-based expert system on an MS SQL server, it is necessary to convert the structure of the slot description table as follows: create a separate table to describe all tree slots and identify the slot using a combination of its name and the object's name. Since the frame structure assumes uniformity in the properties of all objects belonging to the same frame, it is possible to use a single set of records for all similar objects.

In this approach, the "Slot Value" field should be omitted from the slot description table, and a dedicated table should be established to store slot values separately. Similarly, the "Daemon" field can be eliminated by implementing triggers within the frame instance table. Additionally, the "Stored Procedure" field in the frame instance table can be used to store the name of the stored procedure along with details about its parameters. Optional fields have been removed: Tree Name, Stored Procedure, and Parameters.

Table 1. Slot description

Slot name	**frame**	**data type**	**inheritance pointer**	**attribute pointer**
Slot 1	Frame 1	……	……	……
Slot 2	Frame 1	……	……	……
-----	**-----**	……	……	……
Slot M	Frame 1	……	……	……
Slot 1	Frame 2	……	……	……
Slot 2	Frame 2	……	……	……
---	**----**	……	……	……
Slot N	Frame 2	……	……	……

Table 2. Frame description

Object	name	Slot 1	Slot 2	…	Slot M
Object 1	…	…	…		
Object 2	…	…	…		

To implement references and formulas, the following mechanism is used:

For each slot that contains a reference or formula, two fields are created in the table. The first field contains the actual value (which follows the slot's data format), while the second field contains the reference or formula.

In the frame description within the table, the attribute field of the template stores the value indicating whether the slot contains a reference or formula.

The storage of inheritance information in the tree is implemented in Table 3.

Table 3. Tree lists

Tree	Ancestor	Descendant
Tree H	Frame 1	Frame 2
Tree H	Frame 2	Frame 3
Tree H	Frame 1	Frame 5

The use of a similar structure to organize the frame causes issues related to data encapsulation. There are stored procedures for processing data in tables when working with a static frame model. However, if modifications to the model structure are required, this can lead to errors and potential damage to the model.

To address this issue, the following two approaches are proposed:

The first approach assumes that data is initially inserted into the slot description table. This operation is straightforward and does not require an additional integrated procedure. First, a procedure is executed to generate a new table, register it, and update the data in the tables that define the tree structure. This procedure takes as input the names of the new frame and its predecessor.

The second approach is more versatile and streamlines the development process for users or programmers working with the database. Initially, a procedure runs that only requires the number of fields in the new frame as input. This procedure then generates another procedure responsible for creating the frame with the specified number of slots. The generated procedure carries out all necessary steps to create and register a new object in the database. Once this process is completed, the procedure is deleted.

The second approach is implemented using the Transact-SQL language, which allows the execution of multiple nested statements, enabling the creation of complex structures. By utilizing the Execute operator, procedures can be dynamically generated to populate frames and process objects within the model. When working with a tree-based model, several sets of stored procedures are necessary. These include procedures for modifying the model structure, which are created dynamically along with the database, as well as procedures for editing model data and performing data conversions. Additionally, procedures attached to the data and those responsible for monitoring and maintaining model integrity are also dynamically generated or created during database initialization.

APPLİCATİON OF TRANSACT-SQL FOR İMPLEMENTİNG THE LOGİCAL OUTPUT FUNCTİON

The following variants of using the Transact-SQL language for decomposing the function of logical inference in the conversion of multi-agent process model resources are as follows:

1. Intelligent agent output mechanism: The execution algorithm of the intelligent agent is implemented either fully or partially as a stored procedure and is triggered by the scheduler whenever needed.

2. Utilization of intelligent agent rules: The rules governing the behavior of intelligent agents may contain Transact-SQL queries to access basic knowledge or reference stored procedures that implement search and/or computation functions.

3. Solving search and computation problems: Transact-SQL is used for managing and executing search and computation operations in a framework-based system, as multi-agent models that perform resource conversion have a large dimension and high complexity.

This use of Transact-SQL enables a more efficient execution of decision-making operations, enhancing the performance and scalability of multi-agent systems in resource management.

IMPLEMENTATİON OF OBJECT-ORİENTED APPROACH AND UML LANGUAGE FOR THE VİSUAL BUİLDER OF EXPERT SYSTEMS AND THE DESİGNER OF THE INFERENCE ENGİNE

When constructing a conceptual domain model, the UML class diagram serves as the foundation for defining framework structure concepts. Additionally, conceptual graphs are incorporated into the description process, and the integration of data into the conceptual model results in the formation of a knowledge base.

To visually represent the inference engine builder for expert systems, a UML sequence diagram is employed. This diagram illustrates the sequence of method calls between classes during the resolution of a specific problem or scenario. By providing a graphical representation of the problem-solving process, the sequence diagram effectively depicts the procedural calls (methods or daemons) that transition from one framework to another.

These methodologies form the core of the framework-based expert system within the BPsim.MSN decision support system, which is part of the BPsim family. Another system within this family, BPsim.MAS, is designed for modeling situational dynamics. BPsim.MSN facilitates the creation of intelligent agents for problem-solving by utilizing Wizard-based design technology. This implementation relies on UML sequence diagrams and database management through the Transact-SQL language.

To extend the functionality of UML sequence diagrams in the framework-based expert system's visual builder, search diagrams are used. These diagrams guide the decision-making process within the system. When processing a decision search diagram, the integrated interactive expert system mechanism is activated. Users interact in a dialogue mode, responding to system-generated questions and providing the necessary data values to resolve the problem.

The dialogue forms used during system operation are pre-designed by an analyst during the domain class and decision search diagram description phase. This ensures that users receive structured guidance throughout the problem-solving process, enhancing the efficiency and accuracy of decision-making.

APPLİCATİON OF THE FRAMEWORK-BASED EXPERT SYSTEM FOR ANALYZİNG COMMUNİCATİON PROCESSES İN THE NETWORK

Equipment Replacement

The problem of equipment replacement involves generating and evaluating alternative plans for replacing equipment while considering the constraint of a maximum work duration of 20 days. A class diagram has been constructed and populated with input data in the BPsim.MSN system.

The decision search diagram for the equipment replacement problem is shown in Figure 1.

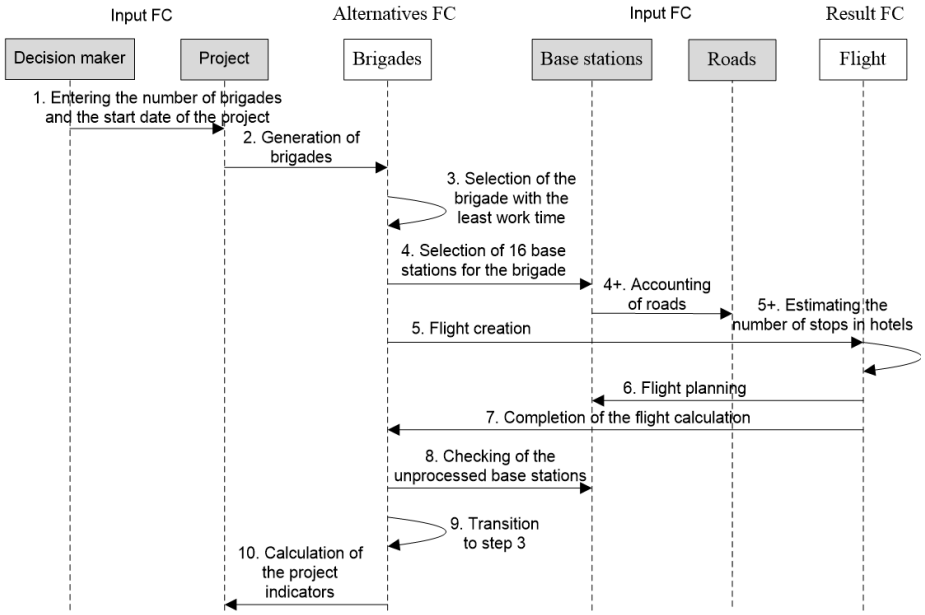

Figure 1. Decision search diagram of the equipment replacement problem

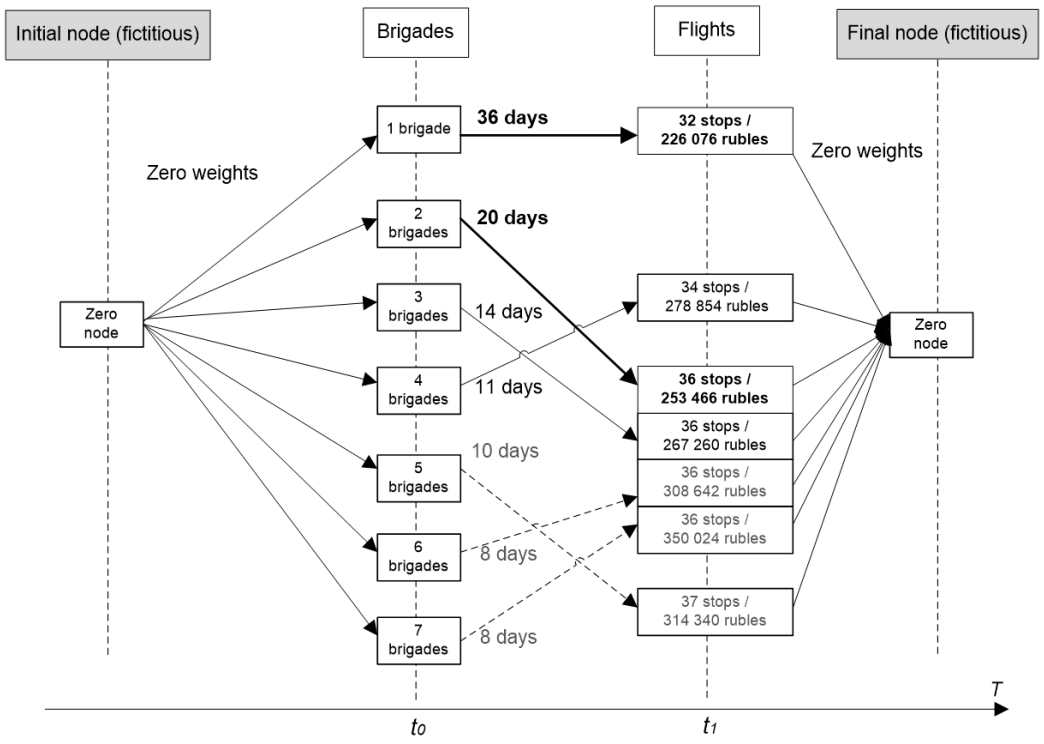

Figure 2. Decision tree of the equipment replacment problem

The implementation of the Bellman method allows solving the problem of evaluating alternatives (Ross et al., 2008). Considering the constraints, the optimal solution for the equipment replacement problem based on the project duration criterion is the deployment of 4 brigades, while for the cost criterion, the optimal solution is the deployment of 3 brigades.

CONCLUSİONS AND FUTURE WORK

An approach for creating a framework-based system using a relational database has been developed. The advantage of the proposed solution is the use of Transact-SQL for designing the

domain model in the form of a framework system, constructing a conceptual domain model, inputting knowledge and data, implementing the inference mechanism, and performing knowledge base searches. This factor reduces the requirements for system programmers, analysts, and knowledge engineers who support the operation of the framework-based system while also automating their work.

The use of an industrial database to store knowledge base information allows for the integration of the framework-based expert system with the corporate information system, ensuring effective implementation in decision support systems.

The proposed approach is applied in the BPsim.MSN decision support system. The BPsim.MSN system has been used to solve the problem of developing and evaluating alternatives in the analysis of equipment replacement processes in communication networks.

Practical recommendations have been obtained regarding the formation of the number of brigades, taking into account cost optimization and the 20-day work duration constraint. Specifically, recommendations have been made to form three brigades for implementing the network equipment replacement process.

Future work is related to the development and implementation of a method that combines multi-agent dynamic modeling and the framework-based expert system to solve the problem of analyzing resource conversion processes.

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IMPACT OF Borassus flabellifer ON THE QUALITY AND NUTRITION OF FIBER-ENRICHED MUFFINS

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ABSTRACT

The increasing global demand for functional and nutrient-rich foods has driven innovation in bakery products. This study explores the use of debittered Borassus flabellifer mesocarp powder (DMP), a natural, fiber-rich ingredient, in muffin formulations to enhance their nutritional profile. Muffins were prepared with varying DMP concentrations (1%, 3%, and 6%) and analyzed for proximate composition, physical characteristics, and sensory properties. Incorporating DMP increased dietary fiber content and moisture retention while reducing fat levels, making these muffins a healthier alternative to conventional formulations. However, higher DMP concentrations (3% and 6%) adversely affected texture and sensory attributes, resulting in denser, harder muffins with reduced height and volume. Muffins containing 1% DMP exhibited physical, textural, and sensory properties closest to the control, achieving the highest panelist acceptability. This research underscores the potential of DMP as a functional ingredient for developing nutritionally enhanced bakery products, with significant implications for innovation and product diversification in the food industry. Further studies are recommended to optimize formulations and expand the commercial applications of DMP-enriched baked goods.

Keywords: Borassus flabellifer, muffins, dietary fiber, functional foods, sensory analysis

INTRODUCTION

Bakery products, such as muffins, are a staple in many diets due to their convenience, versatility, and sensory appeal (Matos, Sanz, & Rosell, 2014). However, these products often lack essential nutrients, including dietary fiber, which is critical for digestive health and chronic disease prevention (Slavin, 2020). Consumer demand for healthier alternatives has spurred interest in incorporating natural, fiber-rich ingredients into bakery formulations (Goswami et al., 2015).

Borassus flabellifer, also known as the palmyra palm, is a versatile plant valued for its rich nutritional profile, particularly its dietary fiber, antioxidants, and bioactive compounds (De Zoysa et al., 2017). Previous studies have highlighted its application in various food products, including beverages and desserts, but its use in baked goods remains underexplored.

Dietary fiber plays a crucial role in improving food functionality and nutritional value. Beyond its physiological benefits, fiber contributes to product stability and texture (Kaack et al., 2006). However, incorporating fiber into bakery products often poses challenges, such as changes in texture, volume, and sensory properties (Aydogdu, Sumnu, & Sahin, 2017). This study aims to address these challenges by evaluating the effects of Borassus flabellifer mesocarp powder on the nutritional and sensory qualities of muffins. By substituting varying levels of wheat flour with DMP, this research seeks to identify the optimal formulation that balances enhanced nutrition with acceptable sensory attributes.

MATERIALS AND METHODS

Experimental Design

Muffins were prepared using a control formulation (0% DMP) and three formulations incorporating DMP at 1%, 3%, and 6%. Proximate analysis, physical properties, textural characteristics, and sensory evaluations were conducted.

Muffin Preparation

The muffin batter was prepared by mixing oil, whole egg, and full milk cream using a mixer (HR1559/55, Phillip, Malaysia) for 2 minutes. Later, wheat flour, sugar, DMP, baking powder, and salt were added to the mixture. The amount of DMP (1-3 g) added to the muffin was determined based on a preliminary study. About 45 g of batter was filled into paper cups and baked at 190°C for 40 minutes in an electric oven (6840SS, Elba, Malaysia). The muffins were then removed from the oven and left to cool at room temperature for 30 minutes on a rack.

Based on the preliminary findings, the DMP required sieving with a 0.5 mm sieve to remove coarse fibers before being added to the muffin formulation. Fiber size and the percentage of coarse fiber removal were determined. Three muffin formulations and a control (without DMP) were prepared using the same quantities of all ingredients except for DMP and wheat flour. Sieved DMP (1 g, 3 g, and 6 g) was incorporated into the new formulations. A similar procedure for muffin preparation was followed, and all DMP muffins were analyzed for quality attributes and compared to the control muffin**.**

Analytical Methods

Proximate composition, including moisture, fat, protein, ash, carbohydrate, and fiber content, was determined (AOAC (2000). Physical parameters such as height, volume, specific volume ((Chaubey, Somani, Kanchan, Sathaye, & Varakumar, 2017), and baking loss (Dhen et al., 2016) were measured.

Textural properties, including hardness, cohesiveness, springiness and resilience, were assessed using a texture analyzer (Stable Micro Systems, Surrey, UK).

Sensory Evaluation

Sensory analysis was conducted according to Buriti et al. (2014) and Ahmad et al. (2015) using a 40-member panel to evaluate color, appearance, aroma, texture, flavor, and overall acceptability on a 9-point hedonic scale.

Statistical Analysis

Data collected were expressed as mean ± standard deviation (SD) for respective analysis. The data was subjected to one way analysis of variance using MINITAB 13.2 (Minitab Inc., Pennsylvania, USA). Differences at $p < 0.05$ were considered to be significant. Relationships between variables for physical-chemical properties of muffin were examined using Pearson correlation coefficients.

RESULTS AND DISCUSSION

Nutritional Composition

The substitution of wheat flour with DMP significantly increased dietary fiber content in the muffins ($p<0.05$). Muffins with 6% DMP exhibited the highest fiber content (4.68%), meeting the uropean Union's definition of a high-fiber product. Additionally, fat content decreased with increasing DMP levels due to the water-absorbing and oil-reducing properties of dietary fiber. This finding aligns with Tungland and Meyer's (2002) observations on fiber-rich formulations.

Moisture content also increased with DMP incorporation, likely due to its water-binding capacity. However, protein and carbohydrate contents showed slight decreases, reflecting the partial substitution of wheat flour.

Table 1: Proximate Composition of Muffin

	Proximate composition (%)					
Formulation (% of DMP)	Moisture	Fat	Protein	Ash	Carbohydrate (by difference)	Crude Fibre
Control (0)	18.99±0.06^{c}	9.70±0.09^{a}	11.95±0.05^{a}	0.83±0.18^{a}	58.53±0.96^{a}	3.20±0.02^{d}
F1 (1)	20.65±0.91^{bc}	9.87±0.09^{a}	11.78±0.00^{b}	0.75±0.08^{a}	56.95±2.39^{ab}	4.48±0.01^{c}
F2 (3)	21.66±0.13^{ab}	9.83±0.11^{a}	11.34±0.05^{c}	0.70±0.15^{a}	56.47±1.09^{b}	4.60±0.02^{b}
F3 (6)	23.58±0.78^{a}	7.08±0.38^{b}	11.50±0.00^{d}	0.76±0.21^{a}	57.08±0.54^{ab}	4.68±0.01^{a}

[1]Mean values in the same column followed by different superscripts differ significantly ($p<0.05$).
[2]The samples were identified as control (100 g of WF/0g of DMP), F1 (99g of WF/1g of DMP), F2 (97g of WF/3g of DMP) and F3 (94g of WF/6g of DMP). DMP: Borassus flabellifer mesocarp, WF: Wheat flour.

Physical Properties

The effect of DMP powder substitution on the height, volume, and specific volume of muffins is shown in Table 6.3. Substitution of wheat flour with DMP powder slightly decreased the height of muffins, but this decrease was statistically insignificant. This outcome aligns with previous findings indicating that adding fiber to bakery products generally reduces product height due to lower specific gravity and reduced air cell retention in the batter (Grigelmo-Miguel, Carreras-Boladeras, & Martín-Belloso, 2001; Aydogdu, Sumnu, & Sahin, 2017). Reduced air bubble

retention and decreased gluten network elasticity are potential contributors to this phenomenon (Martínez-Cervera, 2011).

Volume measurement serves as a crucial indicator of baked product quality, reflecting its visual appeal and structural development. Although no significant differences in muffin volume were observed with increasing DMP levels, a decreasing trend was evident. Muffin volume is closely tied to the amount of air incorporated during mixing and retained during baking. Insoluble fibers, such as those found in DMP, can disrupt gluten networks and reduce the gas-holding capacity of the batter, contributing to volume reduction (Chang, Li, & Shiau, 2015; Walker et al., 2014).

Specific volume, an essential physical property that affects consumer preference, was significantly reduced ($p<0.05$) in muffins with 3% and 6% DMP compared to the control. Lower specific volume is associated with denser crumb structures and less aeration, as fibers interfere with gluten matrix formation. These observations are consistent with studies on fiber-enriched bakery products, including formulations with coffee silverskin, resistant starch, and apple pomace (Aydogdu et al., 2017; Baixauli et al., 2008; Rupasinghe et al., 2008).

The presence of DMP in higher concentrations caused noticeable changes in batter rheology and baking outcomes. The collapse of CO2 gas bubbles during baking, likely due to the high fiber content, contributed to reduced volume and specific volume. Similar effects have been documented in muffins containing lemongrass powder and other plant-based fibers (Lee et al., 2015; Dizlek, 2015).

High specific volume is generally indicative of a porous structure, contributing to a light and spongy texture desirable in muffins and cakes (Martínez-Cervera et al., 2011). The reduction in specific volume observed in DMP muffins underscores the importance of balancing fiber incorporation with the maintenance of desirable structural and sensory attributes.

Table 2: Physical properties of muffin and correlation between the percentages of DMP added in muffin formulation towards; (a) volume of muffin and (b) bake loss rate.

Formulation (% of DMP)	Parameters			
	Height (cm)	Baking Loss Rate (%)	Volume (mL)	Specific Volume mL/g)
Control (0)	$4.97^{a}\pm0.25$	$4.76^{a}\pm0.10$	$88.66^{a}\pm6.46$	$2.01^{a}\pm0.15$
F1 (1)	$4.63^{ab}\pm1.53$	$4.44^{a}\pm0.10$	$82.61^{ab}\pm1.06$	$1.91^{a}\pm0.02$
F2 (3)	$4.40^{ab}\pm1.00$	$2.54^{b}\pm0.22$	$78.51^{b}\pm3.54$	$1.78^{b}\pm0.08$
F3 (6)	$4.23^{b}\pm2.52$	$2.21^{b}\pm0.21$	$76.57^{b}\pm1.04$	$1.73^{b}\pm0.02$
Correlation				
a) Corr. (% DMP, volume)	-0.8157			
b) Corr. (% DMP, bake loss rate)	-0.9627			

[1]Mean values in the same column followed by different superscripts differ significantly ($P < 0.05$).

[2]The samples were identified as control (100 g of WF/0g of DMP), F1 (99g of WF/1g of DMP), F2 (97g of WF/3g of DMP) and F3 (94g of WF/6g of DMP). DMP: Borassus flabellifer mesocarp, WF: Wheat flour.

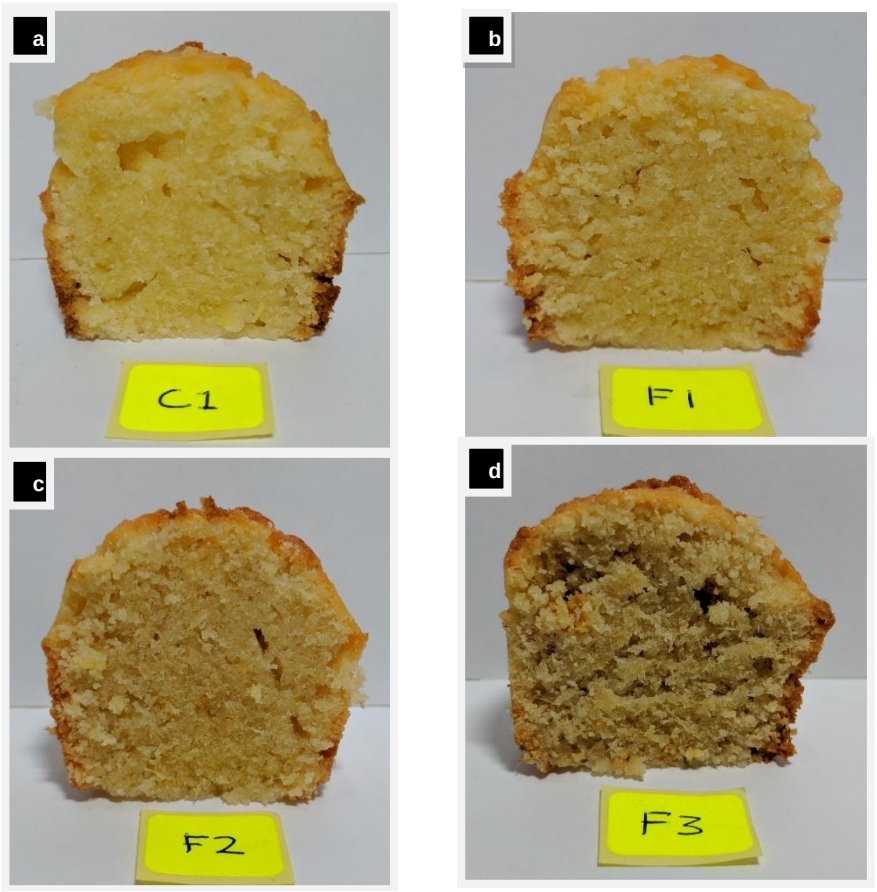

FIGURE 1: VERTICAL CROSS-SECTIONAL VIEW OF MUFFINS CONTAINING DIFFERENT AMOUNT OF DMP, (A) CONTROL MUFFIN WITHOUT DMP, (B) MUFFIN WITH 1% OF DMP, (C) MUFFIN WITH 3% OF DMP (D) MUFFIN WITH 6% OF DMP.

Textural Properties

The texture of baked products, particularly attributes such as hardness and cohesiveness, plays a crucial role in defining their overall quality. These characteristics can be influenced by the addition of fiber (Salvador & Fiszman, 2013). In the case of muffins, substituting wheat flour with DMP resulted in a noticeable increase in texture hardness (Table 6.5). As the percentage of DMP increased, the hardness of the muffins also rose significantly ($p<0.05$). Notably, a positive correlation ($r = 0.786$) was observed between the crude fiber content and muffin hardness. This increase in hardness due to fiber incorporation has been reported in other baked products, such as potato fiber-enriched bread (Kaack, Pedersen, & Nygaard, 2006). Similarly, hardness in muffins and cakes increased when wheat flour was replaced with peach dietary fiber and apple pomace, respectively, likely due to the reduction in air pockets and an increase in density (O'Shea et al., 2012; Rabetafika, Bchir, Blecker, & Richel, 2014). The increased hardness observed in muffins with DMP may be attributed to a decrease in gluten content and an enhanced water absorption capacity, which stems from the higher fiber content of DMP. The decrease in the gluten-forming network structure likely leads to a denser, more compact muffin (Gularte, Gómez, & Rosell, 2011).

Cohesiveness, an important texture parameter, reflects the sensory crumbliness of a product and is indicative of its density and the effort required to chew (Sanz et al., 2009). In this study, the cohesiveness of muffins decreased significantly ($p<0.05$) with increasing DMP substitution (Table 6.5). A similar decrease in cohesiveness was observed when finger millet flour was substituted in flour blends (Rajiv, Soumya, Indrani, & Venkateswara Rao, 2011). Cohesiveness is directly related to gas retention and volume; a more cohesive product retains more gas, resulting in a higher volume (Tess et al., 2015). In this study, the cohesiveness of the muffins showed a strong positive correlation with their hardness after baking, with the DMP muffins displaying correlation values ranging from 0.733 to 0.891.

Springiness, a key indicator of freshness in baked products, refers to the ability of a product to return to its original shape after deforming forces are removed. High-quality muffins typically exhibit a higher springiness value, which signifies better shape recovery (Szczesniak, 2012; Tess et al., 2015). In this study, the springiness of muffins significantly decreased ($p<0.05$) with increasing DMP substitution, except for the muffin with 1% DMP (Table 6.5). A lower springiness value is often associated with a denser matrix and reduced air bubbles within the muffin (Sanz et al., 2009). Similar reductions in springiness were reported when fenugreek seed husk was incorporated into muffins (Rajiv et al., 2012). A strong positive correlation was observed between cohesiveness and springiness values ($r = 0.961$-0.973) in most muffins, except for the 6% DMP substitution, where the correlation was moderately positive ($r = 0.656$). The decreased springiness and cohesiveness in muffins with 6% DMP likely reflect a lower specific volume and a less aerated structure.

Resilience, defined as the ability of a product to recover after deformation, was also influenced by DMP substitution. A decline in resilience (Baixauli et al., 2008) was noted with increasing DMP, likely due to the denser matrix formed in these muffins. The resilience of muffins containing 6% DMP was significantly lower ($p<0.05$) than that of the control (Table 6.5). This reduction in resilience correlates with a decreased number of gas cells in the muffin (Martínez-Cervera et al., 2015). The higher moisture content in the DMP muffins may have contributed to a stickier crumb, which did not recover its original shape after compression, as observed by Martínez-Cervera et al. (2011). This phenomenon is further supported by the positive and strong correlation ($r = 0.712$) between moisture content and resilience in muffins with 6% DMP substitution.

Table3: Textural properties of muffin

Formulation	Parameters			
(% of DMP)	Hardness	Cohesiveness	Springiness	Resilience
Control (0)	$3397.44^{a}\pm111.35$	$0.64^{a}\pm0.01$	$0.86^{a}\pm0.00$	$0.26^{a}\pm0.01$
F1 (1)	$4962.30^{b}\pm48.67$	$0.49^{b}\pm0.02$	$0.80^{ab}\pm0.02$	$0.15^{b}\pm0.01$
F2 (3)	$5009.52^{b}\pm215.75$	$0.48^{b}\pm0.02$	$0.75^{bc}\pm0.03$	$0.14^{b}\pm0.01$
F3 (6)	$5988.01^{c}\pm221.94$	$0.45^{c}\pm0.01$	$0.73^{c}\pm0.02$	$0.12^{c}\pm0.01$

[1]Mean values in the same column followed by different superscripts differ significantly ($P < 0.05$).

[2]The samples were identified as control (100 g of WF/0g of DMP), F1 (99g of WF/1g of DMP), F2 (97g of WF/3g

of DMP) and F3 (94g of WF/6g of DMP). DMP: Borassus flabellifer mesocarp, WF: Wheat flour.

Sensory Evaluation

Sensory evaluation showed that muffins with 1% DMP received the highest scores for flavor, texture, and overall acceptability, closely matching the control sample. However, muffins with 3% and 6% DMP were less favored due to their dense texture and darker appearance. These results suggest that while moderate DMP levels enhance nutritional value without compromising sensory qualities, higher concentrations may reduce consumer acceptability.

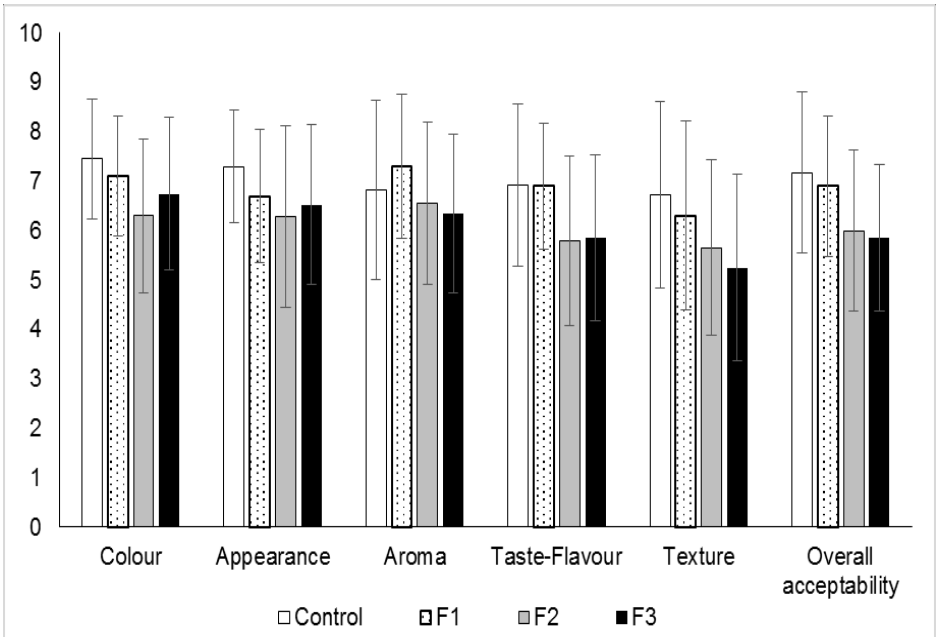

Figure 2: Sensory acceptance (maximum score of 9) of DMP substituted muffin and control muffin (score 1=dislike extremely, 9=like extremely).

CONCLUSION

This study demonstrates the potential of Borassus flabellifer mesocarp powder (DMP) as a functional ingredient in bakery products by enhancing their nutritional value through increased dietary fiber and reduced fat content. However, higher substitution levels of DMP negatively impact the textural and sensory properties of muffins. Muffins with 1% DMP achieve an optimal balance between improved nutrition and sensory appeal, highlighting the ingredient's promise for functional food development. Further research could investigate the synergistic effects of DMP combined with functional ingredients, such as hydrocolloids (e.g., guar gum or xanthan gum), proteins, or emulsifiers, which may improve textural attributes by enhancing moisture retention and structural integrity. This approach could facilitate the broader application of DMP in innovative, nutrient-rich food products.

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EVALUATION OF THERMAL FREE VIBRATION RESPONSE OF FUNCTIONALLY GRADED PLATES WITH POWER-LAW, EXPONENTIAL AND SIGMOID MATERIAL GRADIENTS

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ABSTRACT

Introduction and Purpose: This study evaluates the free vibration analysis of functionally graded material (FGM) plate with power-law, exponential and sigmoid material gradients under thermal environment.

Materials and Methods: It is considered that the FGM plate's material properties grade in the thickness direction according to the power law, exponential law, and sigmoid law, respectively. The proposed FGM plate contains a mixture of aluminum oxide (Al_2O_3) and stainless steel (SUS304), and the metal content decreases from the bottom surface to the top surface of the plate. The material properties of FGM plate are influenced by temperature. A wide range of thermal loads are applied to the plate with uniform temperature rise in the thickness direction. The study has been carried out using the higher-order shear deformation theory (HSDT). The equations of motion of the plate are obtained with Hamilton's method. To find the closed-form solutions of FGM plate, Navier's solution is utilized.

Results: The research focuses on evaluating the effect of material distribution gradient, material composition and temperature rise parameters on the free vibration response of the FGM plate. According to the results of the analysis, the natural frequency response of the structure is significantly affected by the material distribution gradient, material composition and temperature increase.

Discussion and Conclusion: According to the results of the study, it is emphasized that it is important to consider the temperature-dependent material properties of the plates that can be exposed to high temperatures for the free vibration behavior of the plate. In addition, it is determined that by properly adjusting the material distribution gradient and material composition, it is possible to form plate structures that can adapt to the desired mechanical and thermal properties as well as the desired environment conditions.

Keywords: Free Vibration Analysis; FGM Plate; HSDT; Al_2O_3-SUS304; Thermal Load.

INTRODUCTION

Functionally graded materials (FGMs) represent a significant advancement in material science, characterized by a gradual variation in composition and properties across their volume. This unique feature allows FGMs to overcome the limitations of traditional materials, which often exhibit abrupt changes in properties that can lead to stress concentrations, delamination, and failure underload. The continuous gradation of properties in FGMs can be achieved through various methods, including additive manufacturing, which allows for precise control over

material composition at a microstructural level. This capability is particularly valuable in applications where tailored properties are essential, such as in the fabrication of components that must withstand extreme thermal or mechanical stresses (Karimzadeh et al., 2024; Salcedo et al., 2018). For instance, FGMs have been utilized in the design of thermal barrier coatings, where the material must transition smoothly from a high-temperature resistant layer to a substrate that can support mechanical loads (Petit et al., 2018). In structural applications, FGMs have been shown to enhance performance by reducing stress concentrations and improving load-bearing capabilities. Studies have demonstrated that functionally graded beams and plates exhibit superior vibrational characteristics compared to their homogeneous counterparts, making them ideal for applications in dynamic environments (Jun & Li, 2018; Njim et al., 2021; Zghal & Dammak, 2020). The mechanical properties of FGMs can be tailored through the selection of constituent materials and the design of the grading profile. For example, the power law distribution is commonly employed to define the variation of properties across the thickness of the material, allowing for a systematic approach to optimizing performance based on specific application requirements (T. K. Sharma et al., 2023). This flexibility in design is a key advantage of FGMs, enabling engineers to create materials that meet the demands of complex loading scenarios while minimizing the risk of failure (Li et al., 2018; Rizov, 2019).

The gradation of FGM properties can be achieved through various mathematical models, including power law, sigmoid law, and exponential law. Each of these laws offers distinct advantages and applications, making them crucial in the design and analysis of FGMs across various engineering fields. The power law function is one of the most used models for material grading in FGMs. This model allows for a smooth transition between different material phases, which is particularly beneficial in applications where mechanical properties need to be optimized. Research indicates that power law grading can significantly influence the mechanical response of FGMs, including their stiffness and strength characteristics (Abd-Ali & Madeh, 2021). For instance, Ramteke et al. (2021). demonstrated that the deflection and stress responses of functionally graded structures are heavily dependent on the grading pattern, with power-law graded materials exhibiting distinct mechanical behaviors compared to those graded by other laws. In contrast, the sigmoid law provides a different approach to material gradation, characterized by a smooth s-shaped curve that transitions between two extremes. This model is particularly useful in applications where a gradual change in properties is required to minimize stress concentrations at interfaces. Studies have shown that using a sigmoid law can enhance the structural integrity of FGMs, particularly in dynamic loading scenarios, by distributing stresses more evenly throughout the material (Bensaid et al., 2020; J. K. Sharma et al., 2023). For example, Sharma et al. (2023), explored the computational modeling of sigmoid functionally graded materials and found that such gradation significantly affects the natural frequency and dynamic response of the materials. The exponential law, another important grading model, describes the variation of material properties in an exponential manner. This model is particularly advantageous in applications where rapid changes in material properties are necessary, such as in thermal barrier coatings or aerospace components. The exponential function allows for a more pronounced variation in properties near the surface of the material, which can be crucial for applications requiring high thermal resistance or specific mechanical performance under extreme conditions (Helal et al., 2018). N.A. et al. (2018) highlighted the effectiveness of exponential grading in enhancing the thermal performance of functionally graded cylinders, demonstrating that this approach can lead to improved thermal stability and reduced thermal stress. The choice of grading law has significant implications for the performance of FGMs. For instance, the power law is often favored for applications requiring high mechanical strength, while the sigmoid law is preferred for applications where stress distribution is critical. The exponential law, on the other hand, is typically selected for applications involving thermal gradients (Kumar et al., 2020).

The aim of this study is to perform free vibration analysis of FGM plate with power-law, exponential and sigmoid material gradients under thermal environment and to draw conclusions about the effects of material distribution models and temperature loads. The study includes the investigation of the effective mechanical and thermal properties of the metal-ceramic matrix plate with three different dispersion models, the variation of the free vibration response of the plate according to various parameters and the comparison of the FGM distribution functions.

THEORETICAL BACKGROUND AND MATHEMATICAL MODEL

The schematic representation of the proposed FGM plate is presented in Figure 1. For the mathematical constructions of the structure, a cartesian coordinate system (x, y, z) is taken into account. The FGM plate is assumed to be made of a mixture of ceramic and metal, and the material properties of the plate are assumed to be graded in the thickness direction. Here, the top surface of the FGM plate is considered to be ceramic-rich (Al_2O_3) and the bottom surface is considered to be metal-rich (SUS304). The top and bottom surfaces of the FGM plate are at $z = \pm h/2$.

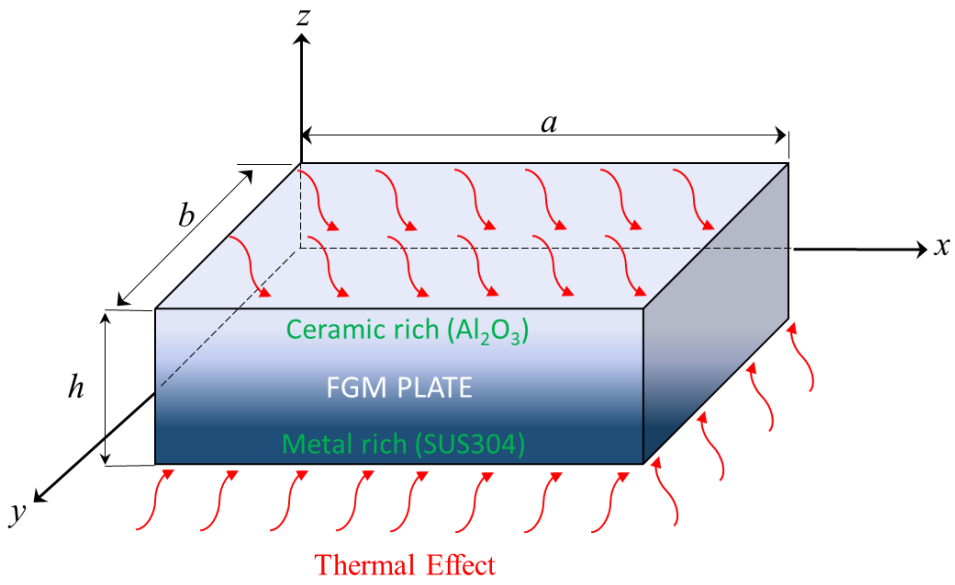


Figure 1. Schematic representation of FGM plate

FGM structures are formed by continuously grading the volume fraction distribution of the constituent materials along the thickness direction. The variation of the volume fraction of the constituent materials enables the mechanical and thermal properties of the plate to change. Here, three different mathematical models are used to describe the mechanical and thermal material properties of the FGM plate. The material properties of the FGM plate are characterized by the dispersion of ceramic and metal components as a function of the power law (P-FGM), exponential law (E-FGM) and sigmoid law (S-FGM).

The effective material properties of FGM plate can be calculated as follows:

$$P(z) = P_{met} + (P_{cer} - P_{met})V_{cer} \quad (1)$$

where $P(z)$ represents the effective material property, P_{cer} and P_{met} denote the mechanical or thermal material properties of Al_2O_3 and SUS304, respectively. In addition, V_{cer} is the volume fraction of Al_2O_3.

The volume fraction of the P-FGM plate can be calculated as:

$$V_{cer} = \left(\frac{1}{2} + \frac{z}{h}\right)^{p} \qquad -\frac{h}{2} \leq z \leq \frac{h}{2} \tag{2}$$

in which p is the power law parameter. According to sigmoid law, the volume fraction of the S-FGM plate can be defined as (Belarbi et al., 2025):

$$\begin{aligned} V_{cer} &= 1 - \frac{1}{2}\left(1 - \frac{2z}{h}\right)^{p} \qquad 0 \leq z \leq \frac{h}{2} \\ V_{cer} &= \frac{1}{2}\left(1 + \frac{2z}{h}\right)^{p} \qquad -\frac{h}{2} \leq z \leq 0 \end{aligned} \tag{3}$$

An exponential function describing the variation in E-FGM plate properties is given by:

$$P(z) = P_{met} e^{\left[\ln\left(\frac{P_{cer}}{P_{met}}\right)\left(\frac{1}{2}+\frac{z}{h}\right)\right]} \qquad -\frac{h}{2} \leq z \leq \frac{h}{2} \tag{4}$$

The variation of the effective material properties (modulus of elasticity (E_{eff}), Poisson's ratio (ν_{eff}), thermal conductivity (κ_{eff}) and thermal expansion (α_{eff})) of FGM plate for P-FGM, S-FGM and E-FGM dispersion patterns of the considered FGM plate with respect to z/h ratio and power law coefficient are given in Figure 2, Figure 3 and Figure 4.

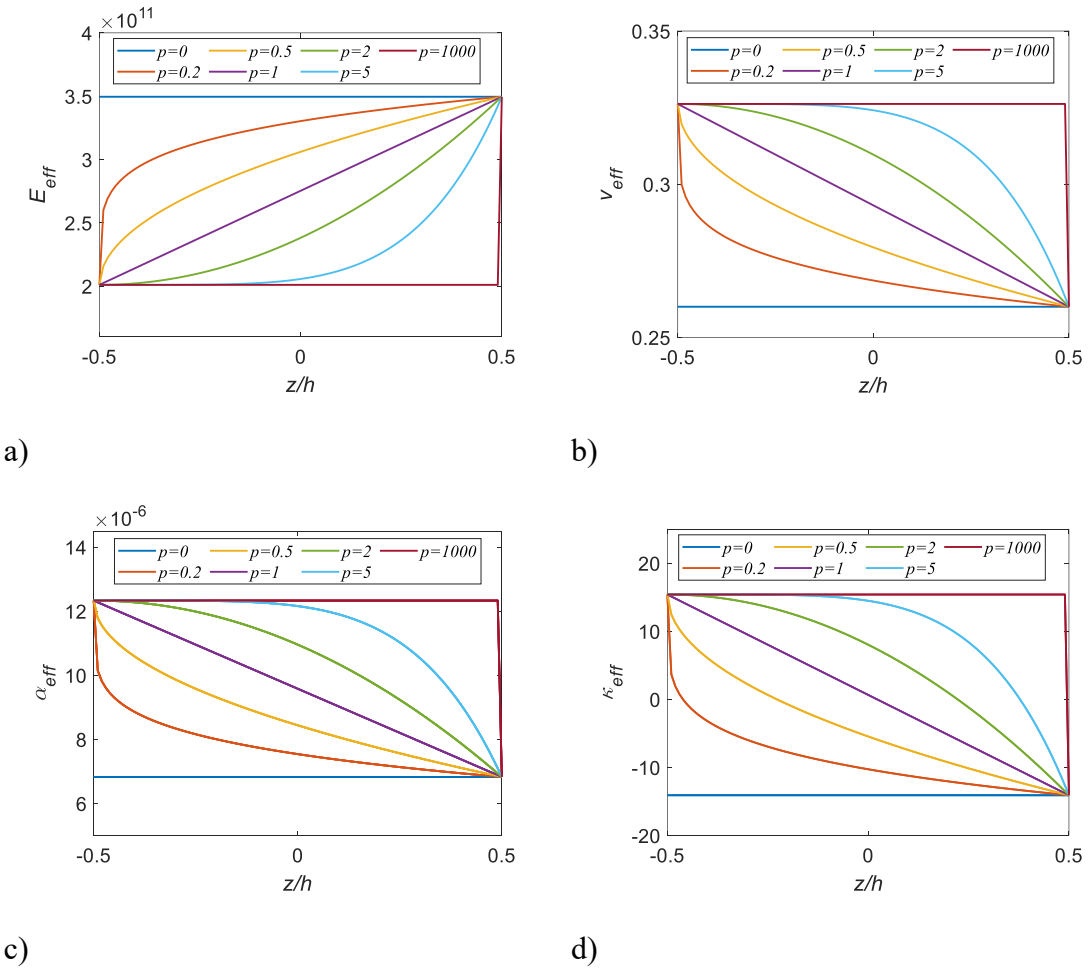


Figure 2. Variation of material properties with p and z/h in P-FGM pattern.

According to Equation 2, the bottom surface of the plate is metal rich, and the top surface is ceramic rich. As shown in Figure 2, for p=0, the plate is completely composed of Al_2O_3, while for $p = \infty$, the plate is completely composed of SUS304. The volume fraction of metal component in the plate increases with increasing p. In addition, at p=1, the plate consists of 50% ceramic and 50% metal.

As shown in Figure 3, for p=1000 in the S-FGM function, the lower half of the plate consists of pure SUS304 while the upper half consists of pure Al_2O_3. For p=0, Al_2O_3 and SUS304 are evenly distributed on the plate and have equal volume fraction. For increasing values of p, the ceramic ratio decreases in the range $-h/2 \leq z \leq 0$ and increases in the range $0 \leq z \leq +h/2$. The variation of the effective material properties of the FGM plate according to the exponential law is presented in Figure 4. According to the figure, the metallic properties, which are dominant on the bottom surface of the plate, are logarithmically replaced by ceramic properties from the bottom surface to the top surface.

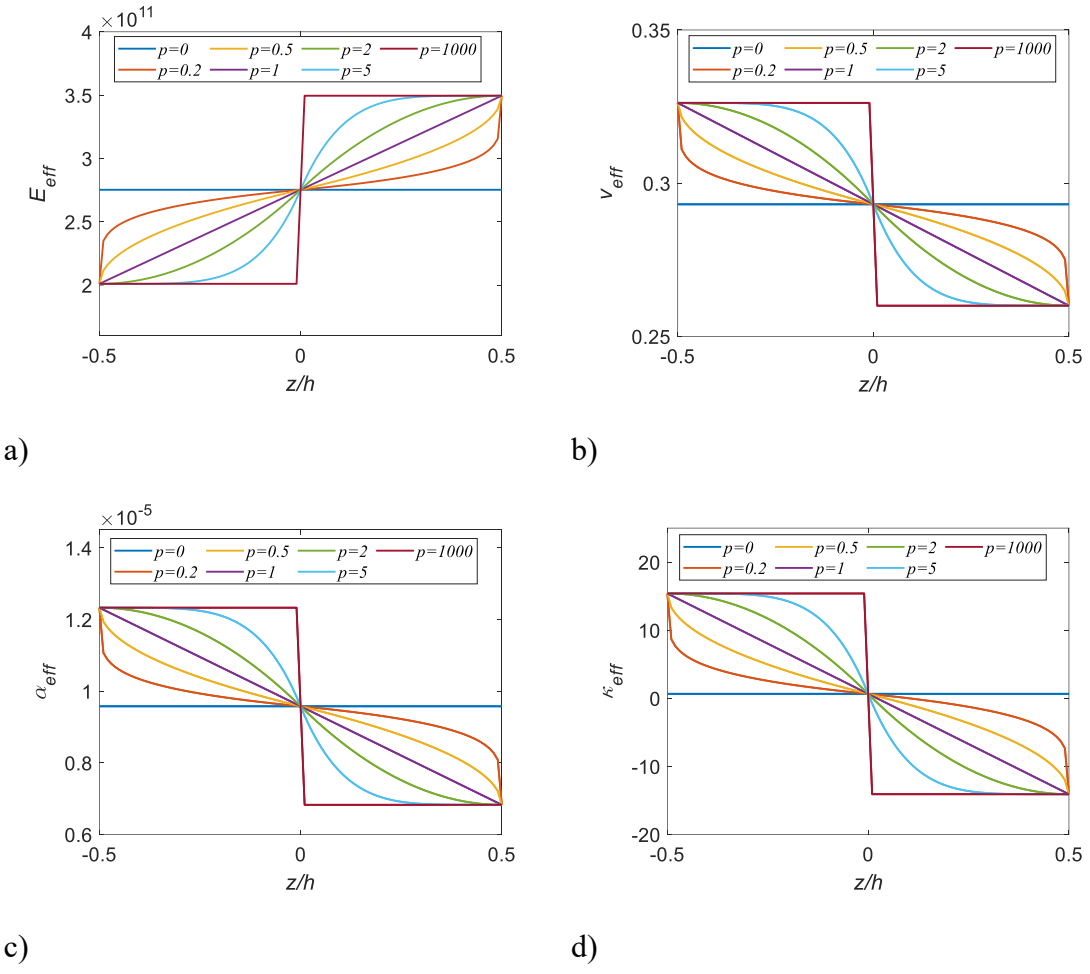


Figure 3. Variation of material properties with p and z/h in S-FGM dispersion pattern.

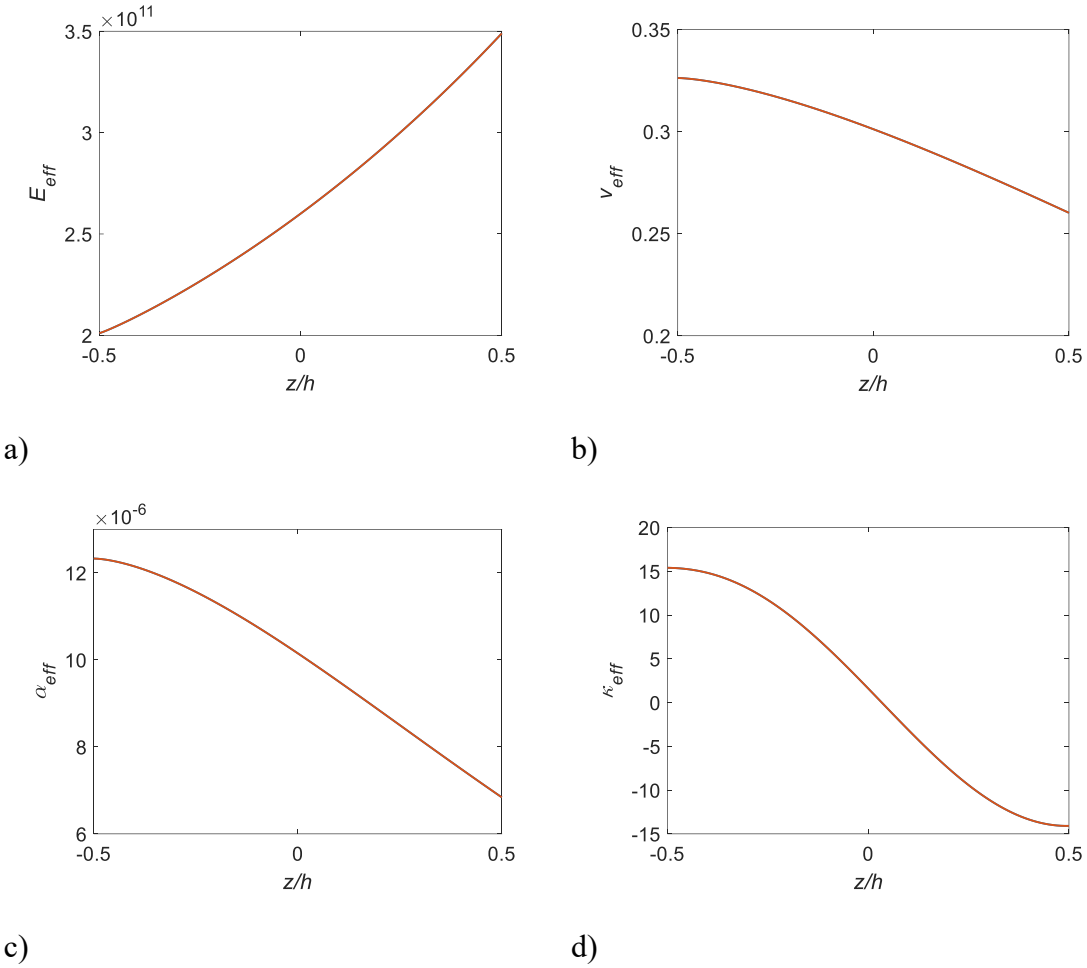


Figure 4. Variation of material properties with p and z/h in E-FGM dispersion pattern.

The temperature dependent mechanical and thermal properties of FGM plate components are obtained by Equation 5 (Reddy & Chin, 1998; Touloukian, 1967).

$$P = P_0(P_{-1}T^{-1} + 1 + P_1T + P_2T^2 + P_3T^3) \quad (5)$$

The temperature-dependent mechanical and thermal properties of Al_2O_3 and SUS304 are given in Table 1.

Table 1. Temperature-dependent material properties (Reddy & Chin, 1998).

Material	Properties	P_{-1}	P_0	P_1	P_2	P_3
Al_2O_3	E (Pa)	0	$349.55x10^9$	$-3.853x10^{-}$	$4.027x10^{-7}$	$-1.673x10^{-1}$
	υ	0	0.26	0	0	0
	$\alpha\ (1K^{-1})$	0	$6.8269x10^{-6}$	$1.838x10^{-4}$	0	0
	$\kappa\ (W/mK)$	-1123.6	-14.087	$-6.227x10^{-}$	0	0
	$\rho\ (kg/m^3)$	0	3750	0	0	0
SUS304	E (Pa)	0	$201.04\ x10^9$	$3.079x10^{-4}$	$-6.534x10^{-}$	0
	υ	0	0.3262	$-2.002x10^{-}$	$3.97x10^{-7}$	0
	$\alpha\ (1K^{-1})$	0	$12.33x10^{-6}$	$8.086x10^{-4}$	0	0
	$\kappa\ (W/mK)$	0	15.397	$-1.264x10^{-}$	$2.09x10^{-6}$	$-7.223x10^{-1}$
	$\rho\ (kg/m^3)$	0	8166	0	0	0

According to the higher-order shear deformation theory, the displacement field can be expressed as follows (Daikh & Zenkour, 2019):

$$\begin{aligned} u(x,y,z) &= u_0 - z\frac{\partial w_0}{\partial x} + f(z)\varphi_1 \\ v(x,y,z) &= v_0 - z\frac{\partial w_0}{\partial y} + f(z)\varphi_2 \\ w(x,y,z) &= w_0 \end{aligned} \tag{6}$$

where f(z) is the shape function. f(z) can be calculated as:

$$f(z) = z\left(1 - \frac{3z^2}{2h^2} + \frac{2z^4}{5h^4}\right) \tag{7}$$

The relationship between strain and displacement can be expressed as:

$$\begin{Bmatrix} \varepsilon_{xx} \\ \varepsilon_{yy} \\ \varepsilon_{zz} \\ \gamma_{xy} \\ \gamma_{yz} \\ \gamma_{xz} \end{Bmatrix} = \begin{bmatrix} \frac{\partial u}{\partial x} + \frac{1}{2}\left(\frac{\partial w}{\partial x}\right)^2 \\ \frac{\partial v}{\partial y} + \frac{1}{2}\left(\frac{\partial w}{\partial y}\right)^2 \\ \frac{\partial w}{\partial z} \\ \frac{\partial v}{\partial x} + \frac{\partial u}{\partial y} + \frac{\partial w}{\partial x}\frac{\partial w}{\partial y} \\ \frac{\partial w}{\partial y} + \frac{\partial v}{\partial z} \\ \frac{\partial w}{\partial x} + \frac{\partial u}{\partial z} \end{bmatrix} \tag{8}$$

The deformations can be organized and written as follows:

$$\begin{Bmatrix}\varepsilon_{xx}\\ \varepsilon_{yy}\\ \gamma_{xy}\end{Bmatrix}=\begin{Bmatrix}\varepsilon_{xx}^{0}\\ \varepsilon_{yy}^{0}\\ \gamma_{xy}^{0}\end{Bmatrix}+z\begin{Bmatrix}\varepsilon_{xx}^{1}\\ \varepsilon_{yy}^{1}\\ \gamma_{xy}^{1}\end{Bmatrix}+f(z)\begin{Bmatrix}\varepsilon_{xx}^{2}\\ \varepsilon_{yy}^{2}\\ \gamma_{xy}^{2}\end{Bmatrix},$$

$$\begin{Bmatrix}\gamma_{yz}\\ \gamma_{xz}\end{Bmatrix}=\frac{df(z)}{dz}\begin{Bmatrix}\gamma_{yz}^{0}\\ \gamma_{xz}^{0}\end{Bmatrix} \tag{9}$$

in which

$$\begin{Bmatrix}\varepsilon_{xx}^{0}\\ \varepsilon_{yy}^{0}\\ \gamma_{xy}^{0}\end{Bmatrix}=\begin{Bmatrix}\dfrac{\partial u_0}{\partial x}\\ \dfrac{\partial v_0}{\partial y}\\ \dfrac{\partial v_0}{\partial x}+\dfrac{\partial u_0}{\partial y}\end{Bmatrix},\qquad \begin{Bmatrix}\varepsilon_{xx}^{1}\\ \varepsilon_{yy}^{1}\\ \gamma_{xy}^{1}\end{Bmatrix}=-\begin{Bmatrix}\dfrac{\partial^2 w_0}{\partial x^2}\\ \dfrac{\partial^2 w_0}{\partial y^2}\\ 2\dfrac{\partial^2 w_0}{\partial x\,\partial y}\end{Bmatrix},$$

$$\begin{Bmatrix}\varepsilon_{xx}^{2}\\ \varepsilon_{yy}^{2}\\ \gamma_{xy}^{2}\end{Bmatrix}=\begin{Bmatrix}\dfrac{\partial \varphi_1}{\partial x}\\ \dfrac{\partial \varphi_1}{\partial y}\\ \dfrac{\partial \varphi_1}{\partial y}+\dfrac{\partial \varphi_2}{\partial x}\end{Bmatrix},\qquad \begin{Bmatrix}\gamma_{yz}^{0}\\ \gamma_{xz}^{0}\end{Bmatrix}=\begin{Bmatrix}\varphi_x\\ \varphi_y\end{Bmatrix} \tag{10}$$

The linear constitutive relations of a plate under the influence of temperature can be written as follows:

$$\begin{Bmatrix}\sigma_{xx}\\ \sigma_{yy}\\ \sigma_{yz}\\ \sigma_{xz}\\ \sigma_{xy}\end{Bmatrix}=\begin{bmatrix}Q_{11} & Q_{12} & 0 & 0 & 0\\ Q_{12} & Q_{22} & 0 & 0 & 0\\ 0 & 0 & Q_{44} & 0 & 0\\ 0 & 0 & 0 & Q_{55} & 0\\ 0 & 0 & 0 & 0 & Q_{66}\end{bmatrix}\begin{Bmatrix}\varepsilon_{xx}-\alpha\Delta T\\ \varepsilon_{yy}-\alpha\Delta T\\ \gamma_{YZ}\\ \gamma_{Xz}\\ \gamma_{xY}\end{Bmatrix} \tag{11}$$

in which

$$Q_{11}=Q_{22}=\frac{E}{1-v^2};\ Q_{12}=vQ_{11}\ ;Q_{44}=\ Q_{55}=\ Q_{66}=\frac{E}{2(1+v)} \tag{12}$$

Force components (N) and moment components (M) can be organized as follows:

$$\begin{Bmatrix}N_{xx}\\ N_{yy}\\ N_{xy}\end{Bmatrix}=\int_{-h/2}^{h/2}\begin{Bmatrix}\sigma_{xx}\\ \sigma_{yy}\\ \sigma_{xy}\end{Bmatrix}dz,\qquad \begin{Bmatrix}M_{xx}\\ M_{yy}\\ M_{xy}\end{Bmatrix}=\int_{h_{-h/2}}^{h/2}\begin{Bmatrix}\sigma_{xx}\\ \sigma_{yy}\\ \sigma_{xy}\end{Bmatrix}z\,dz \tag{13}$$

Stress resultants can be obtained as:

$$\begin{Bmatrix} P_{xx} \\ P_{yy} \\ P_{xy} \end{Bmatrix} = \int_{-h/2}^{h/2} \begin{Bmatrix} \sigma_{xx} \\ \sigma_{yy} \\ \sigma_{xy} \end{Bmatrix} f(z)dz, \qquad \begin{Bmatrix} R_{yz} \\ R_{xz} \end{Bmatrix} = \int_{-h/2}^{h/2} \begin{Bmatrix} \sigma_{yz} \\ \sigma_{xz} \end{Bmatrix} \frac{df(z)}{dz}\, dz \tag{14}$$

Force, moment and stress components can be reorganized as:

$$\begin{Bmatrix} \{N\} \\ \{M\} \\ \{P\} \end{Bmatrix} = \begin{bmatrix} [A] & [B] & [C] \\ [B] & [D] & [F] \\ [C] & [F] & [H] \end{bmatrix} \begin{Bmatrix} \{\varepsilon^0\} \\ \{\varepsilon^1\} \\ \{\varepsilon^2\} \end{Bmatrix}, \qquad \begin{Bmatrix} R_{yz} \\ R_{xz} \end{Bmatrix} = \begin{bmatrix} J_{44} & 0 \\ 0 & J_{55} \end{bmatrix} \begin{Bmatrix} \gamma_{yz}^0 \\ \gamma_{xz}^0 \end{Bmatrix} \tag{15}$$

The expressions $A_{ij}, B_{ij}, D_{ij}, C_{ij}, F_{ij}$, and H_{ij} are presented with:

$$\{A_{ij}, B_{ij}, D_{ij}, C_{ij}, F_{ij}, H_{ij}\} = \int_{-h/2}^{h/2} Q_{ij}\{1, z, z^2, f(z), zf(z), f(z)^2\}dz$$
$$J_k = \int_{-h/2}^{h/2} Q_k \left\{\frac{df(z)}{dz}\right\}^2 dz, (i, j = 1,2,6;\ k = 4,5) \tag{16}$$

The equations of motion of the FGM plate are obtained with the help of Hamilton's principle given below.

$$\delta \int_{t_1}^{t_2} (U - W - T)dt = 0 \tag{17}$$

where U, W and T define the strain energy, virtual work done by external force and the kinetic energy, respectively. The strain energy can be obtained as:

$$\delta U = \int_V \left[\sigma_{xx}\varepsilon_{xx} + \sigma_{yy}\varepsilon_{yy} + \sigma_{xy}\gamma_{xy} + \sigma_{yz}\gamma_{yz} + \sigma_{xz}\gamma_{xz}\right]dV \tag{18}$$

Virtual work done by external forces can be written as:

$$\delta V = \int_A q\delta w\, dA + \int_A \left[\bar{N}_{xx}^0 \frac{\partial w_0}{\partial x}\frac{\partial \delta w_0}{\partial x} + \bar{N}_{yy}^0 \frac{\partial w_0}{\partial y}\frac{\partial \delta w_0}{\partial y}\right] dA \tag{19}$$

In addition, the kinetic energy of the FGM plate can be obtained as follows:

$$T = \frac{1}{2}\int_V \rho(z)\left[\left(\frac{\partial u}{\partial t}\right)^2 + \left(\frac{\partial v}{\partial t}\right)^2 + \left(\frac{\partial w}{\partial t}\right)^2\right] dV \tag{20}$$

in which ρ defines mass density.

By substituting Equations (18-20) in Equation (17), the equations of motion of the FGM plate are derived as follows (Daikh & Zenkour, 2019):

$$\begin{aligned}
&\frac{\partial N_{xx}}{\partial x}+\frac{\partial N_{xy}}{\partial y}=I_0\frac{\partial^2 u_0}{\partial t^2}-I_1\frac{\partial^3 w_0}{\partial x\,\partial t^2}+I_3\frac{\partial^2 \varphi_x}{\partial t^2},\\
&\frac{\partial N_{xy}}{\partial x}+\frac{\partial N_{yy}}{\partial y}=I_0\frac{\partial^2 v_0}{\partial t^2}-I_1\frac{\partial^3 w_0}{\partial y\,\partial t^2}+I_3\frac{\partial^2 \varphi_y}{\partial t^2},\\
&\frac{\partial^2 M_{xx}}{\partial x^2}+2\frac{\partial^2 M_{xy}}{\partial x\,\partial y}+\frac{\partial^2 M_{yy}}{\partial y^2}+q+\bar{N}^0_{xx}\frac{\partial^2 w_0}{\partial x^2}+\bar{N}^0_{yy}\frac{\partial^2 w_0}{\partial y^2}=I_0\frac{\partial^2 w_0}{\partial t^2}\\
&+I_1\left(\frac{\partial^3 u_0}{\partial x\,\partial t^2}+\frac{\partial^3 v_0}{\partial y\,\partial t^2}\right)-I_2\left(\frac{\partial^4 w_0}{\partial x^2\,\partial t^2}+\frac{\partial^4 w_0}{\partial y^2\,\partial t^2}\right)+I_4\left(\frac{\partial^3 \varphi_x}{\partial x\,\partial t^2}+\frac{\partial^3 \varphi_y}{\partial y\,\partial t^2}\right),\\
&\frac{\partial P_{xx}}{\partial x}+\frac{\partial P_{xy}}{\partial y}-R_{xz}=I_3\frac{\partial^2 u_0}{\partial t^2}-I_4\frac{\partial^3 w_0}{\partial x\,\partial t^2}+I_5\frac{\partial^2 \varphi_x}{\partial t^2},\\
&\frac{\partial P_{xy}}{\partial x}+\frac{\partial P_{yy}}{\partial y}-R_{yz}=I_3\frac{\partial^2 v_0}{\partial t^2}-I_4\frac{\partial^3 w_0}{\partial y\,\partial t^2}+I_5\frac{\partial^2 \varphi_y}{\partial t^2}
\end{aligned} \tag{21}$$

where

$$\{I_0,I_1,I_2,I_3,I_4,I_5\}=\int_{-h/2}^{-h/2}\rho(z)\{1,z,z^2,f(z),zf(z),f(z)^2\}dz \tag{22}$$

The displacements can be obtained by the Navier method considering the simply- supported boundary conditions of the FGM plate as given below (Esen & Özmen, 2022; Sobhy, 2013):

$$\begin{aligned}
\{u_0,\varphi_x\}&=\sum_{m=1}^{\infty}\sum_{n=1}^{\infty}\{U_{mn},X_{mn}\}\cos(\lambda x)\sin(\beta y)\,e^{i\omega_n t}\\
\{v_0,\varphi_y\}&=\sum_{m=1}^{\infty}\sum_{n=1}^{\infty}\{V_{mn},Y_{mn}\}\sin(\lambda x)\cos(\beta y)\,e^{i\omega_n t}\\
\{w_0\}&=\sum_{m=1}^{\infty}\sum_{n=1}^{\infty}W_{mn}\sin(\lambda x)\sin(\beta y)e^{i\omega_n t}
\end{aligned} \tag{23}$$

where $\lambda=m\pi/a$ and $\beta=n\pi/b$. Also, U_{mn}, V_{mn}, W_{mn}, X_{mn} and Y_{mn} define the maximum displacements. In addition, ω_n represents the natural frequency. For free vibration response, the governing equations can be organized as follows:

$$([K]-{\omega_n}^2[M])\begin{Bmatrix}U_{mn}\\V_{mn}\\W_{mn}\\X_{mn}\\Y_{mn}\end{Bmatrix}=\begin{Bmatrix}0\\0\\0\\0\\0\end{Bmatrix} \tag{24}$$

in which [K] and [M] are stiffness and mass matrices, respectively. The elements of stiffness and mass matrices are obtained respectively as follows (Daikh & Zenkour, 2019):

$$
\begin{aligned}
&K_{11} = A_{11}\lambda^2 + A_{66}\beta^2, K_{12} = \lambda\beta(A_{12} + A_{66}),\\
&K_{13} = -B_{11}\lambda^3 - \lambda\beta^2(B_{12} + 2B_{66}), K_{14} = C_{11}\lambda^2 + C_{66}\beta^2,\\
&K_{15} = \lambda\beta(C_{12} + C_{66}), K_{22} = A_{66}\lambda^2 + A_{22}\beta^2,\\
&K_{23} = -B_{22}\beta^3 - \beta\lambda^2(B_{12} + 2B_{66}), K_{24} = K_{15},\\
&K_{34} = -F_{11}\lambda^3 - \lambda\beta^2(F_{12} + 2F_{66}), K_{35} = -F_{22}\beta^3 - \beta\lambda^2(F_{12} + 2F_{66}),\\
&K_{44} = J_{44} + H_{11}\lambda^2 + H_{66}\beta^2, K_{45} = \lambda\beta(H_{12} + H_{66}),\\
&K_{55} = J_{55} + H_{66}\lambda^2 + H_{22}\beta^2,
\end{aligned}
\tag{25}
$$

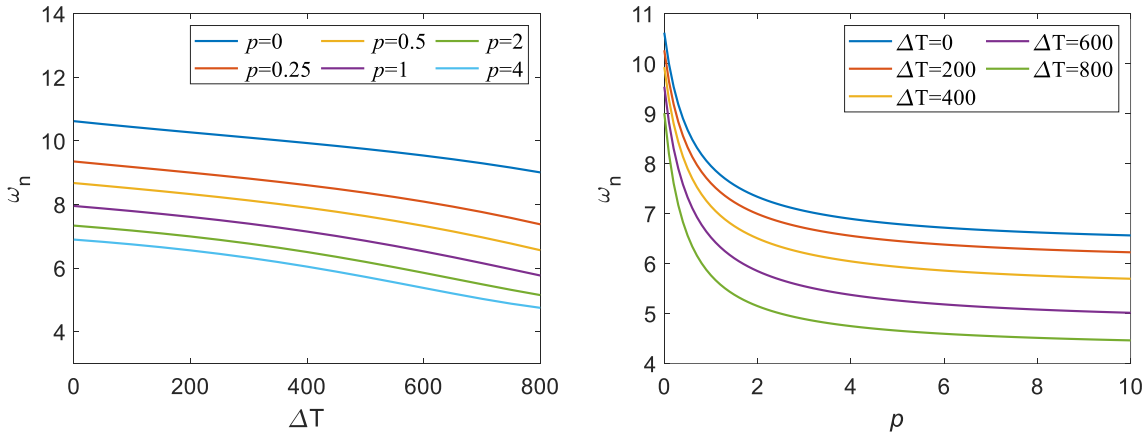
and

$$
\begin{aligned}
&M_{11} = I_0, M_{12} = 0, M_{13} = -\lambda I_1, M_{14} = I_3, M_{15} = 0, M_{22} = I_0\\
&M_{23} = -\beta I_1, M_{24} = 0, M_{25} = I_3, M_{33} = I_0 - I_2(\lambda^2 + \beta^2), M_{34} = -\lambda I_4\\
&M_{35} = -\beta I_4, M_{44} = I_5, M_{45} = 0, M_{55} = I_5
\end{aligned}
\tag{26}
$$

RESULTS AND DISCUSSIONS

In this study, the free vibration response of the FGM plate is analyzed with respect to power law index (p), dispersion patterns (P-FGM, S-FGM and E-FGM) and temperature rise (ΔT). Temperature rise is applied in the range of 0 K to 800 K. The dimensions of the plate are defined as $a = b = 0.45$ m and $h = a/10$. In the analysis, the natural frequency values are considered as dimensionless and calculated with the equation $w_n = w\frac{a^2}{h}\sqrt{\rho_{cer}/E_{cer}}$.

Firstly, the variation of first dimensionless natural frequency values for P-FGM with respect to p and ΔT is examined in Figure 5. As shown in the figures, there is a decrease in the natural frequency values with increasing p. The reason for these decreases is that the FGM material properties approach SUS304 with increasing p. As given in Table 1, the modulus of elasticity values of Al_2O_3 are higher than SUS304. In addition, the dimensionless first natural frequency values decrease significantly with increasing ΔT. The reason for these decreases is the decrease in the stiffness of the plate with increasing temperature.

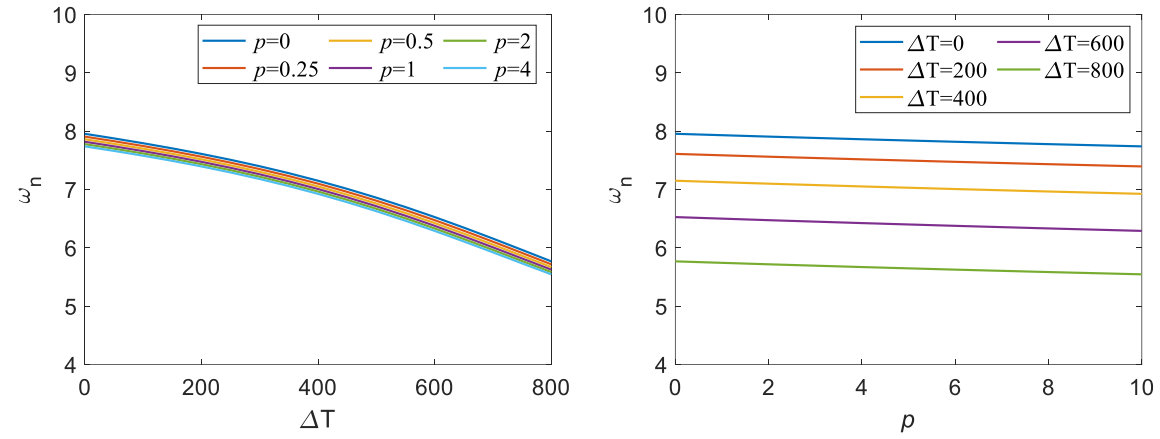


a) b)

Figure 5. Investigation of w_n with respect to p and ΔT in P-FGM.

Figure 6 illustrates the variation of the first dimensionless natural frequency of the plate with S-FGM distribution with respect to p and ΔT. As depicted in the figure, w_n decreases with increasing p. Similarly, the w_n decreases with increasing ΔT. When S-FGM and P-FGM curves

are analyzed, it is seen that there are significant differences. The reason why the p=0 natural frequency values in the P-FGM structure are higher than the p=0 values in the S-FGM structure is that the P-FGM consists completely Al_2O_3 at p=0, while the S-FGM consists of 50% Al_2O_3 and 50% SUS304. The natural frequency values decrease more in S-FGM distribution than P-FGM with the effect of ΔT. However, the natural frequency values of the S-FGM structure are less affected by the change of p. In other words, the natural frequency values decrease less. This is because in the S-FGM structure, although the metal and ceramic volume fractions differ in the top and bottom halves of the plate, they have equal volume fractions overall. Therefore, the application of S-FGM ensures a more uniform stress distribution than P-FGM.



a) b)

Figure 6. Variation of w_n with respect to p and ΔT in S-FGM.

Figure 7 exhibits the variation of the dimensionless natural frequency values of the E-FGM metal-ceramic plate with respect to ΔT. As indicated in the figure, the natural frequency decreases considerably with rising ΔT. This decrease is found to be approximately 27.79% between 0 K and 800 K. While the E-FGM distribution shows a similar trend to the P-FGM distribution in terms of w_n, it is similar to the P-FGM p=5 curves in terms of effective material properties.

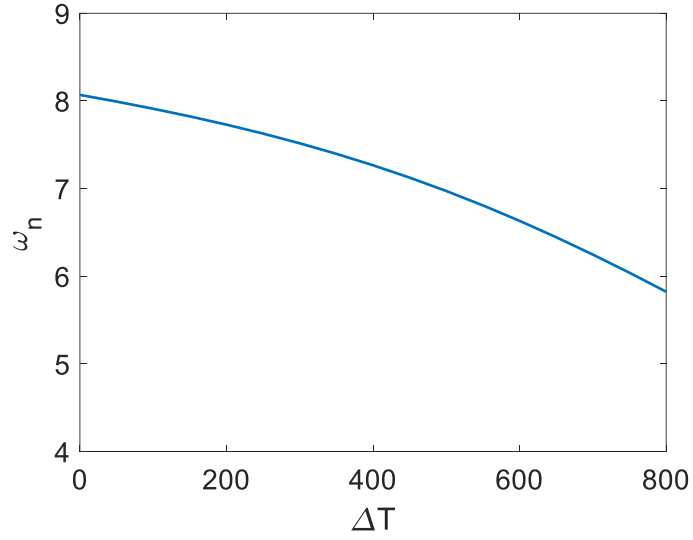


Figure 7. Investigation of w_n with respect to ΔT in E-FGM.

The comparison of the dimensionless natural frequencies of the proposed FGM plate according to P-FGM, S-FGM and E-FGM distribution patterns is presented in Figure 7. For comparison,

the dispersion patterns are ensured to consist of 50% Al_2O_3 and 50% SUS304. As shown in the figure, the w_n values decrease with increasing ΔT in all three models. The largest w_n values are obtained in E-FGM while the smallest w_n values are obtained in P-FGM.

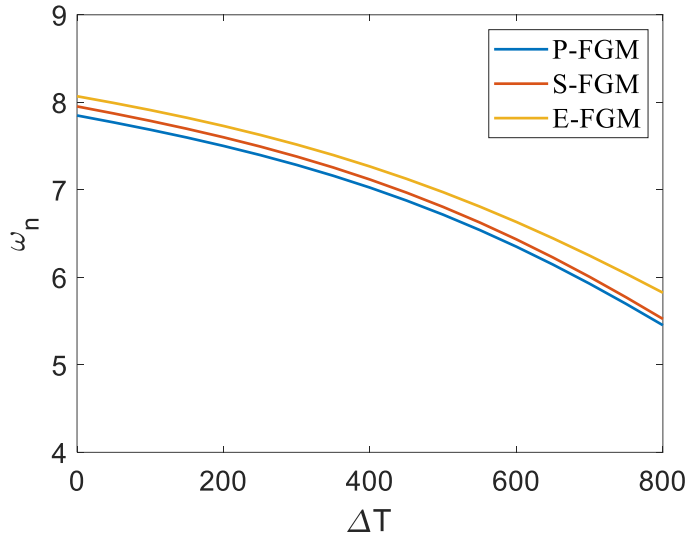


Figure 8. Comparison of w_n values for P-FGM, S-FGM and E-FGM.

CONCLUSIONS

In this study, the free vibration responses of a square FGM plate are investigated with three different FGM distribution functions (P-FGM, S-FGM and E-FGM) under the effect of temperature load. The temperature load is applied with uniform increase between the top and bottom surfaces of the plate. HSDT theory is used to model the plate. The solution of the equations of motion is carried out by Navier's method under simply supported boundary conditions. Since the material properties vary with temperature, the variations of the E_{eff}, ν_{eff}, κ_{eff} and α_{eff} with respect to p and z/h are also investigated. This allowed a clearer interpretation of the obtained free vibration response. Some conclusions are drawn from the analytical simulations. It was found that w_n values are significantly affected by ΔT and that it is vital to include temperature dependent material properties in the modeling in case of temperature fluctuations and high temperatures. It was also found that increasing p has a decreasing effect on the w_n in both P-FGM and S-FGM distributions. This decrease is much smaller in S-FGM than in P-FGM. The reason for this is that with increasing p in P-FGM, the plate characteristics approach either metallic or ceramic properties, while in S-FGM, the lower half of the plate approaches metal properties and the upper half approaches ceramic properties. In other words, the total volume fraction of the components remains constant. From the comparison study, the highest w_n values are obtained with E-FGM while the lowest w_n values are obtained with P-FGM. With the presented study, it is expected to contribute to studies such as modeling plate structures subjected to high temperature and temperature fluctuations, and investigating the effect of different dispersion patterns in FGM plates.

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BIOLOGICAL CONTROL OF GRUB WORMS WHICH ATTACK THE ROOTS OF CROPS

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Abstract:

This work is part of a biological control trial studying the ability of soil microorganisms (Actinomycetes) to inhibit the activity of a number of crop insect pests.

We tried to test the effect of soil actinomycetes extract on:

- White grubs, which live in the soil and attack the roots of all plants,

- Insect pests belonging to the locust family (e.g. grasshoppers, locusts, etc.),

- Hemipteran insects (e.g. aphids) that feed on plant sap, which can cause serious damage to leaves, stems and flowers.

The results show that actinomycete-based pesticides have an effective inhibitory effect on grubs. Actinomycetes, which are beneficial soil bacteria, produce antimicrobial and insecticidal substances that disrupt the metabolism and survival of grubs.

These bio-pesticides are particularly advantageous because they specifically target pests, while being more environmentally friendly than traditional chemical pesticides. Thus, the use of actinomycete-based pesticides offers a promising method for managing grub populations in an environmentally friendly and sustainable way.

Key words: Soil, Biotechnology, Biological agriculture, Actinomycetes, Bio-pesticide.

GLUCOSE DURATION IN THE RANGE AND PERIPHERAL NEUROPATHY IN TYPE 2 DIABETES AND CHRONIC KIDNEY DISEASE

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ABSTRACT

The prognostic value of common and frequently associated diabetic microvascular complications (MVC), namely chronic kidney disease (CKD), cardiac autonomic neuropathy (CAN), peripheral neuropathy (DPN), and retinopathy (DR), is well established. Chronic exposure to hyperglycemia in patients with diabetes mellitus impairs microvascular functions, frequently leading to microvascular complications (MVC). Diabetes related MVC share a common pathophysiology and are often associated in the same individual, posing a significant burden on both the healthcare systems and the patients.

Keywords: Type 2 diabetes, Nephropathy, Glucose, Peripheral neuropathy

The prognostic value of common and frequently associated diabetic microvascular complications (MVC), namely chronic kidney disease (CKD), cardiac autonomic neuropathy (CAN), peripheral neuropathy (DPN), and retinopathy (DR), is well established. Chronic exposure to hyperglycemia in patients with diabetes mellitus impairs microvascular functions, frequently leading to microvascular complications (MVC). Diabetes related MVC share a common pathophysiology and are often associated in the same individual, posing a significant burden on

both the healthcare systems and the patients (Kərimova R.C.,İradə Əliyeva Cəmilyevna.,2024). Among MVC, chronic kidney disease (CKD) has an estimated prevalence of 20–50% in type 1 diabetes (T1D) and type 2 diabetes (T2D) and is the leading cause of end-stage kidney disease (ESKD) . Diabetic neuropathy, with an estimated prevalence of 6% to 51%, refers to a heterogeneous group of medical conditions, including cardiovascular autonomic neuropathy (CAN) and diabetic peripheral neuropathy (DPN), which can be complicated by cardiovascular disease (CVD) and lower-limb disease (Antonello G., Monaco C. L.,2022).

One of the most common microvascular complication of diabetes is diabetic peripheral neuropathy (DPN). The well-recognized risk factors for DPN are hyperglycemia, dyslipidemia and hypertension.

They lead to DPN mainly through inflammation, oxidative stress, sorbitol and advanceq glycatio end products accumulation. Besides, lifestyle-related traits such as body weight management, diet and physical activity play a significant role in DPN development. DPN is the major trigger factor for diabetic foot (including Charcot neuroarthropathy and foot ulceration) which are the main reasons for undaunted lower-limb amputations. The risk of amputation in patients with diabetes is estimated to be more than 25 times greater than in case of people without carbohydrates disorders (Yapanis M., James S., Craig M. E.,20220).

These high differences in prevalence of DPN in diabetic patients between multiple sources may be caused by various criteria for the diagnosis of DPN applied. The diagnostic assessment of neuropathy varies widely and is mostly based on medical history and physical examination evaluating vibration foot sense, temperature or pinprick sensation and foot ulcer. There are also scored clinical instruments usually used in research projects, such as the Michigan Neuropathy Screening Instrument, the Neuropathy Symptom Score and the Neuropathy Disability Score or the Neuropathy Impairment Score (NIS) (Raj R., Mishra R., Jha N., Joshi V.,2022).

In patients with type 2 diabetes, diabetic peripheral neuropathy (DPN) is a prevalent microvascular complication that can lead to severe consequences, including foot ulceration and the need for lower extremity amputation. Roughly half of individuals with diabetes mellitus receive a diagnosis of DPN, and 25–50% of DPN patients experience diabetic neuropathic pain. It is important to note that the prevalence of painful DPN within the diabetic population may be underestimated, as many patients do not proactively report their pain symptoms to healthcare providers. The symptoms and signs of neuropathic pain, such as allodynia and paresthesia, result in disability, emotional distress, and social withdrawal and have a detrimental impact on their quality of life (Antonello G., Monaco C. L.,2022).

While chronic hyperglycemia has traditionally been considered a significant risk factor for the development of DPN, numerous studies have shown that stringent blood glucose control significantly reduces the risk of DPN, primarily in patients with type 1 diabetes, with less favorable outcomes observed in patients with type 2 diabetes4. Furthermore, the significance of glycemic level control in managing diabetic neuropathic pain remains uncertain. This suggests that, alongside maintaining target blood glucose levels, other glycemic variables may play a crucial role in the development of painful DPN. Glycemic variability, defined as the level of fluctuation in blood sugar, has been strongly associated with DPN in patients with type 2 diabetes. Previous case series research indicated that maintaining consistent blood sugar levels with minimal episodes of hypoglycemia or hyperglycemia was associated with lower pain ratings in patients with painful DPN (Yapanis M., James S., Craig M. E.,20220).

Another small-scale study reaffirmed that individuals with painful DPN in patients with type 1 diabetes exhibited worse glycemic stability and more prominent blood sugar variations compared to those with painless neuropathy. Up to this point, research on the association between glycemic variability and painful DPN has been limited, with most studies consisting of case series or cross-sectional studies. Therefore, our study aimed to examine whether glycemic variability, assessed

through the coefficient of variation (CV) of fasting plasma glucose (FPG) and glycated hemoglobin (HbA1c), was associated with an increased risk of painful DPN in a Han Chinese cohort of adult type 2 diabetes patients (Røikjer J., Croosu S. S., Hansen T. M., et al.,2022).

Diabetic kidney disease (DKD) is another chronic microvascular complication of diabetes and the major cause of end stage chronic kidney disease. However, the majority of deaths in the course of diabetes are caused by CVD which precede the stage of DKD when renal replacement therapy is already needed. DKD may affect up to 40% of patients with diabetes (Grunwald S. A., Haafke S.,2022). Among patients with type 1 diabetes mellitus (T1DM) DKD typically develops after at least 10 years of the disease, however in patients with type 2 diabetes mellitus (T2DM) it might be present at the time of diagnosis. Structural changes underlying the pathogenesis of DKD result in the clinical manifestations useful in the diagnosis, such as albuminuria, proteinuria and/or decreased glomerular filtration rate. According to the recommendations of American Diabetes Association and European Association for the Study of Diabetes, screening for DKD should be performed annually in patients diagnosed with diabetes. For patients with T2DM it should be performed at the moment of diagnosis, and for T1DM ones after 5 years from the diabetes onset (Chang W. W., Fei S. Z., Pan N., Yao Y. S.,2022).

Screening should be performed by determining the urinary albumin-to-creatinine ratio (UACR) in a random spot urine collection and estimated glomerular filtration rate (eGFR) calculated on the basis of serum creatinine concentration transformed by a validated formula (preferable the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation. Elevated UACR is defined as ≥30 mg/g. DKD might be diagnosed on the basis of UACR (2 of 3 specimens collected within a 3- to 6-month period) and/or reduced eGFR <60mL/min/1.73m2 together with the absence of signs and symptoms which could be primarily caused by other kidney damage. Furthermore, there is some evidence that patients with microvascular complications are at higher risk of developing cardiovascular events. Also, these microvascular complications seem to be clustered, especially in case of poor glycemic control and longer duration of diabetes (Karimova R,J.,Irada Aliyeva Jamilyevna.,2024).

High blood pressure is a factor involved in CKD progression along with proteinuria and poor control of carbohydrate metabolism. In CKD patients, the objective of antihypertensive treatment is threefold: to reduce blood pressure, reduce the risk of cardiovascular complications and delay CKD progression (Chai S., Wu S., Xin S., et al.,2022).

A systematic review estimates that only 12% of hypertensive diabetes patients have good blood pressure control, although recent data indicate a favourable trend in high blood pressure control. In Spain, in the 2010 PRESCAP study, conducted in Primary Care on a population of almost 13,000 hypertensive patients that included 31% of subjects with diabetes, almost 50% of patients had adequate blood pressure control. Diabetes patients frequently have non-diagnosed nocturnal hypertension, which could in part explain the excessive cardiovascular risk in some patients. Furthermore, in normotensive diabetic patients with years of progression, masked hypertension must be ruled out, which may be present in up to 29% of cases. As regards hypertensive diabetic patients, 4.9% of those who have good blood pressure control at the clinic have poor control in ambulatory blood pressure monitoring (ABPM). As such, the routine use of ABPM with protocol should be considered in diabetes patients, particularly if they have CKD (Røikjer J., Croosu S. S., Hansen T. M., et al.,2022).

In general, clinical blood pressure figures <140/90mmHg are recommended in CKD patients. However, the presence of diabetes may make it advisable to set a rather lower blood pressure target. The recent European Blood Pressure Guidelines sets a general systolic blood pressure target of <140mmHg for all patients, even for high-risk subjects, including those with diabetes and CKD. A more flexible target of 140-150mmHg has been proposed for the elderly.

The American Diabetes Association recommends a general blood pressure control target of <140/80 mmHg in diabetes patients.

CKD is associated with resistance to insulin. However, advanced CKD causes a decrease in renal insulin catabolism, and as such, a reduction in its dose is usually necessary, with it even being possible to discontinue insulin in some patients with T2DM and advanced CKD (burnt-out diabetes) (Raj R., Mishra R., Jha N., Joshi V.,2022).

Insulin treatment in CKD patients requires strict monitoring in order that the aforementioned treatment may be adjusted; it is very important to ensure an appropriate therapeutic education in diabetes. The insulin therapy regimen will adapt to the control objectives and both conventional insulin treatment and intensive therapy may be considered (Lian J.,Wang H., Cui R., Zhang C.,2021).

As a general rule, which should be adapted to each patient on the basis of glycaemia monitoring, we can say that it is not necessary to adjust the insulin dose whenever the GFR does not fall below 60ml/min/1.73m; below this GFR, the dose should be reduced by around 25%, and if it falls below 20ml/min/1.73m it should be reduced by 50%. Dialysis partially reverses the resistance to insulin and its lower catabolism associated with CKD. As a result, a patient's insulin needs determined in a dialysis programme, will depend on the balance between the improvement of insulin sensitivity and the normalisation of insulin metabolism, and as such, treatment individualisation is essential (Chai S., Wu S., Xin S., et al.,2022).

It is recommended to monitor glycaemia in haemodialysis patients and bear in mind that after the session they are more susceptible to developing hypoglycaemia – the dialysate normally contains a glucose concentration of 100mg/dl, and as such, it may be advisable to decrease the insulin dose before dialysis and, in any case, be prepared in case of any post-dialysis hypoglycaemia episodes. It is recommended to use long-acting insulin (glargine, detemir or NPH) for basal requirements, with the addition of fast-acting insulin before meals, if necessary (Grunwald S.A.,Haafke S.,2022). Basal (glargine, detemir) and fast-acting analogues (aspart, lispro, glulisine) induce less hypoglycaemia than human insulins (NPH or regular), with the disadvantage of having a higher cost. In some patients, with very regular meal hours, pre-mixed insulins may be used. For patients with T2DM and stage 5 CKD, the total initial daily insulin dose is usually 0.25IU/kg, with subsequent individualised adjustments, in accordance with glycaemic self-control. The specific features of insulin treatment in dialysis patients are not included in the consensus' targets. It must be highlighted that there are no fixed insulin therapy guidelines and that all clinical practice guidelines recommend individualisation and the support of an expert for diabetes cases that are difficult to control (Lian J., Wang H., Cui R., Zhang C.,2021).

In peritoneal dialysis patients, the administration of intraperitoneal insulin may be preferable to its subcutaneous administration, since it achieves a better glycaemic control, although it worsens the lipid profile (decrease of high density lipoprotein cholesterol, increase of triglycerides). However, it is necessary to take into account that peritoneal dialysate has a very high glucose content, although the most recent intraperitoneal infusions have a lower amount or have replaced glucose with icodextrin. There are no fixed guidelines for these cases and, once again, individualisation is advisable (Chang W. W., Fei S. Z., Pan N., Yao Y. S.,2022).

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TREATMENT OF MYASTHENIC SYNDROME AFTER BOTOX AND HYPERTHYROIDISM

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ABSTRACT

Botulinum toxins are among the most toxic poisons, with a wide spectrum of both therapeutic and cosmetic indications for use. Injections with botulinum toxin are effective for many clinical disorders that involve involuntary muscle activity or increased muscle tone. It is also the most common cosmetic procedure performed world-wide, with estimates of nearly 3 million injections per year. Dynamic wrinkles are the main cosmetic indications for the use of botulinum toxin. The action of botulinum toxins is a result of their potent ability to inhibit neurotransmitter release. There are multiple serotypes of botulinum toxins A-G varying with the molecular size, biosynthesis and cell mechanisms. Type A (BoNT-A) is the most potent and it is used the most commonly.

Keywords: Botox, Hyperthyroidism, Myasthenic syndrome, Treatment

Botulinum toxins are among the most toxic poisons, with a wide spectrum of both therapeutic and cosmetic indications for use. Injections with botulinum toxin are effective for many clinical disorders that involve involuntary muscle activity or increased muscle tone. It is also the most

common cosmetic procedure performed world-wide, with estimates of nearly 3 million injections per year (Geoghegan L, Rodrigues R, Harrison CJ.,2022**)**.

Dynamic wrinkles are the main cosmetic indications for the use of botulinum toxin. The action of botulinum toxins is a result of their potent ability to inhibit neurotransmitter release. There are multiple serotypes of botulinum toxins A-G varying with the molecular size, biosynthesis and cell mechanisms. Type A (BoNT-A) is the most potent and it is used the most commonly. At present, there are three BoNT-A products available worldwide: abobotulinumtoxinA (Dysport), onabotulinumtoxinA (Botox), and incobotulinumtoxinA (Xeomin). Treatment with botulinum toxin is widely viewed as safe, effective and largely devoid of serious side effects. Sequelae that can occur at any site after a botulinum toxin injection include pain, edema, erythema, ecchymosis, and short-term hypesthesia (Lewandowski M, Świerczewska Z.,2022).

These do not differ from side-effects after other types of injections. When botulinum toxin is used properly, the incidence of these complications is low. There are no long-term or life-threatening adverse effects related to botulinum toxin treatment for any cosmetic indications. Moreover, the risk of possible complications can be reduced by means of a thorough analysis of the patient's medical history and the use of the appropriate dose and technique for the injection. On the other hand, injections with botulinum toxin may be responsible for more severe side-effects. They are associated with systemic and generalized botulinum toxin diffusion (Timmermans G, Depierreux F, Wang F.,2019).

Clinical symptoms of myasthenia gravis and systemic Botox effects are very similar. This should be taken into consideration during medical history taking. The injection of high doses of Botox (more than 200 units in every injection) or boostering within less than one month is dangerous (Chegini A.,2017).

Myasthenia Gravis (MG) is one of the first diseases that have been treated with Therapeutic Plasma Exchange (TPE) successfully. MG disease is a muscular disorder caused by autoantibodies directed against acetylcholine receptors (AChR) with hallmark symptoms being muscle weakness and fatigue. It is caused by decrease in the number of Acetylcholine Receptors (AChR) due to autoimmune antibodies in neuromuscular junction. These autoimmune antibodies attack or connect to AChR and then block and/or decrease the receptors or injured postsynaptic membrane in the neuromuscular junction. TPE can be used to reduce plasma levels of Acetylcholine Receptor antibodies (AChR), thereby leading to clinical recovery and providing an effective treatment for acute MG. In contrast to MG, botulinum toxin (Botox) is a naturally occurring neurotoxic protein frequently being used for cosmetic reasons. Small doses of Botox subcutaneously injected can block or minimize muscle contraction. This effect is used to decrease wrinkles of the facial skin and chin providing a smooth appearance (Lewandowski M, Świerczewska Z.,2022).

Differential and common features in ATDs and MG: Both MG and Autoimmune thyroid disease (ATD) diseases are organ specific and antibody-mediated, and both kinds of disorders combine many different pathologies. Patients with ATDs have antibodies against proteins of the thyroid, but the characteristics of the disease differ according to the autoantigen. Patients with HT have serum antibodies reacting with TG, TPO, while patients with GD have antibodies against the receptor of TSH. Myasthenia gravis is due to antibodies against the neuromuscular junction . Similarly to thyroiditis, in MG, several antigens are the targets of the autoantibodies, and the disease features depend upon the nature of the antibodies. Patients with anti-AChR, but not with anti-MuSK antibodies, have thymic pathologies, hyperplasia among the young patients, and thymoma among the oldest patients (Timmermans G, Depierreux F, Wang F.,2019).

Interestingly, in both MG and ATDs, some forms of the disease are IgG4 dependent, an Ig subclass that does not bind to the complement. In MG, anti-MuSK antibodies are IgG4. In ATDs, several subcategories of IgG4-mediated diseases have been identified including a fibrosing

variant of HT, IgG4-related HT, and GD with elevated IgG4 levels . These IgG4 diseases share common mechanisms that involve the mechanical interference of extracellular ligand–receptor interactions by the IgG4 antibodies (Leonardi L., Haggiag S., Petrucci A.,2019).

The mechanisms of action of the antibodies are quite different in MG and ATD, likely due to the nature of the target antigen and its localization. In HT, together with cytotoxic cells, the antibodies contribute to the destruction of the thyroid, leading to hypothyroidism . In the case of GD, the antibodies against TSHR could be stimulatory, blocking or neutral; when the stimulating antibodies predominate, clinical features become obvious . Thus, the antibodies are functional, able to stimulate or to inhibit the secretion of thyroid hormones (Chegini A.,2017).

Fluctuating antibody levels can lead to syndromes alternating between hyperthyroidism and hypothyroidism. In the case of MG, anti-AChR antibodies induce its degradation dependent upon the complement, and its internalization, while anti-MuSK antibodies disrupt the neuromuscular junction and inhibit the retrograde signaling. Recent findings suggest that the anti-AChR antibodies could also have a functional effect, by inducing the overproduction of IL-6, a cytokine that plays a role in muscle biology. It is not clear yet if this mechanism participates to the pathogenic mechanisms or is a compensatory mechanism (Lewandowski M, Świerczewska Z.,2022).

Most of the autoantibodies have a clinical usefulness. Anti-TPO and anti-TSHR antibodies are relevant for the diagnosis of HT and GD, respectively. Anti-TSH receptor antibodies are of interest in GD as they correlate with the disease severity and their levels decrease with therapies. However, anti-TPO and anti-TG Abs are not unique to HT patients since these antibodies are detectable in the majority of GD patients. In the case of MG, the anti-AChR antibodies are very useful for the diagnosis but not for the follow-up. On the other hand, for the group of patients with anti-MuSK antibodies, monitoring its level is relevant, since it correlates with the clinical course (Kassir M, Gupta M, Galadari H.,2020).

Myasthenia gravis after botulinum toxin type a injection: Botulinum toxin type A (BoNT type A) is a neurotoxin produced by Clostridium botulinum, which causes paralysis by presynaptically binding to the cholinergic nerve terminals at the neuromuscular junction and decreasing the release of acetylcholine . BoNT type A, first used to treat strabismus, is now widely used to treat dystonia, spasticity, and other movement disorders, and also autonomic nervous system disorders including hyperhidrosis and sialorrhea . As with the effects of the toxin, the adverse effects are also reversible. The most common and severe adverse effects of the toxin are unwanted and excessive weakness of muscle after injection, paralysis of adjacent muscles caused by diffusion of the toxin and iatrogenic botulism characterized by widespread paralysis including the bulbar muscles. Myasthenia gravis (MG) is an autoimmune disorder of the neuromuscular junction, which is caused by antibodies produced against acetylcholine receptors. Fluctuating weakness is the main characteristic of the disease (Geoghegan L, Rodrigues R, Harrison CJ.,2022).

Botulinum toxin injections (Botox; Allergan, Inc, Irvine, CA) (Dysport; Medicis Aesthetics, Inc, Scottsdale, AZ) (Myobloc; Elan, Inc, San Francisco, CA) are the most common minimally invasive facial procedures performed in the United States and probably worldwide . Two similar patients have been reported with variable ptosis mimicking MG after cosmetic botulinum toxin type A injections. Sunness and Kelman described a 70-year-old woman with variable right upper lid ptosis and diplopia associated with esotropia and hypertropia. A tentative diagnosis of ocular MG was made, and an ice test improved ptosis but not ocular motility. At the second visit, the patient admitted that she had received cosmetic botulinum toxin type A injections around the lids 6 days before the onset of symptoms. Ptosis resolved within 2 weeks and diplopia some time later. Parikh and Lavin encountered a 58-year-old woman with unilateral ptosis after a botulinum toxin type A “party” during which she received a relatively high dose. She also had fatigability

of the lid, but an ice test was negative. Ptosis completely resolved in 12 weeks. All 3 patients with ptosis following botulinum toxin type A injections had clinical evidence of neuromuscular junction impairment with fatigability and Cogan lid twitch sign, and 2 had a positive ice test. Ptosis in all 3 resolved within 2–12 weeks (Lispi L, Leonardi L.,2018).

Reports describing ptosis as a side effect of therapeutic botulinum toxin type A injection generally have not mentioned variability, but the patients described in previous reports and in the present study indicate that variability may occur. This may create potential confusion regarding the diagnosis of MG, particularly if the patient is not questioned about or initially denies botulinum toxin type A injections (Kassir M, Gupta M, Galadari H.,2020).

The etiology of improvement in ptosis following lid cooling is unknown.Cooling may decrease cholinesterase activity and/or increase acetylcholine efficiency at the postsynaptic junction.In patients with myasthenic ptosis, ice applied to a ptotic lid improves ptosis more than 2 mm in most or all individuals. Decreasing temperature seems superior to rest alone, while heat may have the reverse clinical effect. Cooling also improves myasthenic facial weakness , decremental response to repetitive nerve stimulation , and in most,but not all , instances of restricted ocular motility (Lispi L, Leonardi L.,2018).

Improvement of ptosis after cooling of an eyelid for 2 minutes has been reported to be both sensitive and specific for MG . A positive response is considered to be specific for MG because a number of studies have described no improvement in ptosis or ocular motility restriction of nonmyasthenic origin. However, the ice test has been found to be positive in patients with the congenital myasthenic syndrome caused by CHRNE mutations, as well as in patients with ptosis resulting from the cosmetic use of botulinum toxin type A. No study has specifically investigated the effect of cooling on ptosis resulting from neuromuscular junction defects that are not autoimmune in origin (Geoghegan L, Rodrigues R, Harrison CJ.,2022**)**.

While botulism in general is uncommon, wound botulism has become much more common because of an increase in the subcutaneous injection of illicit drugs . At times, the responsible wound is not mentioned nor is it apparent on physical examination. Patients commonly present with bilateral ptosis and facial weakness, dysarthria, and difficulty swallowing . A positive ice test in this setting might be interpreted incorrectly as diagnostic of MG (Leonardi L., Haggiag S., Petrucci A.,2019).

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MICROSTRUCTURE, HARDNESS AND THERMAL PROPERTIES OF HOT-PRESSED SILVER-COATED NYLON-BASED COMPOSITES

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Abstract:

This study presents a comprehensive investigation into the microstructural, mechanical, and thermal properties of hot-pressed composites based on silver-coated nylon granules. The novelty of this work lies in the development of lightweight and thermally efficient materials with potential applications in high-performance engineering systems. Silver coating was applied to nylon granules via electroless deposition, followed by hot pressing to fabricate dense composite samples. Microstructural analysis revealed a uniform distribution of the silver coating, forming a conductive network within the nylon matrix. The hardness of the composite samples increased significantly with the addition of silver, rising from 82 Shore D for pure nylon (PA) to 88 Shore D for silver-coated composites (PA-Ag), demonstrating improved mechanical integrity. Thermal performance tests showed enhanced surface temperatures for PA-Ag composites, which reached 111°C, compared to 108°C for pure PA, under identical heating conditions. This improvement is attributed to the formation of a silver network, which facilitates superior thermal conductivity. The findings highlight the dual benefits of incorporating silver coatings: mechanical reinforcement and thermal conductivity enhancement, making the developed composites promising candidates for applications requiring lightweight, thermally conductive materials. These results contribute to the growing interest in multifunctional polymer-based composites tailored for advanced engineering applications.

Keywords: Electroless silver, nylon, hot-pressing, hardness, electrical conductivity, thermal conductivity

Introduction

The integration of polymer and metal components to produce advanced composites is a widely researched area due to the complementary benefits offered by these materials. Polymers, such as nylon, are valued for their lightweight, flexibility, and chemical stability, while metals like silver provide excellent electrical conductivity, thermal conductivity, and mechanical reinforcement.

Combining these properties can lead to multifunctional materials with applications in electronics, thermal management, and structural engineering (Bijanu et al., 2021; Bloor, Donnelly, Hands, Laughlin, & Lussey, 2005; Trzepieciński et al., 2021). However, the method of incorporating metals into polymers plays a critical role in determining the overall performance of the resulting composite (Kim & Shahinpoor, 2003; Min et al., 2022).

Traditional approaches often involve directly mixing metallic powders into the polymer matrix to enhance conductivity and mechanical properties. While this method is straightforward, it suffers from significant limitations. The dispersion of metal particles within the polymer is often uneven, leading to agglomeration and non-uniform properties in the composite. Additionally, weak interfacial bonding between the polymer matrix and the metallic particles reduces the overall effectiveness of the reinforcement. This lack of strong interfacial interaction often results in lower mechanical performance, poor thermal conductivity, and limited electrical conductivity compared to theoretical predictions (Danes, Garnier, & Dupuis, 2003; Mamunya, Davydenko, Pissis, & Lebedev, 2002).

In contrast, the method used in this study involves coating the surfaces of nylon granules with a uniform silver layer via electroless plating (AKÇAY et al., 2024) before consolidating them into a bulk structure through hot pressing (Bonderer, Feldman, & Gauckler, 2010). This approach offers several key advantages over direct mixing of metal powders into polymers: By coating the individual granules, the silver is distributed evenly across the surface of each particle. During hot pressing, these coatings form continuous metallic networks at the interfaces, eliminating the risk of agglomeration that is common with metal particle mixing. The metallic coating on the granules creates a strong interfacial connection between the granules during the hot-pressing process. This bonding improves load transfer within the composite, resulting in higher mechanical strength and reduced interfacial failure compared to composites with mixed metal powders. Unlike dispersed metallic particles, which may not form connected networks (Brostow, Buchman, Buchman, & Olea-Mejia, 2008; Salih, Nayyef, Alsalam, Journal, & 2015, n.d.), the metallic coatings on the granules naturally merge during hot pressing to create continuous pathways for electrical and thermal conductivity. This significantly enhances the bulk conductivity of the composite. Hot pressing ensures a controlled consolidation process where the coated granules bond tightly with minimal void formation. This results in a dense composite with uniform properties, a critical improvement over methods that struggle with dispersion-related defects (Tiwari & Garcia, 2011; Yu, Ting, Chung, Tsai, & Chen, 2017).

The novelty of this study lies in demonstrating the superiority of this approach for producing high-performance composites. By leveraging electroless plating to uniformly coat nylon granules and hot pressing to consolidate them into bulk composites, this research addresses critical challenges in metal-polymer composites, such as poor interfacial bonding and inhomogeneous property distribution. To the best of our knowledge, no prior study has systematically investigated the combination of these methods for producing dense nylon polymer-metal composites with interconnected metallic networks. This research fills an important gap in the literature, offering a solution to improved mechanical, thermal, and electrical performance. Additionally, it provides insights into how process design influences the structure-property relationships in polymer-metal composites, paving the way for innovations in multifunctional material development.

Experimental Studies

In this study, nylon granules reinforced glass fiber marked as P6-GF40 were procured from Akro-Plastic (Germany). These granules were chosen for their excellent mechanical properties, including high toughness, wear resistance, and chemical stability, making them an ideal substrate for polymer-metal composite fabrication. The nylon granules had an average particle size of

approximately 3 mm and a density of 1.46 g/cm³. As their intrinsic electrical conductivity is in the range of 10^{-12} S/, they require surface modification to enhance their conductivity. For the electroless silver (Ag) plating process, the following chemicals were used, with their high purity ensuring consistent and reliable coating results: silver nitrate ($AgNO_3$) (≥99.9% purity, Sigma-Aldrich) as the silver ion source, ammonia solution (NH_3, 25%) (analytical grade, Merck) to form the silver-ammonia complex $[Ag(NH_3)_2]^+$, and sodium potassium tartrate ($C_4H_4KNaO_6 \cdot 4H_2O$) (≥99% purity, Sigma-Aldrich) as a stabilizer and complexing agent to ensure controlled silver deposition. Deionized water (conductivity ≤0.1 μS/cm) was used throughout the process for solution preparation and rinsing steps to avoid ionic contamination.

The electroless silver plating process for nylon granules was conducted in a series of carefully controlled steps, with all parameters optimized to ensure uniform silver deposition and high adhesion quality. The detailed procedure is as follows: The nylon granules were cleaned to remove any contaminants that might interfere with silver deposition. This step involved immersing the granules in deionized water and subjecting them to ultrasonic agitation at a frequency of 40 kHz for 15 minutes. The cleaned granules were then rinsed with deionized water and air-dried. A 0.1 M silver nitrate ($AgNO_3$) solution was prepared by dissolving the appropriate amount of silver nitrate (≥99.9% purity, Sigma-Aldrich) in deionized water. Ammonia solution (25%, analytical grade, Merck) was then added dropwise to the silver nitrate solution under constant stirring until a clear solution formed, indicating the formation of the silver-ammonia complex $[Ag(NH_3)_2]^+$. The pH of the solution was carefully monitored and maintained at 11–12 during this process. This complex solution was prepared separately and reserved for later use. In a separate container, a 0.2 M sodium potassium tartrate ($C_4H_4KNaO_6 \cdot 4H_2O$) solution was prepared by dissolving the required amount of tartrate in deionized water. The nylon granules were added to this solution, ensuring they were fully immersed. The solution served as both a stabilizer and a reducing environment for the silver deposition. The system was stirred continuously to keep the granules in suspension and facilitate uniform coating. The prepared silver-ammonia complex solution was added dropwise to the granule-containing reducing solution under continuous stirring at room temperature (25°C). The addition rate was carefully controlled at approximately 1 mL per minute to ensure uniform and gradual deposition of silver on the granules. The reaction was allowed to proceed for 30 minutes, during which the reduction of silver ions to metallic silver occurred, forming a uniform silver layer on the granules. After the plating process, the silver-coated nylon granules were collected by filtration and rinsed thoroughly with deionized water to remove any residual chemicals. The granules were then dried in an oven at 60°C for 2 hours to stabilize the silver coating and prepare them for further use. This stepwise process ensured a consistent and homogenous silver layer on each nylon granule, providing the foundation for producing high-performance bulk composites through subsequent hot pressing. The controlled addition of the silver-ammonia complex solution minimized localized over-deposition, enhancing the uniformity of the coating. The uncoated and Ag coated PA granules were given in Figure 1.

Figure 1. Macro view of the (a) PA and (b) PA-Ag granules

The silver-coated nylon granules obtained from the electroless plating process were consolidated into bulk composites using a hot pressing technique. To begin, the granules were inspected to ensure a uniform silver coating and weighed to provide approximately 50 g of material for each pressing cycle. A cylindrical steel mold was prepared by cleaning the surface with ethanol and applying a high-temperature release agent, such as boron nitride spray, to prevent sticking and facilitate easy removal of the composite after pressing. The granules were carefully loaded into the mold, ensuring even distribution to minimize void formation and promote uniform density in the final composite. The mold containing the granules was then placed into a hot press, and the process parameters were carefully controlled. The temperature was set to 220°C, slightly above the melting point of nylon, to allow sufficient polymer flow while avoiding thermal degradation. A pressure of 10 MPa was applied gradually over a period of 5 minutes to ensure uniform compaction and promote strong interfacial bonding between the granules. The system was maintained at the target temperature and pressure for a dwell time of 15 minutes to complete the consolidation process and facilitate the formation of interconnected metallic networks at the granule interfaces. After the dwell time, the mold was cooled under pressure to room temperature (25°C) over a period of 20 minutes to prevent internal stresses and maintain dimensional stability. Once cooled, the pressure was released, and the mold was disassembled. The bulk nylon-Ag composite was carefully extracted from the mold to avoid surface damage. The composite was then visually inspected for defects such as voids, delamination, or incomplete consolidation. Any excess material was machined off to achieve a uniform shape and size for subsequent testing. During the hot pressing process, the metallic silver coatings on the nylon granules merged to form continuous interfacial networks, significantly enhancing the composite's electrical and thermal conductivity. The nylon matrix provided structural support and flexibility, while the silver interfaces created conductive pathways. This method yielded a dense, defect-free composite with well-defined interfacial properties, suitable for further characterization and advanced applications. Figure 2 shows the macro-view of the samples fabricated from uncoated and coated granules.

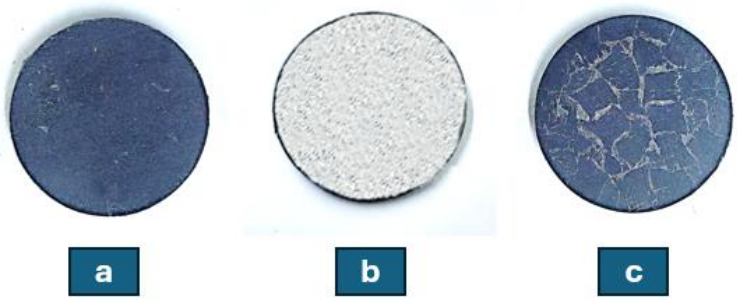

Figure 2. Macro-view of the bulk samples produced from (a) pure PA, (b) PA-Ag granules with (c) polished surface

The characterization of the produced composites focused on microstructural analysis, interfacial studies, hardness evaluation, and electrical performance testing, using tailored experimental methods. Microstructural and interfacial properties were examined using a Leica optical microscope, allowing for the observation of the silver network formation, uniformity of coating, and interfacial bonding between the silver layers and the nylon matrix. This analysis provided critical insights into the effectiveness of the electroless silver plating process and the impact of hot pressing on interfacial integration. The hardness of the composites was evaluated using the Shore D hardness method, which is suitable for assessing the surface hardness of polymer-based materials. This test was conducted by standard protocols, and the results were compared to those of the reference nylon material to quantify the reinforcement effect of the silver interfaces within the composite structure. The thermal properties of the reference nylon and the silver-interface-containing nylon composites were evaluated by placing the samples on a heated plate at the same temperature. The surface temperatures of the samples were monitored over time using a thermal camera (Fluke), allowing for a comparative analysis of their thermal conductivity and heat dissipation characteristics. This method provided insights into the silver interfacial networks' effect on the composites' thermal performance.

Results and Discussion

Granule morphology

Figure 3 illustrates the morphological characteristics of nylon (PA) granules before and after the electroless silver coating process, highlighting the changes in surface structure. In Figure 3a, the morphology of uncoated nylon granules is presented. The left panel displays an array of granules at lower magnification, showing their rectangular geometry and relatively smooth surfaces with minor textural irregularities. The right panel provides a closer view of a single uncoated granule, where the surface exhibits a more detailed structure with visible pores and a rough texture, characteristic of untreated granules. In Figure 3b, the morphology of PA granules after the electroless silver coating process is shown. In the left panel, the granules maintain their rectangular geometry but exhibit a noticeable color change to silver, indicating the successful deposition of the Ag layer. The right panel, showing a single coated granule at higher magnification, reveals that the silver coating has partially filled the initially porous and rough surface. This filling effect reduces the surface roughness and creates a smoother overall texture, while still preserving some of the underlying granule structure. The transformation in surface morphology demonstrates the efficiency of the electroless silver coating process in modifying the granule surface. The reduction in roughness and filling of surface pores by the silver layer are essential for improving the thermal and electrical properties of the granules and ensuring better performance in subsequent applications, such as hot-pressed bulk composite production.

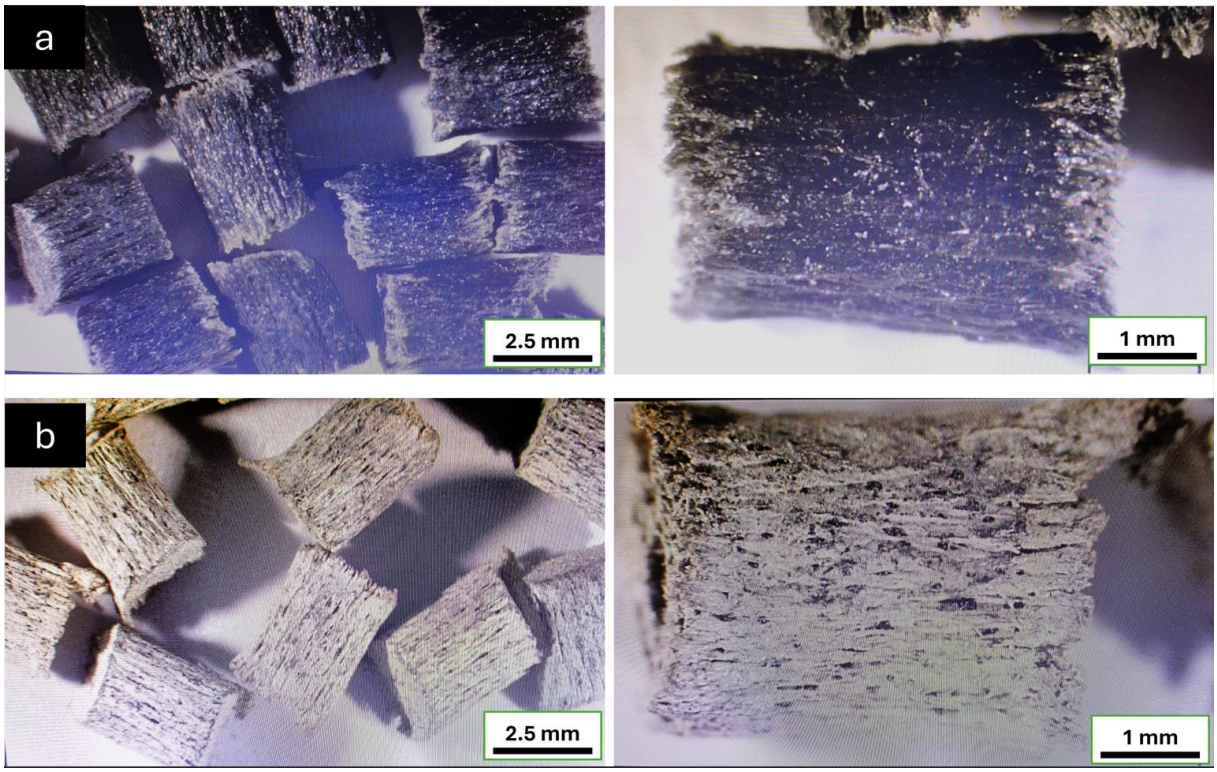

Figure 3. Morphology of the (a) PA and (b) PA-Ag granules

Microstructure

Figure 4 presents the microstructural analysis of the bulk materials, focusing on their morphological and interfacial characteristics. Figure 4a shows tha microstructure of the PA samples with uncoated granules. At low magnification (left), the material exhibits a uniform texture, characteristic of the original polymer matrix. The higher magnification image (right) reveals fine, distributed roughness on the surface, attributed to the intrinsic texture of the uncoated nylon granules. The lack of filler material on the interface indicates the absence of any surface modification or reinforcement. Figure 4b exhibits the microstructure of the PA-Ag samples with Ag-coated granules. At low magnification (left), there are noticeable regions of silver-colored interfaces where Ag deposition has filled the pores of the granules, creating a more homogeneous appearance. At higher magnification (right), the coating appears to smooth out the roughness observed in the uncoated material. Additionally, the Ag layer fills the voids within the granule surface, enhancing the continuity and reducing porosity. This microstructural transformation demonstrates the effectiveness of the electroless silver coating in improving the interface quality and reducing surface irregularities. Such changes are crucial for enhancing thermal and electrical properties, as well as the overall performance of the final composite material.

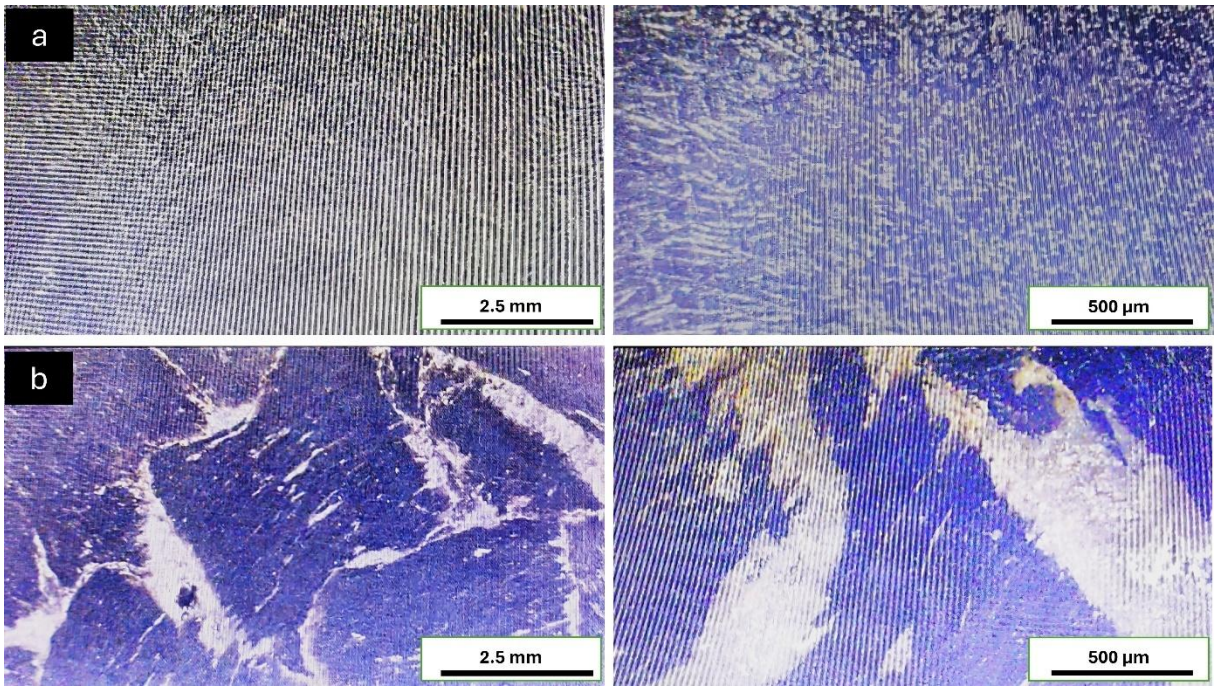

Figure 4. Microstructure of the bulk samples from (a) PA and (b) PA-Ag granules

The microstructure of the material produced using Ag-coated PA granules is visualized in Figure 5, where the formation and distribution of the silver (Ag) network are highlighted using the ImageJ software. This software was utilized to process and analyze microstructural images, providing a clearer understanding of the Ag network's connectivity and morphology. The original image was imported into ImageJ, where adjustments to contrast and brightness were applied to enhance phase differentiation. Following this, a threshold was set to isolate the Ag-rich regions, segmenting the image into Ag areas and the surrounding matrix. The thresholded image was then converted into a binary format, allowing the Ag regions to be distinctly visualized as red against the background. Further processing refined the boundaries of the Ag network, enabling its spatial structure to be more accurately represented. The interconnected Ag network within the composite material offers several significant advantages. Firstly, it enhances thermal conductivity, facilitating efficient heat transfer, which is critical for applications requiring thermal management. Secondly, the continuous Ag phase significantly improves electrical conductivity by providing a pathway for electron flow. Additionally, the Ag network contributes to mechanical reinforcement by distributing stress across the composite, improving its overall mechanical performance. The Ag phase also acts as a barrier against moisture or gas permeability, thereby increasing the material's durability in harsh environments. Furthermore, the intrinsic antibacterial properties of silver add functional value, particularly for applications in biomedical or hygiene-sensitive areas. This visualization technique is crucial for understanding and optimizing the composite's internal structure, allowing its properties to be tailored for specific applications.

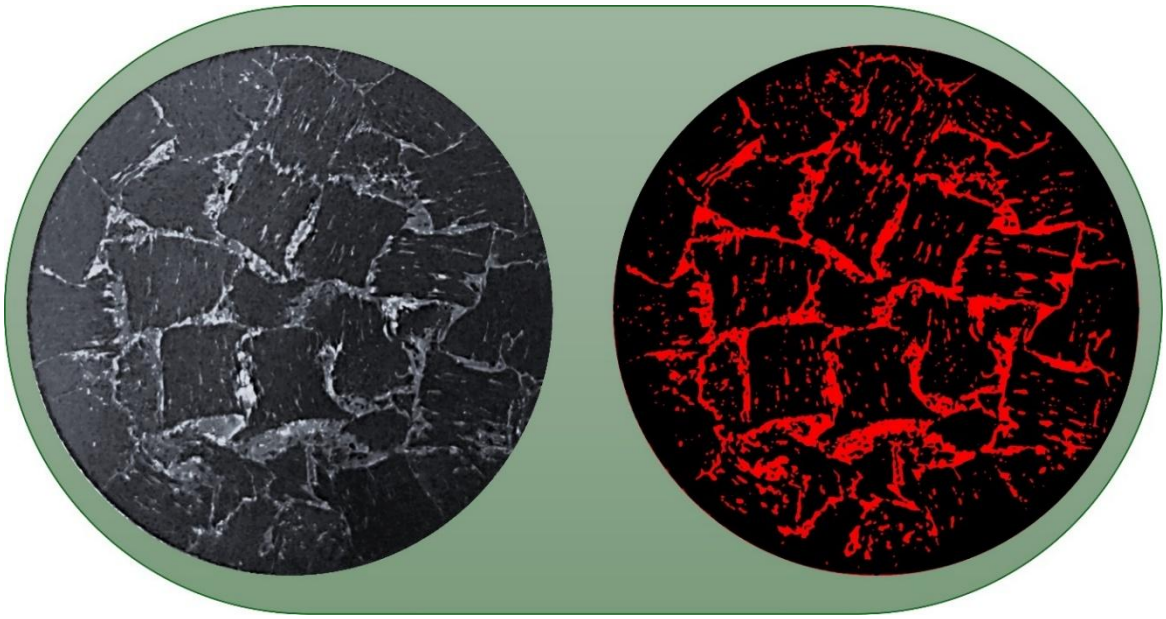

Figure 5. Silver network design by ImageJ in the microstructure of PA-Ag bulk samples

Hardness

Figure 6 illustrates the comparison of hardness values (Shore D) for pure polyamide (PA) and silver-coated polyamide (PA-Ag) samples. The PA-Ag composite exhibits a significant improvement in hardness, with an average value of 88 compared to 82 for the pure PA. This enhancement can be attributed to the incorporation of silver coating, which introduces a reinforcing network within the material. The presence of the Ag phase provides additional resistance to deformation under applied loads, effectively increasing the overall rigidity of the composite. The improved hardness of PA-Ag materials has several practical implications. Higher hardness levels translate to better wear resistance, which is critical for applications where surface durability is essential, such as gears, bearings, or high-load components. Furthermore, the enhancement in mechanical properties due to the Ag network aligns with the microstructural observations, which suggest that the Ag phase contributes to load distribution and stress transfer within the composite. This result demonstrates the potential of Ag-coated polymers for applications requiring a combination of mechanical robustness and additional functionalities, such as thermal or electrical conductivity.

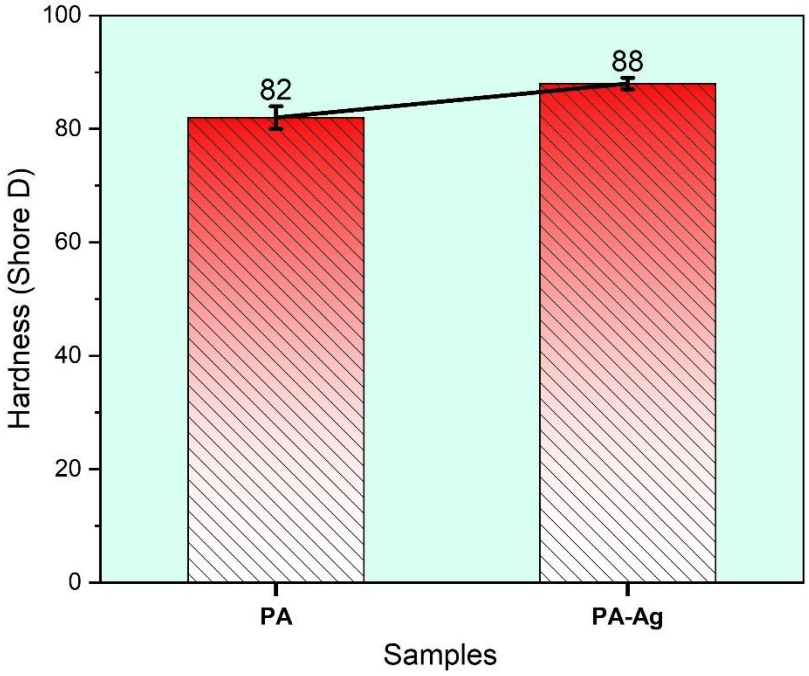

Figure 6. Hardness values of the samples

Thermal properties

Figure 7 depicts the thermal behavior of pure polyamide (PA) and silver-coated polyamide (PA-Ag) samples 30 seconds after being placed on a pre-heated plate set to a specific temperature. The thermal image reveals that the surface temperature of the PA-Ag sample (111°C) is slightly higher than that of the pure PA sample (108°C). This difference highlights the role of the silver (Ag) network in enhancing the thermal conductivity of the composite. The observed increase in temperature for the PA-Ag sample can be attributed to the incorporation of the Ag network, which acts as a thermally conductive pathway within the polymer matrix. Silver, being an excellent thermal conductor, facilitates rapid heat transfer across the material, ensuring a more uniform and efficient distribution of thermal energy. In contrast, the pure PA sample, which lacks such conductive pathways, exhibits slower heat transfer and retains a relatively lower surface temperature. This behavior demonstrates the potential of Ag-coated polymers for applications requiring improved thermal management. The Ag network's ability to enhance heat conduction makes the PA-Ag composite suitable for use in components exposed to fluctuating thermal conditions, such as heat sinks, electronic casings, or thermal interface materials. The synergistic effect of the polymer matrix and the conductive Ag network not only improves the composite's thermal performance but also maintains its lightweight and mechanically robust properties, making it advantageous for advanced engineering applications.

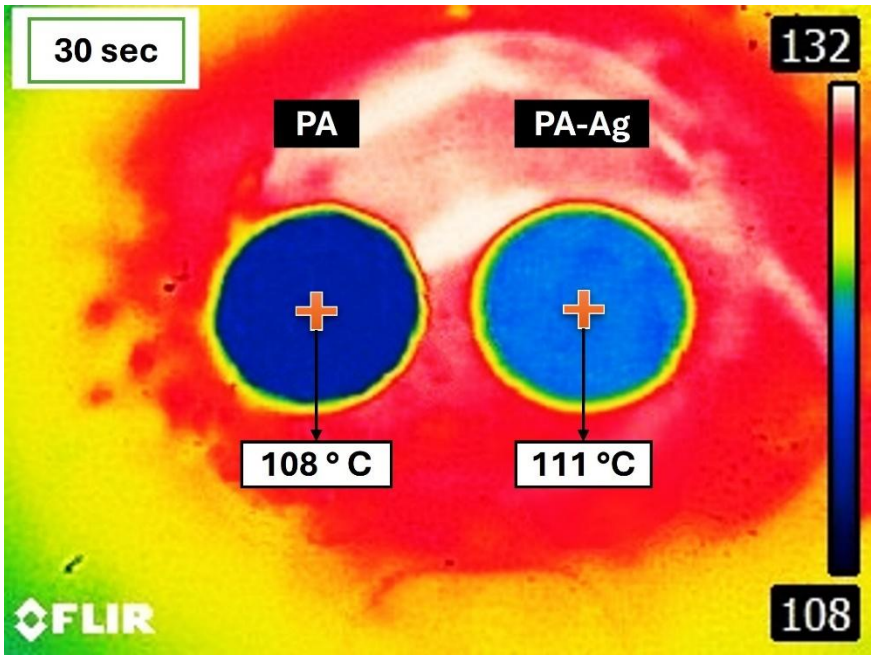

Figure 7. Surface temperature variations of the samples

Conclusions

This study systematically examined the microstructural, mechanical, and thermal performance of silver-coated nylon-based composites, revealing several key findings that contribute to the development of multifunctional polymer composites. The conclusions were given as items as follows:

- The electroless silver coating process successfully formed a uniform silver layer on nylon granules, creating an effective conductive network within the composite.
- The incorporation of silver significantly enhanced the hardness of the composites, with PA-Ag samples achieving a Shore D hardness of 88, compared to 82 for pure nylon (PA).
- Thermal performance evaluations demonstrated that the PA-Ag composites exhibited a 3°C higher surface temperature (111°C) than pure PA (108°C) under identical heating conditions, attributed to the improved thermal conductivity due to the silver network.
- The microstructural analysis confirmed the homogeneous distribution of silver within the matrix, ensuring consistent mechanical and thermal performance.
- The synergistic improvement in mechanical and thermal properties makes these composites suitable for lightweight and high-performance applications, particularly in fields requiring enhanced thermal management.

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RELATIONSHIP BETWEEN NECK MUSCLES CROSS SECTIONAL AREA WITH CRANIO-VERTEBRAL ANGLE AND CERVICAL RANGE OF MOTION AMONG THE SUBJECTS WITH CHRONIC NECK PAIN

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Background: Neck pain, whether acute, subacute, or chronic, affects quality of life and is a leading cause of disability, with 67% of people globally are affected, from which, 20% progressing to chronic pain. MRI is essential for diagnosing musculoskeletal issues, analyzing paravertebral muscles, and measuring muscle fat infiltration, volume, and cross-sectional area. Forward head posture (FHP), which are very common nowadays mostly due to the electronic device overuse, which may have an impact on craniovertebral angle (CV Angle) and Cervical Range of Motion, both are predictors of neck pain.

Purpose: The current study aims to find out the relationship between neck muscles cross sectional area (CSA) with CV Angle and cervical range of motion among the subjects with chronic neck pain.

Methods: A cross-sectional study design, where 72 male and female participants whose age is more than 20 years old, who suffer from chronic neck pain were included in the study. After obtaining an informed consent, all the participant's demographic details (age, gender, height, weight, BMI) were recorded. Following which, all those who underwent MRI, were measured for their neck muscle CSA by a radiologist, at the level of C4 using T1-weighted images. CV angle was measured by taking a lateral photograph. Cervical ROM in all three planes were evaluated by using a Cervical goniometer (CROM).

Results: Pearson's correlation coefficient revealed no significant correlations between Cervical CSA with CV angle ($r = -0.08$, $p > 0.05$) and Cervical range of motion of flexion, extension, side flexion to right and left, rotation to right and left. ($r = 0.01, 0.09, 0.16, 0.14, 0.11$ and 0.14, $p > 0.05$). However, there was a significant positive correlation was found between neck muscle CSA with BMI ($r = 0.30$, $p < 0.05$) and CV angle with duration of pain ($r = 0.32$, $p < 0.05$).

Conclusion: The study results conclude that, there was no relationship exists between neck muscles CSA with CV Angle and cervical range of motion among the subjects with chronic neck pain, which means there was no influence on the cervical posture and range of motion by the neck muscle CSA among the subjects with chronic neck pain. However, BMI could influence the CSA of neck muscles and duration of neck pain could influence the CV Angle.

Key words: Neck Pain, CV Angle, Muscles Cross Sectional Area, Cervical Range of Motion

COMPARATIVE EVALUATION OF OPEN-SOURCE NAC SOLUTIONS FOR ENHANCING NETWORK SECURITY AND POLICIES

AĞ GÜVENLİĞİNİ VE POLİTİKALARINI GELİŞTİRMEK İÇİN AÇIK KAYNAKLI NAC ÇÖZÜMLERİNİN KARŞILAŞTIRMALI DEĞERLENDİRMESİ

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ÖZET

Güçlü ağ güvenliği çözümlerine olan talebin artmasıyla birlikte, Ağ Erişim Kontrolü (NAC), çeşitli BT ortamlarında güvenlik politikalarını uygulamak için kritik bir mekanizma olarak ortaya çıkmıştır. Açık kaynaklı NAC çözümleri, tescilli sistemlere uygun maliyetli ve esnek alternatifler sunmaktadır. Bu çalışma, modern ağ altyapıları için uygunluklarını belirlemek amacıyla önde gelen açık kaynaklı NAC teknolojilerini performans, ölçeklenebilirlik ve özellik setleri açısından değerlendirerek karşılaştırma yapmaktadır. Üç önemli açık kaynaklı NAC çözümü, politika uygulama yetenekleri, entegrasyon kolaylığı, ölçeklenebilirlik, kaynak kullanımı ve topluluk desteği gibi temel ölçütlere göre analiz edilmiştir. Test, gerçek dünyadaki kurumsal kurulumları taklit etmek üzere tasarlanmış kontrollü bir ağ ortamında yürütülmüştür ve her çözüm, cihaz kimlik doğrulaması, sahte cihaz azaltma ve uyumluluk kontrolleri gibi yaygın ağ senaryolarına göre değerlendirilmiştir. Bu ölçütler arasında performansı karşılaştırması için istatistiksel analiz yöntemi kullanılmıştır. Karşılaştırmalı analiz, incelenen NAC çözümlerinin etkinliği ve kullanılabilirliğinde önemli farklılıklar olduğunu ortaya koymaktadır. Bir çözüm ölçeklenebilirlikte mükemmellik gösterirken, diğeri üstün entegrasyon kolaylığı göstermiştir. Açık kaynaklı NAC çözümleri, özellikle esneklik ve maliyet tasarrufunu önceliklendiren kuruluşlar için, tescilli sistemlere uygulanabilir alternatifler sunmaktadır. Bununla birlikte, bir çözümün seçimi büyük ölçüde belirli kurumsal ihtiyaçlara ve kaynak kullanılabilirliğine bağlıdır. Belirlenen sınırlamaları ele almak ve bu çözümler için potansiyel geliştirmeleri keşfetmek için daha fazla araştırma yapılması teşvik edilmektedir.

Anahtar Kelimeler: Ağ Erişim Kontrolü (NAC); Açık Kaynaklı Güvenlik Araçları; Cihaz Kimlik Doğrulaması; Erişim Politikası Yönetimi; BT Altyapı Koruması

ABSTRACT

With the increasing demand for robust network security solutions, Network Access Control (NAC) has emerged as a critical mechanism to enforce security policies in various IT environments. Open-source NAC solutions offer cost-effective and flexible alternatives to proprietary systems. This study evaluates and compares leading open-source NAC technologies in terms of performance, scalability, and feature sets to determine their suitability for modern network infrastructures. Three prominent open-source NAC solutions were analyzed based on key metrics such as policy enforcement capabilities, ease of integration, scalability, resource utilization, and community support. The test was conducted in a controlled network environment designed to mimic real-world enterprise deployments, and each solution was evaluated against common network scenarios such as device authentication, rogue device mitigation, and compliance checks. Statistical analysis method was used to compare the performance across these metrics. The comparative analysis reveals significant differences in the effectiveness and usability of the NAC solutions examined. While one solution demonstrated excellence in scalability, the other demonstrated superior ease of integration. Open-source NAC solutions offer viable alternatives to proprietary systems, especially for organizations that prioritize flexibility and cost savings. However, the selection of a solution is highly dependent on specific institutional needs and resource availability. Further research is encouraged to address the identified limitations and explore potential improvements for these solutions.

Key Words: Network Access Control (NAC); Open-Source Security Tools; Device Authentication; Access Policy Management; IT Infrastructure Protection

GİRİŞ

Bilgi teknolojilerinin hızla gelişim gösterdiği günümüzde, ağ güvenliği kavramının kurumlar için önemi her geçen gün artmaktadır. Tutulan bilgilerin çok sayıda cihazdan geçmesi ve saldırılara savunmasız hale gelmesi ağ güvenliğini organizasyon yapısında önemli bir bileşen haline getirmiştir [1]. Ağda var olan dahili kullanıcıların binaya ve altyapı cihazlarına doğrudan erişimi olduğundan dahili tehditler, harici tehditlere oranla daha fazla hasara yol açma potansiyeline sahiptir [2]. Bu durumu destekler nitelikte, D. Zatonatskiy ve arkadaşları, yaptıkları araştırmada, siber saldırıların kurumlara verdiği zarar açısından en etkili olanlarının iç ağdaki tehditlerden kaynaklandığını belirtmiştir [3]. Son dönemlerde siber güvenlik yatırımları, kurumsal iç ağlarda erişim kontrolünü hedefleyen ürün ve hizmetlere odaklanmaktadır [4]. Bu doğrultuda, ağlarda güvenlik açıklarını en aza indirgemek ve tehditleri etkili bir şekilde yönetmek için geliştirilen Ağ Erişim Kontrolü (Network Access Control- NAC) çözümleri, giderek daha fazla önem kazanmaktadır. Ağ erişim kontrolü (NAC), ağ güvenliğinde önemli bir rol oynar ve ağ erişimini sınırlayarak sadece yetkilendirilmiş kullanıcıların ve cihazların ağ kaynaklarına erişmesini sağlar. Bu güvenlik önlemi hem dışarıdan gelen tehditleri hem de içsel güvenlik risklerini azaltmaya yardımcı olur. Ağ erişim kontrolünün yaygın kullanım durumları şunlardır [8]:

- Kendi Cihazını Getir (BYOD): Çalışanların kişisel cihazlarını kullanmasına izin veren kuruluşlar, bu cihazların güvenliğini sağlamak için ekstra önlemler almalıdır, çünkü her cihaz güvenlik açığı oluşturabilir [19].
- Çalışan Olmayanlar İçin Ağ Erişimi: Satıcılar, ziyaretçiler ve yükleniciler gibi kuruluş dışındaki kişilere sınırlı ağ erişimi sağlanabilir, ancak tüm ağ kaynaklarına erişim izni verilmemelidir.

- IoT Cihazlarının Kullanımı: IoT cihazları, genellikle ağ güvenlik önlemlerinin dışındaki cihazlardır ve yeterli ağ erişim kontrolleri yapılmazsa, siber suçlular bu cihazları ağın içine sızmak için kullanabilir [20].

Bu durumlar, ağ erişim kontrolünün önemini vurgular ve güvenliği sağlamak için dikkatle yönetilmesi gereken alanlardır. Bu çalışmada, açık kaynak NAC türlerinin karşılaştırılması, bu sistemlerin sunduğu güvenlik mekanizmaları ve olası zafiyetleri incelenmekte; kurumsal ağlarda NAC uygulamalarının güvenlik üzerindeki etkileri değerlendirilmektedir. Kapsamın açık kaynak yazılımlardan yana belirlenmesinin en önemli sebebi, açık kaynak yazılımların kullanıcılar tarafından incelenebilmesi, maliyetinin düşük olması ve yazılımın sürekli olarak güncellenmesi [5] gibi özelliklerinin avantajlarına vurgu yapmaktır.

NAC YAPISI VE BİLEŞENLERİ

NAC Bileşenleri

NAC teknolojisi, bir ağın güvenliğini sağlamak adına ağda bağlantı kuran cihazları izlemeye, denetlemeye ve kontrol etmeye yarayan; yalnızca yetkilendirilmiş ve güvenli cihazların ağa erişmesine olanak veren bir ağ güvenlik çözümüdür. İyi tasarlanmış bir NAC çözümünde, son sistem algılama, kimlik doğrulama, değerlendirme, yetkilendirme ve düzeltme gibi birçok önemli bileşen kullanılmaktadır [6]. Bu bileşenler, ağ üzerindeki her cihazın güvenlik durumunu sürekli olarak izler ve ağdaki tehditleri minimize etmek amacıyla dinamik müdahaleler yapar. Örneğin, bir cihazın bağlantı kurmadan önce kimlik doğrulama sürecinden geçmesi, ağın sadece güvenli ve yetkilendirilmiş cihazlarla etkileşimde bulunmasını sağlar. Ayrıca, değerlendirme aşamasında cihazların yazılım güncellemeleri, güvenlik durumu ve uyumluluk politikalarına uygunlukları kontrol edilmektedir. NAC çözümleri, ağdaki cihazların her birini denetleyerek sadece ağ güvenliğini artırmakla kalmaz, aynı zamanda ağ yöneticilerine ağda olan biteni ayrıntılı bir şekilde izleme ve raporlama olanağı da sunar. Bu sayede ağda bulunan her cihazın sağlık durumu ve güvenlik seviyeleri hakkında bilgi sahibi olunabilir. Bu tür bir sistem, ağ yöneticilerinin tehditleri hızla tespit etmelerine ve potansiyel güvenlik açıklarına karşı hızlı bir şekilde önlem almalarına olanak tanır. Ayrıca, NAC çözümleri genellikle çok katmanlı güvenlik özellikleri sunar. Cihazların ağa bağlanmadan önce ve bağlantı sırasında farklı güvenlik kontrollerinden geçmesini sağlayarak, ağda yalnızca güvenli cihazların hareket etmesine imkân tanımaktadır. Şekil 1, NAC mimarisinin genel gereksinimlerini adım adım açıklamaktadır.

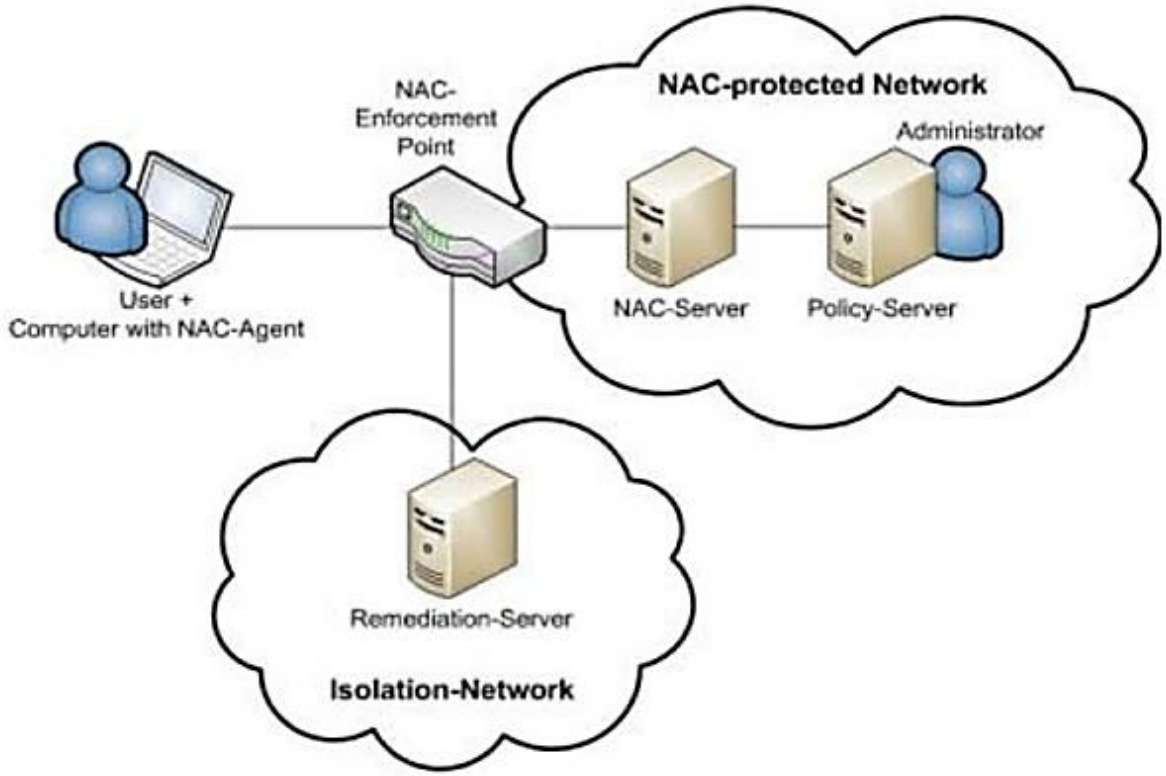
Şekil 1. NAC işlevleri [6]

NAC Mimarisi

Ağ erişim denetiminde iki ana işlev kimlik doğrulama ve yetkilendirmeyken NAC, cihazların geçerli sağlık durumları, uyumluluk politikaları, görünürlükleri gibi özelliklerini denetleyerek istenilen kriterlere uymayan cihazları karantinaya alma gibi ek hizmetler sunar [7]. Bu işlevler, ağ üzerinde yalnızca güvenli cihazların erişim sağlayarak ağ güvenliğini büyük ölçüde artırır. Bu denetimler, ağdaki her cihazın sağlık durumunu kontrol etmenin yanı sıra, cihazların uyumlu

olup olmadığını da sürekli olarak değerlendirir. Cihazlar, belirlenen güvenlik gereksinimlerine uygun olup olmadığına göre sınıflandırılır ve herhangi bir tehdit oluşturabilecek durumlar tespit edildiğinde derhal ağdan izole edilir. Bu tür özellikler, ağda güvenlik açıklarını en aza indirgemek için kritik bir rol oynar.

Ayrıca, NAC sistemlerinin izlediği bir diğer önemli özellik ise cihazların erişim düzeylerinin dinamik bir şekilde yönetilmesidir. Bu yönetim, ağdaki cihazın güvenlik durumu değiştikçe, ağ erişim izinlerinin de anında güncellenmesini sağlar. Örneğin, bir cihazın antivirüs yazılımı güncellenmezse, ağdaki erişimi kısıtlanabilir ya da bu cihaz karantinaya alınabilir. Bu sayede, ağda herhangi bir tehdit veya zafiyet oluşturabilecek cihazların erişimi engellenmiş olur. NAC sistemleri ayrıca ağdaki cihazların her birinin durumu hakkında ayrıntılı raporlama ve izleme sağlar, böylece ağ yöneticileri her zaman en güncel güvenlik bilgilerine sahip olur. Şekil 2 geleneksel NAC mimarisinde bileşenlerin nasıl bir araya getirildiğini tanımlamaktadır.



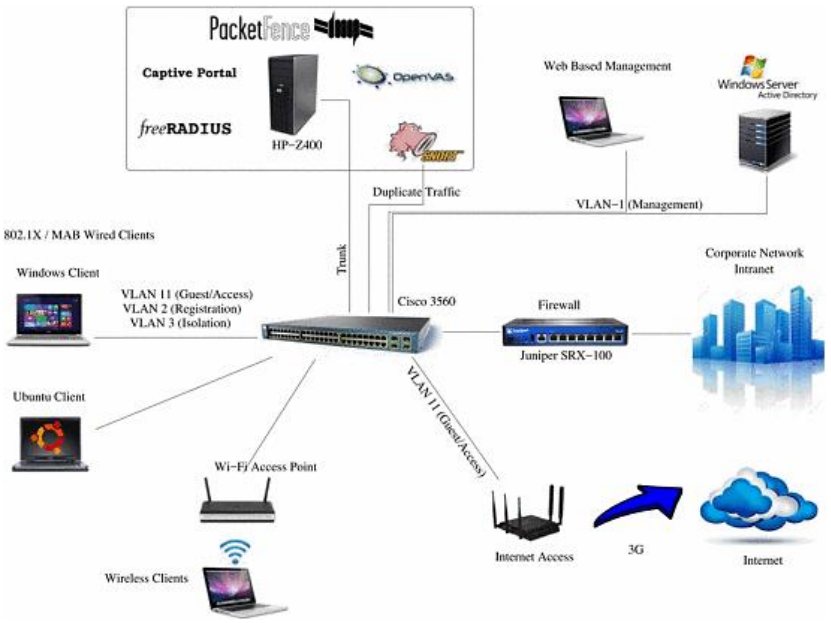
Şekil 2. NAC mimarisi [7]

AÇIK KAYNAK NAC TÜRLERİ

Kurumsal alanda açık kaynak NAC çözümlerinin kıyaslanması kapsamında bildiride incelenecek başlıklar şunlardır: PacketFence, OpenNAC, pfSense ve FreeRADIUS.

PacketFence

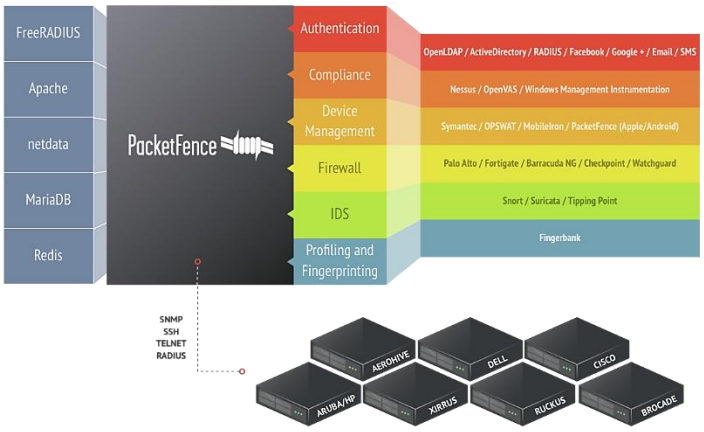
PacketFence, açık kaynaklı ve ücretsiz bir NAC çözümü olarak öne çıkmaktadır. Bu sistem, bireysel kullanıcılar ve toplulukların yanı sıra kurumsal işletmeler için de modüler, esnek ve güçlü özellikler sunmaktadır [9]. PacketFence'in öne çıkan özelliklerinden biri, ticari destek alabilme imkanıdır; sistem, belirli kurumlar için özelleştirilmiş özelliklerin geliştirilmesine olanak sağlar ve bu geliştirmeler açık kaynak versiyona geri kazandırılır [10]. Şekil 4, PacketFence sisteminin kurumsal ağlara entegre edilmesi hakkında bilgi vermektedir.



Şekil 4. Kurumsal ağa entegre edilmiş Packetfence [10]

PacketFence'in öne çıkan özellikleri aşağıdaki gibi sıralanabilir [11];

- **Out-of-Band Dağıtım:** Coğrafi olarak ölçeklenebilir, arıza toleransı yüksek ve büyük ağlar için uygundur.
- **Inline Dağıtım:** Yönetilemeyen ağ ekipmanlarına kolayca entegre edilebilir.
- **802.1X Desteği:** Kablolu ve kablosuz ağlarda güvenli kimlik doğrulama sağlar.
- **Cihaz Kaydı:** Kullanıcılar önce kaydedilir, ardından otomatik ağ erişimi sağlanır; Kabul Edilebilir Kullanım Politikası (Acceptable Use Policy - AUP) gerektirir.
- **Kablosuz Ağ Entegrasyonu:** Kablolu ve kablosuz ağlar için aynı kullanıcı veri tabanı ve güvenlik çözümleri sunar.
- **İnternet Üzerinden Ses İletimi (VoIP- Voice over Internet Protocol) Desteği:** Cisco, HP ve diğer switch satıcılarıyla uyumlu çalışarak İnternet Üzerinden Ses İletimi (VoIP) güvenliğini sağlar.
- **Ağ Anomalisi Tespiti:** Snort veya Suricata araçları ile ağda anormal aktiviteleri tespit eder.
- **Güvenlik Açığı Tarama:** Nessus veya Açık Kaynaklı Güvenlik Açığı Tarama Sistemi (OpenVAS- Open Vulnerability Assessment System) ile cihazlarda güvenlik açığı taramaları yapar.
- **Güvenlik Ajanları Entegrasyonu:** Microsoft Intune ve SentinelOne gibi çözümlerle cihazların uyumlu olup olmadığını kontrol eder.
- **Sanal Yerel Alan Ağı (VLAN- Virtual Local Area Network) İzolasyonu:** Sorunlu cihazları ağdan izole eder. Yönetim Arayüzleri: Web tabanlı ve komut satırı arayüzleri ile yönetim işlemleri yapılabilir; LDAP/Active Directory entegrasyonu sağlar.



Şekil 5. PacketFence bileşen mimarisi [11]

OpenNAC

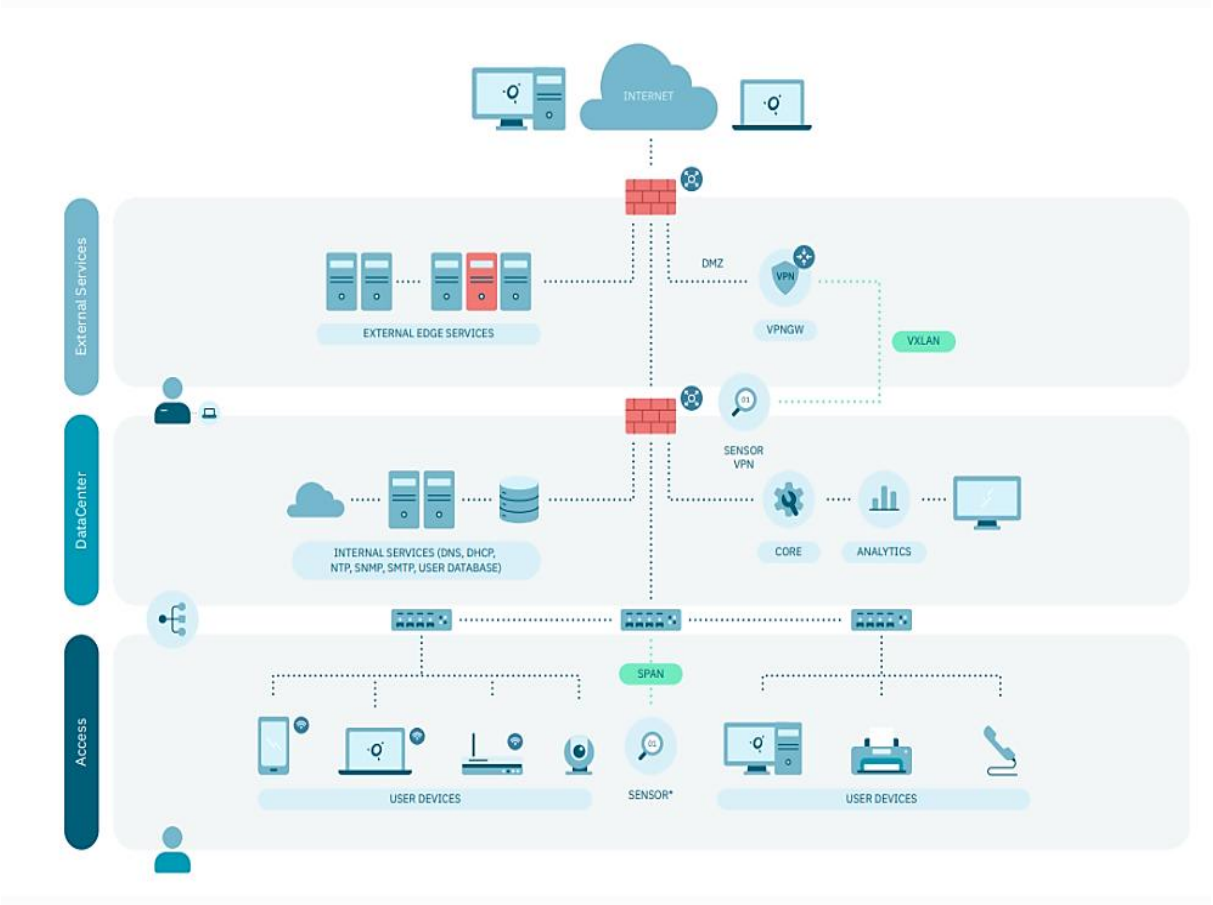
OpenNAC, LAN/WAN ortamlarında ağ erişim kontrolü sağlayan bir yazılım tabanlı platformdur. Kuruluşların tüm erişimleri doğrulamasını, yetkilendirmesini ve denetlemesini sağlayarak ağ güvenliğini artırır. OpenNAC, ağa bağlı cihazlar ve kimlikler gibi varlıkların görünürlüğünü ve kontrolünü sunarak, IoT, iş kesintisi saldırıları ve denetim baskıları gibi tehditlerle başa çıkmalarına yardımcı olur. Modüler yapısı sayesinde kullanıcıların güvenlik ihtiyaçlarına göre özelleştirilebilir. Bu çözüm, merkezi yönetimi ve otomatik görünürlüğüyle ağ güvenliğini verimli bir şekilde yönetmeyi mümkün kılar [12].

OpenNAC avantajları şu maddelerle sıralanabilir [12];

- **Kimlik Doğrulama**: Kullanıcılar ve/veya cihazların kimliklerini doğrulamak için çeşitli bilgi depoları (örneğin, Active Directory) ile entegrasyon sağlar.
- **Yetkilendirme**: Ağa bağlanan her varlığa özel ayrıcalıklar atama imkânı sunar. (Örneğin, belirli bir VLAN ataması).
- **Denetim**: Ağa erişim olaylarını toplar ve değerlendirir, ağdaki faaliyetlerin geçmişine ulaşılabilir.
- **Envanter Yönetimi**: Ağa bağlanan her kimliğin detaylarını içeren yapılandırma yönetim veri tabanı (CMDB) sağlar.
- **Profil Oluşturma**: Kimliklerin belirli bir durumu için profil oluşturma ve bu profilin ağ erişimi için zorunlu olmasını sağlama imkânı.
- **Postür Değerlendirmesi**: Bağlı cihazların davranışlarını gerçek zamanlı olarak değerlendirir ve beklenen parametrelere uyum sağlamayan cihazlara müdahale eder.
- **Tehdit Giderme (Remediation)**: Tehdit tespiti sonrasında gerekli düzeltici eylemleri gerçekleştirir, örneğin, tehlikeye giren cihazları ağdan izole eder.
- **Çift Faktörlü Kimlik Doğrulama (2FA)**: VPN erişimini ikinci bir doğrulama faktörü ile güçlendirir, örneğin Google Authenticator ile.
- **Yerel Ajanda (Native Agent)**: Cihaza kurulan ajanda ile bağlı varlıklardan hızlı bir şekilde bilgi toplar ve tespit edilen tehditlere hızlı tepki verir.
- **SIEM Entegrasyonu**: Üçüncü taraf SIEM sistemleriyle entegrasyon sağlayarak NAC günlüklerini toplar ve kurumsal bilgi sistemlerine iletir.

- **Güvenlik Orkestrasyonu**: OpenNAC Enterprise'ı diğer güvenlik elemanlarıyla (NGFW, antivirüs, IDS, MDM vb.) iletişim kurarak güvenlik orkestrasyonu olarak kullanma imkânı sağlar.
- **Sensor Modülü**: Uygulama seviyesinde ağ trafiğini inceleyerek, ağ davranışlarını sınıflandırır ve NAC tarafından yönetilmeyen ağ segmentlerine de görünürlük kazandırır.

OpenNAC, cihazlar ve kullanıcıların kimliklerine göre ağ kaynaklarına erişimi sınırlamak isteyen büyük şirketler için uygun bir çözümdür. Şekil 6, OpenNAC çözümünün örnek bir şirket senaryosuna entegre edilmiş versiyonunu göstermektedir.



Şekil 6. OpenNAC örnek senaryo [12]

pfSense ve FreeRADIUS

pfSense ve FreeRADIUS entegrasyonu, açık kaynaklı ağ güvenlik çözümleri arasında öne çıkan bir kombinasyondur. pfSense, FreeBSD tabanlı bir güvenlik duvarı ve yönlendirici platformu olarak hem bireysel hem de kurumsal kullanıcılar için özelleştirilebilir bir yapı sunar [17]. FreeRADIUS ise AAA (Kimlik Doğrulama, Yetkilendirme ve Hesaplama) protokolünü destekleyen güçlü bir merkezi kimlik doğrulama sistemi olarak bu yapıyı tamamlar. Bu birleşim, özellikle ağ erişim kontrolü ve kullanıcı doğrulama süreçlerini optimize ederek hem güvenlik hem de yönetim kolaylığı sağlamaktadır [13],[14],[18].

Bu entegrasyon, Captive Portal gibi özelliklerle desteklenerek kullanıcıların ağa erişim sağlamadan önce kimlik doğrulama yapmasını gerektirir. Captive Portal, kullanıcıların kimlik bilgilerini doğrulamak için güvenli bir giriş arayüzü sunar. FreeRADIUS ile entegre edildiğinde, bu süreçte her kullanıcı için benzersiz kimlik bilgileri atanır ve merkezi bir sistem üzerinden

yönetilir. Bu, yalnızca yetkili kullanıcıların erişimini sağlayarak güvenlik tehditlerini azaltır ve ağ yöneticilerine erişim üzerinde tam kontrol sağlar [15].

Yapılan bir çalışmada, pfSense Captive Portal ile FreeRADIUS birlikte kullanılarak bir kablosuz ağda kullanıcı kimlik doğrulama işlemi başarıyla gerçekleştirilmiştir. Kullanıcıların ağ bağlantı talepleri Captive Portal'a yönlendirilmiş ve doğru giriş bilgileri sağlanana kadar internet erişimi engellenmiştir. Ayrıca, geçici bilet sistemi kullanılarak ziyaretçiler için güvenli erişim sağlanmıştır [15].

Bir diğer çalışmada, bir üniversitenin turnike sistemi pfSense ve FreeRADIUS ile entegre edilmiştir. Turnikeden geçen öğrencilerin kimlik bilgileri doğrulanarak yalnızca kayıtlı kullanıcıların ağa erişimine izin verilmiştir. Aynı kimlik bilgilerinin birden fazla cihazda kullanılmasının engellenmesi, ağın güvenliğini artırmıştır [16].

Avantajları

pfSense ve FreeRADIUS'un birlikte kullanımı, aşağıdaki avantajları sunar:

- **Merkezi Kimlik Doğrulama:** Tüm kullanıcılar için kimlik doğrulama, tek bir merkezden yönetilerek güvenlik açıklarını en aza indirir.
- **Kullanıcı Başına Benzersiz Kimlik Bilgileri:** Parola paylaşımı gibi güvenlik tehditleri ortadan kaldırılır ve her kullanıcı için ayrıcalıklı erişim sağlanır.
- **Esneklik ve Uyarlanabilirlik:** Captive Portal, ziyaretçi ve kurumsal kullanıcılar için özelleştirilebilir erişim politikaları sunar.
- **Kullanıcı Dostu Yönetim:** Web tabanlı yönetim arayüzü ile hızlı ve kolay yapılandırma imkânı sağlar [13][14].

NAC Türleri Karşılaştırılması

Açık kaynak NAC çözümleri hem esnekliği hem de özelleştirilebilir yapılarıyla birçok kurum için cazip bir alternatif sunmaktadır. Ancak, her çözüm farklı mimari yapılar, yönetim süreçleri ve entegrasyon kabiliyetleri ile öne çıkmaktadır. Aşağıdaki tablolar, çalışmada seçilen açık kaynaklı NAC çözümlerinin teknik ve işlevsel özelliklerini karşılaştırmalı olarak ortaya koymaktadır.

Tablo 1. PacketFence, OpenNAC, pfSense+FreeRADIUS çözümlerinin işlevsel özelliklerinin karşılaştırılması

Kriter	PacketFence	OpenNAC	pfSense+FreeRADIUS
Kurulum ve Yapılandırma	Karmaşıktır, uzmanlık gerektirir.	Orta seviyede yapılandırma gerektirir.	Kolay, ancak FreeRADIUS entegrasyonu için teknik bilgi gerekir.
Esneklik ve Özelleştirme	Özelleştirilebilir.	Özelleştirilebilir, ancak karmaşık olabilir.	Özelleştirilebilir.
Ağ Güvenliği	802.1X, ağ anomali tespiti, güvenlik açığı tarama özellikleri vardır.	Kimlik doğrulama, yetkilendirme ve denetim sağlar.	Merkezi kimlik doğrulama ve esnek erişim politikaları ile güvenlik sağlar.
Kullanıcı Yönetimi	Kullanıcı kaydı, kabul edilebilir kullanım politikası ve cihaz kaydı sağlar.	Kimlik doğrulama, envanter yönetimi, profil oluşturma özellikleri sunar.	Kullanıcı başına benzersiz kimlik bilgileri ile güvenli yönetim sağlar.
Cihaz Yönetimi	Cihazları ağdan izole etme ve güvenlik açığı taramaları yapabilme özellikleri sunar.	Cihazların postür değerlendirmesi ve tehdit giderme özellikleri sunar.	Cihazları tanımlama ve yönetme özellikleri sunar, ancak daha az özelleştirilebilir.
Maliyet	Açık kaynak, ancak ticari destek maliyetli olabilir.	Açık kaynak, ancak ticari destek gerekebilir.	Ücretsiz ancak FreeRADIUS entegrasyonu için uzmanlık gerekebilir.
Ölçeklenebilirlik	Büyük ağlar için ölçeklenebilir, coğrafi olarak yayılabilir.	Modüler yapısı ile ölçeklenebilir, ancak büyük ölçekler için yapılandırma karmaşık olabilir.	Ölçeklenebilir, ancak ağdaki karmaşıklık arttıkça yönetim zorluğu da artar.

Aşağıdaki tabloda, PacketFence, OpenNAC ve pfSense + FreeRADIUS çözümlerinin temel teknik özellikleri detaylı olarak ele alınmıştır. Bu karşılaştırma, güvenlik açığı tarama, ağ yönetimi ve ağ anomalisi tespiti gibi kritik unsurları içermektedir.

Tablo 2. PacketFence, OpenNAC, pfSense+FreeRADIUS çözümlerinin teknik özelliklerinin karşılaştırılması

Kriter	PacketFence	OpenNAC	pfSense + FreeRADIUS
802.1X Desteği	Var	Var	Var
VLAN İzolasyonu	Var	Var	Var
Kullanıcı ve Cihaz Kimlik Doğrulama	Var	Var	Var
Ağ Anomalisi Tespiti (Snort/Suricata)	Var	Yok	Yok
Güvenlik Açığı Tarama (Nessus/OpenVAS)	Var	Yok	Yok
Captive Portal Desteği	Var	Yok	Var
Web Tabanlı Yönetim Arayüzü	Var	Var	Var
Cihaz Kaydı ve Profil Yönetimi	Var	Var	Yok
Çift Faktörlü Kimlik Doğrulama (2FA)	Yok	Var	Yok
Envanter Yönetimi	Var	Var	Yok
Dış Sistem Entegrasyonu (SIEM, MDM)	Var	Var	Var
Yüksek Ölçeklenebilirlik	Var	Orta	Var
Kolay Kurulum	Orta	Kolay	Kolay
Ağ Yönetimi	Gelişmiş	Orta	Orta

SONUÇ

Bu çalışma, Ağ Erişim Kontrolü (NAC) çözümlerinin, kurumsal ağlardaki güvenlik açıklarını azaltma, tehditleri yönetme ve erişim denetimi sağlama açısından kritik bir rol oynadığını ortaya koymaktadır. Günümüzün hızla gelişen siber tehdit ortamında, yetkisiz erişimleri engellemek ve ağda bağlantı kuran cihazların güvenlik durumlarını sürekli izlemek, etkili bir ağ yönetimi için vazgeçilmez hale gelmiştir. NAC çözümleri, kimlik doğrulama, yetkilendirme ve uyumluluk kontrolleri sağlayarak yalnızca güvenli ve yetkilendirilmiş cihazların ağa erişmesini mümkün kılmaktadır.

Özellikle açık kaynaklı NAC çözümleri, maliyet açısından ticari alternatiflere göre daha avantajlı olmasının yanı sıra, esneklik ve özelleştirilebilirlik açısından da önemli fırsatlar sunmaktadır. Bu çalışmada ele alınan PacketFence, OpenNAC ve pfSense + FreeRADIUS çözümleri, farklı ölçeklerdeki organizasyonların gereksinimlerine göre çeşitli avantajlar sunmaktadır:

- Büyük ölçekli ağlar için PacketFence: Geniş kapsamlı cihaz profilleme, misafir ağı yönetimi ve politika bazlı erişim denetimi gibi özellikleri ile büyük kurumlar ve eğitim kurumları için uygundur.
- Orta ölçekli işletmeler için OpenNAC: Modüler yapısı, Active Directory ve LDAP gibi sistemlerle entegrasyon desteği sayesinde, orta ölçekli işletmeler için merkezi bir ağ güvenliği çözümü sunmaktadır.
- Küçük ağlar için pfSense + FreeRADIUS: Düşük maliyetli, hızlı kurulum ve güvenlik duvarı entegrasyonu gibi özellikleriyle, küçük işletmeler ve ev kullanıcıları için uygun bir çözüm sağlamaktadır.

Bu çözümler yalnızca yetkisiz erişimi önlemekle kalmayıp, aynı zamanda tehdit tespiti, güvenlik açığı analizi, anomali tespiti ve kullanıcı bazlı erişim politikaları gibi ek güvenlik

mekanizmalarıyla kurumsal ağların güvenliğini artırmaktadır. Ancak, her çözümün belirli avantajları ve sınırlamaları bulunduğundan, kurumsal ağların ihtiyaçlarına en uygun çözümün dikkatli bir analiz sonucunda belirlenmesi gerekmektedir.

Sonuç olarak, açık kaynaklı NAC çözümleri, kurumsal ağların güvenliğini artırmak, yetkisiz erişimi önlemek ve ağ erişimini daha verimli bir şekilde yönetmek için etkili ve maliyet açısından uygun seçenekler sunmaktadır. Özelleştirilebilir yapıları, genişletilebilirlik imkanları ve güçlü topluluk desteği sayesinde, organizasyonlar ihtiyaçlarına uygun bir NAC çözümünü entegre ederek ağ güvenliğini daha etkin bir şekilde yönetebilir. Böylece, açık kaynaklı NAC çözümleri, siber saldırılara karşı güçlü bir savunma mekanizması oluşturarak, ağ altyapılarının sürdürülebilir güvenliğini sağlamaya önemli bir katkı sunmaktadır.

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NYLON KUMAŞLARIN DİREKT BOYAR MADDELERLE BOYANMASINDA METALİK MORDAN TUZLARININ KULLANIMININ ARAŞTIRILMASI

INVESTIGATION OF MORDANT APPLICATION IN DIRECT DYEING OF NYLON FABRICS

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ÖZET

Nylon lifleri endüstriyel olarak ilk üretilmiş sentetik lifler olup öncelikle görünüm ve dayanım özellikleri sayesinde en fazla kullanılan üç sentetik liften birisidir. Doğal ve rejenere selülozik lifleri boyayabilen direkt boyar maddelerin uygulanabilmesi için mordanlamaya gerek yoktur. Mordanlamaya gerek duyulmamasının nedeni bu boyar maddelerin selülozik liflere karşı substantivitelerinin yüksek olmasıdır. Bu nedenle bu gruba substantif boyar maddeler de denir. Mordanlar öncelikle doğal boya uygulamalarında boyanın lif içinde tutunabilmesi için uygulanır. Bu çalışmada nylon kumaşlarda direkt boyar madde uygulaması mordan kimyasallarının varlığında gerçekleştirilmiş olup, uygulanan boyama şartları altında daha iyi boyar madde çekimi ve renklendirme özelliklerinin eldesi amaçlanmıştır. Çalışmada dört farklı renkte direkt boyar madde kullanılmıştır. Bu dört farklı direkt boyar madde kullanımı yanı sıra son-mordanlama prosesi ile dokuz farklı mordan kimyasalı ile deneyler gerçekleştirilmiştir. Boyama öncesi ve sonrasında boya çözeltilerinden alınan numunelerin transmitans spektrofotometrede absorbans ölçümleri yapılmıştır. Son-mordanlama ile elde edilen nylon kumaşlar ve mordansız boyama yapılan nylon kumaşların renk ölçümleri reflektans spektrofotometre ile gerçekleştirilmiştir. Elde edilen sonuçlar mordan varlığında nylon liflerinin direkt boyar maddelerle renklendirme özelliklerinin geliştiğini göstermiştir.

Anahtar Kelimeler: Nylon, Direkt Boya, Mordan

ABSTRACT

Nylon fibers are the first synthetic fibers to be produced in industrial scale and they are one of the most consumed synthetic fibers due to their appearance and durability properties. There is no need for mordanting to apply direct dyestuffs to dye natural and regenerated cellulosic fibers.

The reason why mordanting is not necessary is that these dyestuffs have high substantivity towards cellulosic fibers. For this reason, this group is also called substantive dyes. Mordants are used mainly in the application of natural dyes to hold and retain the dye molecules in the fiber. In this paper, nylon fabrics were dyed with direct dyes in the presence of chemical mordants to obtain better exhaustion and coloration properties. Dyeing experiments were performed with direct dyes of four different colors. Post-mordanting dyeing method was applied in the presence of nine different mordants. Light absorbance measurements were conducted on dyeing liquors prior and after dyeing by a transmittance spectrophotometer. Color measurements were conducted with a reflectance spectrophotometer on samples dyed with and without mordants. The results revealed that mordant usage improved the coloration properties of direct dyes on nylon fabrics.

Keywords: Nylon, Direct Dye, Mordant

GİRİŞ

İnsan nüfusunun çoğalması ve teknolojinin gelişmesiyle süregelen refah seviyesinin artması, insanların tüketim alışkanlıklarının değişmesine, daha fazla üretip bunun yanı sıra daha da çok tüketmesine neden olmuştur.

Artan tüketim davranışları, insanların temel ihtiyaçlarının başında olan giyinme ihtiyacına ve dolayısıyla tekstil sektörüne de yansımıştır. Tekstil sektörü günümüzde tarımdan sonra en çok su tüketen ve bununla beraber petrol sanayisinden sonra da doğayı en çok kirleten sektördür.

Tekstil sektöründe özellikle terbiye işlemlerinde (haşıl sökme, ağartma, merserizasyon, boyama ve baskı) çok yüksek miktarla kimyasal ve su tüketilmektedir. Bu kullanılan çeşitli kimyasallar ile doğal ve sentetik tekstil materyallerinin renklendirilmesinde kullanılabilmektedir.

İlk üretilen sentetik tekstil lifi poliamid lifidir. Tekstilde çok farklı alanlarda kullanılan çeşitli poliamid lifleri mevcuttur. Aralarından en çok kullanılan poliamid çeşitleri ise nylon 6 ve nylon 6,6'dır. Nylon, poliamid liflerinin ticari adı olarak kullanılmaktadır.

Nylon liflerinin keşfedilmesiyle beraber bu lifin kimyasal ve fiziksel özellikleri incelenmiş ve bu liflerin renklendirilmesi ilgili pek çok çalışma yapılmıştır. Bu çalışmalar yeni sentetik liflerin keşfine yol açmış ve bu keşifler de renklendirme ve boyama alanındaki çalışmaların hızını arttırmıştır.

Nylon liflerinin yapısı uzun, hetero zincirli sentetik polimerlerden oluşmuş ve moleküllerin neredeyse tamamı lif eksenin doğrultusunda oryante olmuşlardır. Boyama işlemi ise camlaşma geçiş sıcaklığı ve erime sıcaklığı ile kıyaslandığı zaman, kaynama sıcaklığında ancak yapılabilmektedir.

Direkt boyalar 20.yüzyılın başlangıcında endüstriyel üretime geçmiş anyonik karakterli boyalardır. Bu boyalar sulu boyama banyoları içinden selülozik liflere çok yüksek affiniteye sahiptir. Boyama uygulamaları tuz ve sıcaklık kontrolü ile kaynama sıcaklıklarında gerçekleştirilir. Direkt boyaların olumsuz yönü lifler içinde kuvvetli boya-lif bağları oluşturamamalarıdır. Bunun sonucunda direkt boyalı selülozik mamullerin özellikle kullanımları sırasında yıkama haslıkları düşük olmaktadır. Bu olumsuzluğu ortadan kaldırmak için direkt boya uygulamaları sonrasında sentetik fiksasyon maddeleri uygulanmakta fakat bu uygulama da rengin bir miktar değişmesine ve ışık haslıklarının düşmesine neden olmaktadır.

Nylon kumaşlar makro moleküler yapılarında içerdikleri amino ve karboksilik asit grupları nedeniyle asidik boyama şartları altında öncelikle asit ve metal-kompleks boyalar ile boyanırlar. Anyonik karakterli olan bu boyalar nylon liflerinde asidik pH şartları altında iyonik bağlar oluşturarak lif bağlanırlar. Fakat uygulanan asit ve metal-kompleks boyalar moleküler yapılarına bağlı olarak düşük yıkama haslıklarına neden olabilirler. Bu durum için nylon liflerinde boyama

ardından sintan terimi ile verilen sentetik fiksatörler kullanılarak yıkama haslıkları yükseltilmeye çalışılır.

Direkt boyalar anyonik boyalar olduklarından ve nylon lifleri de asidik şartlar altında anyonik boyalar ile boyanabildiklerinden, nylon kumaşlarda direkt boya uygulamaları mümkündür. Fakat elde edilen boyamaların yaş haslıkları düşük kaldığı için nylon boyamada direkt boyalar tercih edilmemekte ve kullanılmamaktadır.

Metalik mordan tuzları insanlık tarihi boyunca öncelikle doğal kaynaklardan elde edilen boyaların, pamuk ve yün gibi doğal liflere uygulamasında kullanılmıştır. Doğal boya molekülleri lif içinde mordandan gelen atomlar/gruplar ile kompleksleşerek, lif içinde suda çözünmez şekilde ve daha kuvvetli bağlarla kalıtlar. Bir başka ifade ile, mordan tuzları boyar madde parçacıklarının lif içinde boyutlarını büyüterek bunların life daha fazla bağlarla tutunmasını sağlarlar. Bu şekilde boyar maddenin haslığını arttırmış olup yıkama şartlarında liften ayrılmasını zorlaştırırlar.

Günümüzde direkt boyar maddeler ile nylon liflerinin boyanması ile ilgili yaygın veya yapılmış herhangi bir çalışma bulunmamaktadır. Bunun en önemli sebebi nylon kumaşlarının boyanmasında asit ve metal-kompleks boyar maddeler dışında diğer anyonik boyar maddelerin yıkama haslıkları açısından alternatif oluşturamamalarıdır. Nylon kumaşların direkt boyalar ile boyanmasında mordan tuzlarının boyandığı ile ilgili bir çalışmaya daha önce rastlanılmamıştır. Çalışmanın yenilikçi yönü, nylon kumaşların boyanmasında hem direkt boyaların hem de mordan kullanımının bir arada olmasının yanı sıra boyama çözeltisinde mordan kimyasalları ve boyar madde dışında başka hiçbir kimyasalın katılmamasıdır. Seçilen çeşitli mordan tuzları ile nylon kumaşa direkt boyaların affinitesinin arttırarak boyamanın düzgünlüğünün arttırılması hedeflenmiştir. Boyama sonucunda mordan kimyasalları varlığında life bağlanan boyar madde miktarı artmış olup daha verimli boyamalar elde edilmiştir. Atık sudaki kirlilik yükünün azaltılması yanında, asit ve metal-kompleks boyar maddelere göre daha uygun fiyata satılan direkt boyaların ticari olarak daha fazla kullanımı ve boyama verimliliklerin arttırılması sağlanabilir.

Boyanan her nylon kumaş numunesinin reflektans ölçümünün yapılması için spektrofotometre kullanılmıştır. Uygulanan mordanlama yönetimi, kullanılan renk, yıkama haslığı sonrası, ekstraksiyon sonrası ve ışık haslığı sonrası olmak üzere her işlemin ardından spektrofotometre ile reflektans ölçümü yapılmış ve bu ölçümler sonucu renkler arasındaki farklar incelenmiştir.

Yapılan boyamanın ardından tüm kumaş numuneleri boya sökümü (ekstraksiyon) yapılarak lif üzerinde kuvvetli bağlar ile tutunamamış boyar maddelerin kumaştan ayrılması incelenmiştir.

MATERYAL ve YÖNTEM

Materyal

Yapılan deneysel çalışmada, dört farklı renkte direkt boya (siyah, mavi, kırmızı ve sarı) ve dokuz metalik mordan kimyasalı varlığında nylon kumaş numuneleri boyanmıştır. Boyama sırasında boyama çözeltilerinden numune alınarak ve boyama sonrası kumaşlarda ekstraksiyon deneyleri yapılarak transmitans ölçümleri alınmış ve boya çekimi, boya fiksasyonu ve boyama verimi hesaplamaları yapılmıştır. Boyanmış kumaşları reflektans ölçümleri ile sonuçlar değerlendirilmiştir. Boyanmış kumaşların yıkama haslığı testleri sonrasında boyamanın başarısı araştırılmıştır.

Çalışmada %100 nylon 6,6 kumaş kullanılmıştır. Çözgü ipliği olarak 310/140 numara (denye/filament sayısı) nylon 6,6 kullanılmıştır. Atkı ipliği olarak 150/72 numara (denye/filament sayısı) nylon 6,6 kullanılmıştır. Kumaş gramajı 65 g/m^2'dir.

Boyamalar Dyestar Infrared numune boyama makinesinde yapılmıştır. Boyama sonrası kumaşların CIELAB renk koordinatları (L*, a*, b*, C* ve h°) ve renk kuvvetleri (K/S) Konica

Minolta CM-3600A masaüstü reflektans spektrofotometrede ve boyama çözeltisi absorbans değerleri Shimadzu UV-1280 transmitans spektrofotometresinde ölçülmüştür.

Bu çalışmada mordan olarak Potasyum Aluminyum Sülfat (Alum), Demir (II) Sülfat, Tannik Asit, Kalsiyum Karbonat, Magnezyum Sülfat, Bakır Sülfat, Gallik Asit, Çinko Sülfat ve Askorbik Asit laboratuvar saflığında kullanılmıştır.

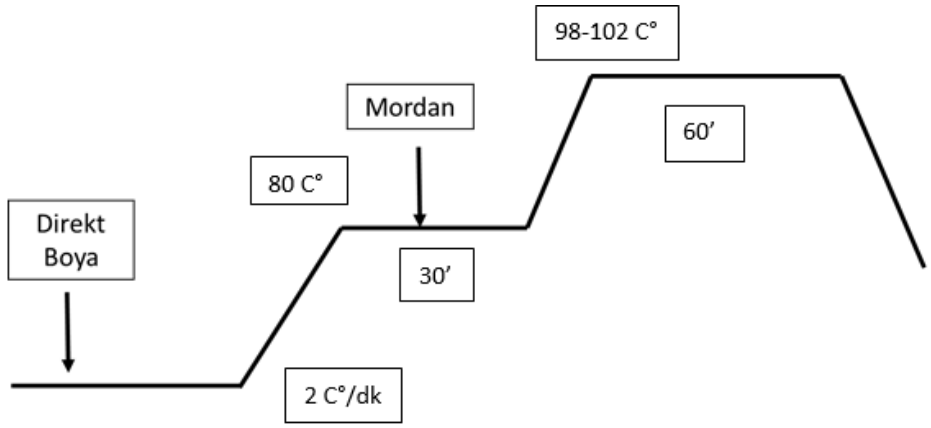
Yöntem

Boyama çalışmaları %1 direkt boya konsantrasyonunda gerçekleştirilmiştir. Boyama çözeltisi pH 5 seçilmiş ve pH ayarı için arıtılmış yumuşak su kullanılmıştır. Boyamalar 1:20 banyo oranında yapılmış, maksimum boyama sıcaklığı olarak 102C° ve boyama süresi 60 dakika olarak seçilmiştir. Mordan miktarı %0.1 olarak düşük bir konsantrasyonda uygulanmıştır.

Mordan uygulaması olarak son mordanlama yöntemi kullanılmıştır.

Nylon kumaş numunelerinin direkt boyalar ile mordan kimyasalları varlığında boyanmasında Şekil 1'de verilen son-mordanlama prosesi kullanılmıştır.

Ekstraksiyon için %20'lik piridin çözeltisi hazırlanmış ve 1 gram boyanmış kumaş numunesi, kaynar piridin çözeltisi içinde muamele edilerek, lif yüzeylerinden direkt boyalar sökülmüştür. Piridin ekstraksiyonunun ardından çözeltinin transmitans ölçümleri yapılmıştır.



Şekil 1. Son Mordanlama Prosesi

Renk ölçüm sonucu ve değerlendirmesi Kubelka-Munk denklemine göre renk derinliği (Renk Kuvveti) olarak verilmiştir. Buna göre: $K/S = (1-R)^2 / 2 \cdot R$ burada;

K : Yüzeyin ışığı absorblama katsayısı

S : Yüzeyin ışığı saçma katsayısı

R : λ Dalga boyundaki kesir reflentans

Elde edilen çözelti absorbansı ve renk kuvveti değerleri kullanılarak yapılan boyamanın başarısı değerlendirilmiştir.

Yüzde çekim (Yüzde boyar madde çekimi);

$$\%E = ({}^{A_0 - A_1}/_{A_0}) \times 100$$

Burada A_0: Boyama başlangıcı çözeltisinin absorbans değeri (λ dalga boyunda)

A_1: Boyama sonunda boyama bitiş çözeltisinin absorbans değeri (λ dalga boyunda)

Yüzde Fiksasyon (Yüzde boyar madde fiksasyonu) ;

$$\%F = (({}^{K}/_{S})_2 / {}^{(K}/_{S})_1) \times 100$$

Burada $(K/S)_1$: Ekstraksiyon öncesi kumaşın K/S değeri (λ dalga boyunda)

$(K/S)_2$: Ekstraksiyon sonrası kumaşın K/S değeri (λ dalga boyunda)

Yüzde Fiksasyon (Boyar madde fiksasyonu) Verimi;

$$\%T = \frac{\%E \times \%F}{100}$$

ARAŞTIRMA ve BULGULAR

Nylon kumaşların direkt boyalar ile boyanmasında, dört farklı renkte, son mordanlama prosesi ile dokuz farklı mordan ile; boyama sonrası ($[K/S]_1$), ekstraksiyon sonrası ($[K/S]_2$), % boya çekimi (%E), % boya fiksasyonu (%F) ve % fiksasyon verimi (%T) sonuçları Tablo1-4'te sunulmuştur. CIELAB renk uzayındaki ren koordinat değeri de verilmiştir.

Elde edilen sonuçlar incelendiğinde, metalik mordanlar varlığında yapılan boyamaların, mordansız boyamalardan daha iyi renk kuvveti ve renk koordinat sonuçları verdiği görülmüştür. Mordan kimyasalları varlığında daha yüksek boya çekimi ve fiksasyonu değerleri elde edilmiş ve bunun sonucunda da daha iyi boyama verimi gerçekleşmiştir.

Yapılan boyamalarda kullanılan direkt boyanın renk nüansına ve dolayısıyla da moleküler yapısına bağlı olarak bazı mordan kimyasalları ve bazı renkler uyum göstermiş, bazılarında ise beklenen renklendirme uyumu elde edilememiştir.

Tablo 1. %1 Siyah Direkt Boyar Madde ile Son Mordanlama

PROSES TİPİ	RENK	MORDAN TİPİ	K/S2	K/S1	%E	%F	%T
STANDART	SİYAH	KÖR BOYAMA	6,49	8,44	41,21	76,90	31,69
SON MORDANLAMA BOYAMA ÖNCESİ		ALUM ($KAl(SO_4)_2 \cdot 12H_2O$)	10,70	10,98	54,46	90,31	19,11
		ÇİNKO SÜLFAT ($ZnSO_4$)	11,61	12,07	64,02	92,04	44,46
		KALSİYUM KARBONAT ($CaCO_3$)	9,48	10,74	68,40	95,60	65,76
		GALLİK ASİT (C7H6O5)	9,48	10,74	31,22	81,01	21,80
		DEMİR II SÜLFAT (FeSO4)	10,20	11,12	59,66	81,81	25,90
		MAGNEZYUM SÜLFAT ($MgSO_4$)	9,25	10,79	66,85	83,68	59,50
		TANNİK ASİT (C76H52O46)	8,82	9,85	35,68	84,61	25,54
		ASKORBİK ASİT (C6H8O6)	9,69	11,82	44,81	77,03	32,49
		BAKIR SÜLFAT (CuSO4)	8,42	10,22	88,89	82,08	55,73
PROSES TİPİ	RENK	MORDAN TİPİ	L*	a*	b*	C*	h
SON MORDANLAMA YIKAMA HASLIĞI SONRASI	SİYAH	KÖR BOYAMA	29,41	1,07	-4,95	5,06	282,2
		ALUM ($KAl(SO_4)_2 \cdot 12H_2O$)	25,1	1,52	-4,13	4,40	290,27
		ÇİNKO SÜLFAT ($ZnSO_4$)	23,97	1,62	-3,99	4,31	292,19
		KALSİYUM KARBONAT ($CaCO_3$)	25,51	1,30	-4,27	4,47	287,00
		GALLİK ASİT (C7H6O5)	25,34	1,61	-3,64	3,98	293,96
		DEMİR II SÜLFAT (FeSO4)	24,88	1,71	-3,41	3,81	296,64
		MAGNEZYUM SÜLFAT ($MgSO_4$)	25,54	1,35	-4,32	4,53	287,40
		TANNİK ASİT (C76H52O46)	26,61	0,55	-4,50	4,53	277,02
		ASKORBİK ASİT (C6H8O6)	24,10	1,80	-3,79	4,20	295,37
		BAKIR SÜLFAT (CuSO4)	26,33	2,54	-4,38	5,07	300,08
PROSES TİPİ	RENK	MORDAN TİPİ	L*	a*	b*	C*	h
SON MORDANLAMA EKSTRAKSİYON SONRASI	SİYAH	KÖR BOYAMA	29,41	1,07	-4,95	5,06	282,2
		ALUM ($KAl(SO_4)_2 \cdot 12H_2O$)	25,59	0,83	-4,69	4,76	280,05
		ÇİNKO SÜLFAT ($ZnSO_4$)	24,75	0,81	-4,84	4,91	279,51
		KALSİYUM KARBONAT ($CaCO_3$)	27,24	0,50	-5,20	5,23	275,59
		GALLİK ASİT (C7H6O5)	27,08	0,51	-4,37	4,40	276,69
		DEMİR II SÜLFAT (FeSO4)	26,07	0,78	-3,83	3,91	281,51
		MAGNEZYUM SÜLFAT ($MgSO_4$)	27,55	0,51	-5,10	5,13	275,73
		TANNİK ASİT (C76H52O46)	28,14	0,00	-4,74	4,74	269,94
		ASKORBİK ASİT (C6H8O6)	26,87	0,64	-5,06	5,10	277,21
		BAKIR SÜLFAT (CuSO4)	29,49	3,47	-7,21	8,01	295,73

Tablo 2. %1 Mavi Direkt Boyar Madde ile Son Mordanlama

PROSES TİPİ	RENK	MORDAN TİPİ	K/S2	K/S1	%E	%F	%T
STANDART	MAVİ	KÖR BOYAMA	1,82	2,72	3,89	66,91	2,60
SON MORDANLAMA		ALUM ($KAl(SO_4)_2 \cdot 12H_2O$)	3,92	5,56	80,70	70,50	56,89
		ÇİNKO SÜLFAT ($ZnSO_4$)	6,76	11,64	86,61	58,08	50,30
		KALSİYUM KARBONAT ($CaCO_3$)	1,83	2,9	12,45	63,10	7,86
		GALLİK ASİT (C7H6O5)	9,16	15,73	93,42	58,23	54,40
		DEMİR II SÜLFAT (FeSO4)	9,76	17,22	84,68	56,68	48,00
		MAGNEZYUM SÜLFAT ($MgSO_4$)	2,41	3,67	23,71	65,67	15,57
		TANNİK ASİT (C76H52O46)	1,15	2,58	5,63	44,57	2,51
		ASKORBİK ASİT (C6H8O6)	4,47	12,31	99,55	36,31	36,15
		BAKIR SÜLFAT (CuSO4)	10,01	15,2	98,54	65,86	64,90
PROSES TİPİ	RENK	MORDAN TİPİ	L*	a*	b*	C*	h
STANDART	MAVİ	KÖR BOYAMA	53,44	-3,44	-23,37	26,63	261,62
SON MORDANLAMA YIKAMA HASLIĞI SONRASI		ALUM ($KAl(SO_4)_2 \cdot 12H_2O$)	40,34	3,73	-19,64	19,99	280,77
		ÇİNKO SÜLFAT ($ZnSO_4$)	31,35	2,34	-24,57	24,68	275,46
		KALSİYUM KARBONAT ($CaCO_3$)	51,76	-2,98	-24,34	24,52	263,00
		GALLİK ASİT (C7H6O5)	26,66	2,50	-23,93	24,07	275,97
		DEMİR II SÜLFAT (FeSO4)	25,20	2,63	-21,46	21,62	277,00
		MAGNEZYUM SÜLFAT ($MgSO_4$)	50,18	-2,26	-25,16	25,26	264,86
		TANNİK ASİT (C76H52O46)	53,54	-4,78	-17,91	18,54	255,03
		ASKORBİK ASİT (C6H8O6)	26,29	5,62	-14,98	16,00	290,55
		BAKIR SÜLFAT (CuSO4)	26,52	2,33	-22,17	22,84	275,86
PROSES TİPİ	RENK	MORDAN TİPİ	L*	a*	b*	C*	h
STANDART	MAVİ	KÖR BOYAMA	57,16	-4,90	-18,41	19,05	255,07
SON MORDANLAMA EKSTRAKSİYON SONRASI		ALUM ($KAl(SO_4)_2 \cdot 12H_2O$)	44,32	-1,90	-18,21	18,31	264,02
		ÇİNKO SÜLFAT ($ZnSO_4$)	38,84	-2,46	-23,72	23,85	264,06
		KALSİYUM KARBONAT ($CaCO_3$)	56,95	-4,75	-18,34	18,95	255,46
		GALLİK ASİT (C7H6O5)	35,83	-2,88	-25,55	25,71	263,54
		DEMİR II SÜLFAT (FeSO4)	32,08	-3,97	-15,67	16,17	255,76
		MAGNEZYUM SÜLFAT ($MgSO_4$)	53,41	-4,57	-20,53	21,03	257,44
		TANNİK ASİT (C76H52O46)	60,92	-5,45	-6,43	8,43	229,69
		ASKORBİK ASİT (C6H8O6)	42,01	-2,22	-16,47	16,62	262,32
		BAKIR SÜLFAT (CuSO4)	33,22	-1,58	-23,12	23,18	266,08

Tablo 3. %1 Kırmızı Direkt Boyar Madde ile Son Mordanlama

PROSES TİPİ	RENK	MORDAN TİPİ	K/S2	K/S1	%E	%F	%T
STANDART	KIRMIZI	KÖR BOYAMA	9,68	12,58	60,18	76,95	46,31
SON MORDANLAMA		ALUM ($KAl(SO_4)_2 \cdot 12H_2O$)	11,9	17,75	86,40	67,04	57,92
		ÇİNKO SÜLFAT ($ZnSO_4$)	11,42	16,48	90,11	69,30	62,44
		KALSİYUM KARBONAT ($CaCO_3$)	12,26	13,73	80,78	89,29	72,13
		GALLİK ASİT (C7H6O5)	13,46	18,06	98,06	74,53	73,08
		DEMİR II SÜLFAT (FeSO4)	9,88	17,67	67,01	55,91	37,46
		MAGNEZYUM SÜLFAT ($MgSO_4$)	13,08	16,19	87,76	80,79	70,90
		TANNİK ASİT (C76H52O46)	13,48	14,21	74,92	99,87	77,43
		ASKORBİK ASİT (C6H8O6)	14,49	17,54	95,41	82,61	78,82
		BAKIR SÜLFAT (CuSO4)	8,59	12,32	89,97	69,72	62,72
PROSES TİPİ	RENK	MORDAN TİPİ	L*	a*	b*	C*	h
STANDART	KIRMIZI	KÖR BOYAMA	53,74	51,32	39,27	64,62	37,42
SON MORDANLAMA YIKAMA HASLIĞI SONRASI		ALUM ($KAl(SO_4)_2 \cdot 12H_2O$)	48,53	53,33	40,03	66,69	36,89
		ÇİNKO SÜLFAT ($ZnSO_4$)	48,31	53,50	39,99	66,80	36,77
		KALSİYUM KARBONAT ($CaCO_3$)	50,00	53,82	39,91	67,01	36,55
		GALLİK ASİT (C7H6O5)	46,70	52,52	39,20	65,54	36,73
		DEMİR II SÜLFAT (FeSO4)	47,82	53,69	40,52	67,27	37,04
		MAGNEZYUM SÜLFAT ($MgSO_4$)	50,15	54,85	41,03	68,50	36,79
		TANNİK ASİT (C76H52O46)	49,06	52,69	37,55	64,70	35,47
		ASKORBİK ASİT (C6H8O6)	48,14	54,77	40,95	68,39	36,78
		BAKIR SÜLFAT (CuSO4)	49,70	44,28	34,54	56,16	37,96
PROSES TİPİ	RENK	MORDAN TİPİ	L*	a*	b*	C*	h
STANDART	KIRMIZI	KÖR BOYAMA	50,6	43,25	29,01	52,09	33,85
SON MORDANLAMA EKSTRAKSİYON SONRASI		ALUM ($KAl(SO_4)_2 \cdot 12H_2O$)	47,46	45,76	28,87	54,11	32,24
		ÇİNKO SÜLFAT ($ZnSO_4$)	47,08	44,59	28,19	52,75	32,29
		KALSİYUM KARBONAT ($CaCO_3$)	44,23	41,84	25,91	49,22	31,77
		GALLİK ASİT (C7H6O5)	43,10	43,84	24,46	50,20	29,15
		DEMİR II SÜLFAT (FeSO4)	45,89	38,55	22,88	44,83	30,69
		MAGNEZYUM SÜLFAT ($MgSO_4$)	45,65	45,12	28,60	53,43	32,37
		TANNİK ASİT (C76H52O46)	49,89	53,62	38,25	65,86	35,50
		ASKORBİK ASİT (C6H8O6)	43,29	44,26	27,39	52,05	31,75
		BAKIR SÜLFAT (CuSO4)	48,81	36,48	24,77	44,10	34,17

Tablo 4. %1 Sarı Direkt Boyar Madde ile Son Mordanlama

PROSES TİPİ	RENK	MORDAN TYPE	K/S2	K/S1	%E	%F	%T
STANDART	SARI	KÖR BOYAMA	6,26	8,88	62,81	70,50	44,28
SON MORDANLAMA		ALUM ($KAl(SO_4)_2 \cdot 12H_2O$)	5,79	9,77	72,50	59,25	42,96
		ÇİNKO SÜLFAT ($ZnSO_4$)	6,35	11,12	87,12	57,10	49,75
		KALSİYUM KARBONAT ($CaCO_3$)	5,42	8,59	76,92	63,10	48,54
		GALLİK ASİT (C7H6O5)	6,3	10,88	75,74	57,90	43,85
		DEMİR II SÜLFAT (FeSO4)	7,67	11,57	15,04	66,29	9,97
		MAGNEZYUM SÜLFAT ($MgSO_4$)	5,17	10,12	78,10	51,09	39,90
		TANNİK ASİT (C76H52O46)	6,95	9,74	65,00	71,36	46,38
		ASKORBİK ASİT (C6H8O6)	7,21	11,37	84,67	63,41	53,69
		BAKIR SÜLFAT (CuSO4)	7,77	10,15	64,53	76,55	49,40
PROSES TİPİ	RENK	MORDANT TİPİ	L*	a*	b*	C*	h
STANDART	SARI	KÖR BOYAMA	74,79	16,16	75,81	77,52	77,96
SON MORDANLAMA YIKAMA HASLIĞI SONRASI		ALUM ($KAl(SO_4)_2 \cdot 12H_2O$)	72,48	16,74	76,39	78,20	77,63
		ÇİNKO SÜLFAT ($ZnSO_4$)	71,00	16,44	75,92	77,68	77,77
		KALSİYUM KARBONAT ($CaCO_3$)	72,49	15,59	74,71	76,32	78,21
		GALLİK ASİT (C7H6O5)	68,84	16,26	70,96	72,80	77,09
		DEMİR II SÜLFAT (FeSO4)	68,28	20,30	71,65	74,47	74,17
		MAGNEZYUM SÜLFAT ($MgSO_4$)	73,16	17,28	76,70	78,62	77,30
		TANNİK ASİT (C76H52O46)	72,24	18,28	76,70	78,85	76,59
		ASKORBİK ASİT (C6H8O6)	72,19	18,40	78,79	80,91	76,85
		BAKIR SÜLFAT (CuSO4)	65,44	24,92	67,19	71,66	69,64
PROSES TİPİ	RENK	MORDANT TİPİ	L*	a*	b*	C*	H
STANDART	SARI	KÖR BOYAMA	67,79	8,62	58,38	59,02	81,59
SON MORDANLAMA EKSTRAKSİYON SONRASI		ALUM ($KAl(SO_4)_2 \cdot 12H_2O$)	67,67	8,77	56,42	57,10	81,15
		ÇİNKO SÜLFAT ($ZnSO_4$)	67,22	8,68	57,51	58,17	81,40
		KALSİYUM KARBONAT ($CaCO_3$)	68,20	8,05	55,71	56,29	81,77
		GALLİK ASİT (C7H6O5)	66,07	9,13	55,72	56,46	80,68
		DEMİR II SÜLFAT (FeSO4)	62,00	16,15	54,12	56,48	73,38
		MAGNEZYUM SÜLFAT ($MgSO_4$)	67,44	8,60	53,52	54,20	80,86
		TANNİK ASİT (C76H52O46)	64,96	11,24	56,58	57,69	78,76
		ASKORBİK ASİT (C6H8O6)	62,87	15,47	54,47	54,47	56,63
		BAKIR SÜLFAT (CuSO4)	61,92	17,58	54,28	57,06	72,04

SONUÇLAR

4 farklı renkte, son mordanlama prosesi ve 9 farklı mordan kimyasalı ile hiçbir mordan kullanılmadan yapılan kör boyama sonuçlarının boyama öncesi renk kuvveti, boyama sonrası renk kuvveti, boyama % verim değeri, % fiksasyon değerleri incelendiği zaman, siyah renk ile

boyanan numunelerde zaman en yüksek fiksasyon oranı ve renk koyuluğu Çinko Sülfat mordanı ile sağlanmıştır (Tablo 1).
Mavi direkt boya ile yapılan çalışmada, 9 farklı mordan kimyasalı ile hiçbir mordan kullanılmadan yapılan kör boyama sonuçlarının boyama öncesi renk kuvveti, boyama sonrası renk kuvveti, boyama % verim değeri, % fiksasyon değerleri incelendiğinde, en başarılı boyamalar Gallik Asit, Bakır Sülfat, Çinko Sülfat ve Demir Sülfat ile elde edilmiştir. (Tablo 2).
Kırmızı direkt boya ile yapılan çalışmalarda ise 9 farklı mordan kimyasalı ile hiçbir mordan kullanılmadan yapılan kör boyama sonuçlarının boyama öncesi renk kuvveti, boyama sonrası renk kuvveti, boyama % verim değeri, % fiksasyon değerleri incelendiğinde en başarılı boyamalar Askorbik Asit, Tannik Asit ve Kalsiyum Karbonat mordanları ile elde edilmiştir. Özellikle Tannik Asit ile yapılan çalışmada sağlanan fiksasyon diğer tüm çalışmalara kıyasla çok yüksektir (Tablo 3.).
Sarı direkt boya ile yapılan çalışmalarda ise en başarılı boyamalar ve en yüksek fiksasyon sonuçları Bakır Sülfat ile elde edilmiştir. (Tablo 4.).
Dört farklı renkteki direkt boyaların nylon kumaşlarda 9 farklı mordan varlığında ve son mordanlama metoduna göre yapılan boyamalarında, kullanılan mordan kimyasalına bağlı olarak mordansız boyamadan daha koyu renkler ve daha yüksek fiksasyon değerleri elde edilmiştir. Bu sonuçlar ışığında; normal şartlarda nylon kumaşların boyanmasında direkt boyalar bir kullanım alanına sahip değil iken, bu boyaların farklı mordan kimyasalları varlığında nylon kumaşları boyayabilecekleri anlaşılmıştır. Öncelikle selülozik mamullerin boyanmasında kullanım alanı olan direkt boyalar daha ekonomik fiyatlara sahip olmalarından dolayı ve uygulanan boyama şartları altında hiçbir yardımcı kimyasala ihtiyaç duyulmadan nylon kumaşların boyanmasında kullanılabilir.
Nylon kumaşların direkt boyalar ile mordan kimyasalları varlığında başarı ile boyandıkları sonucuna ulaşılmıştır.

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NON-COVALENT BONDS IN 1,1- DICHLORODIAZADIENES BASED ON PARA NİTROBENZALDEHYDE

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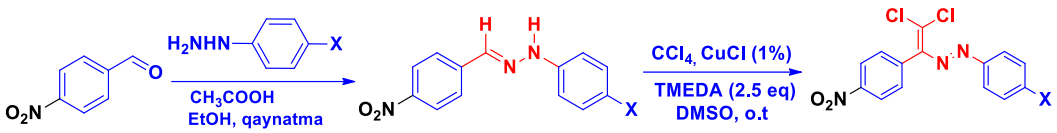
Abstract

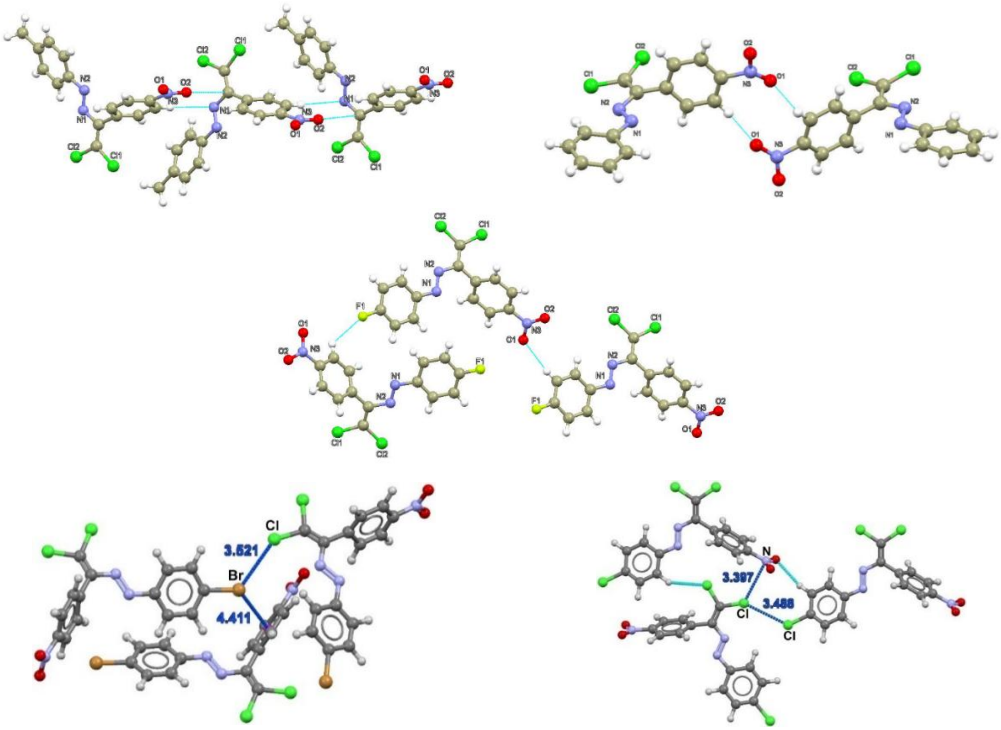
The useful properties and wide application of synthetic analogues of aromatic nitro compounds in industry, medicine, etc. fields make the chemistry of the mentioned compounds relevant in organic synthesis. The main reason for these syntheses is that various functionally substituted derivatives of aromatic nitro compounds have dyestuffs, explosives, high-energy compounds, antimicrobial and other properties. In this regard, the synthesis of 1,1-dichlorodiazadiene derivatives based on p-nitrobenzoaldehydes under the conditions of catalytic olefination reaction is a relevant issue. It should be especially noted that the participation of oxygen and nitrogen atoms in the formation of intramolecular, as well as intermolecular non-covalent interactions (pnicogen, chalcogen) based on the electroacceptor property of the nitro group in these

compounds by the X-ray Structural Analysis (X-ray) method should be studied. Taking all this into account, hydrazones of para-nitrobenzoyl aldehyde with the corresponding phenylhydrazines were obtained and the corresponding compounds were synthesized from their reaction with CCl4 under the same conditions.



Birləşmələrinin sintezi (X-H, CH_3 , OCH_3 , F, Cl, Br)

The structures of the obtained compounds were confirmed by NMR as well as by X-ray research method.



The intermolecular and intramolecular bonds of the compounds are given by broken lines. The effect of the nature of the halogen atoms in the p-position in the compounds on the crystal design has been determined. Thus, unlike chlorine and bromine, the effect of intermolecular non-covalent bonds in the presence of a fluorine atom has not been determined, which is due to the fact that the fluorine atom enters into such bonds very weakly.

Keywords: diclorodiazadiene, catalytic olefination reaction.

SYNTHESIS OF TEREPHTHALIC BIS-DIHALOGENDIAZABUTADIENES BASED ON CATALYTIC OLEFINATION REACTION CONDITIONS

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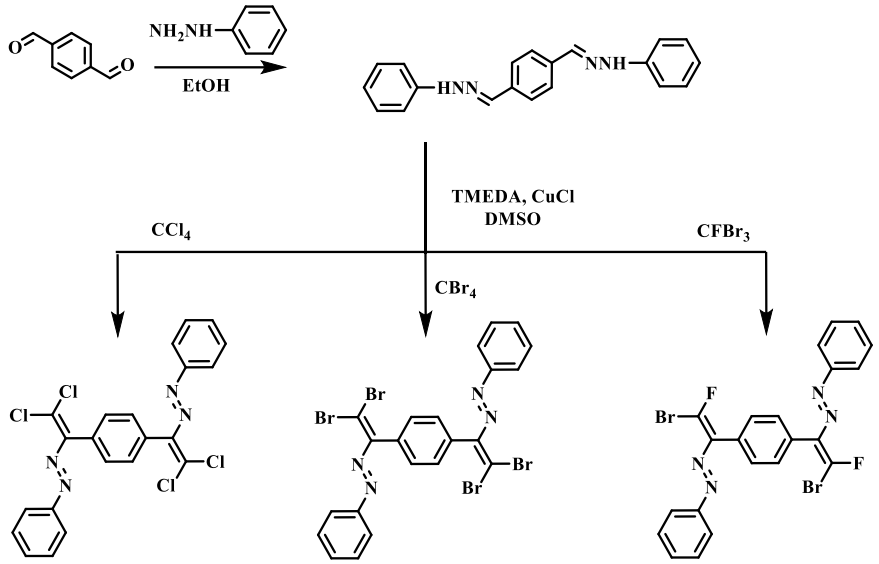
Abstract

During the catalytic olefination reaction, the nature and location of the functional groups in both the aldehyde and the phenylhydrazine fragment during the preparation of compounds with dichlorodiazabutadiene fragments from the corresponding phenylhydrazones of various derivatives of benzoyl aldehyde do not significantly affect the course of the reaction. This indicates that this reaction is a universal method. It should be noted that the synthesis of the corresponding reaction products in high yields was achieved even with bishydrazine. Based on the results obtained from the reactions of mono-carbonyl compounds studied so far, the goal was to conduct reactions with dicarbonyl compounds and these studies were carried out. First, the corresponding bis-phenylhydrazones (containing both electron-acceptor and electron-donor

groups) were synthesized to carry out these reactions on terephthalaldehyde.



Tereftal aldehidinin polihalogenmetanlarla reaksiyası

The structure of the synthesized compounds was studied by NMR method. Thus, a simple and effective method for the synthesis of bis-dichlorodiazabutadiene derivatives from bis-phenylhydrazones of terephthalaldehyde under catalytic olefination reaction conditions was developed.

Keywords: diclorodiazadiene, catalytic olefination reaction.

CHARACTERIZATION AND AUTHENTICATION OF DAIRY PRODUCTS USING FLUORESCENCE SPECTROSCOPY COUPLED WITH CHEMOMETRICS

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Abstract

Due to awareness in quality and authentication of food in this era, it becomes important to develop rapid and non destructive technologies. For this purpose, spectroscopic techniques have played a vital role. There are different spectroscopic techniques among which fluorescence spectroscopy is considered more accurate as it is 1000 times more sensitive than other approaches. The fluorescence spectroscopy gives the peaks at specific wavelength combinations for different flourophores like aromatic amino acids (Tryptophan, tyrosine and phenylalanine,) NADH, FAD, Vitamins (riboflavin, vitamin A, tocopherol and pyridoxine) which are present in various dairy products. The data generated from the fluorescence spectra can be subjected to different preprocessing operation like standard normal variate, multiple scatter correction and de-trending to remove any abnormality in the dataset. The preprocessed data can be analyzed by using various chemometrics tools like principle component analysis and partial least scare regression to characterize and authenticate the food products to eliminate the threat of fraudulent practices. The fluorescence spectroscopy along with chemometrics has proved itself not only for characterization of the process but also determine different quality aspects of raw, semi-finished and finished products. It has been successfully employed to characterize the different dairy products like raw milk, cheese, ice-cream, yogurt and detection of microbial load for the safety and authentication of these dairy based finished products. Therefore, it can be inferred from different applications that fluorescence spectroscopy along with chemometrics is an innovative tool for dairy product processing and authenticity.

PLANT WASTE MATERIALS FOR REMOVAL OF HEAVY METALS FROM WATER

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Abstract

The world's biggest problem is water pollution due to presence of various contaminates and heavy metal ions. The researcher's primary concern is to identify economical and environmentally friendly adsorbent for removal of these contaminates and heavy metal ions from water. Synthetic materials have been prepared and widely used for removal of heavy metals from water. These materials are required lot of chemical and they are expensive. They are also harmful for the environment. Thus, it is still challenging to find novel materials that are affordable, safe for the environment, and very effective for removal of heavy metal ions and other toxic materials. Natural or naturally modified materials have been actively applied as adsorbent to solve the problems. They are inexpensive, widely accessible, and environmental friendly. In this paper our aim is to explore the various plant waste materials applied for removal of heavy metals ions from water.

Keywords: Affordable materials, Heavy metal ions, Natural materials, Plant waste materials

CLIMATE CHANGE AND ITS EFFECTS ON HUMAN HEALTH

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Abstract

Climate change refers to long-term shifts in weather patterns caused by natural and human activities, primarily through the release of greenhouse gases. This phenomenon poses serious threats to ecosystems, economies, and human health globally. Iraq, particularly the city of Najaf, is severely affected by the rising temperatures, water scarcity, and unpredictable weather patterns linked to climate change. These environmental changes have significant consequences on human health, including heat-related illnesses, the spread of infectious diseases, food insecurity, and mental health challenges due to displacement and economic disruptions. The agricultural sector, which is critical to the region, faces declining productivity, exacerbating malnutrition and poverty. Immediate interventions and comprehensive strategies are required to mitigate the impacts of climate change, protect public health, and ensure sustainable living conditions for the population of Najaf and other vulnerable regions in Iraq.

Keywords: Climate change, Global warming, Health impacts, Water scarcity, Food insecurity, Infectious diseases, Heatwaves, Public health

Introduction

Climate change refers to long-term shifts in weather patterns in a particular region, including changes in temperature, precipitation, and wind conditions [1]. These changes can occur due to natural phenomena such as volcanic eruptions, or external factors like variations in solar radiation. However, human activities are now the most significant drivers of climate change [2]. This phenomenon poses one of the most serious threats to life on Earth, including human existence. Therefore, it is imperative for policymakers and stakeholders to develop and implement solutions to combat the effects of climate change and ensure the survival of life on Earth [3-6]. Essentially, climate change can be described as a shift in climatic conditions caused by human activities that release large amounts of greenhouse gases (GHGs) into the Earth's atmosphere. These emissions result from industrialization, urban growth, and the extensive use of environmentally harmful fossil fuels (oil, gas, coal) [7-10].

Causes of Climate Change

Climate change occurs primarily due to the accumulation of greenhouse gases in the Earth's atmosphere. These gases, although naturally present in the atmosphere, have dramatically increased due to human activities [11]. The primary greenhouse gases include:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Fluorinated gases (industrial gases)

While greenhouse gases naturally trap some of the sun's heat, maintaining Earth's average temperature at a level suitable for life, human activities, especially since the Industrial Revolution, have drastically increased their concentrations. As a result, the Earth's average temperature has risen, leading to global warming and altering weather patterns [12].

The Consequences of Global Warming

The effects of global warming are evident and concerning. The most prominent risks to the environment include:

1. Rising Temperatures: Increased global temperatures disrupt the climate system, leading to changes in rainfall patterns and their distribution. As temperatures rise, more water vapor accumulates in the atmosphere, which can either result in heavy rainfall in some areas or severe droughts in others. These shifts in precipitation patterns pose risks to water resources, agriculture, and ecosystems.

2. Melting Ice and Rising Sea Levels: Higher temperatures are causing glaciers and ice caps to melt, contributing to rising sea levels. It is estimated that if current climate change trends continue, sea levels could rise by approximately 88.9 cm by 2100, which would have devastating effects on low-lying coastal regions and islands.

3. More Extreme Weather Events: Climate change is increasing the frequency and severity of extreme weather events such as floods, droughts, and hurricanes. These events pose risks to human health, infrastructure, and the environment.

Impact of Climate Change on Human Health

Climate change has both direct and indirect impacts on human health. While some effects may be beneficial, the majority are negative. Here are some of the key impacts:

1. Direct Health Effects: Extreme weather events such as heatwaves, cold snaps, floods, and droughts have direct impacts on human health. Heatwaves, in particular, can lead to heat exhaustion, dehydration, and heatstroke, while cold snaps can increase the risk of hypothermia and respiratory diseases. Floods and droughts can cause injury, displacement, and even loss of life [13].

2. Health Effects from Ecosystem and Social Disruptions: Climate change disrupts ecosystems, increasing the spread of infectious diseases and altering food production. For example, rising temperatures can lead to the spread of diseases like malaria and dengue fever, as well as malnutrition due to reduced crop yields [14].

3. Mental Health and Social Well-being: Displacement due to extreme weather events, loss of livelihoods, and food insecurity contribute to increased mental health disorders such as anxiety, depression, and post-traumatic stress disorder (PTSD). Communities facing continuous environmental stressors may experience long-term disruption in social and economic activities [15].

Climate Change in Iraq: The Case of Najaf

Table 1 shows summarizing the key environmental and health-related impacts of climate change in Najaf, Iraq

Table 1 The key environmental and health-related impacts of climate change in Najaf

Category	Indicator	Current Status	Projected Status (2050)
Temperature	Average summer temperature	45°C	48°C–50°C
Water Scarcity	Availability of clean water (per capita)	1200 m^3/year	< 800 m^3/year
Agricultural Yield	Wheat and barley production	25% decline (2010–2020)	Further 40% decline expected
Health	Cases of heat-related illnesses	15,000 cases/year	Estimated 30,000 cases/year
Disease Incidence	Waterborne diseases (cholera, typhoid)	500 reported cases/year	1000+ cases/year expected
Sea Level Rise	Coastal area submerged (global impact)	NA	0.8–1 meter rise expected globally

Iraq is among the countries most vulnerable to the adverse effects of climate change, and Najaf, a city in central Iraq, is not immune to these challenges. The region experiences rising temperatures, water scarcity, and shifting weather patterns, all of which have profound implications for the health and well-being of its population [16].

1. Rising Temperatures and Heatwaves

Najaf has witnessed a significant rise in average temperatures over the past few decades. With temperatures often exceeding 50°C (122°F) during summer, prolonged heatwaves can lead to an increase in heat-related illnesses, particularly heatstroke and dehydration. Vulnerable groups, including the elderly, children, and individuals with pre-existing medical conditions, are particularly at risk [17].

Water Scarcity

Najaf, like many other regions in Iraq, faces a severe water crisis. As rainfall becomes more erratic and temperatures rise, water resources are being depleted. This scarcity of clean drinking water contributes to waterborne diseases such as cholera, typhoid, and diarrhea. The reduction in water supply also impacts agricultural production, leading to food insecurity and malnutrition.

Increased Spread of Infectious Diseases

The rise in temperatures and changes in precipitation patterns create favorable conditions for the proliferation of disease-carrying vectors such as mosquitoes. This can result in increased

incidences of diseases like malaria and leishmaniasis. Furthermore, higher temperatures and changing ecosystems can lead to the spread of harmful algal blooms in water sources, which can cause human poisoning and damage marine ecosystems [18].

Impact on Agriculture and Food Security

Agriculture in Najaf is a critical sector for the local economy, but it is heavily dependent on predictable weather patterns. Climate change has caused reduced crop yields due to irregular rainfall and extreme temperatures. With less food available and prices rising, malnutrition becomes a significant health issue, especially among vulnerable populations [19].

Social and Economic Consequences

The combined effects of climate change on health, water, and agriculture can exacerbate poverty, displacement, and conflict. The displacement of populations due to environmental degradation and lack of resources may further strain public health systems, increase unemployment, and disrupt economic activities [20, 21]. Figure 1 shows climate change impact on public health in Najaf, Iraq.

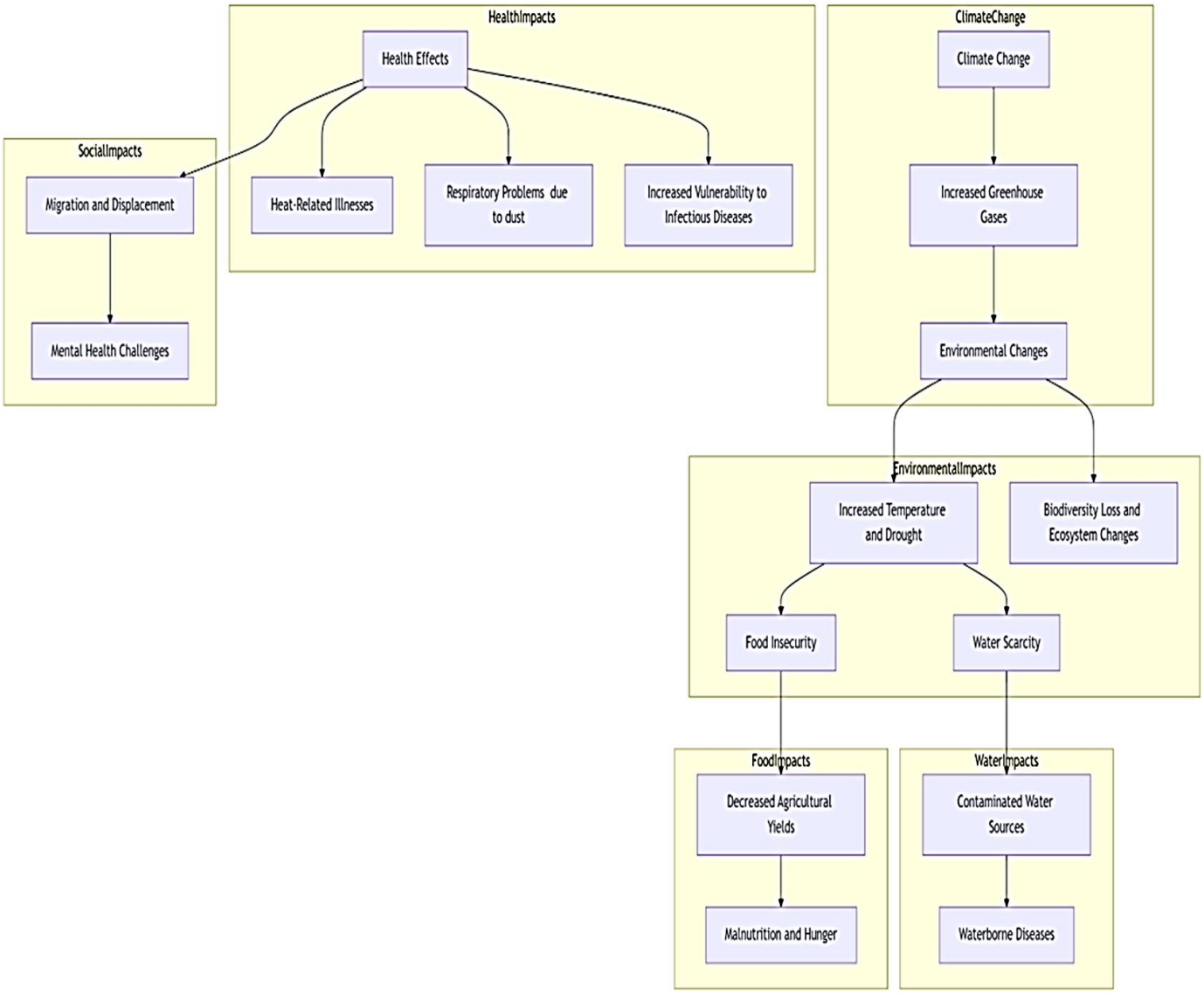

Figure 1 Climate Change Impact on Public Health in Najaf

Future Challenges and Recommendations

The long-term consequences of climate change in Najaf and Iraq as a whole are likely to worsen without immediate intervention. Some potential future challenges include:

1. Severe Water Shortages: It is expected that, within the next 50 years, the availability of drinking water could drop significantly, affecting between 5 and 8 billion people globally. Iraq, with its current water challenges, is particularly vulnerable.

2. Declining Agricultural Productivities soil fertility declines and desertification increases, crop yields are expected to decrease further, putting additional pressure on food security.

3. Increased Natural Disasters: Rising sea levels and more frequent extreme weather events could result in increased displacement, loss of life, and economic disruption.

Table 2 show the critical need for coordinated action to the health and environmental crises arising from climate change in Iraq

Table 2 Summary highlights the critical need for coordinated action to the health and environmental crises arising from climate change

Aspect	Details
Primary Issue	Climate change is causing severe environmental and health challenges in Iraq
Key Environmental Impacts	Rising temperatures, water scarcity, unpredictable weather patterns, and agricultural decline.
Health Impacts	- Heat-related illnesses, such as heatstroke and dehydration. - Increased spread of infectious diseases like malaria, cholera, and typhoid. - Food insecurity leading to malnutrition and related disorders. - Mental health challenges, including anxiety and PTSD, from displacement and economic stress.
Najaf as a Case Study	- Temperatures reaching over 50°C during summer. - Water availability expected to drop below 800 m^3 per capita by 2050. - Agricultural productivity in wheat and barley predicted to decline by an additional 40%. - Doubling of waterborne disease cases by 2050.
Broader Implications	Climate change exacerbates poverty, displacement, and social instability in Iraq.
Proposed Solutions	- Improve water management and agricultural practices. - Develop health infrastructure to combat climate-related diseases. - Implement policies to reduce greenhouse gas emissions and adapt to environmental changes. - Strengthen public awareness and preparedness for climate-related health risks.

Conclusions

The effects of climate change on human health in Najaf, Iraq, are both immediate and long-term. Rising temperatures, water shortages, and changing weather patterns present serious health risks, including heat-related illnesses, infectious diseases, and food insecurity. Addressing these challenges requires coordinated efforts at the local, national, and international levels to mitigate the impacts of climate change and safeguard public health. Strategies should focus on reducing greenhouse gas emissions, improving water management, and enhancing public health

infrastructure to ensure resilience against future environmental changes. By acknowledging the urgent need for action, Iraq, including Najaf, can work towards building a more sustainable and health-conscious future in the face of a changing climate.

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CALCULATING SOMBOR INDEX USING MATLAB

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Abstract

Topological indices are usually used to study the properties of molecular structures. The contribution of topological indices in the medical field is too generous, especially in the field of drug development. This helps to expedite the drug design and is used to study QSAR of pharmaceuticals to assess their molecular characteristics. The Sombor index is one of the topological indices introduced by Gutman in 2021. Calculation of the Sombor index by using a matrix method is presented in this paper. The algorithm for calculating the Sombor index is proposed in this paper, and we validated the same using the MATLAB program. The sample output for the Sombor index is also presented in this paper.

Keywords. Chemical graph, Topological index, Graph, Sombor index, MATLAB program.

IDENTIFICATION AND ANALYSIS OF PLANT GROWTH-PROMOTING RHIZOBACTERIA FROM SORGHUM PLANTS

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Plant development depends on soil, which offers necessary nutrients and a home for helpful bacteria. Its fertility is mostly determined by organic content. Despite the widespread use of chemical fertilizers, their overuse can result in soil degradation. In contrast, plant growth-promoting rhizobacteria (PGPR) offer a sustainable alternative by enhancing nutrient uptake in plants. For this study bacteria were isolated and evaluated for their PGPR traits from the rhizospheric soil of Sorghum bicolor. Various plant growth-promoting traits, including the solubilization of phosphorus (P), potassium (K), and zinc (Zn), ammonia excretion, IAA production, biosurfactant production, and siderophore production were analyzed. Out of 60 isolates, four were selected for further analysis. Germination tests were conducted for all four isolates using the CSV53F variety of sorghum, followed by pot experiments in both sterile and non-sterile soils. The impact of the isolates on the plant growth was evaluated after one month in both soil and plants. Various morphological, physiological, and biochemical parameters were measured, including stem diameter, leaf area, HCN content, and nutrient content (N, P, K, Zn, Fe, Mn). Of all the treatments, the one with a consortium of all four isolates recorded significantly highest Fe, Zn, N, and K concentrations 752 ppm, 82 ppm, 27,750 ppm, and 20,750 ppm respectively in the plant tissues grown in the sterile soil and P recorded 6000 ppm in the non-sterile soil. The consortium not only had the highest fresh and dry weights (4.8g and 1.75g, respectively) but also the largest stem diameter (4.27cm) and leaf area (87.4cm^2). This study concludes that the use of PGPR significantly enhances both the quality and quantity of forage sorghum, highlighting its potential as a sustainable agricultural practice.

THE USE OF BORON-CONTAINING COMPOUNDS IN DENTISTRY

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ABSTRACT

Introduction and Purpose: Compounds containing boron, used in many different areas, have started to be used in health and dentistry in recent years. However, there are few studies regarding the use of boron-containing compounds in dentistry. The objective of the present study was to draw attention to the contribution of the widespread use of boron-containing dental materials in different areas of dentistry to the country's economy.

Discussion and Conclusion: In the few studies conducted on this subject, it has been observed that the inclusion of boron in dental composite materials limits the progression of dental caries with its antibacterial effect in restorative dentistry. It has been reported that mouthwashes and gels containing boric acid have antimicrobial properties and prevent microorganisms from adhering to the surface and forming plaque, minimizing oxidative damage and reducing gingival bleeding. Due to the positive properties of boric acid and its compatibility with bone tissue, it is effective in reducing periodontal inflammation and treating periodontal disease Incorporating boron nitride nanotubes into adhesive resin materials improved the physical-chemical properties and increased mineral deposition on its surface, allowing improved properties of the resin-dentin interface. In a study evaluating the healing of bone tissue around boron nitride-coated titanium implants, no inflammatory reaction developed around an implant, and it was stated that it could be used as an implant coating material due to its physical properties and beneficial effects on bone formation and composition. The mechanical and biological properties of prosthetic dental materials are also increased by adding boron compounds. Further studies are required to develop and use biocompatible boron-containing materials in different application areas of dentistry.

Key Words: Biocompatibility, boron compounds, dentistry, oral health

INTRODUCTION

Dental materials mixed with nanoparticles of different sizes and concentrations, such as silica and titanium dioxide, have been reported to enhance mechanical or physical properties. Metal and other nanoparticles combined with polymers or surface coatings have exhibited potential antibacterial activity. Also, silver, copper, gold, titanium, zinc and boron have also gained particular attention as antimicrobial agents (Besinis et al.,2014; Adams, Lyon&Alvarez, 2006).

Boron is an element that is located in the first row of Group 3A in the periodic table, shown with the symbol "B", with an atomic number of 5, an atomic weight of 10.81, a density of 2.84 g/cm^3, a melting point of 2200 °C and a boiling point of 2250 °C (Kuru &Yarat, 2017). It is a black mineral with semiconductor properties between metal and nonmetal. Boron is not found in elemental form in nature, it is exists as compounds and has the most reserves in our country (Yakıncı& Kök,2016).

Boron compounds are used in glass, ceramics, cleaning, whitening, cosmetics, metallurgy, nuclear, computer, aircraft, energy, agricultural, and health industries. It enters the body through nutrients and drinking water. Recent studies have focused on the biological importance of boron and its positive effects on human health and have emphasized the importance of its role in mineral and hormone metabolisms, bone development, antioxidant immune system, wound healing, energy metabolism, and immune system (Aral et al., 2020; Hakki et al., 2015; Kuru &Yarat, 2017).

Boron compounds have also begun to be used in health and dentistry in recent years due to their durability, insulation, lightness, low price, resistance to tension, increased resistance to chemical effects, and antibacterial properties. There are some reported studies in the literature examining the effects of boron compounds on biomaterials such as polymers, glasses, ceramics and titanium dental implants in the field of dentistry (Alqahtani, 2020; Bohns et al., 2019; Degrazia et al., 2018; Hakki et al., 2015; Ozdemir et .al,2021; Özmeriç et al., 2022). It has been also found that boron compounds exhibit remarkable antimicrobial properties against a wide variety of bacteria, yeasts and fungi (Demirci et al., 2015; Kıvanç et al., 2018).

However; since the studies conducted are few, the possible positive effects of boron compounds in dental materials have not been proven.

The purpose of this study is to draw attention to the contribution of the production, development and widespread use of new boron-containing materials, which have high reserves in Turkey, in different areas of dentistry to the national economy.

DISCUSSION

Although many boron minerals (colemanite, ulexite, tincal) are enriched and used directly as intermediates, commercial borates, which have a widespread use, are produced by chemical production technologies (Eti Maden, 2024).

90% of raw boron products (especially colemanite and tincal) are used in the production of refined boron products such as boric acid, borax decahydrate and pentahydrate. Colemanite crystals are first broken with a hammer to reduce the size. Then, they are ground into agate. Finally, all ground colemanite crystal samples are sieved dry and the desired size fraction is obtained (Güyagüler, 2001). Another of the most commonly used methods is the grinding process in a high-energy ball mill (Alizadeh et al., 2015). In this type of mill, the material is subjected to a solid-state reaction process, which is a repetitive deformation-fracture-cold welding mechanism (Canakci et al., 2014).

Hexagonal boron nitride nanotubes (BNNTs) nanoparticles are two-dimensional nanostructures with outstanding physicochemical and biomedical properties, including excellent biocompatibility, antioxidant activity, and low toxicity (Kaplan et al, 2024). Therefore, in the past years, BNNTs have been added to some materials in dentistry and improvements in the chemical and mechanical properties of the materials have been observed (Degrazia et al. 2018; Bohns et al. 2019; Kıvanç et al., 2018; Kaptan et al, 2024).

Degrazia et al. (2018) incorporated boron nitride nanotubes (BNNT) as filler agents up to 0.1% by weight into methacrylate-based dental adhesive for mechanical reinforcement. They reported that the addition of BNNTs increased the chemical and mechanical properties of the material (degree of polymerization, maximum polymerization rate, contact angle, and micro tensile bond strength), and increased mineral accumulation on the surface allowed the resin-dentin interface bond to increase without cytotoxicity (Degrazia et al. 2018; Bohns et al. 2019).

It has been stated that the addition of boron nitride nanotubes increases the long-term stability of dentin without reducing the vitality of fibroblast cell growth, therefore, the use of BNNTs as a

filler material can reduce the failure rate of existing dentin adhesives. Excess adhesive material after bonding can be easily cleaned from the surface thanks to its water-repellent property (Degrazia et al. 2018; Bohns et al. 2019; Kıvanç et al., 2018).

It has been observed that the inclusion of boron compound in dental composite materials limits the progression of dental caries with its antibacterial effect in restorative dentistry. In studies on the development of dental composites containing boron due to its antibacterial properties, it has been reported that composite materials containing 1%, 5% and 10% sodium pentaborate pentahydrate have an antibacterial effect on S. mutans and have the potential to prevent secondary caries (Demirci et al, 2015).

It has been reported that mouthwashes and gels containing boric acid have antimicrobial properties and prevent microorganisms from adhering to tooth surfaces and forming plaque, thus minimizing oxidative damage and reducing gum bleeding. Due to the positive properties of boric acid and its compatibility with bone tissue, it is also effective in reducing periodontal inflammation and treating periodontal diseases (Aral et al., 2020; Hakki et al., 2015).

In a study where BN-TiO2 nanocomposite was synthesized and added to glass ionomer cement at a certain rate (hBN-TiO2/GIC), it was stated that glass ionomer cement alone showed some antibacterial activity, and the addition of 0.3, 0.7, 1.1 and 1.5% h-BN-TiO2 by weight led to a more pronounced antibacterial effect against St. Mutans (Ma et al, 2022).

Boric acid has been reported to have antibacterial effects on some oral bacteria including Staphylococcus aureus, Streptococcus mutans and Enterococcus faecalis, and to have wound and alveolar bone healing ability (Aral et al., 2020).

The gargara form of boric acid was also found to be superior to CHX in improving periodontal clinical parameters in patients with chronic periodontitis (Aral et al., 2020; Besinis et al, 2014).

Experimental animal studies have shown that boric acid can reduce alveolar bone loss in rats with periodontitis and osteoporosis (Toker et al, 2016).

In an experimental study conducted with rabbits, it was shown that increasing boron intake with sodium borate decahydrate supplementation in addition to a high-energy diet for 4 weeks changed the mineral composition of the tooth and had moderately beneficial effects on the alveolar bone environment (Hakki et al., 2015).

Osseointegration of the dental implant material into the surrounding bone and connective tissue is important for the long-term stability of the implant. Due to their partial contact with the jawbone and gums, dental implants are constantly exposed to oral microorganisms. Even with frequent systemic antibiotics, implant-associated infections can have serious consequences (Özmeric et al, 2022).

Depending on the level of inflammation, peri-implantitis can lead to destruction of the alveolar bone. Various surface treatments can reduce the incidence of implant-related infections. It was stated boron has no adverse effect on osteoblast viability and it increases cell proliferation (Capati et al, 2016). It has been shown that boron containing titanium alloy did not have a cytotoxic effect on osteoblast-like cells.The proliferation and differentiation of osteoblasts is promoted by boron in vitro (Capati et al, 2016; Özmeric et al, 2022).

In a study evaluating the antibacterial effect of boron nitride-coated implants to prevent bacterial colonization, it was stated that boron nitride-coated tubes can reduce bacterial adhesion, show significant bactericidal activity against S. mutans, and promote osteogenic cell adhesion and proliferation, thus reducing the likelihood of peri-implantitis when used as an antibacterial coating for titanium implants (Özmeric et al, 2022).

CONCLUSION

Recent studies have shown that the use of various types of boron compounds can increase both the mechanical and antibacterial properties of dental materials, resulting in various clinical benefits such as improved physical properties, prevention of tooth decay, and improved material surface properties.

The studies examined have shown that the preferred properties and the level of improvement are directly proportional to the boron concentration added to dental materials.

In addition, it is possible to create materials with unique properties by combining the known properties of boron with functional ions of other elements.

However, there are few studies on the use of boron-containing compounds in dentistry. More studies are needed to develop new generation dental materials containing boron and make them the preferred option in different dental treatments in dentistry.

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EVALUATION OF FINANCIAL PERFORMANCE IN TEXTILE FACTORIES WITH MOORA AND COPRAS METHODS

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ABSTRACT

Introduction and Purpose: Decision making refers to a process that has a beginning and an end; work, action, thought and activities follow each other and at the end, one of the alternatives is highlighted. After all criteria are reviewed, the goal is for the decision to be the most appropriate and best among other options. Multi-criteria decision-making methods evaluate multiple criteria together by assigning values to alternatives. The main purpose of multi-criteria decision-making methods is to offer the best solution that provides high satisfaction.

Materials and Methods: In this study, the financial statements of 5 textile companies operating in Turkey for the years 2021, 2022, 2023 and 2024 were accessed from the Public Disclosure Platform (KAP). In order to make a performance evaluation, the main criteria were determined as liquidity ratios, financial structure ratios and profitability ratios by using the data in the financial statements. After determining 3 main criteria and 12 sub-criteria, the arithmetic average of the data of each textile company between the years 2021-2024 was taken and made ready for use with Multi-Criteria Decision Making methods. The performance values of the textile companies were found with the MOORA and COPRAS methods from the Multi-Criteria Decision Making methods.

Results: A ranking was made for the MOORA and COPRAS methods from the best to the worst results. These 2 methods were compared with each other and it was decided that the textile company with the best performance between 2021-2024 was the 3rd textile company.

Discussion and Conclusion: It is seen that the performance rankings of textile companies whose financial evaluations were made with MOORA and COPRAS methods are the same in both methods and this shows that the study is consistent.

Key Words: Multi Criteria Decision Making; MOORA; COPRAS

HISTOLOGICAL TECHNIQUES IN VETERINARY MEDICINE

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Abstract

Histology is a crucial aspect of veterinary medicine, providing insights into animal health and disease. It involves the microscopic study of tissues such as epithelial, connective, muscular, and nervous tissues, which form the basis of organs and systems in animals. These tissues are essential for diagnosing diseases and understanding physiological processes.

Tissue collection and fixation are essential steps in histological analysis, often through biopsies or necropsies. Fixatives like formalin are used to preserve tissue structure and prevent degradation. Tissue samples undergo dehydration, clearing, and embedding in paraffin wax or cryosectioning for stability. Sectioning and staining are performed using a microtome, with Hematoxylin and Eosin (H&E) staining being the most common. Advanced techniques like immunohistochemistry enable the identification of specific proteins or pathogens.

Microscopic analysis is performed using light microscopy, electron microscopy, and confocal microscopy for ultrastructural details. Applications of histological techniques include diagnosis of diseases, animal health research, and comparative studies across species. Automation has streamlined histological processing, improving efficiency and consistency. Digital pathology and artificial intelligence allow for automated analysis of histological samples, reducing human error. Molecular techniques like in situ hybridization expand the scope of histological research, enabling the detection of genetic markers and pathogens in tissues. Challenges in veterinary histology include maintaining sample integrity during processing and addressing variability in results across species. Ethical considerations focus on minimizing harm during tissue collection and ensuring that research benefits animal welfare.

In conclusion, histology is an indispensable tool in veterinary medicine, offering unparalleled insights into tissue health and disease. Continued innovation and integration of advanced technologies will further enhance their impact, improving diagnostic accuracy and advancing animal care.

Key words: Histopathology, Immunohistochemistry, Microscopy in veterinary medicine. Tissue analysis, Veterinary histology

Giriş

Dokuların mikroskobik düzeyde incelenmesi olan histoloji, hayvan dokularının yapısı ve işlevi hakkında ayrıntılı bilgiler sağlayarak veteriner hekimliğinde kritik bir rol oynar. Doku örneklerinin incelenmesi yoluyla, histolojik teknikler veteriner hekimlerin ve araştırmacıların hastalıkları teşhis etmek, hastalık ilerlemesini izlemek ve tedavilerin etkinliğini değerlendirmek için çok önemli olan organların hücresel ve moleküler özelliklerini anlamalarını sağlar. Normal ve patolojik dokular arasında ayrım yapabilme yeteneği, tümörler, enfeksiyonlar ve dejeneratif

hastalıklar gibi durumları belirlemek için temeldir ve histolojik analiz genellikle klinik şüpheleri doğrulayan son tanı adımıdır (Chaudhuri, 2023).

Veterinerlik uygulamasında, histoloji klinik gözlemler ve mikroskobik bulgular arasında bir köprü görevi görerek tanı doğruluğunu artırır. Bu teknik, patolojik değişiklikleri belirlemek için doku örneklerini inceleyen veteriner patologlar için vazgeçilmezdir ve bu sayede daha hedefli terapötik öneriler sunabilirler. Ayrıca, histolojik incelemeler, doku mimarisi, hücre tipleri ve anormalliklerin varlığı hakkında temel bilgiler sağlar ve bunların hepsi uygun bir tedavi planı oluşturmada çok önemlidir (Hassan & Khan, 2024).

Bu makalede, doku hazırlama, boyama ve görüntüleme yöntemleri gibi veteriner hekimliğinde kullanılan temel histolojik teknikleri incelenmektedir. Ek olarak, bu tekniklerin hayvanlarda çeşitli hastalıkların teşhisinde, doku gelişimi ve rejenerasyonunun anlaşılmasında ve histolojinin veteriner araştırmalarını ilerletmedeki rolünde uygulamaları vurgulanmaktadır. Dijital patoloji ve otomatik görüntüleme dahil olmak üzere histolojik uygulamalardaki yenilikler de tartışılmakta ve bu gelişmelerin veteriner teşhis ve araştırmalarının sınırlarını nasıl zorladığı gösterilmektedir.

Veteriner Histolojisinin Temelleri

Histolojik Yapıların Genel Görünümü

Histoloji, dört birincil doku türünün incelenmesini içerir: epitel, bağ dokusu, kas dokusu ve sinir dokusu. Bu doku türlerinin her biri, mikroskop altında gözlemlenebilen, hastalıkların teşhisine ve doku gelişiminin anlaşılmasına yardımcı olan belirli işlevlere ve yapısal özelliklere sahiptir.

• Epitel Doku: Bu doku türü, organları, kan damarlarını ve vücut boşluklarını kaplayarak koruma, emilim ve salgılama için bir bariyer görevi görür. Veteriner teşhisinde, epitel hücrelerindeki değişiklikler enfeksiyonlar, tümörler veya iltihaplı hastalıklar gibi durumları gösterebilir (Kurn & Daly, 2021).

• Bağ Dokusu: Bu doku, diğer dokuları ve organları destekler, bağlar ve korur. Kan, kemik, kıkırdak ve yağ dokusunu içerir. Bağ dokusunun histolojik incelemesi, osteoartrit veya kas-iskelet sistemi yaralanmaları gibi bozuklukları teşhis etmeye yardımcı olur (Rehfeld et al., 2017).

• Kas Dokusu: Düz, kalp ve iskelet kaslarını içeren bu doku, hareketten sorumludur. Kas dokusunu incelemek, refakatçi hayvanlarda ve çiftlik hayvanlarında kas distrofileri veya yaralanmalar gibi durumların teşhisi için çok önemlidir (Gartner, 2015).

• Sinir Dokusu: Bu doku, uyarıları almak ve vücut boyunca sinyalleri iletmekle görevlidir. Nöronlar ve glial hücreleri içerir. Sinir dokusunun histolojisi, ensefalit veya sinir sistemindeki dejeneratif bozukluklar gibi patolojileri ortaya çıkarabilir (Gómez Sánchez et al., 2024).

Veterinerlik Tanısında Doku İncelemesinin Önemi

Veterinerlik hekimliğinde, özellikle klinik belirtiler tek başına yeterli bilgi sağlayamadığında, doku incelemesi doğru teşhis için esastır. Histolojik analiz, genellikle semptomlar klinik olarak belirgin hale gelmeden önce, hastalıkları hücresel düzeyde tanımlamaya yardımcı olur. Kanserleri, iltihaplı hastalıkları, enfeksiyonları ve genetik bozuklukları tespit etmede kritik bir rol oynar. Veteriner patologlar, doku örneklerini inceleyerek hastalığın doğasını, evresini ve olası tedavi seçeneklerini belirleyebilir (Aljehani et al., 2023).

Örneğin, kanser şüphesi olan bir köpekten alınan biyopsinin incelenmesi, iyi huylu ve kötü huylu büyümeler arasında ayrım yapmaya yardımcı olarak zamanında ve uygun tedaviyi kolaylaştırır. Bulaşıcı hastalıklar söz konusu olduğunda, histoloji bakteri, mantar veya virüs gibi patojenlerin varlığını ortaya çıkarabilir ve hedefli terapötik müdahalelere olanak tanır (Rolon, 2023).

Hayvanlarda ve İnsanlarda Histolojik Çalışmalar Arasındaki Farklar

Histolojik teknikler hayvanlarda ve insanlarda büyük ölçüde aynı olsa da, türlere özgü anatomi ve hastalık sunumundaki farklılıklar nedeniyle dokuların nasıl analiz edildiği konusunda önemli farklılıklar vardır. Örneğin, atlar veya geviş getirenler gibi bazı hayvanların özel organları vardır (örneğin, sığırlarda rumen) ve bu dokuların histolojik çalışmaları, bulguları doğru bir şekilde yorumlamak için ek uzmanlık gerektirir. Ayrıca, bazı hastalıklar hayvanlarda insanlara kıyasla farklı şekilde ortaya çıkabilir ve patologların tanı yaklaşımlarını türlere göre uyarlamalarını gerektirir (Marcaník et al., 1976).

Bir diğer fark da referans materyallerinin bulunabilirliğinde yatmaktadır. İnsanlarda yapılan histolojik çalışmalar kapsamlı referans veri tabanlarından faydalanırken, veteriner patologlar genellikle tam olarak belgelenmemiş türlere özgü verilere güvenir ve bu da sonuçların yorumlanmasını zorlaştırabilir (Treuting & Dintzis, 2012). Bu, veteriner tanılarını iyileştirmek için devam eden araştırmalara ve hayvana özgü histolojik özelliklerin daha derin bir şekilde anlaşılmasına olan ihtiyacı vurgulamaktadır.

Sonuç olarak, veteriner histolojisi, hayvanların benzersiz doku yapılarını ve hastalıklarını anlamayı gerektiren uzmanlaşmış bir alandır. Tanıda uygulanması, veterinerlerin daha doğru ve zamanında bakım sağlamasına yardımcı olur ve sonuçta hayvan sağlığı sonuçlarını iyileştirir.

Veteriner Hekimliğinde Histolojik Teknikler

İmmünohistokimya Yöntemleri

Direkt Yöntem

Direkt yöntem, doku örneklerinde hedef antijeni tespit etmek için florofor veya enzimle konjuge edilmiş birincil antikor kullanımını içeren tek adımlı bir tekniktir. Bu yöntem, ikincil antikorlara olan ihtiyacı ortadan kaldırdığı için hızlı ve spesifiktir, böylece arka plan boyama azalır ve çapraz reaksiyon en aza indirilir. Ancak, doğrudan yöntem genellikle sınırlı sinyal amplifikasyonu nedeniyle dolaylı tekniklerden daha az hassastır. Buna rağmen, özellikle hızlı tanımlamanın gerekli olduğu tanı ve araştırma ortamlarında, doku kesitlerinde yüksek oranda ifade edilen antijenleri tespit etmek için veteriner patolojisinde yaygın olarak kullanılır (Zhao et al., 2015).

İndirekt Yöntem

İndirekt IHC yöntemi, hedef antijene bağlanan etiketsiz bir birincil antikor ve ardından birincil antikoru özel olarak tanıyan etiketli bir ikincil antikor kullanır. Bu yöntem, duyarlılığı ve sinyal yoğunluğunu önemli ölçüde artırarak düşük miktarda antijenleri tespit etmek için tercih edilir hale getirir. İkincil antikorların kullanımı, aynı ikincil antikorun aynı türün birden fazla birincil antikoru için kullanılabilmesi nedeniyle daha fazla esneklik sağlar. Dolaylı yöntem, dokuya özgü protein ekspresyonunu incelemek, enfeksiyöz ajanları tanımlamak ve evcil ve vahşi hayvanlarda hastalık mekanizmalarını araştırmak için veterinerlik histopatolojisinde yaygın olarak uygulanır (Lewis & Roth, 2014).

Çözünebilir Enzim İmmun kompleks yöntemi

Çözünebilir enzim immünokompleks yöntemi, peroksidaz-antiperoksidaz (PAP) yöntemi olarak da bilinir, boyama özgüllüğünü artırmak için antikorlar ve enzimler arasında bir kompleks oluşumuna dayanır. Bu teknikte, önce dokuya ikincil bir antikor uygulanır, ardından ikincil antikora bağlanan enzim etiketli antikorların önceden oluşturulmuş bir kompleksi uygulanır. Bu, doğrudan ve dolaylı yöntemlere kıyasla daha yüksek sinyal amplifikasyonuyla sonuçlanır ve bu

da onu düşük ifadeli proteinleri tespit etmek için özellikle yararlı hale getirir. Veterinerlik uygulamalarında, PAP yöntemi sıklıkla tanı patolojisinde, özellikle neoplaztik ve inflamatuar durumların araştırılmasında kullanılır (Ramos-Vara, 2011).

Avidin-Biotin Yöntemi

Avidin-biyotin kompleksi (ABC) yöntemi, yüksek hassasiyeti ve çok yönlülüğü nedeniyle en yaygın kullanılan IHC tekniklerinden biridir. Bu yöntem, birincil antikora bağlanan biyotinlenmiş bir ikincil antikor ve ardından bir avidin-biyotin-enzim kompleksinin eklenmesini içerir. Avidin, biyotine karşı güçlü bir afiniteye sahip olduğundan, birden fazla enzim molekülü antijen-antikor bağlanma bölgesine çekilir ve sinyal yoğunluğunu önemli ölçüde artırır. ABC yöntemi, bulaşıcı hastalıkları, kanser biyobelirteçlerini ve dokuya özgü proteinleri tespit etmek için veteriner patolojisinde yaygın olarak uygulanır. Ek olarak, doku yapıları içindeki antijen lokalizasyonunun ayrıntılı olarak görüntülenmesine olanak tanıdığı için hayvanlarda üreme, nörolojik ve inflamatuar bozuklukları incelemek için özellikle yararlıdır (Okoye & Nnatuanya, 2015).

Doku Toplama ve Fiksasyon

Histolojik analizin ilk adımı, doku örneklerinin dikkatli bir şekilde toplanmasıdır. Biyopsi (canlı bir hayvandan alınan örnek) veya nekropsi (ölümden sonra elde edilen doku) sırasında gerçekleştirilsin, doku bütünlüğünün korunmasını sağlamak için uygun örnekleme teknikleri esastır. Veterinerlik uygulamasında, kontaminasyondan kaçınmak, eserler oluşturmak veya nihai tanıyı etkileyebilecek kritik doku bölgelerini atlamak çok önemlidir. Örneğin, dermatolojik rahatsızlıkları olduğundan şüphelenilen hayvanlardan deri örnekleri toplanırken, veterinerler en bilgilendirici analizi sağlamak için örneğin doğru derinliğini ve yerini dikkate almalıdır (Han et al., 2024).

Toplandıktan sonra, dokular hücre yapılarını stabilize eden ve bozulmayı önleyen kimyasallar olan fiksatifler kullanılarak derhal korunmalıdır. Formalin, hücresel mimariyi ve proteinleri koruma yeteneği nedeniyle veterinerlik histolojisinde en sık kullanılan fiksatiftir, ancak glutaraldehit veya Bouin solüsyonu gibi diğer fiksatifler belirli doku tipleri için kullanılabilir. Fiksasyon süreci hayati önem taşır çünkü uygunsuz fiksasyon, enfeksiyöz ajanların varlığı veya dokudaki hafif patolojik değişiklikler gibi kritik tanı bilgilerinin kaybına yol açabilir (Ajileye & Esan, 2022).

Doku İşleme ve Gömme

Fiksasyondan sonra, doku örnekleri kesit alma ve mikroskobik inceleme için hazırlanmak üzere bir dizi adımdan geçer. Doku işleme olarak bilinen bu süreç, dokuların su içeriğini gidermek için giderek artan alkol konsantrasyonlarına maruz bırakıldığı dehidratasyonu; alkolün gömülmeye izin vermek için ksilen gibi bir çözücü ile değiştirildiği temizlemeyi; ve dokuya parafin mumu emdirildiği gömmeyi içerir. Parafin, kesit alma sırasında ince dilimler oluşturmak için yapısal destek sağlayarak dokuyu sertleştirir (Vialette, 2022).

Bazı durumlarda, özellikle hassas yapıları incelerken veya hızlı sonuçlara ihtiyaç duyulduğunda, kriyoseksiyon kullanılır. Bu teknik, dokuyu parafine gömmek yerine dondurmayı içerir ve kimyasal fiksasyon sırasında kaybolabilecek bazı enzimlerin ve antijenlerin korunmasını sağlar. Kriyoseksiyon, özellikle immünohistokimyasal analiz için veya beyindekiler gibi belirli doku tipleriyle çalışırken faydalıdır (Chaudhuri, 2023).

Kesit Alma ve Boyama

Histolojik analizdeki bir sonraki adım, gömülü dokuyu son derece ince kesitlere ayırma işlemi olan kesit almadır. Bu, 4 ila 10 mikron kalınlığında kesitler kesen ve ayrıntılı mikroskobik incelemeye olanak tanıyan bir mikrotom kullanılarak gerçekleştirilir. Daha sonra ince kesitler, mikroskop altında doku yapılarının görünürlüğünü artıran boyama için cam slaytlara yerleştirilir (Baig & Sinha, 2024).

Veterinerlik histolojisinde kullanılan en yaygın boyalardan biri, çekirdekleri mavi (hematoksilin) ve sitoplazmayı pembe (eozin) boyayan ve doku mimarisine dair temel bir genel bakış sağlayan Hematoksilin ve Eozin'dir (H&E). Daha özel analizler için özel boyalar kullanılır. Örneğin, Periyodik Asit-Schiff (PAS) karbonhidratları ve glikoproteinleri boyar ve bu da mantar enfeksiyonlarını veya belirli tümör tiplerini tanımlamada faydalıdır. Masson'ın Trikrom'u, bağ dokuları ve fibrozun incelenmesine yardımcı olan kolajen liflerini vurgulamak için kullanılan özel bir boyadır (Chaudhuri, 2023).

Ek olarak, immünohistokimya (IHC), veteriner patolojisinde oldukça değerli bir tekniktir. IHC, doku örneklerinde belirli antijenleri tespit etmek için antikorların kullanımını içerir. Bu yöntem, özellikle enfeksiyöz ajanları (bakteri veya virüsler gibi) veya tümör belirteçlerini tanımlamada faydalıdır ve köpek lenfoması veya at sarkoidleri gibi hastalıkların değerlendirilmesinde kesin bir tanı aracı sunar (Chaudhuri, 2023).

Mikroskobik Analiz

Histolojinin nihai amacı, dokuyu mikroskop altında incelemektir. Işık mikroskobu, patologların boyanmış dokuların morfolojisini gözlemlemesine olanak tanıyan en yaygın analiz biçimi olmaya devam etmektedir. Ancak elektron mikroskobu gibi daha gelişmiş teknikler, hücrelerin ultra yapısının ayrıntılı görüntülerini sunarak organeller de dahil olmak üzere daha küçük hücresel bileşenlerin incelenmesini mümkün kılar (Vaishnavi et al., 2024).

Son yıllarda, teknolojik gelişmeler veterinerlik histolojisine konfokal mikroskopi ve floresan mikroskopiyi getirmiştir. Bu görüntüleme teknolojileri gelişmiş çözünürlük ve canlı hücreleri daha ayrıntılı olarak gözlemleme yeteneği sunar. Konfokal mikroskopi, dokuların 3 boyutlu görüntülerini sunarak doku mimarisinin derinlemesine incelenmesine olanak tanırken, floresan mikroskopi, floresan işaretleyicilerle etiketlenmiş belirli hücresel bileşenlerin görüntülenmesini sağlar (Cortese & Verkade, 2023). Bu araçlar, özellikle hayvanlarda tümörler, iltihap ve kök hücre tedavilerinin incelenmesinde, veteriner hekimlere hastalık süreçleri ve doku rejenerasyonu hakkında daha kapsamlı bir anlayış sunar.

Histolojik Tekniklerin Uygulamaları

Hayvan Hastalıklarının Tanısı

Histopatoloji, çeşitli hayvan hastalıklarının tanısı için paha biçilmez bir araçtır. Kanserler, bulaşıcı hastalıklar ve paraziter enfeksiyonlar gibi anormallikleri tespit etmek için kritik olan hücresel düzeyde doku örneklerinin ayrıntılı bir şekilde incelenmesine olanak tanır. Örneğin, histolojik teknikler, köpeklerde meme bezi tümörleri veya kedilerde lenfomalar gibi evcil hayvanlarda tümör tiplerinin belirlenmesinde önemlidir ve veteriner hekimlerin doğru tanıyı koymasını ve en uygun tedavi planlarını belirlemesini sağlar (Moura, 2024).

Bulaşıcı hastalıklar söz konusu olduğunda, histolojik inceleme doku örneklerinde bakteri, virüs veya mantar gibi patojenlerin varlığını ortaya çıkarabilir. Örneğin, histopatolojik analiz sıklıkla köpek parvovirüsü ve at gribi gibi viral enfeksiyonları ve bruselloz gibi bakteriyel enfeksiyonları tanımlamak için kullanılır (Rolon, 2023). Benzer şekilde, protozoa (Toxoplasma gondii gibi)

veya helmintler (sığırlarda Fasciola hepatica gibi) tarafından oluşturulanlar da dahil olmak üzere parazitik enfeksiyonlar, doku incelemesi yoluyla teşhis edilebilir ve aksi takdirde fark edilmeyebilecek enfeksiyonları tanımlamanın ve doğrulamanın bir yolunu sunar.

Histolojik tekniklerin bir diğer kritik uygulaması da postmortem analizdir. Veteriner patologlar, ölen hayvanlardan alınan dokuları inceleyerek, hastalık, travma veya zehirlenme olsun, ölüm nedenini belirleyebilirler. Bu, özellikle ölüm nedeninin hemen belli olmadığı durumlarda önemlidir ve hayvan sahiplerine ve veteriner hekimlere gelecekteki önlemeler için hayati bilgiler sağlar (Rolon, 2023).

Hayvan Sağlığında Araştırma

Histolojik teknikler, hayvan sağlığı araştırmalarının ilerlemesinde de çok önemlidir. Bu teknikler, dokuların çeşitli tedavilere, ilaçlara veya çevresel toksinlere nasıl tepki verdiğine dair derinlemesine çalışmalara olanak tanır. Örneğin, araştırmacılar hücresel yapıyı inceleyerek ve herhangi bir toksisite veya anormal büyüme belirtisi belirleyerek yeni bir ilacın karaciğer dokusu üzerindeki etkilerini araştırabilirler. Benzer şekilde, histopatoloji gen terapileri veya aşıları içeren çalışmalarda doku tepkilerini izlemeye yardımcı olur ve bunların etkinliği ve olası yan etkileri hakkında fikir verir (Jiang & Zhao, 2023).

Dahası, histoloji hayvan fizyolojisi ve patolojisi anlayışımıza önemli ölçüde katkıda bulunur. Bilim insanları farklı doku tiplerini inceleyerek, kardiyovasküler hastalıklar veya solunum bozuklukları gibi hastalıkların hücresel düzeyde organları nasıl etkilediğini inceleyebilir, tanı doğruluğunu ve tedavi stratejilerini iyileştirebilir. Histolojik veriler ayrıca veteriner hekimlere hastalıkların doğal ilerleyişi hakkında bilgi vererek sonuçları tahmin etmeye ve vakaları daha etkili bir şekilde yönetmeye yardımcı olur (Jasim et al., 2022).

Karşılaştırmalı Çalışmalar

Histoloji, veterinerlik ve insan tıbbı arasındaki boşlukları kapatmaya yardımcı olan karşılaştırmalı çalışmalarda önemli bir rol oynar. Bilim insanları hayvanların ve insanların doku yapılarındaki benzerlikleri ve farklılıkları inceleyerek zoonotik hastalıklar (hayvanlardan insanlara bulaşanlar) hakkında fikir edinebilir ve ortak patojenik mekanizmaları belirleyebilir. Örneğin, sığırlarda tüberkülozun histolojik çalışmaları, hastalığın insanlara ve diğer hayvanlara nasıl yayılabileceği konusunda temel bilgiler sağlayarak daha iyi kontrol stratejilerine yardımcı olmuştur (Jawahar et al., 2024).

Ek olarak, evrimsel biyoloji histolojik araştırmalardan faydalanır, çünkü farklı türler arasındaki dokuların karşılaştırılması türlere özgü farklılıklar hakkında önemli içgörüler ortaya koyar. Çeşitli hayvanlardaki dokuların farklı ortamlara uyum sağlamak için nasıl evrimleştiğini anlamak, hem veterinerlik bakımı hem de daha geniş biyolojik araştırmalar için değerli bilgiler sağlayabilir. Histolojik çalışmalar ayrıca koruma çabalarına da katkıda bulunur, çünkü nesli tükenmekte olan türlere ait dokuların incelenmesi, biyolojik çeşitliliğin korunması ve türlerin yok olmasının önlenmesi için stratejilerin geliştirilmesine yardımcı olabilir (Mazzarini et al., 2021).

Veteriner Histolojisinde Yenilikler ve İlerlemeler

Histolojik İşlemede Otomasyon

Veteriner histolojisindeki son gelişmeler, doku işlemenin birçok yönüne otomasyonu getirmiş ve histolojik analizlerin verimliliğini ve tutarlılığını önemli ölçüde artırmıştır. Doku yerleştirme, kesit alma ve boyama için otomatik sistemler, yüksek verimli işlemeyi garanti ederek insan

hatasını ve örnekler arasındaki varyasyonu azaltır. Bu sistemler, aynı anda büyük hacimli örnekleri işleyebilir ve bu da özellikle yoğun veterinerlik uygulamaları ve araştırma ortamlarında faydalıdır. Otomasyon ayrıca doku slaytlarının hazırlanmasında daha fazla hassasiyet sağlar ve daha doğru teşhislere ve araştırma bulgularına yol açar (Alhammad et al., 2023).

Otomasyonun histolojik iş akışlarına entegre edilmesi, tekniklerin standardizasyonunu da kolaylaştırmış ve patologların ve araştırmacıların birden fazla örnek ve laboratuvarda tutarlı sonuçlar elde etmesine yardımcı olmuştur. Veterinerlik araştırmaları büyümeye devam ettikçe, otomatik histolojik işleme olan bağımlılığın artması ve hem tanısal doğruluğu hem de araştırma yeteneklerinin artması bekleniyor (Omair et al., 2023).

Dijital Patoloji ve Yapay Zeka'nın Histolojik Örnekleri Analiz Etmedeki Rolü

Veterinerlik histolojisinde ortaya çıkan bir alan olan dijital patoloji, histolojik örneklerin analiz edilme biçiminde devrim yarattı. Bu teknik, geleneksel cam slaytların dijitalleştirilmesini ve doku kesitlerini yüksek çözünürlüklü monitörlerde görüntülemek ve analiz etmek için bilgisayar sistemlerinin kullanılmasını içerir. Yapay zekanın (AI) dijital patolojiye entegre edilmesi, otomatik görüntü analizini mümkün kılarak bu yeniliği bir adım öteye taşıyor. AI algoritmaları, patologların ince doku değişikliklerini tespit etmelerine, anormal hücreleri tanımlamalarına ve hastalıkları geleneksel yöntemlerden daha hızlı ve doğru bir şekilde teşhis etmelerine yardımcı olabilir (Greeley et al., 2024).

Veterinerlik hekimliğinde, AI destekli dijital patolojinin uygulanması, kanser, enfeksiyonlar ve inflamatuar durumlar gibi hastalıkların teşhisinde özellikle ümit vericidir. Veterinerler, görüntü analizini otomatikleştirerek karmaşık doku örneklerinin kapsamlı bir şekilde incelenmesini sağlayarak zamandan tasarruf edebilir ve tanı güvenini artırabilirler. Dahası, AI tabanlı sistemler sürekli olarak öğrenmektedir, bu da daha fazla veriyi analiz ettikçe doğruluklarının zamanla arttığı anlamına gelir (Fatima et al., 2024).

Veterinerlik Uygulamalarında Moleküler Tekniklerin Kullanımı

Moleküler teknikler, doku işlevi ve hastalık mekanizmaları hakkında daha derin içgörüler sağlamak için giderek daha fazla veterinerlik histolojisine entegre edilmektedir. Yerinde hibridizasyon (ISH), doku kesitleri içinde belirli nükleik asit dizilerinin lokalizasyonuna izin veren bu tür bir yöntemdir. Bu teknik, özellikle viral enfeksiyonları, genetik mutasyonları belirlemede ve hayvan dokularındaki gen ekspresyon modellerini değerlendirmede faydalıdır (Monné Rodríguez et al., 2023).

Örneğin, ISH, enfekte hayvanların dokularında köpek distemper virüsünün varlığını belirlemek için kullanılmış ve virüsün nasıl yayıldığını ve dokulara nasıl zarar verdiğini daha iyi anlamamızı sağlamıştır. PCR tabanlı teknikler ve yeni nesil dizileme gibi diğer moleküler yöntemler, kanser, genetik bozukluklar ve viral enfeksiyonlar gibi hastalıklara katkıda bulunan genetik materyalin ve mutasyonların tespitini sağlayarak histolojik analizleri daha da geliştirir. Bu moleküler tekniklerin veterinerlik histolojisine dahil edilmesi, hassas teşhis ve hedefli tedaviler için potansiyeli genişleterek hayvan bakımını iyileştirir ve veterinerlik araştırmalarını ilerletir (Gazalle et al., 2023).

Zorluklar ve Etik Hususlar

Hayvan Dokusu Örneklemesinin Etik Yönleri

Veterinerlik histolojisindeki en önemli etik kaygılardan biri, tanı ve araştırma için elzem olan ancak hayvan refahı hakkında sorular ortaya çıkaran hayvan dokularının örneklenmesidir.

Biyopsi veya otopsi için olsun, doku örneklerinin toplanması, veterinerlerin tanı doğruluğu ihtiyacını hayvanlara insani muamele ile dengelemesini gerektirir. 3R ilkesi (Değiştirme, Azaltma, İyileştirme) gibi etik yönergeler ve düzenlemeler, mümkün olan yerlerde alternatiflerin kullanımını teşvik ederek, kullanılan hayvan sayısını en aza indirerek ve acıyı azaltmak için yöntemleri iyileştirerek gereksiz zararı azaltmaya yardımcı olur (Rinwa et al., 2024).

Ek olarak, özellikle başka nedenlerle ötanazi uygulanan hayvanlarda doku örneklemesi yapıldığında, sahiplerinden bilgilendirilmiş onam almak (uygun olan yerlerde) ve prosedür için uygun gerekçelendirme sağlamak hayati etik uygulamalardır. Bu, araştırma veya teşhis prosedürlerinin haklı bir amaç için yürütülmesini ve hayvan refahını gereksiz yere tehlikeye atmadan veteriner hekimliğinin ilerlemesine katkıda bulunulmasını sağlar (Yadav et al., 2024).

Örnek Bütünlüğünü ve Standardizasyonu Korumada Teknik Zorluklar

Örnek bütünlüğünü korumak, veteriner histolojisinde bir diğer önemli zorluktur. Doku örnekleri, sonuçların yanlış yorumlanmasına yol açabilecek otolizi (kendi kendine sindirim) veya çürümeyi önlemek için toplandıktan hemen sonra uygun şekilde saklanmalıdır. Formalin gibi fiksatiflerin kullanımı kritik öneme sahiptir, ancak doku işleme, fiksasyon süresi ve depolamadaki tutarsızlıklar histolojik sonuçların kalitesini ve yeniden üretilebilirliğini etkileyebilir. Ayrıca, türler veya organlar arasındaki farklılıklar gibi doku tiplerindeki farklılıklar, uygun korumayı sağlamak için özel yaklaşımlar gerektirir ve bu da standardizasyonu veteriner histolojisinde karmaşık ve devam eden bir zorluk haline getirir. Farklı laboratuvarlardan alınan histolojik örnekleri karşılaştırırken standardizasyon da zordur, çünkü her tesisin dokuları işleme, boyama ve kesme için kendi protokolleri olabilir. Bu tekdüzelik eksikliği, özellikle çok merkezli çalışmalarda tanılarda değişkenliğe yol açabilir ve veterinerlik uygulamaları ve araştırma kurumları arasında tutarlı protokollere ve kalite kontrol önlemlerine olan ihtiyacı vurgular (Ajileye & Esan, 2022; Koehler et al., 2024).

Veterinerlik Histolojisinde Nitelikli Profesyonellere İhtiyaç

Veterinerlik histolojisi, karmaşık doku yapılarını ve anormallikleri yorumlamak için yetenekli profesyoneller gerektiren oldukça uzmanlaşmış bir alandır. Veterinerler, patologlar ve histoteknologlar, histolojik tekniklerin hem teknik hem de biyolojik yönlerini anlamak için kapsamlı bir eğitime ihtiyaç duyarlar. Örneklerin uygunsuz şekilde elleçlenmesi, işlenmesi veya analizi, hayvanların tedavisini önemli ölçüde etkileyebilecek hatalı tanılarla sonuçlanabilir. Ayrıca, elektron mikroskobu ve dijital patoloji gibi gelişmiş görüntüleme teknikleri, sofistike ekipman ve yazılımları kullanma ve yorumlama konusunda uzmanlık gerektirir (Orakpoghenor, 2024).

Histolojik incelemelerin karmaşık yapısı göz önüne alındığında, sürekli eğitim ve uzmanlaşmış eğitim programlarına olan ihtiyaç artmaktadır. Veterinerlik müfredatına modern gelişmeleri dahil etmek ve teknisyenler için uygulamalı eğitim sağlamak, veterinerlik histolojisi alanında yüksek standartları korumak için çok önemlidir. Teknoloji geliştikçe ve yeni teşhis araçları ortaya çıktıkça, histolojinin veterinerlik tıbbındaki rolü, hem geleneksel hem de son teknoloji tekniklerde deneyimli profesyonellere giderek daha fazla bağlı olacaktır (Carioto, 2014).

Sonuç

Histolojik teknikler, veteriner hekimliğinin temel bir parçasıdır ve doku yapısı, hastalık süreçleri ve genel hayvan sağlığı hakkında paha biçilmez içgörüler sağlar. Hücresel ve doku düzeyindeki değişikliklerin ayrıntılı incelemesini sağlayarak, bu yöntemler enfeksiyonlardan ve kanserlerden otoimmün bozukluklara kadar çok çeşitli hastalıkların teşhisinde önemli bir rol oynar. Veteriner

histolojisi yalnızca hastalık teşhisine yardımcı olmakla kalmaz, aynı zamanda çeşitli durumların hayvanları mikroskobik düzeyde nasıl etkilediğini anlamada önemli bir araç görevi görür ve böylece tedavilerin ve terapötik stratejilerin geliştirilmesini artırır.

Alan ilerlemeye devam ettikçe, inovasyona ve son teknolojilerin entegrasyonuna olan ihtiyaç artmaktadır. Dijital patolojinin ve otomasyonun rutin histolojik süreçlere dahil edilmesi, teşhislerin hızını ve doğruluğunu iyileştirme potansiyeli sunmaktadır. Ek olarak, immünohistokimya ve in situ hibridizasyon gibi moleküler araçlar gibi teknikler, veteriner histolojisinin yeteneklerini genişleterek dokuya özgü moleküler mekanizmalar ve hastalık ilerlemesi hakkında daha derin bir anlayışa olanak sağlıyor.

Veteriner histolojisinin değerini daha da artırmak için, konfokal ve floresan mikroskopisi gibi yeni görüntüleme yöntemlerinin entegrasyonu araştırılmaya devam edilmelidir. Bu teknolojiler, doku yapılarının ve hücresel aktivitenin üstün görselleştirilmesini sunarak veteriner hekimliğinde hem tanı hem de araştırma yeteneklerini ilerletir. Veterinerlik profesyonellerinin bu gelişmelerden haberdar olmaları, uygulamalarının ve araştırma çabalarının hayvan sağlığını ve refahını iyileştirmek için en son metodolojiler ve teknolojilerle uyumlu kalmasını sağlamaları çok önemlidir.

Veteriner histolojisinin geleceği, mevcut tekniklerin sürekli iyileştirilmesinde ve ortaya çıkan teknolojilerin benimsenmesinde yatmaktadır ve bu da nihayetinde daha iyi hastalık tespiti, tedavisi ve hayvan fizyolojisinin anlaşılmasına katkıda bulunmaktadır. Alan geliştikçe, doku örneklemesi ve araştırmayla ilişkili etik hususlar ile yenilik arasında bir denge sağlamak, hayvan refahının veterinerlik pratiğinde ön planda kalmasını sağlamak önemlidir.

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STEM CELL

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ABSTRACT

Stem cells, classified into embryonic stem cells (ESCs), adult stem cells, and induced pluripotent stem cells (iPSCs), are used in veterinary medicine for their potential in personalized therapies. Adult stem cells, particularly mesenchymal stem cells (MSCs) derived from bone marrow or adipose tissue, are commonly used due to their ease of collection and ethical considerations. iPSCs, which involve reprogramming adult cells into a pluripotent state, are gaining traction for personalized therapies.

Stem cells function through differentiation into specific cell types, enabling tissue regeneration and repair. They also exert paracrine effects by releasing bioactive molecules that reduce inflammation, modulate the immune response, and promote healing. These mechanisms make stem cells valuable in treating chronic and degenerative conditions.

Applications of stem cells in veterinary medicine include orthopedic diseases, neurological disorders, internal medicine, and wound healing. Orthopedic conditions, neurological disorders, internal medicine, and wound healing are some of the applications of stem cells.

However, stem cell therapies face challenges such as high costs, variability in animal responses, and the need for standardized protocols. Future directions for veterinary stem cell research include advancements in technologies like CRISPR gene editing and 3D bioprinting, as well as efforts to establish stem cell banks for various species and expand their applications in wildlife conservation and regenerative farming. As research progresses, stem cells could redefine the standards of care in veterinary medicine, benefiting both companion animals and livestock.

Key Words: Bone Marrow; Embryonıc Stem Cell; Induced Pluripotent Stem Cell

Giriş

Kendini yenileme ve özelleşmiş hücre tiplerine farklılaşma konusundaki benzersiz yetenekleriyle karakterize edilen kök hücreler, rejeneratif tıpta güçlü bir aracı temsil etmektedir. Çeşitli hücre tipleri üretebilen farklılaşmamış hücreler olarak tanımlanan kök hücreler embriyonik, yetişkin ve indüklenmiş pluripotent kök hücreler (iPSC'ler) olarak sınıflandırılır. Hasarlı dokuları onarma, değiştirme ve eski haline getirme potansiyelleri, onları hem insan hem de veterinerlik tıbbında çok değerli kılmaktadır (Kaur et al., 2024).

Veteriner hekimlikte kök hücrelerin önemi son yıllarda katlanarak artmıştır. Veteriner hekimler, aksi takdirde tedavisi zor veya imkansız olan durumları ele almak için kök hücre tedavilerinden yararlanmaya başlamıştır. Osteoartrit, tendon yaralanmaları ve böbrek yetmezliği gibi kronik hastalıklar gibi durumlar artık kök hücreler kullanılarak yönetilmekte ve hem refakatçi hem de çiftlik hayvanlarında daha iyi sonuçlar için yeni umutlar sağlamaktadır. Kök hücre araştırmaları

sadece klinik uygulamalar için değil, aynı zamanda hayvan biyolojisi ve hastalık mekanizmaları hakkındaki anlayışımızı ilerletmek için de yollar açmıştır (Farshan, 2024).

Kök hücrelerin veterinerlik tıbbındaki dönüştürücü potansiyeli, hayvan sağlığındaki kritik zorlukları ele alma yeteneklerinde yatmaktadır. Doku rejenerasyonu ve onarımı için minimal invaziv bir seçenek sunarak iyileşme sürelerini kısaltmakta ve yaşam kalitesini artırmaktadırlar. Ayrıca, üreme teknolojilerindeki ilerlemeler yoluyla nesli tükenmekte olan türlerde genetik çeşitliliğin korunması için umut vaat etmektedirler. Alan ilerledikçe, kök hücreler veterinerlik uygulamalarında bakım standartlarını yeniden tanımlamaya ve hem evcil hem de vahşi hayvanlara küresel ölçekte fayda sağlamaya hazırlanıyor (Anggraeni & Ana, 2024).

Veterinerlik Bağlamında Kök Hücre Türleri

Embriyonik Kök Hücreler (ESC'ler)

Embriyonik kök hücreler (ESC'ler) blastosist aşamasındaki embriyoların iç hücre kütlesinden türetilir ve herhangi bir hücre tipine farklılaşma yeteneğine sahiptir, bu da onları pluripotent yapar. Veteriner hekimlikte potansiyel uygulamaları arasında rejeneratif tedaviler ve gelişim biyolojisine yönelik ileri araştırmalar yer almaktadır. ESC'ler doğumsal anormalliklerin tedavisi ve ciddi yaralanmaları olan hayvanlarda doku onarımı için yeni çözümler sunabilir. Bununla birlikte, etik hususlar, özellikle embriyoların kaynağı ve araştırmalarda kullanılmasının ahlaki sonuçları ile ilgili olarak, veterinerlik uygulamalarında kullanımlarını önemli ölçüde sınırlamaktadır. Bu endişeler, terapötik faydaları en üst düzeye çıkarırken etik çatışmaları en aza indirmeye odaklanan dengeli bir yaklaşım gerektirmektedir (Ratna et al., 2024).

Yetişkin Kök Hücreler

Yetişkin kök hücreleri veya somatik kök hücreler, vücuttaki çeşitli dokularda bulunan multipotent hücrelerdir. Bunlar arasında, kemik iliği ve yağ dokusundan elde edilen mezenkimal kök hücreler (MSC'ler) veterinerlik tıbbında özellikle önemlidir. MSC'ler kemik, kıkırdak ve bağ dokusuna farklılaşma kapasiteleri nedeniyle değerlidir, bu da onları hayvanlarda osteoartrit ve bağ yaralanmaları gibi kas-iskelet sistemi bozukluklarının tedavisi için ideal hale getirir. Adipoz doku, köpekler ve atlar gibi refakatçi hayvanlarda erişilebilirliği ve bolluğu nedeniyle veterinerlik uygulamalarında yaygın bir MSC kaynağıdır. Kemik iliği, hasat edilmesi biraz daha invaziv olsa da, enflamatuar ve dejeneratif durumların yönetiminde kök hücre tedavileri için bir başka önemli kaynak olmaya devam etmektedir (Kaur et al., 2024).

İndüklenmiş Pluripotent Kök Hücreler (iPSC'ler)

İndüklenmiş pluripotent kök hücreler (iPSC'ler) veteriner rejeneratif tıpta çığır açan bir yeniliği temsil etmektedir. iPSC'ler, deri veya kan hücreleri gibi somatik hücrelerin yeniden programlanarak pluripotensi kazanmasıyla üretilir. Bu teknik, embriyonik kök hücrelere olan ihtiyacı ortadan kaldırarak ESC kullanımıyla ilgili birçok etik kaygıyı gidermektedir. Veterinerlik bağlamında, iPSC'ler hastalık modellerinin incelenmesinde, genetik bozuklukların araştırılmasında ve hayvanlar için kişiselleştirilmiş tedavilerin geliştirilmesinde önemli bir rol oynamaktadır. Ayrıca, üreme için germ hücreleri oluşturarak veya türe özgü hastalıkların araştırılması için dokular üreterek nesli tükenmekte olan türlerin korunması için potansiyel sunmaktadırlar. İPSC'leri oluşturmak için bir hayvanın kendi hücrelerini kullanma yeteneği, terapötik uygulamalar sırasında bağışıklık reddi riskini de azaltır (Wang et al., 2024).

Veteriner hekimlik, her bir kök hücre türünün kendine özgü avantajlarından yararlanarak, etik ve pratik zorlukların üstesinden gelirken hayvan sağlığı ve refahını iyileştirme konusunda adımlar atmaya devam etmektedir.

Hayvanlarda Etki Mekanizmaları

Doku Onarımı için Spesifik Hücre Tiplerine Farklılaşma

Kök hücrelerin hayvanlardaki birincil etki mekanizması, özelleşmiş hücre tiplerine farklılaşma yeteneklerinde yatmaktadır. Bu özellik doku onarımı ve rejenerasyonu için kritik öneme sahiptir. Örneğin, mezenkimal kök hücreler (MSC'ler) kondrositlere (kıkırdak hücreleri), osteositlere (kemik hücreleri) ve miyositlere (kas hücreleri) farklılaşarak hasarlı veya dejenere olmuş dokuları onarabilir. Veteriner hekimlikte bu özellik, kıkırdak hasarının hareket kabiliyetini ve yaşam kalitesini önemli ölçüde etkilediği atlarda ve köpeklerde osteoartrit gibi durumların tedavisinde yaygın olarak kullanılmaktadır. Kök hücre tedavisi, kayıp veya hasarlı dokuyu işlevsel hücrelerle değiştirerek iyileşmeyi artırmak için minimal invaziv bir çözüm sağlar (Khaveh et al., 2024).

Artrit Gibi Durumlarda Bağışıklık Düzenleyici Etkiler

Farklılaşmanın ötesinde, kök hücreler güçlü bağışıklık düzenleyici özellikler sergiler ve bu da onları artrit gibi iltihaplı durumların yönetiminde etkili kılar. Örneğin MSC'ler, enflamasyonu azaltarak ve aşırı aktif bağışıklık hücrelerini baskılayarak bağışıklık tepkisini modüle eden biyoaktif moleküller salgılar. Bu, kronik eklem hastalıkları, otoimmün bozukluklar ve diğer enflamatuar durumlardan muzdarip hayvanlarda semptomları hafifletebilir. Anti-enflamatuar etkiler sadece ağrı ve şişliğin azaltılmasına yardımcı olmakla kalmaz, aynı zamanda doku rejenerasyonu için daha elverişli bir ortam yaratır (Srinivasan & Ghone, 2024).

Parakrin Sinyalizasyon Yoluyla İyileşmenin Artırılması

Kök hücreler ayrıca parakrin sinyalizasyon yoluyla dolaylı olarak iyileşmeyi destekler. Farklılaşmak yerine, çeşitli büyüme faktörleri, sitokinler ve hücre dışı veziküller salgılayarak çevredeki hücreleri doku onarımı ve yenilenmesi için uyarırlar. Bu mekanizma, atçılık tıbbında tendon ve bağ hasarı gibi yumuşak doku yaralanmalarında özellikle önemlidir. Vasküler endotelyal büyüme faktörü (VEGF) gibi büyüme faktörleri anjiyogenezi teşvik ederek yaralı dokulara kan akışını artırır ve iyileşmeyi hızlandırır. Benzer şekilde, parakrin sinyalizasyonun anti-apoptotik ve skarlaşma önleyici etkileri, komplikasyonların azalmasıyla daha iyi fonksiyonel iyileşmeye katkıda bulunur (Kaur et al., 2024).

Bu çeşitli mekanizmalardan (farklılaşma, bağışıklık modülasyonu ve parakrin sinyalizasyon) yararlanarak, kök hücre tedavisi veterinerlik tıbbında çok yönlü ve etkili bir yaklaşım olarak ortaya çıkmış, çok çeşitli koşulları ele almış ve ihtiyacı olan hayvanlar için sonuçları iyileştirmiştir.

Veteriner Hekimlikte Kök Hücre Uygulamaları

Ortopedik Hastalıklar

Kök hücre tedavisi, başta atlar, köpekler ve kediler olmak üzere hayvanlarda ortopedik hastalıkların tedavisinde yaygın olarak kullanılmaya başlanmıştır. Osteoartrit, tendon yaralanmaları ve kırıklar gibi genellikle hareketliliği ve yaşam kalitesini bozan durumlar, mezenkimal kök hücreler (MSC'ler) kullanılarak etkili bir şekilde yönetilmektedir. Örneğin, atlarda MSC'ler askı bağ yaralanmalarını ve kıkırdak dejenerasyonunu tedavi etmek için sıklıkla

kullanılmakta, iyileşme sürelerini önemli ölçüde azaltmakta ve sonuçları iyileştirmektedir. Benzer şekilde, köpek ve kedilerde, osteoartrit için MSC'lerin intraartiküler enjeksiyonları, inflamasyonu azaltma, eklem hareketliliğini artırma ve hastalığın ilerlemesini yavaşlatma konusunda umut verici sonuçlar göstermiştir (Raza et al., 2024).

Nörolojik Bozukluklar

Kök hücrelerin nörolojik bozuklukları ele alma potansiyeli, veteriner hekimlikte giderek artan bir ilgi alanıdır. MSC'ler ve nöral kök hücreler, omurilik yaralanmalarında rejenerasyonu teşvik etme ve nörodejeneratif hastalıkların etkilerini hafifletme yetenekleri açısından araştırılmaktadır. Hayvan modellerinde, bu tedavilerin motor fonksiyonları iyileştirdiği ve yaralanma bölgelerinde skarlaşmayı azalttığı görülmüştür. Veterinerlik uygulamaları, kök hücre temelli tedavilerin geleneksel cerrahi müdahalelere bir alternatif sağlayabileceği köpeklerde intervertebral disk hastalığı gibi durumları içerecek şekilde genişlemektedir (Chernigova et al., 2024).

.Dahili Tıp Uygulamaları

Kök hücreler aynı zamanda karaciğer hastalığı, kronik böbrek hastalığı ve kalp rahatsızlıkları gibi kronik iç hastalıkların tedavisinde de ilerleme kaydetmektedir. Kedilerde yaygın olan kronik böbrek hastalığı vakalarında, kök hücre tedavisi hasarlı böbrek dokusunu yenileme ve iltihaplanmayı azaltma yeteneği açısından incelenmektedir. Benzer şekilde, MSC'ler doku onarımını teşvik ederek ve bağışıklık tepkilerini modüle ederek karaciğer fibrozisi ve kalp rahatsızlıklarının tedavisinde umut vaat etmektedir. Bu uygulamalar, kronik hastalıkları olan hayvanların yaşam kalitesini iyileştirmek ve yaşam sürelerini uzatmak için umut veriyor (Chernigova et al., 2024).

Yara İyileşmesi ve Cilt Rejenerasyonu

Kök hücrelerin yara iyileşmesini artırma ve cilt yenilenmesini teşvik etme yeteneği, veterinerlik tıbbında bir başka hayati uygulamadır. Kök hücreler hem küçük hem de büyük hayvanlarda yanık, laserasyon ve diğer deri yaralanmalarını tedavi etmek için kullanılmaktadır. Parakrin sinyal mekanizmaları anjiyogenezi, kolajen üretimini ve epitelizasyonu uyararak iyileşme sürecini hızlandırır. At tıbbında, kök hücre tedavileri özellikle büyük, iyileşmeyen yaraların yönetiminde, enfeksiyon risklerinin azaltılmasında ve kozmetik ve fonksiyonel sonuçların iyileştirilmesinde başarılı olmuştur (Lin et al., 2024).

Kök hücre uygulamaları, çeşitli hayvan türlerinde geniş bir yelpazedeki koşulları ele alarak veterinerlik tıbbında devrim yaratmaya devam etmekte, sağlık sonuçlarını ve genel refahı iyileştiren gelişmiş terapötik seçenekler sunmaktadır.

Hayvanlar için Kök Hücre Araştırmalarında Gelişmeler

Çeşitli Türler için Kök Hücre Bankalarının Geliştirilmesi

Kök hücre bankalarının kurulması, veterinerlik tıbbında önemli bir ilerlemeyi temsil etmekte, tedavi ve araştırma amaçlı güvenilir bir yüksek kaliteli kök hücre kaynağı sunmaktadır. Bu bankalar köpekler, kediler, atlar ve sığırlar dahil olmak üzere çeşitli türlerden kök hücreleri depolayarak veteriner hekimlerin çok çeşitli koşullar için özel tedavilere erişmesini sağlar. Kriyoprezervasyon teknikleri, kök hücrelerin güçlerini kaybetmeden uzun süreler boyunca saklanmasına olanak tanıyarak klinik kullanım için anında kullanılabilirlik sağlar. Örneğin, kök

hücre bankaları, optimal sonuçlar için zamanında müdahalenin çok önemli olduğu at tıbbında akut yaralanmaların yönetimi için çok değerlidir (Abbas et al., 2023).

Yaban Hayatı Koruma ve Egzotik Hayvan Bakımında Kök Hücre Kullanımı

Kök hücre araştırmaları, yaban hayatının korunması ve egzotik hayvanların bakımı için giderek daha fazla uygulanmaktadır. Kök hücrelerin rejeneratif potansiyeli, geleneksel tıbbi seçeneklerin sınırlı olabileceği nesli tükenmekte olan türlerdeki yaralanma ve hastalıkların tedavisi için yeni bir umut sunuyor. Örneğin, dejeneratif eklem hastalıklarından muzdarip çitalarda doku hasarını onarmak veya nesli kritik derecede tehlike altında olan amfibilerde üremeyi desteklemek için kök hücre tedavileri araştırılmaktadır. Ayrıca, kök hücreler hastalıklara dirençli doku ve organlar geliştirmek için kullanılmakta ve bulaşıcı hastalıklar veya çevresel değişiklikler tarafından tehdit edilen türlerin hayatta kalma olasılıklarını artırmaktadır (Kimura et al., 2024).

Tedaviyi Geliştirmek için Genetik Düzenleme Araçlarının Entegrasyonu

CRISPR-Cas9 gibi gelişmiş genetik düzenleme araçlarının kök hücre araştırmalarıyla entegrasyonu, veterinerlik tıbbında benzeri görülmemiş fırsatların önünü açıyor. Araştırmacılar, kök hücrelerin genetik yapısını hassas bir şekilde değiştirerek, terapötik etkinliklerini ve güvenliklerini artırabilirler. Örneğin, genetik düzenleme, belirli hastalıklara dirençli kök hücreler oluşturabilir veya hasarlı dokuları onarma yeteneklerini geliştirebilir. Çiftlik hayvanlarında bu teknolojiler, hastalıklara dirençli ırklar geliştirmek veya üretkenliği etkileyen genetik bozuklukları düzeltmek için kullanılabilir. Ayrıca, genetik düzenleme ve kök hücrelerin kombinasyonu, klonlama ve türlerin korunmasındaki uygulamalar için araştırılmakta ve hem evcil hem de vahşi hayvan bakımındaki faydasını daha da genişletmektedir (El-Husseiny et al., 2022).

Kök hücre araştırmalarındaki bu ilerlemeler veterinerlik tıbbında devrim yaratarak hayvan sağlığı, korunması ve refahı için yenilikçi çözümler sunmaktadır. Teknolojiler gelişmeye devam ettikçe, kök hücrelerin veterinerlik bilimindeki potansiyel uygulamalarının genişlemesi ve hayvan refahını ve ekolojik dengeyi iyileştirmek için yeni olanaklar sunması muhtemeldir.

Etik ve Pratik Hususlar

Hayvanlardan Kök Hücre Temini ve İzolasyonunda Karşılaşılan Zorluklar

Veterinerlikte kullanım için kök hücrelerin elde edilmesi, özellikle kaynak bulma ve izolasyonla ilgili özel zorluklar içerir. Hayvanlardan embriyonik kök hücrelerin (ESC'ler) toplanması, embriyoların tahrip edilmesi nedeniyle etik kaygıları gündeme getirmektedir ve bu durum veterinerlik veya kamu bağlamlarında yaygın olarak kabul görmeyebilir. Ayrıca, mezenkimal kök hücreler (MSC'ler) gibi yetişkin kök hücrelerin kemik iliği veya yağ dokusu gibi dokulardan izole edilmesi, donör hayvanlarda rahatsızlığa veya risklere neden olabilecek invaziv prosedürler gerektirir. Hücre verimi ve gücündeki değişkenlik terapötik sonuçları etkileyebileceğinden, izole edilen hücrelerin kalitesini ve tutarlılığını sağlamak da teknik engeller oluşturmaktadır (Millar, 2011).

.Veterinerlik Uygulamalarında Düzenleyici Gözetim

Kök hücre tedavilerinin veterinerlik tıbbında uygulanması, ilgili bölgeye ve türe bağlı olarak değişen derecelerde düzenleyici denetime tabidir. Amerika Birleşik Devletleri'ndeki FDA gibi düzenleyici kurumlar, kök hücre ürünlerinin hayvanlarda güvenliğini, etkinliğini ve etik

kullanımını sağlamak için kılavuzlar sağlamaktadır. Bununla birlikte, kök hücre biliminin gelişen doğası, mevcut düzenlemelerde boşluklar yaratmakta ve doğrulanmamış veya yetersiz izlenen tedavilerden kaynaklanan potansiyel risklere yol açmaktadır. Veteriner hekimler, hayvan refahını korurken tedavilerin belirlenmiş standartlara uygun olmasını sağlamak için bu düzenlemeleri dikkatle takip etmelidir (Mertz et al., 2024).

İnovasyon ile Refah ve Etik Kaygıların Dengelenmesi

Kök hücre araştırmaları büyük umut vaat etse de, bu araştırmaların gelişimi etik hususlar ve hayvan refahı ile dengelenmelidir. Özellikle araştırmanın ilk aşamalarında hayvanlar üzerinde deneysel tedavilerin kullanılması, potansiyel yan etkiler ve öngörülemeyen komplikasyonlar konusunda endişelere yol açmaktadır. Kök hücrelerin hem toplanması hem de uygulanması sırasında insancıl muamelenin sağlanması ve rahatsızlığın en aza indirilmesi çok önemlidir. Ayrıca, kök hücre ürünlerinin ticarileştirilmesiyle ilgili etik sorular ortaya çıkmaktadır, çünkü erişilebilirlik bu gelişmiş tedavileri karşılayabilecek mal sahipleri veya endüstrilerle sınırlı olabilir. Etik çerçevelere ve şeffaflığa öncelik vererek, veterinerlik alanı güven ve sorumluluğu korurken kök hücre yeniliklerini ilerletebilir (Mertz et al., 2024).

Bu hususları ele alırken, veteriner hekimler ve araştırmacılar etik uygulamaları teşvik etmede, düzenlemelere bağlı kalmada ve kök hücre tedavilerinin faydalarının hayvan refahından veya kamu güveninden ödün vermeden gerçekleştirilmesini sağlamada kilit bir rol oynamaktadır.

Vaka Çalışmaları ve Başarı Hikayeleri

Refakatçi Hayvanlarda ve Çiftlik Hayvanlarında Kök Hücre Tedavilerine Örnekler

Kök hücre tedavisi, köpekler, kediler ve atlar gibi evcil hayvanların yanı sıra çiftlik hayvanlarında da çeşitli durumların tedavisinde kayda değer başarılara yol açmıştır. Köpeklerde, adipoz dokudan elde edilen kök hücreler osteoartriti yönetmek için etkili bir şekilde kullanılmıştır. Örneğin, çalışmalar eklem içi MSC enjeksiyonlarından sonra hareketlilikte önemli gelişmeler ve ağrı skorlarında azalmalar olduğunu göstermektedir. Kronik böbrek hastalığı olan kediler de kök hücre tedavilerinden faydalanmış, inflamasyonda kayda değer azalmalar ve böbrek fonksiyonlarında iyileşmeler görülmüştür (Ikudayisi, 2024).

Çiftlik hayvanlarında kök hücre tedavileri, süt sığırlarında tendon ve bağ yaralanmalarını yönetmek ve dişi domuzlarda üreme bozukluklarını ele almak için araçlar olarak ortaya çıkmaktadır. Bu uygulamalar yalnızca üretkenliği artırmakla kalmaz, aynı zamanda aksi takdirde kronik veya zayıflatıcı koşullara rejeneratif çözümler sağlayarak hayvan refahını da teşvik eder (Lanci et al., 2024).

Sonuçlar ve Devam Eden Klinik Çalışmalar

Çok sayıda klinik çalışma, veteriner hekimlikte kök hücre tedavilerinin potansiyelini keşfetmeye devam etmektedir. Örneğin, atların askı bağ yaralanmaları üzerine devam eden araştırmalar, kök hücre tedavilerinin uzun vadeli etkinliğini değerlendirmekte olup, hızlandırılmış iyileşme ve azaltılmış nüks oranlarında umut verici sonuçlar göstermektedir. Benzer şekilde, intervertebral disk hastalığı olan köpekler için MSC tabanlı tedaviler, sinir rejenerasyonu ve fonksiyonel iyileşme üzerindeki etkilerini değerlendirmek için incelenmektedir (Reis et al., 2024).

Bu tedavilerin sonuçları, özellikle yaşam kalitesini iyileştirme ve geleneksel ilaçlara bağımlılığı azaltma konusunda genellikle yüksek başarı oranları göstermektedir. Bununla birlikte, kök hücre uygulamalarının uzun vadeli güvenliği ve etkinliği aktif bir araştırma alanı olmaya devam

etmektedir. Veteriner hekimler ve araştırmacılar arasındaki işbirliği çabaları, kök hücre temelli veteriner bakımında yeni atılımların önünü açarak sürekli ilerlemeler sağlamaktadır.

Veterinerlik alanı, bu vakaları ve klinik sonuçları belgeleyerek, kök hücrelerin hayvan sağlığı ve refahını iyileştirmedeki dönüştürücü potansiyelinin altını çizen ikna edici bir kanıtlar bütünü oluşturmaktadır.

Veteriner Kök Hücre Tedavisindeki Zorluklar

Evcil Hayvan Sahipleri ve Çiftçiler için Yüksek Maliyetler ve Erişilebilirlik

Veteriner hekimlikte kök hücre tedavilerinin yaygın olarak benimsenmesinin önündeki başlıca engellerden biri yüksek maliyettir. Kök hücrelerin tedarik edilmesi, izole edilmesi ve genişletilmesi süreçleri, özel uygulama teknikleriyle birleştiğinde bu tedavileri pahalı hale getirmektedir. Refakatçi hayvanlar için, birçok evcil hayvan sahibi, özellikle tekrarlanan müdahaleler gerektiren kronik veya karmaşık durumlar için maliyeti engelleyici bulabilir. Ekonomik uygulanabilirliğin genellikle sağlık hizmeti kararlarını belirlediği hayvancılık ve çiftlik ortamlarında, bu tür tedaviler potansiyel faydalarına rağmen maliyet etkin olarak değerlendirilmeyebilir. Bu durum, özellikle kırsal veya düşük kaynaklara sahip bölgelerde erişilebilirliği ve benimsenmeyi sınırlamaktadır (Moreira et al., 2024).

Türler ve Bireyler Arasında Tepkilerin Değişkenliği

Bir diğer önemli zorluk ise farklı türlerin ve tek tek hayvanların kök hücre tedavilerine nasıl yanıt verdiğinin değişkenlik göstermesidir. Türe özgü fizyoloji, kök hücrelerin kaynağı ve tedavi edilen durumun doğası gibi faktörlerin tümü terapötik sonuçları etkileyebilir. Örneğin, mezenkimal kök hücreler (MSC'ler) köpek osteoartritinin tedavisinde umut verici sonuçlar gösterirken, kediler veya atlardaki benzer uygulamalar daha az öngörülebilir sonuçlar verebilir. Bu değişkenlik, tedavi protokollerini optimize etmek ve terapötik etkinliği tahmin etmek için daha hedefli ve türe özgü araştırmalara duyulan ihtiyacın altını çizmektedir (Liu et al., 2024).

Standartlaştırılmış Protokollere ve Uzun Vadeli Çalışmalara Olan İhtiyaç

Veteriner kök hücre tedavisinde standartlaştırılmış protokollerin olmaması kritik bir zorluk teşkil etmektedir. Kök hücre tedariki, işlenmesi ve uygulanmasındaki farklılıklar tutarsız sonuçlara yol açabilir ve çalışmalar arasında sonuçların karşılaştırılmasını zorlaştırabilir. Dahası, bu alanda kök hücre tedavilerinin dayanıklılığını ve güvenliğini değerlendirecek yeterli sayıda uzun vadeli çalışma bulunmamaktadır. Özellikle embriyonik veya indüklenmiş pluripotent kök hücrelerde (iPSC'ler) tümör oluşumu veya immün reaksiyonlar gibi potansiyel yan etkilere ilişkin sorular devam etmektedir. Standartlaştırılmış protokoller geliştirmek ve bunlara bağlı kalmak ve uzunlamasına araştırmalar yürütmek, bu endişeleri gidermek ve bu alanda güven oluşturmak için gereklidir (Nicpoń & Zielińska, 2020).

Veterinerlik alanı, bu zorlukların üstesinden gelerek kök hücre tedavilerinin geliştirilmesini ve erişilebilirliğini ilerletebilir, faydalarının yaygın olarak bulunmasını ve etkili bir şekilde gerçekleştirilmesini sağlayabilir.

Veterinerlik Kök Hücre Araştırmalarında Gelecek Yönelimler

Rejeneratif Tarım Uygulamalarında Kök Hücre Kullanımı

Kök hücre teknolojilerinin rejeneratif tarıma entegrasyonu, tarımda sürdürülebilirliğin iyileştirilmesi için önemli bir umut vaat etmektedir. Kök hücreler, hasarlı dokuları yenileyerek veya kronik hastalıkların etkilerini hafifleterek çiftlik hayvanlarının sağlığını ve üretkenliğini artırmak için kullanılabilir. Örneğin, kök hücre temelli tedaviler süt sığırlarında kas-iskelet sistemi yaralanmalarını onarmak veya yetiştirme programlarında doğurganlığı artırmak için kullanılabilir. Bu tür uygulamalar antibiyotiklere ve diğer ilaçlara olan bağımlılığı azaltabilir, küresel gıda güvenliği sorunlarını ele alırken daha sürdürülebilir ve etik tarım uygulamalarına katkıda bulunabilir (Romanek et al., 2023).

Hayvanlarda Transplantasyon için Laboratuvarda Yetiştirilen Organlardaki Gelişmeler

Çığır açan bir araştırma alanı, veterinerlik uygulamaları için laboratuvarda yetiştirilen organların geliştirilmesini içeriyor. Bilim insanları kök hücreleri kullanarak böbrek, karaciğer ve kalp dokuları gibi organların belirli hayvan türlerine göre biyomühendislikle üretilmesi olasılığını araştırıyor. Bu gelişmeler, organ yetmezliği olan hayvanlar için tedavi seçeneklerinde devrim yaratabilir ve donör hayvanlara ihtiyaç duymadan hayat kurtaran çözümler sunabilir. Henüz ilk aşamalarında olsa da bu araştırma, refakatçi hayvanların yaşamlarını önemli ölçüde uzatma ve çiftlik hayvanlarının sağlığını ve verimliliğini artırma potansiyeline sahiptir (Roberts, 2023).

İnsan ve Veteriner Hekimliğini Bütünleştiren Tek Sağlık Girişimleri Potansiyeli

"Tek Sağlık" yaklaşımı insan, hayvan ve çevre sağlığının birbiriyle bağlantılı olduğunu kabul eder. Veterinerlik tıbbındaki kök hücre araştırmaları, türler arasında aktarılabilir bilgiler sağlayarak bu çerçevede önemli bir rol oynayabilir. Örneğin, hayvanlar için geliştirilen tedaviler, osteoartrit veya nörolojik bozukluklar gibi benzer durumlar için insan tıbbi tedavilerini bilgilendirebilir. Benzer şekilde, yaban hayatının korunmasında kök hücre uygulamalarının incelenmesi biyoçeşitliliği artırabilir ve dolaylı olarak insanların dayandığı ekosistemlere fayda sağlayabilir. Veterinerlik ve insan tıbbı araştırmacıları arasındaki ortak çabalar muhtemelen ilerlemeleri hızlandıracak ve her iki alana da fayda sağlayacaktır (Lee et al., 2023).

Veteriner kök hücre araştırmaları, gelecekteki bu yönelimleri takip ederek hayvan sağlığı, tarımsal sürdürülebilirlik ve küresel tıp alanlarındaki acil zorlukları ele alma ve önümüzdeki yıllar için yenilikçi çözümler üretme potansiyeline sahiptir.

Sonuç

Veteriner hekimlikte kök hücre tedavisi, hayvan bakımını dönüştürme potansiyelini ortaya koyarak dikkate değer adımlar atmıştır. Ortopedik ve nörolojik hastalıklar için rejeneratif çözümlerden yara iyileşmesi ve dahili tıpta çığır açan uygulamalara kadar, kök hücreler hayvan sağlığı ve refahını iyileştirmede çok yönlü bir araç olarak ortaya çıkmıştır. Dahası, kök hücre bankacılığı, laboratuvarda yetiştirilen organlar ve genetik düzenleme alanındaki ilerlemeler, olasılıkların kapsamını genişleterek bu alan için parlak bir geleceğin sinyallerini vermektedir.

Bununla birlikte, tedavi sonuçlarındaki değişkenlik, standartlaştırılmış protokollere duyulan ihtiyaç ve kök hücre tedariki ve uygulamasındaki etik hususlar gibi zorlukların ele alınması için araştırmaların sürdürülmesi şarttır. İnovasyonu sorumlu uygulamalarla dengelemek, kök hücre tedavilerinin güvenli, etkili ve daha geniş bir hayvan yelpazesi ve bakıcıları için erişilebilir kalmasını sağlamak için kritik öneme sahip olacaktır.

Veteriner hekimliği için vizyon, kök hücrelerin tedavi alanında devrim yarattığı, daha sağlıklı hayvanları ve daha sürdürülebilir çiftçilik uygulamalarını teşvik ederken Tek Sağlık girişimleri aracılığıyla daha geniş bilimsel anlayışa katkıda bulunduğu bir vizyondur. Devam eden araştırma ve işbirliğiyle, kök hücrelerin hayvan sağlığını yeniden şekillendirme potansiyeli sınırsızdır ve daha şefkatli ve bilimsel olarak gelişmiş bir gelecek için umut vermektedir.

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THEORETICAL INVESTIGATION OF STRUCTURAL, ELASTIC AND ELECTRONIC PROPERTIES OF $AuCu_3$ TYPE XIn_3 (X= Sc, Pt, and Lu) COMPOUNDS: FIRST-PRINCIPLES CALCULATION

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ABSTRACT

We have studied the structural, elastic and electronic properties of XIn_3 (X: Sc, Pt and Lu) by using density functional theory, the planewave pseudopotential method within the local density approximation (LDA) and strain-stress method. $ScIn_3$ and $LuIn_3$ compounds have mechanical stability according to obtained elastic constants, and therefore, they are mechanically stable in their cubic $AuCu_3$-type crystal structure. However, the $PtIn_3$ compound has no mechanical stability according to obtained elastic constants, and therefore, $PtIn_3$ is not mechanically stable in the cubic $AuCu_3$-type crystal structure.

The lattice parameters of $ScIn_3$ (4.394 Å), $PtIn_3$ (4.303 Å), and $LuIn_3$ (4.460 Å) are in very good agreement with the experimental values of 4.479 Å, 4.44 Å, and 4.57 Å, respectively. It has been seen that the value of C_{11} is greater than the value of C_{44} for $ScIn_3$ and $LuIn_3$ compounds, signaling that these compounds present a weaker resistance to pure shear deformation compared to resistance to unidirectional compression. However, the C_{44} and E_H values for $PtIn_3$ are negative, so the $PtIn_3$ compound is predicted to be brittle. $ScIn_3$ and $LuIn_3$ compounds are ductile according to the Poisson's ratio (σ), the ratio of B_H/G_H and the Cauchy pressure (C_P). The mechanical properties obtained from elastic constants of studied compounds have been investigated and discussed in detail.

The electronic properties indicate that the In 5p states of XIn_3 (X: Sc, Pt and Lu) play a significant role in the electronic density of states near the Fermi level. In addition, for the compound $ScIn_3$, the most significant contribution to $N(E_F)$ came from the Sc 3d, In 5p, In 5s, and Sc 4s orbitals, respectively. For the compound $PtIn_3$, the greatest contribution to $N(E_F)$ came from the In 5p, In 5s, Pt 5d, and Pt 6p orbitals, respectively. For the compound $LuIn_3$, the most important contribution to $N(E_F)$ came from the In 5p, Lu 5d, In 5s, and Lu 6s orbitals, respectively. The calculated electronic structure and density of states results reveal that all compounds have metallic properties and are mainly composed of In 5p, X d, and In 5s states.

Key Words: Density-functional theory, first principles calculation, structural properties, elastic properties, mechanical properties, electronic properties.

THE ROLE OF ADVANCED TREATMENT IN BORON REMOVAL: CASE STUDY ON PLANT RESPONSES

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ABSTRACT

Introduction and Purpose: Boron is widely found in water and soil, although its average concentration remains relatively low. While the concentration of boron in the Earth's crust reaches up to 10 mg/L, it ranges from only 0.01 to 1.5 mg/L in water resources. However, concentrations can significantly increase in regions where boron is mined (Wolska & Bryjak, 2013). Turkey holds the largest boron reserves in the world. Furthermore, boron is classified as a critical element, and its extraction holds strategic importance. On the other hand, advanced treatment technologies are required for boron removal due to its very small ionic radius. The objective of this study is to assess the need for advanced treatment methods to address potential high concentrations of boron in surface waters and to investigate its effects on plants.

Materials and Methods: The efficiency of advanced membrane technologies for boron removal was investigated. On the other hand, two plant species commonly grown in Turkey were selected for the case study: thyme and mint. The seedlings of these plants with the same size were obtained from local vendors. Boron solutions of 0, 3, 5, 7 and 10 mg/L were prepared using drinking water and boric acid salt, respectively. Each plant seedling was immersed in 300 mL of boron solution. Water samples were taken on the starting day and on different days and boron concentrations were measured with inductively coupled plasma-optical emission spectrometry (ICP-OES). At the end of 14 days, the experimental study was stopped and samples were taken from the leaves and roots of the plants. While chlorophyll measurements were made on plant leaves, the roots of thyme with a fine root structure were stained with Syto-9 and propidium iodide dyes and examined under a confocal laser scanning microscope (CLSM).

Results: No significant boron removal was observed in the water samples collected over the 14-day period. Conversely, the plant leaves exhibited a rapid loss of their green color, accompanied by a reduction in chlorophyll content. According to the results obtained from CLSM, the number of dead cells in the roots increased after 14 days, and significant deterioration in cell structures was observed (Fig. 1).

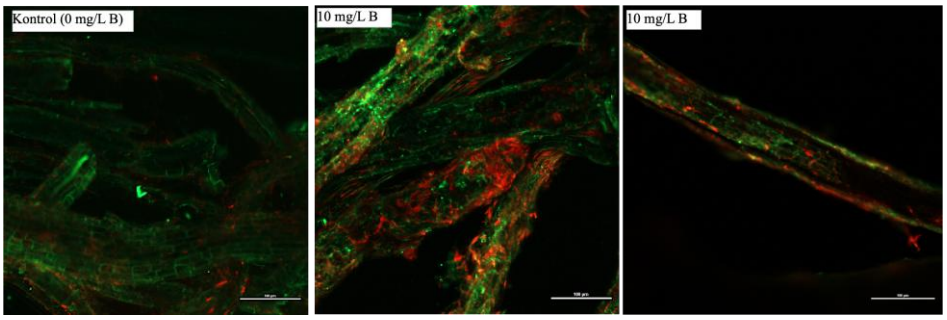

Figure 1. CLSM image of thyme roots after 14 days.

Discussion and Conclusion: The results of the study indicated that elevated boron concentrations in aquatic environments have a direct toxic effect on plants. Therefore, it has been determined that advanced membrane technologies, such as reverse osmosis, are necessary for surface water sources where boron concentrations are increasing. Additionally, given the growing use of boron in cleaning and personal care products, an increase in boron concentrations in surface waters may occur due to the inability of existing wastewater treatment plants to effectively remove boron. In such cases, the demand for advanced treatment technologies for boron removal will likely rise.

Keywords: Boron removal; Advanced Treatment; Membrane Treatment; Toxicology

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AVALABILITY OF CAROTENOIDS FROM ANIMAL ORIGIN FOODS

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ABSTRACT

Carotenoids are a group of fat-soluble pigments that are biosynthesized by photosynthetic organisms such as cyanobacteria, plants and algae and also by some fungi and bacteria that can not perform photosynthesis. They are responsible for the purple, orange, yellow and red color of many foods. Besides boosting the immune system, they reduce the risks of degenerative disesases and also certain cancers such as prostate, ovarian breast and cervical. They are known as beauty promoters of human skin and so they are used as biological additive in cosmetics. Carotenoids comprise of more than 700 compounds some of which are lutein, astaxanthin, lycopene and α-carotene. Fruits and vegetables are known as the main sources of carotenoids whereas animal sources also comprise many functional carotenoids. Animals can not synthesize carotenoids and so animal carotenoids occur as a result of accumulation from their diet and as a result of modifications through metabolic reactions. Eggs are one of the most consumed animal origin food in the worldwide. Egg yolk comprise many biologically active carotenoids. Modifications and enrichments in the diet of laying hens effects the carotenoid profile of these egg yolks. Some types of carotenoids are added as commercial additive product to feed of animals. These carotenoids can be detected in different parts of animals such as muscle tissue, liver, subcutaneous fat etc. in different quantities. Carotenoids are sensitive compounds so cooking, heating, light exposure may lead degradations.

Keywords: Carotenoid, pigment, animal-origin, plant-origin, fat-soluble.

INTRODUCTION

Carotenoids are fat-soluble pigments that contain many double bonds in their structure. They have various color features due to their conjugated bonds. At least seven conjugated double bonds are necessary for a specific color composition. Carotenoids are responsible for the red, yellow and orange color of the foods. The intensity of the color rises with the number of conjugated bonds. Lycopene, which is one of strongest antioxidant carotenoids, gives red color to food, contains eleven conjugated double bonds whereas phytoene, that is colorless has only five conjugated double bonds (Turkcan & Okmen, 2012). Carotenoids can be synthesized by plants and some microorganisms. They have many vital functional roles such as photoprotection and photosynthesis in plants. Carotenoids also supply precursors for plant hormones such as strigolactones and abscisic acid (Sun et al., 2022). Human and animals can not synthesize these multifunctional compounds and so their proven chronic disease prevention makes them essential for a healthy diet. Carotenoids are secondary metabolites of plants and they have protective effects against various conditions such as temperature alterations, drought, bacterial and also fungal stresses (Swapnil et al., 2021). Plastids are the major locations in the plant cells for the

biosynthesis and accumulation. Amyloplasts are primarily located in the tubers, roots and seeds of plants and they are the main storage space for starch granules. Lutein, violaxanthin and zeaxanthin can accumulated in these plastids. Chloroplasts are the center of photosynthesis. β-carotene, lutein, neoxanthin and violaxanthin accumulate in comparatively large amounts in chloroplasts. In etioplasts that are mostly found in dark-grown tissues comprise many kinds of carotenoids mainly violaxanthin and lutein (Park et al., 2002; Lopez et al., 2008). These biologically active compounds have antioxidant properties and so they are able to prevent and minimize the symptoms of several diseases some of which are Alzheimer, cancer, diabetes, hypertension and obesity (Bhatt & Patel, 2020). Free radicals and reactive molecules that are derived from oxygen that are called reactive oxygen species (ROS), are necessary for some vital physiological functions and redox homeostasis etc. in the body whereas excessive ROS production in human body causes oxidative stress and ROS leads serious damages in DNA, membranes and proteins. Chronic and degenerative diseases and also aging process are the results of these damages (Jomova et al., 2023). Unhealthy meals, lack of physical activity, medication, water and air pollution, alcohol intake, smoking, radiation, negative lifestyles induce more and more reactive oxygen species Human body has its own endogenous antioxidants besides exogenous antioxidants that people get in their diet are crucial for counteracting oxidative stress that is created by reactive oxygen species (Pham-Huy et al., 2008). Adequate consumption of foods rich in carotenoids is highly related with prevention of several disorders such as cardiovascular diseases, several types of cancer, eye-related diseases etc. (Khoo et al., 2019). These bioactive pigments are multifunctional compounds for medical sector, food and feed industries (Patel et al., 2022). Carotenoids can be divided into two groups according to their vitamin A conversion property. α-carotene, β-carotene and β-cryptoxanthin are known as provitamin A carotenoids, that means they can be converted to vitamin A (retinol) enzymatically. Lycopene, lutein and zeaxanthin are some of non-provitamin A carotenoids.

Due to photosynthetic nature of fruit and vegetables, they are the major sources of carotenoids. Among plant-derived foods fruits, vegetables, cereals, legumes and then herbs are known to be rich in carotenoids, respectively. Animal-origin foods are not assumed as good sources of carotenoids whereas their bioavailability can be higher in many animal products. Different plant and animal based sources and their biological availability will be discussed in detail.

Carotenoid Content of Plant-Origin Food

Phototrophic bacteria, algae and plants are the good sources of carotenoids due to their photosynthesis function. They have vital roles in plants some of which are harvesting light for photosynthesis, preventing formation of reactive oxygen species, attracting insects for seed dispersal and pollination through their attractive colors in fruits and flower parts of plants (Alcaino et al., 2016). Pumpkin, sweet potatoes, apricots, leafy vegetables such as spinach, broccoli and carrots are good sources of beta-carotene. Beta- carotene and other carotenoids can also protect skin against UV-induced damages. Sun protection of beta- carotene and lycopene is not as high as a topical sunscreen that applied on directly to skin but dietary carotenoid intake enhances the dermal defense against UV-irradiation (Stahl & Sies et al., 2012). Leafy vegetables are also rich sources of some other kind of carotenoids such as zeaxanthin, lutein, alpha-carotene, violaxanthin and neoxanthin. Tomato and tomato products are the richest source of lycopene. Depending on the variety, the lycopene amount of tomato may be up to 4,2 mg/ 100 g. Processed tomato products such as ketchup and tomato sauce contain higher amounts of lycopene than raw tomatoes due to concentration during processing (Palozza et al., 2011). Lycopene is known as the strongest antioxidant among carotenoids in terms of singlet oxygen quenching ability. Antioxidant effect of lycopene is ten times greater than that of alpha-tocopherol and twice that of beta-carotene. Lycopene is rather stable during food processing whereas very long heating times and very high temperatures may affect it (Shi et al., 2008). Tomato processing by-products

such as tomato seeds and skin, tomato pomace can also contain high amounts of lycopene and beta-carotene. Neoxanthin and violaxanthin were reported to exist in the leaves of higher plants. However these carotenoids are unavailable commercially. They are mostly expected to be produced by heterologous microorganisms through metabolic pathway engineering. Some other carotenoids such as zeaxanthin, lutein, lycopene, beta carotene reported to be present in the blood serum of human whereas antheraxanthin and violaxanthin are not present in the serum (Takemura et al., 2021). Zeaxanthin and lutein are marked by ocular antioxidant characteristics. Both of these carotenoids are reported to lower risk of developing cataracts and age-related macular degeneration (Basu et al., 2001). Leafy vegetables like spinach, lettuce, parsley, kale, broccoli etc., durum wheat, corn and egg yolk are high in lutein and zeaxanthin.

Carotenoid Content of Animal-Origin Food

Vegetables and fruits are still the main sources of carotenoids whereas various livestock products also contain noteworthy amounts of them as a result of ingestion. Milk, eggs, meat include appropriate amounts of carotenoids. Fish and shellfish are rich in some carotenoids. Feed is the key factor for the deposition of carotenoids in livestock products. Carotenoids in the feedstuff are released and exposed to a number of metabolic reactions in the digestive system of animal and finally transferred to bloodstream followingly accumulate in the tissues and organs of animal. Although not being primary source for carotenoids, livestock products provide better stability and higher bioavailability for these phytochemicals because of their unique fat composition in their structure (Conboy Stephenson et al., 2021).

Carotenoid additives in poultry and livestock diets are commonly applied. Lutein, astaxanthin, beta-carotene and canthaxanthin are the most added carotenoids in feedstuff. Besides, vegetable and fruit by-products are evaluated in livestock and poultry diets. Al-Wandawi et al. (1985) reported that tomato by-products including peels and seeds make up about 10-40 % of all processed tomatoes Lutein, lycopene and beta-carotene can be extracted via hexane, ethanol and ethyl acetate from various tomato industrial wastes such as tomato pomace, seeds, skin etc.

The effects of various carotenoid supplemented feedstuff to eggs, milk, meat and liver that come from various animal species were reported in literature. Orhan et al. (2021) reported lycopene amount of egg yolk as 2,40 μg/g that comes from laying hens fed with 20 mg/kg lycopene added feedstuff, as commercial additive product, for 90 days. Hammershoj et al. (2010) claimed α-Carotene egg yolk as 1,29 μg/g that comes from laying hens fed with purple haze carrots that chopped into 5 to 10 mm pieces providing 4,63 mg/day α-Carotene per hen, for 90 days. They reported the α-Carotene content of egg yolk 0,01 μg/g for control group. Muramoto et al. (2003) searched about the β-carotene content of meat comes from steers which fed with 750 mg/day of β-carotene for per steer for 28 days. β-carotene content of control group was reported to be 0,023 μg/g whereas meat from steers fed with feedstuff that supplemented with commercial additive product was 0,154 μg/g. Akiba et al. (2001) searched about the effects of 15 and 30 mg/kg astaxanthin in feed of chickens for 21 days. Meat from these chickens determined to be contain 0,17 and 0,20 μg/g astaxanthin, respectively in pectoralis major muscles. Xu et al. (2014) added marigold extract containing about 2 % lutein to diet of cows in the form of 2,3 and 4 g/day of lutein for per cow for 84 days. Bovine milk determined to be contain 7,0; 12 and 15.0 μg/L lutein. The control group reported to be contain 5,9 μg/L in this study.

Carotenoids are also used as naturally derived colorants. Low cost and high stability of synthetic food colorants make them unique for many processed food. Consumers tend to pay for more natural foodstuff due to health concerns about processed foods. Turmeric, saffron and paprika are the best-known sources of natural food coloring substances. High amounts of capsilutein, capsorubin, violaxanthin and zeaxanthin are found in paprika. It is frequently used in snacks,

soups, meat products and pickles owing to its yellow, orange and red colors (Sigurdson et al., 2017).

Colostrum, the mammary glands' first secretion after giving birth, has the highest concentration of carotenoids among other foods. It has a deep yellow color due to its high carotenoid content. After the third week of breastfeeding, the color of milk turn white due to lower amount of carotenoids compared to foremilk. Mature milk has about 4.1 g/100 ml fat content while that of colostrum is about 2.6 g/100 ml. Breast milk, the best nutrition source for the newborn, include zeaxanthin, lutein, α-carotene, β-cryptoxanthin β-carotene and lutein. It is reported that the amount of carotenoids reduces gradually with duration of breastfeeding (Zia-Ul-Haq et al., 2021).

CONCLUSION AND DISCUSSION

Proven health benefits of carotenoids makes them essential for human diet. Scavenging activity for reactive oxygen species, association with reduced risk of some chronic disesases such as diabetes, cardiovascular diseases, obesity etc., protecting eyes against blue light damages are some of health promoting effects of these substances. Fruits and vegetables are known as the primary sources because of their photosynthesis ability. Livestock animals and poultry can deposit carotenoids as a result of carotenoid rich diet. Livestock products, poultry products are gaining more and more attention due to their better bioavailability of various carotenoids. Their stronger adipose tissue and fat content make them sufficient sources of carotenoids. The solubility and availability of carotenoids in plant origin food may also be enhance with fat intake and addition of vegetable oils to human diets accompainied with fruit and vegetable rich diet.

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