İZMİR KÂTİP ÇELEBİ UNIVERSITY

İZMİR Uluslararası Misafir Öğrenci Derneği

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FEDERATION OF INTERNATIONAL STUDENT ASSOCIATIONS
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7th International Students Science Congress

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Preface

Dear Participants, Colleagues, and International Students,

It is a great honor and privilege for us to present the Proceedings Book of the 7th International Students Science Congress to the authors and participants of the event. We hope that you will find it useful, exciting, and inspiring.

In the last six years we organized our congresses in order to bring together young international researchers working in various science areas and this has really motivated all of us. Just like last year, we held our congress in a hybrid format this year. The first day of the congress, May 12, was totally live in-person which gathered more than 200 participants. In the morning of this first day, two intriguing presentations were given by the invited speakers: Assoc. Prof. Dr. Levent Aydın, of İzmir Kâtip Çelebi University, who spoke about the "Transhumanism Posthumanism and Engineering" and Prof. Dr. Çetin Kaya Koç, of Koç Lab, who spoke about the "Cryptography". Face-to-face presentations were made by other participants in the afternoon of the first day. The second day of the event comprised of eight online sessions which were performed over Zoom and livestreamed on YouTube; you may access the videos of these sessions on our Youtube channel. (İzmir Uluslararası Misafir Öğrenci Derneği)

We accomplished the seventh congress again with great enthusiasm. On the two days congress, about two hundred-fifty young researchers and academicians from twenty-eight different countries gathered and a total of eighty-eight papers were presented in sixteen sessions. Forty-eight of the papers were presented live, and forty papers were presented online. On the other hand, forty-seven papers were presented by international (non-Turkish) participants, while forty-one papers were presented by Turkish participants.

The congress particularly encouraged the interaction of international research students and developing academics with the more established academic community in an informal setting to present and to discuss new and current work. Their contributions helped to make the Congress as outstanding as it has been. The Congress provided a setting for discussing recent developments in a wide variety of topics including Agricultural Engineering, Architecture, Biology and Bioengineering, Chemistry and Chemical Engineering, Civil Engineering, Computer Science and Engineering, Electrical, Electronics and Communication Engineering, Energy, Food Engineering, Geology Engineering, Mechanical Engineering, Mathematics, Metallurgical and Materials Engineering, Mechatronics Engineering, Nanotechnology, Physics, Textile engineering, Urban and Regional Planning.

We would like to thank all participants for their contributions to the Congress and for their contributions to these Proceedingss Book. It is our pleasant duty to acknowledge the support from İzmir Kâtip Çelebi University, Federation of International Student Associations (UDEF), The Scientific and Technological Research Council of Türkiye (TÜBİTAK) and our main organizer İzmir International Guest Student Association.

I would like to express my sincere gratitude and appreciation to our organizing committee and all the students who worked voluntarily during the event.

The continuing success of this congress series means that planning can now proceed with confidence for the 8th International Students Science Congress to be held in 2024; probably both online and inperson again.

We thank all authors, participants, and volunteers for their contributions.

Prof. Dr. Mehmet Çevik
Congress Chair

Önsöz

Değerli Katılımcılar, Meslektaşlarım ve Uluslararası Öğrenciler,

7. Uluslararası Öğrenciler Fen Bilimleri Kongresi Tam Metin Kitabını etkinliğin yazarlarına ve katılımcılarına sunmak bizler için büyük bir onur ve ayrıcalıktır. Bunu yararlı, heyecan ve ilham verici bulacağınızı umuyoruz.

Son altı yıldır çeşitli bilim dallarında çalışan genç uluslararası araştırmacıları bir araya getirmek amacıyla kongrelerimizi düzenledik ve bu hepimizi gerçekten motive etti. Geçen yıl olduğu gibi bu yıl da kongremizi hibrid bir şekilde düzenledik. Kongrenin ilk günü olan 12 Mayıs'ta, 200'den fazla katılımcının bir araya geldiği tamamen canlı bir etkinlik gerçekleşti. Bu ilk gün öğleden önce, davetli konuşmacılarımız tarafından iki ilgi çekici sunum yapıldı: İzmir Kâtip Çelebi Üniversitesi'nden Doç. Dr. Levent Aydın "Transhumanism Posthumanism and Engineering" ve Koç Lab'dan Prof. Dr. Çetin Kaya Koç "Cryptography" hakkında konuştular. İlk gün öğleden sonra diğer katılımcılar tarafından yüz yüze sunumlar yapıldı. Etkinliğin ikinci gününde sekiz çevrimiçi oturum Zoom üzerinden gerçekleştirildi ve YouTube üzerinden canlı olarak yayınlandı; bu oturumların videolarına Youtube kanalımızdan ulaşabilirsiniz.

Yedinci kongremizi de yine büyük bir istek ve heyecanla gerçekleştirdik. İki gün süren kongrede, yirmi sekiz farklı ülkeden yaklaşık ikiyüz elli genç araştırmacı ve akademisyen bir araya geldi ve on altı oturumda toplam seksen sekiz bildiri sunuldu. Bildirilerin kırk sekiz tanesi canlı yüz yüze, kırk tanesi ise çevrimiçi olarak sunuldu. Öte yandan, kırk yedi bildiri uluslararası (Türk olmayan) katılımcılar tarafından, kırk bir bildiri ise Türk katılımcılar tarafından sunuldu.

Kongre, özellikle fen bilimleri alanında eğitimlerine devam eden uluslararası öğrencilerin ve genç akademisyenlerin önlerindeki akademik camia ile etkileşimlerini gayet samimi bir ortam sunarak teşvik ederken, yeni ve güncel çalışmalarını sunmaları ve tartışmaları için de güzel bir fırsat sağlamış oldu. Onların katkıları sayesinde Kongre olabildiğince seçkin ve nitelikli bir düzeye ulaşmış oldu. Kongre, Ziraat Mühendisliği, Mimarlık, Biyoloji ve Biyomühendislik, Kimya ve Kimya Mühendisliği, İnşaat Mühendisliği, Bilgisayar Bilimi ve Mühendisliği, Elektrik, Elektronik ve Haberleşme Mühendisliği, Enerji, Gıda Mühendisliği, Jeoloji Mühendisliği, Makine Mühendisliği, Matematik, Metalürji ve Malzeme Mühendisliği, Mekatronik Mühendisliği, Nanoteknoloji, Fizik, Tekstil Mühendisliği, Kentsel ve Bölgesel Planlama, vb. çok çeşitli konulardaki son gelişmeleri tartışmak için keyifli bir ortam sağladı.

Tüm katılımcılara kongremize ve dolayısıyla tam metin kitabımıza yaptıkları katkılardan dolayı teşekkür ederiz. Ayrıca verdikleri destek ile bu kongrenin gerçekleşmesine katkı sağlayan İzmir Kâtip Çelebi Üniversitesi'ne, Uluslararası Öğrenci Dernekleri Federasyonu'na (UDEF), Türkiye Bilimsel ve Teknolojik Araştırma Kurumu'na (TÜBİTAK) ve ana organizatörümüz İzmir Uluslararası Misafir Öğrenci Derneği'ne teşekkürlerimizi arz ederiz.

Organizasyon komitemize ve etkinlik süresince gönüllü olarak çalışan tüm öğrencilere içten şükran ve takdirlerimi sunuyorum.

Bu kongre dizisinin devam eden başarısı, 2024'te düzenlenmeyi hedeflediğimiz 8. Uluslararası Öğrenciler Fen Bilimleri Kongresi için planlamanın artık güvenle ilerleyebileceği anlamına geliyor; bu kongremiz de muhtemelen hem çevrimiçi hem de yüz yüze olacak.

Katkılarından dolayı tüm yazarlara, katılımcılara ve gönüllülere teşekkür ederiz.

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Invited Speakers / Davetli Konuşmacılar

Cryptography

Prof. Dr. Çetin Kaya Koç
Koç Lab

Transhumanism, Posthumanism and Engineering

Assoc. Prof. Dr. Levent Aydın
İzmir Kâtip Çelebi University

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Özet

Suçlunun cezalandırılması durumuna tarihsel süreç içinde hemen her dönemde rastlanmaktadır. Suçun tanımının günden güne değişmesi durumu cezalandırma yöntemlerine de yansıdığından, zamana ve kültüre göre değişiklik gösteren ıslah anlayışı da bu bağlamda mekanları farklı biçimlerde şekillendirebilmektedir. Bu konuda son zamanlarda, mimarinin kullanıcı davranışını yönlendirebilme ve iyileştirebilme etkisi üzerinde durulmakta, bu sebeple tasarımcıların bakış açıları da dikkate alınmaktadır. Hatta bazı ülkelerde bu konudaki önerilerin daha kolektif ve yapıcı bir platform üzerinde toplanması sağlanarak modeller, mimari yarışmalar beraberinde elde edilebilmektedir.

Buradan yola çıkarak, yapılan çalışmada ilk olarak cezaevlerinin, yer yer cezalandırma usullerine de bağlı olarak, tarihsel süreçteki gelişimi incelenmiştir. Devamında, günümüze kadar olan sürecin ardından, 21. yüzyılda cezaevi mimarisini şekillendiren bir olgu olarak 'yarışma' konusu, güncel yaklaşımları algılayabilmek adına araştırma kapsamına dahil edilmiştir. Çalışmada ele alınan ve bu alandaki en güncel örneklerden olan 'Prison Puzzle' adlı mimari fikir yarışması projeleri üzerinden, uluslararası platformdaki yeni yaklaşımları görebilmek adına senkronize bir okuma gerçekleştirilmiştir. Gerçekleştirilen okumada sırasıyla, problem tanımları, kuramsal yaklaşımlar ve tasarım önerileri irdelenmiş olup, her katılıma dair anahtar kavramlar çıkarılmıştır. Değerlendirme kısmında ise, bu yarışma kapsamındaki projelerde konunun nasıl ele alındığı ve sunulan fikirlerin nasıl mekansallaştığı karşılaştırmalı olarak incelenmiş, ardından gelinen noktada cezaevi mimarisinin nereye evrildiği hakkında birtakım çıkarımlar yapılmıştır.

***Anahtar Sözcükler*:** Suç, ceza, cezalandırma, cezaevi mimarisi, mimari yarışmalar, yeni yaklaşımlar

Giriş

Günümüzde cezaevleri hürriyeti bağlayıcı nitelikteki cezaların infazının gerçekleştirildiği resmî kurumlardır. Cezaevlerinin durumlarını ve nasıl inşa edileceklerini hem toplumun suçlu bireylere karşı bakış açıları hem de devletlerin ceza politikaları belirlemektedir. Cezaevlerinin mimari tasarımları ile toplumdaki hâkim ideolojiler arasında birtakım bağlar bulunmaktadır ve bu duruma bağlı olarak cezaevlerinin mimarilerindeki değişimler ile toplumlarda cezalandırmaya yönelik yaşanan ideolojik değişimler arasında ilişki kurmak mümkündür [1].

Suçlunun cezalandırılması durumuna tarihsel süreçte hemen her dönemde rastlanmaktadır. Suç kavramının günden güne değişmesi durumu cezalandırma yöntemlerine de yansıdığından, zamana ve kültüre göre değişiklik gösteren ıslah anlayışı bu bağlamda mekanları farklı biçimlerde şekillendirebilmektedir. Güncelliğini koruyan çoğu cezalandırma tipi suçluları iyileştirmekten ziyade sadece kapatmaya yönelik olduğundan aslında üretilen mimarlığın da suçluları cezalandırdığı söylenebilir. Dolayısıyla mahkûmu tekrar cezalandırmanın önüne geçecek ve insani koşullarda iyileştirebilecek yeni model önerilerine ihtiyaç duyulmaktadır. Bu konu günümüzde gündeme yarışmalar aracılığıyla taşınmaktadır.

Kentsel mekanların ve mimari yapıların elde edilmesinde önemli bir role sahip olan yarışmalar, süreç içerisinde geliştirdiği fikirler doğrultusunda, mimarlığın geleceği hakkında birtakım ipuçları verebilmektedir [2]. Buradan yola çıkarak, yapılacak çalışmanın amacı, seçilen mimari fikir yarışması projeleri kapsamında cezaevi mimarlığında yeni yaklaşımlar üzerine bir okuma gerçekleştirmektir. Araştırmada incelenecek olan yarışma, cezaevi konulu mimari yarışmaların kısıtlılığı da göz önünde bulundurularak, bu alandaki en güncel örneklerden olması ve uluslararası platformda önerilen modelleri inceleyebilme olanağı sunması sebepleriyle seçilmiştir.

Çalışma dört bölümden oluşmaktadır. Giriş bölümünde çalışmanın amacı ve yöntemi anlatılmıştır. İkinci bölümde tarihsel süreçte değişen cezalandırma yöntemlerinden ve beraberinde ortaya çıkan

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cezaevi modellerinden bahsedilmiştir. Ardından Prison Puzzle adlı uluslararası mimari fikir yarışması ele alınmış ve yarışma kapsamında önerilen cezaevi modelleri belirlenen kriterler üzerinden irdelenmiştir. Bu kriterler;

- problem tanımları ve eleştirdikleri yönler,
- kuramsal yaklaşımları ve çözüm önerileri,
- tasarım yaklaşımları ve nasıl mekansallaştıkları,

şeklinde sıralanabilir. Ek olarak, projeler üzerinden okunan yaklaşımlar ve getirilen öneriler ışığında, tablolarda daha kolay okunabilmeleri adına, her proje için anahtar kavramlar çıkarılmıştır. Sonuç bölümünde ise okunan yarışma projeleri karşılaştırmalı olarak incelenmiş ve yarışma kapsamındaki projeler üzerinden bu alandaki güncel yaklaşımlar hakkında bazı çıkarımlar yapılmıştır.

Cezalandırma ve Cezaevlerinin Gelişimi

Sicilya'da, Yontma taş devrine ait olan bir mağara duvarına, ayağa kalktığı takdirde kendisini boğacak biçimde bağlanarak oturtulmuş bir adam ve çevresinde ayakta duran insanların olduğu bir durum resmedilmiştir. Cezalandırma tarihinin insanlık tarihi kadar eskilere dayandığını ispatlar nitelikte olan bu oyma, aynı zamanda cezalandırmanın da en eski kaydı olarak değerlendirilmiştir. Ceza hukuku açısından bakıldığında ise günümüze kadar ulaşan en eski kanunname 'göze göz' anlayışı ile düzenlenen Hammurabi Kanunlarıdır. Babil'de Akad dilinde yazılmış olan bu kanunname ileriki dönemlerde hazırlanacak olan İbrani, İslami şeriat, Antik Yunan, Roma ve Avrupa kanunları gibi diğer kanunnameler için de bir altlık niteliği taşımaktadır. Önceki dönemlere bakıldığında tazminat ve para cezalarının ağırlıklı olduğu görülmektedir. Bu kanunname ise ağır cezalarıyla bilinmektedir ve en kalıcı prensibi olan 'kısas' üzerine kurulmuştur. Bu nedenledir ki hala dünyada Hammurabi ismi intikam ile özdeşleştirilmektedir [3]. Mezopotamya'daki diğer uygarlıklardan Asur, Sümer ve Hitit dönemlerindeki eserler incelendiğinde cezalarının uygulanmasını bekleyenler için bir alandan bahsedildiği görülmüştür. Aynı dönemde Platon ise, o döneme kadar olan anlayışın aksine, cezanın amacının intikam yerine caydırma ve ıslah etmeye yönelik olması gerektiğini öne sürmüştür. Ayrıca aslında üç tip cezaevinin olması gerektiğini ve bunlardan birinin şüphelilerin beklediği tutukevleri, ikincisinin norm dışı bireylerin kaldığı ıslahevleri, üçüncüsünün de asıl cezanın infazı için kent çeperlerine konumlanan hapishaneler olduğunu belirtmiştir [4].

17. yüzyıla kadar hapishaneler özgürlüğü kısıtlayıcı cezaların yerine getirildiği kurumlar olarak kullanılmamışlardır. Bir başka ifadeyle kapatılma mekanları binlerce yıldır var olmakla beraber günümüzdeki gibi bir fonksiyonda değil, farklı amaçlarla kullanılmışlardır. Hapishaneler o dönemde, cezalandırılma durumları olan kimseler için devlet eli altında bulundurulan tutukevleri ya da ölüm cezası kesinleşen kişilerin infazına kadar bekletildiği yerler olarak görülmüşlerdir. Hatta bu mekanlar, siyasi mücadeleler sırasında yaşanan iktidar değişimlerinde düşmanlarının kan akmadan ortadan kaldırılmasının sağlanması amacıyla ömür boyu kapatıldıkları yerler dahi olmuşlardır. Orta Çağ'a kadar olan cezalandırmalar genellikle beden bütünlüğünün bozulması ya da ölüm şeklinde gerçekleştiğinden, hapis cezalarının ve bu cezaların uygulanacağı mekanların bulunmadığı sonucuna varılmıştır. Bu sebepledir ki, özgürlüğü kısıtlayan cezaların doğuşu, hapishanelerin doğuşu ile ilişkilendirilmektedir [5].

Orta Çağ'a bakıldığında hapis cezaları için ödünç mekanların kullanıldığı görülmektedir. Sanıkların, esasen askeri bir yapı olan kalelerde yargılandıkları, şehir kapılarının, şatoların ve manastırların hapis cezalarının infazında kullanıldıkları bilinmektedir. Hatta dönemin ikonik infaz yerlerinden biri de hükümlülerin ölüme terkedildikleri zindanlardır. Buna örnek olarak Bastille ve Yedikule Zindanları gösterilebilir [4].

18. yüzyılda ise hapsetmenin ceza mekanizması içindeki yerinin belirginleştiği anlaşılmaktadır. Bu dönemin en önemli örneği ise Newgate Hapishanesidir. Aslında 12. Yüzyılda şüphelilerin yargılandıkları süreçte beklemeleri ya da infazları amacıyla kullanılan bu yapı büyük Londra yangınında yıkılır ve yeniden inşa edilir. Newgate yeniden inşası sırasında, kadınlar, erkekler ve borçlular için üç bölüme ayrılmış ve bu grupların bir araya getirilmesi fikri o dönem için etkileyici bulunmuştur. Görkemli bir dış görünüşe sahip olan yapı, uzun vadede kalabalık koğuş sistemlerine ve sağlık koşullarının yetersizliğine çözüm getirememiştir [6].

İlerleyen süreçte birtakım kurallar doğrultusunda yeni sistemler oluşturulmuştur. Buna örnek olarak Pensilvanya ve Panoptikon sistemlerinde, sonraki dönemlere de ışık tutan bir yaklaşım olarak, koğuş sisteminden hücre sistemine geçilmiştir. İlk olarak Pensilvanya sisteminde, dönemde yaygın olan mala karşı işlenen suçlar karşılığında, ölüm yerine hapis cezası alan kişiler bir hücreye kapatılarak dini geleneklerine bağlı olarak kendileri ve Tanrı ile baş başa bırakılmışlardır. Bu yaklaşım beraberinde

affedilmeleri için dua etmeleri ve bu sayede bağışlanmaları hedeflenmiştir. Daha sonraları Pensilvanya sistemine rakip olarak karma bir sistem önerilmiş ve adını inşa edildiği eyaletten alan Auburn sistemi ortaya atılmıştır. Bu sistem ise mahkumların hem birbirleriyle hem de gardiyanlarla konuşmalarının yasaklanması üzerine kurulmuştur. Böylelikle iletişimi tamamen izole eden ve tamamen yalnızlaştırmaya yönelik olan bir mekanizma üretilmiştir. Hücre sisteminde tasarlanan ve 18. yüzyılın ikonik cezaevi modeli olan Panoptikon 'da ise hücre ilkesi aslında tersine döndürülmüştür. Jeremy Bentham'ın modelinde merkezde bir gözetleme kulesi, çevresinde ise çember şeklinde bir bina bulunmaktadır. Gözetleme kulesi çemberin içine bakan pencerelere sahiptir ve dışarıdan bakan bir kişi bu pencerelerin içini görememektedir ancak kuleden bakıldığında tüm hücreler görülebilmektedir. Yani yaklaşımı itibari ile kapatma ve ışıktan mahrum bırakma işlevlerini yok saydığı için hücre sistemine ters köşe yapmaktadır. Bir diğer deyişle Panoptikon modelinde görünürlük aslında bir tuzaktır [7].

20. yüzyılda hapishanelerde şekil itibari ile yeni model arayışları olduğu görülmektedir. Bu modeller; avlu modeli, ışınsal model, dikdörtgen hücre bloğu modeli, telefon direği(omurga) modeli, kampüs modeli ve gökdelen modelidir. Tasarımlarda kullanım sıklığına bakıldığında da avlu modeli ve telefon direği(omurga) modeli öne çıkmaktadır [4]. Telefon direği modeline başvurulmasının sebepleri; hücrelerin daha fazla ışık alabilmesi, bina içindeki erişimin kolaylığı ve gözetleme-güvenlik açısından avantajlı olması şeklinde sıralanabilir. Sık kullanılan modellerden bir diğeri olan avlu modeli ise özellikle 1950-1960 yılları arasında Portekiz ve Türkiye gibi gelişmekte olan ülkelerde yoğun biçimde tercih edilmiştir. Bu modeli avantajlı kılan özellik orta bölümdeki avlunun sosyalleşme ve egzersiz açısından kullanıcılara fazla imkân sunmasıdır. Ancak daha sonraları modeldeki bina içi sirkülasyonunun kullanışsız olması ve maliyetli bulunması sebepleriyle terkedilmiştir. En güncel modellerden gökdelen modeli ise dikey bir mimari tasarıma sahip olup, gelişmiş ülkelerde hafif suçlardan hüküm giyen mahkumlar için kullanılmaktadır. Kent merkezlerinde tabanda az yer kaplaması sebebiyle avantajlı görülen gökdelen modelinin en iyi örnekleri olarak Auckland Cezaevi ve Chicago Islahevi gösterilmektedir [8].

Günümüzde refah düzeyi yüksek ülkelerde cezaevi mimarisi ayrı bir önem kazanmaktadır. Bunların ilk örneklerinden, Norveç'teki Halden cezaevi 2010 yılında inşa edilmiş olup, eğitim, sağlık, meslek edinme ve sosyal destek mekanizmalarını bünyesinde barındıracak şekilde tasarlanmıştır. Temel amaç mahkûmun psikolojisini gözeterek topluma kazandırma ve yeniden suça yönelmesinin önüne geçmektir. Halden cezaevinde belirli şartlar dahilinde mahkumlar evlerine gidebilmekte, dışarıda gezebilmekte, çalışabilmekte ve sanat-spor aktivitelerinde bulunmalarına fırsat verilmektedir [1]. 21. yüzyılın yenilikçi cezaevlerine bir diğer örnek de Danimarka'da 250 mahkûm için tasarlanan Storstrøm hapishanesidir. Diğer adı yeni devlet hapishanesi olan Storstrøm'da sokak-meydan konsepti beraberinde çeşitli eğlence ve çalışma tesisleri de bulunmaktadır. İnsan ölçeğinde tasarlanan bu cezaevinin çevre duvarlarının iki yanına geniş peyzaj tasarımları eklenerek kullanıcıya bir kent kurgusu sunulmuştur. Ayrıca çevre duvarlarının dinamik ve şekilli tasarımı sayesinde dış dünya ile mahkûmun iletişimi kesilmemiş ve daha az kısıtlayıcı bir his oluşturulması amaçlanmıştır. Tasarım ekibi bu tasarımı "Mahkumlar uyanık oldukları tüm saatleri cezaevi ortamında geçiriyorlar, bu nedenle cezaevi mimarisi yaşamlarının ve deneyim evrenlerinin son derece önemli bir parçasıdır. Bunun için kasıtlı olarak çok çeşitli ve teşvik edici bir ortam yarattık. Farklı alanların ve peyzaj elemanlarının birleştirilmesi bireyin yeniden sosyalleşmesine ve topluluğa karşı saygı oluşturmasına katkıda bulunacaktır" şeklinde açıklamıştır [9]. 21. yüzyıl cezaevi mimarisine örnek olarak ele alınan iki yapı da 2000 sonrasında mimari yarışmalar vasıtasıyla elde edilmişlerdir. İki örnekte de konsept olarak yenilikçi arayışların olduğu, kapatılmanın kontrollü gerçekleştiği, suça yeniden yönelmenin azaltılmasının, suçlunun topluma tekrar kazandırılmasının ve hayatına etik şartlarda devam edebilmeyi öğrenmesinin sağlanmasının hedeflendiği açıktır. Mimari tasarımlarında da tarihsel süreçte bu kısma kadar karşılaştığımız örneklerin aksine, parmaklıklar yerine güvenli camların tercih edildiği görülmektedir. Yarışma beraberinde elde edilen bu iki yapının hem konsept hem de tasarım yaklaşımları, kolektif ortamda üretilen mimarlığın, bu çalışma özelinde bakıldığında norm dışında kalan suçlu bireyler için, umut vaat ettiğini gösterir niteliktedir.

'Prison Puzzle' Yarışma Projelerinin İncelenmesi

Son yıllarda uluslararası platformlarda sosyal meseleleri ele alan ve bunlar üzerine çözüm arayan birtakım yarışmalar düzenlenmektedir. Bu oluşumlardan biri olarak, 2013 yılında İsveçli mimar Per Linde tarafından kurulan Combo Competitions, 2015 yılında Prison Puzzle adlı uluslararası mimari fikir yarışmasını açarak katılımcıları, mimarlığın belirli bir kapsamın dışında kalan sorunları çözebilecek bir araç olarak kullanılmasına teşvik etmiştir. Etik gerekçelerle uzak durmak yerine yüzleşilmesi gereken konulardan biri olan hapishaneler üzerine düşündüren bu yarışmada, mevcut sistemdeki bazı problemler belirlenmiş ve bu yönde sorular sorularak henüz doğru bir cevap bulamamış olan bu soruna çözüm aranmıştır. Bu bağlamda sorulan sorular,

- Mükemmel hapishane diye bir şey var mıdır?
- Mimarlık, davranışları etkileyen ortamları şekillendirmeye nasıl yardımcı olabilir?
- Teoride bile zıt olan, mahkûm, mağdur ve toplum gibi aktörlerin karşıt ihtiyaçlarını karşılamak mümkün müdür?
- Serbest kalan mahkûmların yeniden suç işleme eğilimlerini azaltmak için neler yapılabilir?

şeklindedir. Tekrar suç işleme olasılığının düşürülmesinde, hapis cezaları ile doğrudan ilişkili, mahkûm, mağdur ve toplum gibi unsurların da göz önünde tutulması istenen yarışmada proje alanı, Amerika Birleşik Devletleri'nde bulunan Arizona çölü olarak belirlenmiştir. Burada istenen, 500 kişi kapasiteli ve orta güvenlikli bir hapishane tasarımıdır [10].

Bu alandaki en güncel örneklerden biri olan Prison Puzzle yarışması, cezaevleri konusunun uluslararası platformda nasıl ele alındığını ve bu alandaki yeni yaklaşımları okumayı mümkün kılmaktadır. Buradan yola çıkarak, yarışma kapsamındaki projelerin belirlenen kriterler doğrultusunda incelenmesi hedeflenmiştir. Aynı zamanda projelerin tablolarda daha kolay okunabilmeleri adına, her proje için anahtar kavramlar çıkarılmıştır. Katılımlar, ödül grubu projeleri ve diğer projeler şeklinde iki aşamada okunmuştur. Ödül grubu projelerine ait inceleme Tablo 1'de verilmiştir.

Tablo 1. Ödül grubu projeleri incelemesi

ÖDÜL GRUBU

Proje Adı + Anahtar Kavramlar	Problem Tanımı/Eleştiri	Kuramsal Yaklaşım/Öneri	Tasarım	
1. (Proto)Prison: *Toplumla iletişim, tekrar suça yönelme, alternatif enerji, panoptikon*	Mevcut sistemdeki yalıtılmış hapishaneler sebebiyle toplumda damgalanan ve serbest kaldıktan sonra sosyal hayata entegre olamayan mahkumlar	Toplumla sürekli etkileşim, alternatif enerjileri araştırma merkezi, mahkumu araştırma sürecine dahil ederek eğitmek	Panoptikon uyarlaması, Avlu modeli	
2. To the Moon and Back Again: *Toplumla etkileşim, tekrar suç işleme, dış dünyayla görsel bağlantı (şeffaf bariyerler)*	Mahkum ve toplum arasındaki bağlantısızlık ve mahkumun yeniden suç işleme eğilimi	Dış dünyayla etkileşimin kesilmemesi adına bariyerlerin şeffaf ya da kullanıcıyı rahatsız etmeyecek şekilde olması, toplumu ve tanınabilir bir kentsel modeli yansıtması adına oluşturulan köy yapısı	Köy kurgusu, Kampüs modeli	
3. Borderless Prison: *Sınırsızlık, gözetim, mahkumların eğitimi, özgürlük*	Mahkum sayısının artışına bağlı olarak kalabalıklaşan hapishaneler, mevcut sistemdeki gergin ve statik modeller kusurlu	Yeni ve dinamik ağ olarak hapishaneyi makineleştirme, hareketli kontrol kulesi beraberinde fiziksel engellerin terkedilmesi, buna bağlı olarak mahkumu özgürlükle ödüllendirme	Fiziksel engeller yerine proje alanının sınırsızlığından yararlanan ve bölgesel bir hat oluşturan yatay platform	
Mansiyon-Catharsis: *Aşamalı ceza süreci (Arınma/altşma-itaat etme/dış dünyaya hazırlık), maneviyat, panoptikon*	Mahkumun yeniden suç işleme eğilimi, kötü hapishane koşulları, toplum tarafından damgalanma	Ceza sürecini aşamalara ayırma: arınma, itaat etme ve dışarıya hazırlık	Aşamalara göre sırasıyla; Panoptikon uyarlaması, Dünya üzerinde herhangi bir yer, Panoptikon uyarlaması	
Mansiyon-Plug-In Prison: *Sanal kontrol, farkındalık, teknoloji, rehabilitasyon*	Toplum tarafından damgalanma, yeniden suç işleme eğilimi ve mahkum bilinci	VR teknolojisi ve kontrollü ortamların kombinasyonu	Yeraltına yerleşim	

İkinci aşamada ele alınan diğer katılımlara ait projeler ise alfabetik sırayla incelenmiş olup, Tablo 2'de verilmiştir.

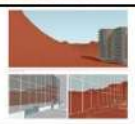
Tablo 2. Diğer projelerin incelemesi

DİĞER PROJELER (Alfabetik Sıra)

Proje Adı + *Anahtar Kavramlar*	**Problem Tanımı/Eleştiri**	**Kuramsal Yaklaşım/Öneri**	**Tasarım**	
A Good Prison: *Aşamalı süreç, ütopya, şeffaflık, panoptikon*	İyi hapishane nedir?	Hapishanedeki evrelerin bölümlere ayrılması, aktivite ve etkileşim alanı olarak avlunun kullanılması	Avlu modeli	
A River Runs Through It: *Suyun hareketi, güneş ışığı, zaman algısı, alternatif enerji*	Hapsedilme sürecinde dışarıda aynı hızla devam eden zamanın mahkum için bir süre sonra durması ya da bulanıklaşması	Suyun iyileştirici yönüyle mahkumun buluşturulması, suyun hareketini kullanarak hapishane için gerekli enerjinin elde edilmesi, su ve güneş ışınlarının yönlendirilmesi ile mahkumda zaman algısının tekrar oluşturulması	Suyu ve güneş ışınlarını yönlendirerek mahkuma zaman algısını tekrar kazandıracak dev bir saat	
Big Rock Candy Mountain: *Mahkûm-mağdur-toplum-yönetim ilişkisi, buluşma, uzlaşma, yüzleşme*	Mahkum, mağdur, toplum ve cezaevi çalışanlarına aynı anda nasıl yardım edilebilir?	İnsani koşulların sağlanması, mahkum, mağdur ve toplumdan bireylerin merkezde bir araya getirilmesi/yüzleştirilmesi	Işınsal model	
Busted: *Geleceğe dair varsayımlar, ihtiyaca göre fonksiyon ekleme, kendi toplumunu oluşturma*	X	Yeni bir Vegas yaratma konsepti, sonraki yıllara dönük şekillenen fonksiyon ve kullanıcı varsayımları, gittikçe artan kapasiteye bağlı olarak bir süre sonra alanın kendi toplumunu yaratması	Uzun vadede ihtiyaç duyulacak birimlerin birbirine eklenmesiyle oluşacak şehir kurgusu	
Clinamen Prison: *Eğitim, süblimasyon (bastırılmış dürtüleri kabul edilebilir kanallara yönlendirme), amfitiyatro*	Bireylerin dürtüleri nasıl yönlendirilebilir?	Mahkumda süblimasyon mekanizmasının harekete geçirilmesi, dışarıyla görsel iletişimin sağlanması	Amfitiyatro	
Exile: *Sürgün, aşamalı ceza süreci, kendi toplumunu oluşturma, ters panoptikon (mahkûm gözetlenen değil gözetleyen)*	Yasanın (Three Strike Law), mahkumlardaki yeniden suç işleme konusunu yeterli şekilde ele almaması	Tekrar suç işleyen mahkumun cezaevi yerine çöldeki sürgün kulesine gönderilmesi, böylelikle hem hapishanelerdeki ekonomik yükün hem de cezaevi nüfusunun hafifletilmesi, ceza sürecinin düşeyde aşamalara bölünmesi, aşamaların geçilmesi için eğitimin zorunlu tutulması	Sürgün kulesi, gökdelen modeli	
Factory Prison: *Mesleki eğitim, kapitalist yaklaşım (düşük ödemelerle çalıştırılan mahkumlardan maksimum verim alma), insani makine oluşturma*	X	Fabrika şeklinde kullanıma yönelik kurgu, düşük maliyetli iş gücü olarak mahkumun çalıştırılması üzerine kurulu kapitalist bir düzen, bu durumun sonraki yaşamları için bir meslek eğitimi olması ve bunun mahkumu olumlu etkileyeceği varsayımı	Düşük beceri gerektiren üretim ve paketleme alanı devamında sıralanan kontrol ve nakliye fonksiyonları çevresinde gelişen lineer model	
Game of the Wild Prison: *Oyun, adalar, hayatta kalmayı öğrenme, tekrar suça yönelmeme*	Mahkumun yeniden suç işleme eğilimi	Oyun kurgusu beraberinde mahkuma içinde bulunulan şartlarda hayatta kalmanın öğretilmesi, kendi kendini eğitmesi, alım-satım yaparak serbest kaldıktan sonra etik yollardan da kazanç elde edebileceği konusunda motive edilmesi	Bazı noktalardan bağlı olan adalar	
Hydro-Logic: *Su metaforu (arıtma sürecinin başında kirli olan, sonradan temizlenen-mahkûm gibi), sürdürülebilir enerji, topluma kazandırma*	Cezaevi ve sürdürülebilirlik konularının birlikte ele alınmasının gerekliliği	Atık su arıtma tesisi oluşturmak, suyun dönüşümünü mahkum açısından sembolik hale getirmek, arıtma sürecine ile eşzamanlı olarak ceza sürecini mahkum durumuna göre aşamalara bölmek	Lineer model	
Inversed World: *Eğitim (suç işlemenin temel sebebi eğitimsizlik), yaşam koşullarının iyileşmesi, gözetleme*	Geleneksel ceza yöntemlerinin insanlık dışı olduğu ve çağdaş sistemde mahkumun insani şartlara kavuşturulması gerektiği	Suçun temeli olarak kabul edilen eğitimsizliğin giderilmesi ve mahkumun sosyalleştirilmesi, bunun bir opsiyon olarak kalmaması ve mahkumun zorunlu olarak tercih etmesi için gerekli şartların sağlanması	Dikdörtgen hücre bloğu modeli	
Lex Talionis: *Eğitim, aşamalı ceza süreci, adalet, ikilikler (hayatın içindeki zıtlıklara gönderme)*	İnsan doğasının sabit bir verisi olmadığı, koşullar, eğitim ve fırsatlar beraberinde şekillenebileceği	Ceza sürecinin düşeyde kademelenmesi, dip kısımdan başlayıp aldığı eğitim beraberinde gelişme kaydederek yüzeye ulaşması	Yeraltına yerleşim	

Tablo 2. Diğer projelerin incelemesi (devamı)

DİĞER PROJELER (Alfabetik Sıra)

Proje Adı + ***Anahtar Kavramlar***	**Problem Tanımı/Eleştiri**	**Kuramsal Yaklaşım/Öneri**	**Tasarım**	
Maze: *Yalnızlaştırma, düşündürme, aşamalı ceza süreci (hazırlanma-iyileşme-özgürlük)*	Tüm insanların doğalarında hata yapma eğiliminin var olduğu, ancak bu durumun düşüncenin iyileştirilmesi vasıtasıyla çözülebileceği	Tamamı bir puzzle olarak görülmüş ve hazırlanma, iyileşme, özgürlük şeklinde aşamalar beraberinde mahkuma yaşatılacak deneyimler ile sahip olacağı özgürlüğün değerinin farkına varmasını sağlamak	Yer altına yerleşim	
Monument and Reverence: *Cezalandırmayan mimari, anıtsallık, rehabilitasyon, görsel bariyer*	Mimarinin ceza ve adalet sistemindeki rolünün sessiz olduğu kadar önemli de olduğu	Öncelik rehabilitasyon, arazinin sınırsızlığını doğal sınırlar olarak kullanma, anıtsal bir duruş ve mahkumda saygı duygusunun uyandırılması	Gökdelen modeli	
More Than a Corridor: *Sosyalleşme, eğitim, tekrar suça yönelmeme, topluluk içinde yaşamayı öğrenme*	Tekrar suç işleme eğiliminin ortadan kalkması ve topluma kazandırılmanın gerekliliği, geleneksel sistemdeki negatif fiziki koşullar	Ana kurgunun bir koridor üzerinden gitmesi ve mahkumun hem sosyal hem de eğitim alanlarının her yerden erişebileceği şekilde konumkandırılması	Koridor kurgusu	
Nine Levels of Repentance: *Tembelleşme, farklı işlerde çalıştırma, cehennem, eğitim, aşamalı ceza süreci*	Amerika'daki cezaevlerinin en büyük sorunu mahkumların ceza sürecini pasif ve asosyal geçirmesi, bu durumun şiddeti doğurması	İnsan hayatının doğal birer parçası olan okula gitme, öğrenme, çalışma ve para kazanma durumlarının burada da farklı katmanlarda ve gittikçe insani düzeye gelen bir düzende sağlanması	Gökdelen modeli	
Oasis Commune: *Tekrar suça yönelme, sosyalleşme, organik gıda yetiştiriciliği, araştırmalara katılma*	Hapishanelerin, konumları gereği mahkum ile tüketim toplumu arasındaki bağları koparması ve bu durumun hapishane içinde kendi kendini idare eden bir topluluk oluşturmak için ideal olması	Organik gıda yetiştiriciliği üzerine bilimsel araştırmalar, iklim değişikliğinden dolayı mahsulün zarar görmesini engellemek adına tarımsal bir deney istasyonu kurulması, böylelikle mahkumların serbest kaldıktan sonra da yararını görececkleri birer yeşil yakalı işçi profillerinin oluşması	Topluluk yaşamına referans olarak Pueblo Kızılderililerinin yerleşimlerinden ilham alınarak tasarlanan apartman tarzı kütleler	
Oasis: *Deneysel hapishane, sürdürülebilirlik araştırmaları, günlük üretim, beceri kazanma*	Günümüzdeki cezaevlerinin bu konuyu tek boyutlu ele alması ve herkes için aynı yöntemi uygulamasının yanlış olduğu	Günlük üretimin yapılacağı bir vaha kurgusu, mahkumda üretim bilinci beraberinde oluşacak sorumluluk duygusu	Kotun alçaltılması beraberinde önerilen oval kurgu	
Over the Place: The Utopia: *Doğal mekân, tekrar suça yönelme, rehabilitasyon*	X	Alanı daha parlak ve ışık alan mekanlar haline getirebilmek amacıyla eklenen iç bahçeler beraberinde mahkumu sakinleştirerek rehabilite etmek	Bölgede doğal bir iz oluşturmak ve fiziksel bariyerleri kaldırmak amacıyla yerden yükseltilmiş kütle	
Prisondam: *Arazideki yeni potansiyeller, su öğesi, baraj fikri, alternatif enerji, esnek mekanlar*	X	Yerleşim için eski kabilelerin örnek alınması ve bu doğrultuda bölgeye su öğesinin getirilmesinin potansiyelleri açığa çıkaracağı varsayımı, getirilen suyun ona dik yerleştirilen kütle ile hareketi sonucu enerji elde edilmesi ve bir baraj haline gelmesi, kademeli yeleşimin mahkumlara çalışmak için alanlar tanımlaması ve onları geliştirmesi	Doğal eğime kademeli yerleşim ve su öğesinin getirilmesi ile oluşturulan baraj	
Prison Puzzle: *Toplumda damgalanma, farkındalık, bitki yetiştirme, sabrın öğretilmesi*	Ceza alma durumunun en büyük dezavantajının toplumdaki damgalanma olduğu ve mahkumun dış dünyadaki tüm canlılardan uzaklaştığı	Bitki yetiştiriciliği ile hem negatif düşüncelerden uzaklaşarak travmaların atlatılması hem de emek ve sabır duygularının kazandırılması	Lineer model	
Re-socialization Complex: *Toplumdan uzaklaşma, sosyalleşme, kent kurgusu, gerçek hayatın illüzyonu*	Geleneksel hapishanelerin şehirlerin çeperlerine yerleştirilmesi ve mahkum ile toplum arasında derin bir mesafe oluşturması	Bunun önüne geçebilmek adına bir şehir illüzyonu oluşturulması, günlük hayatta şehirde karşılaşılan tüm alanlar ile simgelere yer verilmesi ve mahkumların hücrelerinden çıkıp çalışma alanlarına gidişlerinin ileride evlerinden çıkıp işe gitme durumlarının provası niteliğinde olması	Mikro şehir kurgusu	
Sophronesterion: *Birleştirici yaklaşım, görsel bariyerler-peyzaj, mikro şehir yaratma*	Cezaevlerinin mimari açıdan ele alınış şekillerinin ikililik barındırması, mahkumun hem refahının hem de cezasının sağlanması	Bütünlük amacıyla bir şehir oluşturulması ve sonraki yaşamı için mahkumu 'iş gücü olarak çalıştırıp' meslek edindirilmesi	Mikro şehir kurgusu	

Tablo 2. Diğer projelerin incelemesi (devamı)

DİĞER PROJELER (Alfabetik Sıra)

Proje Adı + *Anahtar Kavramlar*	**Problem Tanımı/Eleştiri**	**Kuramsal Yaklaşım/Öneri**	**Tasarım**	
Sustainable Confinement: *İyileştirme, sorumluluk, aile kurgusu, beceri kazandırma*	İşlenen suçun mahkumu sonsuza dek suçlu biri yapmayacağı, iyileşebilmesinin mümkün olduğu	Kendi kendine yeten bir topluluk kurgusu, toprakla ilgilenme ve kendisi dışında insanlardan da sorumlu olma bilinci	Yükseltilmiş kütle içinde avlu kurgusu	
The Mountain: *Kontrol, eğitim, sosyalleşme, ters panoptikon (mahkûmun izlenen değil izleyen olması)*	Psikolojik kontrol adına panoptikonun iyi bir örnek olarak görülmesi ancak günümüz şartlarına göre revize edilmesinin gerekliliği	Eğitimsizliğin ve asosyalliğin suçu tetiklediği kabulü üzerine eğitim, sosyal aktiviteler ve hobi alanları ile donatılması	Avlulu model	
The Restorative Detention Complex: *Pozitif sosyal enstitü, duvarların kalkması, günlük hayatın yansıtılması*	Amerika'daki cezaevi sisteminin çökmekte olduğu, tekrar suça yönelme oranlarının artış gösterdiği ve bu durumun mahkum beraberinde mağdur ve toplumu da ilgilendirdiği	Dış duvarların ayrıştırıcı etkisinden dolayı tamamen kaldırılması, pozitif bir sosyal ortamın sunulması, mahkumun becerilerinin geliştirilmesi	Avlulu model	
305182 Numaralı Proje: *Sınır olarak zeminden yükselme, uzlaşma, öğrenme, meditasyon*	Cezaevlerindeki sınır kavramının sorgulanması	Duvar ve parmaklık gibi negatif elemanların kaldırılması, mahkuma kesintisiz bir manzara sunulması, kendilerini geliştirebilecekleri öğrenme alanları, meditasyon alanları	Fiziksel bariyerleri kaldırmak ama erişimi kısıtlayarak güvenliği de sağlamak adına yerden yükseltilmiş kütle	
767791 Numaralı Proje: *Ceza ve serbest kalma süreci arasında bir tampon bölge, eğitimin mahkûmun günlük yaşantısına entegre edilmesi*	Düşük eğitim düzeyi, kısıtlı beceriler ve asosyallik durumlarının bireyleri suça iten neden olduğu, yeniden suç işleme eğiliminin üzerine düşünülmesi gerektiği	Mahkumu cezanın hemen ardından serbest bırakmak yerine dışarıdaki hayata alıştırarak karışmasını sağlamak ve çıkışından önce tampon bir bölgede tutmak	Avlulu model	
799757 Numaralı Proje: *Yeni panoptikon (kule değil yarık şeklinde), gücün arka plana itilmesi, enerji üretimi*	Panoptikon referansı, bu ikonik modelin revize edilmesinin gerekliliği	Klasik panoptikon modelinde merkezde bulunan kuleye sosyal alanların yerleştirilmesi, yönetim ve gözetleme birimlerinin de çepere itilmesi vasıtasıyla güç göstergesinin ikinci plana alınması	Avlulu model	
822097 Numaralı Proje: *Eğitim, sosyalleşme, beceri kazanma, süreç içinde döngü*	Kapatılma durumu bir ceza mıdır yoksa bir ders midir?	Öğrenme, sosyalleşme ve hobi edinme gibi durumların mahkumu iyileştireceğine inanılması	Fonksiyonlara ayrılmış döngüsel kurgu	
937344 Numaralı Proje: *Özgürlük çağrışımı, katmanlı kurgu, cezaevi içi şiddetin önlenmesi*	Sürekli dört duvar arasında kapalı tutulmanın negatif etkileri olduğu	Özgürlük fikrini çağrıştıran elemanların mahkumla bir araya getirilmesi	Yükseltilmiş kütle içinde fonksiyonlar beraberinde farklılaşan katmanlar	

Sonuç ve Değerlendirme

Son zamanlarda, mimarinin kullanıcı davranışını yönlendirebilme ve iyileştirebilme etkisi üzerinde durulmakta, bu sebeple tasarımcıların da bakış açıları dikkate alınmaktadır. Cezaevi mimarlığındaki, 'lüks' ya da 'kusursuz' olarak nitelendirilen güncel örnekler (Halden Prison ve Storstrøm Prison), önerilerin daha kolektif ve yapıcı bir platform üzerinde toplanması sağlanarak, hükümetler tarafından açılan mimari yarışmalar beraberinde elde edilmiştir. Tarihsel süreçte, tasarım disiplinine uzak kimseler tarafından üretilmiş örnekleri bulunan cezaevleri ve sonuçları göz önüne alındığında, tasarımcıların söz sahibi olmasının ve çok yönlü olarak ele alınması gereken bu alanda, insanların hem davranışları hem de psikolojilerini yönlendirme etkisi bulunan mimarlık disiplini içerisinde değerlendirilmesinin gerekliliği açıktır.

Çalışma kapsamında ele alınan 'Prison Puzzle' adlı yarışmanın projeleri üzerinden güncel tasarım önerileri belirlenen kriterler doğrultusunda incelenmiş ve bu doğrultuda, ele alınan problem ya da eleştirilen noktalara, saptanan sorunlar için önerilen çözümlere ve bu çözümlerin tasarımın genel kurgusuna nasıl yansıdığına dikkat edilmiştir. İki aşamada gerçekleştirilen değerlendirmede ilk olarak ödül grubu projeleri ele alınmıştır.

İnceleme doğrultusunda, jüri tarafından başarılı bulunarak ödüllendirilen projelerin üzerinde durdukları ana temalar ve bu temaların projeye yansıtılma biçimleri değerlendirildiğinde;

- Öncelikle ödül grubundaki tüm projelerin ilk aşamada birer problem tanımı bulunduğu ve bu doğrultuda önerdikleri çözümlerin belirlenen sorunlar karşısında tutarlı olduğu,

- Üzerinde durulan ortak problemlerin, 'mahkûm-toplum arasındaki bağlantısızlık', 'mahkumların serbest kaldıktan sonraki tekrar suç işleme eğilimleri' ve 'hapishaneden sonraki hayatlarında, toplumdaki damgalanmadan dolayı sosyal hayata entegre olamamaları' şeklinde olduğu,
- Önerilerde ise öne çıkan noktaların 'toplum ile mahkûm arasında iletişim kurma, dışlamayı engelleme', 'ceza sürecini aşamalara ayırma' ve 'mahkûma istihdam sağlanabilmesi adına eğitime tabi tutma' şeklinde olduğu,
- Birincilik ödülü alan projenin, proje alanı olan Amerika'nın iki büyük problemini, cezaevleri ve alternatif enerji konusunu ortak olarak ele aldığı,
- İlk iki ödüle ait projelerin uygulanabilirliklerinden dolayı tercih edilmiş olabilecekleri,
- Üçüncülük ödülü alan projenin fiziksel engelleri kaldırarak, proje alanının sınırsızlığını doğal bir sınır olarak kullanması ve bununla beraber mahkûma kendi alanı içinde bir özgürlük sunması fikrinin başarılı bulunabileceği,
- Mansiyon ödülü alan iki projenin ise, ödül grubundaki ilk üç projeye kıyasla günümüz için biraz uzak bir çözüm olarak göründüğü ancak gelişen teknoloji göz önünde bulundurularak, ikinci mansiyon ödülünü alan projenin önerdiği 'VR teknolojisi' ile zihin kontrol etme ve mahkûmu simülasyona tabi tutma önerisinin yakın gelecek için mümkün olabileceği yönünde çıkarımlar yapılmıştır.

Diğer katılımcıların üzerinde durdukları ana temalar ve bu temaların projeye yansıtılma biçimleri genel olarak değerlendirildiğinde;

- Eleştirilen noktaların, 'mevcut çoğu cezaevinin hala insanlık dışı şartlarda olduğu', 'mahkumun serbest kaldıktan sonraki yaşamında tekrar suç işleme eğiliminin önüne geçilmesi gerektiği', 'bireyi suça iten sebeplerin temelinde, eğitimsizlik, kısıtlı beceriler ve asosyallik olduğu', 'cezaevlerindeki sınır kavramlarının tekrar sorgulanması gerektiği' şeklinde olduğu,
- Hala tartışmalı olan ve henüz net bir cevabı bulunamayan 'cezaevlerinin doğasında bir ikililik barındırdığı ve bu ikiliğin bir tarafında mahkuma insanca muamele ederek refahını sağlayacak şartlar sunulması olduğu, ancak aynı zamanda da suç işleyen ve cezalandırımış bir birey olduğunun unutulmaması' sorusu,
- Önerilen çözümlere bakıldığında ise ortak kaygının fiziksel bariyer, duvar ve parmaklık gibi olumsuz elemanları ortadan kaldırma ve kullanıcıyı motive etme yönünde olduğu,
- Bu kaygının tasarıma yansıma şeklinin de bazı projelerde yerden yükseltilme, bazılarında alçaltılmış kotlara yerleştirilme gibi topografik düzenlemelerle, bazı projelerde ise proje alanı olan çölün sınırsızlığının doğal sınır olarak kullanılmasıyla olduğu,
- Dış dünya ile bağlantı kurmanın mahkum psikolojisi üzerinde olumlu etkiler yaratacağı sebebiyle, mahkumun çevreyle görsel iletişim kurabilmesi adına geniş ve engelsiz açıklıklara yer verildiği,
- Bazı projelerin ise cezaevi konusunu, iklim değişikliği ve sürdürülebilirlik gibi güncel konular beraberinde ele aldığı,
- Mahkumu bu doğrultuda toprakla ve bahçe ile ilgilenmeye yönlendirerek bu uğraşın, sonraki yaşamında da meslek haline gelmesinin amaçlandığı,

yönünde çıkarımlar yapılmıştır.

Ödül grubu projeleri ve diğer projelerdeki ortak noktalara bakıldığında ise;

- Cezaevi alanındaki en ikonik örneklerden Panoptikon'a birçok projede referans verildiği, yer yer örnek alınarak yer yer de eleştirip revize ederek ele alınan bu modele, günümüzdeki yaklaşımların altlık arayışlarında tutunulmaya çalışıldığı gözlenmiştir.
- Diğer yandan bazı projelerde, getirilen fikirler doğrultusunda mekânsal kurgunun bir tipolojiye hapsedilmeden, tipoloji konusu dışında mekana dair fikirlerin üretilmesi de önemli bir nokta oluşturmaktadır.
- Son olarak, katılımların büyük bir kısmındaki genel yaklaşımın, mahkumun ceza sürecini aşamalara bölmek ve bu süreçleri farklı katmanlarda geçirmelerini sağlamak yönünde olduğu gözlenmiştir. Aslında bu yaklaşımın, çoğu tasarımda bulunan parçalı kurguya da açıklık getirmektedir.

Bulunulan platform her ne kadar 'gerçek dünya'daki maliyet, uygulanabilirlik, vb. gibi etkenlerden uzak görünse de ödüllendirilen yaklaşımlara bakılarak, seçimlerin bir kısmının hala kontrollü bir biçimde yapıldığı söylenebilir.

Ele alınan problemler ve öneriler genel anlamda pozitif ve insancıl olsa da, bazı yaklaşımlarda mahkumu ağır işlerde çalışabilecek iş gücü olarak gören ve bunu 'mesleki eğitim' adının arkasına gizleyen önerilerin de varlığı farkedilmiştir. Tüm bunlar gözetilerek cezaevlerinin gelişimindeki tek

aktörün aslında mahkum olmadığı, devletlerin ceza politikalarının yanı sıra toplumun da suçluya bakış açısının belirleyici olduğu düşünülmektedir. Öte yandan çalışma boyunca karşılaşılan, yenilikçi, insancıl ve mahkumun serbest kaldıktan sonraki sürecine de yatırım yapılmasını öneren projelerin varlığı, eskilerden günümüze, suç işleyen bireye bakış açısının ne denli değiştiğini ve bu durumun hem cezalandırmanın yöntemine hem de mimari yaklaşımlara fazlasıyla yansıdığını gözler önüne sermektedir.

Referanslar

[1] Fridhov I, Grøning L. Penal ideology and prison architecture. Prison, Architecture And Humans. 2018; 269-286.

[2] Gökmen HS. Yarışma kültürüne katkılar. Mimarlık Dergisi. 2018;(400):37-39.

[3] Lyons L. Cezalandırmanın tarihi. Çev. Zengilli S. Paris Yayınları, 2017.

[4] Şanlı E. Ceza infaz kurumlarının mimarisi ve tarihsel gelişimi [internet]. Academia; 2019 [Erişim tarihi: 13 Nisan 2020]. Erişim adresi: https://www.academia.edu/38423793/Ceza_%C4%B0nfaz_Kurumlar%C4%B1n%C4%B1n_Mimarisi_ve_Tarihsel_Geli%C5%9Fimi.

[5] Artuk M, Alşahin M. Hapis cezalarının ve cezaevlerinin tarihi gelişimi. Marmara Üniversitesi Hukuk Fakültesi Hukuk Araştırmaları Dergisi. 2016;21(2):297-338.

[6] Johnston N. Forms of constraint: history of prison architecture. Chicago: University of Illinois Press; 2000.

[7] Gül N. Dünyada ve ülkemizde cezaevi mimarlığı ve güncel tasarım ölçütlerinin irdelenmesi [Yüksek lisans tezi]. İstanbul: Yıldız Teknik Üniversitesi; 2015.

[8] Ağcakale S. Ceza mimarlığı [Yüksek lisans tezi]. İstanbul: İstanbul Teknik Üniversitesi; 2010.

[9] CF Moller Architects. Danish State Prison [internet]. Archello; 2010 [Erişim tarihi: 10 Mayıs 2023]. Erişim adresi: https://archello.com/project/danish-state-prison.

[10] Prison puzzle brief summary [internet]. Combo Competitions; 2015 [Erişim tarihi: 9 Mayıs 2020]. Erişim adresi: https://www.combocompetitions.com/prison-puzzle.

Morphological Analysis of Ksar Tadjrouna in Laghouat, Algeria

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Abstract

Algeria is endowed with a very important heritage, reflecting the passage of different civilizations and cultures, their conservation and enhancement constitutes one of the main challenges practice of architectural preservation.

Currently, Algeria like all the countries of the world is faced with a phenomenon of demographic growth accompanied by economic development, which has caused excessive urban sprawl characterized by standardized architecture, causing neglect and abandonment of the old districts of cities. This has created the problem of abandonment, marginalization and degradation of this heritage.

The Ksar of Tadjrouna in Laghouat, Algeria is one of the 5 Ksours of Laghouat (located on an archaeological site) which is characterized by its richness of urban fabric. Also, it is characterized by its seniority which allows us to take it as a conceptual landmark of traditional architecture.

The objective of our study is for the protection of the urban heritage in Algeria from degradation and the need for its safeguard by the morphological analysis of Ksar Tadjrouna in Laghouat which is an example which requires operations of conservation and preservation.

Keywords: Morphological analysis, traditional architecture, Ksar of Tadjrouna, Laghouat, Algeria

Introduction

Algeria has a very important heritage, reflecting the passage of several civilizations and interior cultures, their conservation and enhancement is one of the main issues and concerns of the practice of architectural preservation.

This theme is therefore not only interested in monuments and historic sites but also encompasses the cores and historic districts of cities which, considered as memory, reflect cultural; architecture and history values of the society which is living there.

This heritage which, in the sense of the different experiences, must be approached as a whole, in its diversity. “It is the living memory, symbol of a popular culture with strong meanings, which crosses the architectural quality of the buildings and places as well as the urban harmony of the fabric.” [1].

Currently these urban centers are in decline, faced with the difficulties of their conservation and their integration into the contemporary city, it “is transformed at the pace and in the image of the populations and activities that mark the dynamism. This is the case, and even more so, with the initial core of all cities, which has a rich past and carries a future which must be able to bear witness to its history, be part of the present and integrate finally these monuments to their future. There; moreover, lies the interest and the challenge of revitalization and enhancement interventions: safeguarding the architectural and urban built heritage without slowing down development” [1].

This phenomenon bears the interest of the degradation of urban heritage in Algeria and the need for its safeguard by our study of the Ksar Tadjrouna in Laghouat which is an example that requires conservation and enhancement operations.

Materials and Methodology

Study Area

The town of Laghouat shares its limits with two towns of the highlands (Tiaret and Djelfa) and two others of the South which are (El Bayadh and Ghardaia) (See Fig. 1). So, the town of Laghouat constitutes an open door to the great south. It is located at: 410 km from Algiers (capital); 103 km from Djelfa 187 km from Ghardaïa, 270 km from Tiaret and 230 km from El Bayadh. [2]

Figure 1. The location of Laghouat [3]

The town of Tadjrouna located in the southwest of Laghouat province (82km from Laghouat). The Ksar is located in the southeast of Tadjrouna city. [4]

Figure 2. The location of Tadjrouna

Research Methodology

The morphological approach is defined as a tool for understanding traditional fabrics in a clear and explicit way the complexity of the morphological relationships that reign in old neighborhoods through two modes which are:

The mode of distribution (parcel and street system) and the mode of occupation (built and open spaces system) [5]. We can present the processes of this approach in the following diagram: (See Fig. 3)

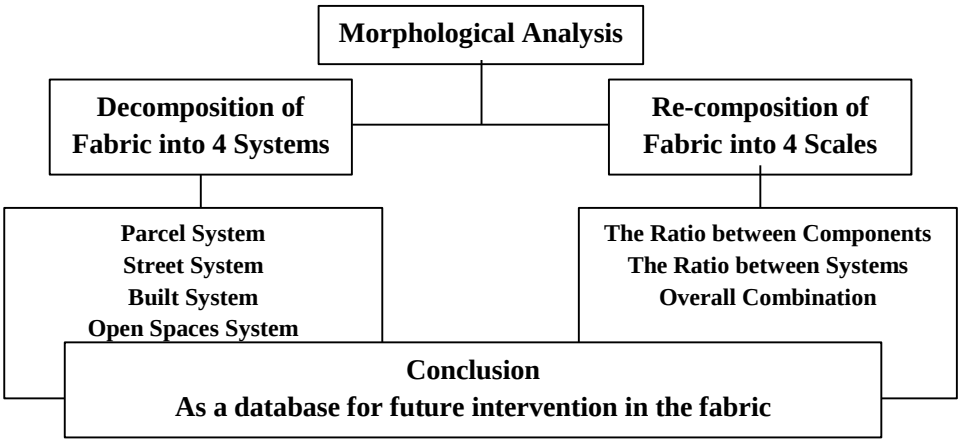

Figure 3. The processes of morphological analysis

Results and Discussion

Morphological Analysis of Ksar Tadjrouna

Among the traditional fabrics we have our case study; it is the Ksar Tadjrouna which is characterized by its seniority which allows us to take it as a conceptual landmark of traditional architecture. The morphological analysis of Ksar Tadjrouna is shown in Table 1 and 2.

Table 1. The decomposition of Ksar Tadjrouna

Decomposition			
Parcel System	Street System	Built System	Open Spaces System
▪ Directions of parcels are hierarchical, this means that => a preferential direction ▪ Directions of the plots: The fundamental directions of the plot are mainly linked to a natural limit (valley). ▪ A variant of plots of different dimensions.	▪Orthogonal Encounter: the hierarchy of the streets does not modify the frontal continuity of the space prevails on the lateral side. ▪ Inclusion of linear system with loop system (hierarchical).	▪ Planar built: the buildings are attached to each other on all sides to form a continuous mass. ▪ No ramified planar built. ▪ The type of volumes: building with a central courtyard.	▪ Planar Building: The differentiation between private free space and public free space tends to be done automatically. ▪ A certain balance between the full and the empty.

Table 2. The re-composition of Ksar Tadjrouna

Re-composition		
Topological Ratio Between Systems	The Ratio Between The 4 Systems	The Ratio Between Systems
▪ Hierarchical plot: is characterized by a hierarchy between the main road and secondary streets. ▪ The plot has a rectangular proportion.	▪ The free space is very clearly subdivided into a public zone (P) and a private zone (p), in this case the private space is isolated from all sides.	▪ After the combination between the built system and the street system, we obtain the tissues of: ▪ Planar built system - linear street with hierarchized plot. -We have the case of building aligned on the street.

After this morphological analysis, we can emerge the characteristics that present the identity of Ksar Tadjrouna which must be taken into account in each intervention:

- The fabric characterized by a no ramified planar built.
- Introverted architecture with the courtyard in the house as the basic unit.
- Hierarchical street system from public to private (street, alley and blind alley).
- The blind alley is 3m and 7m for the commercial street.
- The template is limited in between (ground floor to the first floor).

The notion of privacy presented by:

- The use of a public to private crossing space provided by the places.
- The arrangement of the entrance doors in relation to each other.
- Simple facades characterized by treatment of the doors or windows.

This study has allowed us to understand the elements that help the success of the interventions and to put certain parameters considered as reference elements and basic principles for the operations on the Ksar.

Also, shows that the revaluation of the Ksar is a very large operation and proposes interventions that allow the preservation of the Ksar.

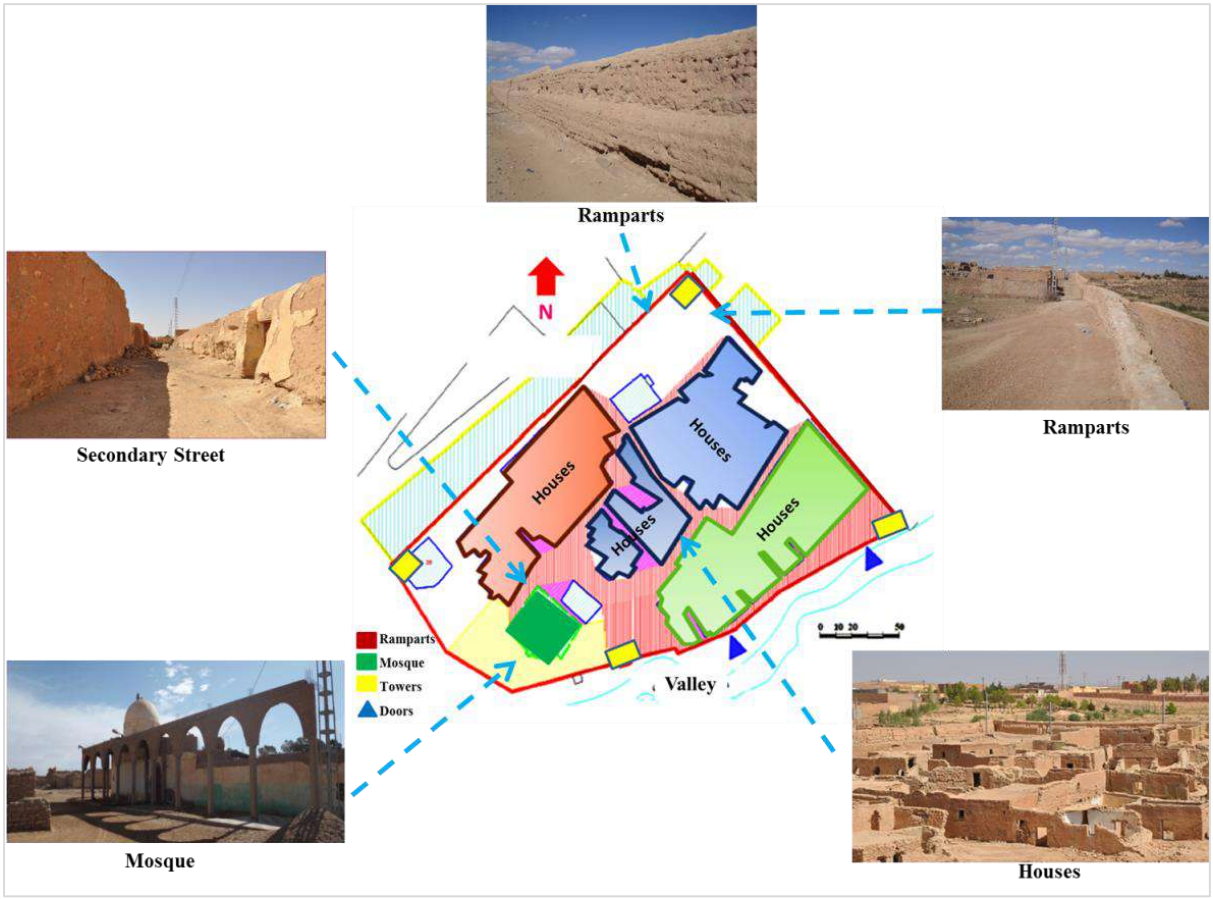

Figure 4. The current state of Ksar Tadjrouna

Diagnosis

According to several visits to the Ksar, the pathologies noticed in the Ksar Tadjrouna are as follows:

- The use of heterogeneous materials (cement).
- Superficial cracks.
- The degradation of the plaster.
- Degradation of the base of walls.
- The capillary rise.
- Degradation of doors.
- Collapse of walls.

Most of the causes of these pathologies are:

- Water stratification
- Absence of maintenance
- Rainwater infiltration

The Proposed Strategy (Intervention)

The main objective of our study is the protection of ksar Tadjrouna through its morphological analysis and the valuation of its tourist potential and the attraction of its inhabitants who have deserted it.

Experience has shown that any architectural heritage conservation policy which consists solely of to clog the cracks, renew the plasters and make new the buildings, finds it difficult to fix the population which resides there and did not allow the return of the population which had left it.

For this reason, we propose a renovation plan which includes various planning operations (rehabilitation and restoration operations), in the objective to provide: the Ksar with a basic infrastructure for the inhabitants who still reside there.

Also, to make it find its cultural and spiritual role through the creation of:

- A tourist route inside the ksar which initially passes through the place of the mosque, the typical house (the house of El-kaid), the place of El-Sahli, the tower.
- Guest houses near the place of EL-Sahli and the restaurant.

Intended to receive national tourists who come to visit it and attracting international tourists by encouraging cultural tourism.

Conclusion

The Ksar of Tadjrouna has a cultural, historical and tourist importance, it has a particular identity.

In our work, on the level of analysis, we tried to make a morphological analysis of Ksar Tadjrouna by relating the space and the successive events operated on this Ksar. In addition we were able to see the importance of the rehabilitation and requalification of the various systems and components of Ksar which had a degradation and distortion.

This led us to propose recommendations related to certain aspects of urban life and to integrate some social, environmental, architectural dimensions, etc.

- The reassignment of certain heritage buildings to accommodate certain cultural and commercial activities: library, open-air museum restaurant, etc.
- The requalification of public places that have been marginalized.
- Improving the urban landscape through the urban renovation of facades.

All these proposals and solutions were brought from the desirable theoretical framework to be applied in reality, the final objective that we wish to achieve to propose the Ksar Tadjrouna to the classification as a safeguarded sector in order to be able to ensure its conservation as a testimony of a rich and characterizing civilization.

References

[1] Hamma W. Intervention Sur Le Patrimoine Urbain, Acteurs Et Outils, Le Cas De La Ville Historique De Tlemcen. Master thesis. Abou Bekr Belkaid Tlemcen University, 2011.

[2] PPMVSA. Plan Permanent de Mise en Valeur et de Sauvegarde des Sites Archéologiques, la direction de la culture de la wilaya de Laghouat, 2018.

[3] Anonymous. OnTheWorldMap, https://ontheworldmap.com/algeria/, 2012. (Date of access: 03.05.2023)

[4] Direction De La Culture De Laghouat. «Etude Des 5 Ksours De Laghouat», 2017.

[5] Borie A, Denieul F. Etude et document sur le patrimoine culturel, Méthode d'analyse morphologique des tissus urbains traditionnels, UNESCO. Paris, France, 1984.

Globalization and the Rise of Individualism in Algeria from an Architectural Perspective

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Abstract

In an increasingly globalized world, where boundaries are blurred and connections strengthened, the field of architecture finds itself deeply influenced by this phenomenon. Algeria, like many other regions, has undergone urban and architectural transformations in recent decades, making the study of globalization's impacts on architecture a crucial endeavour. This qualitative research aims to evaluate the specific influences of globalization on the architectural landscape of Batna City in Algeria. Utilizing secondary data and observations, this study investigates the rise of individualism and detached houses in Batna City, which have witnessed notable architectural variations in recent decades. By analysing the underlying reasons behind the production of detached house samples and their connection with the rise of individualism, this research sheds light on the intersecting economic, political, and cultural forces of globalization that shape the built environment in Batna. The findings of this study reveal that globalization, along with economic and political shifts, urban expansion, and technological advancements, has contributed to the proliferation of individualism in Batna. It becomes evident that individualism is not a recent phenomenon but rather a trend that emerged shortly after independence and deepened in the post-2000s era. The manifestation of individualism is highly influenced by the forces of globalization and the media's portrayal of Western culture. This research holds significance for the field of architecture in Algeria, providing valuable insights into the impacts of globalization on architectural trends and the built environment. By understanding these influences, architects and policymakers can better navigate the challenges and opportunities presented by globalization, ensuring the continued development of culturally sensitive and contextually relevant architectural designs.

Keywords: Globalization, individualism, Algeria, Batna, detached houses, single-family homes

Introduction

Although worldwide processes have linked nations for ages, what has changed today is the intensity and complexity of these processes and the resulting networks. Globalization has become an unstoppable force, connecting nations and shaping the world into a single system [1]. It is driving by digital networks, the internet that enables the transactions across national boundaries and the flow of information and ideas across borders [2].

The three pillars of globalization, namely economic, political, and cultural dimensions that play a pivotal role in this transformative process. Transnational corporations and financial flows drive the economic pillar. The political pillar establishes a new world order with political interference in other countries' affairs. The cultural pillar sees culture commodified like never before [3].

The field of architecture has not been immune to the influence of globalization. Ching, Jarzombek, and Prakash argue that uncertainty and constant reinvention have become defining features of architecture in the era of globalization [4]. This phenomenon affects urban systems, as dominant economies and cultures impose their patterns on less competitive countries, resulting in generality and sameness policies [5].

According to Assayed, he states that while some studies have explored the effects of globalization on architecture in the Arab world, research in this area remains limited [6]. In this aspect, Al-Naqeeb states that field studies are required to understand the impact of globalization more precisely [7]. Notably, Al-Saffar Mazen Dhafer Moussa's study on the impact of globalization on Iraq's urban and architectural system highlights the importance of exploring variables such as the architect, recipients, production processes, and architectural products [8]. Moreover, architects and designers themselves are consumers of design methods, ideas, trends, and products.

In the case of Algeria, existing research on globalization in the humanities and social sciences has primarily focused on areas unrelated to the relationship between globalization and architecture. However, investigating and assessing the effects of this phenomenon on the built environment is crucial due to its significant local and global impact on architecture.

In the early 1980s, the changes in the global economy forced Algeria to implement economic reforms and restructure its economy via policies of neo-liberalization and privatization. In its 2002 annual examination of the Algerian economy, the International Monetary Fund stressed the importance of prioritising the private sector over the public sector due to the latter's insufficiencies [9]. Then, a shift from a socialist economy to a free market economy took place when the state's ownership of the means of production and its defining role in policymaking were transferred to the private sector. The latter acquired a new 'freedom' of activities and initiatives as the purchase, sale, and consumption of goods that increased in diversity [10].

Consequently, this 'liberalization' encouraged the private sector in Algeria and promoted fundamental changes in the fields of architecture and urban development. The signs of this change can be seen in the physical environment of Algerian cities, especially with regard to housing [11]. Notably, Article 52 of the 1996 Constitution, as amended in 2008, granted property owners the freedom to use and construct their properties as they saw fit within state regulations [12]. Consequently, architects and real estate agencies in Algeria embraced this newfound freedom, leading to a diverse range of housing designs and construction practices over the past two decades.

By examining the effects of globalization on Algerian architecture, this study aims to shed light on the intersections of economic, political, and cultural forces, and their impact on the built environment. It seeks to deepen our understanding of the architectural transformations and the manifestation of individualism influenced by globalization and the media's portrayal of Western culture.

How it began?

In 1962, following Algeria's independence, the government rejected capitalism due to its association with Western countries and the Western economic system [13]. However, in 1989, amidst a major political and economic crisis, the country underwent significant changes. The new constitution marked the end of socialism and ushered in a free market economy system. This shift had a profound impact on urban policy, giving rise to new modes of construction governance influenced by neoliberal orientations and the promotion of construction projects financed by private funds. [14].

Algeria faced a challenging period in the late 20th century, known as the 'black decade,' characterized by internal conflicts and a civil war. It was not until the presidency of Abdelaziz Bouteflika in 1999 that efforts were made to establish a strong state and reshape the international perception of Algeria. During Bouteflika's tenure, the country experienced significant growth in housing construction, fuelled by revenue generated from hydrocarbon exports [15]. As a result, urban policy underwent transformations, introducing new regulations, laws, and measures [16], as encouraging and facilitating the establishment of new local private construction institutions, organizing innovative project competitions, and importing development technologies to meet local needs [17].

How it influenced Batna?

Batna City, renowned for its high level of urbanization, is currently grappling with the challenges of urban sprawl and increased land consumption [18]. In the context of neo-liberalization, the local authorities in Batna have been unable to adequately address the pressing housing needs due to financial constraints. As a result, private individuals have seized the opportunity to exercise their 'freedom' by selling their lands for individual construction purposes [19]. Consequently, a stark contrast between old and new designs in terms of individual housing has emerged within the city's neighbourhoods, notably in terms of architectural styles and building materials used in the current built environment [20]. Owners, residents, designers, real estate agencies, and private construction firms have actively contributed to the creation and prioritization of diverse housing types, both in terms of quantity and quality.

Toward Individualism

The trend of extended family houses in Algeria has gradually given way to smaller family housing units since the country's independence, resulting in significant impacts on the built environment and housing structures. This shift towards individualism, as noted by Djiar, has led to an increased preference for independent living among Algerian communities. Many individuals perceive the inner spaces of older houses as unnecessary and outdated, considering them to be a waste of space (See Fig. 1, 2). Consequently, a growing number of people have opted for independent living arrangements without the presence of strangers or relatives, contrasting with the traditional courtyard houses where multiple

families would reside together. This change in domestic lifestyle has contributed to the rise of individualism. Batna City serves as a notable example of this trend, as the number of individual housing units has steadily increased since independence and particularly in recent decades, accounting for nearly half of the city's total surface area [21] (See Fig. 3, 4).

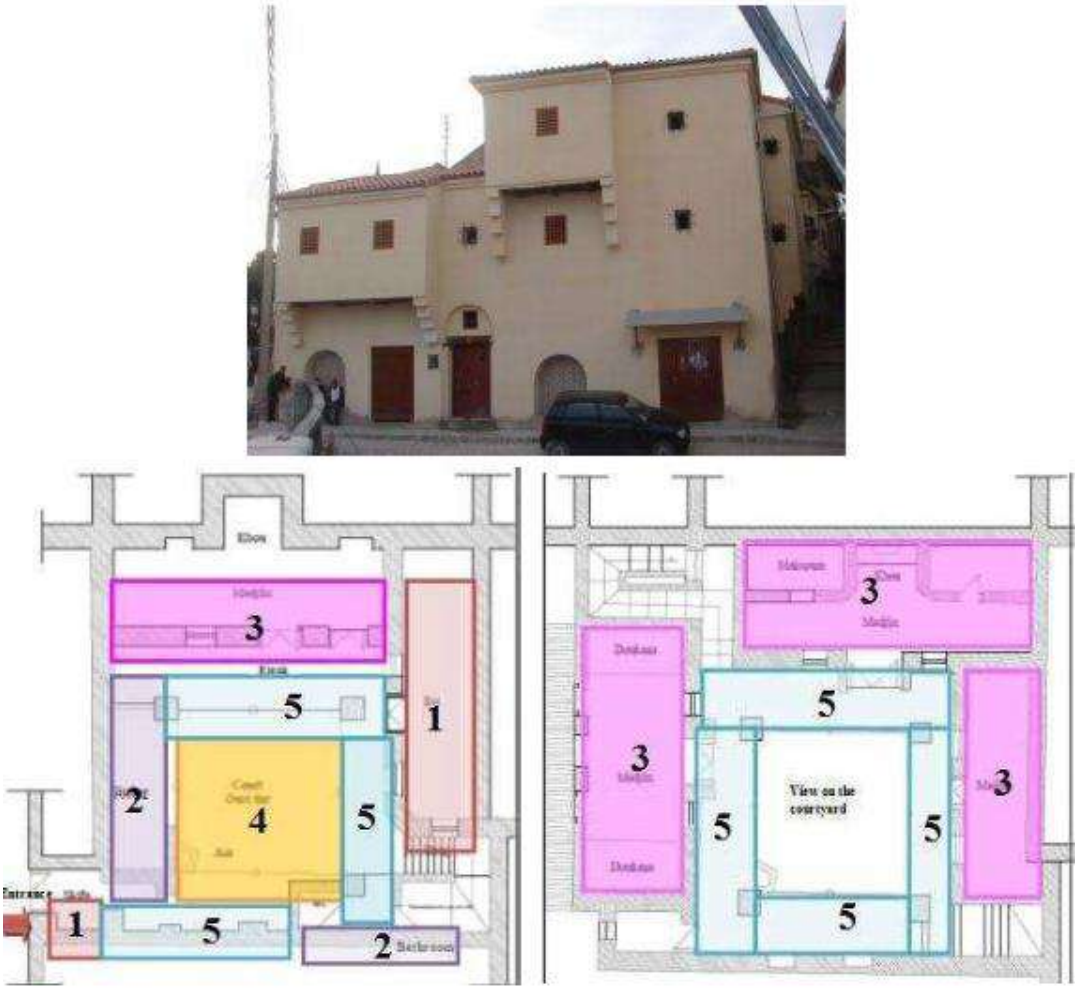

Figure 1. View and layout of a courtyard house in the City of Constantine, Algeria (ground floor left, first floor right) Key: 1 = Public (skiffa); 2 = Semi-public (Services); 3 = Private (Female and family living, or bedroom; 4 = Open space (Courtyard); 5 = Transitional spaces [29].

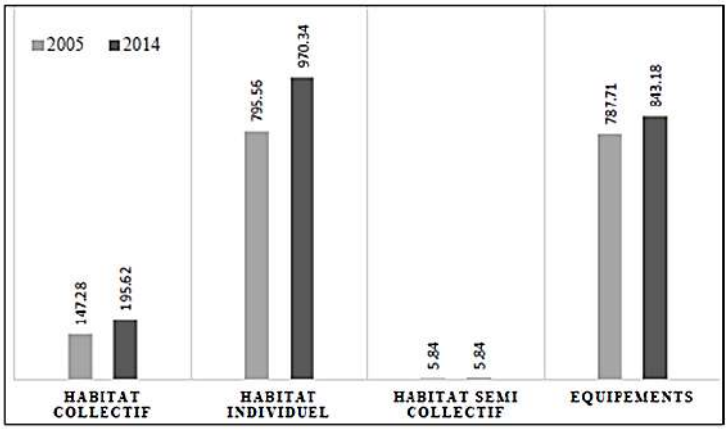

Figure 3. The cumulative area of the different types of constructed spaces in the city of Batna [30].

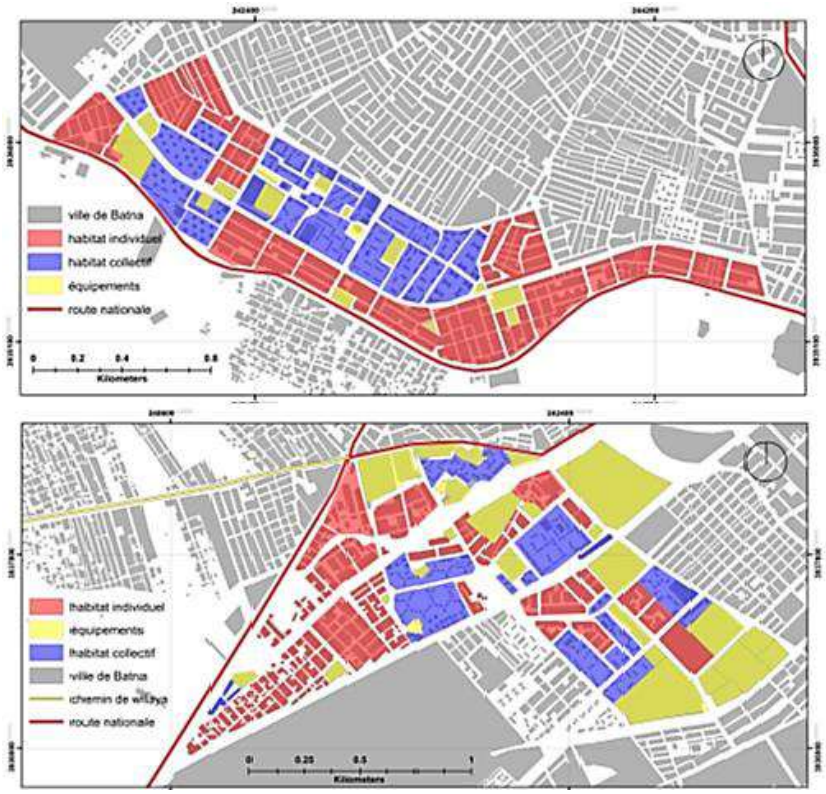

Figure 4. The division of the different types of constructed areas in Batna City [31]

Figure 3 illustrates the growth of Batna City's built environment surfaces from 2005 to 2014. The graph clearly demonstrates a substantial disparity between the surface areas of individual homes and other components of the built environment. On the other hand, Figure 4 provides a comprehensive breakdown of the surface area occupied by each building type in Batna. Notably, single-family homes exhibit both the largest surface area and the highest growth rate, as indicated by the accompanying statistics. These findings highlight the increasing prominence and rapid expansion of single-family housing within the city.

Another significant aspect to consider is the impact of globalization on architectural styles and the disappearance of traditional Algerian architectural characteristics. Some studies argue that the interaction with the 'modern world' through globalization has led to an increased adoption of 'Western' architectural styles, which he deems unsuitable for local conditions and demands, consequently eroding the appeal of traditional Algerian architecture [22]. Similarly, some suggest that as Algerian society embraces modernity, the concepts of nation-state and self-determination diminish [23]. Furthermore, the lack of cultural awareness and knowledge among architects and designers, resulting in a built environment in Batna that lacks a distinct architectural character [24]. The mentioned claims align closely with King's assertion that capitalist consumerism and other modes of production and ideologies have replaced the nation-state, influencing architectural identities and globalizing architectural production through the internationalization of images, trade, information, technology, communication facilities, and computer-aided design (CAD) methods [25]. However, it is crucial to acknowledge that the architectural characteristics of Batna City's built environment are shaped by a multitude of factors, including historical, economic, social, and political influences, each with its unique background and circumstances of creation.

The figures presented bellow depict various examples of individual houses in the city of Batna, both in the immediate aftermath of independence and in recent years. The samples from the post-colonial era exhibit a conventional and modest architectural form, characterized by standard construction materials. However, a noticeable shift can be observed in the individual houses constructed in Batna since the 2000s. These newer dwellings display architectural styles seemingly influenced by Western culture, incorporating contemporary designs and modern materials.

Figure 5. Views on the Manifestation of Individualism in Batna during the Period Following Colonial Rule (F.Nadjla, personal communication, August 22, 2022)

Figure 6. Views on the Manifestation of Individualism in post-2000s in Batna (F.Nadjla, personal communication, August 22, 2022)

Conclusion

The rise of globalization in the late twentieth century has significantly impacted the architectural landscape in Algeria, particularly in cities like Batna. This study has explored the influence of globalization on the built environment and the field of architecture in Batna, shedding light on the spread of individual houses and their connection to the concept of 'individualism.' This influence can be observed in two distinct phases.

The first phase occurred immediately after the post-colonial era, where individuals residing in courtyard houses began to construct individual housing units, seeking greater individuality and modernity. Therefore, individualism, emphasizing individual autonomy and freedom, emerged not only as a recent phenomenon but also during the post-colonial era.

The second phase, which took place in the post-2000s, was characterized by political and economic shifts towards a free-market system and the increasing impact of globalization. The rapid development of internet and digital networks played a significant role in shaping the architectural identity of Algeria through the internationalization of images, trade, information, technology, communication facilities, and computer-aided design methods. Individualism further intensified during this period, as citizens in Batna became increasingly convinced that individual houses were their preferred choice. This was influenced by media portrayal and the desire to emulate Western trends.

In conclusion, the influence of globalization, economic and political shifts, and technological advancements has contributed to the proliferation of individualism in Batna's built environment. This research reveals that individualism is not solely a recent phenomenon but a trend that emerged shortly after independence and deepened in the post-2000s. Its manifestation is highly shaped by the forces of globalization and the media's portrayal of Western culture. The study highlights the significant impact of globalization on architectural trends, particularly the rise of individual houses, in Batna and underscores the need for further exploration of this phenomenon in the field of architecture.

References

[1] Sassen S. Global networks, linked cities. New York: Routledge; 2002.

[2] Young R. Postcolonialism: An Historical Introduction. Oxford, UK: Blackwell Publishers; 2001.

[3] Elkhouli OA. From the introduction, Arabs and Globalization. Center for Arab Unity Studies, intellectual seminar, 1998. (Title translated from Arabic by the author).

[4] Ching F, Jarzombek M, Prakash V. A Global History of Architecture. Hoboken, NJ: Wiley; 2011.

[5] Al-Jabri MA. Globalization and Cultural Freedom. Arab Future Magazine. 1998; (228): 3. (Title translated from Arabic by the author).

[6] Assayed Y. Globalization, Fundamentalism and Postmodernism. Cairo: Academic Library; 1995. (Title translated from Arabic by the author).

[7] Al-Naqeeb K. An Intervention. In: Elkhouli OA, ed. Arabs and Globalization. Center for Arab Unity Studies; 1998:446. (Title translated from Arabic by the author).

[8] Al-Saffar MDM. Globalization and its Impact on the Urban System. Iraqi Journal of Architecture. 2010;6 (19): 6. (Title translated from Arabic by the author).

[9] Zouhair, Hambali. The Role of the State in the Era of Globalization: A Case Study of Algeria. PhD dissertation. Larbi Ben M'hidi University, Algeria. 2011, p. 177. (Title translated from Arabic by the author).

[10] Meliani H, Aghrout A, Ammari A. Economic Reforms and Foreign Direct Investment in Algeria. In: Aghrout A, Bougherira A, eds. Algeria in Transition: Reforms and Development Prospects. 1st ed. Routledge; 2004: 92-98.

[11] Abdelkader, Djeflat. "Liberalisation and Technological Change in Algeria: Assessment of the New Regulatory Framework." In The Global Challenge of African Business and Economic Development in the New Millennium, edited by A. Ogbuehi and G. Ogunmokun, 1-2-6. International Academy of African Business and Development Journal. St. Joseph University, Atlantic City, New Jersey, USA, 2000.

[12] Bin Azza, Sadiq. The Role of Management in Implementing Urban Regulations in Algerian Legislation. PhD dissertation, University of Batna, 2012. (Title translated from Arabic by the author).

[13] Boutabba, H. (2013). Spatial Specificities and Social Logics of a New Type of Domestic Habitat in Eastern Hodna: the "Diar Charpenti" Type (Doctoral dissertation, Mohamed Khider University). (Title translated from French by the author).

[14] Bin Azza, Sadiq. The Role of Management in Implementing Urban Regulations in Algerian Legislation. PhD dissertation, University of Batna, 2012. (Title translated from Arabic by the author).

[15] Metz HC. Algeria: a country study. Federal Research Division, Library of Congress; 1994. p. 99.

[16] Samir, Merdji. Metamorphosis Architecture of The Urban Landscape Constantine: From the Colonial City to the New City (PhD dissertation). Constantine Mahmoud Mentouri University, Algeria; 2010. (Title translated from French by the author).

[17] McDougall, J. (2017). A History of Algeria. Cambridge: Cambridge University Press, 338-339.

[18] Crowley, P. (2017). Introduction: Algeria: Nation, Culture and Transnationalism 1988–2015. In Algeria: Nation, Culture and Transnationalism: 1988-2015 (pp. 9). Liverpool University Press.

[19] Abdelkader, Djeflat. "Liberalisation and Technological Change in Algeria: Assessment of the New Regulatory Framework." In The Global Challenge of African Business and Economic Development in the New Millennium, edited by A. Ogbuehi and G. Ogunmokun, 1-2-6.

[20] International Academy of African Business and Development Journal. St. Joseph University, Atlantic City, New Jersey, USA, 2000.

[21] Djiar, K. A. (2009). Locating architecture, post-colonialism and culture: contextualisation in Algiers. The Journal of Architecture, 14 (2), 175-176.

[22] Abdelhalim, Bendib. (2017). Geomatization of Land Use Planning Instruments for Management; Coherent And Sustainable Space - Case of The City Of Batna. (Doctoral dissertation, Batna University). (Title translated from French by the author).

[23] Nedjai, Fatiha. "Urban Planning Instruments between Land Owner and Application Case Study: The City of Batna." PhD dissertation, University of Batna, 2015, p. 272. (Title translated from French by the author).

[24] Khireddine, Dounia and Aichour, Boudjemaa. "Batna City from Organized Planning to Distortion (Case Study Biskra Road Axis - Algeria)." Mediterranean Journal of Social Sciences, vol. 13, no. 1, 2022, pp. 78.

[25] King, A. D. (1995). Spaces of Global Cultures: Architecture, Urbanism, Identity. Routledge.

A Review on Impact of Agrochemicals on Human Health and Natural Environment

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Abstract

Agrochemical exposure periods and levels, types of agrochemicals used, and various environmental conditions of the areas are factors for acute and chronic poisoning on human health and the environment. Although agrochemicals are the result of modern technology that depends on inorganic fertilizers and pesticides but their continuous use against agricultural pests and disease vectors poses serious threats to both human health and the environment. Overuse of these chemicals has severe effects on humans and the environment that may lead to immediate and long-term effects. In developing countries, it is very difficult to find out the impact on the environment due to a lack of awareness, training, and adequate knowledge of using agrochemicals. Investigating farmers' awareness of agrochemicals residues and their behaviors regarding the application is important in order to reduce human factors that negatively affect environmental safety. The review focuses on a summary of both national and international studies regarding the impact of pesticide and chemical fertilizer residues on nature, both humans and the environment. This review has revealed the hazardous effect like cancer, neural disorders, and other health-related problems and environmental risks associated with agrochemical exposure.

Keywords: Agrochemicals, human health, environmental impact

1. Introduction

Despite being an expensive input, agrochemicals (pesticides and fertilizers) are viewed as a means of advancing crop production technology. Increased crop production is ensured by balanced use, optimum doses, proper technique, and appropriate timing of pesticide applications. The requirement for fertilizers and pesticides for crops differ according to soil and meteorology. [1] The developing world makes extensive use of agrochemicals, and the need for pesticides is rising as a result of the current crop production system, which places a premium on high agricultural yields. Pesticides, which are composed of chemicals that can control pests or influence plant growth, have given poor nations one method to raise yields. Many farmers in underdeveloped nations believe that using pesticides is the best way to safeguard their crops against pests, which tend to pose their biggest threat and this year have spread to portions of Africa. As such, pesticides can provide the only form of crop insurance available.[2] Pesticides are substances, tools, or organisms that have been chemically synthesized and are frequently used in agriculture to control, eliminate, combat, or repel pests, diseases, and parasites. Based on their chemical makeup, pesticides—which contain both organic and inorganic moieties—can be divided into many classes. These pesticides include organochlorines, organophosphates, carbamates, formamidines, thiocyanates, organotin, dinitrophenols, synthetic pyrethroids, and antibiotics. [3] Due to the fact that farmers frequently lack proper personal protective equipment (PPE) and frequently lack the ability to read labels, which are typically the primary source of safety instructions, health risks related to the handling and use of pesticides are more prevalent in developing nations. On these subjects, farmers rarely have access to in-person training. When residential areas are close by, pesticide use issues may go beyond the farming region. Children are especially vulnerable to the dangers of pesticides due to their use and storage in homes. Statistics reveal that a sizable number of suicides occur each year as a result of pesticides. According to the Network of African Science Academies, 2019 the market for neonicotinoid insecticides is expanding at the quickest rate. These pesticides have lower human toxicity than earlier classes of pesticides, but still pose problems for pollinators and aquatic organisms and are partially banned in the EU. Over the longer term, neonicotinoid use could have serious implications for biodiversity and the environment.[2]

Agrochemical Exposure and Poisoning

No segment of the population of developing countries like Bangladeshis completely protected against exposure to agrochemicals (pesticides) and the potentially serious health effects. Despite their popularity and extensive use, there is serious concern about health risks arising from the exposure of farmers when mixing and applying pesticides or working in treated fields [4]. Although the effects of pesticide use are frequently not noticed, there is evidence that farmers, their families, and those who live close to farmed areas may face long-term health problems [5]. In developing countries, incidents involving handlers of pesticides occur more often and the health impacts may be more immediate, given a frequent lack of PPE and minimal education about the correct way to spray chemicals. Approximately 20% of the 800,000 persons who commit suicide each year die from pesticide ingestion. The negative health effects associated with pesticide use include respiratory, integumentary, cardiovascular, gastrointestinal, and neurological problems. In Morocco, there were over 2000 different causes of acute pesticide poisoning between 2008 and 2014, 50 % of the pesticides involved were classes I (extremely or highly hazardous) and II (moderately hazardous) according to WHO classifications [6]. Cancer is one of the longer-term impacts that are hardest to precisely link to pesticide use. Consuming food that has residues beyond legal limits can have negative effects on one's health [7]. However, in West Africa, episodic studies by local scholars, students, donor projects, and public health agencies allow three cautious generalizations. First, dichlorodiphenyltrichloroethane (DDT, a type of pesticide) residues from spraying programs can linger for decades in the food chain, with milk, meat, fish, and even human breast milk affected. It is difficult to emphasize the harm that pesticides cause to children. Pesticides stored inside homes are also common causes of childhood poisoning [2]. The extension initiatives, particularly the plant protection department, have vanished in Somalia. This situation led to a lack of awareness of the proper use of pesticides, lack of plant quarantine and pesticide regulations and this encouraged the import of internationally banned synthetic chemicals to Somalia, for example, DDT, Aldrin, Aldicarb, and Nicotine sulfate which have a high risk of poisoning. Organophosphorus, carbamates, and organochlorines can act as endocrine disruptors and alter hormone function in addition to their primary function as pesticides by blocking, mimicking, replacing, or acting to subvert the roles that hormones naturally play in living species. In this survey it observed that the majority of farm workers apply pesticides without protective gear, use empty containers of pesticides as utensils, agro-dealers sell pesticide products together with food items in the same places, also ignore of considering the right dose, time and direction of the wind. If this situation continues for some decades, it may cause chronic diseases to humans, the environment, animals, and agroecosystem areas degradation at large [8].

2. Human Health Hazard

The links between agrochemicals and human health were suspected as early as the 1960s and 1970s. In locations with significant pesticide use, US epidemiologists noticed an extraordinary increase in Non-Hodgkin's Lymphoma cases [9]. Agrochemicals have an impact on more than just the environment and nonhuman biota. Humans can be exposed to agrochemicals directly for unintentional, deliberate, or occupational reasons as well as indirectly through residues in food and the environment. Infant and kid exposure to harmful pesticides is a serious problem, especially in crowded urban tenements and slums. Several more recent studies and reviews bring to light some critical health implications of agrochemical exposure.

2.1 Acute illness

The typical symptoms of acute pesticide poisoning in humans are fatigue, headaches and body aches, skin discomfort, skin rashes, poor concentration, feelings of weakness, circulatory problems, dizziness, nausea, vomiting, excessive sweating, impaired vision, tremors, panic attacks, cramps, etc., and in severe cases coma and death [10]. Diagnosis of acute pesticide poisoning generally occurs when one or more of these symptoms, which appear in a short time after contact with pesticides, are detected. 16% of respondents cited eye discomfort, 21% headaches, 6% dizziness, 5% skin irritation, and 7% vomiting after handling pesticides as the survey's most noticeable health issues. The interviews further revealed that 30% of the respondents experienced multiple health effects, with the duration of the ailment also being quite significant. Traders indicated an average duration of 7 hours in terms of eye irritation, 13 hours for headaches, and 21 hours for dizziness [11].

2.2 Chronic illness

Besides causing acute poisoning, pesticides can also cause chronic illnesses if they are incorporated over a longer period, even if the amounts taken up are relatively small. The workers in agrochemical production centers, as well as across other stages of the supply chain, retailers, and pesticide applicators

are directly exposed. People who live near agricultural fields or are present there are also affected. There are cases of inadvertent consumption (homicides), as well as the planned consumption of chemicals as a method of suicide. Several studies show multiple health problems due to exposure, such as birth defects, cancer, and neurological disorders. However, a person's health situation and mitigating behaviors will decide how much of an impact this has on them. Bioconcentration is the process in which the accumulation of the chemical in an organism occurs from the surrounding air or water. For instance, DDT, for example, is fat-soluble and accumulates in fish or human fatty tissue (lipids). Other chemicals, such as glyphosate, are digested and eliminated from the body.

A recent report by the UN Environment Program observes a significant association between occupational and residential exposure to pesticides and adverse health outcomes, including cancers and neurological, immunological, and reproductive effects. Based on clinical research conducted in laboratories, an extensive account of the physiochemical, toxicokinetic, and toxicodynamic features, stages of intoxication, symptoms of poisoning, and treatments relating to commonly used pesticides has been gathered. Health damage due to pesticide poisoning has been a public health issue ever since the beginning of the widespread use of chemical pesticides in agriculture. Mortality or morbidity (acute or chronic) are consequences.

The Task Force of WHO published the first global assessment on human pesticide poisoning in 1990, which estimated one million cases and a fatality rate of 20,000 per year. Due to its widespread availability, intentional pesticide poisoning as a method of suicide is fairly popular, especially in developing nations. Globally, 110,000–168,000 suicides were reported by this method annually over the 2010–2014 period, which accounts for 14–20% of total suicides.

Under real-world circumstances, exposure from many sources, such as air, water, food, and beverages, is highly frequent. The consumption of agricultural foods and animal products exposes people to a variety of chemical residues. In human systems, this chemical cocktail may have additive effects and be more dangerous than a single molecule. Renal damage is consistent with chronic kidney disease incidence in Sri Lanka and was reported to be linked to the synergistic effects of exposure to glyphosate with other pollutants like paraquat, under stressful physical labor conditions, such as high temperatures in lowland tropical regions [12].

3. Impact of Agrochemicals on Environment

3.1 Adverse effects on non-target Animals, microbial community, and non-target plants

Birds and other small wild animals are under threat because of the use of pesticides [4]. According to the farmers, the most significant environmental effects of pesticides usage were, the decline in abundance of pollinating bees (40%) and butterflies (18%), the disappearance of the red-billed oxpecker (20%), and other non-target insects dying (12%) when or after spraying and wildlife mortalities (10%). The birds disappeared when the government subsidized a common facility for livestock in the 1980s. Since then, the birds have only been observed in forest areas. Only 3% of the farmers had seen signs of poisoned birds so the alternative that the birds moved to another habitat for other reasons, such as the lack of ticks and insect parasites on the animals cannot be excluded. The populations of helpful soil microorganisms can decrease when soil is heavily treated with pesticides and other agrochemicals. Overuse of chemical fertilizers and pesticides has effects on the soil organisms that are similar to overuse of antibiotics in humans. Indiscriminate use of chemicals might work for a few years, but after a while, there are not enough beneficial soil organisms to hold on to the nutrients [4].

Weeds are intended to be killed by herbicides. So, it is not surprising that they can injure or kill desirable species if they are applied directly to them. In addition to killing non-target plants outright, Pesticide exposure can kill non-target plants directly in addition to having sublethal effects on them. Phenoxy herbicides, including 2,4-D, can injure nearby trees and shrubs if they drift onto leaves [13].

Many insects do not cause damage, but on the contrary, are most useful. Bees produce honey and are also important for the pollination of various crops, contributing to a good yield. It may also happen that an insect that at first caused no trouble in the crop becomes a pest after spraying because its natural enemy was removed, even though this was not the intention. This is one more reason for not spraying more frequently than necessary. You could also enquire into alternative control methods, such as those mentioned in the introduction, or consider using pesticides that are selective in their action. If the active ingredient of a pesticide only slowly departs from the environment, it is considered persistent. Persistent compounds can accumulate in the environment, in the soil, or in the food chain. Eventually, however, they also accumulate in meat, fish, or milk. In this way, humans also become exposed to the pesticide. A prime example of a persistent pesticide is DDT. Another effect of excessive spraying is that the harmful organism becomes tolerant (less sensitive) to the pesticide used. More and more pesticides must then be used to obtain the same degree of control, with all the harmful consequences involved for

humans and the environment. Moreover, the resistance of the harmful organism simply increases so that it becomes necessary to use a different pesticide to which the pest is not yet resistant [14]. Threatened plant species are particularly at risk from this. When soil microbes and beneficial insects are destroyed as a result of pesticide treatment, plants might also experience indirect effects. Herbicide contamination of water could also have devastating effects on aquatic plants. Oxadiazon was reported to significantly lower algal growth in one research [15].

3.2 Water Contamination

Agriculture development is closely related to the use of pesticides. The use of pesticides has helped in preventing the losses caused by pest attacks and has improved the production potential of crops, but these excess quantities are leaching down to groundwater and causing pollution. [16] Although the agricultural soil is the primary recipient of agrochemicals, water bodies that are adjacent to agricultural areas are usually the ultimate recipient of agrochemicals residues. There is a suspicion that agrochemical residues are common in surface water systems, especially in irrigation drains, which ultimately pollute the pond and river water, and can harm the aquatic environment. [4] On farms, agrochemicals are used to either increase soil fertility, eradicate weeds, or combat pests and diseases—actions designed to boost agricultural output and meet human demand for food. Gravity causes water that falls on the earth's surface to continue to seep in until a saturation zone is achieved. Thus, the relative rate of percolation and degradation within the soil profile, which processes are regulated by climate, soil characteristics, chemical characteristics, application rate, aquifer depth, and farming practices, determines the risk of contamination. Due to the higher capacity of sand for infiltration than clay, agrochemical use on sandy soil has a higher potential to leach to groundwater. If the parent compound's degradation rate is greater than its rate of percolation through the soil profile, groundwater contamination is also less likely to happen. Adsorption describes how firmly a particular agrochemical sticks to the soil while traveling down with water. The length of time a chemical remains in its original form in the soil is known as persistence. Groundwater vulnerability or susceptibility, which is independent of the kind of pollution, is the result of the contributions of these variables. In regions with high rainfall, agrochemicals like nitrogen-based fertilizers and herbicides left unused by plants may leak to contaminate groundwater. After the chemicals have been utilized, this contamination may not occur for several days or even months. Some common compounds that are mobile and difficult to attenuate in the subsoil make up the most prevalent pollutant. The use of agrochemicals such as fertilizers and pesticides constitutes an important aspect of modern agriculture as they are needed to control various pests and improve soil fertility. The benefits are increased supplies of food, but problems arise when significant amounts of agrochemicals accumulate as residue in soils and percolate into groundwater. [17]

4. Conclusion

Global production, consumption, and export of chemical pesticides often follow unscientific practices, augmented by aggressive marketing. As a result, even substances that are prohibited in one nation may be exported to another. Additionally, the importing nations, which are mainly developing nations, have either lax rules or little enforcement of existing regulations. This is made worse by technical developments that call for greater use of these chemicals, such as the ability to tolerate herbicides through genetic engineering. Agrochemicals on the other hand are considered a quick, easy, and inexpensive solution for controlling weeds and insect pests and increasing yield in agricultural landscapes. However, the use of pesticides comes at a significant cost. Almost every aspect of our environment has been poisoned by pesticides. The long-term effect of low-level exposure to one agrochemical is highly influenced by concomitant exposure to other agrochemicals. Most of the farmers are not capable of taking decisions on pest management and pesticide application. Often, they apply pesticides when there is no real need, or they use the wrong chemicals at the wrong doses, methods, and times. As a result, they kill the beneficial organisms easily and create pest resistance causing greater problems and crop losses.

Pesticides should be strictly handled according to the regulations which contribute to the reduction of the adverse effects of pesticides on human health and environment. However, existing regulatory and management protocols are based on assessment frameworks that suffer from methodological drawbacks. As a result, the usage of agrochemicals judged safe by these frameworks has steadily increased worldwide. The impact of pesticide mixtures and synergistic long-term ecological repercussions are not taken into account by the present assessment frameworks. The assessment frequently fails to take into account the interconnectedness of the sinks and the complex nature of the agrochemicals' environmental impact. This leads to the legal usage of various agrochemicals that have the potential to have long-term negative effects on the environment and human health. For a green environment and reducing chronic

effects, biological solutions can play an effective role. Biofertilizer is a super alternative to chemical fertilizers. Biopesticide also becomes an alternative solution for pest control. IPM and using several natural products and biological agents also give us hope to minimize the adverse effect of agrochemicals.

Conflict of Interest

The author declares no conflict of interest.

References

[1] Bhandari, G. (2014). An Overview of Agrochemicals and Their Effects on Environment in Nepal. *Applied Ecology and Environmental Sciences*, *2*(2), 66–73. https://doi.org/10.12691/aees-2-2-5

[2] Sarkar, S., Dias Bernardes Gil, J., Keeley, J., Möhring, N., & Jansen, K. (n.d.). *The use of pesticides in developing countries and their impact on health and the right to food Policy Department for External Relations*. https://doi.org/10.2861/28995

[3] Bohmont BL. (1990). The standard pesticide user's guide. Upper Saddle River (NJ): Prentice Hall.

[4] Kumar Biswas, S., Rahman, S., Kobir, S. M. A., Ferdous, T., & Banu, N. A. (2014). A Review on Impact of Agrochemicals on Human Health and Environment: Bangladesh Perspective. *Plant Environment Development*, *3*(2), 31–35.

[5] Larsen, A. E., Gaines, S. D., & Deschênes, O. (2017). Agricultural pesticide uses and adverse birth outcomes in the San Joaquin Valley of California. *Nature Communications*, *8*(1). https://doi.org/10.1038/s41467-017-00349-2

[6] World Health Organization (WHO). (2019). Suicide, Newsroom, Facts sheet. *Detail*.

[7] Joko, T., Dewanti, N. A., & Dangiran, H. L. (2020). Pesticide poisoning and the use of personal protective equipment (PPE) in Indonesian farmers. *Journal of environmental and public health*.

[8] Dayib Abubakar, M. (2019). *Effect of Pesticides on the Agro Ecosystem in Somalia; The socio-economic impact of fishing on food security in Mogadishu The socio economic impact of fishing on food security in Mogadishu View project*. https://doi.org/10.13140/RG.2.2.24573.41442

[9] Gupta, A. (2012). *Pesticide use in south and South-East Asia: Environmental public health and legal concerns*. http://www.inflibnet.ac.in/infonet/

[10] Bödeker, W., & Dümmler, C. (1993). Pestizide und Gesundheit. *Auflage, Verlag CF Müller, Karlsruhe*.

[11] Dasgupta, S., & Meisner, C. (2005). *Pesticide traders' perception of health risks: evidence from Bangladesh* (Vol. 3777). World Bank Publications.

[12] Devi, P. I., Manjula, M., & Bhavani, R. v. (2022). *Annual Review of Environment and Resources Agrochemicals, Environment, and Human Health*. https://doi.org/10.1146/annurev-environ-120920

[13] Dreistadt. S.H., J.K. Clark and M.L. Flint. (1994). An integrated pest management guide. University of California Division of Agriculture and Natural Resources; Pests of landscape trees and shrubs. Publication 3359.

[14] Boland, Jeroen., & Koomen, Irene. (2004). *Pesticides: compounds, use and hazards*. Agromisa.

[15] U.S. EPA. (1996). Office of Prevention, Pesticides, and Toxic Substances. Reregistration eligibility decision (RED): trifluralin.

[16] Khanna, R., Gupta, S., & Richa Khanna, C. (2018). Agrochemicals as a potential cause of ground water pollution: A review. *~ 985 ~ International Journal of Chemical Studies*, *6*(3).

[17] Aderemi Adeoye, P., Kazaure, S., & Richard Adeolu, A. (2013). Scientia Agriculturae Effect of Agrochemicals on Groundwater Quality: A Review. In *Sci. Agri* (Vol. 1, Issue 1). www.pscipub.com/SA

The Effect of Amino Acid Applications on Fruit Quality in "Kırmızı" Pistachio Variety

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Abstract

Pistachio (*Pistacia vera L.*) is an important type of nut fruit in Türkiye and has value in terms of health and nutrition. Amino acids, which are one of the essential components in the process of protein synthesis in plants, are also called biostimulants. Today, these components affect fruit quality and yield positively and are used specially to increase the resistance of plants to stress. In this study, which was carried out in Demirci district of Manisa province in 2020 to determine the effect of amino acid application in different doses (0, 5, 7.5 and 10 ml/lt) on some fruit characteristics of "Kırmızı" pistachio cultivar, the treatments were applied from leaves twice (2) in May and June.

Accordingly, 7.5 ml/lt (12.97 mm) and 10 ml/lt (12.70 mm) applications were found to be statistically significant in terms of fruit width. In addition, the most positive results in terms of fruit size (24.90 mm), fruit weight (1.03 g), nut weight (0.37 g) and kernel ratio (36.19%) were obtained from 10 ml/lt amino acid application. In addition, with amino acid applications, the kernel color changed from yellow to green tones and gained a brighter color. The most effective application in terms of color values was determined as amino acid at a dose of 7.5 ml/lt. As a result, amino acid applications have a positive effect in terms of improving quality properties.

Keywords: Pistacia vera L., amino acid, dose, fruit characteristics

Introduction

Pistachio (*Pistacia vera* L.), a member of the *Anacardiaceae* family, has an important value in terms of horticultural crops. Among the species in the genus *Pistacia*, pistachios are particularly notable for giving edible nuts widely accepted in markets (Ferguson et al., 2005). Pistachio species can be grown in the northern and southern hemispheres, especially in microclimates with temperatures ranging from 30 to 40˚C. Ideal conditions for pistachio cultivation are regions that are hot and dry in summers and cold and rainy in winters (Tekin et al., 1995; Şen and Sandal, 2015). Pistachio production in Turkey is mainly carried out in Southeast Anatolia and also in the high altitudes of the Aegean, Mediterranean and Central Anatolian Regions.

Turkey is among the important producer countries in the world. Turkey ranks third row in the world in pistachio production after Iran and the USA (FAO, 2022). The Southeastern Anatolia Region accounts for 91 percent of Turkey's total pistachio production (TUIK, 2023). Gaziantep, Şanlıurfa, Adıyaman and Siirt are the provinces that contribute significantly to pistachio production in Turkey (Sarpkaya, 2014). While the total number of pistachio trees in the country was 70.087.123 in 2018, this number increased to 79.163.245 in 2021. Similarly, the number of fruit bearing trees increased from 49.557.873 in 2018 to 55.464.465 in 2021 (TUIK, 2023). While pistachio production was 119.355 tons in 2021, it reached 239.289 tons in 2022 with a significant increase (TUIK, 2023).

This species, which has high economic value in Turkey, is very important in terms of health and nutrition due to its antioxidant and antimicrobial effects. Pistachio fruits are commonly consumed as a snack food and utilized as a food additive.

Given its significance, the pistachio necessitates careful and attentive cultivation practices. Pistachio trees have problems such as bud and nut drop, blank nut, lack of splitting and deformities. These problems can be caused by factors such as insufficient fertilization, pollination and fertilization problems, adverse environmental conditions, deterioration of carbohydrate, mineral and growth regulators intake.

To achieve a high yield from the pistachio plant, providing appropriate care and attention is of utmost importance. Among various factors, amino acids play a crucial role in supporting the plant's growth.

Amino acids are indispensable components with a wide array of functions in plants. They fundamental building blocks for enzymes and proteins, which are vital for plant metabolism and structural development. In addition, amino acids act as nitrogen donors or precursors for synthesizing various compounds critical for plant growth and development, such as nucleotides, chlorophyll, hormones, and secondary metabolites. Amino acids can be acquired by plants through direct uptake from the soil or assimilation from inorganic nitrogen sources such as nitrate and ammonium (Tegeder and Rentsch, 2010). In the current study, it was aimed to determine the effect of 3 different doses of amino acid application on some fruit characteristics of "Kırmızı" Pistachio variety in Demirci district of Manisa province, where cultivation is widespread.

Materials and methods

This study was conducted in Demirci district of Manisa province in 2020. "Kırmızı" pistachio variety was used as plant material. This variety, which constitutes a large part of our production, is superior in terms of aroma. It is known as "Turkish Pistachio" in world markets. In addition, the inflorescence structure is dense, the nut is small and long, and the nut inflorescence is easily separated (Özçağıran et al., 2014).

The amino acids were sprayed on the trees at doses of 5, 7.5 and 10 ml/lt. As the control group, only water was sprayed on the trees. Applications were made to the trees in two periods, in May (small fruit period) and June. For this purpose, the commercial preparation of the company "Hektaş" was applied.

30 fruit samples harvested for each replication were used in the analysis. Average nut and kernel weight were determined on precision electronic scale (0.01 g) then the kernel ratio (%) was calculated. Nut length was measured along the fruit axis using a digital caliper with a precision of 0.01 mm, while fruit width was measured at the widest points perpendicular to the fruit axis using the same digital caliper. Blank rate was determined (%). Fruit color was measured by a CR400 model minolta colorimeter in CIE L*, a*, b*.

The experiment was carried out according to the design of the random blocks, with 3 replications and 3 trees per replication. The data were subjected to analysis of variance using IBM® SPSS® Statistics 19 statistical software (IBM, NY, USA). Significant differences between averages were defined by Duncan test at the $P<0.05$ significant level.

Results

The effects of different concentrations of amino acids on pistachio nut were investigated, and their impact was compared. Various parameters were measured, including nut width (mm), nut length (mm), nut weight (g), kernel weight (g), kernel ratio (%), and blank ratio (%). Accordingly, nut width, length and weight values showed significant differences depending on the applications (Table 1).

The highest value in terms of nut width was obtained from 7.5 ml/l application, and it formed a different statistical group. Other applications were included in the same group. The maximum nut length was determined at 24.90 mm and 10 ml/l application. Similarly, the highest nut weight of 1.03 g was determined in 10 ml/l application. This was followed by 0.96 g and 7.5 ml/l application. Although there was no statistical difference in terms of other characteristics, it was observed that amino acid applications made a positive contribution compared to the control group.

Table 1. Some nut features depending on applications

Application	Nut width (mm)	Nut length (mm)	Nut weight (g)	Kernel weight (g)	Kernel ratio (%)	Blank ratio (%)
5 ml/lt	12.07 b	23.37 b	0.88 b	0.29	33.63	16.67
7.5 ml/lt	12.97 a	23.40 b	0.96 a	0.34	34.94	15.00
10 ml/lt	12.70 b	24.90 a	1.03 a	0.37	36.19	16.67
Control	11.63 b	22.67 b	0.85 b	0.28	33.18	15.00

The results suggest that the application of different concentrations of amino acids did not significantly affect the lightness (L*) and red-green chromaticity (a*) values of the pistachio fruits (Table 2). However, subtle variations were observed in the yellow-blue chromaticity (b*) values, with slightly higher values observed at the 7.5 ml/l concentration. Statistical differences in color values were not determined. In general, positive values were determined in 7.5 and 10 ml/lt amino acid applications according to untreated trees.

Table 2. Color parameter values

Application	L*	a*	b*
5 ml/lt	48.91	-10.85	26.31
7.5 ml/lt	50.20	-11.35	29.59
10 ml/lt	48.75	-11.56	27.21
Control	46.41	-10.85	26.32

Discussion

Amino acids play a role in increasing plant yield, improving quality and supporting overall growth and development. Especially during critical periods for the plant, amino acids perform essential functions in the biosynthesis of organic compounds and cell division (Ahmed and Abd El-Hameed, 2003; Sabry et al., 2009).

In a study conducted by Rahdari et al. (2012) on pistachio trees of the "Ohadi" variety, the use of amino acids demonstrated a significant increase in pistachio yield, quality, and weight compared to the control group. In another study, which included Ohadi, Akbari, and Kalehghoochi pistachio varieties in Iran, the effect of polyamines, organic acids and amino acid combinations was examined. Compared to the control group, it is stated that the yield increases and the percentage of blank decreases (Kamiab et al., 2015). Molaie et al. (2013), the effects of foliar application of amino acid compounds on photosynthesis and yield were investigated in Momtaz and Ohadi pistachio cultivars. Accordingly, it is reported that the applications significantly affect the protein content, but are ineffective in the percentage of blank. Amino acid application was made in Chandler walnut variety, which is a nut fruit in the same ecology. Similar to this study, it has been stated that the application affects the nut weight positively (Acarsoy Bilgin and Mısırlı, 2021).

Furthermore, another study investigating (Delicious and Granny) varieties of apples suggested that foliar spraying of amino acids significantly increased the quality and quantity of apples (Arabloo et al., 2017). Similarly, a two-year study on Canino apricots reported that the application of amino acids and micronutrients significantly increased fruit weight and quality in both seasons. The authors also suggested that amino acids and micronutrients should be foliar applied to Canino apricot trees at least three times (El-Badawy et al 2019). Moreover, a study conducted on Manfaloti pomegranate trees found that spraying amino acids increased on fruit dimensions (Mohamed et al., 2020). Likewise, it was claimed that amino acid application was more effective in terms of fruit weight, size, length, and diameter on guava plants. A significant increase was recorded in treated trees compared to untreat ones (Almutairi et al., 2020).

Conclusions

Based on the findings of the present investigation and analogous studies, it is substantiated that the application of amino acids through spraying techniques exerts a noteworthy favorable impact on the overall fruit quality and crop productivity. In terms of the properties examined in the research, it was concluded that 10 ml/lt amino acid application is more effective and can be recommended.

References

Atlı, H. S., Arpacı, S., Akgün, A., Özgüven, A. I., & Özgüven, F. (1999). Bazı Antepfıstığı Çeşitlerinin Hasat Zamanının Saptanması ve Makineli Hasadın Uygulanabilme Durumunun Araştırılması. Türkiye III. Ulusal Bahçe Bit. Kong. S, 248, 251.

Arpacı, S., Atlı, H. S., & Tekin, H. (1999). Verim Çağındaki Antepfıstıklarında Budama Tekniğinin Geliştirilmesi. Tarım ve Köyişleri Bakanlığı Tar. Araşt. Gn. Müd., Yayın, (11 S 31).

Ahmed, A.M.,& Abd El-Hameed, H.M. (2003) Growth, uptake of some nutrients and productivity of red roomy vines as affected by spraying of some amino acids, magnesium and boron' Minia J. Agric. Res. And Develop, 23: 649-666.

Altuntas, E., ve Mutlu, A. (2007). Antepfıstığı (Pistaciavera L.) Kabuklu ve İç Meyvesinin Bazı Fiziksel Özelliklerinin Belirlenmesi. GOÜ. Ziraat Fakültesi Dergisi, 2007, 24(1), 19-25

Arabloo, M., Taheri, M., Yazdani, H., & Shahmoradi, M. (2017). Effect of foliar application of amino acid and calcium chelate on some quality and quantity of Golden Delicious and Granny Smith apples. Trakia J Sci, 15(1), 14-19.

Aygün, M. ve Gürsoy, S. (2020). Antep Fıstığı (Pistaciavera L.) Üretimi Yapan İşletmelerin Tarımsal Mekanizasyon Düzeylerinin Belirlenmesi: Türkiye, Siirt İli Örneği. Türkiye Tarımsal Araştırmalar Dergisi. 2020; 7(2): 136 - 142. 10.19159/tutad.675257

Acarsoy Bilgin, N., & Mısırlı, A. (2021). Effects of Some Biological Foliar Applications On Fruit Characteristics Of 'Chandler' Walnut Variety. 31st International Scientific-Expert Conference of Agriculture and Food Industry (AGRIFOOD 2021) 27-28 September 2021, Ege University, Izmir, Turkey. 174-180.

Almutairi, K. F., Saleh, A. A., Ali, M. M., Sas-Paszt, L., Abada, H. S., and Mosa, W. F. (2022). Growth Performance of Guava Trees after the Exogenous Application of Amino Acids Glutamic Acid, Arginine, and Glycine. Horticulturae, 8(12), 1110.

Anonim, (2023). Türkiye İstatistik Kurumu istatistikleri. http://www.tuik.gov.tr

Barghchi, M., & Alderson, P. G. (1989). Pistachio (Pistacia vera L.) IN: Biotechnology in Agriculture and Forestry, Trees II. Springer-Verlag, Berlin, 5, 69-97.

Bilim, H. I. C. ve Polat, R. (2006). Antepfıstığı çıtlatma makinası tasarımı. Tarım Makinaları Bilimi Dergisi, 2(3), 203-209.

Bozorgi, M., Memariani, Z., Mobli, M., Salehi Surmaghi, M. H., Shams-Ardekani, M. R., & Rahimi, R. (2013). Five Pistacia species (P. vera, P. atlantica, P. terebinthus, P. khinjuk, and P. lentiscus): a review of their traditional uses, phytochemistry, and pharmacology. The Scientific World Journal, 2013.

Crane, J. C., &Iwakiri, B. T. (1985). Vegetative and reproductive apical dominance in pistachio. HortScience, 20(6), 1092-1093.

Davies, D.D. (1982). 'Physiological aspects of protein turn over' Encycl. Plant Physiol., 45: 481- 487.

Eskandari S (1999) evaluation of the results of Amygdalus hybrids and introduce better clones in sahand horticultural station. First National Amygdalus Congress. [In Persian].

Ertürk Y. E., Geçer M.K., Gülsoy E. ve Yalçın S., 2015. "Antepfıstığı Üretimi ve Pazarlaması". Iğdır Üniversitesi Fen Bilimleri Enstitüsü Dergisi Cilt: 5, Sayı: 2, Sayfa: 43-62.

El-Badawy, H. E. M. (2019). Effect of Spraying Amino Acids and Micronutrients as Well as their Combination on Growth, Yield, Fruit Quality and Mineral Content of Canino Apricot Trees. Journal of Plant Production, 10(2), 125-132.

Ferguson, L., Polito, V., & Kallsen, C. (2005). The pistachio tree; botany and physiology and factors that affect yield. Pistachio production manual, 4th ed. Davis, CA, USA, University of California Fruit & Nut Research Information Center, 31-39.

Fathalizadeh, J., Bagheri, V., Khorramdelazad, H., Kazemi Arababadi, M., Jafarzadeh, A., Mirzaei, M.R., Hajizadeh, M.R. (2015). Induction of apoptosis by pistachio (Pistacia vera L.) hull extract and its molecular mechanisms of action in human hepatoma cell line HepG2. Cellular and Molecular Biology, 61(7), 128-134

Galston AW, Kaur-Sawhney R, Altabella T, Tiburcio F (1997) Plant polyamines in reproductive activity and response to abiotic stress. Botanica Acta. 110, 197–207.

Kamiab, F., Heidari Salehabad, M., & Zamanibahramabadi, E. (2015). Evaluation the effects of foliar treatments of polyamines and some organic acids on quantitative and qualitative traits in some pistachio cultivars. Journal of Nuts, 6(02), 131-142.

Molaie, H., Panahi, B., & Tajabadipour, A. (2013). The effect of foliar application of some amino acid compounds on photosynthesis and yield of two commercial cultivars in pistachio orchards of Kerman province in Iran. International Journal of Agriculture and Crop Sciences, 5(23), 2827.

Mohamed, A. K., Abdel-Galil, H. A., & Galal, N. (2020). Effect of some nutrients and amino acids spraying on yield and fruit quality of Manfalouty pomegranate. SVU-International Journal of Agricultural Sciences, 2(2), 18-29.

Polat, R., Güner, M., Erdoğan, D., Gezer, İ., Atay, Ü. &Aktaş, T. (2017). Determination of optimum shaking frequency and amplitude of prototype body shaker used for mechanical harvesting of pistachio. 45. Symposium "Actual Tasks on Agricultural Engineering", Opatija, Croatia, 2017 (pp. 597-603).

Rentsch, D., Schmidt, S., & Tegeder, M. (2007). Transporters for uptake and allocation of organic nitrogen compounds in plants. FEBS letters, 581(12), 2281-2289

Rajaei, A., Barzegar, M., Mobarez, A. M., Sahari, M. A., & Esfahani, Z. H. (2010). Antioxidant, anti-microbial and antimutagenicity activities of pistachio (Pistachia vera) green hull extract. Food and chemical toxicology, 48(1), 107-112.

Rahdari, P., Panahi, B., & Mozaphari, A. (2012). Effect of free amino acids spray on the some nutrient elements accumulation in pistachios (pistachio vera L.), Ohadi (Fandoghi) cultivar. Advances in Environmental Biology, 1780-1786.

Sabry, G.H., MervatRizk, S., & Abd El-Wahab, M.A. (2009) Influence of effective micro-organisms, seaweed extract and amino acids application on growth, yield and bunch quality of Red Globe grapevines' J. Agric. Sci. Mansoura Univ., 34: 5901-5921.

Sarpkaya, K., 2014. Antep Fıstığında Karazenk Hastalığına Neden Olan Pseudocercospora Pistacina'nın Biyolojisi, Epidemiyolojisi ve Mücadelesine Yönelik Çalışmalar, Ç.Ü. Doktora Tezi, 120 sayfa.

Seifaddinipour, M., Farghadani, R., Namvar, F., Mohamad, J., & Abdul Kadir, H. (2018). Cytotoxic effects and anti-angiogenesis potential of pistachio (Pistacia vera L.) hulls against MCF-7 human breast cancer cells. Molecules, 23(1), 110.

Şen, Ö.,& Sandal, E. K. (2015). Gaziantep ilinde antep fıstığı üretimi ve maliyet-kazanç analizi. Coğrafyacılar Derneği Uluslararası Kongresi Bildiriler Kitabı, 21, 23.

Tekin, H., Arpacı, S., Atlı, S., Karaca, R., Mart, C., & Turan, K. (1995). Antepfıstığı yetiştirme tekniği. Antepfıstığı Araştırma.

Tegeder, M., & Weber, A. P. (2008). Metabolite transporters in the control of plant primary metabolism. Control of primary metabolism in plants, 22, 85-120.

Tegeder, M., & Rentsch, D. (2010). Uptake and partitioning of amino acids and peptides. Molecular plant, 3(6), 997-1011.

Kanatlı Hayvan Beslemede Bal Arısı Ürünlerinin Yem Katkı Maddesi Olarak Kullanımı

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Özet

Kanatlı hayvan beslemede büyümeyi teşvik etmek amacıyla uzun yıllar bilinçsizce kullanılan antibiyotiklerin ürünlerde kalıntı problemine ve patojen bakterilerde direnç gelişimine neden olmalarından dolayı Avrupa Birliği Ülkeleri'nde ve Türkiye'de yem katkı maddesi olarak kullanımları yasaklanmıştır. Bu gelişmelere müteakip antibiyotiklerin yerine kullanılabilecek doğal ürün arayışı hız kazanmıştır. Günümüzde doğal, gıda güvenliğini sağlayabilen, mevcut mevzuatlarla uyumlu ve sürdürülebilir hayvansal üretime uygun katkı maddeleri olarak enzimler, probiyotikler, prebiyotikler, simbiyotikler, organik asitler ve bitkisel ekstraktlar/uçucu yağlar önerilmektedir.

Son yıllarda antibiyotik alternatifi ürünler kapsamında çeşitli bal arısı ürünleri üzerinde de önemle durulmaktadır. Bu bağlamda değerlendirilen bal arısı ürünleri ise bal, arı sütü, propolis, arı poleni, arı zehiri ve arının farklı gelişim safhalarındaki formlarıdır (larvalardır). Çeşitli karbonhidratlar, organik asitler, proteinler, amino asitler, yağ asitleri, mineraller, vitaminler, aroma maddeleri, enzimler, polifenoller, flavonoidler, fenolik asitler gibi bileşenleri içeren bu ürünlerin kanatlı hayvanlarının fizyolojisini dolayısıyla performansını etkileyebileceği belirtilmektedir. Ancak, günümüze değin yem katkı maddesi olarak bal arısı ürünlerinin kullanım potansiyellerinin incelendiği çalışmalarda çelişkili sonuçlara ulaşılmıştır.

Bu bildiride, bal arısı ürünleri hakkında bilgi verilerek kanatlı hayvanların beslenmesinde yem katkı maddesi olarak kullanımlarına ilişkin çalışmalar irdelenecektir.

Anahtar Kelimeler: Kanatlı hayvan, bal arısı ürünleri, yem katkı maddesi

Giriş

Hayvansal protein kaynakları, insanların yeterli özellikle de dengeli beslenebilmesi için ayrı bir öneme sahiptirler. Bu bağlamda, daha kısa sürede ve ucuza üretilme olanağı sunan ve dini açıdan yasaklı olmayan kanatlı ürünleri [1, 2] kontrolsüzce artan dünya nüfusunun gıda güvencesi açısından stratejik öneme sahiptirler. Nitekim, günümüzde tavuk ürünleri dünyada ve ülkemizde en çok üretimi ve tüketimi yapılan hayvansal gıdalardır. FAO [2022]'nun son yayınladığı verilere göre et üretimi son 20 yılda yaklaşık %45 oranında artarken 2020 yılı itibarı ile tavuk eti üretimi %35'lik bir oranla en yüksek paya sahip olmuştur. Tavuk yumurtası üretimi ise 2000 ile 2020 yılları arasında %69 oranında bir artış göstermiştir [3]. Tavukçuluk sektöründe yaşanan bu gelişmeler ise işletme sayılarının ve kapasitelerinin artması, yüksek verimli hibritlerin kullanılması, optimum bakım, besleme ve sağlık koruma programlarının uygulanması, yem teknolojisindeki gelişmeler ve yem katkı maddeleri gibi biyoteknolojik ürünlerin yaygın kullanılması ile yakından ilişkilidir [4].

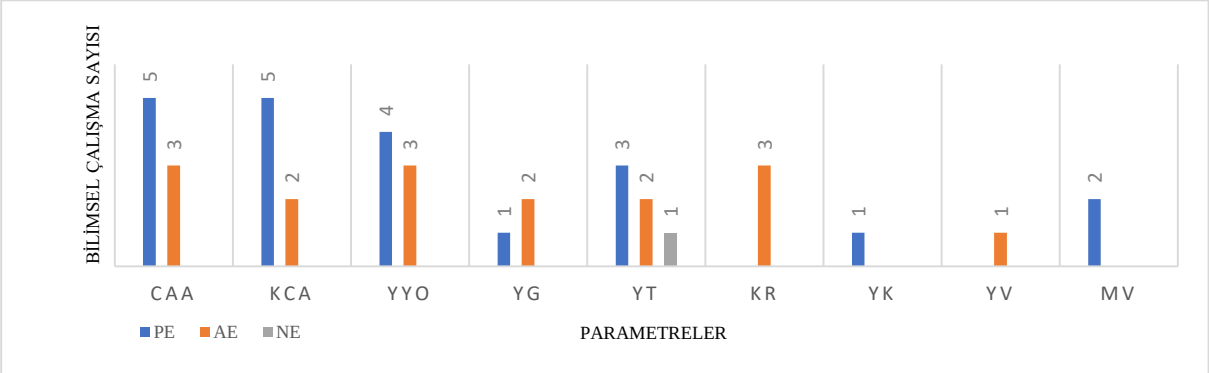
Hayvan beslemede yem katkı maddesi olarak ilk kullanılan ürünler hormonlar ve antibiyotiklerdir. Tavukçuluk sektöründe özelikle antibiyotikler büyümeyi teşvik edici özelliğinden [5] dolayı 1951 yılından itibaren ABD'de yemlere ilave edilmeye başlanmış ve zaman içerisinde küresel çapta kullanılır hale gelmiştir [6]. Antibiyotikler, patojenlerde ölümcül veya ölümcül olmayan hasarlar oluşturarak, bakteriyel toksin üretimini ve temel besin maddelerinin bakteriyel kullanımını azaltarak, vitaminlerin ve diğer büyüme faktörlerinin sentezini uyararak, bağırsak epitelinin kalınlığını inceltip besin maddelerinin emilimini arttırarak, bağırsak mukozası epitel hücre dönüşümünü ve bağırsak hareketliliğini azaltarak büyüme performansını iyileştirmişlerdir [7]. Ancak, antibiyotiklerin uzun yıllar sub-terapötik dozlarda aşırı kullanılması dirençli bakteri şuşlarının gelişmesine [8, 9, 10] ve hayvansal ürünlerde kalıntı problemine [11, 12] neden olmuştur. Bahsedilen bu gelişmelerin insan ve hayvan sağlığını tehdit eder boyutlara ulaşmasından dolayı antibiyotiklerin hayvan yemlerinde yem katkı maddesi olarak kullanılmaları 2006 yılında Avrupa Birliği ülkelerinde ve Türkiye'de tamamen yasaklanmıştır. Bu durum, yem katkı sektöründe doğal yem katkı maddeleri arayışlarını hızlandırmıştır.

Bazı araştırıcılar ideal bir antibiyotik alternatifini, antibakteriyel etki yanında besin maddelerinin kullanılabilirliğini artırarak büyüme ve yemden yararlanmayı olumlu etkileyen madde veya maddeler olarak tanımlamışlardır [13, 14, 15]. Bu kapsamda günümüze değin enzimler, organik asitler, probiyotikler, prebiyotikler, simbiyotikler ve fitobiyotikler gibi birçok doğal ve biyoteknolojik ürünlerin yem katkı maddesi olarak kullanılabilirliğine ilişkin çalışmalar yapılmıştır [15]. Son yıllarda, antibiyotik alternatifi olarak multifonksiyonel özellikteki çeşitli arı ürünlerinin kullanım potansiyellerini belirlemeye yönelik bilimsel çalışmalar da yürütülmüştür. Bu bildiride; bal, arı sütü, polen, arı zehiri, propolis ve arı larvalarının yapısı hakkında bilgi verilmiş ve ilgili bal arısı ürünlerinin kanatlı hayvanların beslenmesinde performans, ürün kalitesi ve bağışıklık sistemi üzerine etkilerine ve antimikrobiyal aktivitelerine ilişkin istatistiki bilgilendirme yapılmıştır.

Balın Yapısı ve Kanatlı Hayvan Beslemede Kullanımı

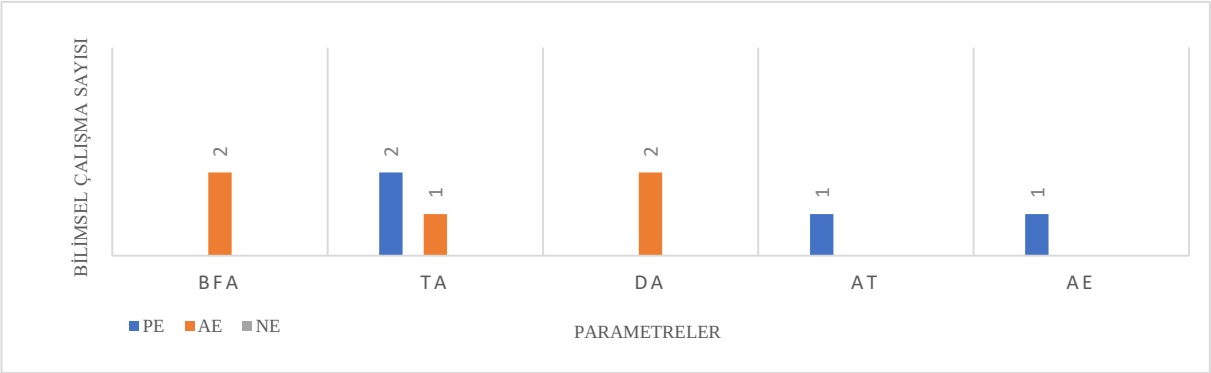
Bal, Türk Gıda Kodeksi Bal Tebliği' ne göre arılar familyasının (*Apidea*), bal arısı *(Apis Mellifera)* türü tarafından üretilen bir üründür ve 'bitki nektarlarının, bitkilerin canlı kısımlarının salgılarının veya bitkilerin canlı kısımları üzerinde yaşayan bitki emici böceklerin salgılarının, bal arısı tarafından toplandıktan sonra kendine özgü maddelerle birleştirerek değişikliğe uğrattığı, su içeriğini düşürdüğü ve petekte depolayarak olgunlaştırdığı, doğası gereği kristallenebilen doğal ürünü' olarak tanımlanır [16]. Bal, nektarın kaynağına göre; çiçek ve salgı balları, bitki çeşitlerine göre; multifloral ve monofloral ballar olmak üzere ikiye ayrılmaktadır. Balın kimyasal yapısı coğrafi ve botanik kaynağına göre değişiklik göstermekle beraber yaklaşık %82 karbonhidrat, %15-23 su, 0.02-1.03 g/100 g mineral madde, %0.3 protein, vitamin, organik asit, fenolik bileşikler ve serbest aminoasit gibi makro ve mikro bileşenlerden oluşmaktadır [17, 18]. Bal; antimikrobiyal [19, 20], antioksidan [21], antikanserojenik [21, 22] ve fizyolojik fonksiyonları destekleyici özelliklere [23, 24, 25] sahiptir. Belirtilen bu etkiler balın yapısındaki flavonoidler ve fenolik asitler gibi polifenoller, tiamin, riboflavin, α-tokoferol, askorbik asit gibi vitaminler, salisilik asit, sülfidril grupları, karotenoid türevleri, enzimler, organik asitler, Maillard reaksiyon ürünleri, amino asitler ve proteinler ile ilişkilendirilmektedir [26, 27].

Yapılan literatür taramasında kanatlı hayvanların beslenmesinde balın kullanıma yönelik 11 adet çalışmaya ulaşılmış ve bunların 8'i etlik piliçler [28, 29, 30, 31, 32, 33, 34, 35], 2'si yumurtacılar [36, 37] ve 1'i bıldırcınlar [38] ile yürütülmüştür. Bahsedilen çalışmaların 7'sinde bal içme suyuna [32, 33, 34, 35, 36, 37, 38], 4'ünde yeme ilave edilerek uygulanmıştır [28, 29, 30, 31]. Yeme ve suya ilave edilen balın kullanım düzeyleri ise sırasıyla 1g/kg -20 g/kg ve 10 ml/l-60 ml/l arasında değişim göstermiştir. Balın performans ve ürün kalitesi ile bağışıklık sistemi ve antibakteriyel aktivite üzerine etkileri konuyla ilgili çalışmalarda belirlenen bulgular doğrultusunda pozitif, negatif ve anlamsız etki şeklinde sayısal olarak Grafik 1 ve 2'de belirtilmiştir.



PE: Pozitif etki; AE: Anlamsız etki; NE: Negatif etki; CAA: Canlı ağırlık artışı; KCA: Kesim canlı ağırlığı; YYO: Yemden yararlanma oranı; YG: Yaşama gücü; YT: Yem tüketimi; KR: Karkas randımanı; YK: Yumurta kalitesi; YV: Yumurta verimi; MV: Maliyet verimliliği

Grafik 1. Balın kanatlılarda performans ve ürün kalitesine etkileri



BFA: Bursa fabricius ağırlığı; TA: Timus ağırlığı; DA: Dalak ağırlığı; AT: Antikor titreleri; AE: Antimikrobiyal etki

Grafik 2. Balın kanatlılarda bağışıklık sistemi ve antimikrobiyal aktivite üzerine etkileri

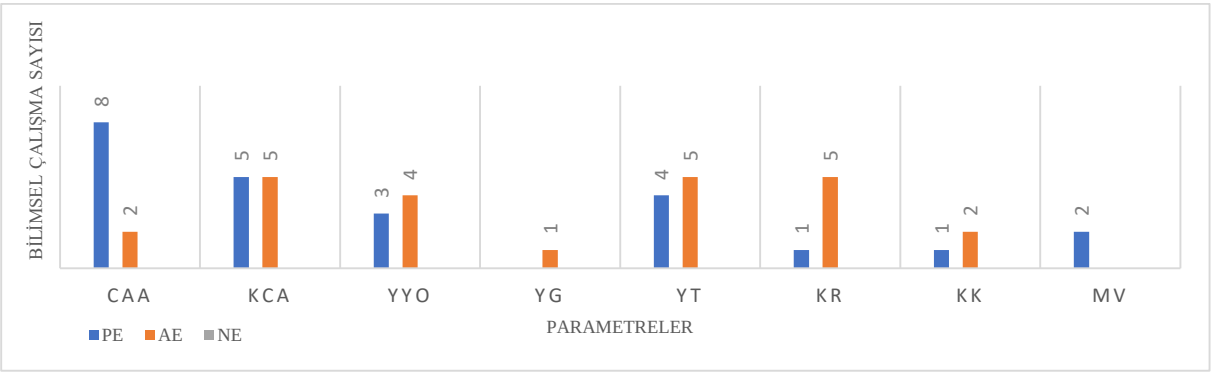
Polenin Yapısı ve Kanatlı Hayvan Beslemede Kullanımı

Polen, çiçekli bitkilerin erkek üreme organında meydana gelen ve n kromozomlu erkek gameti taşıyan ve koruyan çeşitli şekil ve boyutlarda olabilen erkek üreme hücresinin adıdır. Arılar, böcekler ve rüzgâr vasıtasıyla dişi üreme organına ulaştırılan polen taneciği yumurtalığa inerek dişi üreme hücresi ile birleşir ve bu sayede bitkiler nesillerinin devamlılığını sağlayan tohumlarını oluştururlar. Polenin dış duvarı, eksin olarak adlandırılır ve çok dayanıklı olan sporopollenin denilen bir yapıdan oluşur. İç tabaka ise selülozdan yapılmıştır ve tipik bitki hücre duvarı yapısındadır [39, 40].

Arılar için polen, gelişimlerinin tamamlanmasında ve salgı bezlerinin gelişerek arı sütü üretiminde önemli bir protein kaynağıdır. Polen olmaksızın kolonide yavru üretimi gerçekleşemez ve koloninin devamlılığı sağlanamaz [39].

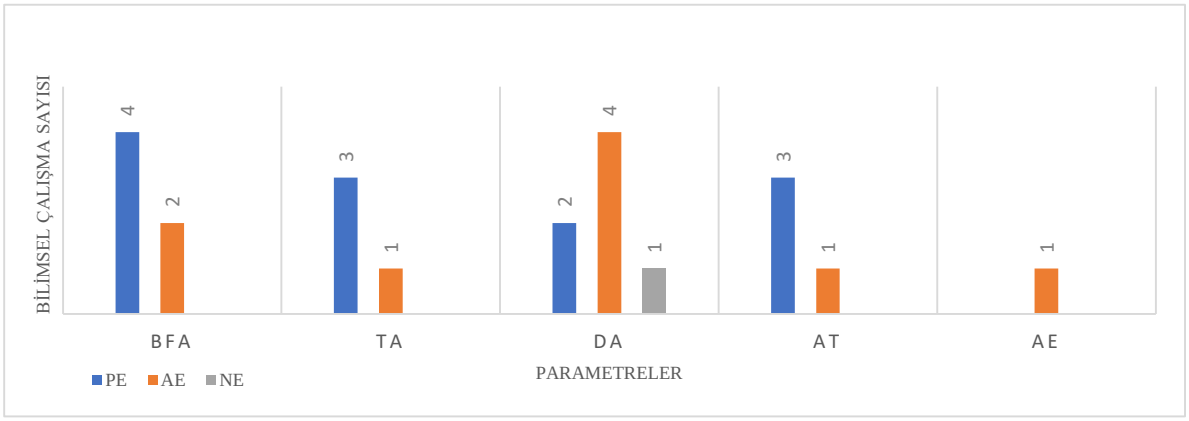
Arı poleni zengin bir besin kaynağıdır ve içeriğinde proteinler, çeşitli aminoasitler, karbohidratlar, yağ asitleri, lipidler, steroller, vitaminler, terpenler, fenolik maddeler, enzimler ve mineraller bulunur. Bu besinsel içeriği ve sağlık faydaları nedeniyle geleneksel tıpta, alternatif diyetlerde ve takviye gıdalarda uzun yıllardır kullanılmaktadır [40].

Kanatlı hayvanların beslenmesinde polen kullanımı ile ilişkili 17 adet çalışmaya ulaşılmış ve bunların 13'ü etlik piliçler [41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53], 3'ü bıldırcınlar [38, 54, 55] ve 1'i yumurtacılarda [56] yürütülmüştür. Tüm çalışmalarda polen yeme ilave edilerek hayvanlara verilmiş ve kullanım düzeyi 300 mg/kg-45 g/kg arasında değişmiştir. Polenin performans ve ürün kalitesi ile bağışıklık sistemi ve antibakteriyel aktivite üzerine etkileri konuyla ilgili çalışmalarda belirlenen bulgular doğrultusunda pozitif, negatif ve anlamsız etki şeklinde sayısal olarak Grafik 3 ve 4'de belirtilmiştir.



PE: Pozitif etki; AE: Anlamsız etki; NE: Negatif etki; CAA: Canlı ağırlık artışı; KCA: Kesim canlı ağırlığı; YYO: Yemden yararlanma oranı; YG: Yaşama gücü; YT: Yem tüketimi; KR: Karkas randımanı; KK: Karkas kalitesi; MV: Maliyet verimliliği

Grafik 3. Polenin kanatlılarda performans ve ürün kalitesine etkileri



BFA: Bursa fabricius ağırlığı; TA: Timus ağırlığı; DA: Dalak ağırlığı; AT: Antikor titreleri; AE: Antimikrobiyal etki

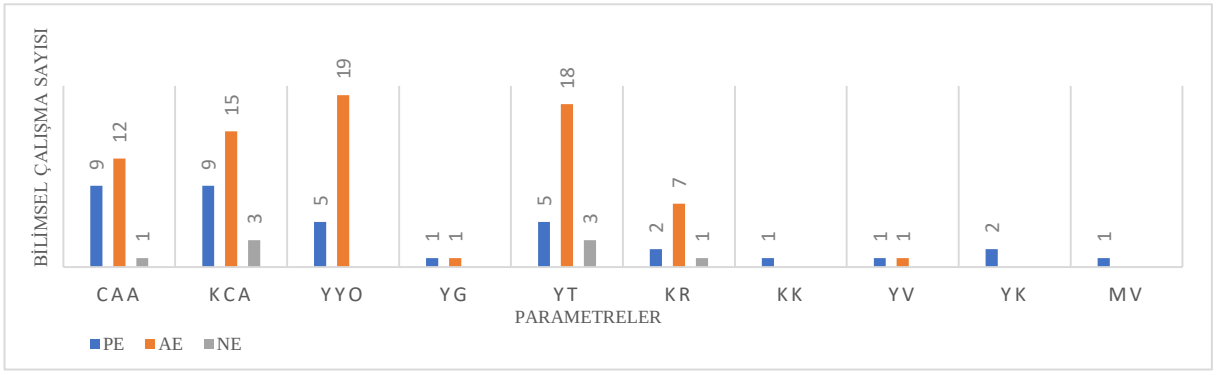
Grafik 4. Polenin kanatlılarda bağışıklık sistemi ve antimikrobiyal aktivite üzerine etkileri

Propolisin Yapısı ve Kanatlı Hayvan Beslemede Kullanımı

Propolis; işçi arıların ağaç kabuklarından, bitkilerin dal, filiz ve tomurcuklarından arka bacaklarındaki polen sepetçiklerinde topladığı reçinemsi maddeleri ve bitki salgılarını içermektedir. İşçi arılar bu maddeleri ve bitki salgılarını başlarında bulunan salgı bezlerinden salgılanan enzimlerle biyokimyasal değişikliğe uğratıp bir miktar balmumu karıştırarak propolisin son hali olan yapışkan organik maddeyi üretirler. Propolis edinildiği bitkisel kaynağına göre, kirli sarıdan koyu kahverengiye kadar değişen renkte olup oda sıcaklığında yarı katı halde bulunur [57, 58].

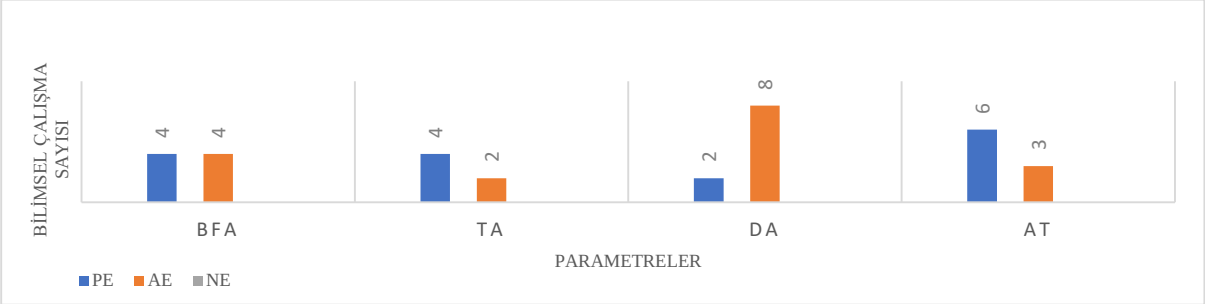
Propolis, gıda olarak tüketiminden ziyade tıbbi faydaları ile öne çıkan bir üründür. Yapılan araştırmalar, propolisin 300'den fazla bileşik içerdiğini göstermiştir. Propolisin içeriğinde, polifenoller (flavonoidler, fenolik asitler ve esterleri), alkoller, aldehitler, alifatik ve aromatik asitler ve esterleri, terpenoidler, steroidler, şekerler, aminoasitler ve inorganik bileşikler gibi çeşitli kimyasal bileşikler bulunur. Sahip olduğu zengin içerik nedeniyle insan ve hayvan sağlığına olumlu etkiler taşıdığı düşünülmekte ve potansiyel bir ürün olarak birçok bilimsel çalışmaya konu olmaktadır [59, 60].

Kanatlı hayvan beslemede kullanılabilirliği en fazla incelenen arı ürünü propolistir. Bu bildiri kapsamında irdelenen parametreler esasında 29 adet çalışma değerlendirilmiştir (Grafik 5 ve 6). Yürütülen bu çalışmaların 23' ünde etlik piliçler [43, 44, 45, 51, 52, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78], birinde yumurtacı tavuklar [79], dördünde bıldırcınlar [38, 55, 80, 81] ve birinde ördekler [82] hayvan materyali olarak kullanılmıştır. İlgili çalışmaların tamamında propolis katı formda 10 mg/kg-40 g/kg veya sıvı formda 0,5 ml/l-80 ml/kg arasında değişen düzeylerde yeme ilave edilmiştir.



PE: Pozitif etki; AE: Anlamsız etki; NE: Negatif etki; CAA: Canlı ağırlık artışı; KCA: Kesim canlı ağırlığı; YYO: Yemden yararlanma oranı; YG: Yaşama gücü; YT: Yem tüketimi; KR: Karkas randımanı; KK: Karkas kalitesi; YV: Yumurta verimi; YK: Yumurta kalitesi; MV: Maliyet verimliliği

Grafik 5. Propolisin kanatlılarda performans ve ürün kalitesine etkileri



BFA: Bursa fabricius ağırlığı; TA: Timus ağırlığı; DA: Dalak ağırlığı; AT: Antikor titreleri

Grafik 6. Propolisin kanatlılarda bağışıklık sistemi ve antimikrobiyal aktivite üzerine etkileri

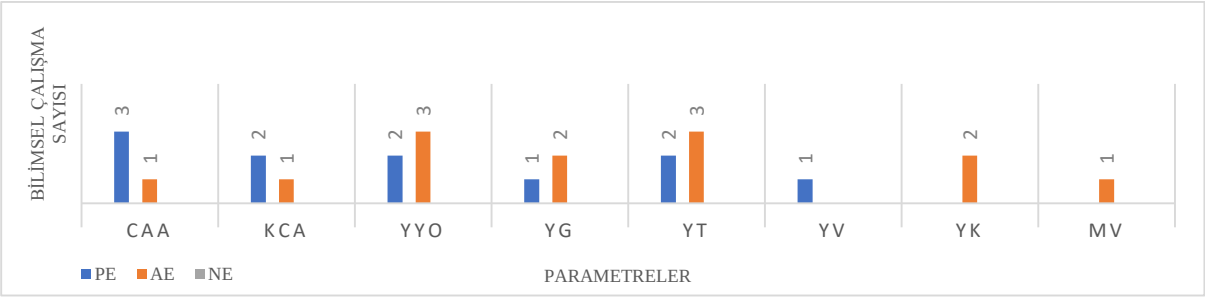
Arı Sütünün Yapısı ve Kanatlı Hayvan Beslemede Kullanımı

Arı sütü; 5-15 günlük genç işçi arıların (*Apis mellifera* L.) hipofaringeal ve mandibular bezlerinden salgıladıkları, beyazımsı-sarı renkte, homojen, viskoz ve yapışkan bir madde olup, tadı ekşi, kokusu keskin fenolik yapıda ve ortalama 1,1 g/cm³ yoğunlukta arı kolonileri için hayati öneme sahip bir üründür. Yumurtlamadan sonraki ilk üç günlük dönemde tüm larvalar, 3. günden sonra ise sadece ana arı olarak yetiştirilecek larvalar ve çıkış sonrasında ana arılar tüm yaşamları boyunca sadece arı sütü ile beslenirler [83].

Arı sütü, yaklaşık %60-70 oranında su, %9-18 protein, %7-18 karbonhidrat, %3-8 lipit, %0,8-3 mineraller ve tiamin, riboflavin ve folik asit gibi vitaminler, ayrıca çeşitli hormonlar, 10-hidroksi-2-dekanoik asit ve çeşitli polifenoller gibi 185 kadar biyoaktif bileşen içerir [83, 84].

Arı sütü içerdiği biyoaktif bileşenler sayesinde besleyici olma özelliğinin yanı sıra sağlık üzerine olumlu etkilere de sahiptir. Yapılan araştırmalarda arı sütünün antibakteriyel, antitümoral, antiaging, immünomodülatör, antioksidan, antialerjik, antiülseratif, kardiyoprotektif, afrodizyak ve hiperlipidemi gibi biyolojik etkilere sahip olduğu, bazı solunum yolu hastalıkları (alerjik rinit, astım), pankreatit, premenstrüel sendrom ve kemik kırıklarında iyileşmeyi hızlandırdığı ve saç uzamasını, spermatogenezisi ve büyümeyi stimüle ettiği belirlenmiştir [83, 84].

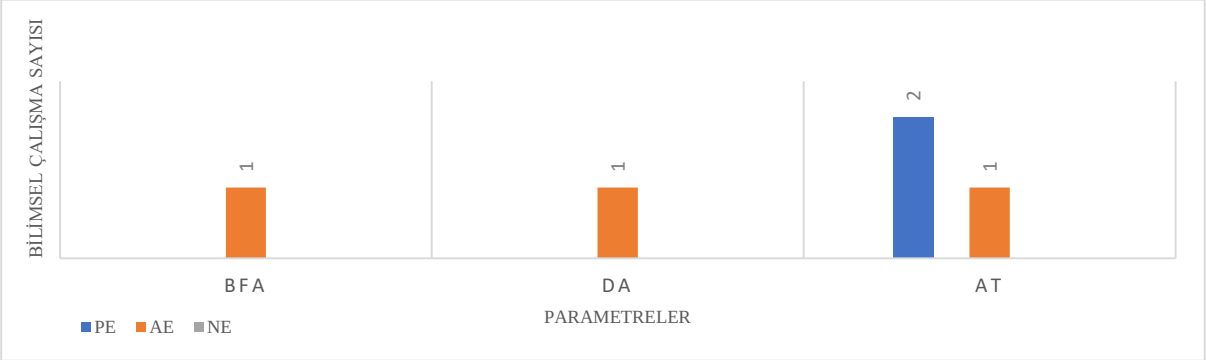
Yüksek biyolojik değerine rağmen kanatlı hayvanların beslenmesinde arı sütünün performans, ürün kalitesi ve bağışıklık sistemi üzerine etkileri ve antimikrobiyal etkinliği ile ilgili akademik veri tabanlarında sadece 6 bilimsel çalışmaya ulaşılabilmiştir [38, 80, 85, 86, 87, 88]. Bu durum, arı sütü üretiminin zor ve mevsime bağlı olması ve az miktarlarda üretilebilmesi ile ilişkili olabilir. Ulaşılan çalışmaların 3'ü bıldırcınlarda [38, 80, 88] ve diğer 3'ü tavuklarda gerçekleştirilmiştir. Denemelerde 0,2 mg/kg CA[1]-500 mg/kg CA arasında değişen düzeylerde kullanılan arı sütü, distile su içerisinde ya da saf haliyle hayvanlara bireysel olarak verilmiştir. Arı sütünün performans ve ürün kalitesi ile bağışıklık sistemi ve antibakteriyel aktivite üzerine etkilerine ilişkin çalışmalarda belirlenen bulgular doğrultusunda pozitif, negatif ve anlamsız etki şeklinde sayısal olarak Grafik 7 ve 8'de belirtilmiştir.



PE: Pozitif etki; AE: Anlamsız etki; NE: Negatif etki; CAA: Canlı ağırlık artışı; KCA: Kesim canlı ağırlığı; YYO: Yemden yararlanma oranı; YG: Yaşama gücü; YT: Yem tüketimi; YV: Yumurta verimi; YK: Yumurta kalitesi; MV: Maliyet verimliliği

Grafik 7. Arı sütünün kanatlılarda performans ve ürün kalitesine etkileri

[1] CA: Canlı ağırlık



BFA: Bursa fabricius ağırlığı; DA: Dalak ağırlığı; AT: Antikor titreleri

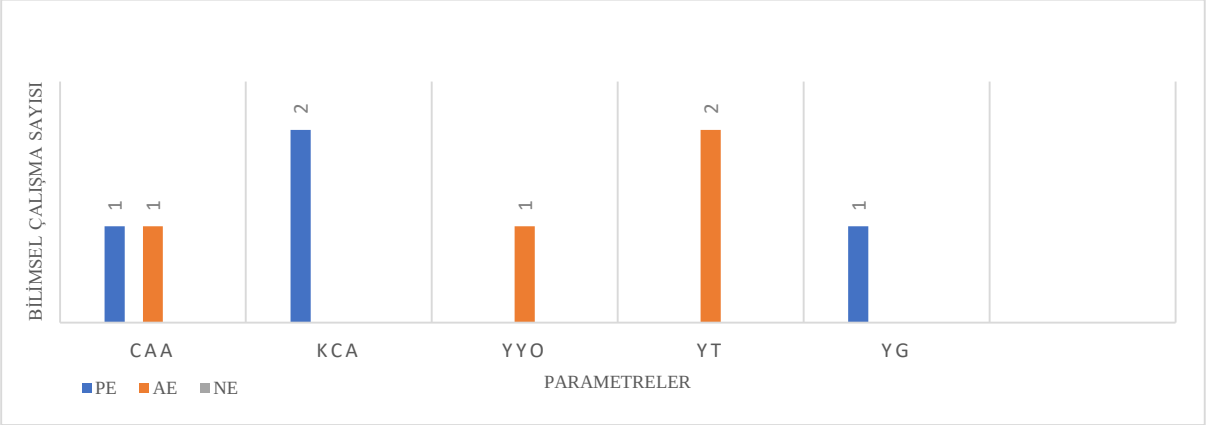
Grafik 8. Arı sütünün kanatlılarda bağışıklık sistemi ve antimikrobiyal aktivite üzerine etkileri

Arı Zehrinin Yapısı ve Kanatlı Hayvan Beslemede Kullanımı

Arı zehri işçi ve ana arının karın kısmında bulunan zehir bezleri tarafından salgılanarak zehir kesesinde biriktirilen dış salgı ürünüdür. Kimyasal yapısında peptitler, enzimler, aktif aminler, şekerler, yağlar, amino asitler, uçucu yağlar madde grupları altında birçok bileşik bulunmaktadır. Tanımlanan bileşiklerden melittin, histamin, hyalüronidaz, apamin, amino asitler, proteinler, MCD (mast cell degranulation) peptidi, fosfolipaz-A hedef canlıda çeşitli biyolojik tepkilerden sorumlu farmakolojik açıdan önem taşıyan maddelerdir. Arılar bu salgıları kendilerini ya da kolonilerini savunmak ya da rakip ana arıyı saf dışı bırakmak için batırdıkları iğnelerinden akıtarak kullanırlar [89, 90].

Geleneksel tıpta çeşitli hastalıkların tedavisinde uzun yıllar kullanılan arı zehiri, günümüzde tanımlanan biyolojik fonksiyonlarından dolayı apiterapi uygulamalarında yaygın olarak değerlendirilen bir ürün haline gelmiştir. Eklem, kalp-damar, sinirsel ve cilt hastalıkları başlıca kullanım alanlarıdır [91].

Yapılan literatür taramasında ulaşılan çalışmalardan sadece 3'ü bu bildiri kapsamında irdelenen parametreler dikkate alındığında değerlendirmeye alınabilmiştir (Grafik 9) [92, 93, 94]. Tamamı etlik piliçler ile yürütülen bu çalışmalarda arı zehri yeme [92], içme suyuna [93] ve sprey solüsyonuna [94] ilave edilmiştir.



PE: Pozitif etki; AE: Anlamsız etki; NE: Negatif etki; CAA: Canlı ağırlık artışı; KCA: Kesim canlı ağırlığı; YYO: Yemden yararlanma oranı; YT: Yem tüketimi; YG: Yaşama gücü.

Grafik 9. Arı zehrinin kanatlılarda performans ve ürün kalitesine etkileri

Etlik piliçlerde arı zehrinin bağışlık sistemi üzerine etkisini irdeleyen sınırlı sayıda çalışma bulunmaktadır [92, 94]. Arı zehrinin ağıza spreyleme yoluyla 2,1 mg/ml düzeyinde verildiği araştırmada, antikor titrelerinin anlamlı düzeyde yükseldiği belirtilmiştir [94]. Ancak, yeme 10, 50, 100, 500 µg/kg düzeyinde arı zehri ilave edilen diğer çalışmada, Bursa fabricious ve dalak ağırlığı uygulamalardan etkilenmemiştir [92].

Bal Arısı Larvasının Yapısı ve Kanatlı Hayvan Beslemede Kullanımı

Arılar ana arı tarafından petek gözlerine bırakılan döllenmiş veya döllenmemiş yumurtalardan gelişir. Döllenmiş yumurtalardan işçi ve ana arı, döllenmemiş yumurtalardan ise erkek arı meydana gelir. Ancak bu farklılaşmanın gerçekleşmesi, ana arıya bağlı olarak erkek ve dişi üreme hücrelerinin

birleşip birleşmemesi dışında, petek gözlerinin boyutlarına, larvaların beslenme şekli ve süresine de bağlıdır. Bütün bal arıları yaşamlarını; yumurta dönemi, larva, prepupa, pupa ve ergin olmak üzere 5 farklı formda geçirirler. Yumurtlandıktan ergin olarak petek gözünden çıkana kadar geçen süre; ana arıda yaklaşık 15-16 gün, işçi arıda 20-21 gün ve erkek arıda 22-24 gündür [95].

Bal arısı larvaları sahip olduğu zengin biyoaktif bileşenleri nedeniyle dünyanın çeşitli yerlerinde geleneksel tıpta bazı beşerî rahatsızlıkların tedavisinde kullanılmaktadır. Arı larvalarının ana bileşenlerini her ne kadar aminoasitler oluştursa da, yapısında proteinler, karbonhidratlar, yağlar, polifenoller, vitaminler, mineraller olarak isimlendirilen madde grupları altında birçok molekül tanımlanmıştır. Ayrıca, yapılarında yaşa bağlı olarak değişen düzeylerde cinsiyet hormonlarının bulunduğu da bildirilmektedir [96, 97].

Kanatlı hayvanların beslenmesinde bal arısı larvasının performans üzerine etkisini inceleyen 2 adet bilimsel çalışmaya ulaşılmıştır [98, 99]. Yürütülen bu araştırmalarda hayvan materyali olarak etlik piliçler kullanılmış ve 2.5, 4 ve 7.5 g/piliç/gün bal arısı larvası ağız yoluyla (şırınga vasıtasıyla) verilmiştir. Araştırıcılar, bal arısı larvasının etlik piliçlerde performansı önemli düzeyde etkilemediğini bildirmişlerdir.

Sonuç

Kanatlı hayvanların beslenmesinde yem katkı maddesi olarak arı ürünlerinin kullanım portansiyellerini irdeleyen çalışmalara ait bulgulardan; arı ürünü çeşidine göre etki şeklinin ve düzeyinin değiştiği anlaşılmaktadır. Bu durum, kullanılan arı ürününün kimyasal bileşiminde tanımlanan polifenoller (flavonoid aglikonlar, fenolik asitler, aldehitler, ketonlar ve alkoller), steroidler, terpenoidler, amino asitler, inorganik bileşikler, yağ asitleri ve enzim türevlerinin biyolojik etkileri ile yakından ilişkilidir. Özellikle polifenoller ve terpenoid grupları antioksidan, antimikrobiyal, immünomodülatör ve anti-inflamatuar etkileri kanıtlanmış bileşiklerdir. Ancak, incelenen arı ürünlerinin yapısındaki bu bileşenlerin standardize edilememesi etkinliğinde farklılıklara neden olabilmektedir.

Diğer yandan, kanatlı endüstrisinde bir ürünün yem katkı maddesi olarak kabul görmesi etkinlik düzeyi kadar kolay, yeterli miktarda ve ekonomik üretilebilmesine de bağlıdır. Belirtilen bu faktörlerin gerçekleşme düzeyleri ise arı ürünlerin mevsime bağlı üretilmelerinden ve insan beslenmesi ile apiterapi uygulamalarında kullanılmalarından dolayı değişkenlik göstermektedir.

Referanslar

[1] Alexandratos N, Bruinsma J. (2012). World Agriculture Towards 2030/2050: The 2012 Revision.

[2] Kleyn FJ, Ciacciariello M. Future demands of the poultry industry: will we meet our commitments sustainably in developed and developing economies? World's Poult. Sci. J. 2021; 77(2):267-278.

[3] Fao, 2022; World food and agriculture–statistical yearbook 2022. Rome.

[4] Açıkgöz Z, Kırkpınar F. Early nutritional practices in broiler production. Hayvansal Üretim (J. Anim. Prod.). 2017; 58(1):66-73.

[5] Moore PR, Evenson A, Luckey TD, Mccoy E, Elvehjem C, Hart EB. Use of sulfasuxidine, streptothricin, and streptomycin in nutritional studies with the chick. J. Biol. Chem. 1946; 165:437-441.

[6] Jones FT, Ricke SC. Observations on the history of the development of antimicrobials and their use in poultry feeds. Poult. Sci. 2003; 82(4):613-617.

[7] Prescott JF, Baggot JD. Antimicrobial therapy in veterinary medicine. 2nd ed. Ames, IA: Iowa State University Press; 1993. pp. 564-565.

[8] Wegener HC. Antibiotics in animal feed and their role in resistance development. Current opinion in microbiology. 2003; 6(5):439-445.

[9] Phillips IM, Casewell T, Cox B, De Groot C, Friis R, Jones C, Nightingale R. Preston, and J, Waddell. Does the use of antibiotics in food animals pose a risk to human health? a critical review of published data. J. Antimicrob. Chemother. 2004; 53:28 – 52.

[10] Abd El-Hack ME, El-Saadony MT, Saad AM, Salem HM, Ashry NM, Ghanima MMA, ... El-Tarabily KA. Essential oils and their nanoemulsions as green alternatives to antibiotics in poultry nutrition: a comprehensive review. Poultry Science. 2022; 101(2):101584.

[11] Thanner S, Drissner D, Walsh F. Antimicrobial resistance in agriculture. Mbio. 2016; 7(2):E02227–E02215. Doi:10.1128/Mbio.02227-15.

[12] Founou LL, Founou RC, Essack SY. Antibiotic resistance in the food chain: a developing country-perspective. Frontiers İn Microbiology. 2016; 7:1881.

[13] Seal BS, Lillehoj HS, Donovan DM, Gay CG. Alternatives to antibiotics: a symposium on the challenges and solutions for animal production. Anim. Health Res. Rev. 2013; 14(1):78-87.

[14] Huyghebaert G, Ducatelle R, Van Immerseel F. An update on alternatives to antimicrobial growth promoters for broilers. Vet. J. 2011; 187(2):182-188.

[15] Gadde U, Kim WH, Oh ST, Lillehoj HS. Alternatives to antibiotics for maximizing growth performance and feed efficiency in poultry: a review. Anim. Health Res. Rev. 2017; 18(1):26-45.

[16] Anonim 2020. Türk Gıda Kodeksi Bal Tebliği (Tebliğ No: 2020/7). (Erişim tarihi: 18.06.2023)

[17] Mutlu C, Erbaş M, Tontul SA. Bal ve diğer arı ürünlerinin bazı özellikleri ve insan sağlığı üzerine etkileri. Akademik Gıda. 2017; 15(1):75-83.

[18] Pavlova T, Stamatovska V, Kalevska T, Dimov I, Assistant G, Nakov G. Quality characteristics of honey: a review. Proc. Of University Of Ruse. 2018; 57(book 10.2.):31-37

[19] Bogdanov S. Nature and origin of the antibacterial substances in honey. LWT-Food Sci. Technol. 1997; 30(7):748-753.

[20] Kwakman PH, Van Den Akker JP, Güçlü A, Aslami H, Binnekade JM, De Boer L, ... Zaat SA. Medical-grade honey kills antibiotic-resistant bacteria in vitro and eradicates skin colonization. Clinical Infectious Diseases. 2008; 46(11):1677-1682.

[21] Spilioti E, Jaakkola M, Tolonen T, Lipponen M, Virtanen V, Chinou I, ... Moutsatsou P. Phenolic acid composition, antiatherogenic and anticancer potential of honeys derived from various regions in greece. Plos One. 2014; 9(4):E94860.

[22] Orsolić N, Knezević A, Sver L, Terzić S, Hackenberger BK, Basić I. Influence of honey bee products on transplantable murine tumours. Vet. Comp. Oncol. 2003; 1(4):216-226.

[23] Moghazy AM, Shams ME, Adly OA, Abbas AH, El-Badawy MA, Elsakka DM, ... Mohamed BA. The clinical and cost effectiveness of bee honey dressing in the treatment of diabetic foot ulcers. Diabetes Res. Clin. Pract. 2010; 89(3):276-281.

[24] Kajiwara S, Gandhi H, Ustunol Z. Effect of honey on the growth of and acid production by human intestinal bifidobacterium spp.: an in vitro comparison with commercial oligosaccharides and inulin. J. Food Prot. 2002; 65(1):214-218.

[25] Wang Y, Li D, Cheng N, Gao H, Xue X, Cao W, Sun L. Antioxidant and hepatoprotective activity of vitex honey against paracetamol induced liver damage in mice. Food & Function. 2015; 6(7):2339-2349.

[26] Aljadi AM, Kamaruddin MY. Evaluation of the phenolic contents and antioxidant capacities of two Malaysian floral honeys. Food Chemistry. 2004; 85(4):513-518.

[27] Bertoncelj J, Doberšek U, Jamnik M, Golob T. Evaluation of the phenolic content, antioxidant activity and colour of Slovenian honey. Food Chemistry. 2007; 105(2):822-828.

[28] Obun CO, Yahaya MS, Olafadehan OA, Kehinde AS, Adeyemide OA, Farouk IU, Allison DS. Effect of honey-flavoured diets on the performance and relative organ weights of finisher broiler chickens. Nig. J. Anim. Prod. 2011; 38(1):64-72.

[29] Jibrin DG, Garba ZA, Kelechi M. Effect of honey flavoured sorghum distillers' waste on the performance and nutrient digestibility of broilers. Int. J. Innov. Sci. Res. Technol. 2021; 6(8):624-634.

[30] Hamed M. The physiological response to bee honey application in broiler chicken diets. Scientific Journal Of Agricultural Sciences. 2019; 1(2):87-93.

[31] El-Medany NM, El-Azeem A, El-Faham AI, Hamed MM. Effect of some natural feed additives to substitute antibiotic as growth promoters on growth performance, carcass characteristics and economic efficiency of broiler chicks: 2-bee-pollen. Egypt. J. Nutr. Feeds. 2017; 20(2 Special):113-122.

[32] Ashoori J, Kasmani FB, Mehri M, Divani A. Effects of early feeding with probiotics and honey on broiler performance. In Proceeding of 5th International Conference on Economic Management and Agricultural Sciences. 2015; Held At Anzali. Iran (Pp. 1-4).

[33] Jimoh AA, Ayuba U, Ibitoye EB, Raji AA, Dabai YU. Gut health maintenance in broilers: comparing potential of honey to antibiotic effects on performance and clostridial counts. Nig. J. Anim. Prod. 2017; 44(1):106-113.

[34] Abioja MO, Ogundimu KB, Akibo TE, Odukoya KE, Ajiboye OO, Abiona JA, ... Osinowo OA. Growth, mineral deposition, and physiological responses of broiler chickens offered honey in drinking water during hot-dry season. Int. J. Zool. 2012; 2012.

[35] Oke OE, Sorungbe FO, Abıoja MO, Oyetunjı O, Onabajo AO. Effect of different levels of honey on physiological, growth and carcass traits of broiler chickens during dry season. Acta Agric. Slov. 2016; 108(1):45-53.

[36] Abioja MO, Adekunle MO, Abiona JA, Sodipe OG, Jegede AV. Laying performance, survival rate, egg quality and shell characteristics in laying pullets offered honey in drinking water during hot season. Agricultura Tropica Et Subtropica. 2016; 49(1-4):12-19.

[37] Sabo M, Runka U, Usman H. Comparatıve performance of layer straın chicks reared in semı arid region and fed honey as an additive. Fudma J. Agric. Agric. Technol. 2022; 8(2):7-11.

[38] Babaei S, Rahimi S, Torshizi MAK, Tahmasebi G, Miran SNK. Effects of propolis, royal jelly, honey and bee pollen on growth performance and immune system of japanese quails. In Veterinary Research Forum. 2016; Vol. 7, No. 1, P. 13. Faculty of Veterinary Medicine, Urmia University, Urmia, Iran.

[39] Gönül S. (2016). Polen fermentasyonunun fenolik bileşiklerin biyoyararlılığı ve profilleri üzerindeki etkisi. Yüksek Lisans Tezi, İTÜ Fen Bilimleri Enstitüsü, İstanbul, Türkiye.

[40] Mayda, N. (2020). Arı poleni ve arı ekmeğinin palinolojik, kimyasal ve antioksidan kapasitelerinin belirlenmesi. Yüksek Lisans Tezi, Hacettepe Üniv., Biyoloji Blm., Ankara, Türkiye.

[41] Adhikari A, Adhikari B, Dhungana SK, Ko-Eun L, Arun GC, Sang-Mo K, ... Lee IJ. Effect of bee pollen and probiotics on growth performance, organs, and thigh meat ph of broiler cobb 500. J. Microbiol. Biotechnol. Food Sci. 2017; 7(1):79.

[42] Hascík P, Elimam IOE, Bobko M, Kacániová M, Cubon J, Tkácová J, Trembecká L. The ph value of broiler breast and thigh muscles after addition probiotic, bee pollen and propolis into their feed mixture. J. Microbiol. Biotechnol. Food Sci. 2015; 4:52.

[43] Prakatur I, Miškulin I, Galović D, Steiner Z, Lachner B, Domaćinović M. Performance indicators of broilers fed propolis and bee pollen additive. Poljoprivreda. 2019; 25(1):69-75.

[44] Hosseini SM, Vakili Azghandi M, Ahani S, Nourmohammadi R. Effect of bee pollen and propolis (bee glue) on growth performance and biomarkers of heat stress in broiler chickens reared under high ambient temperature. J. Anim. Feed Sci. 2016; 25(1):45-51.

[45] Al-Kahtani SN, Alaqil AA, Abbas AO. Modulation of antioxidant defense, ımmune response, and growth performance by inclusion of propolis and bee pollen into broiler diets. Animals. 2022; 12(13):1658.

[46] Petričević V, Lukić M, Škrbić Z, Rakonjac S, Stanojković A, Nikšić D, Živković V. Production parameters, microbiological composition of ıntestines and slaughter performance of broilers fed with bee pollen. Züchtungskunde. 2022; 94(1):36-46.

[47] Hashmi MS, Hasèík P, Elimam I, Garlík J, Marek B, Miroslava K. Effects of bee pollen on the technical and allocative efficiency of meat production of Ross 308 broiler. Int. J. Poult. Sci. 2012; 11(11):689.

[48] Hašèík P, Elimam I, Garlík J, Kacániová M, Cuboò J, Bobko M, Abdulla H. İmpact of bee pollen as feed supplements on the body weight of broiler ross 308. Afr. J. Biotechnol. 2012; 11(89):15596-15599.

[49] Farag SA, El-Rayes T. Research article effect of bee-pollen supplementation on performance, carcass traits and blood parameters of broiler chickens. Asian J. Anim. Vet. Adv. 2016; 11(3):168-77.

[50] Trembecká L, Haščík P, Čuboň J, Bobko M, Cviková P, Hleba L. Chemical and sensory characteristics of chicken breast meat after dietary supplementation with probiotic given in combination with bee pollen and propolis. J. Microbiol. Biotechnol. Food Sci. 2017; 7(3).

[51] Haščík P, Trembecká L, Bobko M, Čuboň J, Kačániová M, Tkáčová J. Amino acid profile of broiler chickens meat fed diets supplemented with bee pollen and propolis. J. Apic. Res. 2016; 55(4):324-334.

[52] Attia YA, Al-Khalaifah H, Ibrahim MS, Abd Al-Hamid AE, Al-Harthi MA, El-Naggar A. Blood hematological and biochemical constituents, antioxidant enzymes, immunity and lymphoid organs of broiler chicks supplemented with propolis, bee pollen and mannan oligosaccharides continuously or intermittently. Poult. Sci. 2017; 96(12):4182-4192.

[53] De Oliveira MC, Da Silva DM, Loch FC, Martins PC, Dias DMB, Simon GA. Effect of bee pollen on the immunity and tibia characteristics in broilers. Braz. J. Poult. Sci. 2013; 15:323-327.

[54] Sarıkaya Y, Tufan T, Bolacalı M. Bıldırcın rasyonlarına polen ilavesinin besi performansı ve karkas parametreleri üzerine etkisi. Harran Üniv. Vet. Fak. Derg. 2018; 7(1):26-31.

[55] Canogullari S, Baylan M, Sahinler N, Sahin A. Effects of propolis and pollen supplementations on growth performance and body components of Japanese quails. Arch. Geflugelk. 2009; 73:173-178.

[56] Abuoghaba AA, Ismail II. Impact of bee pollen supplementation on productive performance, some hematological parameters, blood constituents and semen physical characteristics of Sinai chickens. Egypt. Poult. Sci. J. 2018; 38(2):621-635.

[57] Tutkun E. (2000). Teknik arıcılık el kitabı. Türkiye Kalkınma Vakfı Yayın, (6), 235.

[58] Özcan M, Ceylan DA, Ünver A, Yetişir R. Türkiye'nin çeşitli bölgelerinden sağlanan polen ve propolis ekstraktlarının antifungal etkisi. Uludağ Arıcılık Dergisi. 2003; 3(3):27-34.

[59] Marcucci MC. Propolis: chemical composition, biological properties and therapeutic activity. Apidologie. 1995; 26(2):83-99.

[60] Hepşen İF, Tilgen F, Er H. Propolis: Tıbbi özellikleri ve oftalmolojik kullanımı. J. Turgut Ozal Med. Cent. 1996; 3(4):386-391.

[61] Daha AA, Taha NM, Lebda MA, Elfeky MS. Effects of propolis and ginger on broiler performance and immune organ weight in broilers. Alex. J. Vet. Sci. 2022; 74(1):1-7.

[62] Jabbar AM, Al Mashhdani HE, Farhan SH. Effect of adding Iraqi bee propolis in diet on production performance and histological traits in broilers. Indian J. Ecol. 2022; (18):597-601.

[63] Domaćinović M, Prakatur I, Miškulin I, Kenjerić DČ, Šerić V, Prakatur B, ... Kenjerić FČ. The effects of propolis supplementation on weight gain, feed conversion and selected biochemical blood parameters of. J. Hyg. Eng. Des. 2021; 34:138-143.

[64] Daza-Leon C, Gomez AP, Álvarez-Mira D, Carvajal-Diaz L, Ramirez-Nieto G, Sanchez A, ... Betancourt L. Characterization and evaluation of colombian propolis on the intestinal integrity of broilers. Poult. Sci. 2022; 101(12):102159.

[65] Torki M, Soltani J, Mohammadi H. Effects of adding ethanol extract of propolis and cumin essential oil to diet on the performance, blood parameters, immune response and carcass traits of broiler chicks. Iran. J. Appl. Anim. Sci. 2015; 5(4):911-918.

[66] Dosoky W, AbdelRahman MH, Al-Rumaydh ZI. Effect of propolis as natural supplement on productive and physiological performance of broilers. Journal of the Advances in Agricultural Researches. 2022; 27(4):674-686.

[67] Daneshmand A, Sadeghi GH, Karimi A, Vaziry A, Ibrahim SA. Evaluating complementary effects of ethanol extract of propolis with the probiotic on growth performance, immune response and serum metabolites in male broiler chickens. Livestock Science. 2015; 178:195 201.

[68] Gheisari A, Shahrvand S, Landy N. Effect of ethanolic extract of propolis as an alternative to antibiotics as a growth promoter on broiler performance, serum biochemistry, and immune responses. Veterinary world. 2017; 10(2):249.

[69] Eyng C, Murakami AE, Duarte CRA, Santos TC. Effect of dietary supplementation with an ethanolic extract of propolis on broiler intestinal morphology and digestive enzyme activity. J. Anim. Physiol. Anim. Nutr. 2014; 98(2):393-401.

[70] Eyng C, Murakami AE, Santos TC, Silveira TGV, Pedroso RB, Lourenço DAL. Immune responses in broiler chicks fed propolis extraction residue-supplemented diets. Asian-Aust. J. Anim. Sci. 2015; 28(1):135.

[71] Mohamed RI, Mosaad GM, Abd El-wahab HY. Effect of feeding propolis on growth performance of broilers. J. Adv. Vet. Res. 2018; 8(3):66-72.

[72] Shihab IM, Ali BH. Effect of propolis in diet supplementation on the immune response against Newcastle disease and hematological picture in broiler chicks. Al-Anbar J. Vet. Sci. 2012; 5(2):40-46.

[73] Kleczek K, Wilkiewicz-Wawro E, Wawro K, Makowski W, Murawska D, Wawro M. The effect of dietary propolis supplementation on the growth performance of broiler chickens. Polish Journal of Natural Sciences. 2014; 29(2):105-117.

[74] Zafarnejad K, Afzali N, Rajabzadeh M. Effect of bee glue on growth performance and immune response of broiler chickens. J. Appl. Anim. Res. 2017; 45(1):280-284.

[75] Açıkgöz Z, Yücel B, Altan Ö. The effects of propolis supplementation on broiler performance and feed digestibility. Arch. Geflügelk. 2005; 69(3):117-122.

[76] Seven PT, Seven I, Yılmaz M, Şimşek ÜG. The effects of Turkish propolis on growth and carcass characteristics in broilers under heat stress. Anim. Feed Sci. Technol. 2008; 46(1-2):137-148.

[77] Abbas RJ. Effect of dietary supplementation with differing levels of propolis on productivity and blood parameters in broiler chicks. Basrah J. Vet. Res. 2014; 13(2):164-180.

[78] Ziaran HR, Rahmani HR, Pourreza J. Effect of dietary oil extract of propolis on immune response and broiler performance. Pak. J. Biol. Sci. 2005; 8(10):1485-1490.

[79] Galal A, Abd El-Motaal AM, Ahmed AMH, Zaki TG. Productive performance and immune response of laying hens as affected by dietary propolis supplementation. Int. J. Poult. Sci. 2008; 7(3):272-278.

[80] Seven PT, Arslan AS, Özçelik M, Şimşek ÜG, Seven İ. Effects of propolis and royal jelly dietary supplementation on performance, egg characteristics, lipid peroxidation, antioxidant enzyme activity and mineral levels in Japanese quail. Eur. Poult. Sci. 2016; 80:138.

[81] Silici S, Karabaccak M, Balci E, Çankaya S. Effect of the propolis on the performance and carcass characteristics of growing quail. Mellifera. 2007; 7-(13-14):20-26.

[82] Abdel-Rahman MA, Mosaad GM. Effect of propolis as additive on some behavioural patterns, performance and blood parameters in Muscovy broiler ducks. J. Adv. Vet. Res. 2013; 3(2):64-68.

[83] Apan MA, Zorba M, Kayaboynu Ü. Bal Arısı Ve Bal Arısı Ürünleri. Sinop Üniversitesi Fen Bilimleri Dergisi. 2021; 6(2):202-223.

[84] Parlakpınar H, Polat S. Apiterapi ürünlerinin biyokimyasal içeriği. Atayoğlu AT, editör. Apiterapi. 1. Baskı. Ankara: Türkiye Klinikleri; 2021. p.38-48.

[85] Goma A, Tawfeek M, El Kelawy H. İmpact of royal jelly, gibberellic acid and testosterone treatments on some productive, egg quality traits and economic efficiency in local chicken strain, during the summer season of egypt. Journal of Productivity and Development. 2021; 26(4):843-863.

[86] Mahmoud FA. Impact of Chinese royal jelly on performance, behaviour and some blood parameters in broilers reared under high stocking density. Asian J. Anim. Vet. Adv. 2016; 11:620-628.

[87] Al-Mufarrej SI, El-Sarag MSA. Effects of royal jelly on the humoral antibody response and blood chemistry of chickens. J. Appl. Anim. Res. 1997; 12(1):41-47.

[88] Seven I, Şimşek, ÜG, Gökçe Z, Seven PT, Arslan A, Yılmaz Ö. The effects of royal jelly on performance and fatty acid profiles of different tissues in quail (Coturnix coturnix japonica) reared under high stocking density. Turk. J. Vet. Anim. Sci. 2014; 38(3):271-277.

[89] Genç F, Cengiz MM. (2019). Bal arısı (Apis mellifera L.) Anatomisi, genetik ve ıslahı ile ana arı yetiştiriciliği. Atilla ATİK (Ed.). Çankaya / Ankara: Gece Kitaplığı. ISBN: 978-605-288-857-5.

[90] Çaprazlı T, Kekeçoğlu M. Bal arısı zehrinin kompozisyonunu ve üretim miktarını etkileyen faktörler. Uludağ Arıcılık Dergisi. 2021; 21(1):132-145.

[91] Bogdanov S. Bee venom: composition, health, medicine: a review. Peptides. 2015;1:1-20.

[92] Kim DH, Han SM, Keum MC, Lee S, An BK, Lee SR, Lee KW. Evaluation of bee venom as a novel feed additive in fast-growing broilers. Br. Poult. Sci. 2018; 59(4):435-442.

[93] Han SM, Lee KG, Yeo JH, Oh BY, Kim BS, Lee W, et al. Effects of honeybee venom supplementation in drinking water on growth performance of broiler chickens. Poult Sci. 2010; 89(11):2396-2400.

[94] Jung BG, Lee JA, Park SB, Hyun PM, Park JK, Suh GH, Lee BJ. Immunoprophylactic effects of administering honeybee (Apis melifera) venom spray against Salmonella gallinarum in broiler chicks. J. Vet. Med. Sci. 2013; 75(10):1287-1295.

[95] Korkmaz, A. Anlaşılabilir Arıcılık. Samsun Tarım ve Orman İl Müdürlüğü.2013.

[96] Yücel B, Şahin H, Yıldız O, Kolaylı S. Bioactive components and effect mechanism of Apilarnil. J. Anim. Prod. 2019; 60(2):125-130.

[97] Sidor E, Dzugan M. Drone brood homogenate as natural remedy for treating health care problem: a scientific and practical approach. Molecules. 2020; 25(23):5699.

[98] Yücel B, Açıkgöz Z, Bayraktar H, Şeremet Ç. The effects of apilarnil (drone bee larvae) administration on growth performance and secondary sex characteristics of male broilers. J. Anim. Vet. Adv. 2011; 10(17):2263-2266.

[99] Altan Ö, Yücel B, Açıkgöz Z, Şeremet Ç, Kösoğlu M, Turgan N, Özgönül AM. Apilarnil reduces fear and advances sexual development in male broilers but has no effect on growth. Br. Poult. Sci. 2013; 54(6):744-748.

Etlik Piliçlerin Beslenmesinde Ham Protein İçeriğinin Kısıtlanması

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Özet

Etlik piliçlerde besleme; büyüme ve üretim performansı, hayvan sağlığı ile refahın korunmasında önemli bir rol oynamaktadır. Kanatlı hayvanlar sindirim, emilim, bağışıklık ve enzimatik aktivite gibi hayati fonksiyonlarında proteine ihtiyaç duymaktadır. Ancak kanatlı beslemede kullanılan protein kaynaklarının sınırlı olması ve dışkı ile atılan azotlu bileşiklerin çevre kirliliğine neden olması sürdürülebilir üretim yapmayı hedefleyen işletmelerde problem teşkil etmektedir. Dışkı ile atılan azotlu bileşiklerin; çalışanların ve hayvanların sağlığı ile toprak ve yer altı suları üzerinde olumsuz etkilere sahip olduğu bilinmektedir. Karma yemlerdeki ham protein (HP) düzeyinin düşürülmesi; ekonomik, çevre dostu ve refah düzeyi yüksek bir hayvansal üretim yapmaya olanak sağlamaktadır. Ancak karma yemdeki HP düzeyi kısıtlandığında aminoasit ihtiyacı tam olarak karşılanamamaktadır. Bu nedenle karma yemlere belirli sentetik amino asitlerin (metiyonin ve lizin) veya protein sindirilebilirliğini artırmak amacıyla özellikle bitirme döneminde proteaz enziminin ilavesi önerilmektedir.

Bu bildiride, etlik piliçlerde karma yemlerin HP düzeyini düşürerek aminoasit veya enzim ilavesi ile üretim performansı, çevre, hayvan sağlığı ve refahı üzerine etkileri ile ilgili literatür verileri değerlendirilerek incelenecektir.

Anahtar Kelimeler: Aminoasit, enzim, etlik piliç, kısıtlı protein, sürdürülebilirlik

Giriş

Dünya nüfusunun 2050 yılına kadar 9.7 milyara [1] ve beyaz et üretiminin yaklaşık 200 milyon tona ulaşması beklenmektedir [2]. Kanatlı beslemede protein kaynağı olarak kullanılan soya fasulyesi üretiminin ise iki katına çıkması gerekmektedir [3]. Ancak soya fasulyesi gibi ithal edilen protein kaynakları ile sürdürülebilir, çevre dostu ve ekonomik beyaz et üretimi olumsuz etkilenmektedir [4]. Bu nedenle beslenme uzmanları, etlik piliçlerin protein ihtiyacının nasıl karşılanacağı konusunda endişe duymaktadır. Kanatlı endüstrisinde, nitrojen atıklarından kaynaklanan çevre kirliliğini azaltmak, ekonomik ve sürdürülebilir bir üretim yapmak amacıyla ham protein (HP) düzeyinin kısıtlanması ile hem protein açığı hem de çevre kirlenmesi sorunlarına olumlu yönde katkı sağlanabileceği düşünülmektedir [5].

Hayvan beslemede en pahalı ve ikincil önemli besin madde bileşeni olarak protein kabul edilmektedir. Etlik piliçlerde HP ileal sindirilebilirliği %57-90 arasında olmaktadır [6]. Proteinin sindirilmemiş kısmı (%10-43) ise sekumdaki bakteriler tarafından fermantasyona tabi tutulmaktadır [7]. Kanatlı karma yemlerindeki sindirilmemiş protein ve fazla aminoasitlerin atılımı esas olarak dışkı ile ürik asit halinde olmaktadır. Altlıktaki ürik asit ve sindirilmemiş proteinin mikrobiyal bozunması sonucu ise amonyak (NH_3) oluşmaktadır. Etlik piliçlerde kümes içerisindeki NH_3 ve nitrojen (N) bileşiğine uzun süre maruz kalan hayvanlarda üretim performansında düşme ve sağlık problemleri gözlemlenmektedir [8]. Dışkı ile atılan NH_3 ve N içeriğinin artışı ile etlik piliçlerde ayak ve diz lezyonları görülmektedir [9]. Altlıktaki NH_3 miktarının artması ile hava kalitesi de olumsuz etkilenmektedir [9]. Aynı zamanda dışkı ile atılan azotlu bileşikler; çalışanların ve hayvanların sağlığını olumsuz etkilerken, toprak ve yer altı suları için çevre kirletici olarak da risk oluşturmaktadır [10]. Bregendhal ve ark. [11] karma yemdeki HP düzeyinin %1 düzeyinde azaltılmasının, N atılımını %10 azalttığını ifade etmişlerdir. Ancak kısıtlı protein ile beslemenin büyüme ve üretim performansı üzerinde olumsuz etkileri olabileceği göz ardı edilmemelidir [12]. Bu nedenle, etlik piliç karma yemlerindeki HP düzeyi düşürülürken aynı zamanda büyüme, üretim performansı ve et kalitesini iyileştirmek (karın ve deri altı yağını azaltarak) amacıyla aminoasit ve enzim ilavesi önerilmektedir [13].

Bu derlemede, etlik piliçlerde kısıtlı protein ile besleme, kısıtlı protein içeren karma yemlere aminoasit veya enzim ilavesi ve bu uygulamaların çevresel etkileri, hayvan sağlığı, büyüme ve üretim performansı ile ilişkileri ele alınarak bu konuya yönelik bilgilere ve önerilere yer verilmiştir.

Etlik piliçlerde kısıtlı ham protein ile besleme

Kanatlı beslemede kısıtlı HP ile beslemeye yönelik çalışmalar ilk olarak 1940'lı yılların başında gündeme gelmiştir [6]. Ancak üretim performansı üzerindeki olumsuz etkileri nedeniyle bu uygulama pratikte yaygınlaşamamıştır. Son yıllarda bazal karma yemlerin protein içeriğinin düşürülmesine yönelik ilgi ve bu konudaki araştırmalar artmıştır [14]. Kısıtlı HP ile beslemenin temel amacı N atılımını azaltarak çevre kirliliğini azaltmaktır. Ayrıca N atılımının azalması ile birlikte altlık kalitesinin iyileşmesinden dolayı ayak tabanı dermatit insidansının azalacağı ve hayvan refahının artacağı bilinmektedir [15].

Karma yemlerdeki HP içeriğinin %3'e kadar düşürülmesinin büyüme performansı ve et kalitesini etkilemediği bildirilmiştir [16]. Greenhalgh ve ark. [17] etlik piliçlerde kısıtlı HP ile beslemeyle altlık kalitesi artırılarak NH_3 üretiminin azalmasıyla hayvan refahının da iyileştiğini belirtmişlerdir. Bazı araştırmacılar ise, kısıtlı HP ile beslemenin, yağ birikimindeki artışlarla ilişkili olarak büyüme performansını olumsuz etkilediğini bildirilmişler [18].

Etlik piliçlerde kısıtlı ham protein ile beslemede aminoasit ilavesi

Günümüzde bazal karma yemlerdeki HP içeriğinin gerçek protein gereksinimden yüksek olduğu bilinmektedir [19]. Son yıllarda, yapılan genetik ve ıslah çalışmaları ile hayvanların ihtiyaç duyduğu protein ve aminoasit miktarları değişmiştir. Etlik piliçlerde kısıtlı HP ile beslemede ihtiyaç duyulan aminoasitler dengeli ve yeterli düzeyde bulunmalıdır [20].

Yem sektöründeki sentetik aminoasitlerin gelişmesi, kanatlı beslemede karma yem HP içeriğinin azaltmasına olanak sağlamıştır [21]. Karma yemlere ilave edilen aminoasitler, protein düzeyinin düşürülmesine fırsat sağlamakla birlikte aynı zamanda çevre dostu ve refah düzeyi iyileştirilmiş bir üretim yapmaya imkân vermektedir [22]. Fancher ve Jensen [23] etlik piliçlerde 215 g/kg veya 160 g/kg HP + aminoasit ve potasyum ilavesinin büyüme ve üretim performansı üzerine etkilerini incelemiştir. Düşük HP ile beslenen hayvanlarda yemden yararlanma oranının iyileştiği ancak abdominal yağ ağırlığının arttığını bildirmişlerdir. Van Harn ve ark. [24] başlangıç ve bitirme yemlerindeki HP içeriğini sırasıyla 22 ve 23 g/kg düzeylerine düşürüp dallanmamış zincirli amino asitlerin ilavesinin üretim performansı üzerine etkilerini incelemişlerdir. Sonuç olarak, HP düzeylerinin düşürülmesi ve aminoasit ilavesi ile canlı ağırlık artışı ve yemden yararlanma oranında istatistiksel olarak önemli bir fark görülmediğini ifade etmişlerdir. Belloir ve ark. [25] amino asit takviye edilerek kısıtlı HP ile beslemede HP'deki her yüzde bir düzeyindeki düşmenin N atılımında %13 düzeyinde azalma sağladığını ve altlıktaki NH_3 miktarının da azaldığını belirtmişlerdir [26].

Kidd ve ark. [21] ise lizin, treonin, valin, izolösin ve arginin içeren sentetik aminoasitlerin ilavesi ile bazal karma yemdeki soya fasulyesi küspesi ve HP içeriğinde sırasıyla %50 ve %20'nin üzerinde azaltma yapılabileceğini ifade etmişlerdir. Kop- Bozbay ve ark [27] yaz koşullarında etlik civciv başlangıç yemine (0-15 gün) %22 ile %20 HP içerikli ve farklı düzeylerde dallanmış zincirli amino asit (L-lösin, L-izolösin ve L-valin) karışımının sırasıyla 1.0, 0.25, ve 0.25; 1.0, 0.25 ve 0.75 g/kg düzeylerinde ilavesinin üretim performansı ve et kalitesini etkilemediğini bildirmişlerdir.

Etlik piliçlerde kısıtlı ham protein ile beslemede enzim ilavesi

Enzimler; proteinlerin, minerallerin, amino asitlerin ve vitaminlerin biyokimyasal süreçlerinde katalizör olarak görev almaktadırlar [28]. Endojen enzimler hayvan vücudunda salgılanmasına rağmen konsantrasyonları özellikle yem tüketiminin hızla arttığı büyütme döneminde protein sindirimi için yeterli olmayabilir [29]. Ekzojen enzimler ise bitkilerden, hayvanlardan ve mikroorganizmalardan elde edilmektedir [30]. Kanatlı beslemede yem sindirilebilirliğini iyileştirmek amacıyla pektinazlar, amilazlar, selülaz, galaktosidazlar, β-glukanazlar, ksilanazlar, fitazlar, proteazlar ve lipazlar kullanılan ekzojen enzimlerdir [31]. Enzim ilavesi, ileumda besin maddelerinin sindirilebilirliğini artırdığından gübre ile daha az besin maddesinin atılımını sağlaması yanısıra bu substratların zararlı mikroorganizmalarca değerlendirilememesi nedeniyle mikroflara üzerine de olumlu etkiler yaparak hayvan sağlığını iyileştirmektedir. Etlik piliçlerde ekzojen enzimlerin kullanılmasının, yemden yararlanma oranını iyileştirdiği, sindirim viskozitesini azalttığı, besinlerin sindiriminin ve emiliminin artması ile yem tüketimi ve canlı ağırlığı arttırdığı bilinmektedir [7].

Kanatlı hayvanlar, ideal protein sindirimi için ekzojen proteolitik enzimlere ihtiyaç duymaktadır [32]. Ding ve ark. [33] yaptıkları çalışmada, HP'nin önemli bir kısmının sindirilmeden dışkı ile atıldığını ifade etmişlerdir. Jabbar ve ark. [34] etlik piliçlerin 15-28. günler arasında farklı HP düzeyleri

(%17, %19 ve %21) ile proteaz ilavesinin (0 ve 30.000 IU/kg) maliyet, büyüme ve üretim performansı üzerine etkilerini incelemişlerdir. Araştırıcılar HP düzeyinin %19 olduğu ve proteaz ilave edilen bazal karma yemler ile beslenen hayvanlarda büyüme ve üretim performansı bakımından olumlu etkilerin olduğunu ve yem maliyetinin azaldığını belirtmişlerdir. Nastain ve ark. [35] ise düşük protein (%19.5) ve proteaz ilavesi (12.500 HUT/kg) ile beslenen etlik piliçlerin iç organlarının (karaciğer, safra kesesi, pankreas ve kalp) ağırlığında istatistiki olarak önemli bir fark olmadığını belirtmişlerdir.

Sonuç

Etlik piliçlerde, en pahalı ve elzem besin madde bileşenlerinden olan HP düzeyinin azaltılması ile üretim maliyeti düşürülebilir. Son yıllarda özellikle yoğun üretimde HP düzeyinin düşürülmesi sonucu hem NH_3 emisyonlarınının azaldığı hem de hayvan sağlığı, refahı ve büyüme performansından ödün vermeden çevre dostu bir üretim yapma fırsatı sağlanabildiği belirtilmiştir. Etlik piliçlerde karma yemdeki HP içeriğinin %1 düşürülmesi ile azot atılımında %13 azalma olduğu ifade edilmiştir. Ancak etlik piliç karma yemlerinde HP düzeyinin %2-3 azaltılması performansı olumsuz etkilemezken bu düzeyin %3'den fazla olmasının olumsuz etkilediği ve hayvan vücudunda yağ birikimine neden olduğu ifade edilmektedir. Sürdürülebilir kanatlı işletmelerinde standart besleme normlarından daha düşük HP kullanılarak hazırlanan karma yemlere belirli sentetik amino asitlerin (metionin ve lizin) ilave edilmesi önerilmektedir. Protein ve aminoasit sindirilebilirliğini artırmak amacıyla ise bitirme döneminde proteaz enziminin ilave edilmesi tavsiye edilmektedir.

Kaynaklar

[1] Birleşmiş Milletler, Ekonomik ve Sosyal İşler Bakanlığı, Popülasyon Bölümü, 2019 .

[2] Alexandatos N, Bruinsma J. World Agriculture Towards 2030/2050: The 2012 Revision. Food and Agriculture Organization of the United Nations (FAO) 2012; ESA Working Paper No. 12-03.

[3] Ray DK, Mueller ND, West PC, Foley JA. Yield trends are insufficient to double global crop production by 2050. PloS one 2013; 8(6), e66428.

[4] Leinonen I, Kyriazakis I. How can we improve the environmental sustainability of poultry production? Proc Nutr Soc. 2016; 75 (3): 265-273.

[5] Selle PH, Chrystal PV, Liu SY. The cost of deamination in reduced-crude protein broiler diets. In Proc Aust Poult Sci Symp. 2020 ; 31: 63-66.

[6] Macelline SP, Wickramasuriya SS, Cho HM, Kim E, Shin TK, Hong HS, Kim JC, Pluske JR, Choi HJ, Hong GG, Heo JM. Broilers fed a low protein diet supplemented with synthetic amino acids maintained growth performance and retained intestinal integrity while reducing nitrogen excretion when raised under poor sanitary conditions. Poult Sci. 2020; 99 (2); 949-958.

[7] Wilkie DC, Van Kessel AG, White LJ, Laarveld B, Drew MD. Dietary amino acids affect intestinal Clostridium perfringens populations in broiler chickens. Can J Anim Sci. 2005; 85(2); 185-193.

[8] Miles DM, Branton SL, Lott BD. Atmospheric ammonia is detrimental to the performance of modern commercial broilers. Poult Sci. 2004; 83(10): 1650-1654.

[9] Dunlop MW, Moss AF, Groves PJ, Wilkinson SJ, Stuetz RM, Selle PH. The multidimensional causal factors of 'wet litter'in chicken-meat production. Sci Total Environ. 2016; 562: 766-776.

[10] Attia YA, Bovera F, Wang J, Al-Harthi MA, Kim WK. Multiple amino acid supplementations to low-protein diets: effect on performance, carcass yield, meat quality and nitrogen excretion of finishing broilers under hot climate conditions. Animals. 2020; 10(6): 973.

[11] Bregendahl K, Sell JL, Zimmerman DR. Effect of low-protein diets on growth performance and body composition of broiler chicks. Poult Sci. 2002; 81(8): 1156-1167.

[12] Hilliar M, Hargreave G, Girish CK, Barekatain R, Wu SB, Swick RA. Using crystalline amino acids to supplement broiler chicken requirements in reduced protein diets. Poult Sci. 2020; 99(3): 1551-1563.

[13] Gharib-Naseri K, Dorigam JC, Doranalli K, Morgan N, Swick RA, Choct M, Wu SB. Bacillus amyloliquefaciens CECT 5940 improves performance and gut function in broilers fed different levels of protein and/or under necrotic enteritis challenge. Anim Nutr. 2021; 7(1): 185-197.

[14] Chrystal PV, Moss AF, Khoddami A, Naranjo VD, Selle PH. Impacts of reduced-crude protein diets on key parameters in male broiler chickens offered maize-based diets. Poult Sci. 2020; 99(1); 505-516.

[15] van Harn J, Dijkslag MA, van Krimpen MM. Effect of low dietary protein levels on performance in broilers. In 21st Euro Symp Poult Nutr. ESPN 2017. Spain, 185.

[16] Badawi MES, Ali AH, El-Razik WMA, Soliman MH. Influence of low crude protein diets on broiler chickens performance. Adv Anim Vet Sci. 2019; 7(s2):26-33.

[17] Greenhalgh S, McInerney BV, McQuade LR, Chrystal PV, Khoddami A, Zhuang MAM, Liu SY, Selle PH. Capping dietary starch: protein ratios in moderately reduced crude protein, wheat-based diets showed promise but further reductions generated inferior growth performance in broiler chickens. Anim Nutr. 2020; 6(2): 168-178

[18] Siegert W, Wild KJ, Schollenberger M, Helmbrecht A, Rodehutscord M. Effect of glycine supplementation in low protein diets with amino acids from soy protein isolate or free amino acids on broiler growth and nitrogen utilisation. Br Poult Sci. 2016; 57(3): 424-434.

[19] Ferguson NS, Gates RS, Taraba JL, Cantor AH, Pescatore AJ, Ford MJ, Burnham DJ. The effect of dietary crude protein on growth, ammonia concentration, and litter composition in broilers. Poultry Science 1998;77(10): 1481-1487.

[20] Santonja GG, Georgitzikis K, Scalet BM, Montobbio P, Roudier S, Delgado Sancho L. Best available techniques (BAT) reference document for the intensive rearing of poultry or pigs. EUR 2017; 28674 EN, 11:898.

[21] Kidd MT, Maynard CW, Mullenix GJ. Progress of amino acid nutrition for diet protein reduction in poultry. J Anim Sci Biotech. 2021; 12(1): 1-9.

[22] Hernández F, López M, Martínez S, Megías MD, Catalá P, Madrid J. Effect of low-protein diets and single sex on production performance, plasma metabolites, digestibility, and nitrogen excretion in 1-to 48-day-old broilers. Poult Sci. 2012; 91(3): 683-692.

[23] Fancher BI, Jensen LS. Male broiler performance during the starting and growing periods as affected by dietary protein, essential amino acids, and potassium levels. Poult Sci. 1989; 68(10): 1385-1395.

[24] Van Harn J, Dijkslag MA, Van Krimpen M. Effect of low dietary protein levels on performance, litter quality and footpad lesions in broilers. Poult Sci. 2019; 98:4868-4877.

[25] Belloir P, Méda B, Lambert W, Corrent E, Juin H, Lessire M, Tesseraud S. Reducing the CP content in broiler feeds: impact on animal performance, meat quality and nitrogen utilization. Animal 2017; 11(11): 1881-1889.

[26] Van Emous RA, Winkel A, Aarnink AJA. Effects of dietary crude protein levels on ammonia emission, litter and manure composition, N losses, and water intake in broiler breeders. Poult Sci. 2019; 98(12): 6618-6625.

[27] Kop-Bozbay C, Akdag A, Atan H, Ocak N. Response of broilers to supplementation of branched-chain amino acids blends with different valine contents in the starter period under summer conditions. Anim Biosci. 2021; 34(2): 295.

[28] Alagawany M, Elnesr SS, Farag MR. The role of exogenous enzymes in promoting growth and improving nutrient digestibility in poultry. Iran Vet Res. 2018; 19(3): 157.

[29] Ndazigaruye G, Kim DH, Kang CW, Kang KR, Joo YJ, Lee SR, Lee KW. Effects of low-protein diets and exogenous protease on growth performance, carcass traits, intestinal morphology, cecal volatile fatty acids and serum parameters in broilers. Animals 2019; 9(5): 226.

[30] Velázquez-De Lucio BS, Hernández-Domínguez EM, Villa-Garcia M, Diaz-Godinez G, Mandujano-Gonzalez V, Mendoza MN, Cervantes JA. Exogenous enzymes as zootechnical additives in animal feed: a review. Catalysts 2021; 11(7): 851.

[31] Ojha BK, Singh PK, Shrivastava N. Enzymes in the animal feed industry. In Enzymes in food biotechnology. Academic Press 2019; 93-109.

[32] Ayalew H, Zhang H, Wang J, Wu S, Qiu K, Qi G, Tekeste A, Wassie T, Chanie D. Potential feed additives as antibiotic alternatives in broiler production. Fron Vet Sci. 2022; 9.

[33] Ding XM, Li DD, Li ZR, Wang JP, Zeng QF, Bai SP, Su SW, Zhang KY. Effects of dietary crude protein levels and exogenous protease on performance, nutrient digestibility, trypsin activity and intestinal morphology in broilers. Livest Sci. 2016; 193: 26-31.

[34] Jabbar A, Tahir M, Alhidary IA, Abdelrahman MA, Albadani H, Khan RU, Selvaggi M, Laudadio V, Tufarelli V. Impact of microbial protease enzyme and dietary crude protein levels on growth and nutrients digestibility in broilers over 15–28 days. Animals. 2021; 11(9): 2499.

[35] Nastain FS, Mahardhika BP, Ridla M, Mutia R. Visceral organ weight of broiler chicken fed different level protein and protease enzyme supplementation diet. In IOP Conference Series: Earth and Environmental Science 2021. June; 788(1): 012032. IOP Publishing.

SPSS Paket Programı ile Parametrik Olmayan Testlerin Veri Kullanarak Uygulanması

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Özet

Bilimsel çalışmalarda bir hipotezin test edilmesi için istatistiksel analizler yapılarak elde edilen sonuçlardan bir yorumda bulunması, ilgili araştırmaların güvenirliğini artırmaktadır İstatistiksel analizler veri yapısına bağlı olarak parametrik ve parametrik olmayan testler şeklindeki iki yönteme göre yapılmaktadır. Parametrik testlerin kullanılması için bazı ön şartların sağlanması gerekmektedir. Bu şartların yerine getirilemediği durumlarda parametrik olmayan yöntemler kullanılmaktadır. Parametrik olmayan testler parametrik testlerin gerektirdiği varsayımlara ihtiyaç duymamaktadır. Özellikle, veri setinin küçük olduğu, sayımla elde edilen ve verilerin normal dağılım göstermediği koşullarda kullanılmaktadır. Parametrik testlerin karşılıkları olarak kullanılan parametrik olmayan testlerinden en yaygınları; Mann Whitney U Testi, Kruskall Wallis H Testi, Friedman Testi, Ki-Kare Bağımsızlık Testi, Spearman Korelasyon Analizi, Wald-Wolfowitz Testi, Kolmogorov-Smirnow Testi, Jonckheere-Terpstra Testi, Wilcoxon Testi ve İşaret Testleridir. Bu çalışmada, yaygın kullanılan parametrik olmayan testlerden Wilcoxon, Kruskal-Wallis ve Mann-Whitney testleri tanıtılarak SPSS programı ile uygulaması gerçekleştirilmiştir. Bilimsel çalışmalarda hipotezlerin test edilmesi için yapılan istatistiksel analizler, elde edilen sonuçların yorumlanmasıyla birlikte araştırmaların güvenirliğini artırmaktadır. Bu analizler, veri yapısına bağlı olarak parametrik ve parametrik olmayan testler olmak üzere iki farklı yöntemle gerçekleştirilir. Parametrik testler, belirli ön şartların sağlanmasını gerektirirken, bu şartlar karşılanamadığında parametrik olmayan yöntemler tercih edilir. Parametrik olmayan testler, parametrik testlerin istediği varsayımlara ihtiyaç duymadan kullanılabilir. Özellikle veri setinin küçük olduğu, sayımla elde edilen ve normal dağılım göstermeyen verilerin bulunduğu durumlarda bu testler tercih edilir. Mann-Whitney U Testi, Kruskal-Wallis H Testi, Friedman Testi, Ki-Kare Bağımsızlık Testi, Spearman Korelasyon Analizi, Wald-Wolfowitz Testi, Kolmogorov-Smirnov Testi, Jonckheere-Terpstra Testi, Wilcoxon Testi ve İşaret Testleri gibi parametrik olmayan testler en yaygın kullanılanlardır. Bu çalışmada, popüler parametrik olmayan testlerden Wilcoxon, Kruskal-Wallis ve Mann-Whitney testlerinin tanıtımı yapılarak, bu testlerin SPSS programıyla nasıl uygulanacağına dair bir araştırma yapılmıştır.

Anahtar Kelimeler: Parametrik olmayan testler, SPSS, istatistiksel analiz

Giriş

Birçok istatistiksel analiz yöntemi, verilerin belirli koşulları sağlamasını gerektirmektedir. Bu koşullar, analiz için güvenilir sonuçlar elde etmek adına önemlidir. Parametrik ve parametrik olmayan testler (non-parametrik), istatistiksel analizlerde sıklıkla kullanılan yöntemler arasında yer almaktadır. Ancak, her bir testin uygulanabilmesi için gerekli koşulların bilinmesi ve verilerin bu koşullara uygunluğunun değerlendirilmesi önemlidir. Parametrik testlerde, verilerin normal dağılıma sahip olması gerekir, bunun için de verilerin şansa bağlı ve bağımsız olarak elde edilmesi, interval (aralık) ölçek kullanılması ve popülasyon varyanslarının homojen olması gibi koşullar sağlanmalıdır [5].

Parametrik testler normal dağılıma sahip verilere uygulanır. Ancak, ordinal yapıdaki ya da normal dağılım göstermeyen verilere parametrik test uygulaması uygun değildir. Bu durumda, parametrik olmayan testler tercih edilmelidir [1,2].

Parametrik olmayan testler, verilerin dağılımına daha az bağımlı olan testlerdir. Bu testler, değişkenlere ilişkin gözlemlerin şansa bağlı ve bağımsız olarak elde edildiğini varsaymaktadır. Bu nedenle, analize başlamadan önce verilerin normal dağılıma uygun olup olmadığının veya diğer koşulların sağlanıp sağlanmadığının test edilmesi gereklidir. Eğer koşulların sağlanıp sağlanmadığı kesin olarak bilinmiyorsa, verilerin analizinde parametrik olmayan testleri kullanmak daha güvenli bir yaklaşım olacaktır [3,6]. Parametrik olmayan testlerin en büyük avantajı, popülasyon hakkında bilgi

olmadığında güvenle kullanılabilmesidir. Örneğin, örnek hacmi çok küçük olduğunda istatistiklerin örneklem dağılımı normal dağılıma yaklaşmaz ve bu durumda parametrik olmayan bir test kullanılması gerekmektedir. Parametrik olmayan testler, parametrik testlere göre genellikle daha pratik ve kolaydır. Ancak, parametrik olmayan testlerin bazı dezavantajları da vardır. Aynı koşullar altında parametrik testlere göre daha az güçlüdürler. Bu da parametrik olmayan testlerde ikinci tip bir hata olasılığının daha yüksek olduğu anlamına gelir [5].

Parametrik olmayan testlerin en büyük avantajı, popülasyon hakkında bilgi olmadığında güvenle kullanılabilmesidir. Özellikle örnek hacmi çok küçük olduğunda, istatistiklerin örneklem dağılımı normal dağılıma yaklaşmaz ve bu durumda parametrik olmayan bir testin kullanılması gerekmektedir. Parametrik olmayan testler, genellikle parametrik testlere göre daha pratik ve kolay uygulanabilirler. Ancak, parametrik olmayan testlerin bazı dezavantajları da bulunmaktadır. Parametrik testlere kıyasla aynı koşullar altında daha az güçlüdürler, bu da parametrik olmayan testlerde ikinci tip bir hata olasılığının daha yüksek olduğu anlamına gelir [5].

Parametrik olmayan testler

Mann-Whitney U testi, bağımsız örneklemelerin karşılaştırılmasında kullanılan bir parametrik olmayan istatistiksel test yöntemidir. Mann-Whitney U testi, iki bağımsız grup arasında medyan değerlerinin karşılaştırılması amacıyla kullanılır. Bu test, sürekli değişkenleri sıralı hale dönüştürerek gruplar arasındaki sıralama farkını değerlendirir. Medyan değerlerin karşılaştırılması, gruplar arasındaki istatistiksel anlamlılığı belirlemek için kullanılan temel ölçüttür. Mann-Whitney U testi, grupların medyanlarını karşılaştırarak iki grup arasında farklılık olup olmadığını saptamak için güçlü bir non-parametrik test yöntemidir [3]. Bu testte, veriler sıralı hale dönüştürülerek analiz edildiği için, verilerin asıl dağılımı önemli değildir. Sıfır hipotezi, örnekler aynı popülasyondan alınmış veya örneklerin alındıkları popülasyonlar birbirinden farklı olmamalıdır şeklindedir. Mann-Whitney U testi, Wilcoxon sıra-toplam testiyle aynı güçte bir non-parametrik test yöntemidir. Ancak, veriler aralık ölçekli ve normal dağılıma sahipse, t-testi kullanılması tercih edilebilir. Bu durumda t-testi ile yapılan analizde, ortalamalar arasındaki farkın test edilmesi mümkündür. Bununla birlikte, verilerin ölçek tipine ve dağılım özelliklerine göre doğru test yönteminin seçilmesi önemlidir. Büyük örneklemeler için Mann-Whitney U testinin gücü, t-testine göre yaklaşık olarak %95'tir [5].

Mann-Whitney U testi, bağımsız örneklemelerin karşılaştırılmasında kullanılan etkili bir parametrik olmayan istatistiksel test yöntemidir. Bu test, iki bağımsız grup arasındaki medyan değerlerinin karşılaştırılması amacıyla kullanılır. Mann-Whitney U testi, gruplar arasındaki sıralama farkını değerlendirmek için sürekli değişkenleri sıralı hale dönüştürmektedir. Bu sayede, gruplar arasındaki istatistiksel anlamlılığı belirlemek için medyan değerlerin karşılaştırılması temel bir ölçüt olarak kullanılmaktadır. Mann-Whitney U testi, non-parametrik bir test yöntemi olduğundan verilerin asıl dağılımının önemi bulunmamaktadır. Bu testte, sıfır hipotezi örneklerin aynı popülasyondan alındığını veya alındıkları populasyonlar arasında farklılık olmadığını varsaymaktadır. Mann-Whitney U testi, Wilcoxon sıra-toplam testiyle benzer güçlü bir non-parametrik test yöntemidir. Ancak, veriler aralık ölçekli ve normal dağılıma sahipse, t-testi kullanılması tercih edilebilir. T-testi ile yapılan analizde, ortalamalar arasındaki farkın test edilmesi mümkündür. Verilerin ölçek tipine ve dağılım özelliklerine göre doğru test yönteminin seçilmesi önemlidir. Büyük örneklemelerde, Mann-Whitney U testinin gücü t-testine kıyasla yaklaşık olarak %95'tir. Bu nedenle, büyük örneklem durumlarında Mann-Whitney U testi tercih edilebilir bir seçenektir [5].

Wilcoxon sıralama testi, parametrik olmayan bir istatistiksel test yöntemi olarak bilinir ve birçok uygulama alanında kullanılmaktadır. Bu test, eşleştirilmiş veri setleri üzerinde karşılaştırmalar yapma amacı taşır. Genellikle ölçülen bir değişkenin zaman içindeki veya farklı koşullar altındaki değişimini değerlendirmek için tercih edilen bir yöntemdir. Wilcoxon sıralama testi, parametrik testlerdeki normal dağılım ve varyans homojenliği gibi varsayımlara ihtiyaç duymaz. Bu özelliği sayesinde, özellikle normal dağılıma uygun olmayan veri setlerinde güvenilir sonuçlar elde etmek için tercih edilen bir yöntemdir. Test, eşleştirilmiş ölçümleri içeren veri setlerinde kullanılır ve eşleştirilmiş örneklerin farklarını sıralayarak çalışır. Wilcoxon sıralama testinin çalışma prensibi, eşleştirilmiş örneklerin farklarının sıralama işlemine tabi tutulması ve bu sıralamaların toplamı üzerinden test istatistiğinin hesaplanmasıdır. Test istatistiği, eşleştirilmiş farkların sıralama toplamı üzerinden elde edilir ve bu toplam, testin gücü ve anlamlılığına ilişkin bilgiler sağlar. Wilcoxon sıralama testi, birçok avantaja sahip bir yöntem olarak öne çıkar. Öncelikle, normal dağılıma uygun olmayan veri setlerinde güvenilir sonuçlar elde etmek için kullanılabilir. Ayrıca, ölçek düzeyi ne olursa olsun (ordinal veya interval), verilerin analizinde kullanılabilir. Bu da farklı türde ölçümleri içeren veri setlerinde geniş bir uygulama alanı sunar. Ayrıca, testin uygulanması kolaydır ve yorumu açıktır [3,7].

Kruskal-Wallis testi, parametrik olmayan bir test olarak, sıfır hipotezinin test edilmesinde en yaygın kullanılan ve tek yönlü varyans analizi için iyi bir alternatif sunan bir yöntemdir. Kruskal-Wallis testi, en az iki bağımsız örneğin aynı popülasyondan çekildiğini iddia eden sıfır hipotezinin test edilmesinde kullanılır. Bu test, alternatif hipotezi en az bir popülasyon medyanının diğer populasyondan farklı olduğu şeklinde kabul eder. Kruskal-Wallis testi, bağımsız, şansa bağlı ve en az aralık ölçekle elde edilen sürekli değişkenlerin analizinde kullanılır. Tek yönlü varyans analizi (F-testi) ile karşılaştırıldığında güçlü bir non-parametrik test yöntemidir. Kruskal-Wallis testinin güç etkinliği yaklaşık olarak 0.955'tir, bu da F-testi için n≅95 olduğunda Kruskal-Wallis testinin gücünün F-testi ile aynı olduğunu gösterir. Bu durumda, Kruskal-Wallis testi oldukça güçlü bir non-parametrik test yöntemidir [3,8]. Dağılımların aynı olduğu ve sadece merkezi eğilim ölçütlerinin farklı olduğu durumlarda, asimptotik oransal etkinlik genellikle 0.864'ün altına düşmez ve belirli durumlarda 1'den büyük olabilir Kruskal -Wallis testi, belirli bir yöndeki farklılıkları tespit edemez. Ancak, bu durum için Jonckheere-Terpstra sıralı alternatifler testi kullanılabilir. Jonckheere-Terpstra testi, sıralanmış veriler üzerinde farklılıkları değerlendirerek belirli bir yöndeki eğilimleri tespit etmek için kullanılır [2].

Bu çalışmada parametrik olmayan testlerden olan ve sıklıkla kullanılan Mann-Whitney U, Wilcoxon sıralama ve Kruskall Wallis testlerinin tanıtılarak SPSS'de uygulama aşamalarının gösterilmesi amaçlanmıştır.

Materyal ve Metot

Çalışmada ele alınan parametrik olmayan testlerden Mann-Whitney U, Wilcoxon sıralama ve Kruskall Wallis testlerinin SPSS uygulamaları 3 ayrı veri seti üzerinde gerçekleştirilmiştir. Mann-Whitney U testi için Bir yem katkı maddesinin sindirimdeki etkisinin araştırılması amacıyla 8 koç ve 8 koyun toplamda 16 hayvan kullanılmıştır. Wilcoxon sıralama testi için bir X hormonu denemesi için 10 tavuk kullanılmış ve hormon verilmeden önce ve verildikten sonra leptin seviyeleri ölçülmüştür. Kruskal-Wallis testi için 18 tavuk kullanılmış farklı korku etkenleri uygulanarak Tonik Immobility (TI) süreleri dakika olarak ölçülmüştür.

Bulgular

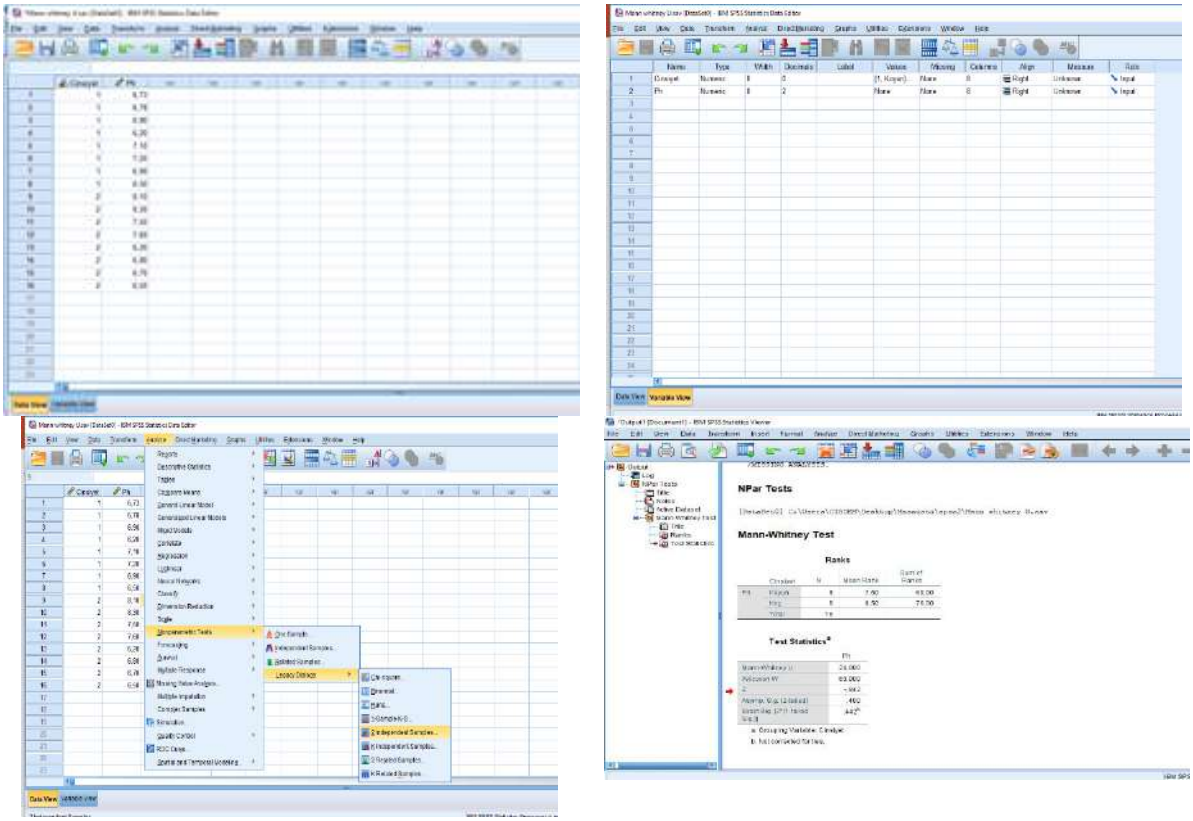
Mann-Whitney U testi

Bir yem katkı maddesinin sindirimdeki etkisinin araştırılması amacıyla 8 koç ve koyuna bu madde verilerek rumen sıvılarında Ph miktarları incelenmiştir (Tablo 1)

Tablo 1. PH miktarları

Koç	Koyun
8.10	6.73
8.30	6.78
7.30	6.90
7.60	6.20
6.20	7.10
6.80	7.20
6.70	6.90
6.50	6.50

Rumen sıvılarındaki Ph miktarları bakımından koç ve koyunlar arasında fark olup olmadığını araştırmak için Mann-Whitney U testi uygulanır. Testin SPSS istatistik paket programındaki uygulama aşamaları Şekil 1'de verilmiştir.



Şekil 1. Mann-Whitney U testi uygulaması

Elde edilen (0.400>0,05). Sonuca göre cinsiyetler arasında rumen Ph miktarı açısından farklılık görülmemiştir (p>0,05).

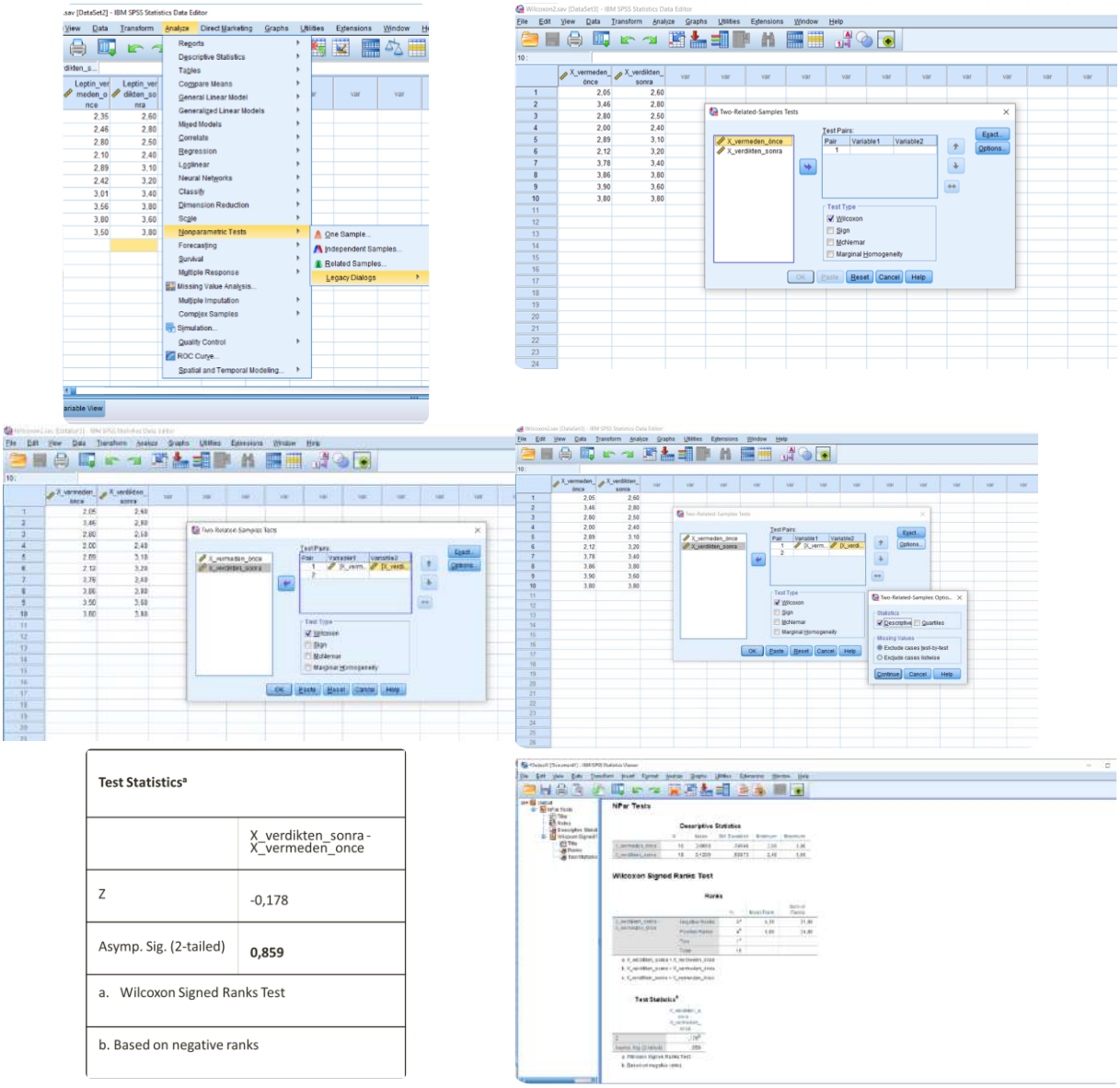
Wilcoxon sıralama testi

Bir X hormonu denemesi için rastgele 10 tavuk seçilmiş ve bu tavukların hormon verilmeden önce ve verildikten sonra kanlarındaki leptin seviyeleri ölçülmüş ve Tablo 2'de verilmiştir.

Tablo 1. Leptin seviyeleri

Hormon vermeden önce Leptin değerleri	Hormon verildikten sonra Leptin değerleri
2.35	2.60
2.46	2.80
2.80	2.50
2.10	2.40
2.89	3.10
2.42	3.20
3.01	3.40
3.56	3.80
3.80	3.60
3.50	3.80

X hormonu denemesinde hormon verilmeden önce ve hormon verildikten sonra tavukların kanında ölçülen leptin seviyeleri arasında fark olup olmadığını araştırmak için Wilcoxon Sıralama testi uygulanır. Testin SPSS istatistik paket programındaki uygulama aşamaları Şekil 2'de verilmiştir.



Test Statistics[a]	
	X_verdikten_sonra - X_vermeden_once
Z	-0,178
Asymp. Sig. (2-tailed)	**0,859**
a. Wilcoxon Signed Ranks Test	
b. Based on negative ranks	

Şekil 2.Wilcoxon sıralama testi uygulaması

Bu sonuçlara göre tavukların leptin hormonları arasında istatistiksel açıdan anlamlı bir fark olmadığı tespit edilmiştir (Z = 0,178, P = 0,859).

Kruskal-Wallis testi

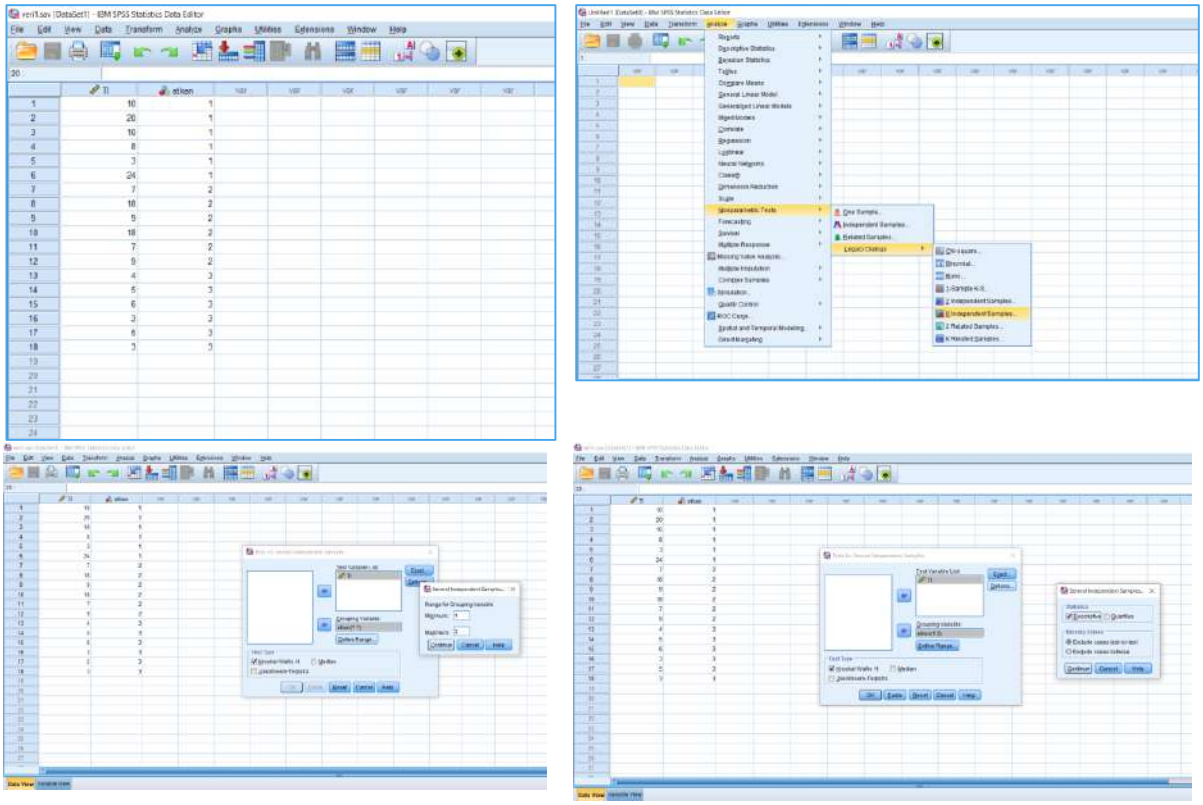
18 tavuk rastgele olarak üç gruba ayrılmış ve her gruptaki hayvanlara farklı korku etkenleri uygulanarak Tonik Immobility süreleri dakika olarak ölçülmüş ve Tablo 3'de verilmiştir.

Tablo 3. Korku etkileri

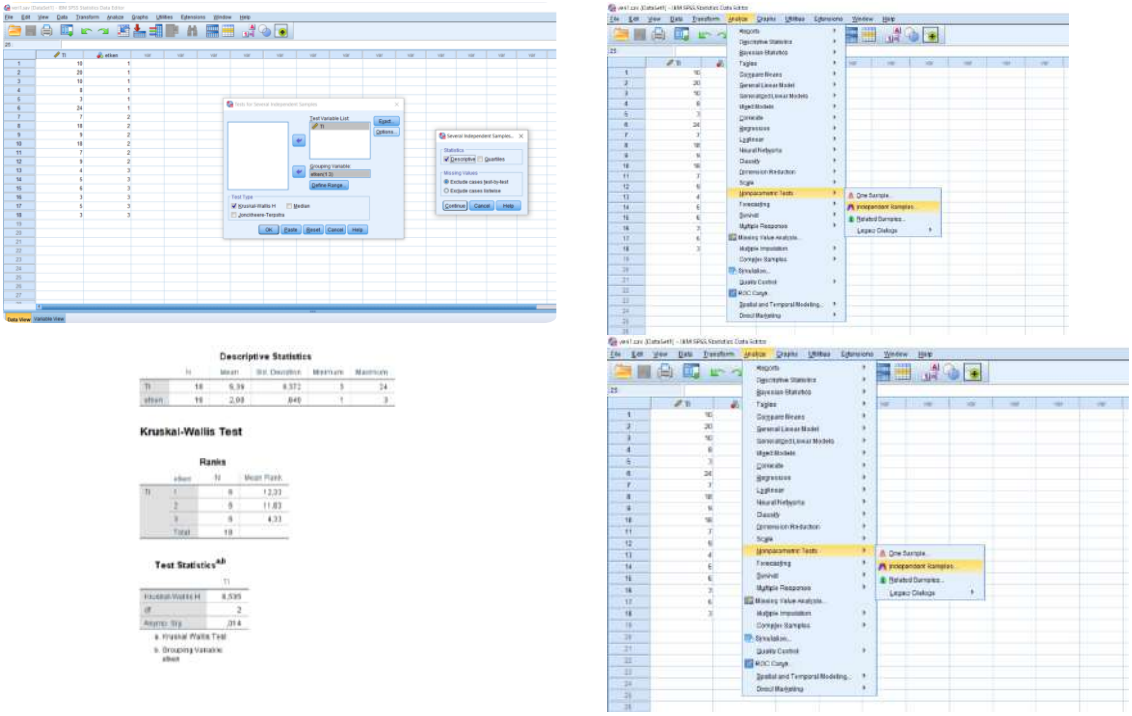
Korku Etkenleri		
Etken 1	Etken 2	Etken 3
10	7	4
20	18	5
10	9	6
8	18	3
3	7	5
24	9	3

Korku etkenlerine göre Tonik Immobility süreleri (dak.) arasında fark olup olmadığını araştırmak için Kruskal-Wallis testi uygulanır. Testin SPSS istatistik paket programındaki uygulaması iki yoldan verilmiştir (Şekil 3 ve 4).

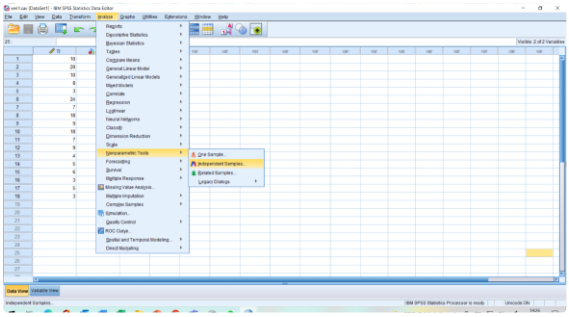
1. yol:

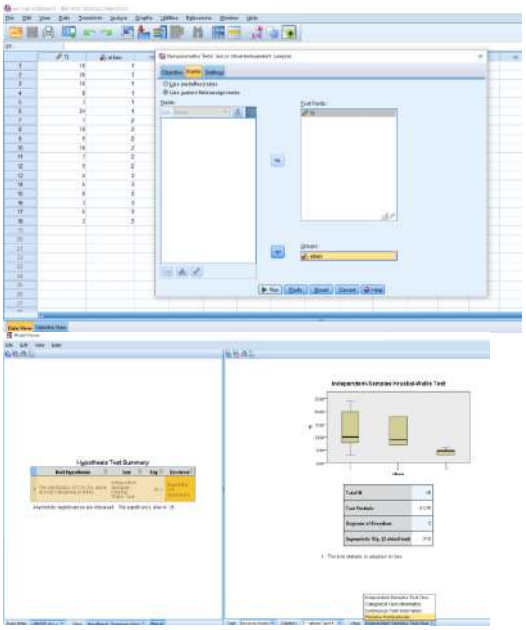


Şekil 3. Kruskal-Wallis testi uygulaması (1. yol)



2. Yol





Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of TI is the same across categories of etken.	Independent-Samples Kruskal-Wallis Test	,014	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

Each node shows the sample average rank of etken.

Sample 1-Sam...	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
3-2	7,500	3,068	2,445	,014	,043
3-1	8,000	3,068	2,608	,009	,027
2-1	,500	3,068	,163	,871	1,000

Şekil 4. Kruskal-Wallis testi kullanarak uygulaması (2. yol)

Elde edilen (0.014<0,05) (bu sonuçlara göre TI süreleri üzerine korku etmenlerinden en az biri diğerlerinden farklıdır (p<0,05). Burada 3. Etken hem 2. hem de farklıdır

Sonuç

Veri analizinde parametrik ve parametrik olmayan testler arasında doğru seçimi yapmak, verilerin dağılımına uygunluğun doğru bir şekilde değerlendirilmesini gerektirir. Normal dağılıma uygun olan veri setlerinde parametrik testlerin kullanılması kabul edilebilirken, ordinal yapıdaki ya da normal dağılım göstermeyen veriler için parametrik testlerin kullanılması daha sakıncalı olabilir. Testlerin uygulanabilmesi için gereken koşulların iyi bilinmesi ve verilerin bu koşullara uygunluğunun değerlendirilmesi önemlidir. Bu sayede, doğru ve güvenilir sonuçlar elde edilebilir ve analizlerin bilimsel geçerliliği sağlanmış olur. Sonuç olarak, veri analizinde parametrik ve parametrik olmayan testler arasında doğru seçimi yapmak, verilerin dağılımına uygunluğun doğru bir şekilde değerlendirilmesini gerektirir. Parametrik testler, normal dağılıma uygun olan veri setlerinde kullanılabilirken, ordinal yapıya sahip ya da normal dağılım göstermeyen veriler için parametrik olmayan testler tercih edilmelidir. Testlerin uygulanabilmesi için gereken koşulların iyi bilinmesi ve verilerin bu koşullara uygunluğunun değerlendirilmesi önemlidir. Bu değerlendirme sayesinde, analizlerin doğru test yöntemiyle yapılması ve doğru sonuçların elde edilmesi sağlanmaktadır. Ayrıca, analizlerin bilimsel geçerliliği de bu şekilde sağlanmış olmakta, verilerin doğru test yöntemiyle analiz edilmesi, sonuçların güvenilirliğini artırmakta ve elde edilen bulguların yanıltıcı olma olasılığını azaltmaktadır. Bu nedenle, veri analizi sürecinde parametrik ve parametrik olmayan testler arasında doğru seçimi yapmak için verilerin dağılımını ve testlerin gerektirdiği koşulları dikkate almak önemlidir. Bu şekilde, analizlerin doğruluğu ve bilimsel geçerliliği sağlanarak, sağlam temellere dayalı sonuçlar elde edilebilmektedir.

Referanslar

[1] Balcı, Ali. (2006), Sosyal Bilimlerde Araştırma, Yöntem, Teknik ve İlkeler, Pegem A Yayıncılık, Ankara.

[2] Daniel, Wayne W. (1990), Applied Nonparametric Statistics, PWS-KENT Publishing Company, Boston.

[3] Kalaycı, Ş. (2010), "SPSS Uygulamalı Çok Değişkenli İstatistik Teknikleri", Asil Yayın Dağıtım, Ankara

[4] Karagöz, Y. (2010). Parametrik olmayan tekniklerin güç ve etkinlikleri. Elektronik Sosyal Bilimler Dergisi, 9(33), 18-40.

[5] Kartal, Mahmut. (2006), Bilimsel Araştırmalarda Hipotez Testleri, Nobel Yayın Dağıtım, Ankara.

[6] Özdamar, Kazım. (2002), Paket Programlar ile İstatistiksel Veri Analizi 1, Kaan Kitabevi, Eskişehir.

[7] Özdamar, Kazım. (2003), SPSS ile Biyoistatistik, Kaan Kitabevi, Eskişehir.

[8] Ruxton G. D., Beauchamp G. (10 June 2008). "Some Suggestions About Appropriate Use Of The Kruskal-Wallis Test", Institute of Biomedical And Life Sciences, University of Glasgow Faculty of Veterinary Medicine, University of Montreal, MS. Number: D08-00178

Et Hayvanlarının Beslenmesinde Alternatif Protein Kaynağı: Mikroalgler

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Özet

Beyaz ve kırmızı et; hayvansal kaynaklı proteinlerin en önemlilerindendir. Hayvansal üretimde sürdürebilirliğin artırılması için alternatif yem protein kaynakları kullanımının teşvik edilmesi, Covid-19 gibi pandemi durumlarında yurt dışından yem tedarik sorunlarının çözümü, rekabet koşulları ve üretim maliyetindeki artışı nedeniyle son yıllarda daha fazla önem kazanmaktadır. Alternatif protein kaynakları içinde, çiftlikte yetiştirilen baklagil tohumları, böcek unları ve mikroalgler sürdürebilir olmayan soya veya kolza küspesi yerine kullanılabilmeleri nedeniyle günümüzde hayvan beslemede tercih edilmeye başlamıştır. Yapılan araştırmalar mikroalglerin hem kümes hayvanları hem de ruminant hayvanların beslenmesinde performans ve kaliteyi artırmak amacıyla kullanılabileceğini göstermektedir.

Bu bildirinin amacı; geleceğe yönelik alternatif protein kaynaklarından biri olan mikroalglerin besin değerleri ve kompozisyonları açıklanarak fonksiyonelliği ile kümes ve ruminant hayvanların beslenmesinde büyüme performansı, et kalitesine yönelik bazı çalışmalar ve besi performansı uygulanabilirliği hakkında bilgi vermektir.

Anahtar Kelimeler: Mikroalg, besi performansı, et kalitesi, sürdürülebilirlik

Giriş

Küresel nüfustaki artış gelirdeki artışla birleştiğinde, 2050 yılına kadar hayvansal ürünlere yönelik toplam talebin iki katına çıkması beklenmektedir [1] ve bu da dünya çapında en çok tüketilebilen hayvansal kaynaklı proteinlerden biri olan etler üzerinde etkili olacaktır. Ülkemizde hayvancılık, tarım sektörü ve tarıma dayalı ekonominin en yüksek toplam hasılaya sahip alt sektörünü oluşturmaktadır. Hayvancılık ile uğraşan işletmeler maksimum verim ve minimum masrafı hedeflemektedir. Nihai hedef, eti tüketici için daha sağlıklı bir ürüne dönüştürmektir bu nedenle ürünlerin kalitesini arttırmak birincil amaç olmalıdır. Hayvanların yaşama ve verim payı besin madde gereksinimlerini karşılayan, belirli sınırlar içerisinde yedirildiği zaman hayvanların sağlığına zarar vermeyen, organik ve inorganik her türlü materyale yem denir. Hayvancılık giderlerinde toplam maliyetin %70'ini yem masrafları oluşturmaktadır. Mısır ve soya fasulyesi gıda bitkileri hayvan yemi için iki ana geleneksel yem olduğundan, bu artan et talebi hayvansal tarım için özellikle dramatik olacaktır [2]. Görünüşe göre, mısır ve soya fasulyesinin mevcut tahsisleri sürdürülemez ve bu nedenle gıda, yem ve biyoyakıt endüstrileri arasındaki dengeyi korumak için bu bileşenlere alternatifler gereklidir. Arazi bozulması, su yoksunluğu ve sert iklim değişiklikleri de hayvancılık için bir diğer zorluklardandır. Buna göre, yeni sürdürülebilir hammaddeler ve kaynak, iyileştirilmiş verimlilik, hayvancılık üretim sistemlerinin sürdürülebilirliğinde alternatif ve hayati bir rol oynayacaktır.

Günümüzde mısır ve soya fasulyesi gibi yem hammaddelerinin yerine alternatif protein kaynakları arayışı devam etmektedir. Hayvanların beslenmesinde alternatif olarak kullanılacak yem kaynaklarının kullanmadan önce sahip oldukları avantajlar ve dezavantajlar özellikle dikkate alınmalıdır [3]. Bu anlamda yemlerin avantajı olarak aminoasit ve flavonoid, hem avantaj hem de dezavantaj olabilecek tanen, dezavantaj olacak mikotoksin, alkoloid, ağır metaller içeriklerinin bilinmesi önemlidir [4]. Son yıllarda yapılan çalışmalarda en çok tercih edilen alternatif protein kaynağı olan mikroalgler besin değeri, kompozisyonu ve üretimi bakımından soya fasulyesi gibi dışa bağımlı olduğumuz protein kaynakları yerine ideal bir yem hammaddesi olarak karşımıza çıkmaktadır.

Algler / Mikroalgler

Algler, dünyada yaklaşık 3,5 milyar yıl önce ortaya çıkan ve ilk yaşam formu olarak kabul edilen sucul fotosentetik ökaryotları tanımlamak için kullanılan ve birbirleriyle akraba olmayan çeşitli grupları içine alan resmî olmayan bir terimdir. Mikroalgler: denizlerde ve tatlı sularda yaşayan ve fotosentez

yapabilen tek hücreli canlılardır. Hücre boyutlarına göre mikroalg ve makroalg olmak üzere temel olarak iki gruba ayrılır. 60 m uzunluğa ulaşabilen çok hücreli organizmalar (makroalgler) ve 0.2 ila 2 mm büyüklüğünde tek hücreli organizmalar (mikroalg veya fitoplankton) olarak ayrılırlar [5]. Geleneksel olarak renklerine göre sınıflandırılırlar: *Cholophyceae* (yesil renkli algler), *Rhodophyceae* (kırmızı renkli algler), *Cyanophyceae* (mavi yesil algler) ve *Pheophyceae* (kahverengi algler).

Mikroalgal biyoteknoloji geleneksel tarıma benzer olsa da, mikroalglerin karasal bitkilere göre birçok avantajı vardır:

1. Geleneksel yemlerden daha yüksek verimliliğe sahiptirler (örneğin; soya danesi ile karşılaştırıldığında 21 kat; dane mısırla karşılaştırıldığında ise 49 kat fazla miktarda protein üretmektedir [6] ve zorlu iklim koşullarında, çöl ve kıyı bölgeleri gibi diğer mahsullerin yetiştirilemediği bölgelerde yetiştirilebilirler.
2. Mikroalgler, çoklu doymamış yağ asitleri, proteinler, amino asitler, pigmentler, antioksidanlar, vitaminler ve mineraller gibi biyolojik değeri yüksek maddeler içermektedirler.
3. Bunlarla birlikte, mikroalglerin ana avantajı, atmosferde fazla miktarda bulunan CO_2 tutmaları ve O_2 üretmeleri, böylece 'sera etkisinin' azaltılmasına yardımcı olmalarıdır [7].

Et Hayvanlarının Beslenmesinde Mikroalg Kullanımı

Mikroalgler yüzyıllardır bilinmektedir, ancak ticari büyük ölçekli üretimleri, 1960'ların başında Japonya'da başlamış ve daha sonra diğer Asya ülkelerine, Avustralya, Fransa, Norveç ve ABD'ye yayılmıştır [8]. 30.000'den fazla mikroalg türünün bulunduğu tahmin edilmektedir, ancak bunlardan sadece yüzünün kimyasal bileşimi incelenmiştir ve sadece birkaçının endüstriyel miktarlarda yetiştirildiği tahmin edilmektedir [9]. Yaygın türler, *Schizochytrium sp., Chlorella sp., Arthrospira sp., Isochrysis sp.* ve *Porphyridium sp.* mükemmel besinsel bileşimi ve bileşimindeki düşük yapısal karbonhidrat içeriğine atfedilen kolay sindirilebilirlik nedeniyle dünya çapında üretilen alglerin %50'si yem üretiminde kullanılmaktadır [10]. Sürdürülebilir olmayan soya küspesi gibi yem hammaddelerine alternatif olabilecek protein kaynakları içerisinde mikroalglerin özellikle ruminant hayvanların beslenmesinde öncelikle kullanılması önerilmektedir [11]. Çünkü ruminantlar, mikroalglerde bulunan protein olmayan nitrojenleri kullanabildikleri ve alg organizmalarının hücre duvarlarını sindirdikleri için bu yeni yem maddesinin umut verici hedefleri gibi görünmektedir [11].

Mikroalglerin geviş getiren hayvanların beslenmesinde kullanılma potansiyeline rağmen, bilgiler hala sınırlıdır ve literatürde mikroalglerin ruminantların verim ve et/süt gibi hayvansal ürünlerin kalitesi üzerindeki etkileri konusunda sınırlı sayıda görüş bulunmaktadır. Hayvan beslemede az miktarda mikroalg biyokütlesinin kullanılmasının, immün sistemin güçlenmesine, antiviral ve antibakteriyel etkiye, bağırsak fonksiyonunu ve probiyotik kolonizasyon stimülasyonunu geliştirerek hayvanların fizyolojisine fayda sağlayabileceği bildirilmektedir. Bütün bu etkiler bir araya geldiğinde, büyümeyi teşvik etme, yem dönüşüm oranı ve üreme performansı iyileşmeye ile sonuçlanabileceği bildirilmektedir [12].

Mikroalgler tam alg unu, yağı alınmış alg unu, kurutulmuş veya dondurarak kurutulmuş algler şeklinde hayvan yemlerine ilave edilebilmektedir. Bu farklı formlar farklı yüzdelerde yağ içermekte kullanım miktarları da buna göre değişmektedir. Hayvansal üretim için kullanılan mikroalglerin besin değeri oldukça değişkendir. Bunu; kullanılan mikroalgin türü ve kimyasal kompozisyonu ile (örn. Protein, lipitler, polisakkaritler, vitaminler, antioksidanlar ve mineraller) hayvanın göstereceği adaptasyon etkiler. Son zamanlarda yapılan çalışmalar, su ürünleri yetiştiriciliği yanı sıra ruminant hayvanlar, kümes hayvanları diğer evcil hayvanların rasyonlarında kullanılan mikroalglerin yüksek besin değerine sahip olduğunu göstermiştir. Çizelge 1'de hayvan yemi olarak kullanılan ana mikroalg türlerinin kimyasal bileşimi ele alınmıştır.

Çizelge 1. Hayvan yemi olarak kullanılan ana mikroalg türlerinin kimyasal bileşimi (tüm değerler kuru madde bazında ifade edilir.) [12]

Mikroalgler	*Arthrospira platensis*	*Chlorella sp.*	*Isochrysis sp.*	*Schizochytrium sp.*
Ham Protein (%)	60.3–65.8	37.7–47.8	27.0–45.4	12.1
Ham Karbonhidratlar (%)	17.8–22.6	18.1–27.5	13.3–18.0	32.0
Ham Selüloz (%)	0.5–1.8	0.4–1.4	< 18.0	0.6
Ham Yağ (%)	1.8–7.3	13.3–20.9	17.2–27.3	38.0–71.1
DHA (g/kg)	< 3.0	< 26.0	< 34.0	104–204
EPA (g/kg)	< 2.5	< 4.0	< 3.5	20.0
Kül (%)	6.5–9.5	6.2–7.3	9.7–16.1	8.2
Ca (g/kg)	1.3–14.0	0.1–5.9	5.6	VY*
P (g/kg)	1.2–9.6	9.6–17.6	0.3–26.5	VY*
Karotenoidler (mg/kg)	330–5040	8–80	760	8–1800

*VY: Veri yok

Mikroalgler ruminant rasyonlarına mısır veya yoğun yem yerine enerji kaynağı olarak, lipid ilavesi şeklinde, kısmi oranda soya veya kolza küspesinin yerine protein kaynağı olarak veya yemin antioksidan içeriğini iyileştirmek için ilave edilebilirler. Ayrıca kullanılan substrata göre mikro alglerin hayvanın rumen parametrelerini olumsuz etkilemeden rumenden metan salınımı azaltıcı etkisi olduğu bildirilmektedir [14]. Yapılan bazı çalışmalarda da, alglerin aşırı miktarda kullanılmasının yemin lezzetliliği ve tüketimine, rumen metabolizmasına, süt üretim ve süt yağına olumsuz etkileri olabileceği de bildirilmektedir. Bu nedenle ilave edilecek alg miktarı ve rumen korunmuş formlarının kullanılarak bu olumsuz etkilerin azaltılması gerekmektedir.

Çizelge 2. Rasyona mikroalgler ilavesi yapılan kuzu besisi performansı ve et kalitesine yönelik bazı çalışmalar [12]

Mikroalg Türü	**Rasyondaki kullanım miktarı ve süresi**	**Hayvanın başlangıç ağırlığı / yaşı- ırkı-adedi**	**Araştırma Bulguları ve Sonuçlar**	**Kaynak**
Arthrospira platensis	6 hafta boyunca % 0-10-20	24 adet 37,6 kg ve 6 haftalık sütten kesilmiş Dorset- White Suffolk, Black Suffolk, Merino atalarından alınan 4 farklı ırk kuzu	Günlük canlı ağırlık artışı üzerinde etkisi yoktur. Vücut ağırlığında artış (% 10 doz) Sırt yağ tabakasında artış (% 20 doz)	[16]
Isochrysis sp.	% 4, 14,7 ile 26,2 kg arasında	14,7 kg ile sütten kesilmiş erkek kuzu Manchego ırkı	Günlük canlı ağırlık artışı, Günlük ortalama yem tüketimi, yemden yararlanma oranı, karkas ağırlığı, karkas verimi ve sırt yağ kalınlığı üzerine etkisi yoktur. Etin kimyasal bileşim (yağ, protein, nem ve kül), renk ve pH üzerinde hiçbir etkisi yoktur MUFA, PUFA, CLA, EPA, DPA, DHA ve TBARS'ın artması, E vitamini azalması	[17]
Şizochytrium spp	18 hafta boyunca % 1-3	Canadian Arcott ırkı 44 adet 22,7 ± 3,90 kg erkek ve dişi kuzular	Günlük canlı ağırlık artışı, Günlük ortalama yem tüketimi, yemden yararlanma oranı ve karkas özellikleri üzerinde etkisi yoktur, Sırt yağ kalınlığında artış, SFA ve PUFA üzerinde etkisi yok, Toplam n-3 FA, EPA ve DHA artışı, n-6 / n-3 oranının azalması	[18]

*MUFA: Tekli Doymamış Yağ Asitleri, PUFA: Çoklu Doymamış Yağ Asitleri, CLA: Konjuge Linoleik Asit, SFA: Doymuş Yağ Asitleri, FA: Yağ Asitleri, LCPUFA: Uzun Zincirli Doymamış Yağ Asitleri, EPA: Eikozapentaenoik Asit, DHA: Dokozahekzaenoik Asit, DPA: Dokozapentaenoik Asit, TBARS: Tiyobarbitürat reaktif maddeler.

Çizelge 2'de mikroalglerin kuzu besisinde performans ve et kalitesine yönelik yapılan çalışmalardan bazılarına ait bilgiler sunulmuştur. Mikroalgler ile yapılan sınırlı sayıdaki bu çalışmalar değerlendirildiğinde, kuzu besisinde mikroalg kullanımının performans üzerine etkisinin olmadığı [15], ancak et kalitesinde özellikle etin yağ asidi profilinde bir iyileşme olduğu (MUFA, PUFA, CLA, EPA, DPA, DHA ve TBARS'ın artması) görülmektedir. Bu nedenlerle, son birkaç yılda, geviş getirenlerin rasyonlarında, özellikle etin yağ asidi profilini iyileştirmek, PUFA ile zenginleştirmek için mikroalgler kullanılmaktadır. Ruminantlar, alglerde bulunan protein olmayan nitrojenleri de kullanabildikleri ve alg organizmalarının hücre duvarlarını sindirdikleri için bu yeni yem maddesinin umut verici hedefleri gibi görünmektedir [11]. Bunun yanında hayvan türü ve verim yönüne göre mikroalg kullanımın etkileri konusunda çalışmalar halen çok yetersizdir ve ihtiyaç vardır [16].

Çizelge 3'de son yıllarda yapılan çalışmalarda birden çok mikroalg türünün rasyona farklı seviyelerde kullanılarak kümes hayvanlarının büyüme performansı ve et kalitesi parametreleri üzerinde bildirilen çelişkili bulgular, kullanılan mikroalg türüne, konsantrelerine, rasyonlarda kullanılan farklı doz seviyelerine ve hayvanın yaşına bağlı olabilir.

Çizelge 3. Rasyona mikroalgler ilavesi yapılan kümes hayvanlarının büyüme performansı ve et kalitesine yönelik bazı çalışmalar [12]

Mikroalg Türü	**Rasyondaki kullanım miktarı ve süresi**	**Hayvanın başlangıç ağırlığı / yaşı- ırkı- adedi**	**Araştırma Bulguları ve Sonuçlar**	**Kaynak**
Arthrospira sp.	16 gün boyunca % 4-8	678 g ve 21 günlük erkek civcivler	ADG üzerinde etkisi yok Semitendinosus ve sartorius kaslarından L * (% 4 dozaj) azalması Psoas superficialis ve Psoas sartorius kaslarından * (% 4 doz) ve tüm kaslardan b * (% 8 doz) artışı	[19]
Chlorella sp.	42 gün boyunca % 0.1-0.2	1 günlük yaştaki erkek pekin ördekleri	ADG ve yem alımının artması G: F üzerinde etkisi yok Göğüs etinde b *, pH ve kesme kuvvetinde, bacak etinde L * ve b * 'de artış	[20]
Şizochytrium sp. (DHA-Gold ekst.)	21. günden 35. güne kadar % 3.7-7.4	21 günlük broyler piliçleri	FCR ve karkas verimi üzerinde etkisi yok ADG artışı (% 7.4 dozaj), ADFI (% 7.4 dozaj) Renk, pH, pişirme kaybı, kesme kuvveti ve MUFA üzerinde etkisi yoktur SFA, toplam n-3 FA, LCPUFA, EPA, DHA, n 6 / n-3 oranı ve TBARS artışı Toplam n-6 FA, E vitamini, lezzet ve genel kabul edilebilirliğin azalması	[21]
Şizochytrium sp. (DHA-Gold ekst.)	21. günden 35. güne kadar % 7.4	21 günlük broyler piliçleri	ADG, ADFI ve karkas veriminin artması FCR azalması. PH ve pişirme kaybına etkisi yok SFA, toplam n-3, LCPUFA, EPA, DHA, lezzetsiz ve TBARS artışı MUFA, toplam n-6, PUFA / SFA oranı, n-6 / n-3 oranı, E vitamini, lezzet ve genel kabul edilebilirliğin azalması	[22]

*MUFA: Tekli Doymamış Yağ Asitleri, PUFA: Çoklu Doymamış Yağ Asitleri, CLA: Konjuge Linoleik Asit, SFA: Doymuş Yağ Asitleri, FA: Yağ Asitleri, LCPUFA: Uzun Zincirli Doymamış Yağ Asitleri, EPA: Eikozapentaenoik Asit, DHA: Dokozahekzaenoik Asit, DPA: Dokozapentaenoik Asit, TBARS: Tiyobarbitürat reaktif maddeler.

Sonuç

Literatürlerde var olan değerlendirmelere dayanılarak, besinsel bakış açısından mikro alglerin özellikle yüksek protein ve ham yağ içerikleri nedeniyle kuzu ve etlik piliç rasyonlarında alternatif protein kaynağı olarak kullanılabileceği sonuçlarına varılabilir. Çalışmalarda daha çok rasyona ilave edildiğinde lezzet azalmasına bağlı olarak oluşabilecek yem tüketimindeki düşmenin performans üzerine olumsuz etkisi olmadan, et kalitesinde iyileşme şeklinde sonuçlar vermesinin önemli olduğu

bildirilmektedir. Mikroalgler, çevrenin korunması ve doğal kaynakların sürdürülebilir yönetimi üzerine de olumlu etkileri vardır. Ancak, mikroalglerin et hayvanların beslenmesinde kullanılma potansiyeline rağmen, bilgiler hala sınırlıdır ve literatürde mikroalglerin verim ve et/süt gibi hayvansal ürünlerin kalitesi üzerindeki etkileri konusunda sınırlı sayıda görüş bulunmaktadır. Nitekim Avrupa Birliği Horizon 2020 projeleri çerçevesinden 2019 yılında başlayan ve 2023 yılında tamamlanacak olan bir proje de 'Microalgae Protein Ingredients For The Food And Feed of The Future' hayvan beslemede kullanımlarına yönelik bazı stratejiler belirlenecektir. Bu projede mikroalglerin üretim ölçeklenebilirliği ve optimizasyonu, üretim maliyetleri, değer zinciri riskleri, güvenlik, yasal düzenlemeler ve tüketici güveni ve kabulü gibi önemli konular ele alınmaktadır. Gelecekte, hayvan beslemede alternatif protein kaynaklarından biri olarak mikroalglerin önemli olduğu görüşü de gittikçe yaygınlaşmaktadır.

Kaynakça

[1] Food and Agriculture Organization of the United Nations. 2007. The State of Food and Agriculture. http://www.fao.org (1 Mayıs 2020).

[2] Food and Agriculture Organization of the United Nations. 2011. Food Insecurity in the World. http://www.fao.org (1 Mayıs 2020).

[3] SOLID (Sustainable organic and low put dairying) 2016. Feeding home-grown protein and novel feeds to dairy cows. Technical Note 2. Produced by The Organic Research Centre, UK.

[4] Cömert Acar M, Kırpınar F, Şayan Y, ve Mert S. 2019. Organik Yemler ve Alternatif Organik Yem Proteini Kaynakları. VI. Organik Tarım Sempozyumu 15-17 Mayıs 2019, Sözlü Bildiri, İzmir-Türkiye.

[5] Harlin MM, and Darley WM, 1988. The algae: an overview. In: Lembi CA, Waaland JR, editors. Algae and human affairs. Cambridge, UK: Cambridge University Press. p 3–27.

[6] ICOPP 2014. Improved Contribution of local feed to support 100% Organic feed supply to Pigs and Poultry. Editors: Jo Smith, Catherine Gerrard and John Hermansen. SYNTHESIS REPORT SEPTEMBER, Archived: http://orgprints.org/28078/.

[7] Gouveia L, Sousa J, Moura P, and Bandarra, NM. 2010. Microalgae - source of natural bioactives as functional ingredients. Food Sci. Technol. Bull.: Funct. Foods 7 (2), 21–37.

[8] Spolaore P, Joannis-Cassan , Duran E, and Isambert A. 2006. Commercial applications of microalgae. J Biosci Bioeng 101: 87–97.

[9] Gouveia L, Batista AP, Sousa I, Raymundo A, and Bandarra NM. 2008. Microalgae in novel food products. In: Papadopoulos, K.N. (Ed.), Food Chemistry Research Developments. Nova Science Publishers, New York, NY, USA, pp. 1–37.

[10] Yaakob Z, Ali E, Zainal A, Mohamad M, and Takriff MS. 2014. An overview: biomolecules from microalgae for animal feed and aquaculture. J. Biol. Res. 21, 6.

[11] Altomonte I, Salari F, Licitra R, and Martini M. 2018. Use of microalgae in ruminant nutrition and implications on milk quality – A review. Livestock Science, 214 (2018) 25–35.

[12] Madeira MS, Cardoso C, Lopes PA, Coelho D, Afonso C, Bandarra NM, and Prates José AM. 2017. Microalgae as feed ingredients for livestock production and meat quality: A review. Livestock Science, 205, 111-123.

[13] Esmail SH. 2019. Dietary manipulation for less methane output. https://www.dairyglobal.net/Nutrition/Articles/2019/6/Dietary-manipulation-for-less-methane-output-442022E/ (21 Ağustos 2020).

[14] EL-Sabagh MR, Eldaim MAA, Mahboub DH, and Abdel-Daim M. 2014. Effects of Spirulina Platensis algae on growth performance antioxidative status and blood metabolites in fattening lambs. J. Agric. Sci. 6, 3.

[15] Koeleman E. 2018. Microalgae: Not too much in dairy cow diets. https://www.allaboutfeed.net/New-Proteins/Articles/2018/5/Microalgae-Not-too-much-in-dairy-cow-diets-290138E/ (15 Temmuz 2020).

[16] Holman BWB, Kashani A, and Malau-Aduli AEO. 2012. Growth and body conformation responses of genetically divergent Australian sheep to Spirulina (Arthrospira platensis) supplementation. Am. J. Exp. Agric. 2, 160–173.

[17] Fuente-Vázquez J, Díaz-Díaz-Chíron MT, Pérez-Marcos C, Cañeque-Martínez V, Sánchez-González CI, Álvarez-Acero I, Fernández-Bermejo C, and Rivas-Cañedo A. 2014. Linseed,

microalgae or fish oil dietary supplementation affects performance and quality characteristics of light lambs. Span. J. Agric. Res. 12, 436–447.

[18] Meale SJ, Chaves AV, He ML, McAllister TA. 2014. Dose-response of supplementing marine algae (Schizochytrium spp.) on production performance, fatty acid profiles, and wool parameters of growing lambs. J. Anim. Sci, 92, 2202–2213.

[19] Toyomizu M, Sato K, Taroda H, Kato T, and Akiba Y. 2001. Effects of dietary Spirulina on meat colour in muscle of broiler chickens. Br. Poult. Sci. 42, 197–202.

[20] Oh ST, Zheng L, Kwon HJ., Choo, Y. K., Lee, K. W., Kang, C. W., and An, B. K., 2015. Effects of dietary fermented Chlorella vulgaris (CBT®) on growth performance, relative organ weights, cecal microflora, tibia bone characteristics, and meat qualities in Pekin ducks. Asian Australas. J. Anim. Sci., 28, 95–101.

[21] Ribeiro T, Lordelo MM, Alves SP, Bessa RJB, Costa O, Lemos JPC, Ferreira LMA, Fontes CMGA, and Prates JAM. 2013. Direct supplementation of die tis the most efficient way to enriching broiler meat with n-3 long-chain polyunsaturated fatty acids. Br. Poult. Sci., 54, 753–765.

[22] Ribeiro T, Lordelo MM, Costa P, Alves SP, Benevides WS, Bessa RJB, Lemos JPC, Pinto RMA, Ferreira LMA, Fontes CMGA, and Prates JAM. 2014. Effect of reduced dietary protein and supplementation with a docosahexaenoic acid product on broiler performance and meat quality. Br. Poult. Sci. 55, 752–765.

Bazı Alternatif Yem Kaynaklarının Hayvan Beslemede Kullanım Olanakları

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Özet

Hayvancılık endüstrisinde işletme maliyetinin %60-80'ini oluşturan yem giderleri maliyet ve sürdürülebilir üretim bakımından önemlidir. Son yıllarda özellikle hayvan beslemede yaygın olarak kullanılan mısır, soya ve diğer yem hammaddelerinin fiyat artış eğilimi göstermesi nedeniyle alternatif yem kaynaklarına olan ilgi giderek artmaktadır. Gelecekte yem hammadde stoklarının yetersizliği ve fiyatlarının yükselmesi beklenen bir durumdur. Bu nedenle hayvan beslemede alternatif yem kaynakları olarak kullanılabilecek hammaddelerin incelenmesi gerekmektedir. Alternatif yem kaynakları arasında ülkemizde faaliyet gösteren çeşitli gıda ve tarım firmalarından yan ürünler olarak elde edilen fındık küspesi, fıstık küspesi, bisküvi-gofret kırığı, yüksek proteinli kurutulmuş çözünürlü damıtık tahıl (DDGS), kuru maya, pirinç kepeği, zeytin küspesi, mısır özü küspesi, keten tohumu küspesi, mercimek kırığı, mercimek kepeği, pirinç kırığı, bulgur kırığı, nohut kırığı ve yüksek proteinli ayçiçek tohumu küspesi sayılabilir.

Bu makalede söz konusu alternatif yem kaynaklarının kuru madde, ham kül, ham yağ, ham protein, nişasta, şeker, ham selüloz, nötr deterjan lif, asit deterjan lif ve asit deterjan lignin içerikleri ve hayvan beslemede potansiyel yem değerleri ile ilgili araştırmaların sonuçları incelenecektir. Sürdürülebilir hayvan besleme ve yem maliyetlerinin azaltılması perspektifleri ile alternatif bazı yem hammaddelerinin hayvan beslemede kullanım olanakları, yaygın olarak kullanılan mısır, buğday, arpa, soya fasulyesi ve ayçiçeği tohumu küspesi gibi yem kaynakları ile karşılaştırılarak irdelenecektir.

Anahtar Kelimeler: Alternatif yem kaynakları, hayvan besleme, yem

Giriş

Gıda ve Tarım Örgütü [1] ve Uluslararası Yem Endüstrisi Federasyonu [2] raporuna göre, 2050 yılına kadar hayvansal protein ihtiyacının 2 kat artacağı öngörülmektedir. Nüfusun ve yoğun üretimin artması ile gıda rekabeti de tahıl fiyatlarının yükselmesine neden olacaktır. Bu durumun üretim maliyetini ve hayvansal ürün tüketimini olumsuz etkileyeceği beklenmektedir [1,3].

Hayvancılık endüstrisinde, işletme maliyetinin %60-80'ini oluşturan yem giderleri ekonomik, çevre dostu ve sürdürülebilir üretim için önem arz etmektedir [4]. Dahası son yıllarda özellikle hayvan beslemede yaygın olarak kullanılan mısır, soya ve diğer yem hammaddelerinin sürekli fiyat artış eğilimi göstermesi nedeniyle alternatif yem kaynaklarına olan ilgi her geçen gün artmaktadır [5]. Günümüzde hayvan beslenmede ana protein kaynağı olarak bitkisel proteinler kullanılmaktadır [6]. Özellikle soya gibi ithal edilen protein kaynaklarına bağımlılık sürdürülebilir ve çevre dostu üretimi olumsuz etkilemektedir [7]. Bu amaçla, soya alternatifi protein kaynağı olarak yerel, yan sanayi ürünleri, algler, böcekler ve solucanlar gibi omurgasızların karma yemlere ve rasyonlara ilavesi ile sürdürülebilir ve çevre dostu bir hayvansal üretimin yapılabileceği bildirilmiştir [5, 8]. Hayvan beslemede enerji yemlerinden en çok mısır, buğday ve arpa kullanılmaktadır. Dünya'da ekilebilir arazinin %33'ü yem hammaddesi üretimi amacıyla kullanılmaktadır [5]. Gelecek yıllarda kontrolsüz nüfus artışıyla birlikte bu ürünlerin insan ve hayvan beslemesinde kullanılması ile ciddi bir rekabetin oluşacağı öngörülmektedir. Bu nedenle, gelecekte yem hammadde stoklarının yetersizliği ve hammadde fiyatlarının yükselmesi gibi durumlarla karşılaşılabilmesi beklenen bir durumdur [9]. Bu amaçla, özellikle yerel ve yan sanayi ürünlerinin hayvan beslemede kullanılması önem arz etmektedir. Çoğunlukla tahıl değirmenciliği, yağlı tohum çıkarma, bira fabrikası, malt üretimi, meyve ve sebze işleme gibi tarımsal işletme endüstrilerinden elde edilen tarımsal sanayi yan ürünleri, büyük bir hayvan yemi kaynağı oluşturmaktadır [10].

Bir kaynağın yem hammaddesi olarak kullanılabilmesi için; besin madde içeriğinin uygun olması, toksik etkisinin bulunmaması, sindirilebilir olması ve hayvanlar tarafından sevilerek tüketiliyor olması gerekmektedir [9]. Ucuz yem hammaddeleri temini geçmişten günümüze ciddi bir sorun oluşturmuştur.

Bu sorunun çözümü için alternatif yem kaynaklarının araştırılıp, yetiştiricinin kullanımına sunulması önemle üzerinde durulması gereken bir konudur [11]. Hayvansal üretimde verimlilik ve sürdürülebilirlik, kaliteli ve ucuz yem teminiyle doğrudan ilişkilidir. Çiftlik hayvanlarının beslenmesinde kullanılan yemlerin ucuz ve kaliteli kaynaklardan temin edilmesi, üretim performansını iyileştirmesi ve yem maliyetinin azaltılmasında önemli bir yere sahiptir. Hayvancılığımızın geçmişten günümüze en önemli sorunlarından biri kaliteli ve ucuz yem ihtiyacının düzenli karşılanamamasıdır. Yem hammaddeleri üretiminin yetersiz olması, alternatif yem kaynaklarının ve sanayi yan ürünlerinin hayvan beslemede yem olarak değerlendirilmesi konusunu gündeme getirmiştir [12].

İnsan ve hayvan beslenmesinde gıda rekabeti alternatif protein kaynaklarına olan ilginin artmasına neden olmaktadır. Bitki, meyve ve sebzelerden elde edilen yağların yan ürünleri olarak kabul edilen küspelerin (kekler) hayvanlar için umut verici alternatif protein kaynakları olabileceği düşünülmektedir. Bu yan ürünlerin büyük bir kısmının acık alanlara atılarak önemli düzeyde çevre sorunlarına neden olduğu bilinmektedir. Ayrıca, hayvan beslenmesinde kullanımları ile hayvan yemlerinin maliyetinin düşürebileceği düşünülmektedir [13].

Bu derlemede, bazı alternatif yem kaynaklarının hayvan beslemede kullanım olanakları ele alınarak bu konuya yönelik bilgilere ve önerilere yer verilmiştir.

Bazı Alternatif Yem Kaynakları

Fındık küspesi, yıllık ortalama 500.000 ton üretim miktarına sahip olduğumuz fındıktan yan ürün olarak elde edilmektedir. Türkiye, dünya fındık üretimi ve ihracatında birinci sırada yer alarak dünya fındık üretiminin %80'ini, dünya ihracatının ise yaklaşık %70'ini gerçekleştirmektedir. Yağı çıkarılarak işlenen iç fındıktan geriye kalan kısım olan fındık küspesinin, proteince zengin (ortalama %40), buna karşın selülozca fakir (ortalama %9) olmasından dolayı kanatlıların karma yemlerinde protein kaynağı olarak kullanılabilecek değerli bir yem hammaddesi olduğu belirtilmiştir [14].

Bisküvi-gofret kırığı, üretim esnasında ürün kalitesini etkileyen aksaklıkların oluşmasıyla doğrudan satışa sunulamayacak (artık/yan) kısmı oluşturmaktadır. Bu aşamada gıda artık/yan ürünlerinin birçok kısmı anında imha edilirken çevre kirliliğine ve israfa yol açılabilmektedir. Bunun yanı sıra düşük teknolojiler kullanılarak elde edilen, ekonomik getirisi az ürünlerin (hayvan yemi, gübre, vb.) üretiminde bu hammaddeler kullanılabilmektedir [15]. Protein içeriği %7-8, yağ içeriği %12-13 ile iyi bir enerji yemi olabileceği saptanmıştır.

Kurutulmuş çözünürlü damıtık tahıl (DDGS), çeşitli enzimler ve mayaların bir kombinasyonu ile gerçekleştirilen fermantasyon yoluyla etanol üretiminin mısır bazlı yan ürünüdür. DDGS'nin besin içeriğinin; ham protein %28-32 ve ham yağ %7-10 değerine sahip olduğu bilinmektedir. Teknolojik gelişmeler, sindirilemeyen lifin daha fazla ayrılması ve kuru öğütme işleminin iyileştirilmesi yüksek proteinli DDGS'nin (HP-DDGS) ortaya çıkmasına neden olmuştur. Böylece ürünün ham protein içeriği %50-52 değerine yükselmiştir. Ancak düşük esansiyel aminoasit içeriği nedeniyle büyüme performansı, gelişme, metabolik fonksiyonlar ve sağlık üzerine olumsuz etkilere neden olabileceği belirtilmiştir. Bununla birlikte esansiyel amino asitlerin eklenmesiyle desteklenen HP-DDGS'nin alternatif protein kaynağı olarak kullanımının artırılabileceği düşünülmektedir [16].

Kuru maya hücresinin %75'i su ve %25'i kuru maddedir. Kuru maddesinin %89-95'i ise organik maddelerden oluşmaktadır. Organik maddeler içerisinde en büyük payı %40-60 ile ham protein almaktadır. Ham proteinin %64-70'i gerçek protein, %20-26'sı nükleik asit, nükleotidler ve yaklaşık %10'u pepton ve aminoasitlerdir. Dünyada bol olarak bulunan çok çeşitli endüstri artık ve atıkları tek hücreli canlıların üretilmesi amacıyla kullanılabilmektedirler. Böylece çevre sorununun çözümlenmesi ve çevre dostu üretim yapılması sağlanabilmektedir [17, 18]. Chand ve ark. [19] etlik piliçlerin rasyonuna soya küspesi yerine farklı dozlarda (3.5-7.0-10.5 g/kg) maya (*Saccharomyces cerevisiae*) ilavesinin performans üzerine etkilerini araştırdıkları çalışmada, tüm muamele gruplarında canlı ağırlığın arttığını ve yemden yararlanmanın olumlu etkilendiğini bildirmişlerdir.

Pirinç kepeği, pirincin işlenmesi sırasında ortaya çıkan en önemli yan üründür. Kavuzu alınmamış pirince kaba pirinç adı verilmektedir. Kaba pirincin yaklaşık %20'si kavuzdur. Kaba pirinçten kavuz uzaklaştırıldığında elde edilen ürün kahverengi pirinç olarak isimlendirilir ve diğer tane yemlerle yapısal olarak benzerlik gösterir. Pirinç kepeği, kahverengi pirincin perikarpından dış katmanların uzaklaştırılması sonrası tanenin beyazlaştırılması esnasında yan ürün olarak ortaya çıkar. Beyazlaştırma işleminin son aşamasında, bolca endosperm ve parçalanmış embriyo içeren parlatılmış kepek adı verilen ürün elde edilir. Pirinç kepeğinin kimyasal bileşimindeki değişiklikler pirincin çeşidine ve işleme yöntemine bağlı olarak değişiklik göstermektedir [20]. Dilelis ve ark. [21] besin madde içeriğini, ham protein %12.6, ham selüloz %9.7, ham yağ %19.7 ve ham kül %10.7 olarak bildirmişlerdir. Besi bitirme döneminde bulunan sığırların rasyonlarındaki mısırın, %30 düzeyine kadar pirinç kepeği ile ikamesinin besi performansı ve karkas parametrelerini etkilemediği ifade edilmiştir [22].

Zeytin küspesi, zeytinden yağ çıkarıldıktan sonra geriye kalan yağ, çekirdek, kabuk ve posadan oluşan bir yan üründür. Zeytin küspesinin içerdiği besin madde miktarları ham protein %5-10, ham yağ %4-6, ham selüloz %35-40 ve ham kül %7-10 olarak bildirilmiştir. [23].

Mısır özü, tane ağırlığının %5-14'ünü oluşturur [24]. Öz yüksek oranda çekirdek yağı, suda çözünür protein, suda çözünür karbonhidratlar, vitaminler ve mineraller içermesi bakımından gıda endüstrisinde bir yağ kaynağı olarak çeşitli alanlarda kullanılmaktadır. Yağ ekstraksiyonundan sonraki mısır özü küspesinde ham protein %15-30 arasında bulunmaktadır. Bu nedenle iyi bir potansiyel protein kaynağıdır [25].

Keten (*Linum usitatissimum*) yağ ve lif amacıyla yetiştirilen eski kültür bitkileri arasındadır. Keten tohumu %41 yağ, %20 ham protein, %20 nötral deterjan lifi (NDF) içermektedir. Yağ alım işleminden sonra yan ürün olarak yüksek protein değerine sahip küspesi elde edilmektedir. Yumurta tavuklarında performans, yumurta kalitesi, yumurta lezzeti ve yumurta yağ asidi kompozisyonu üzerine herhangi olumsuz etki bırakmaması nedeniyle keten tohumu küspesi soya fasulyesi küspesinin %10'u yerine kullanılabilir [26].

Mercimek (*Lens culinaris Medic*) ülkemizde önde gelen bir yemeklik tane baklagil türüdür. Mercimek işleme tesislerinde kabuk soyma ünitesini takip eden çıtlatma (kırma) işlemi sonrası mercimek unu ve mercimek kepeği açığa çıkmaktadır. Mercimek işleme ünitesinde ayıklama işlemi ile işlemeye uygun olmayan mercimekler ve kırık mercimekler ayrılmaktadır. Mercimek kırığı besin madde içeriği ham protein %25-29 ham selüloz %5-8, ham yağ %1-3 ve ham kül %3-4 arasında saptanmıştır [27]. Mercimek kırığı, zengin protein içeriği sayesinde hayvan beslemede alternatif protein yemi olarak görülmektedir.

Pirinç (*Oryza sativa*) nişasta bakımından oldukça zengindir ve ham protein değeri %7-8 olarak bilinmektedir. Pirinç işleme sırasında ayrılan kırık tanelerden oluşan yan ürünün hayvan yemi olarak kullanılabileceği belirtilmiştir [28]. Kırık pirinç kaliteli nişasta içeriği sayesinde önemli bir enerji yemidir. Hayvan beslemede yaygın olarak kullanılan mısır ve buğdaya belirli oranlarda ikame olarak kullanılabilir.

Bulgur kırığı hayvan beslemede buğday ikame yemi olarak kullanılabilecek önemli kaynaklardan biridir. Buğday ayıklanıp, yıkanıp, kaynatılıp, kurutulduktan sonra kepek çıkartma ve kırılma işlemleri değirmenler tarafından yapılmaktadır. Bulgur üretim işleminin sonunda ürünler renk ayırıcı makinesinden geçirilerek insan tüketimine uygun olmayan kırık ve bozuk taneler ayrılır ve yan ürün olarak kırık bulgur elde edilir [29].

Nohut, insan beslenmesinde kullanılan, kuru tanesinde yüksek oranda sindirilebilirliği yüksek protein bulunduran, esansiyel aminoasitler ve bazı mineral maddeler bakımından oldukça zengin bir yemeklik tane baklagil cinsidir [30]. Nohutun besin madde içeriği ham protein %22.5, ham selüloz %1.5, ham yağ %5.1 ve ham kül %2.6 olarak saptanmıştır [31]. Tane nohut, çiğ olarak kanatlı rasyonlarında %20 düzeyine kadar kullanıldığı zaman verimde önemli düşüşlere neden olmadan soya küspesi yerine ikame edilebilmektedir [32]. Ancak, anti-besinsel faktörlerin varlığının nohutun kanatlı rasyonlarında kullanılmasını sınırlayan bir faktör olduğu bildirilmiştir [33].

Ayçiçeği küspesinin ham protein içeriği işleme metoduna göre %25 (kabuklu)-%50 (kabuksuz) arasında değişim gösterir. Amino asitlerden lizin yetersiz, metiyonin ve arginin soya küspesinden daha yüksek orandadır [34]. Ayçiçeği küspesinin kabuk oranın azaltılması ile protein oranı %42-44 düzeyine çıkartılabilir. Esansiyel aminoasitler ile birlikte kullanımda soya fasulyesi küspesine alternatif bir yem kaynağıdır.

Sonuç

Nüfus artışı ile birlikte hayvansal gıda tüketimi artmaya devam etmektedir. Hayvansal üretim sektörünün hayvanlar ve çevre için daha sağlıklı olan, maliyeti düşük yem yönetim stratejileri geliştirmesi gerekmektedir. Hayvan yemlerini elde ederken doğal kaynakların daha az kullanılması önemlidir. Hayvansal üretimde küresel olarak en yaygın kullanılan enerji kaynağı mısır, bitkisel protein kaynağı ise soya fasulyesi küspesidir. Balık unu ise hayvan rasyonlarında kullanılan önemli bir hayvansal protein kaynağıdır. Bu üç yem bileşeni, geleneksel hayvan konsantre yemlerinin önemli bir parçasını oluştururlar. Özellikle gelişmekte olan ülkeler insan gıdası ve hayvan yemi talepleri arasında pazar rekabeti ile karşı karşıya kalmaktadırlar ve bu eğilim "yem-gıda rekabeti" olarak etiketlenmiştir [35]. Hayvan beslemede bazı alternatif yem kaynaklarının üretim döngüsü içerisine alınmasının ekonomik, çevre dostu ve sürdürülebilir üretimi sağlayabileceği düşünülmektedir.

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Kaynaklar

[1] FAO. Fisheries and Aquaculture Information and Statistics. 2014.

[2] IFIF. What is the global feed industry? International Feed Industry Federation Factsheet; International Feed Industry Federation (IFIF): Wiehl, Germany. 2019.

[3] Cerisuelo A, Calvet S. La alimentación en producción intensiva de animales monogástricos: Un elemento clave para reducir su impacto ambiental. ITEA, Información técnica económica agraria. 2020; 116(5), 483-506.

[4] Herrero M, Thornton PK, Notenbaert AM, Wood S, Msangi S, Freeman HA, Bossio D., Dixon J, Peters M, Van dee Steeg J, Lynam J, Parthasarathy Rao P, Macmillan S, Gerard B, Mcdermott C, Sere C, Rosegrant, M. Smart investments in sustainable food production: revisiting mixed crop-livestock systems. Scien. 2010; 327(5967), 822-825.

[5] Lassaletta L, Estellés F, Beusen AH, Bouwman L, Calvet S, Van Grinsven HJ, Doelman JC, Stehfest E, Uwizeye A, Westhoek H. Future global pig production systems according to the shared socioeconomic pathways. Sci Total Environ. 2019; 665 (1): 739-751.

[6] Patsios SI, Dedousi A, Sossidou EN, Zdragas A. Sustainable animal feed protein through the cultivation of Yarrowia lipolytica on agro-industrial wastes and by-products Sustainab. 2020; 12(4), 1398.

[7] Leinonen I, Kyriazakis I. How can we improve the environmental sustainability of poultry production? Proc Nutr Soc. 2016; 75 (3): 265-273.

[8] Tallentire CW, Mackenzie SG, Kyriazakis I. Environmental impact trade-offs in diet formulation for broiler production systems in the UK and USA. *Agricul Sys.* 2017; *154*, 145-156.

[9] İpçak, HH, Özüretmen S, Alçiçek A, Özelçam H. Alternatif protein kaynaklarının hayvan beslemede kullanım olanakları. Hayvansal Üret. 2018; 59(1), 51-58.

[10] Fernandez MLP. Unlocking the potential of agro-industrial by-products. https://www.farm4tradesuite.com/blog/unlocking-the-potential-of-agro-industrial-by-products 2018.

[11] Alçiçek A, Akkan S, Özkan K, Taluğ M, Karaayvaz K, Basmacıoğlua H. Konserve sanayi yan ürünü bezelye artıklarının silolanma imkanı ve yem değeri üzerine bir araştırma. Ege Üniv. Ziraat Fakül Derg. 2002; 39(3).

[12] Alçiçek A, Kılıç A, Ayhan V, Özdoğan M. Türkiye'de kaba yem üretimi ve sorunları. Türkiye Ziraat Mühendisliği VII. Teknik Kongresi. 2010; (2),1071-1080.

[13] Sobczak M, Panicz R, Eljasik P, Sadowski J, Tórz A, Żochowska-Kujawska J, Barbosa V, Domingues V, Marques A, Dias J. Quality improvement of common carp (*Cyprinus carpio L.*) meat fortified with n-3 PUFA. Food Chem Toxi. 2020;139, 111261.

[14] Gençoğlu H, Deniz G, Orman A, Türkmen İİ. Broyler rasyonlarında fındık küspesinin kullanılma olanaklarının araştırılması. Uludağ Üniv. Vet. Fakül. Derg. 2011; 30(1), 29-34.

[15] Salur Z. Bisküvi sanayisi artık/yan ürünlerinin ekstrüde çerez gıda üretiminde kullanımı. Karamanoğlu Mehmetbey Üniversitesi Fen Bilimleri Enstitüsü Yüksek Lisans Tezi 2021.

[16] Suehs, BA, Gatlin DM. Evaluation of a commercial high-protein distiller's dried grain with solubles (HP-DDGS) product in the diet of Juvenile Nile Tilapia (*Oreochromis niloticus*). Aquacult. Nutr. 2022.

[17] Katırcıoğlu H, Aksöz N. Tek hücre proteini. Orlab Mikr. Derg. 2003; 1(8), 34- 49.

[18] Küçükyılmaz K, Bozkurt M, Çatlı AU, Çınar M, Bintaş E. Yeme dehidre maya ve humat bileşik katılmasının etlik piliçlerin performans ve bazı kesim özellikleri üzerine etkileri. Süleyman Demirel Üniv. Ziraat Fakül. Derg. 2012; 7(1), 83-92.

[19] Chand N, Khan I, Khan RU. Replacement of soybean meal with yeast single cell protein in broiler ration: the effect on performance traits. Pakistan J. Zool. 2014; 46(6):1753-1758.

[20] Özkan, H. Pirinç kepeği kapsayan etlik piliç rasyonuna enzim karışımı katkısının performans üzerine etkisi. Adnan Menderes Üniv, Sağlık Bilimleri Enstitüsü Yüksek Lisans Tezi 2014.

[21] Dilelis F, Augusto Vidal da Costa G, Cristina Amorim Ribeiro de L, Débora Costa Barroso C, Tulio Leite R. Metabolizable energy of rice bran, cottonseed meal and wheat bran for slow-growing broilers at two ages. Ciência Anim Brasileira, 20, e46537. Epub September 30, 2019.

[22] Meral Y. Besi sığırlarının bitirme dönemi rasyonlarında pirinç kepeğinin kullanım olanakları. Uludağ Üniversitesi Sağlık Bilimleri Enstitüsü Hayvan Besleme ve Beslenme Hastalıkları Anabilim Dalı Doktora Tezi 2015.

[23] Martín L, Carrapiso AI, García A, Petrón MJ. Effect of talc and water addition on olive oil quality and antioxidants. European Journal of Lipid Science and Technology, 2013; 115(5), 583-588.

[24] Nasir M, Butt MS, Anjum FM, Jamil A, Ahmad I. Physical and sensory properties of maize germ oil fortified cakes. International J. Agricult. Biolgy. 2009; 11(3), 311-315.

[25] Rausch KD, Eckhoff SR. Maize: Wet Milling. Encyclopedia of Food Grains: Second Edition (2nd ed. Vol. 3-4). Elsevier Ltd. 2015.

[26] Göçmez İ. Keten ve kanola tohumu küspesi kullanımının yumurtacı tavuklarda performans ve yumurta kalitesine etkileri. Namık Kemal Üniversitesi Fen Bilimleri Enstitüsü Yüksek Lisans Tezi 2018.

[27] Ciurescu G, Vasilachi A, Habeanu M, Dragomir C. Effects of dietary lentil seeds inclusion on performance, carcass characteristics and cecal pH of broiler chickens. Indian J. Anim. Sci, 2017; 87(9), 1130-1134.

[28] Karadağ E. Alternatif yem hammaddesi olarak gıda endüstrisi yan ürünlerinin, besin madde özelliklerinin farklı analiz yöntemleriyle saptanması Namık Kemal Üniversitesi Fen Bilimleri Enstitüsü Yüksek Lisans Tezi 2021.

[29] Baysal A. Beslenme kültürümüz. Kültür Bakanlığı Yayınları, Ankara. 1993.

[30] Akçin A. Yemeklik Tane Baklagiller, Ders Kitabı. Selçuk Üniv. Yayınları: 43, Ziraat Fakültesi Yayınları 1988;(8) 377.

[31] Danek-Majewska A, Kwiecień M, Winiarska-Mieczan A, Haliniarz M, Bielak A. Raw chickpea (*Cicer arietinum L.*) as a substitute of soybean meal in compound feed for broiler chickens: effects on growth performance, lipid metabolism, fatty acid profile, antioxidant status, and dietary value of muscles. Animals, 2021;11(12), 3367.

[32] Bampidis VA, Christodoulou V. Chickpeas (*Cicer arietinum L.*) in animal nutrition: A review. Anim Feed Scien .Technology, 2011; *168*(1-2), 1-20.

[33] Şengül AY, Hakan İ, Şengül Ö. Yemlik tane nohutun (*Cicer arietinum L.*) kanatlı rasyonlarında kullanılma imkânları. Atatürk Üniv. Ziraat Fakül. Derg. 2019; 50(3), 305-311.

[34] Korkut AY, Hoşsu B. Balık Besleme ve Yem Teknolojisi II. E.Ü. Su Ür. Fak. Yay. 1998; (54), 250.

[35] Tona GO. Current and future improvements in livestock nutrition and feed resources. Animal Husbandry and Nutrition. 2018; 147-169.

Antibiotics Abuse: A Common Phenomenon in Nigeria and Pakistan

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Abstract

Antibiotics abuse remains a global health concern adversely affecting developing and developed nations of the world. Antibiotics are meant to achieve a static or cidal effect on targeted bacteria. However, antibiotics abuse prevents the intended results for its use. Uncontrolled dosage and negligence of prescription from qualified medical practitioners remain the major source of antibiotics abuse. The effects may be life threatening and may eventually lead to death. This study takes a look at resident's awareness of antibiotics abuse and its effects. Nigeria and Pakistan (most populated nations in West Africa and South Asia respectively) were the research areas used in the survey. The research involved 1000 respondents. 52.6% of the respondents were females while 46.8% were male out of which the highest age group (48.6%) of respondents falls within 21 to 30. Almost all respondents are aware of the role of antibiotics in disease treatment and 82.2% respondents have taken antibiotics in the last 12 months against infections ranging from Sexually Transmitted Diseases (STDs), Coughs and many more. From the survey, more than 70% of the participants attested to using antibiotics without prescription from a qualified physician. Furthermore, 20% of respondents have been hospitalized for antibiotics abuse. The study showed that antibiotics abuse is still a menace ravaging our society. We therefore recommend that health regulatory authorities in these countries to emulate the measures put in place by developed nations to eradicate this menace in our society.

Keywords: Antibiotics, pathogens, antibiotic resistance, antimicrobials

Introduction

The use of antibiotics to treat infections has been a practice for many years and this has been instrumental in reducing morbidity and mortality due to infectious diseases. As much as the use antibiotics have contributed to disease management, the increasing rate of antimicrobial resistance (AMR) to a wide range of antibiotics is changing the narratives by making treatment ineffective, complicating patient management and increasing morbidity and mortality due to microbial infection [1-7]. AMR is a systemic global and important public health issue plaguing the world and as such requires a state of urgency in the healthcare, veterinary, and agriculture sectors of most countries. Statistically, an annual estimated 700,000 deaths have been documented to be caused by AMR and if this continues, by 2050, a projected 10 million annual deaths will be from AMR globally with Africa and South Asia bearing the highest burden of deaths [8]. AMR does not only have negative impacts on individuals as these resistant microbes are easily transmitted among humans as well as from the environment to humans. Evidence of this is found in nosocomial infection where admitted patients get infected from the hospital environment [8]. The World Health Organization (WHO) established the Global Action Plan (GAP) in a bid to raise global awareness and campaign on the effects of AMR while encouraging best practices among health workers, members of the public and policy makers to avoid further spread of AMR. The GAP uses effective communication, education and training as tools of raising awareness and understanding the concept of AMR [8, 2]. The effectiveness of the GAP has been justified through measure of the antimicrobial usage and related reduction in the cost of antimicrobial therapy and changes in resistant and susceptibility rate.

AMR being a systemic problem requires systemic solutions as such in tackling AMR, all societal levels including policy makers, public and medical and health professionals must contribute their quota in reducing the spread of resistance. Unfortunately, many low-middle income countries (LMICs) such

as Nigeria and Pakistan are lagging behind in the implementation of the GAP and the systemic solutions in most of their health care institutions [8, 9]. Like other LMICs, infections boom due to resistant strains of microbes have been reported in Pakistan and Nigeria. This infection boom is responsible for increased prevalence of AMR with significant negative effect on the health care system [7]. Among the LMICs, Pakistan is the third highest antibiotic consumer with 0.8 to 1.3 billion defined daily doses [10, 7]. Similarly, Pakistan is ranked by WHO among top 5 countries with highest number of resistant bacteria related neonatal death [11].

Antimicrobial abuse, overuse and misuse as well as inadequate infection control are other actors that have been implicated to aggravate the exponential rise in the spread of AMR. AMR related death has been reported to be highest in sub-Saharan Africa with systematic analysis of 27.3 deaths per 100,000 adult population between ages 20.9-35.3 years [12]. While conducting research on knowledge and practices in the use of antibiotics among a group of Nigerian university students, a researcher posited that a high rate of antibiotic consumption exits due to their purchase of antibiotics from unofficial sources without a physician's prescription as well as incomplete dosage during antimicrobial therapy [17]. Also reported inadequate antibiotic knowledge and negative attitudes towards antibiotics use among consumers in a survey conducted in some communities in Jos, Plateau State, Nigeria [16].

Researchers have reported an increasing alarming rate in the antimicrobial resistance pattern in Nigeria and Pakistan to *Escherichia coli, shigella,* non-typhoidal *salmonella,* carbapenem-resistant enterobacteriaceae, vancomycin-resistant enterococci and extended-spectrum beta-lactamase-producing gram-negative rods [2]. Other reported cases of resistance to antibiotics in Nigeria include emergence of a community-associated methicillin-resistant *Staphylococcus aureus* in southwest Nigeria [13], the rapid evolution of flouroquinolone-resistant *Escherichia coli* [14], and high antibiotic resistance rates among common Gram-positive and Gram-negative isolates from various clinical specimens in a tertiary hospital in Nigeria [15]. These earlier studies suggest localization of information and more studies need to be done. Currently, there is paucity of information on the prevalence of antibiotic abuse and low awareness at the national level, hence, this x-rays the current public knowledge on antimicrobial prevalence and awareness within the Nigerian and Pakistan population.

Materials and Methods

Data Collection and Procedure

The online survey was made compatible with the computer and hand-held devices users and was conducted between February and April 2023. This study engaged a total of One thousand (1000) participants using the referral method across social media. The participants were drawn from Nigeria and Pakistan. This survey was conducted using a structured questionnaire in English, which include questions about Demographic, incidence and frequency of antibiotics usage, knowledge of antibiotics and resistant, and perceptions of antibiotic resistance. The study was an online survey and a semi-structured web-based questionnaire was used for data collection. The questionnaire had 31 sections consisting of 60 items in total. To ensure content validity of the instrument, the initial draft of the questionnaire was reviewed by experts from each region and necessary corrections were made. The survey was conducted online with the use of Google Forms. The link to the survey was shared via Facebook groups, LinkedIn and WhatsApp. Consents of the prospective participants were sought before they participate in the survey. The participants were encouraged to take the survey at a stretch and help refer through the link provided.

Data Analysis

Data obtained were analysed using Statistical Package for Social Sciences (SPSS) version 21. Descriptive statistics (frequencies and percentages) were used to analyse the socio-demographic characteristics of the participants and the distribution. Analysis of Variance (ANOVA) was used to analyse parameters and the means were compared Pakistan and Nigeria.

Results

Socio-Demographic Characteristics

Table 1 shows the demographic characteristics of the respondents. Out of the 1000 respondents who participated in this study, 643 were from Nigeria while 357 were from Pakistan. More than half of the respondents were female (52.6%), 94% attained tertiary level of education while more than 67% were either civil servant or student.

Incidence and frequency of antibiotic usage

Figure 1 and 2 show the incidence and frequency of antibiotic usage in the last 12 months among the respondents. More than two-third (82.2%) of the respondents have used antibiotics in the last 12 months most of who used it 2-5 times (56.1%) during this period.

Knowledge of antibiotics and antibiotic resistance

Table 2 shows the knowledge of antibiotics and antibiotic resistance. More than 70% of the respondents were aware of the fact that antibiotics often have some side effects, 83.6% know that bacteria can become resistant to antibiotics, and 80% of them also know that the more we use antibiotics, the higher the risk of developing resistance. On the other hand, less than half of the respondents (37.6%) were aware that antibiotic resistance can spread from animals to humans. Also, only 38.6% know that antibiotic resistance can spread from person to person while just (35.4%) were aware that travelling from one location to another can bring about resistance to antibiotics.

Table 1: Socio-demographic characteristics of the participants

		Nigeria		Pakistan		
		N	%	N	%	N (%)
Total sample size (N=1000)		643	64.3	357	35.7	
Age group	Below 20	31	4.8	18	5.0	49(4.9)
	21-30	307	47.8	179	50.1	486(48.6)
	31-40	227	35.3	128	35.9	355(35.5)
	41-50	62	9.6	27	7.6	89(8.9)
	Above 50	16	2.5	5	1.4	21(2.1)
	Total	643	100.0	357	100.0	1000(100.0)
Gender	Male	284	44.2	184	51.5	468(46.8)
	Female	357	55.5	169	47.4	526(52.6)
	Prefer not to say	2	0.3	4	1.1	6(0.6)
	Total	643	100.0	357	100.0	1000(100.0)
Level of education	Primary	3	0.5	2	0.5	5(0.5)
	Secondary	38	5.9	17	4.8	55(5.5)
	Tertiary	602	93.6	338	94.7	940(94.0)
	Total	643	100.0	357	100.0	1000(100.0)
Occupation	Student	226	35.1	128	35.9	354
	Civil servant	203	31.6	116	32.5	319
	Medical and health personnel	76	11.8	38	10.6	114
	Trader	31	4.8	16	4.5	47
	Artisan	23	3.6	10	2.8	33
	Others	84	13.1	49	13.7	133
	Total	643	100.0	357	100.0	1000(100.0)

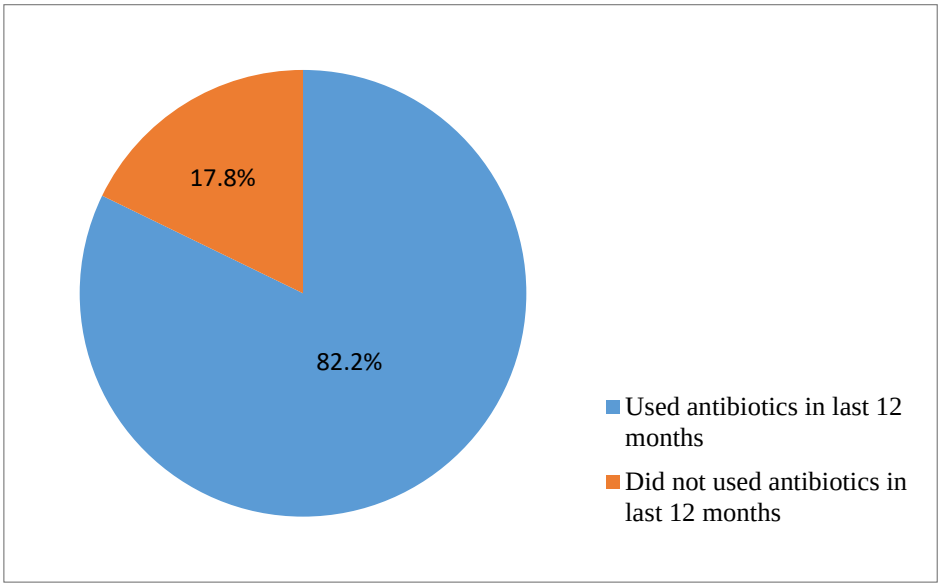

Figure 1: Incidence of antibiotic usage in the last 12 months

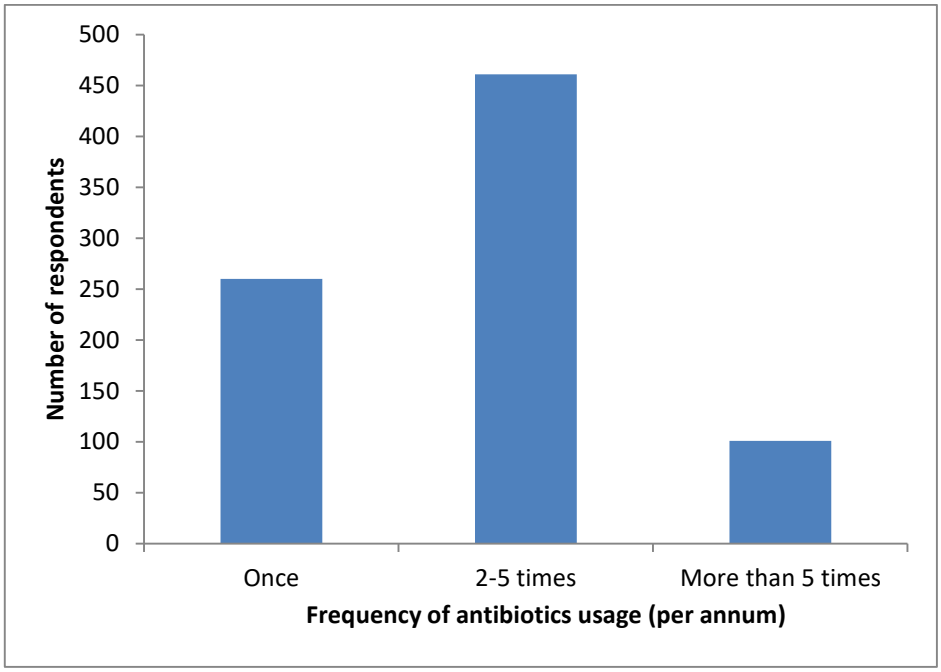

Figure 2: Frequency of antibiotic usage in the last 12 months

Table 2: Knowledge of antibiotics and antibiotic resistance

		Nigeria		Pakistan		
		N	%	N	%	N (%)
Total sample size (N=1000)		643	64.3	357	35.7	
Antibiotics often cause side effects	True	427	66.4	289	81.0	716(71.6)
	False	106	16.5	14	3.9	120(12.0)
	I don't know	110	17.1	54	15.1	164(16.4)
	Total	643	100.0	357	100.0	1000(100.0)
Antibiotics remove the body's normal flora	True	307	47.7	219	61.3	526(52.6)
	False	133	20.7	35	9.8	168(16.8)
	I don't know	203	31.6	103	28.9	306(30.6)
	Total	643	100.0	357	100.0	1000(100.0)
Once one begins to feel better, one can stop antibiotics therapy	True	187	29.1	157	44.0	344(34.4)
	False	426	66.3	170	47.6	596(59.6)
	I don't know	30	4.6	30	8.4	60(6.0)
	Total	643	100.0	357	100.0	1000(100.0)
Bacteria can become resistant to antibiotics	True	539	83.8	297	83.2	836(83.6)
	False	60	9.3	8	2.2	68(6.8)
	I don't know	44	6.9	52	14.6	96(9.6)
	Total	643	100.0	357	100.0	1000(100.0)
The more we use antibiotics, the higher the risk of developing resistance	True	510	79.3	290	81.2	800(80.0)
	False	73	11.4	22	6.2	95(9.5)
	I don't know	60	9.3	45	12.6	105(10.5)
	Total	643	100.0	357	100.0	1000(100.0)
People can become resistant to antibiotics	True	532	82.8	276	77.3	808(80.8)
	False	58	9.0	32	9.0	90(9.0)
	I don't know	53	8.2	49	13.7	102(10.2)
	Total	643	100.0	357	100.0	1000(100.0)
Resistance can spread from animals to humans	True	232	36.1	144	40.3	376(37.6)
	False	204	31.7	87	24.4	291(29.1)
	I don't know	207	32.2	126	35.3	333(33.3)
	Total	643	100.0	357	100.0	1000(100.0)
Resistance can spread from person to person	True	233	36.2	153	42.8	386(38.6)
	False	260	40.4	112	31.4	372(37.2)
	I don't know	150	23.3	92	25.8	242(24.2)
	Total	643	100.0	357	100.0	1000(100.0)
Travelling from one location to another can bring about resistance to antibiotics	True	212	33.0	142	39.8	354(35.4)
	False	261	40.6	106	29.7	367(36.7)
	I don't know	170	26.4	109	30.5	279(27.9)
	Total	643	100.0	357	100.0	1000(100.0)

Misconceptions on the use and abuse of antibiotics

Table 3 shows the misconceptions on the use and abuse of antibiotics. More than 65% of the respondents agreed that antibiotics can make one recover quickly when having cough and catarrh. Also,

more than 80% also agreed that the body can fight off mild infections without necessarily using antibiotics. In contrast, more than half (60.5%) of the respondents disagreed that left over antibiotics can be saved up for future use while 88.8% also disagreed on the acquisition of antibiotics without doctor's prescription. Similarly, 93.4% believed that it is good to conduct necessary tests before using antibiotics.

General attitude on acquisition, use and hygienic practices to reduce antibiotics resistance

Table 4 shows the general attitude of respondents on acquisition, use and hygienic practices to reduce antibiotics resistance. Majority of the respondents (68.4%) confirmed that they often wait and see if an infection will clear off on its own whenever they get an infection. Also, 89.1% of the respondents usually practice hand sanitation to prevent the spread of common infections while 77.3% always use doctor's prescription to purchase antibiotics from pharmacy. However, only 28.3% of them attested that pharmacies in their various locations only sell antibiotics with doctor's prescription.

Perception on doctors and Health professionals in antibiotics use and resistance

Table 5 shows the perception on doctors and Health professionals in antibiotics use and resistance. More than three-quarter of the respondents (78.4%) were of the opinion that doctors should always conduct a thorough examination on patient before administering antibiotics; 79.2% also agreed that doctors should take time in providing information on risks in the use of antibiotics to patients; while 77.1% agreed that pharmacists should take time to inform patients on how to use antibiotics purchased.

Table 3: Misconceptions on the use and abuse of antibiotics

Total sample size (N=1000)		Nigeria N=643		Pakistan N=357		Total
		N	%	N	%	N (%)
Amoxicillin, Ciprofloxacin and Streptomycin are antibiotics	Agree	604	93.9	286	80.1	890(89.0)
	Disagree	3	0.5	6	1.7	9(0.9)
	I don't know	36	5.6	65	18.2	101(10.1)
	Total	643	100.0	357	100.0	1000(100.0)
Antibiotics can make one recover quickly when having cough and catarrh	Agree	408	63.5	250	70.0	658(65.8)
	Disagree	168	26.1	66	18.5	234(23.4)
	I don't know	67	10.4	41	11.5	108(10.8)
	Total	643	100.0	357	100.0	1000(100.0)
The body can fight off mild infections without necessarily using antibiotics	Agree	534	83.2	297	83.2	831(83.1)
	Disagree	84	13.1	32	9.0	116(11.6)
	I don't know	24	3.7	28	7.8	53(5.3)
	Total	643	100.0	357	100.0	1000(100.0)
Left over antibiotics can be saved up for future use	Agree	233	36.2	154	43.2	387(38.7)
	Disagree	405	63.0	200	56.0	605(60.5)
	I don't know	5	0.8	3	0.8	8(0.8)
	Total	643	100.0	357	100.0	1000(100.0)
It is okay to acquire antibiotics without doctor's prescription	Agree	59	9.2	47	13.2	106(10.6)
	Disagree	580	90.2	308	86.3	888(88.8)
	I don't know	4	0.6	2	0.5	6(0.6)
	Total	643	100.0	357	100.0	1000(100.0)
It is good to conduct necessary tests before using antibiotics	Agree	614	95.5	320	89.7	934(93.4)
	Disagree	20	3.1	34	9.5	54(5.4)
	I don't know	9	1.4	3	0.8	12(1.2)
	Total	643	100.0	357	100.0	1000(100.0)

Table 4: General attitude of respondents on acquisition, use and hygienic practices to reduce antibiotics resistance

Total sample size (N=1000)		Nigeria N=643		Pakistan N=357		Total
		N	%	N	%	N (%)
If I get an infection, I often wait and see if it will clear off on its own	Yes	391	60.8	293	82.1	684(68.4)
	No	249	38.7	60	16.8	309(30.9)
	May be	3	0.5	4	1.1	7(0.7)
	Total	643	100.0	357	100.0	1000(100.0)
I usually practice hand sanitation to prevent the spread of common infections	Yes	578	89.9	313	87.7	891(89.1)
	No	63	9.8	42	11.8	105(10.5)
	May be	2	0.3	2	0.5	4(0.4)
	Total	643	100.0	357	100.0	1000(100.0)
I always use doctor's prescription to purchase antibiotics from pharmacy	Yes	505	78.5	268	75.1	773(77.3)
	No	133	20.7	86	24.1	219(21.9)
	May be	5	0.8	3	0.8	8(0.8)
	Total	643	100.0	357	100.0	1000(100.0)
Pharmacies in my location only sell antibiotics with prescription	Yes	174	27.1	109	30.5	283(28.3)
	No	332	51.6	173	48.5	505(50.5)
	May be	137	21.3	75	21.0	212(21.2)
	Total	643	100.0	357	100.0	1000(100.0)

Table 5: Perception on doctors and health professionals in antibiotics use and resistance

Total sample size (N=1000)		Nigeria N=643		Pakistan N=357		Total
		N	%	N	%	N (%)
Doctors should always conduct a thorough examination on patient before administering antibiotics	Strongly agree	417	64.8	190	53.2	607(60.7)
	Agree	112	17.4	65	18.2	177(17.7)
	Neutral	19	3.0	43	12.1	62(6.2)
	Disagree	25	3.9	36	10.1	61(6.1)
	Strongly disagree	70	10.9	23	6.4	93(9.3)
	Total	643	100.0	357	100.0	1000(100.0)
Doctors should take time in providing information on risks in the use of antibiotics to patients	Strongly agree	332	51.6	105	29.4	437(43.7)
	Agree	202	31.4	153	42.9	355(35.5)
	Neutral	27	4.2	29	8.1	56(5.6)
	Disagree	2	0.3	22	6.2	24(2.4)
	Strongly disagree	80	12.5	48	13.4	128(12.8)
	Total	643	100.0	357	100.0	1000(100.0)
Pharmacists should take time to inform me on how to use antibiotics purchased	Strongly agree	356	55.4	108	30.2	464(46.4)
	Agree	191	29.7	116	32.5	307(30.7)
	Neutral	19	3.0	67	18.8	86(8.6)
	Disagree	6	0.9	22	6.2	28(2.8)
	Strongly disagree	71	11.0	44	12.3	115(11.5)
	Total	643	100.0	357	100.0	1000(100.0)

Discussion

Microbial infections have been a nightmare for healthcare system since centuries and we have been able to control them with a promising success, thanks to multiple range of antibiotics. However, we are already at the verge of disaster with the same candidates (i.e. antibiotics resistance). The global burden of antibiotic resistance is of extreme concern. The World Health Organization terms antimicrobial resistance (AMR) as the endurance of multiple microorganisms to antimicrobials that were formerly operational as an antidote to infections. The advent of AMR is a modern-day social problem and a universal priority for health policy [18]. It is a matter for immediate discussion for healthcare regulatory authorities. Healthcare professionals are battling to cope with this emerging challenge [19]. It is a fact that a well-organized use of medication is always the best way to handle any disease particularly the ones having high risk of resistance and modulations [20]. Irrational use of antibiotics completely led to AMR with increasing fatalities annually. This has generated a heavy burden on already struggling economies like Nigeria and Pakistan [21-23]. AMR is a leading cause of death around the world with the highest burdens in low-income countries. This is often attended to unprofessionally [24-26].

The data presented in the present study depicts the current situation of healthcare system in Nigeria and Pakistan. It is unfortunate that even in this modern era, these countries still fall short of proper execution of health and safety protocols. It is imperative not to disregard the statistics that high percentage of survey respondents are well educated and aware of basic knowledge but when we link the abuse of antibiotics to literacy levels in highly populated countries like Pakistan and Nigeria, we easily understand how AMR is grounded in these countries [27]. Furthermore, age is undeniably a critical aspect considering health as it impacts the body's capability to defend or withstand possible infections. At adolescence, immune system is strong with infections possibilities generally lower. It has also been reported that elderly and kids' population is more susceptible to infections and can contribute more to AMR particularly when mistreated [28-30]. It could be linked with their lack of knowledge about antibiotics abuse, compromised/ immature immunity and non-cooperative behavior. Healthcare practitioners are crucial part of any society and unprofessional practices from them is disastrous to the overall health and wellbeing of population [31-32]. Doctors prescribing stacks of antibiotics without proper microbial analysis of infections worsen this global menace. In addition, Pharmacies selling antibiotics without prescriptions are also to be blamed. Thus, health regulatory authorities along with community heads should ensure honest use of antibiotics together with strict directives by law enforcement agencies. Doctors and pharmacists should insist and remind patients firmly to complete their antibiotics course. It is indeed saddening categorizing antibiotics abuse as a global challenge. Antibiotics has really saved a lot of lives in the last century [33].

Conclusion

The study showed that antibiotics abuse is still a menace ravaging our society. Thus, health regulatory authorities along with community heads should ensure honest use of antibiotics together with strict directives by law enforcement agencies. Therefore, we insist on taking strict and consistent measures to curb this menace. We also suggest a well-planned sensitization on AMR to the public through electronic, social and print media. This may eventually decrease AMR burden in the countries studied in this research.

References

[1] Chukwu EE, Oladele DA, Awoderu OB, Afocha EE, Lawal RG, Abdus-salam I, Ogunsola FT, Audu RA. A national survey of public awareness of antimicrobial resistance in Nigeria. Antimicrobial Resistance & Infection Control. 2020; 9(1):72. https://doi.org/10.1186/s13756-020-00739-0

[2] Chukwu EE, Oladele DA, Awoderu OB, Afocha EE, Lawal RG, Abdus-salam I, Ogunsola FT, Audu RA. A national survey of public awareness of antimicrobial resistance in Nigeria. Antimicrobial Resistance & Infection Control. 2020;9(1):72. Available from: https://doi.org/10.1186/s13756-020-00739-0

[3] Davey P, Marwick CA, Scott CL, Charani E, McNeil K, Brown E, Gould IM, Ramsay CR, Michie S. Interventions to improve antibiotic prescribing practices for hospital inpatients. Cochrane Database Syst Rev. 2017 Feb 9;2(2):Cd003543. Available from: https://doi.org/10.1002/14651858.CD003543.pub4.

[4] Langdridge D, Davis M, Gozdzielewska L, McParland J, Williams L, Young M, Smith F, MacDonald J, Price L, Flowers P. A visual affective analysis of mass media interventions to

increase antimicrobial stewardship amongst the public. Br J Health Psychol. 2019;24(1):66-87. Available from: https://doi.org/10.1111/bjhp.12339.

[5] Price L, Gozdzielewska L, Young M, Smith F, MacDonald J, McParland J, Williams L, Langdridge D, Davis M, Flowers P. Effectiveness of interventions to improve the public's antimicrobial resistance awareness and behaviours associated with prudent use of antimicrobials: a systematic review. J Antimicrob Chemother. 2018;73(6):1464-1478. doi:10.1093/jac/dky076.

[6] Shallcross LJ, Davies DS. Antibiotic overuse: a key driver of antimicrobial resistance. Br J Gen Pract. 2014;64(629):604-605. doi:10.3399/bjgp14X682561.

[7] Waseem H, Ali J, Sarwar F, Khan A, Rehman HSU, Choudri M, Arif N, Subhan M, Saleem AR, Jamal A, Ali MI. Assessment of knowledge and attitude trends towards antimicrobial resistance (AMR) among the community members, pharmacists/pharmacy owners and physicians in district Sialkot, Pakistan. Antimicrobial Resistance & Infection Control. 2019;8(1):67. doi:10.1186/s13756-019-0517-3.

[8] Aika, I. N., & Enato, E. (2022). Health care systems administrators' perspectives on antimicrobial stewardship and infection prevention and control programs across three healthcare levels: a qualitative study. Antimicrobial Resistance & Infection Control, 11(1), 157. https://doi.org/10.1186/s13756-022-01196-7

[9] Nagel, J. L., Stevenson, J. G., Eiland, E. H., 3rd, & Kaye, K. S. (2014). Demonstrating the value of antimicrobial stewardship programs to hospital administrators. Clin Infect Dis, 59 Suppl 3, S146-153. https://doi.org/10.1093/cid/ciu566

[10] Klein, E. Y., Van Boeckel, T. P., Martinez, E. M., Pant, S., Gandra, S., Levin, S. A., Goossens, H., & Laxminarayan, R. (2018). Global increase and geographic convergence in antibiotic consumption between 2000 and 2015. Proc Natl Acad Sci U S A, 115(15), E3463-e3470. https://doi.org/10.1073/pnas.1717295115

[11] Laxminarayan, R., Matsoso, P., Pant, S., Brower, C., Røttingen, J. A., Klugman, K., & Davies, S. (2016). Access to effective antimicrobials: a worldwide challenge. Lancet, 387(10014), 168-175. https://doi.org/10.1016/s0140-6736(15)00474-2

[12] Murray CJ, K. S., Sharara F, Lucien S, Aguilar R, Gray A. (2022). Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. Lancet, 399(10325), 629-655. https://doi.org/10.1016/s0140-6736(21)02724-0

[13] Ghebremedhin, B., Olugbosi, M. O., Raji, A. M., Layer, F., Bakare, R. A., König, B., & König, W. (2009). Emergence of a community-associated methicillin-resistant Staphylococcus aureus strain with a unique resistance profile in Southwest Nigeria. J Clin Microbiol, 47(9), 2975-2980. https://doi.org/10.1128/jcm.00648-09

[14] Lamikanra, A., Crowe, J. L., Lijek, R. S., Odetoyin, B. W., Wain, J., Aboderin, A. O., & Okeke, I. N. (2011). Rapid evolution of fluoroquinolone-resistant Escherichia coli in Nigeria is temporally associated with fluoroquinolone use. BMC Infect Dis, 11, 312. https://doi.org/10.1186/1471-2334-11-312

[15] Okesola, A., & Oni, A. (2009). Antimicrobial resistance among common bacterial pathogens in South Western Nigeria. American-Eurasian Journal of Agricultural and Environmental Science, 5(3), 327-330.

[16] Auta A, Banwat SB, David S, Dangiwa DA, Ogbole E, Tor-anyiin AJ. Antibiotic use in some Nigerian communities: knowledge and attitudes of consumers. Trop J Pharm Res. 2013;12(6):1087-1092. https://doi.org/10.4314/tjpr.v12i6.33

[17] Igbeneghu OA. Knowledge and practices in the use of antibiotics among a group of Nigerian university students. Int J Infect Control. 2013;9(1). https://doi.org/10.3396/ijic.v9i1.10539

[18] Glasdam S, Loodin H, Wrigstad J. Articulations of antimicrobial resistance in trade union financed journals for nurses in Scandinavia–A Foucauldian perspective. Nurs Inquiry. 2021;28(3):e12396.

[19] Gröndal H. Harmless, friendly and lethal: antibiotic misuse in relation to the unpredictable bacterium Group A streptococcus. Sociol Health Illn. 2018;40(7):1127-1141.

[20] Olaniyan JO, Ghaleb M, Dhillon S, Robinson P. Safety of medication use in primary care. Int J Pharm Pract. 2015;23(1):3-20.

[21] Ventola CL. The antibiotic resistance crisis: part 1: causes and threats. Pharm Therapeutics. 2015;40(4):277.

[22] Larsson DJ, Flach CF. Antibiotic resistance in the environment. Nat Rev Microbiol. 2022;20(5):257-269.

[23] Sabtu N, Enoch DA, Brown NM. Antibiotic resistance: what, why, where, when and how? Br Med Bull. 2015;116(1).

[24] Bush K, Courvalin P, Dantas G, Davies J, Eisenstein B, Huovinen P, Jacoby GA, Kishony R, Kreiswirth BN, Kutter E, Lerner SA. Tackling antibiotic resistance. Nat Rev Microbiol. 2011;9(12):894-896.

[25] Yelin I, Kishony R. Antibiotic resistance. Cell. 2018;172(5):1136.

[26] Frieri M, Kumar K, Boutin A. Antibiotic resistance. J Infect Public Health. 2017;10(4):369-378.

[27] Grace D. Review of evidence on antimicrobial resistance and animal agriculture in developing countries.

[28] Beckett CL, Harbarth S, Huttner B. Special considerations of antibiotic prescription in the geriatric population. Clin Microbiol Infect. 2015; 21(1):3-9.

[29] Ulset VS, Czajkowski NO, Kraft B, Kraft P, Wikenius E, Kleppestø TH, Bekkhus M. Are unpopular children more likely to get sick? Longitudinal links between popularity and infectious diseases in early childhood. PLoS One. 2019;14 (9):0222222.

[30] Guo H, Hildon ZJL, Lye DCB, Straughan PT, Chow A. The associations between poor antibiotic and antimicrobial resistance knowledge and inappropriate antibiotic use in the general population are modified by age. Antibiotics. 2022; 11(1):47.

[31] Haenssgen MJ, Xayavong T, Charoenboon N, Warapikuptanun P, Khine Zaw Y. The consequences of AMR education and awareness raising: outputs, outcomes, and behavioural impacts of an antibiotic-related educational activity in Lao PDR. Antibiotics. 2018;7(4):95.

[32] Ghiga I, Pitchforth E, Stålsby Lundborg C, Machowska A. Family doctors' roles and perceptions on antibiotic consumption and antibiotic resistance in Romania: a qualitative study. BMC Primary Care. 2023;24(1):1-15.

[33] Pruden A. Antimicrobial Resistance in the Environment: Informing Policy and Practice to Prevent the Spread. Environmental Science & Technology. 2022;56(21):14869-14870.

Fig (*Ficus carica*) Valorization via ABE Fermentation into Organic Acids and Solvents

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Abstract

The concern on the adverse environmental effects of global warming and fossil fuel challenged human intellect to find renewable, sustainable and environmentally friendly fuel substitutes. This was fully supported by governmental and non-governmental organizations across the globe. The fig (*Ficus carica*) is an edible Mediterranean fruit that is abundantly cultivated in Turkiye. Waste figs are carcinogenic and toxigenic. Thus, it's a good option to converting it into value added products. The main objective of this research is to study the effects of cations (Zn^{2+}, Mg^{2+} and Mn^{+}) and electron mediators (Neutral red and Methyl viologen) on the acetogenesis and solventogenesis stages of the ABE process. One factor at a time (OFAT) simple experimental design was employed in this study. Organic acids (lactic, acetic and butyric acid) and organic solvents (ethanol, acetone and butanol) are the main product of the ABE (Acetone-Butanol-Ethanol) fermentation. From the results, maximum concentrations of Lactic, acetic, butyric acid, ethanol, acetone and butanol were recorded at $MV_{15(mg/L)}$, $Mg_{400(mg/L)}$, $Mg_{400\ (mg/L)}$ $NR_{15(mg/L)}$, $Mn_{56(mg/L)}$, and $MV_{15(mg/L)}$ respectively.

Keywords: Fig, ABE fermentation, butanol, organic acids

Introduction

The major categories of biofuel with extensive research in the 21st-century categorization are biobutanol, bioethanol and biodiesel as classified by [1]. Furthermore, biofuel has enjoyed continued support and acceptance from funding organizations and the populace respectively due to its renewable nature and beneficial effects which include a reduction in fossil fuel dependence. Butanol is the only biofuel type capable of substituting the use of petrol and other fuel sources in engines. Its less corrosiveness and volatility give it good credit. These features also give biobutanol a comparative advantage over bioethanol (another fuel substitute).

The ABE (Acetone-Butanol-Ethanol) process, a two (2) stage microbial mediated fermentation process is often used for butanol production from biomass. Acetogenesis (production of organic acids majorly lactic, acetic, butyric and propionic acid) and solventogenesis (production of organic solvents acetone, butanol and ethanol) are the two steps involved in ABE fermentation [2]. Clostridia are major microbial genera involved in butanol production via the Acetone-Butanol-Ethanol (ABE) fermentation pathway [3]. Many researchers have reported the roles of cations and electron mediators in improving ABE solvents concentration. Thus, this research is aimed at studying the effects of cations (Zn^{2+}, Mg^{2+} and Mn^{+}) and electron mediators (Neutral red and Methyl viologen) on the acetogenesis and solventogenesis stages of the ABE process.

Materials and Methods

Experimental design

One factor at a time (OFAT) simple experimental design was employed in this study. The ranges and levels of Cations (Zn^{2+}, Mg^{2+} and Mn^{+}) and electron mediators (Neutral red and Methyl viologen) are found in Table 1.

Table 1. Experimental ranges for process factors

Type	Factors	Low value (-1)	High value (+1)
Cations (mg/L)	Mn^{+}	5.6	56
	Zn^{2+}	4.0	40
	Mg^{2+}	400	1800
Electron mediators (mM)	Neutral red	1.0	15
	Methyl viologen	1.0	15

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Substrate preparation, Experimental setup and analytical methods

Waste figs were microwave pretreated at hydrolysis conditions of substrate concentration 100g/L, particle diameter 370.72 µm, pH 4.96, microwave power 253.67 W and time 50 mins with a total sugar concentration of 82g/L obtained. Batch fermentation with 310ml capacity serum bottles were used with 3 g/L yeast extract, 10 g/L meat extract, 0.2 g/L L-cysteine, 0.025 g/L resazurin, 2 g/L $(NH_4)_2SO_4$ and fig hydrolysate fermentation media constituents. Media sterilization was done and all fermentation bottles passed under nitrogen gas. Fermentation lasted for 144 hours. *C.pasteuranium* DSM 525 was used as microbial source in this study. 40 g L^{-1} glucose, 20 g L^{-1} $CaCO_3$, 10 g L^{-1} yeast extract and 0.1 g L^{-1} L-cysteine were used as the growth media for 10% v/v *C.pasteuranium* DSM 525. pH range 7.0-7.5 was ensured throughout the study. Daily samples were carefully centrifuged at 8000 rpm before subjecting clear supernatants to total sugar concentration analysis with a UV-Vis spectrophotometer using the Dubois method [4]. Simple sugars, Total Volatile Fatty Acids and Solvents concentration were determined using HPLC [5].

Results

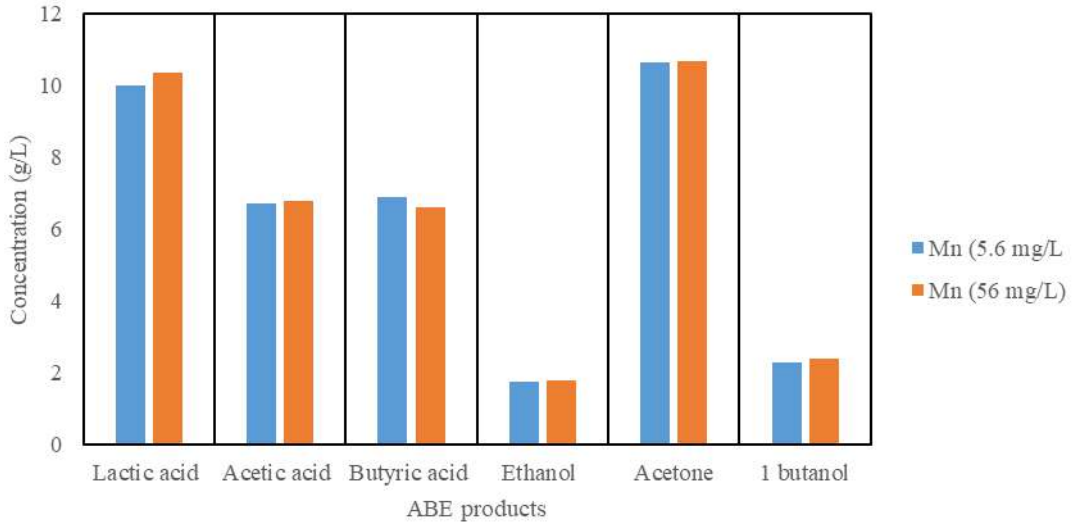

Fig.1. Effect of Manganese on ABE products

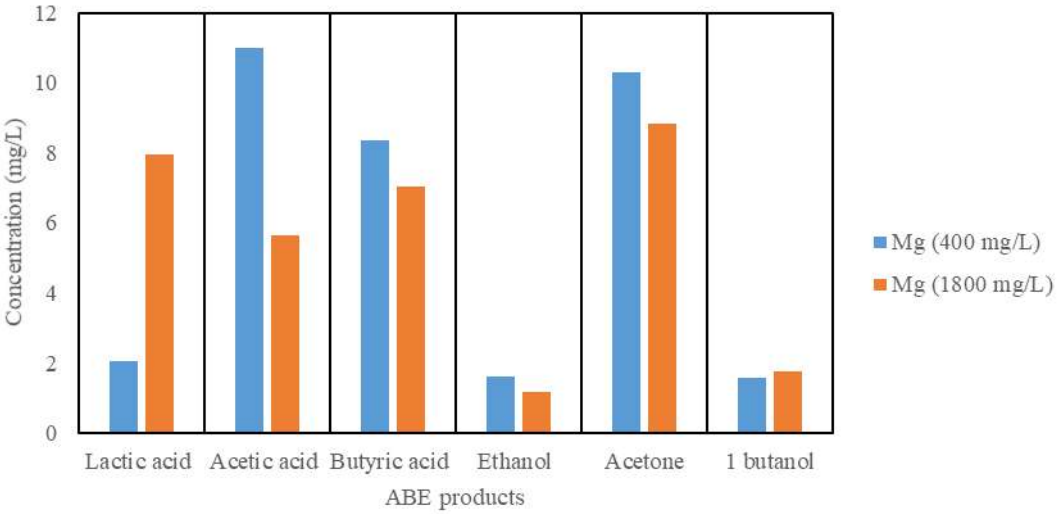

Fig.2. Effect of Magnesium on ABE products

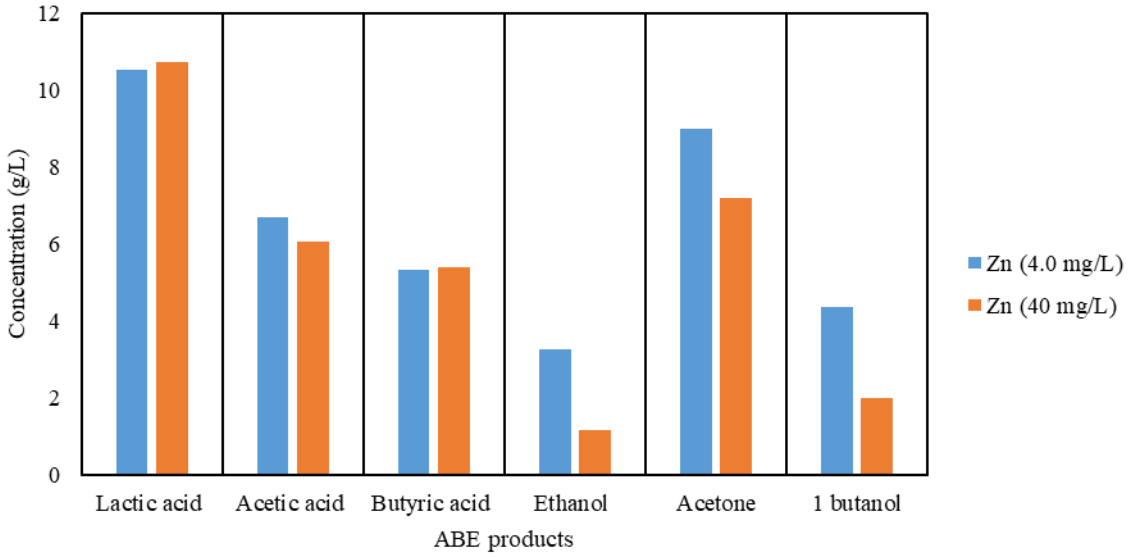

Fig.3. Effect of Zinc on ABE products

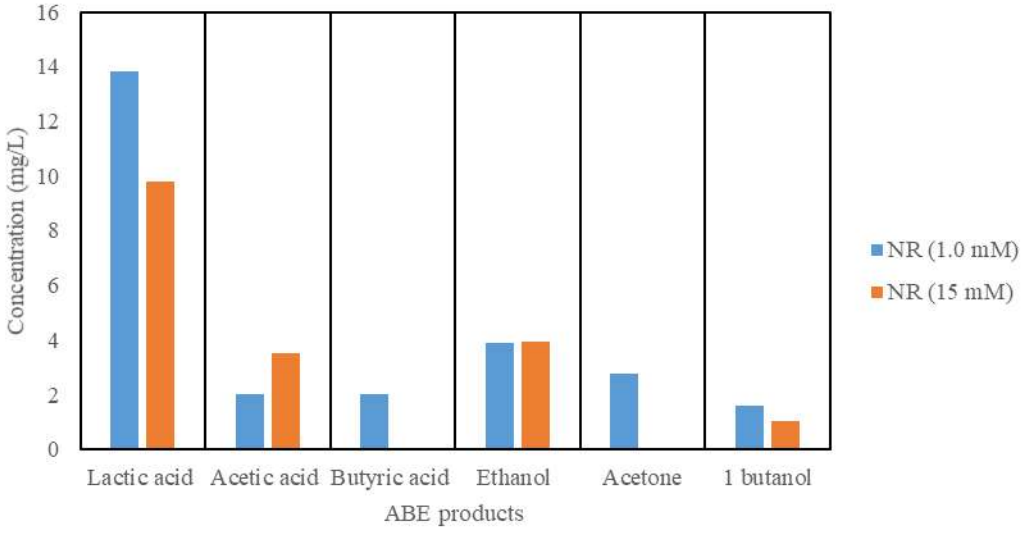

Fig.4. Effect of Neutral red on ABE products

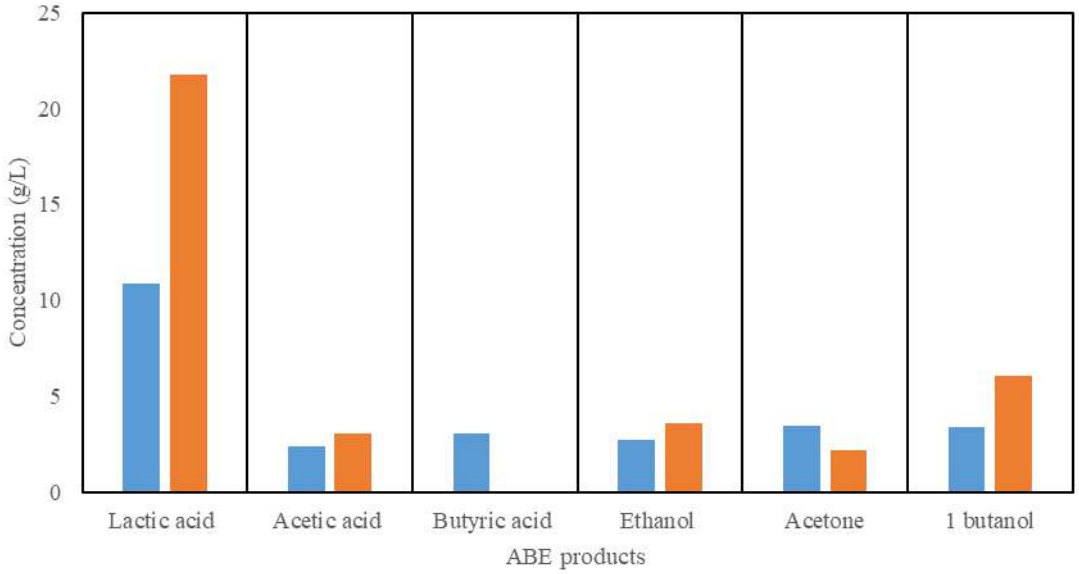

Fig.5. Effect of Methyl viologen on ABE products

Discussion

Fermentation media composition plays a vital role in the success of the ABE products and most especially in the concentration of butanol obtainable. Thus, **Figures 1-5** shows the ABE products obtained in this study for the metals and electron mediators tested. Authors like Mukherjee et al. **[6]** have reported that starvation or supplementation of cations into fermentation media supports butanol biosynthesis in clostridial strains. In addition, supplementation of either Zn^{2+} or Ca^{2+} in the control medium resulted in an improved butanol titer of 15.4 g L^{-1} and 13 g L^{-1} respectively **[6].** Furthermore, Monot et al. **[7]** reported that $MnSO_4$ presence in fermentation media does not significantly affect butanol production.

Previous studies indicated that the activity of butanol dehydrogenase (enzyme needed for butanol production) could be better recovered in vitro from the buffer containing Zn^{2+}, implying the relationship between Zn^{2+} and butanol production **[8]**. The role of cations and electron mediators directly influence microbial growth, substrate utilization and concentration of ABE fermentation products. Thus, our experimental design was aimed at checking the effects of cations (Zn^{2+}, Mg^{2+} and Mn^{+}) and electron mediators (Neutral red and Methyl viologen) at the minimum and maximum levels as shown in Table 1. No published work in recent literature exists on the comprehensive study of the effects of cations and electron mediators on ABE fermentation.

Cations majorly have cellular role in microorganisms and important for microbial growth and maintenance of structural integrity of the cell membrane. However, electron mediators acts by **i**ncreasing NADH levels and reducing hydrogenase enzymes to favor solvents production (most especially butanol)

Conclusion

This research gives an insight into the possibility of producing organic acids and solvents simultaneously via the ABE fermentation with Fig (*Ficus carica*) and *C.pasteuranium* DSM 525 as fermentation biomass and inoculum respectively. Furthermore, 120 hour of fermentation is recommended for product maximum. Beyond this time butanol concentration starts to diminish. From this study, highest concentrations of Lactic, acetic, butyric acid, ethanol, acetone and butanol were recorded at $MV_{15(mg/L),}$ $Mg_{400(mg/L)}$, $Mg_{400\ (mg/L)}$ $NR_{15(mg/L),}$ $Mn_{56(mg/L),}$ and $MV_{15(mg/L)}$ respectively.

References

[1] Jáchym, M, Jaroslav, K, Martin, H. Transition metals promoting Mg-Al mixed oxides for conversion of ethanol to butanol and other valuable products: Reaction pathways. Applied Catalysis A: General. 2021; 626. doi.org/10.1016/j.apcata.2021.118380.

[2] Siqueira, MR, Perrone, OM, Metzker, G, Lisboa, DCD, Thomeo, JC, Boscolo, M. Mol. Catal. 2019; 476.

[3] Moon, HG, Jang, HG, Cho, C, Lee, C, Binkley, R, Lee, SY. One hundred years of clostridial butanol fermentation, FEMS Microbiol. Lett. 2016; 363 fnw001.

[4] Dubois, M, Gilles, KA, Hamilton, JK, Rebers, PAT, Smith F. Colorimetric method for determination of sugars and related substances. Analytical Chemistry. 1956; 28:350-356.

[5] Tosuner, ZV, Taylan, GG, Ozmihci, S. Effects of rice husk particle size on biohydrogen production under solid state fermentation. International Journal of Hydrogen Energy. 2019; 44:18785-18791

[6] Mukherjee, M, Sarkar, P, Goswami, G, Das, D. Regulation of butanol biosynthesis in Clostridium acetobutylicum ATCC 824 under the influence of zinc supplementation and magnesium starvation. Enzyme and Microbial Technology. 2019; 129: 109352. doi:10.1016/j.enzmictec.2019.05.009

[7] Monot, F, Martin, JR, Petitdemange, H, Gay, R. Acetone and butanol production by Clostridium acetobutylicum in a synthetic medium, Applied Environmental Microbiology. 1982; 44: 1318–1324.

[8] Walter, KA, Bennett, G, Papoutsakis, ET. Molecular characterization of two Clostridium acetobutylicum ATCC 824 butanol dehydrogenase isozyme genes. Journal of Bacteriology. 1992; 174: 7149–7158.

Plasticity Based Nonlinear Finite Element Analysis of Steel Fiber Reinforced Concrete Beams

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Abstract

In this study, a blind simulation was carried out to predict the response of full-scale steel fiber-reinforced concrete beams (SFRC) subjected to four-point bending. For this purpose, an experimental study was selected from the literature. Bending tests of two beam specimens with prismatic geometry of 300x500x4400 and 150x250x2000 mm were simulated using the non-linear finite element (NLFE) code ABAQUS/Explicit [1]. In the full-scale numerical models, concrete, and steel rebars were discretized in space by eight-node reduced integration linear brick elements (C3D8R) and linear beam elements (B31), respectively. Additionally, concrete damage plasticity (CDP) constitutive model was adopted for concrete and the stress-strain relationship of steel reinforcements was established based on the piecewise functions given in Turkish Building Earthquake Code (TBEC) 2018 [2]. The embedded element technique was used to establish a perfect bond between concrete brick elements and steel reinforcement beam elements. Therefore, concrete elements were selected to be host elements while steel reinforcement was embedded in the host material. Support conditions and loading plates were explicitly modeled using eight-node brick element (C3D8R) as rectangular prisms. The interaction between the plates and beam specimen was provided by tie constraint. Results from the numerical analyses included load-displacement curve and crack pattern variables which are considered to verify the experimental results.

Keywords: Non-linear finite element analysis, bending behavior of fibrous reinforced concrete beams

1. Introduction

In the last 50 years, fibers, specifically steel fibers, have been used in various non-structural members such as industrial floor slabs and concrete pavements as reinforcing elements with a discrete and discontinued property [3]. Up until today, researchers have conducted numerous experimental studies [4], [5], [6], [7] to understand the behavior of reinforced concrete members having fibers.

Instead of performing time-consuming and expensive tests, numerical methods are alternative tools to predict the response of reinforced concrete (RC) members having fibers. The current study aims to investigate the accuracy, sensitivity, and reliability of the plasticity-based NLFE method in representing member behavior. For this purpose, an experimental study was selected from the literature [8]. The study investigated the pure flexural behavior of plain and fibrous reinforced concrete beams under four-point bending. Two of the RC beams w/steel fibers were used to be numerically modeled through three-dimensional ABAQUS software to perform verification work by comparing the numerically and experimentally obtained load-deflection response, cracking pattern, and failure mode of the members.

2. Selected Experimental Study

In the selected study [8], four-point bending tests of five simply supported RC beams were performed. Two of the beams had plain concrete with stirrups while the rest had fibrous concrete without stirrups. Three different sizes of beams were manufactured to evaluate the size effect. The dimensions of utilized beams in the numerical analysis are summarized in Table 1 and denoted by “S” and “L” letters referring to small and large beam sizes, respectively. Moreover, the symbol “SF” stands for concrete w/fiber. In the experimental study, the reinforcement ratios were selected between 0.64% and 0.72%. The mechanical and physical properties of rebars are summarized in Table 2. No shear reinforcement was used in the beams w/fibers to investigate the contribution of hooked-end steel fibers to the shear strength. The compressive strength of fibrous concrete was 72 MPa. The hooked-end steel fibers have a diameter of 0.55 mm and a length of 35 mm. The volume fraction of steel fiber was 0.75% for all SFRC beams. The mechanical properties of steel fibers can be found in [8]. The volume fraction

of steel fiber was selected based on the recommendations of [9]. All beams were investigated under four-point flexural load using a universal testing machine (UTM) with a maximum capacity of 2000 kN and applied monotonically through displacement control. The results including the load-displacement, failure modes, and crack patterns are used to validate the numerical model.

Table 1: Dimensions of the selected specimens

	Length (mm)	Clear Span (mm)	Height (mm)	Width (mm)	Effective Depth (mm)
S-SF	2000	1700	250	150	53
L-SF	4400	3700	500	300	58

Table 2: The details and properties of steel reinforcement

	D#	Reinforcement ratio ρ (%)	A_s (mm^2)	f_y (MPa)	E_s (GPa)	ε_y	ε_u
S-SF	D10	0.72	71.3	491	200	0.0025	0.20
L-SF	D19	0.65	286.5	473	200	0.0024	0.19

3. Numerical Method

Four-point bending simulations were conducted by ABAQUS software which is capable of performing nonlinear finite element analysis by use of explicit time integration method. Full-scale models of the specimens were created, Figure 1, and fibrous concrete material was discretized in space using eight-node reduced integration linear brick elements (C3D8R) while linear beam elements were used for steel rebars. The embedded element technique was used to establish a perfect bond between concrete brick elements and steel reinforcement beam elements. For this purpose, concrete elements were selected to be host elements while steel reinforcement was embedded in the host material. Support conditions and loading plates were explicitly modeled using eight-node brick elements (C3D8R) as rectangular prisms with the dimension of 300x300x50 mm in length, width, and thickness, respectively, Figure 1. The interaction between the plates and the beam specimens was provided by general contact explicit with a frictional coefficient of 0.35. Mesh sensitivity analysis was also studied for both type of beams as 10-, 15-, 20-mm, and 20-, 25- and 30-mm mesh size configurations for small and large beam specimens, respectively. Considering the required solution time and sensitivity, an optimum mesh size of 15- and 25- mm were selected for the small and large beams.

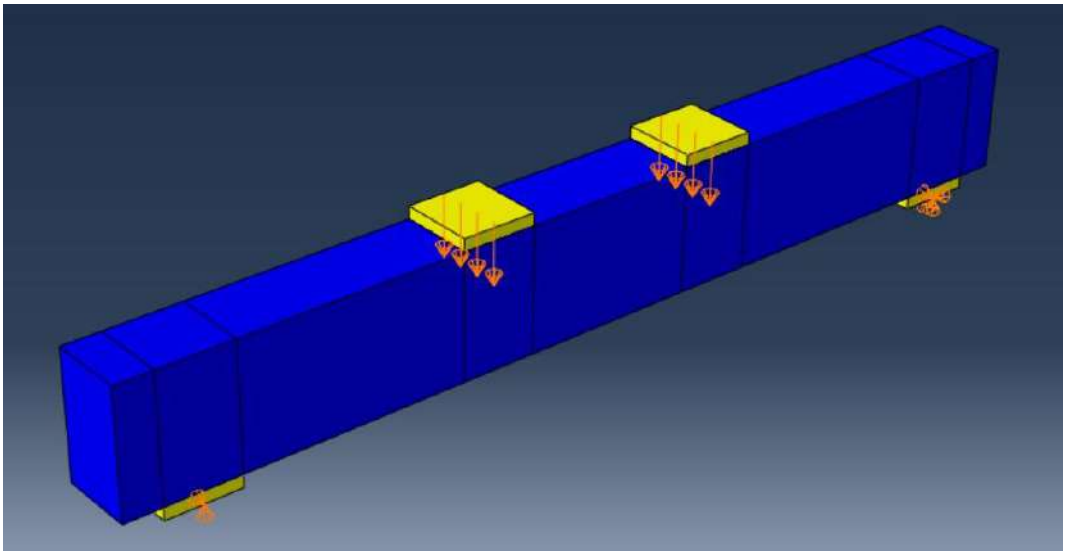


Figure 1. Numerical model of steel fiber reinforced concrete beam

3.1 Modeling of Fibrous Concrete

Fibrous concrete material was modeled using the concrete damage plasticity model (CDP). This plasticity-based model follows a non-associated plastic flow rule and employs the yield function proposed by [10] which was later revised by [11]. In the CDP model, the material behavior is controlled not only by plasticity but also by the two major failure mechanisms as tension cracking and compression crushing, Figure 2 [12].

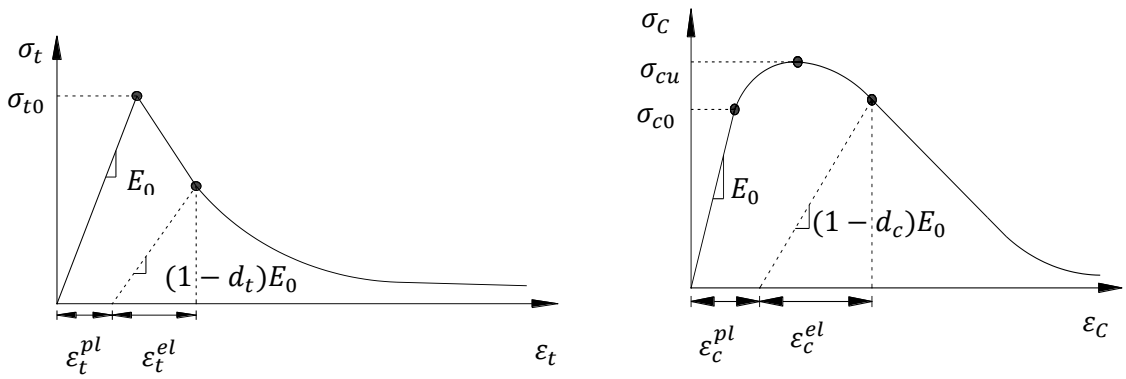


Figure 2. Tension (left) and compression (right) behavior of concrete [12]

These failure mechanisms described by strain softening branch of material and result in isotropic (scalar) stiffness degradation or damage. The degraded stiffness (E) is presented by Equation 1 in which d is the damage parameter and E_0 is the undamaged elastic stiffness. In the current study, d was defined based on the relatively simple damage model proposed by [10]. According to the model, degradation occurs only in the softening region and can be specified for tension and compression as shown in Equation (2) [10], [13]. In the Equation, f is either the tensile or compressive strength of concrete material and σ is the current stress level.

In the CDP model, the damaged states of material for both tension and compression are characterized by two hardening variables, namely as equivalent (effective) plastic strain in tension (ε_t^{pl}) and compression (ε_c^{pl}). However, the input strain is inelastic strain in ABAQUS and was calculated by Equation 3. In the equation, the compressive elastic strain was computed using Equation 4, and the compressive plastic strain was automatically converted from the user-provided stress-inelastic strain curve via Equation 5.

$$E = (1-d)E_0 \tag{1}$$

$$d = 1 - {}^{\sigma}/_{f} \tag{2}$$

$$\varepsilon_c^{in} = \varepsilon_c - \varepsilon_c^{el} \tag{3}$$

$$\varepsilon_c^{el} = \frac{\sigma_c}{E_0} \tag{4}$$

$$\varepsilon_c^{pl} = \varepsilon_c^{in} - \frac{d_c}{(1-d_c)}\frac{\sigma_c}{E_0} \tag{5}$$

The uniaxial compressive response of fibrous concrete material was taken from the available test results in the selected study [8] and converted into stress versus inelastic strain using Equation (3), Figure 3 (left). The Elastic modulus of the concrete is estimated by assuming the stress-strain curve is linear until $0.4f_c'$ value. On the other hand, the tension stiffening effect was also considered through a fracture energy-dependent model, Simplified Diverse Embedment Model (SDEM), which was proposed by Lee [14] for concrete having fibers. For this purpose, post-failure stress versus cracking displacement was calculated and illustrated in Figure 3 (right).

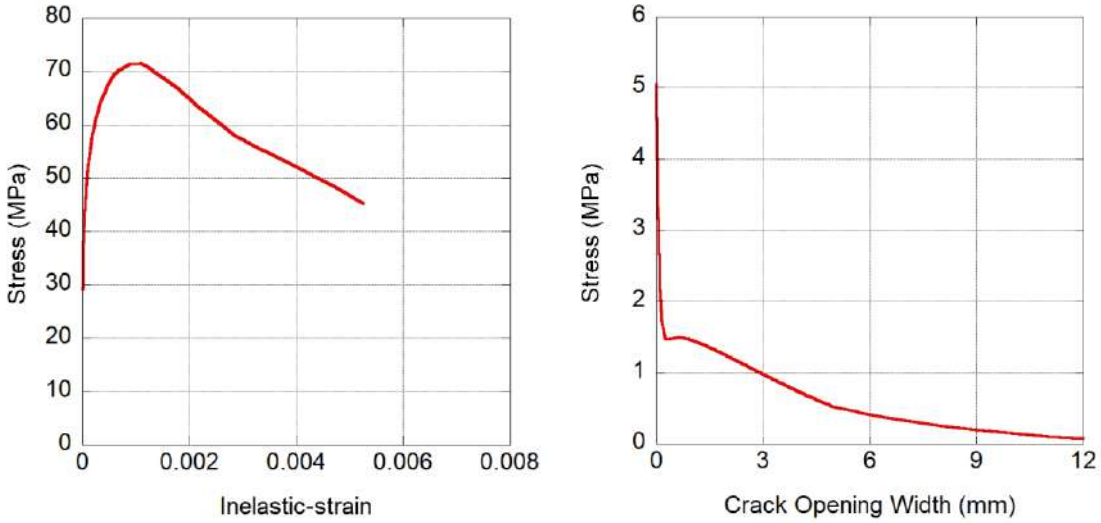


Figure 3. Compression behavior of concrete with fiber (left), tensile behavior of concrete with hooked-end fibers (right)

3.2 Modeling of Rebars

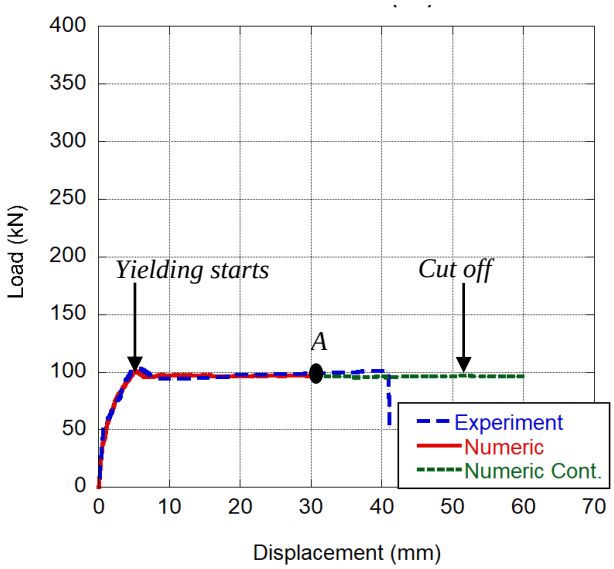
The stress-strain relationship of steel reinforcements was established based on the piecewise functions given in Turkish Building Earthquake Code (TBEC) 2018 [2] and afterwards, converted into the true stress-strain curve using Equations 6 and 7. In the Equations σ_{true} is the true stress, σ_{nom} is the engineering or nominal stress while ε_{true} is the true strain, and ε_{nom} is the engineering strain. The plastic range of material behavior was introduced to ABAQUS by subtracting the elastic strain from the overall strain.

$$\sigma_{true} = \sigma_{nom}(1 + \varepsilon_{nom}) \tag{6}$$

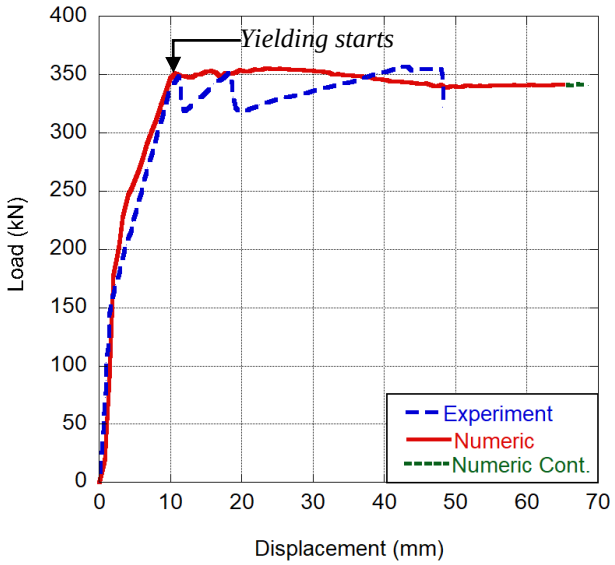
$$\varepsilon_{true} = \ln(1 + \varepsilon_{nom}) \tag{7}$$

4. Results and Discussion

Experimental and numerical load-deflection curves of the beams are presented in Figure 4. As can be seen from the Figure, small beam behavior under load could be captured precisely, including the softening behavior of fibrous concrete which ends up with a gradual decrease of flexural load carrying capacity after the peak (or yield) load is reached. However, large beam load-deflection curves exhibited partial agreement. Though the general trend of the curve fits well before yielding of tensile reinforcements, the fluctuation in the post-yield region due to the softening of fibrous concrete material was not observed in the numerical results.



(a) Small beam specimen



(b) Large beam specimen

Figure 4. Relationship of midspan deflection with load

Clarification of ultimate (failure) deflection is critical in determining the proper crack patterns for the numerical analysis. As a result, the analyses were terminated at a specific mid-span deflection. This was decided based on either the minimum plastic strain in the outermost concrete layer yielding to crush or the ultimate strain in rebars reaching rupture. The crushing strain of fibrous concrete was set to 0.01 as advised by ACI 544 [15] since the steel fiber additive increases the ductility of the material. Furthermore, the ultimate (or rupture) strain of rebars was taken as specified in the selected study, 0.2. In both numerical analyses, a crushing occurred at the outermost concrete layer since the specified minimum plastic strain value (0.01) was exceeded, Figure 5. Once the concrete crushed analyses were terminated. This point was marked by point "A" in Figure 4 (a) and the rest of the curve was disregarded in load-deflection curves.

The computed tension damage profiles could be compared to their experimental counterparts after determination of the numerical ultimate (failure) deflection and presented in Figure 6 and Figure 7. As can be seen from the Figures, two major flexural cracks, indicating a crack localization phenomenon, were captured in both of the analyses identical to that of the experiment. Finally, it should be noted that a rebar rupture type of failure was reported in the experimental study while the numerical analyses were terminated due to concrete crushing.

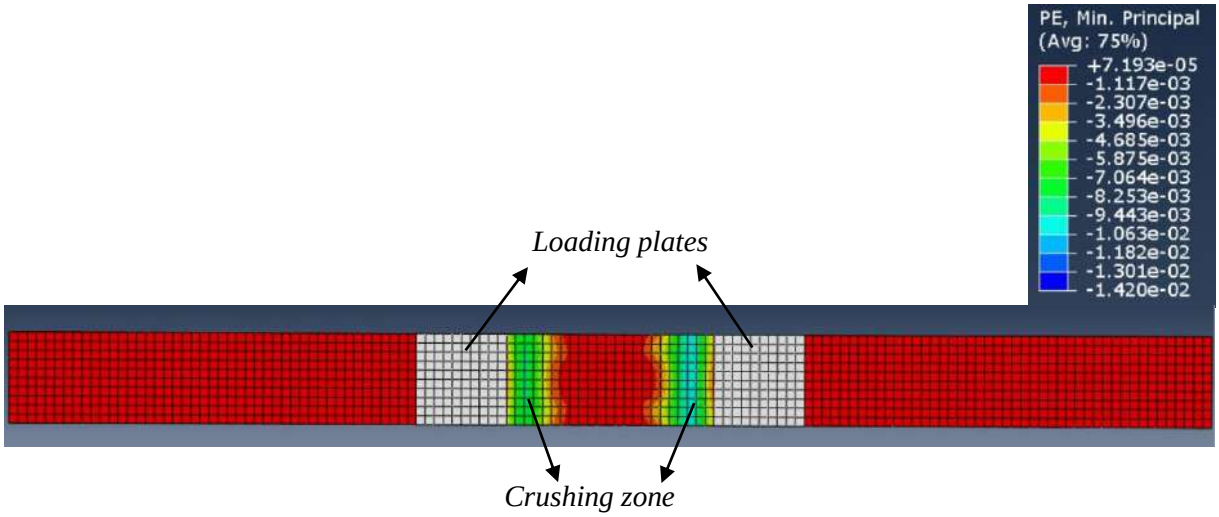


Figure 5. The top view of the small beam illustrates the concrete crushes at the outermost layer

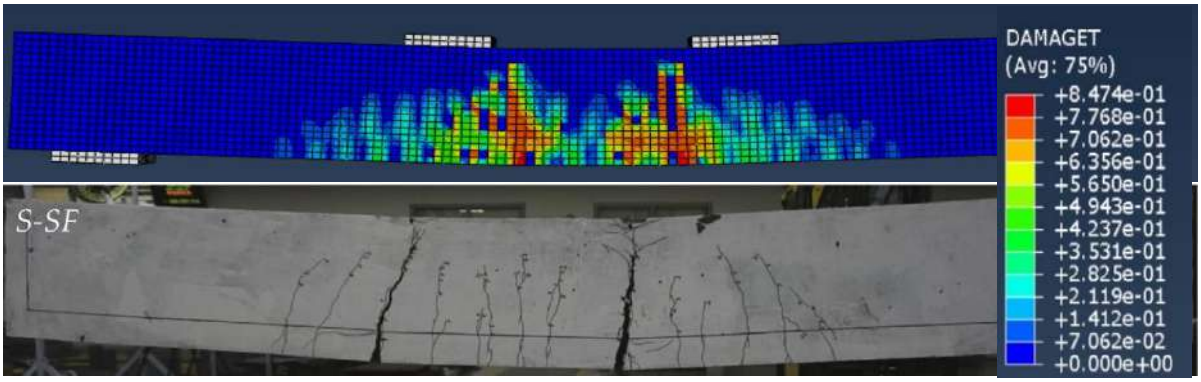


Figure 6. Cracking profile of small beam specimen

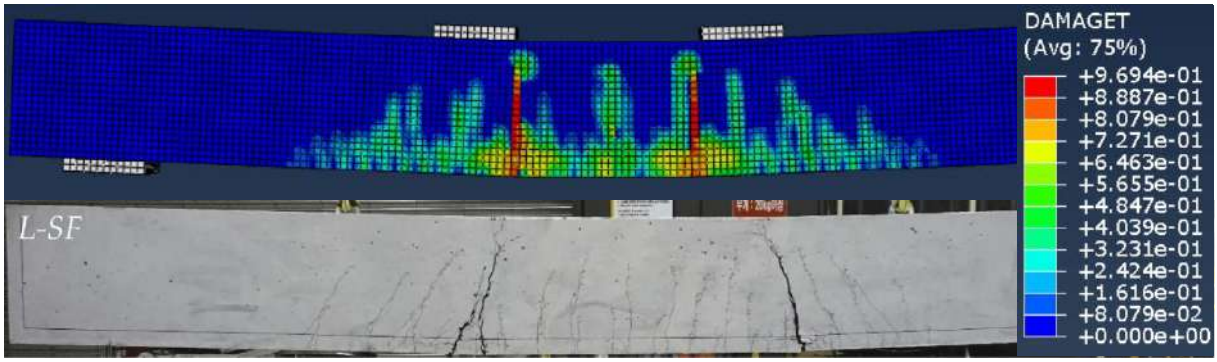


Figure 7. Cracking profile of large beam specimen

5. Conclusion

A numerical study was conducted on two RC beams having different sizes and 0.75% steel fiber content. The main objective of this research was to understand the efficiency of plasticity-based NLFE method in representing the bending behavior of fibrous RC beams.

Based on the discussions made above, the following conclusions could be drawn:

- The selected numerical approach predicted quite satisfactorily the behavior under load of a relatively small beam specimen having the dimensions of 2000x250x150 mm, and a tensile reinforcement ratio of 0.72%.
- In case of increasing the beam dimensions while keeping the steel fiber ratio identical to that of the small beam and decreasing the tensile reinforcement ratio to 0.65%, resulted in some discrepancies in the load-deflection curve specifically at the post-yield region. A further investigation should be carried out to understand the possible reasons for this consequence.
- Major flexural crack patterns could be captured satisfactorily free from the size of the beams.
- The failure modes of the beams emerged in the form of concrete crushing, unlike the rebar rupture occurring in the experimental study.

References

[1] ABAQUS CAE. Finite Element Software. Dassault Systemes Simulia Corporation, 2017.

[2] Afet ve Acil Durum Yönetimi Başkanlığı. “Turkish Building Earthquake Code”. Ankara, Türkiye, 2018.

[3] ACI Committee 544.1-96, “Report on Fiber Reinforced Concrete”. American Concrete Institute. 1996

[4] M. A. Cankaya and C. Akan. “An Experimental and Numerical Investigation on the Bending Behavior of Fiber Reinforced Concrete Beams”. Turkish Journal of Civil Engineering, 34(1), 59-78

[5] M. Singh, A. H. Sheikh, M. S. Mohamed Ali, P. Visintin, and M. C. Griffith. “Experimental and numerical study of the flexural behaviour of ultra-high performance fibre reinforced concrete beams”. Construction and Building Materials. 138: 12-25, 2017.

[6] D. Y. Yoo, and Y. S. Yoon. “Structural performance of ultra-high-performance concrete beams with different steel fibers”. Engineering Structures. 102: 409-423, 2015.

[7] A. Meda, F. Minelli, and G. A. Plizzari. “Flexural behaviour of RC beams in fibre reinforced concrete”. Composites: Part B. 43: 2930-2937, 2012.

[8] D. Y. Yoo, T. Yuan, J. M. Yang, and Y. S. Yoon. "Feasibility of replacing minimum shear reinforcement with steel fibers for sustainable high-strength concrete beams". Engineering Structures. 147: 207-222, 2017.

[9] ACI Committee 318. Building code requirements for structural concrete (ACI 318-14) and commentary (318R-14). Farmington Hills: American Concrete Institute. 2014.

[10] Lubliner J., Oliver J., Oller S. and Onate E. "A plastic-damage model of concrete." International Journal of Solids and Structures, 25(3), 299-326., (1989).

[11] Lee J. and Fenvers G. L. "Plastic-damage model for cyclic loading of concrete structures." Journal of Engineering Mechanics, 124(8), 892-900, (1998).

[12] Hibbitt, Karlsson, Sorensen. "ABAQUS Theory Manual, User Manual and Example Manual, Version 6.13". Providence, RI, Simulia. Inc. (2000).

[13] Yu T. et al. "Finite element modeling of confined concrete—II: Plastic-damage model." Engineering Structures, 32, 680-691, (2010).

[14] S. C. Lee, J. Y. Cho, and F. J. Vecchio. "Simplified Diverse Embedment Model for Steel Fiber Reinforced Concrete Elements in Tension". ACI Materials Journal. 110(4): 403-412, 2013.

[15] American Concrete Institute (ACI) 544.4R-18, 2018. Guide to Design with Fiber-Reinforced Concrete. Michigan, USA.

Review of Patents, Utility Models and Research for Green Construction Materials in Kenya

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Abstract

There is need for the construction industry to adopt green approaches, to counter increase in demand, while promoting sustainability. Intellectual property rights (IPR) provide temporal territorial exclusivity- with some limitation. Hence, innovators and researchers in green construction materials (GCM) could take advantage of IPR in GCM, to promote research, attract research and development (R&D) funds and benefit commercially. The study can aid in promotion of IPR economic benefits in GCM, through status quo and challenges review.

This review study was based on 182 Kenya Industrial Property Institute (KIPI) accessible journals between 2003 and 2021, on patents or utility models applications/grants perceived as GCM. There was a low level for GCM patents and utility models application/grants in Kenya. Only 10 results, in Kenya accessible industrial/intellectual property (IP) journals. This was possibly due to challenges, as reviewed herein. The study also identified some other GCM researches, for Kenya, but no reflection to advance to patent or utility models application. This study recommends for further research to determine reasons impending GCM researchers from applying for IP protection, addressing bottlenecks and promoting education and awareness on IPR. Efforts should be geared towards enhancement of patent protection and valuation, so as to attraction of funds in GCM research and innovation and increase economic benefit that comes with the right monopoly, licensing or intangible assets sales.

***Keywords*:** patents, utility models, Kenya, green construction materials

1. Introduction

There is need for the construction industry to adopt green approaches so as to counter the increase demand for infrastructure due to rapid population growth, modernization and urbanization, while mitigating against climatic change, negative waste impacts and construction environmental footprint.

In order to ensure that new materials meet the required safety and quality standards, adequate research and innovations, are vital. IP tools can potentially provide commercial incentive to researchers, public institutions, innovators and investors, to promote beneficial research and development of sustainable materials [1]. Discussion paper, reported that there were low numbers of patents application from Kenya's universities, this contradicted expectation. According to Sylvance Sange-(then) acting managing director, Kenya industrial property institute- as reported by [2], referred to Kenya as intellectually rich- as exhibited by number of publications by academics- but the knowhow was yet being fully translated into commercially viable IP assets oftentimes.

IPR provide temporal territorial exclusivity, with consideration to limitation. Hence, innovators and researchers in GCM could take advantage of IPR in GCM, to promote research, attract research and development (R&D) funds and benefit commercially. This research aims at investigating the patents and utility models relating to GCM in Kenya, and can aid in promotion of IPR economic benefits in GCM, through identification of IPR challenges. .

1.1. Registration and Legal framework for IP in Kenya and regional

The industrial property act, 2001 came into force on May 1st, 2002, aimed at promoting inventions and innovative activities, facilitating the technology acquisition through grant and regulation of patents, utility models, technovations and industrial designs and provision of power to Kenya industrial property institute (KIPI), with a revised edition 2016 (2012) [3], and miscellaneous

amendments in 2017, by '*the statute law (miscellaneous amendments) act 2017* [4]. Industrial property regulation 2002 legal notice No. 50 came into force on 1st May 2002 [5].

Kenya's '*Guideline for the examination of patents, utility models and industrial designs'* is intended for provision of guidance in the practice and procedure for intellectual property application for granting and registering of patents, utility models and industrial designs, according to industrial property act 2001 and industrial property regulation 2002 [6], and any revisions or amendments in the relevant acts or/and regulations revisions thereafter. Kenya is a member of Africa regional intellectual property organization-ARIPO [7].

1.2. Issues and challenges relating to IP in Kenya

According to [8], on IP review of Kenya information technology (IT) challenges included: difficultly in carrying out valuation due to insufficiency of specific data on invention cost, advertising cost per IP; insufficiency of IP valuation management organization in Kenya; the secrecy about IP, in Kenya; inadequate enforcement of IP law; IP asset not accepted as collateral; insufficiency of laws; insufficiency of strategy and policy; timeframe considered as being too long and investors identified entity as being ineffective and cumbersome process; small patent application, possibly due to fee amounts, that were considered high for tech startup and incompetency of staff at Kenya industrial property institute. According to [9], enforcement of intellectual property right posed challenge to right holders and counterfeit products in Kenya were reported to present major impediment to U.S. businesses in Kenya. [10], on securitization of IP in Kenya identified some challenges as: insufficiency in capacity of IP asset valuation services in the country, and absence of IPs liquid market and insufficiency of definite law to regulate securitization and IP enforcement, could be a great risk to lenders. According to [1] discussion paper, on study in Kenya indicated challenges such as: low patent commercialization hence hard for investors mostly individuals to benefit from invention; long and tedious patenting process; limited research and development (R & D) funding; limited benefits from patenting and limited IP knowledge. [11], identified challenges such as:- staffing of IP management and implementing institution, attracting and maintenance of multi-disciplinary staff at institutions and not much research conducted to establish if IPR laws and management institutions contribution to overall country development. According to Sylvance Sange- former acting managing director, KIPI- as reported by [2], IP theft- illegally trading pirated and counterfeit good- were identified as a major challenge and KIPI was working with enforcement agencies to tackle the challenges e.g. through awareness and training.

1.3. Study area

Kenya is a country in the East of Africa, Sub-Saharan Africa region. The equator cuts through the nation. Figure 1 shows the map of Kenya and the bordering nations including Somali, South Sudan, Ethiopia, Uganda and Tanzania. Kenya also has a coast line for Indian Ocean.

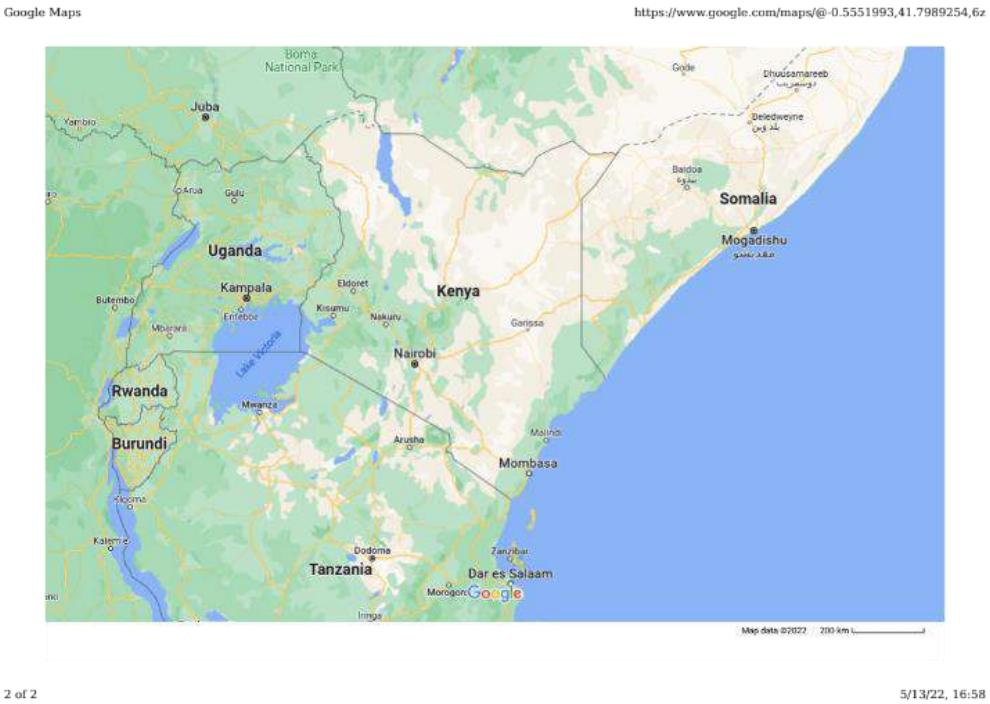

Figure 1. Map of Kenya [12]

2. Green Buildings and Construction Materials for Kenya and globally

2.1. Research, Review and institutional framework on Green buildings and Materials

According to sessional paper no. 3 [13], the national and county government in Kenya, are required to develop strategies of promoting green housing including green building materials.

Khaemba and Mutsune [14] performed research on green building adoption in Kenya, ranked 26 green building rating attributes, with "build/construct using recycled or salvaged building materials" and "use of materials that can be renewed or replenished rapidly" attributes were rated at moderately high importance, both ranked 14, in top 5 attributes "energy and atmosphere" category had 2 attributes with ranking 1 & 4 while the "water efficiency" category also had 2 attributes with ranking 3 & 5. According to another study [15], the clay brick incorporated concrete indicated product could be utilized for non-loading bearing members using waste clay bricks would solve environmental threat due to the waste and promote conservation of natural aggregate. Onchiri et al. [16] investigated the use of sugarcane ash as partial replacement of cement in self-interlocking earth blocks stabilization, for silty-gravel soils, results indicated an optimum compressive strength at a ratio of sugarcane bagasse to cement was 1:1.5, and the study recommended further investigation of water absorption behavior of the stabilized self-interlocking blocks. The combination of waste plastic and sisal fibre in [17] improved bitumen retention characteristic for asphalt concrete incorporated with 5% waste plastic [HDPE (High density polyethylene) and LDPE (Low density polyethylene)] and 0.3% sisal fibre, the bitumen loss was 0% as compared to 6.5% for control mixture, hence the modified asphalt concrete showed best bitumen retention. Ndinyo et al. [18] incorporated reclaimed asphalt concrete (RAC) aggregate as partial aggregate replacement, harvested from bituminous surface removal ("milling"), the RAC aggregate had engineering properties suitable for application in low volume road surfacing, with savings in coarse aggregate.

Another study by [19], for investigation of the more sustainable option for proposed Ndarugu student centre (NSC), Nairobi, Kenya, between usage of cross laminated timber (CLT) and "sustainable" (30% fly ash) concrete, indicated that generally, CLT under correct circumstances has a large potential for climate mitigation, but disregard of proper circumstances, CLT could potentially result to significant system wide emission, 10-times greater than that of concrete NSC's worst case scenario, large risk related to CLT if not addressed beforehand could prevent its appropriate adoption. Workshop by FSD Kenya affordable housing team, for the stimulation of knowledge transfer and collaboration between Tanzania and Kenya on CLT usage in housing was held on 8th February 2022, and as reported by [20], if properly developed, with enough knowledge and competency, CLT benefit include:- 1) More environmentally friendly during construction, wood being the raw material that is renewable, hence CLT is a carbon store; 2) Faster timeframe for building and storing quality control, since CLT are prefabricated and numbered in the factory; 3) Good insulation properties and no storage of heat; 4) Provision of significant opportunities for jobs and economy.

Based on [21] study, that utilized inactivated termite soils as pozzolanic materials, sourced from Nduru village, Siaya Kenya and also used sisal fibre from Muja farm, Kiambu, Kenya recommended, the use of 10% inactivated termite clay soils for partial cement replacement and up to 2% sisal fibre for roof tiles construction, with cement sand ratio of 1:2 and water to cement (binder) ratio of 0.5.

2.2. Patent and Utility model application/grants

The study was based on 182 number of Kenya industrial property institute (KIPI) accessible journals between 2003 to 2021, the selection was conducted majorly by use of some key words searches, where patents or utility models applications and/or grants were evaluated as incorporating green construction materials as shown in table 1. However, some of journals were not accessible.

Table 1. Summary for relating to green building patents or utility models applications/grant in 182 KIPI journals [2003 to 2021]

S/No	Ref.	Title (short description)	Type of application/grant; Journal/source
1	[22]	Method of construction of floor slab (earth & cement mixture)	Patent[granted]; Kenya Industrial property institute (2021)
2	[23]	Construction material from plastic and water Hyacinth (waste plastic & water hyacinth mixture)	Utility model national application [granted]; Kenya Industrial property institute (2020a)
3	[24]	Interlocking building and construction components manufactured from plastic (no binder require, used quarry dust)	Utility model; Kenya Industrial property institute (2019)
4	[25]	Almino pozzolana (almino pozzolana, mixed with cement, can reduce paint requirement)	Patent application (national) and utility model; Kenya Industrial property institute (2018)
5	[26]	Hollow modules of pre-cast reinforced concrete that uses waste plastic material as part of raw material (utilize waste plastic)	Patent application; Kenya Industrial property institute (2009)
6	[27]	Production of wood plastic technology (wpvc) material & wpvc product (part of pvc can be substitutes with agricultural waste)	Utility model publication; Kenya Industrial property institute (2017)
7	[28]	Plastic poles for fixing traffic signs (Uses recycled plastic)	Utility model publication; Kenya Industrial property institute (2014)
8	[29]	Turning waste plastic into resin-bonded roofing tiles (Use polyethylene plastic from recycle waste)	Utility model registration; Kenya Industrial property institute (2013)
9	[30]	Pozzolana based cement from industrial and agricultural waste materials	Patent application filed No. KE/P/03/00394
10	[31]	Structured engineered wood	Patent application

The patent application [31], that included multilayers of composite materials glued or bonded to wood, and can also be applicable to composite materials of plant fiber, synthetic fiber, polymer composite, glass fiber, nylon, rubber and plastic [31], was deemed to be related to GCM in terms of usage incorporation of non-traditional materials such as plant fiber possibly from waste or renewable agricultural products and potential improved insulation property. Patent application by [32], aimed at getting a sustainable eco-friendly construction material from renewable sources- seed fibre.

Based on Table 1 for review of the 182 accessible IP journals by KIPI, between 2003 and 2021, only 10 were qualified under green construction material, for patent and utility model grants or applications.

2.3. Selected global patents applications or grants relating to green construction materials

Some related GCM patent applications or grants in various parts of the world are shown in Table 2.

Table 2. Summary for selected patents applications/grant globally relating to GCM

Ref.	Title (short description)	Application/grant
[33]	Formed building materials material (comprise of a sequestered CO_2)	Patent application (Patent cooperation treaty-PCT); application (China); active & abandoned applications in US;
[34]	Green cement for sustainable construction (use melanoidin from spent wash (e.g. distillery waste), as a binder, reducing/absorption of CO_2.	PCT; application (China);
[35]	Self-igniting green bricks based on construction waste (has parts, waste plastic & waste bamboo wood)	Granted (China), in 2011;
[36]	Bricks for construction and preparation method thereof (Has stone powder as construction waste)	Granted (China);
[37]	Green concrete prefabricated pile for strengthening soft foundation and construction method (includes, industrial waste slag such as coal ash)	Granted (China);
[38]	Method of making a sheet of building materials; (Can incorporate proportion of recycled resin such as recycled high density polyethylene)	Grant no 08894901 (US); related documents/applications/grants in :- Republic of Korea, European patent office, China, Australia, PCT, Brazil, New Zealand, Canada, Mexico and USA;
[39]	Recyclable surface covering and method and system for manufacturing a recyclable surface covering (Utilize recycled material/rubber)	Application or grants in USA, Canada & European patent office
[40]	Carbonated bonded construction products from steel-making residues and method of making the same (can utilized waste glass and/or fly ash)	US and related document in:-Poland, China, Canada, Slovenia, Portugal, Spain and European patent office
[32]	An unique sustainable construction material extracted from wrightia tinctoria seed fibre and analyzing its properties thereof (sustainable eco-friendly construction material from renewable sources)	
[41]	Composite building material (green fiber cement facing)	Patent application/grant:- in Mexico-granted, Czech, Japan, Australia, Argentina & Malaysia

Other include, in summary:

A method for manufacturing light weight construction material using waste product and light weight construction material using waste product (such as sewage sludge, remicon sludge, spend foundry sand, power plant ash incinerator residue, grinding stone residue, discarded asbestos and steel dust) and light weight construction material manufactured thereby, by [42].

Patent application no 143142279 in USA, titled: asphalt material recycling system method, by [43] included an asphalt roofing material recycling system and method that utilized recycle, new and/or used asphalt material.

3. Discussion

Based on the review of the 182 IP journals by KIPI, between 2003 and 2021, only 10 results were qualified as GCM in Kenya. However, researches by [15, 16, 17, 18, 21] on construction materials in Kenya is an indicator that other researches on GCM have been conducted, but the same were not

translated to patent application in Kenya. [8, 9, 11] identified enforcement or implementing institutions related to IP as challenges in Kenya. Also, [2, 9] indicated issue of counterfeit/ illegal products as a challenge. [8, 1] indicated the tedious process as a challenge. Other challenges included insufficiency of laws and valuation issue [8, 10], limited R & D funding & fee issue, limited IP knowledge [1], secrecy on IP and staff incompetency [8], issue of staffing (multi-disciplinary staff) [11]. Hence, based on previous studies, IP related issues and challenges in Kenya identified included financial, systematic, human, insufficient awareness and commercial/valuation that potentially hindered application of IP protection for green construction materials.

According to [19], on investigation of the more sustainable option for proposed Ndarugu Student Centre (NSC), Nairobi, Kenya, between usage of cross laminated timber (CLT) and "sustainable" (30% fly ash) concrete, indicated that generally, CLT under correct circumstances has a large potential for climate mitigation. Hence, various researches mentioned had promising potential for assorted green products ranging from woods, cement concrete and asphalt concrete. There is need for patent or utility model applications related to sustainable wood or wood products.

4 application/grant, including [23, 26, 28, 29] utilized waste or recycled plastic. [27, 30] utilized agricultural waste, while for [31] plant fibre composite materials was one of the alternative material. [22, 24, 25, 30] applications or grants indicated utilization of earth; quarry dust (a waste) with no binder required; almino pozzolana and Pozzolana based cement from industrial and agricultural waste, respectively, hence potentially reduction on cement requirement. Portland cement has significant carbon footprint per unit production. Also, on a global scale, review were done for patent applications/grants relating to GCM.

Promotion of green building materials is supported by Republic of Kenya (2016), sessional paper no. 3, whereby the national and county government in Kenya, are required to develop strategies of promoting green housing including green building materials. Therefore, based on this, there is availability of policy backing that would aid in the IP process, potentially benefit construction players, researchers and other relevant stakeholders.

4. Conclusions and Recommendations

Based on the review of this study, only 10 patents or utility model applications qualified from the 182 KIPI journals, as GCM, a significant number included utilization of waste plastic or agricultural/industrial waste materials. A comparison with scientific researches, a significant number of researches in the subject did not apply for patent or utility model protection in Kenya. Review of some patent application or/and grants on GCM or method globally was presented and based on those, most patent application were in the developed states. There was a low level for GCM patents and utility models application/grants in Kenya, this was possibly due to IPR challenges- indicated in this study- in Kenya.

Based on previous studies, IP related issues and challenges in Kenya identified included financial, systematic, human, insufficient awareness and commercial/valuation, that potentially hindered application of IP protection for green construction materials. The challenges identified possibly hinder massive applications for utility models and patent for GCM innovations in Kenya.

This study recommends for further research to determine reasons for researches not to apply for IP protection, address any bottlenecks, promoting education and awareness on IPR. Also, this research recommends further study on whether or not investment in patent or utility model is feasible in Kenya and reasons thereof for any challenges in application and utilization of IP benefits. Efforts should be geared towards enhancement of patent protection and valuation, so as to attraction of funds in GCM research and innovation and increase economic benefit that comes with the right monopoly, licensing or intangible assets sales. Studies on GCM should be put into consideration on durability (long-term and adverse environment/conditions), development of standards/codes of practice, safety & heath and upcycling for value addition techniques/technologies, to reduce uncertainnesses, promote human development and also increase economic potential. Various IP tools may be used to attract investment for the same.

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References

[1] Kiveu M. Patenting in Kenya: Status and challenges, Discussion paper no. 14. Kenya: KIPPRA, 2012; https://repository.kippra.or.ke/bitstream/handle/123456789/2504/DP141.pdf?sequence=1&isAllowed=y

[2] Mbuimine F. Strengthening Kenya's IP landscape. WIPO Magazine, August 2016 [Online]. https://www.wipo.int/wipo_magazine/en/2016/04/article_0007.html

[3] Republic of Kenya. Industrial property act, 2001 revised edition 2016 [2012]. In kipi.go.ke [pdf]. Availed from: http://www.kipi.go.ke/images/docs/legal/Industrial_Property_Act_3_of_2001.pdf

[4] Republic of Kenya. The statute law (miscellaneous amendments) act 2017, April 19th, 2017. In kipi.go.ke [pdf]. Availed from: http://www.kipi.go.ke/images/docs/legal/Misc_Amendments_%20Act_No11_of_%202017.pdf

[5] Republic of Kenya. Industrial property regulation 2002. In kipi.go.ke [pdf]. Availed from: http://www.kipi.go.ke/images/docs/ipr2002.pdf

[6] Kenya Industrial property institute-KIPI. Guideline for the examination of patents, utility models and industrial designs. Kenya Industrial property institute-KIPI 2007. In kipi.go.ke [pdf] http://www.kipi.go.ke/images/docs/guidelines%20to%20patenting.pdf

[7] Africa regional intellectual property organization-ARIPO. Member states. In aripo.org [Online]. Availed from: https://www.aripo.org/member-states/ [Accessed: 17 March 2023]

[8] Viffa consult. Intellectual property- A case review of Kenya's IT sector. May 18th, 2015; In viffaconsult.co.ke [Online]. Availed: https://viffaconsult.co.ke/intellectual-property-a-case-review-of-kenyas-it-sector/

[9] International trade administration, U.S. Department of commerce. Kenya- Country commercial guide: Protecting intellectual property. In trade.gov [Online]. Availed from: https://www.trade.gov/country-commercial-guides/kenya-protecting-intellectual-property

[10] Ndonji M. The securitization of IP in Kenya.. In: mitullahshakolaw.com [Online]. Availed from: https://mitullahshakolaw.com/the-securitization-of-intellectual-property-in-kenya/ [Accessed: 16-June-2022]

[11] Kameri-Mbote P. Intellectual property protection in Africa: An assessment of the status of laws, research and policy analysis on Intellectual Property Rights in Kenya. International Environmental Law Research Centre, IELRC Working paper 2005-2; https://ielrc.org/content/w0502.pdf

[12] Googlesmap. [online]. Maps.googles.com

[13] Republic of Kenya. National housing policy for Kenya, sessional paper no. 3. April, 2016. In housingandurban.go.ke [pdf]. Availed from: https://www.housingandurban.go.ke/wp-content/uploads/2019/10/Updated-Sessional-Paper-No.3-of-2016-National-Housing-Policy.pdf

[14] Khaemba P, Mutsune T. Potential for green building adoption: Evidence from Kenya. GJBR 2014; 8(3):69 – 76. https://www.theibfr.com/download/gjbr/2014-gjbr/gjbr-v8n3-2014/GJBR-V8N3-2014.pdf

[15] Odera BJ, Mutuku RN, Kabubu CK. Mechanical characteristics of normal concrete partially replaced with crushed clay bricks." IJCIET 2015; 6(1): 62-75. https://iaeme.com/MasterAdmin/Journal_uploads/IJCIET/VOLUME_6_ISSUE_1/IJCIET_06_01_008.pdf

[16] Onchiri R, Kiprotich J, Sabuni B, Busieney C. Use of sugarcane bagasse ash as a partial replacement for cement in stabilization of self-interlocking earth blocks. IJCIET 2014; 5(10): 124-30. https://iaeme.com/MasterAdmin/Journal_uploads/IJCIET/VOLUME_5_ISSUE_10/IJCIET_05_10_012.pdf

[17] Mungathia T, Gariy ZA, Nyomboi T. Analysis of bitumen draindown characteristic of sisal-plastic modified open graded asphalt. JAGST 2021; 20(1): 94 – 106. https://ojs.jkuat.ac.ke/index.php/JAGST/article/view/182/183

[18] Ndinyo CS, Gariy A, Mulei SM. Suitability of a mix of reclaimed asphalt concrete, virgin aggregates and a cationic emulsion as a cold mix surfacing material for low volume roads. In: JKUAT scientific technological and industrialization conference, 14 - 15th Nov. 2013. http://ir.jkuat.ac.ke/handle/123456789/3362?show=full

[19] Mohajer M. Quantifying the attributional and the consequential impacts of Kenya's future timber construction developments. University of Edinburgh, Business school. In iied.org [pdf]. https://pubs.iied.org/sites/default/files/pdfs/2021-10/20556g.pdf

[20] Shah. Driving greener housing using regionally sources cross laminated timber. In fsdkenya.org [Online] Availed: https://www.fsdkenya.org/blogs-publications/driving-greener-housing-using-regionally-sourced-cross-laminated-timber/

[21] Otieno MO, Assessment of the feasibility of using sisal fibre reinforced cement mortar with termite clay soil for roofing tiles. Msc. Thesis, SMARTEC, JKUAT, Kenya, 2016. [Online pdf]. http://ir.jkuat.ac.ke/bitstream/handle/123456789/2109/Otieno%2C%20Meshack%20Oduor%20MSc%20%20in%20Construction%20Engineering%20and%20Management-2016.pdf?sequence=1&isAllowed=y

[22] Floor slab of earth, by Holcim technology ltd. (2021, August 19), Kenya patent: 5715, In Kenya Industrial property institute-KIPI Journal, No. 2021/10, kipi.go.ke [Online: pdf]. Available: https://www.kipi.go.ke/index.php/past-ip-journals

[23] Construction material from plastic and water hyacinth, by Sagini MN, Kiboiywo E. (2020, December 17), Kenya utility model registration: 321. In Kenya Industrial property institute-KIPI Journal, No. 2020/12, kipi.go.ke [Online: pdf]. Available: https://www.kipi.go.ke/index.php/past-ip-journals

[24] Interlocking building and construction components manufactured from plastic, by Muita JM. (2019, July 2), Kenya utility model application no.: KE/U/2019/1223, Kenya Industrial property institute-KIPI Journal, No. 2019/07, [Online: pdf]. Available: https://www.kipi.go.ke/index.php/past-ip-journals

[25] Almino pozzolana, by Njuho SN. (2018, August 28). Kenya utility model application no.: KE/U/2018/1030, Kenya Industrial property institute-KIPI Journal, No. 2018/10, [Online: pdf]. Available: https://www.kipi.go.ke/index.php/past-ip-journals

[26] Hollow modules of pre-cast reinforced concrete that uses waste plastic material as part of raw material, by Njenga AM. (2004, August 17). Kenya patent application no.: KE/P/2004/000424, Kenya Industrial property institute-KIPI Journal, No. 2009/08, [Online: pdf]. Available: https://www.kipi.go.ke/index.php/past-ip-journals

[27] Production of wpvc material and wpvc products, by Gichobi CG. (2015, March 27). Kenya utility model application no.: KE/U/2015/500, Kenya Industrial property institute. Industrial property journal, No. 2017/01, [Online: pdf]. Available: https://www.kipi.go.ke/index.php/past-ip-journals

[28] Plastic poles for fixing traffic signs, by Devani B. (2011, August 18). Kenya utility model application no.: KE/U/2011/000223, Kenya Industrial property institute. Industrial property journal, No. 2014/02, [Online: pdf]. Available: https://www.kipi.go.ke/index.php/past-ip-journals

[29] Turning waste plastic into resin-bonded roofing tiles, by Ochieng B, Oscar AJ. (2013, April 08). Kenya utility model grant No. 47. Kenya Industrial property institute, Industrial property journal, No. 2013/04, [Online: pdf]. Available: https://www.kipi.go.ke/index.php/past-ip-journals

[30] Pozzolana based cement from industrial and agricultural waste materials, (2003, September 11). Kenya Patent application No. KE/P/03/00394, Kenya Industrial property institute, Industrial property journal, No. 2003/005, [Online: pdf]. Available: https://www.kipi.go.ke/index.php/past-ip-journals

[31] Structured engineering wood, by Waweru DK. (2020, March 11). Kenya Patent application No. KE/P/2020/3620. Kenya Industrial Property Institute. Industrial property journal, No. 2020/11, [Online: pdf]. Available: https://www.kipi.go.ke/index.php/past-ip-journals

[32] An unique sustainable construction material extracted from wrightia tinctoria seed fibre and analyzing its properties thereof, by Habibunnisa S, Ruben N, Chand MSR, Reddy SR. (2020, May 09). Patent application No. IN202041019727. https://patentscope.wipo.int/search/en/detail.jsf?docId=IN297815654&_cid=P20-L41JKP-87558-1

[33] Formed building materials, by Chen I, Devenney M, Ha E, Calas G, Lu P, Camire C, Baurcier W, Kendall T. (2012, October 23). Patent application No (Patent Co-operation treaty PCT): WO2013/074252A1. [Online] https://patents.google.com/patent/WO2013074252A1/en

[34] Green cement for sustainable construction, by Arockiadoss T. (2010, October 19). Patent application No (Patent Co-operation treaty PCT): WO2012/010936A1. [Online]

https://patents.google.com/patent/WO2012010936A1/no
https://patentimages.storage.googleapis.com/ea/11/02/c9c4bec2662700/WO2012010936A1.pdf

[35] Self igniting green bricks based on construction waste, by Kesheng X, (Application date: 2018, June 01). China, Patent application No. 201810553686.5. [Online]. https://patentscope.wipo.int/search/en/detail.jsf?docId=CN233999998&_cid=P10-L3VB47-88999-1

[36] Bricks for construction and preparation method thereof, by Huoyan L. (Grant date: 2011, February 9). China patent, Grant no. 101701482. [Online]. https://patentscope.wipo.int/search/en/detail.jsfdocId=CN83894579_cid=P10-L3VB47-88999-1

[37] Green concrete prefabricated pile for strengthening soft foundation and construction method, by Jianwei Y, Weilin Z, Zhifeng C, Liwei H, Tingting Y, Anquan X. (Grant date: 2018, August, 7). China patent No.: CN106082901. https://patentscope.wipo.int/search/en/detail.jsf?docId=CN179624837&_cid=P10-L3VKPV-18404-1

[38] Method of making a sheet of building materials, by Wensel GF, Suggit R. (Grant date: 2014, November, 25). US Patent Grant No. 08894901. https://patentscope.wipo.int/search/en/detail.jsf?docId=US43340858&_fid=AU181430684

[39] Recyclable surface covering and method and system for manufacturing a recyclable surface covering, by Rodge AB, McFall J. (2018, July, 24). US Patent No. 10,029,447B2 https://patents.google.com/patent/US10029447B2/en, https://patentimages.storage.googleapis.com/2f/3b/e5/e7ddf369084aab/US10029447.pdf

[40] Carbonated bonded construction products from steel-making residues and method of making the same, by Shao Y, Mahoutian M, Ghouleh Z (2020, April, 28) . US Patent No.: 10,633,288B2. https://patents.google.com/patent/US10633288B2/en?q=recycled+building+material

[41] Composite building material, by Deford HD, Gleeson JA, Merkley DJ. (2005, September, 13). US Patent No.: 6,941,720B2. https://patents.google.com/patent/US6941720?oq=sustainable+construction+material+research

[42] A method for manufacturing light weight construction material using waste product and light weight construction material using waste product and light weight construction material manufactured thereby, by S-L, Lee. (filing date: 2012, July, 6) . International PCT patent application No.: PCT/KR2012/005373. https://patentscope.wipo.int/search/en/detail.jsf?docId=WO2013006011&_cid=P20-L41MKA-03282-1

[43] Asphalt material recycling system method, by Zickell R, Zickell TJ. (Application date: 2014, June, 25). US patent Application No.: 14314279. Patentscope. https://patentscope.wipo.int/search/en/detail.jsf?docId=US128618002&_cid=P20-L41PEI-17234-1

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A Design Perspective on the Stability of Timber Beams Under Lateral Torsional Buckling

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Abstract

Lateral torsional buckling (LTB) of timber beams is an important out-of-plane behavior mode due to large depth/width ratios and long span lengths, as in steel beams. A beam that is subjected to a lateral torsional buckling failure would deform under an applied load or moment until the critical moment (M_{cr}) is reached, after that, a slight increase in the applied moment will create large out-of-plane deformations, and the beam will buckle by deflecting laterally and twisting. If the compression zone of the beam is braced by using out-of-plane nodal lateral bracing, these deformations can be prevented. In timber structures, specifications of the nodal bracing for timber beams are not clear enough to provide easy-to-use calculations in Eurocode 5. This study aims to investigate the optimum level of the bracing stiffness using the brace force - brace stiffness relationship, so that bracing calculations are easier to be applied. As the nature of nodal bracing, it is expected to observe lesser brace forces as the brace stiffness increases. However, this effect balanced itself at optimum brace stiffness. After the ideal stiffness value is reached, any brace stiffness greater than this value does not increase substantially the buckling capacity of the beam. In this paper, the study is conducted using a validation of Finite Element Analysis (FEA) coupled with experimental studies from the literature. Also, different sizes of the specimens were generated using the FEA procedure to conduct a matrix of cases that includes both brace stiffnesses and sizes of timber beams. These matrices are then presented in graphs that demonstrate the optimum level to stabilize the beams. The Eurocode 5 effective length design concept was used for the calculations. This study provides easy-to-use bracing calculations to reduce the effect of LTB on timber beams.

Keywords: Timber beam stability, lateral torsional buckling, bracing, finite element analysis, brace force

Introduction

Lateral torsional buckling is the behavior of an unrestrained beam or beam-column when it experiences simultaneous in-plane displacement, lateral displacement, and twisting. As in other structure materials, this behavior can also be observed in timber beams. A timber beam that experiences lateral torsional buckling would deform under an applied load or moment until the critical moment (M_{cr}) is reached, after the critical moment, a slight increase in the applied moment or load will create large out-of-plane deformations, and the beam will buckle by deflecting laterally and twisting (See Fig.1.).

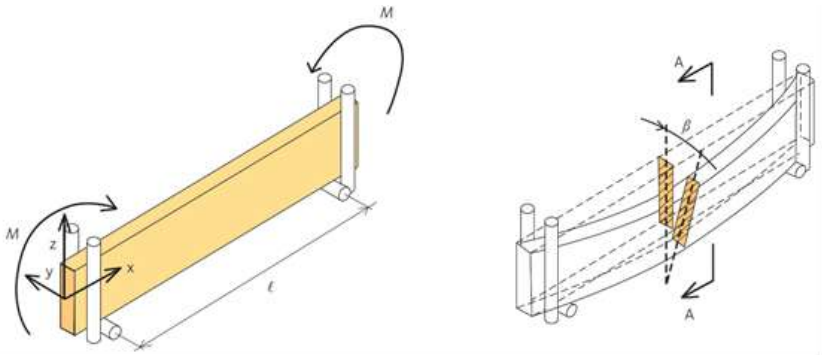


Fig.1. Lateral Torsional Buckling of Beam [1]

These out-of-plane deformations can be prevented by bracing the compression zone of the beam with lateral bracing. However, the specifications for the bracing of timber beams are not clear enough both in Eurocode 5[2] and in the literature.

There are several studies in the literature that have been conducted on the subject of lateral torsional buckling of timber beams and the use of bracings. Hooley and Madsen [3] conducted an experimental program observing the lateral torsional buckling behavior of rectangular cross-section wooden beams to develop design equations on lateral torsional buckling strength.

Winter [4] has developed a simple and elementary method that permits one to calculate lower limits of the strength and rigidity of lateral support to provide "full bracing" to columns and beams. Song and Lam [5] presented a study on the stability capacity and lateral bracing force of wood beam-columns subjected to biaxial eccentric compression load. According to the test results, a numerical analysis model was developed and verified by the test results. The model was found to provide good predictions of the maximum axial compression load and the ratio of the lateral bracing force to the axial compression load. Ye Hu [6] conducted an analytical and numerical investigation for the lateral torsional buckling analysis of a wooden beam with a mid-span lateral brace subjected to symmetrically distributed loading. Two models are developed; one for the case of a rigid brace and another one for the case of a flexible brace. The validity of both models is verified against 3D finite element analyses in ABAQUS [7].

Although the literature that summarized refers to lateral torsional buckling behavior in wooden beams and the use of bracings on this behavior, there is no clearness about the optimal brace stiffness value that is required to conserve the stability of the beam. Therefore, the study that was conducted will eliminate the uncertainty in the literature and provide easy-to-use bracing calculations to reduce the effect of LTB on timber beams. The study is conducted using a validation of Finite Element Analysis (FEA) coupled with experimental studies from the literature. Also, different sizes of the specimens were generated using the FEA procedure to conduct a matrix of cases that includes both brace stiffnesses and sizes of timber beams. These matrices are then presented in graphs that demonstrate the optimum level to stabilize the beams.

Methodology

The simplified equation of lateral torsional buckling for a simply-supported beam under a constant moment is:

$$M_u = \frac{\pi}{L_u}\sqrt{EI_yGJ} \quad (1)$$

Eurocode 5[2] provides two design methods to generalize the lateral torsional buckling solutions to include beams with different boundary conditions and loading patterns. The first one is the effective length approach and the other one is the equivalent moment factor approach. The effective length approach was used in this study. According to this approach, the critical moment formula has been modified according to different boundary conditions and loading situations in which the moment is induced and the cases where the load is applied at the compression (or tension) face rather than the centroidal axis of the beam. The design span in the formula was replaced by what is termed the "effective length", L_{ef}, of the beam, and Equation 2 was obtained:

$$M_{cr} = \frac{\pi}{L_e}\sqrt{EI_yGJ} \quad (2)$$

where;

M_{cr} : critical bending moment
E : modulus of elasticity
I_y : second moment of area about y-axis
G : shear modulus
J : polar moment of inertia
L_e : effective length (obtained by adjusting the design span to take account of the effect of the moment distribution and end fixing conditions)

Values for commonly used cases in timber design are given in Table 1.

Table 1. Effective length as a ratio of span [8]

Beam Type	Loading Type	L_{ef}/L
Simply Supported	Constant Moment	1
	Uniformly Distributed Load	0,9
	Concentrated Force at Midspan	0,8
Cantilever	Uniformly Distributed Load	0,5
	Concentrated Force at the Free End	0,8

The effective length approach provides shorter unbraced lengths by using out-of-plane nodal lateral bracing in the compression zone of the beam. Therefore, the moment capacity of the beam is increased and the lateral deformation of the beam is prevented. The calculations for brace stiffness that are required to prevent lateral buckling are provided by Eurocode 5 [2]:

$$C = k_s \frac{N_d}{a} \tag{3}$$

where,

C : minimum spring stiffness
k_s : modification factor with the value given in Table 2.
N_d : mean design compressive force in the braced element
a : bay length, (See Fig. 2.)

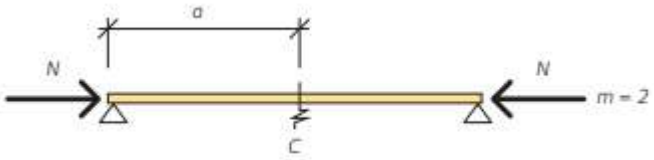


Fig. 2. Bay length [1]

The design stabilizing force F_d at each support is:

$$F_d \begin{cases} \frac{N_d}{kf,1} \rightarrow For\ structural\ beam \\ \frac{N_d}{kf,2} \rightarrow For\ glulam\ and\ LVL \end{cases}$$

where *kf,1* and *kf,2* are modification factors with the values given in Table 2.

Table 2. Values of modification factors for the design of bracings [8]

Modification Factor	Value
ks	4
kf,1	50
kf,2	80
kf,3	30

This expression can also be used for the lateral stabilizing force Fd required for the compressive edge of a rectangular beam in bending if the compressive force is determined as:

$$N_d = (1 - k_{crit}) \frac{M_d}{h} \tag{4}$$

where;

M_d : maximum design bending moment
h : beam depth
k_{crit} : factor accounting 100ort the effect of lateral buckling

Finite Element Model

Models that were used for the analyses were taken from the study of Q. Xiao et al [9]. Two Spruce-Pine-Fir (SPF) No. 1/No. 2 grade lumber joists were modeled by the finite element program "ABAQUS"[7]. There are three faces of wooden beams; the L face is perpendicular to the longitudinal direction, the R face is perpendicular to the radial direction and the T face is perpendicular to the tangential direction. Each of these three faces has a modulus of elasticity (EL, ET, ER) along the longitudinal, tangential, and radial directions, respectively. Also on each face, there are two Poisson's ratios (vLT and vLR) and two shear modulus (GLT and GLR) about the longitudinal-tangential direction and longitudinal-radial direction, respectively, and one Poisson's ratio (vRT) and one shear modulus (GRT) about radial and tangential direction. Since the difference between the properties in the radial and tangential direction can be considered insignificant, ET = ER, vLT = vLR, and GLT = GLR. Therefore the mechanical properties ET = ER = 700 Mpa, GRT = 51,5 Mpa, v= vLT = vLR = 0,347, and vRT = 0,469 for all specimens. The other mechanical properties and the dimensions of the specimens are given in Table 3.

Table 3. Geometric and Mechanical Properties of the Specimens

Specimen No	Geometric Parameters (mm)			Material Properties (MPa)	
	Width	Depth	Span	E	G
1	38	286	4200	6469	479
2	38	286	2100		

The C3D8 brick element from the Abaqus library was used to model the lateral torsional buckling of wooden beams. The C3D8 element has 8 nodes, each having three translational degrees of freedom (DOFs).

A mesh sensitivity analysis was conducted and it suggests that reasonable results can be achieved when the element dimension in the longitudinal direction is twice its width or depth. Therefore, the meshing part is fully characterized by the number of elements (m1; m2; m3) along the beam clear span m1, the cross-section height m2, and its width m3. Furthermore (m1; m2; m3) were taken as (552, 74, 10) and m3 was arranged by the changing span dimensions (See Fig. 3.).

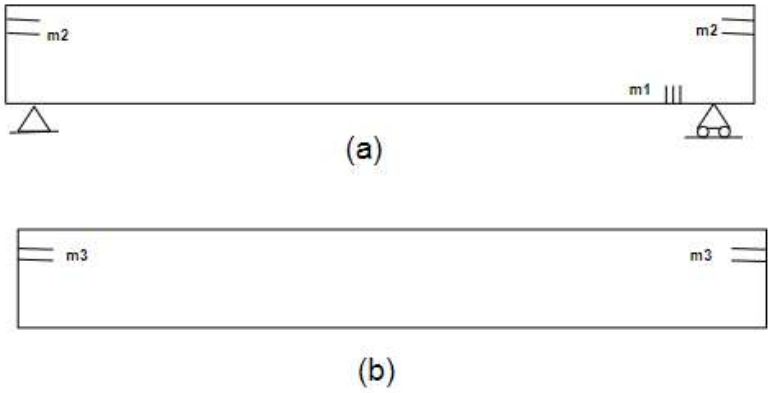


Fig. 3. Parameters that define the FEA mesh (a) front view (b) top view

For the boundary conditions of the beams, two types of constraints were implemented:

(a) Displacements within the plane of the cross-section: Vertical displacements were restrained along horizontal lines DC and D`C` along the underside of the section. Also, the horizontal displacements were restrained along vertical lines AD, BC, A`D`, B`C`, DC, and D`C`.

(b) Longitudinal displacements at the location of the support: At one end (Point E), the longitudinal displacement was restrained but at the other end, Point E' was set free to move longitudinally.

Boundary conditions of both experiment and FEA are shown in Figures 4 and 5.

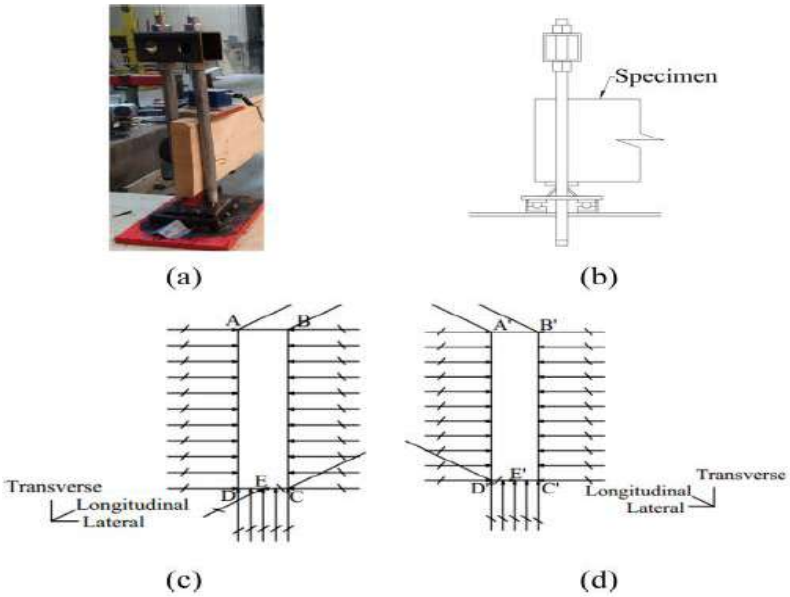


Fig. 4. (a) Experimental end detail, (b) Elevation of experimental end detail, (c) DOFs restrained at left end, (d) DOFs restrained at the right end [1]

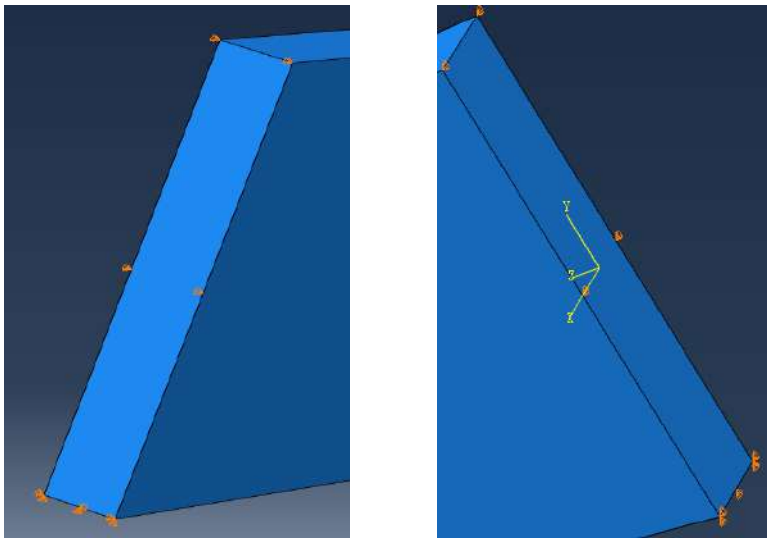


Fig.5. Left and right ends in the ABAQUS[7] model

In the article, the beams were subjected to a mid-span load applied at the top edge of the beam in the experiment part. The load was applied on a small area and remained vertical as the beam buckled laterally. Therefore, in the Abaqus model, the applied load was distributed over an area of 6 x 6 elements to approximately compete with the conditions of the experiment.

A linearly elastic eigenvalue buckling analysis was used in the FEA model to determine the elastic buckling resistance of the beams. The eigenvalue buckling analysis is a linear perturbation procedure to estimate the critical loads by solving the system of equations:

$$([K_o] + \lambda_i[K_G])\{v_i\} = 0 \qquad (5)$$

where $[K_0]$ is the elastic stiffness matrix with respect to the base state, $[K_G]$ is the geometric matrix, λ_i represents the eigenvalues, corresponding to the buckling mode shapes $\{v_i\}$.Nodal lateral braces were applied to the models by using linear elastic spring elements. Brace stiffness values were increased from zero to the point where the change in eigenvalue is nearly zero. At that point, the brace element acted like a support and the displacement value was close to zero.

Model Verification

The model utilized for the finite element analysis (FEA) study was rigorously validated by Q. Xiao et al. [9], establishing its credibility. To ensure the verification, two beams were carefully selected

from the total of 18 and modelled using ABAQUS [7] with the finite element scheme specified in the Finite Element Model section of this paper. Upon comparing the results, a maximum variation of 2% was observed between the FEA model and the corresponding experimental study. This slight difference can be attributed to the uncertainties present in the material properties of SPF lumber, as discussed in detail in the article. The inherent variability in material properties, including species variations, moisture content, and manufacturing processes, may contribute to the disparities observed between the predicted FEA model response and the actual experimental observations.

Results

The FEA results of braced beams are given in Fig. 6. Fig.6.a and Fig.6.b show the shape of both specimen 2100 and 4200 before the analysis. Fig.6.c. and Fig.6.d show the buckling mode shape of both beams before the brace element was applied. As it's seen in the figures the lateral displacement and the angle of twist peak at the mid-span and vanish at the supports. Fig.6.e and Fig.6.f represent the buckling mode shapes of both beams with an intermediate brace set on both the top and bottom of the beams. It shows the second buckling mode shape of beams with the brace set.

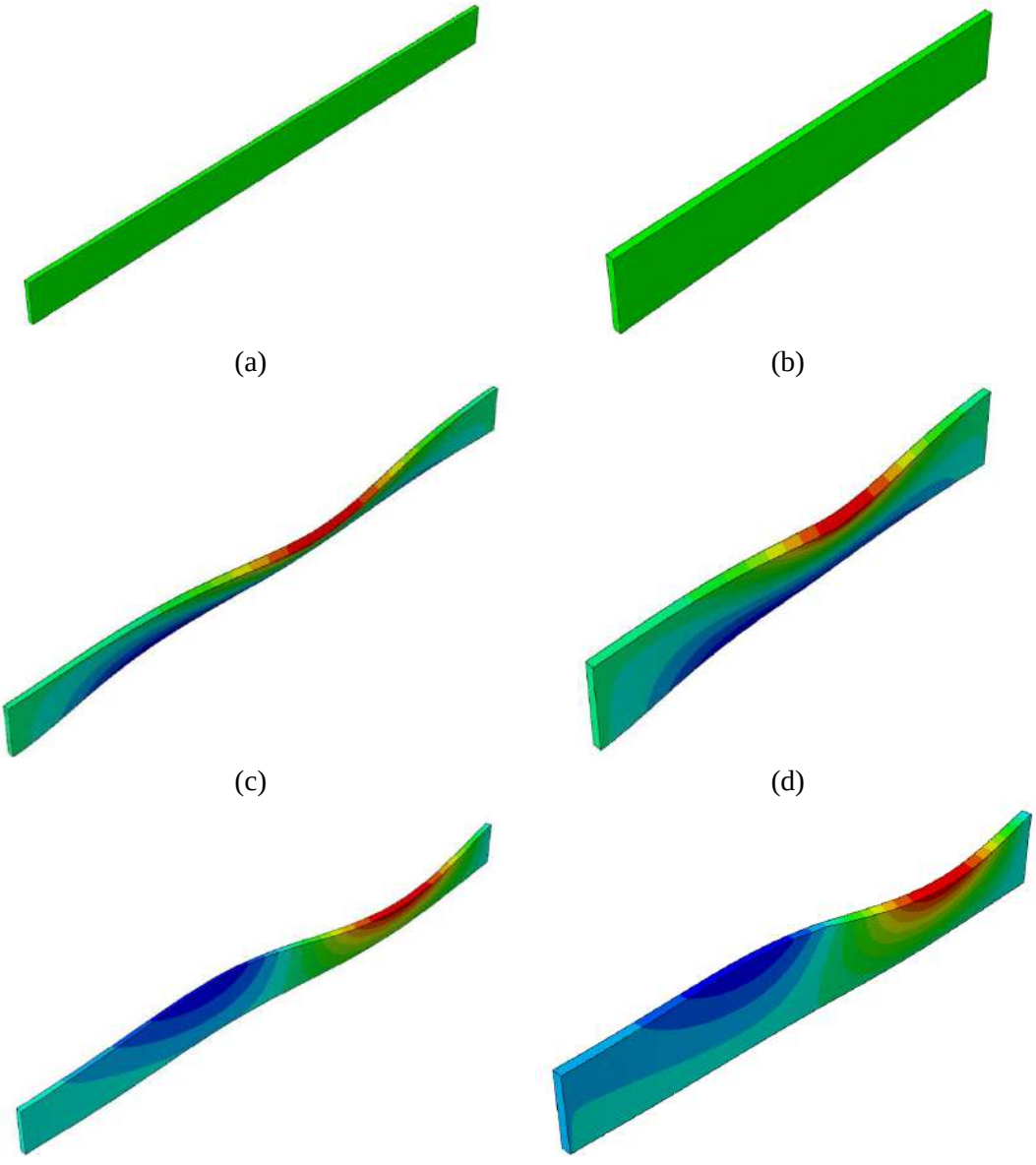


Fig.6. (a) FEA model of 4200 mm span beam before the analysis, (b) FEA model of 2100 mm span beam before the analysis, (c) Analysis result of 4200 mm span beam without brace element, (d) Analysis result of 4200 mm span beam without brace element, (e) Analysis result of 4200 mm span beam with an intermediate brace element, (f) Analysis result of 2100 mm span beam with an intermediate brace element,

Brace force – brace stiffness curves of the beams were drawn and presented in Figure 10. As is seen in Fig.10, when the brace stiffness increases, the brace force demand substantially increases

however after some point the demand of the brace force is reduced with respect to the corresponding moment level. Maximum brace force demand is approximately %6 for the beam with a 2100 mm span and % 0, 77 for the beam with a 4200 mm span according to the graphs. Also, the minimum stiffness values that required preventing lateral torsional buckling are shown in the graphs with the orange lines. The specification-specified stiffness values were obtained by using the bracing calculations in Eurocode 5[2]. For the beam with a 2100 mm span length, bracing calculations are given below.

$$C = k_s \frac{N_d}{a} \longrightarrow N_d = (1 - k_{crit})\frac{M_d}{h}$$

$$k_{crit}\begin{cases} 1 & \lambda_{rel,m} \leq 0{,}75 \\ 1{,}56 - 0{,}75\lambda_{relm} & 0{,}75 < \lambda_{rel,m} \leq 1{,}4 \\ \frac{1}{\lambda_{relm}^2} & 1{,}4 < \lambda_{rel,m} \end{cases} \longrightarrow \lambda_{rel,m} = \sqrt{\frac{f_{m,k}}{\sigma_{mcrit}}}$$

$f_{m,k}$= 11 MPa *for the Spruce − Pine − Fir Lumber*

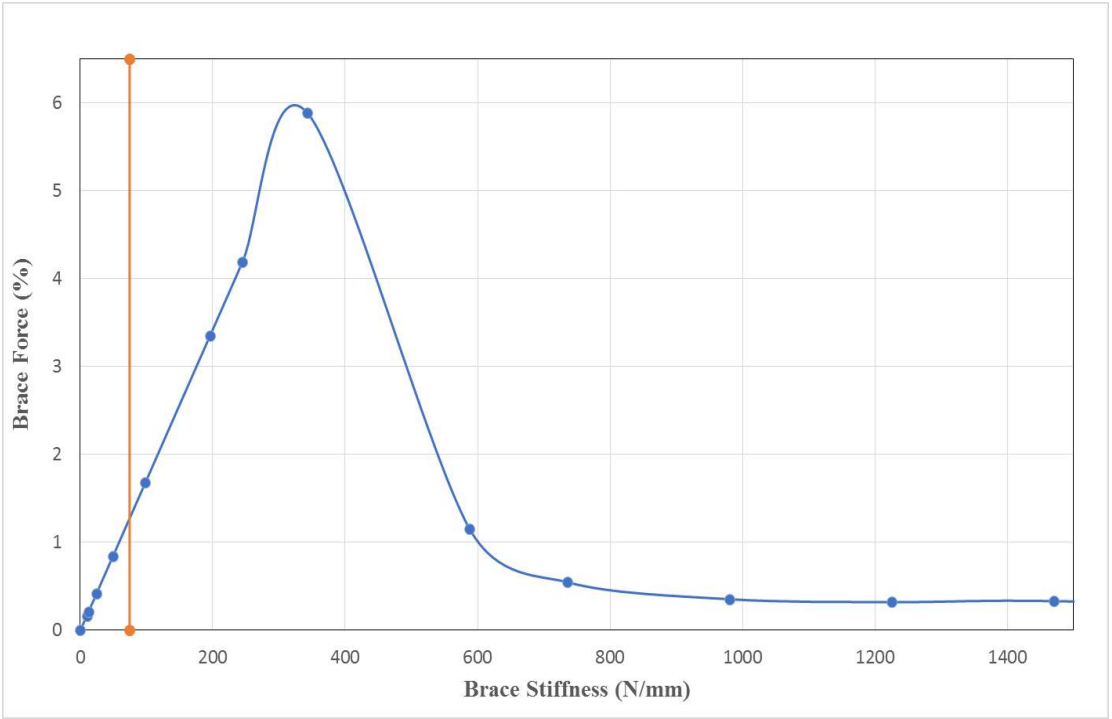
$$\sigma_{mcrit} = \frac{0{,}78.b^2}{h l_{ef}} \epsilon_{0,05} = \frac{0{,}78.38^2}{286.2100}.6469 = 12{,}13147\ MPa$$

$$\lambda_{rel,m} = \sqrt{\frac{11}{12{,}13147}} = 0{,}952 \qquad k_{crit}=0{,}846 \qquad \gamma = 29{,}859 \qquad M_d = 1663200.\gamma\ \ N.mm$$

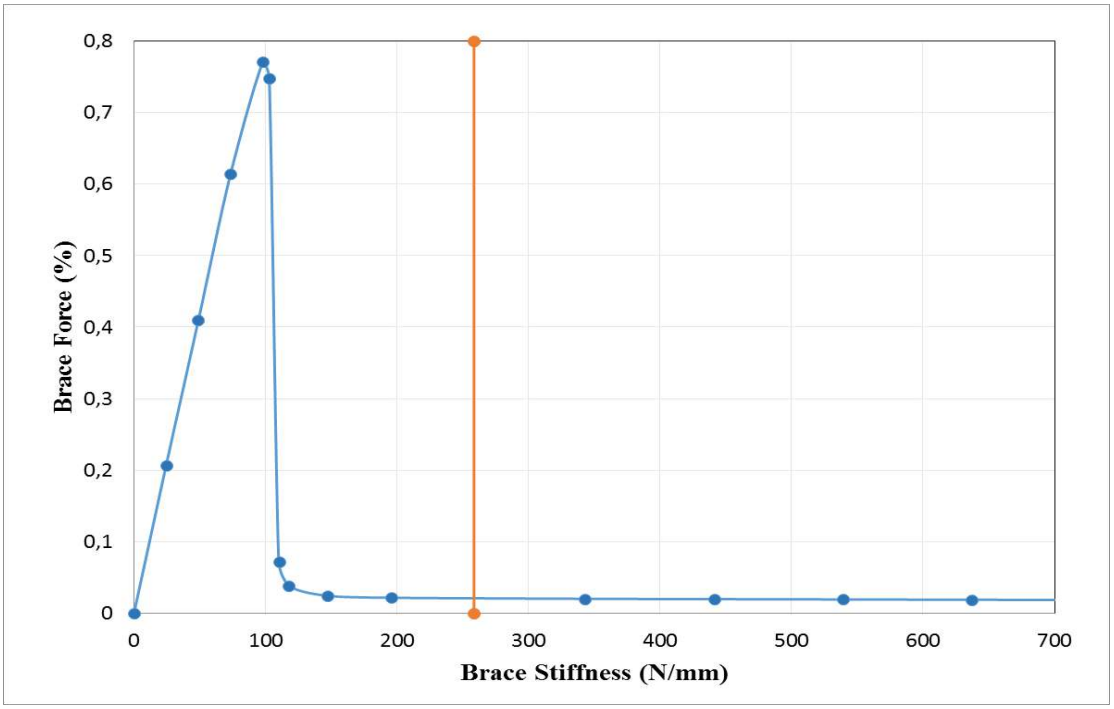
$$N_d = 26740{,}8\ N.mm \qquad C = k_s \frac{N_d}{a} = 4\frac{26740{,}8}{1050} = 101{,}87\ \frac{N}{mm}$$

$k_s = 4$ *from Table2. and* $a = 1050$ *according to Fig.2.*

The stiffness value of the beam with a 4200 mm span was calculated in the same way and the stiffness value was found 297,663 N/mm. When the calculated optimum stiffness values are compared with the FEA analysis results, the brace force corresponding to the calculated stiffness points is much lesser than the FEA result and lesser than the force that beams can resist. Therefore, by enhancing the brace stiffness, the buckling load capacity of the beam can be increased and the buckling of the beam can be prevented more effectively.



(a)



(b)

Fig.10. (a) 2100 mm span length and (b) 4200 mm span length

Conclusion

A comprehensive parametric study was undertaken to examine the optimal level of bracing stiffness for simplified bracing calculations according to Eurocode 5 [2]. The study utilized two timber beams sourced from the research conducted by Q. Xiao et al. [9]. Both beams were modelled with and without bracing elements, and subsequently subjected to linear eigenvalue analysis using a finite element program.

Based on the findings discussed above, it can be inferred that the calculated optimum stiffness, as per Eurocode 5[2], is lower than the stiffness determined by the FEA model for the beam with a span length of 2100 mm. Additionally, at this span length, the brace force corresponding to the calculated stiffness point is found to be lower than the load that the beams can withstand. This suggests that increasing the brace stiffness would result in achieving sufficient buckling load capacity.

However, for the beam with a span length of 4200 mm, the calculated stiffness value surpasses that obtained from the FEA model. This indicates that Eurocode 5 [2] overestimates the required brace stiffness to prevent beam buckling. Consequently, by reducing the brace stiffness, buckling of the beam can still be effectively prevented.

Overall, these findings highlight the significance of selecting appropriate brace stiffness values to ensure structural stability while avoiding unnecessary stiffness requirements. By accurately determining the optimal stiffness, designers can optimize the performance of timber beams and effectively mitigate the risk of buckling.

References

[1] Xiao, Q. (2014). Lateral torsional buckling of wood beams (Doctoral dissertation, Université d'Ottawa /University of Ottawa).

[2] EN 1995-1-1 Eurocode 5-Design of timber structures, Part 1–1, general: common rules and rules for buildings. Brussels (Belgium): CEN; 2014

[3] Hooley, R. F., & Madsen, B. (1964). Lateral stability of glued laminated beams. Journal of the Structural Division, 90(3), 201-218.

[4] Winter, G. (1958). Lateral bracing of columns and beams. Journal of the Structural Division, 84(2), 1561-1.

[5] Song, X., & Lam, F. (2009). Laterally braced wood beam-columns subjected to biaxial eccentric loading. Computers & structures, 87(17-18), 1058-1066.

[6] Hu, Y. (2016). Lateral torsional buckling of wooden beams with mid-span lateral bracing (Doctoral dissertation, Université d'Ottawa/University of Ottawa).

[7] Abaqus, G. (2011). Abaqus 6.11. Dassault Systemes Simulia Corporation, Providence, RI, USA.

[8] SS-EN 1995-1-1: 2004, 6.3.3. and 9.2.5.3.

[9] [9] Xiao, Q., Doudak, G., & Mohareb, M. (2017). Numerical and experimental investigation of lateral torsional buckling of wood beams. Engineering Structures, 151, 85-92.

Laboratory Comparison of SBS and PROpolymer MA123 Modified Asphalt Mixture

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Abstract

In order to enhance the properties of asphalt mix, especially rutting resistance in Iraq due to high temperature, different modifier types have been adopted. Recent studies have shown that in Iraq, the polymer in the form of SBS is highly effective and gives good results in resistance to rutting and other defects. However, its use increases the cost of asphalt concrete and its difficulty storing, leading to the investigation of alternative polymers that should be more reasonable than the SBS polymer. This study examined a polymer named PROpolymer MA123 to measure its applicability to modified asphalt mix. For this purpose, the Asphalt mix was modified with 0.5% of PROpolymer MA123 from asphalt weight. The results showed that applying the new alternative polymers resulted in equal or better performance than the SBS-modified samples.

Keywords: Rutting, SBS, PROpolymer MA123, asphalt mix

Introduction

One of the most prevalent pavement defects in Iraq is rutting. The pavement has longitudinal stripes that can extend for many kilometers and have a depth of tens of centimeters (Figure 1). Unnoticed by drivers, depressed ruts in the road frequently cause accidents and slow down traffic movement on the roads [1-3].

Figure 1. Rutting in Iraq

The performance of the asphalt mixture has been improved, and the pavement's service life has been increased via the employment of several modification types in asphalt road building during the last 20 years. In general, polymer or chemical modification can create modified asphalt mixtures. However, the polymer is the modification type recommended for usage by most organizations. The polymers improve the bitumen's properties and, thus, the performance of the asphalt mixture. Elastomers and plastomers are two categories of polymers that are differentiated based on the physical characteristics and the function of modifiers in enhancing the bituminous qualities. Additionally, reactive elastomeric terpolymer type has begun to spread in modern asphalt roads [4-6].

Many studies have demonstrated that SBS polymer-modified bitumen is highly effective and produces positive results in resistance to rutting and other defects. However, its usage raises the price of

asphalt concrete. Also, it takes a lot of work to store for a long time [7-9]. Thus, finding more affordable and straightforward alternatives than SBS polymer is essential. In this study, the effectiveness of PROpolymer MA123 has been tested to obtain an asphalt mix with high rutting resistance.

Material

This study used 70/100 neat bitumen grade supplied by Gazprom company. To measure the bitumen characteristics, some conventional tests have been conducted for the base bitumen, such as penetration and softening point tests. Table 1 shows the test results according to the GOST (Russian standard) specification.

Table 1. Properties of the neat bitumen

Test	Results	Specification limits
Penetration (25 ºC; 0.1 mm)	85	71-100
Softening point (ºC)	49	47 (min.)
Ductility (25 ºC; cm)	100	62 (min.)
Ductility (0 ºC; cm)	4	3.7 (min.)
Flash point (ºC)	298	230 (min)
Brittleness temperature (ºC)	-21	-21 (min)

The PMB samples were prepared using two polymers, SBS and PROpolymer MA123. The asphalt mixture compositions are demonstrated in Table 2.

Table 2. Mixture compositions

Materials	Composition No.1	Composition No.2	Composition No.3
Crushed stone (%)	55.0	55.0	55.0
Sand (%)	35.0	35.0	35.0
Mineral powder (%)	10	10	10
Neat bitumen (%)	4.6	0	5.1
PMB (%)	0	5.2	0.0
Ma123			0.5 % of asphalt mix

Methods

Density Test

The principle of the method is to determine the average density of samples made in the laboratory or selected from the structural layers of road pavements, taking into account the pores in within the pavement. In this test method, samples are weighed in air then immersed for 30 minutes in a vessel with water having a temperature of (20 ± 2) ° C, so that the water level in the vessel is at least 20 mm higher than the surface of the samples, after that the samples are weighed in water.

Residual Porosity

The aspect of the test method is to determine the volume of pores present in a compacted mixture. The residual porosity of asphalt samples V, %, is determined based on the previously established average and true densities.

Compressive Strength

In this method, the samples are tested at different temperatures using water bath like (50 ± 2) °C, (20 ± 2) °C or (0 ± 2) °C. The temperature (0 ± 2) °C is achieved by mixing water with ice. Samples from hot mixes are kept at a given temperature for 1 hour in water. The sample taken from the water bath is placed in the center of the lower plate of the press, then the upper plate is lowered and stopped

above the level of the sample surface by 1.5-2 mm. After that, the press motor is turned on and the sample is loaded.

Shear Resistance

The loading rate of the samples for both compression schemes is the same which is equal to (50.0 ± 1.0) mm / min. Before testing, the samples and the crimping device are kept for 1 hour at a specified temperature (50 ± 2) °C in water. The sample taken from the water bath is installed in the center of the lower press plate in the first compression scheme or in the lower part of the crimping device in the second compression scheme. During the test of the sample, the maximum reading of the force meter is recorded, which is taken as the breaking load. At the same time, with the help of the displacement indicator, the ultimate deformation corresponding to the breaking load or the beginning of the yield stage is measured.

Results and Dicussion

The obtained results are shown in Figures 2-6.

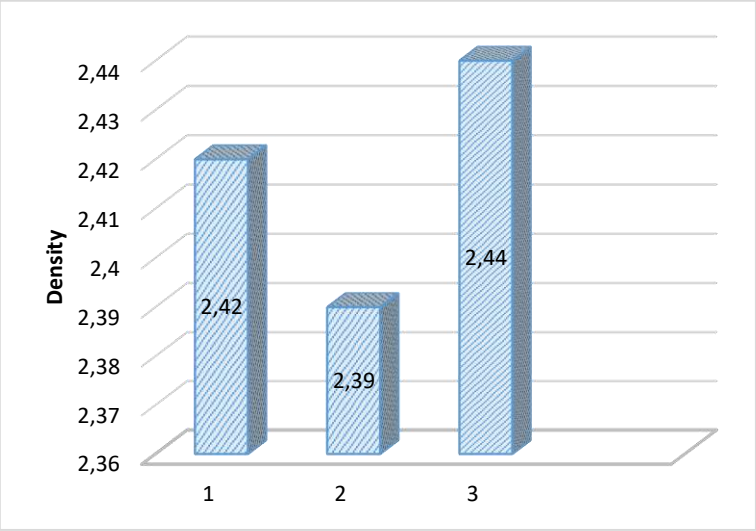

Figure 2. Density results

The average density of the four compositions, which ranges from 2.39 to 2.44, varies slightly (Figure 2). The outcomes demonstrate that adding SBS polymer to the mixture for the second composition causes the density value to drop significantly. The addition of PMB to the mixture resulted in a reduction in compaction efficiency. Compared to a typical mix, the mixtures have a lower density due to the PMB's elastic characteristic. On the other hand, the PROpolymer MA123 is applied as a modification to the mixture may cause the density to increase compared to the other compositions.

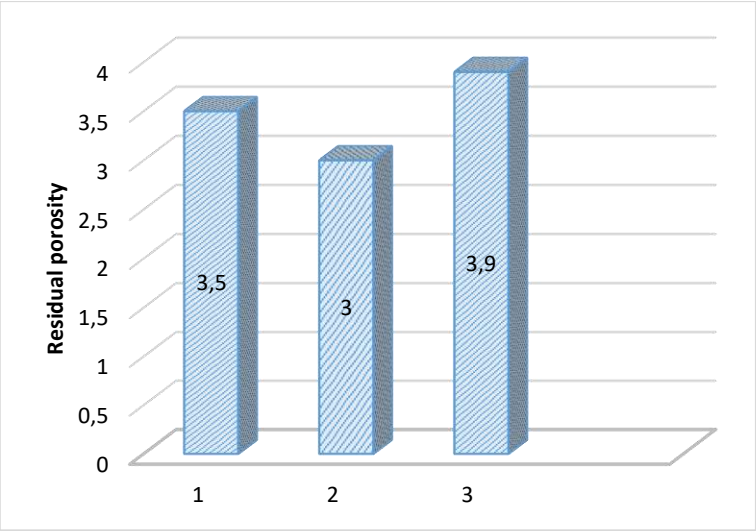

Figure 3. Residual porosity

It is evident from the observed data that the residual porosity results for the three compositions are within the accepted ranges (Figure 3). The loss of adhesion or cohesion is the primary cause of water damage. Compared to the other compositions, composition No. 3 had somewhat higher water saturation. This would suggest that the sample with the PROpolymer MA123 would show greater adhesion and cohesiveness than the characteristics of samples at low temperatures.

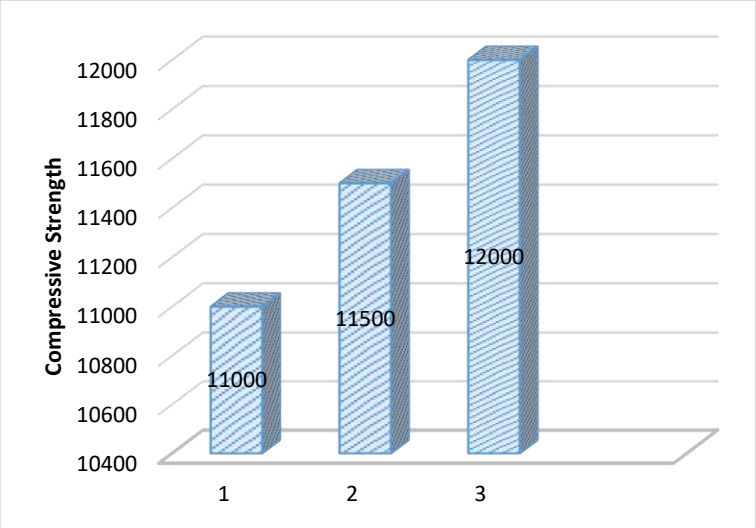

Figure 4. Compressive Strength

All compositions' compressive strength at 60 °C is above the minimum standard limit (Figure 4). The inclusion of MA123 in composition No.3 yielded a higher compressive strength compared to the conventional mixture (No.1). The addition of PMB (combination No.2) increased compressive strength due to the increase in viscosity of the bitumen as the utilized elastomeric polymer (SBS) forms discrete particles in the bitumen and its function as a thickener. Based on the above result, PROpolemer MA123 (composition No.3) showed better behavior than other compositions.

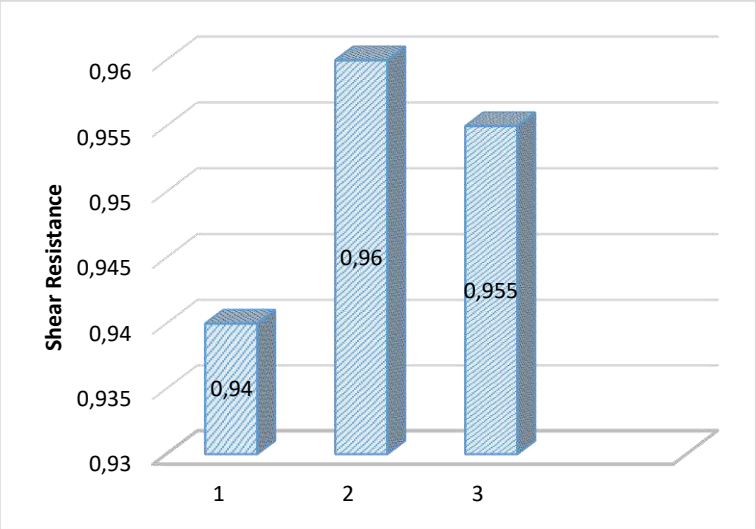

Figure 5. Shear Resistance Using Uniaxial Compression

Composition No. 1 has a low internal friction coefficient compared to the other compositions (Figure 5). The findings, however, are all still over the minimal threshold (min. 0.89). The internal friction coefficient of the asphalt mixes was raised by adding PROpolymer MA123 to composition No. 3. This shows that PROpolymer MA123 has a high internal friction coefficient due to its high concentration. Internal friction angle is significantly influenced by bitumen viscosity as well. High viscosity PROpolymer MA123 causes the particles to interlock more closely, increasing the internal friction angle of the modified asphalt mixture.

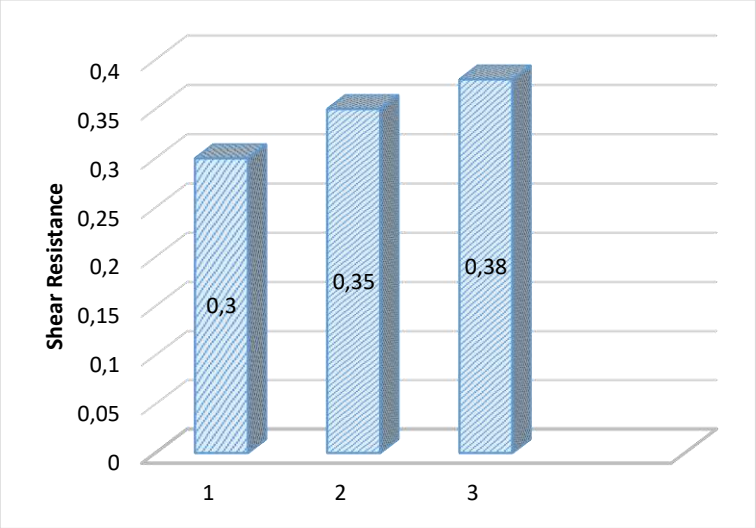

Figure 6. Shear Resistance Using Marshall Stability Breaking Head

All mixtures produced a cohesion value greater than the minimum demanded (minimum 0.3 MPa) (Figure 6). The control sample (composition No. 1) showed the lowest cohesion compared to the other compositions. The cohesiveness value significantly increased due to the PROpolemer MA123's inclusion in composition No. 3.

Conclusion

The purpose of the study is to use several conventional tests to compare the PROpolymer MA123 and the SBS polymer. The results of the study can be summed up as follows:

1. Results show good porosity; water damage due to adhesion/cohesion loss. Composition No. 3 has higher water saturation, indicating better adhesion/cohesiveness.
2. All compositions meet the minimum compressive strength standard at 60 °C. Composition No. 3 with MA123 has the highest strength.
3. Composition No. 1 has low internal friction but still meets the threshold. Adding PROpolymer MA123 to Composition No. 3 increases internal friction.
4. All mixtures exceed the minimum cohesion requirement. Composition No. 1 has the lowest cohesion, while No. 3 with PROpolymer MA123 has the highest.

References

[1] Hilal MM, Fattah MY. Evaluation of Resilient Modulus and Rutting for Warm Asphalt Mixtures: A Local Study in Iraq. Applied Sciences. 2022;12(24):12841.

[2] Albayati AH, Lateif RH. Evaluating the performance of high modulus asphalt concrete mixture for base course in Iraq. Journal of engineering. 2017, 31;23(6):14-33.

[3] AL Sa'adi AH, Al-Khafaji FF, Hashim TM, Hussein ML, Ali YA, Ali AH, Jebur YM, Ali LH, Al-Mulali MZ, Al-Khazraji AA. Prospect of using geotextile reinforcement within flexible pavement layers to reduce the effects of rutting in the middle and southern parts of Iraq. Journal of the Mechanical Behavior of Materials. 2022; 13;31(1):323-36.

[4] Almusawi A, Sengoz B, Ozdemir DK, Topal A. Economic and environmental impacts of utilizing lower production temperatures for different bitumen samples in a batch plant. Case Studies in Construction Materials. 2022; 1;16: e00987.

[5] Diab A, Pais J, Chen S, Gupta A, Li X, You L, Hasan MR. High, intermediate and low temperature performance appraisal of elastomeric and plastomeric asphalt binders and mixes. Journal of Elastomers & Plastics. 2022;54(2):225-46.

[6] Almusawi A, Sengoz B, Topal A. Evaluation of mechanical properties of different asphalt concrete types in relation with mixing and compaction temperatures. Construction and Building Materials. 2021; 25;268:121140.

[7] Sengoz B, Isikyakar G. Evaluation of the properties and microstructure of SBS and EVA polymer modified bitumen. Construction and Building Materials. 2008; 1;22(9):1897-905.

[8] Almusawi A, Shoman S, Lupanov AP. Assessment of the effectiveness and the initial cost efficiency of hot recycled asphalt using polymer modified bitumen. Case Studies in Construction Materials. 2023; 1;18:e02145.

[9] Zhu J, Lu X, Kringos N. Experimental investigation on storage stability and phase separation behaviour of polymer-modified bitumen. International Journal of Pavement Engineering. 2018; 2;19(9):832-41.

Kendinden Yerleşen Harç Üretiminde Süper Akışkanlaştırıcı Toz Katkı Türünün İncelenmesi

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Özet

Farklı kombinasyonlarda hazırlanan harçlar, inşaat sektöründe farklı amaçlarla yaygın olarak kullanılan malzemelerdendir. Harç malzemeler genellikle genel amaçlı örgü harcı, sıva harcı ve/veya yapıştırma harcı uygulamaları için kullanımları sıklıkla görülmektedir. Teknik olarak daha yüksek niteliğe sahip formlarda üretilip tamir-tarama uygulamaları için kullanılabildiği gibi, bina yalıtımına yardımcı olma amaçlı kullanımlarının yanı sıra tesviye amaçlı şap uygulamalarında da kullanımları görülmektedir. Her bir uygulama yerine göre harcın bileşenleri, kompozisyonu, uygulamadaki kıvamı ve sertleşmiş harç formundaki teknik özellikleri birbirinden farklılıklar göstermektedir. Özellikle son yıllarda kendinden yerleşen, uygulamada sıkılaştırma ve vibrasyona ihtiyaç duymaksızın kullanım yerinde kolaylık sağlayan ve yüksek mukavemet özelliklerine de sahip harç kombinasyonları giderek önem kazanmaktadır. Bu amaçla geliştirilmiş harç türevlerinin sıklıkla tesviye amaçlı şap uygulamalarında kullanımları görüldüğü gibi, yatay düzlemde tamir-tarama amaçlı harç uygulamalarında da kullanımları görülebilmektedir. Ancak, harcın kendinden yerleşebilme özelliğini sağlayan ana etken parametrelerin teknik olarak detayları yeterince tecrübe edinilmemiştir. Bu bağlamda, ince tane boyutuna sahip malzemelerden yapılan bir harcın kendinden yayılabilme özelliğine etken bileşenlerinin araştırılması ve optimum uygulama koşullarının belirlenmesi önem arz etmektedir.

Bu çalışmada, çimento bağlayıcılı farklı orijinlere sahip ince taneli agrega malzemelerin ana bileşen malzeme olarak kullanıldığı ve yenil nesil kategorisinde nitelendirilen 2 ayrı farklı türdeki süper akışkanlaştırıcı toz katkı malzemesinin kullanımıyla oluşturulan alternatif harç karışımlarının deneysel olarak teknik özellikleri karşılaştırmalı olarak analiz edilmektedir.

Çalışma kapsamında öncelikle kendinden yerleşen harç kombinasyonunun karışım bileşenlerinin ön değerlendirmesi amacıyla bir seri çimento+agrega+toz katkı formundan oluşan referans bir harç karışımı tasarlanarak teknik değerleri belirlenmiştir. Daha sonra, çalışma kapsamı detaylandırılarak hafif ve doğal gözenekli agrega malzeme kullanılarak yeni karışım tasarımları olarak bir seri alternatif malzeme bileşenli harç karışımları oluşturulmuştur. Her bir harç tasarımı için ayrı ayrı test örnekleri hazırlanarak, her bir karışımın kıvamı, kendinden yayılabilme özellikleri, yoğunluk gibi teknik değerlerinin yanı sıra, elde edilen sertleşmiş harç örneklerinin mekanik dayanım değerleri analiz edilmiştir.

***Anahtar kelimeler*:** Harç, kendinden yerleşen şap, akışkanlaştırıcı, katkı, analiz

1. Giriş

Kendiliğinden yerleşen (yayılan) harçlar (KYH), vibrasyona ihtiyaç duymadan yerleşebilme, sık donatıların arasından geçebilme gibi özelliklere sahip olması sebebiyle uygulama sırasında kullanım kolaylığı sağlamaktadır. Geleneksel harç malzemeleriyle aynı içeriğe sahip ve kendiliğinden yerleşme özelliği kimyasal katkı/katıların ilavesiyle sağlanabilmektedir. Kendiliğinden yayılan şap harcı, genellikle bağlayıcılar, dolgu malzemeleri, yeniden dağılabilir polimerler ve katkılardan oluşan kompozit bir yapıya sahiptir. İlk pompalanabilir kendiliğinden yayılan zemin kaplama malzemesi 1970'lerin ortasında geliştirilmiştir [1]. Geliştirilen ilk üründe, bir üst döşeme uygulamadan önce beton zeminleri düzleştirmenin kolay ve hızlı bir yolunu elde etmek amacıyla Portland çimentosu, kazein bazlı akıcı bir madde ile birlikte bağlayıcı olarak kullanılmıştır [2]. Genellikle üç temel kullanımı yeri söz konusudur. İlk olarak; yatay yüzeyleri düzleştirmek, zemin seviyelerini yeni eşiklere uyacak şekilde yükseltmek veya yırtma veya malalama zahmeti ve masrafı olmadan eski zeminlere yeni bir soluk getirmek için kullanılır. Örnek olarak PVC fayans, seramik, granit seramik, mermer, doğal granit, parke, halı, lamine parke, laminant parke, kauçuk döşeme gibi malzemelerin

altında zemini düzeltmek, tesviyeye, teraziye getirmek için kullanılabilir [3]. İkinci kullanım yeri ise, zemin kaplamasına ihtiyaç duymadan gerçek bitmiş zemin olarak hareket etmek için projenin başlangıcından itibaren kendiliğinden yayılan harcı son kat uygulama olarak yapmaktır. Kendiliğinden yayılan harcın üçüncü kullanımı ise, köprü veya yol gibi uygulamalarda hasarlı beton için onarım malzemesi olarak kullanılır. Özellikle ulaşılması güç olan bölgelerin tamiratında avantajları da en önemli kullanım alanlarındadır [4].

Kendiliğinden yerleşen harç, herhangi bir titreşim veya sıkıştırma gerektirmez. Geleneksel şaplar, yüzey kusurlarını düzeltmek ve zeminlere eğim vermek için kullanılan yapı malzemeleri arasında değerlendirilmektedir. Geleneksel çimento esaslı şaplar, yüzey düzlemek için fazladan işçilik gerektirmekte ve normal yoğunluklu agregalar kullanılarak üretildiği için binalarda fazladan ölü yük oluşturmaktadır. Günümüzde yaygın olarak kullanılan kendiliğinden yayılan harç malzemelerin yoğunluk aralığı çoğunlukla 2000 ile 2200 kg/m^3 arasında olup 2400 ile 2600 kg/m^3 arasında değişen normal harç yoğunluk değerlerinden daha düşüktür [5-7]. Bu nedenle, binalarda uygulandığı alanlarda binanın ölü yükünü azaltıcı önemli bir etken sağlar. Kendiliğinden yerleşen harçların en dikkat çekici dezavantajı, yüksek akışkanlık özelliğinden dolayı dikey yüzeylerde uygulanamıyor olmasıdır. Kimyasal katkılar harcın veya betonun taze ve sertleşmiş haldeki özelliklerini iyileştirebilmek için kullanılırlar. Kimyasal katkı maddeleri, çimento ile etkileşime girerek fiziksel, kimyasal ya da fiziko-kimyasal bir reaksiyona girip betonun/harcın özelliklerini değiştirirler [8]. Bu uygulama şeklinin temel etkisi genelde fizikseldir. Eğilme ve/veya basınç dayanım özelliklerini iyileştirmek, geçirimsizlik ve durabilite özelliklerini geliştirmek, tane yoğunluk farklılığı sebebiyle harç matrisinde oluşan tane ayrışmasına (segregasyona) uğramadan harç hamurunun kıvamını artırmak, rötreyi azaltmak ve priz süresinin ayarlanması gibi birçok olumlu özelliğe sahiptir. Suda çözünebilen bu katkılar genel olarak üç amaç doğrultusunda gruplandırılır; Su/çimento oranını minimalize edip yüksek dayanımlı beton elde etmek, akışkanlık sağlayıp işlenebilirliği artırmak ve hidratasyon ısısının düşürülmesi gereken yapılarda çimento miktarının azaltılmasına karşın aynı işlenebilirliği sağlamak. Su azaltıcı katkılar, yüksek oranda su azaltıcı (süper akışkanlaştırıcı), su tutucu, hava sürükleyici, priz hızlandırıcı, sertleşme hızlandırıcı, priz geciktirici, su geçirimsizlik katkıları olarak 8 tür katkı sınıfı mevcuttur [9]. Çalışma doğrultusunda kullanılacak katkılar ise su azaltma yeteneği olan katkılardır. Bu katkı türleri kendi aralarında; Su azaltma yeteneği %10-15 arası olanlar normal akışkanlaştırıcı, su azaltma yeteneği %15-30 arası olanlar süper akışkanlaştırıcı, su azaltma yeteneği %30'dan fazla olanlar hiper akışkanlaştırıcı olarak 3 farklı sınıfta yer alır [9] Güncel uygulamalarda kullanımları da görülen Polikarboksilat bazlı katkılar, melamin sülfonat formaldehit polikondanseleri, polinaftalin sülfonatlar ve modifiye edilmiş lignosülfonat bazlı katkılar süper akışkanlaştırıcı katkılara örnek olarak verilebilir. Süper akışkanlaştırıcılar su içerisinde eriyen boşluklu kimyasal dizilişleri ile suyun yüzey gerilimini düşüren, çimento topaklaşmasını önleyerek daha etkili hidratasyon reaksiyonların gerçekleşmesini sağlayan organik maddelerdir. Süper akışkanlaştırıcı katkıların en önemli niteliği uzun makro moleküllerinin çimento taneleri üzerinde adsorplanması ve bunun sonunda taneleri dağıtmaları, böylece daha kapsamlı bir hidratasyona olanak sağlamaları, ayrıca sıvı ortamdaki viskoziteyi ve kayma eşiğin düşürerek yerleşmeyi kolaylaştırmalarıdır [10]. Süper akışkanlaştırıcı kimyasal katkılar, aynı işlenebilirlikte daha az miktarda karışım suyu kullanılarak beton üretimine olanak sağlar. Bununla birlikte, kimyasal katkıların gelişim süreci irdelendiğinde ihtiyaca yönelik ve uygulamalarda ortaya çıkan sorunların çözülmesi amacıyla sürekli bir gelişme eğilimi sergilediği görülebilmektedir. Bu akışkanlaştırıcı katkılar gelişim sürecindeki tecrübe edinilen bulgulara bağlı olarak sıralı nesil kategorileri olarak da nitelendirebildikleri görülmektedir. Bu bağlamda, lignosülfonat bazlı süper akışkanlaştırıcı katkılar 1. nesil olarak adlandırılmışlardır. Lignosülfonatlar genellikle yüksek oranda şeker içeriği nedeniyle priz gecikmesine sebep olmuş ayrıca bu katkının sürüklediği hava kabarcıklarının çapı donma/çözünme direncinde etkili havanın çapından büyük olması ve bu nedenle dayanımı düşürmesinden kaynaklı değişime ihtiyaç oluşturmuştur. Konu üzerinde yapılan çalışmalarda bu sorunların giderilmesi amacıyla lignosülfonat içeriğindeki şeker rafine edilerek modifiye edilmiş lignosülfonatlar geliştirilmiştir. Bu katkının optimum su kesme yüzdesi literatürde %10 olarak belirtilmiştir [11]. Su kesme özellikleri %10-15 oranındadır. 2 nesil olarak adlandırılan katkılar ise melamin (smf) ve naftalin formaldehit sülfonatlardır. Bu katkıların kullanımı sırasında karşılaşılan en büyük sorun ise zamanla betonda meydana gelen işlenebilirlik kaybıdır. Bu sorunun çözümü katkı oranını arttırmak olarak belirlenmiş ve bu da maliyeti arttırdığından yeni bir katkı türü ihtiyacı oluşturmuştur [11]. Bu problemler sonucunda 3. nesil polikarboksilat bazlı akışkanlaştırıcılar geliştirilmiştir. Bu katkılarda yüksek işlenebilirlik ve yüksek (%30) oranda su kesme özelliğine sahip olabildikleri rapor edilmiştir [11]. Bu çalışma kapsamında 2 farklı süper akışkanlaştırıcı olan polikarboksilat ve melamin sülfonat katkılarının reolojik özelliklerini irdeleyip karşılaştırmak amaçlanmaktadır. Çalışma kapsamındaki test ve incelemeler TS EN 13813 "*Şap Malzemeleri ve*

Zemine Uygulanan Şaplar-Şap Malzemeleri- Özellikler ve Gerekler" [12] standardında öngörülen prensiplere göre yapılmıştır. Araştırma bulgularından hangi tür süper akışkanlaştırıcı toz katkının bu harç kombinasyonları için daha uygun sonuçlar oluşturduğu ve katkı kullanımıyla oluşan avantaj ve dezavantajlar karşılaştırmalı olarak tartışılmıştır.

2. Materyal ve Metot

2.1 Test Örneklerinde Kullanılan Malzemeler

Bu çalışmada agrega malzemesi olarak kare göz açıklıklı elekler ile sınıflandırılmış 0-1 mm ve 1-4 mm boyutunda yoğunlukları 1500±5 kg/m^3 standart kum agrega kullanılmıştır. Harç karışımlarının işlenebilirlik ve dayanımını artırmak amacıyla polikarboksilat ve melamin sülfonat olarak 2 tür akışkanlaştırıcı katkı kullanılmıştır. Bu katkılar toz formunda, düşük sıcaklıklarda kullanılabilen, beyaz renkli, suda kolay çözünebilen ve yoğunlukları ortalama 550±50 kg/m^3 olan yeni nesil süper akışkanlaştırıcılardır. Şap harçlarına katılan elyaf lif katkılar hamur içerisinde düzgün dağılan ve rastgele yönlenen lifler olması sebebiyle çekme ve basınç gerilmelerine karşı matris yapıda önemli birer donatı vazifesi görürler. İncelikleri ortalama 5-27 µm arasında değişen liflerdir. Bu lif katkısı, şap harcının yüksek mukavemet ve basınç dayanımı sağlaması, yüksek sıcaklık dayanımı ve gelişmiş darbe dayanımı sağlaması amacıyla kullanımı düşünülmüştür. Bununla birlikte lif katkısı ayrıca şap harcının priz sonrası oluşabilecek rötre çatlaklarını ve mikro çatlakları engellemesi, şapın su geçirgenliğini azaltılmasına katkı sağlaması, sertleşmiş şap yüzeyinin yüzey aşınması ve tozumasını önlemesi gibi teknik avantajları sebebiyle de kullanımı düşünülmüştür. Dolgu maddesi olarak maksimum tane boyutu 75 mikron olan kuvars ve şap harcının dayanım değerini arttırmak amacıyla mukavemet arttırıcı polimer toz katkı (yoğunluğu 550±35 kg/m^3) kullanılmıştır. Ana bağlayıcı materyal olarak CEM I 42.5R Portland Çimento kullanılmış olup, karma suyu olarak şehir şebeke suyu kullanılmıştır.

2.2 Malzemelerin Kullanım Oranları ve Örneklerin Hazırlanması

Çalışma kapsamında hazırlanan tüm karışımlarda toplam katı miktarı 1800gr olarak sabit tutulmuştur. Mukavemet attırıcı katkı oranı toplam karışımın ağırlıkça %0,3'ü ve lif katkı oranı da %0,1'i olarak tüm karışımlarda sabit kullanılmıştır. Karışım suyu oranı ise çimento oranına göre belirlenerek eşdeğer serilerde eşit oranda tutularak hazırlanmıştır. Optimum katkı oranını belirlemek için iki ayrı seri seri karışımda çimento ağırlığının %0,25 ve %0,35'i oranlarında polikarboksilat bazlı akışkanlaştırıcı, ayrıca çimento ağırlığının %1,25 ve %1,75'i oranlarında da melamin sülfonat katkısı olacak şekilde ayrı karışım serileri hazırlanmıştır. Dolgu maddesi olarak kullanılan kuvars kullanım oranı ise çimento ve diğer karım bileşenlerinin ağırlığından geri kalan oranın %16'sı olarak sabit değerde kullanılmıştır. Kum oranı ise karışım tasarımlarında bağlayıcı malzeme, akışkanlaştırıcı, dolgu katkıları ve lif katkı miktarları toplamı haricinde, agrega olarak ince kum malzemenin etkinliğinin irdelenmesi amacıyla toplam agrega malzemenin ağırlıkça %60'ı 0-1 mm kum ve ağırlıkça %40'ı 1-3 mm kum malzemeden oluşacak şekilde tasarlanmıştır. Deney şap harcı örneklerinin hazırlanmasında çimento oranları her katkı oranı için sırasıyla %30, %34, %38, %42 ve %45 olarak belirlenmiştir. Karışımın Su/Katkı oranı yüksek dozaj çimentodan başlanarak giderek azaltılmıştır. Çimento esaslı kendiliğinden yayılan şap harcının üretiminde 2 farklı tür akışkanlaştırıcı katkıların kullanımının harcın performansına etkisinin analizi amacıyla bu çalışma kapsamında toplamda 12 ayrı karışım tasarımı yapılmış ve karışım bileşenleri 1800 gr harç üretimi için kullanılan malzeme miktarları olarak Tablo1- Tablo 4'te sırasıyla verilmiştir.

Tablo 1. KYH karışım tasarımı (ağırlıkça %0,25 polikarboksilat süper akışkanlaştırıcı kullanımlı)

Karışım Kodu	Çimento (%)	0-1 mm Kum (%)	1-4 mm Kum (%)	Dolgu (75 mikron kuvars) (%)	Lif (%)	Akışkanlaştırıcı Katkı (%0,25)	Mukavemet Artırıcı Katkı (%)	Karışım Suyu (%)
PH1-1	30	35	23,33	11,2	0,1	0,075	0,3	0,45
PH1-2	34	32,97	21,98	10,56	0,1	0,085	0,3	0,45
PH1-3	38	30,95	20,63	9,92	0,1	0,095	0,3	0,45
PH1-4	42	28,93	19,29	9,28	0,1	0,105	0,3	0,45
PH1-5	45	27,41	18,28	8,8	0,1	0,1125	0,3	0,45

Tablo 2. KYH karışım tasarımı (ağırlıkça % 0,35 polikarboksilat süper akışkanlaştırıcı kullanımlı)

Karışım Kodu	Çimento (%)	0-1 mm Kum (%)	1-4 mm Kum (%)	Dolgu (75 mikron kuvars) (%)	Lif (%)	Akışkanlaştırıcı Katkı (%0,35)	Mukavemet Arttırıcı Katkı (%)	Karışım Suyu (%)
PH2-1	30	34,99	23,32	11,2	0,1	0,105	0,3	0,45
PH2-2	34	32,95	21,97	10,56	0,1	0,119	0,3	0,45
PH2-3	38	30,93	20,62	9,92	0,1	0,133	0,3	0,45
PH2-4	42	28,91	19,23	9,28	0,1	0,147	0,3	0,45
PH2-5	45	27,39	18,26	8,8	0,1	0,1575	0,3	0,45

Tablo 3. KYH karışım tasarımı (ağırlıkça % 1,25 melamin sülfonat süper akışkanlaştırıcı kullanımlı)

Karışım Kodu	Çimento (%)	0-1 mm Kum (%)	1-4 mm Kum (%)	Dolgu (75 mikron kuvars) (%)	Lif (%)	Akışkanlaştırıcı Katkı (%1,25)	Mukavemet Arttırıcı Katkı (%)	Karışım Suyu (%)
MSH1-1	30	34,83	23,21	11,2	0,1	0,375	0,3	0,5
MSH1-2	34	32,76	21,85	10,56	0,1	0,425	0,3	0,5
MSH1-3	38	30,72	20,48	9,92	0,1	0,475	0,3	0,5
MSH1-4	42	28,68	19,12	9,28	0,1	0,525	0,3	0,5
MSH1-5	45	27,14	18,1	8,8	0,1	0,5625	0,3	0,5

Tablo 4. KYH karışım tasarımı (ağırlıkça % 1,75 melamin sülfonat süper akışkanlaştırıcı kullanımlı)

Karışım Kodu	Çimento (%)	0-1 mm Kum (%)	1-4 mm Kum (%)	Dolgu (75 mikron kuvars) (%)	Lif (%)	Akışkanlaştırıcı Katkı (%1,75)	Mukavemet Arttırıcı Katkı (%)	Karışım Suyu (%)
MSH2-1	30	34,72	23,15	11,2	0,1	0,525	0,3	0,5
MSH2-2	34	32,67	21,78	10,56	0,1	0,595	0,3	0,5
MSH2-3	38	30,62	20,39	9,92	0,1	0,665	0,3	0,5
MSH2-4	42	28,56	19,03	9,28	0,1	0,735	0,3	0,5
MSH2-5	45	27	18	8,8	0,1	0,7875	0,3	0,5

Bu karışım tasarımlarına göre karışımda yer alan malzemeler birlikte bir mikser kabı içerisinde düşük devirli karıştırma ortamında homojen bir toz form elde edilinceye kadar ortalama 3 dakika karıştırılmıştır. Sonrasında belirlenen sabit su/çimento oranında karışıma karma suyu eklenerek karıştırma işlemine 3 dakika boyunca topaklanma olmaksızın homojen bir karışım elde edilinceye kadar karıştırılmaya devam edilmiştir. Elde edilen taze harç daha sonra test örneklerinin kalıplanması ve ayrıca yaş harç ölçümleri için hazır hale getirilmiştir. Karıştırma sonrasında test örneklerinin kalıplanması 20±2°C de yaklaşık 15 dakikalık süre içerisinde yapılmıştır. Yaş taze harç formundaki test örneklerinin öncelikle yayılma tablası yöntemi kullanılarak "mm" biriminde yayılma değerleri kıvam değerlendirmelerinin yapılabilmesi amacıyla yapılmıştır. Test örneklerinin TS EN 13813 standardında öngörülen eğilme dayanımı, basınç dayanımı, priz alma ve su emme gibi parametrelere uygunluğunu test etmek amacıyla her katkı türü ve her katkı oranı için ayrı ayrı 6'şar adet örnek TS EN 13892-1'de belirtildiği şekilde hazırlanmış olup, 50x50x50 mm^3'lük küp numune kalıpları kullanılmıştır. Tüm test örnekleri 1 gün sonra kalıptan çıkarılıp daha sonra 7 gün boyunca nemli ortamda bekletilmiştir. 7. günden sonra numuneler normal oda sıcaklığındaki ortamda bekletilmiştir. Taze yaş harcın karışım sonrası birim hacim ağılık değerleri ölçülmüş olup, bununla birlikte kalıptan çıkarılmış harç örneklerinin sırasıyla 1. gün, 7. gün ve 28. günde birim hacim ağılık değerleri ölçülerek kaydedilmiştir. Ayrıca karma işlemi sonrası her bir taze harç karışımının kıvam değerleri

yayılma tablası yöntemiyle ölçülmüştür. Priz alma sürecindeki test örneklerinin 7. ve 28. günlerde TS EN 13892-2'de öngörüldüğü prensiple basınç dayanımı değerleri deneysel olarak belirlenmiştir. Basınç dayanımı deneyinde numunelere deney cihazının yatak yüzeyi ve yatak plakaları temiz bir bezle silinmiş ve numune, döküm esnasında altta kalan yüzeye yük uygulanacak şekilde, ayarlama tertibatı kullanılarak deney cihazına yerleştirilerek testler uygulamıştır. Hazırlanan her bir karışıma ait test örneklerinden priz süresi tayini ve sertleşmiş harç örneklerinin atmosfer ortam koşullarında su emme analizleri de yapılarak, matris yapılarındaki gözeneklilik değerleri belirlenmiştir.

3. Araştırma Bulguları

Çimento esaslı kendiliğinden yayılan şap harcının üretiminde akışkanlaştırıcı katkı oranı ve türünün harcın performansına etkisinin analizi amacıyla farklı alternatif karışım tasarımlarında hazırlanan test örneklerinin bazı analiz bulguları sırasıyla Tablo 5 - Tablo 8'de verilmiştir. Polikarboksilat esaslı süper akışkanlaştırıcı katkılı harçlarda her iki katkı oranında toz yığın birim hacim ağırlık (BHA) 1290 kg/m^3-1340 kg/m^3 arasında değişmektedir. Melamin sülfonat bazlı süper akışkanlaştırıcı katkılı karışımlarda ise toz yığın yoğunluğu 1140 kg/m^3 ile 1460 kg/m^3 arasında değişmektedir. Her iki tür akışkanlaştırıcı kullanımında çimento oranı azaldıkça yaş harcın yayılma değerlerinin azaldığı ve dolayısıyla kendinden yayılma performansının düştüğü belirlenmiştir. Bunda etken olan faktör, çimento oranının azalması süper akışkanlaştırıcı katkı oranını düşürmekte, buna bağlı olarak su ihtiyacını azaltmakta ve harcın yayılma değerini düşürmektedir. Yayılma değeri polikarboksilat katkılı harçlarda 150 mm ile 350 mm arasında, melamin sülfonat katkılı karışımlarda ise 100 mm ile 290 mm arasında değişmektedir.

Tablo 5. Ağırlıkça %0,25 polikarboksilat süper akışkanlaştırıcı katkılı KYH örneklerinin analiz bulguları

Karışım Kodu	Toz Yoğunluk (kg/m^3)	Yaş Yoğunluk (kg/m^3)	Yayılma Değeri (mm)	Sertleşmiş BHA, 7d (kg/m^3)	Sertleşmiş BHA, 28d (kg/m^3)	Basınç Dayanımı (7.gün) (N/mm^2)	Basınç Dayanımı (28.gün) (N/mm^2)	Su Emme (%)	Görünür Gözeneklilik (%)
PH1-1	1343	2124	15	2321	2302	34,10	42,34	5,07	11,31
PH1-2	1319	2106	27	2228	2210	30,10	40,13	4,46	10,16
PH1-3	1332	2001	29	2208	2164	36,00	48,64	4,53	9,88
PH1-4	1290	2090	31	2181	2121	51,35	46,20	4,42	9,26
PH1-5	1300	2000	32	2119	2062	46,23	48,10	4,25	8,80

Tablo 6. Ağırlıkça %0,35 polikarboksilat süper akışkanlaştırıcı katkılı KYH örneklerinin analiz bulguları

Karışım Kodu	Toz Yoğunluk (kg/m^3)	Yaş Yoğunluk (kg/m^3)	Yayılma Değeri (mm)	Sertleşmiş BHA, 7d (kg/m^3)	Sertleşmiş BHA, 28d (kg/m^3)	Basınç Dayanımı (7.gün) (N/mm^2)	Basınç Dayanımı (28.gün) (N/mm^2)	Su Emme (%)	Görünür Gözeneklilik (%)
PH2-1	1342	2081	27	2308	2312	35,00	45,00	4,95	11,15
PH2-2	1340	2100	29	2229	2201	35,00	47,00	4,45	10,06
PH2-3	1317	2012	31	2000	2019	38,74	61,30	4,73	9,30
PH2-4	1305	2000	32	2113	2087	44,60	64,30	4,34	8,97
PH2-5	1306	2010	35	2176	2044	32,50	46,20	3,81	8,11

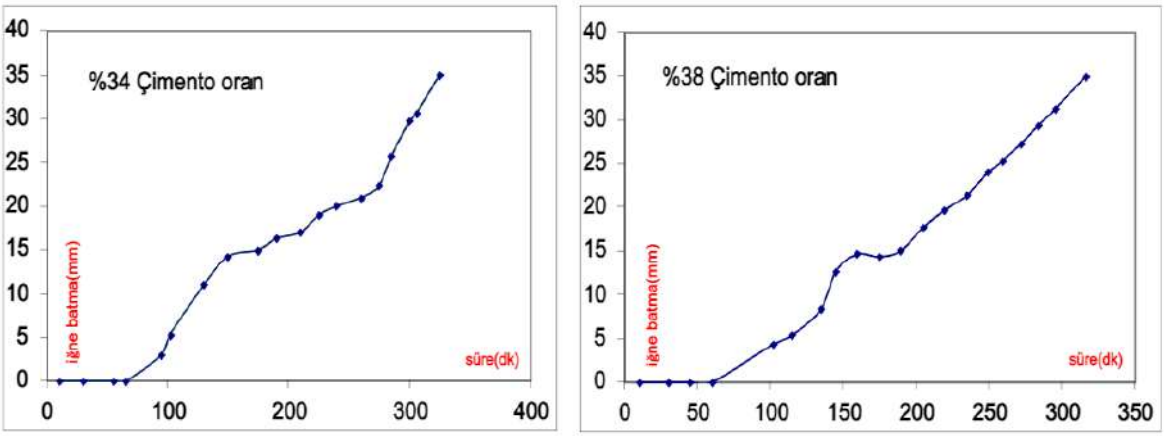
Tablo 7. Ağırlıkça %1,25 melamin sülfonat bazlı süper akışkanlaştırıcı katkılı KYH örneklerinin analiz bulguları

Karışım Kodu	Toz Yoğunluk (kg/m^3)	Yaş Yoğunluk (kg/m^3)	Yayılma Değeri (mm)	Sertleşmiş BHA, 7d (kg/m^3)	Sertleşmiş BHA, 28d (kg/m^3)	Basınç Dayanımı (7.gün) (N/mm^2)	Basınç Dayanımı (28.gün) (N/mm^2)	Su Emme (%)	Görünür Gözeneklilik (%)
MSH1-1	1460	2048	10	2271	2217	15,00	21,50	4,10	9,10
MSH1-2	1314	2080	16	2152	2104	20,00	22,50	4,14	8,63
MSH1-3	1333	2048	22	2132	2088	23,77	24,50	4,04	8,18
MSH1-4	1357	1995	24	2045	2000	18,50	40,32	4,13	8,17
MSH1-5	1314	2055	27	2088	2054	16,30	28,50	3,99	8,25

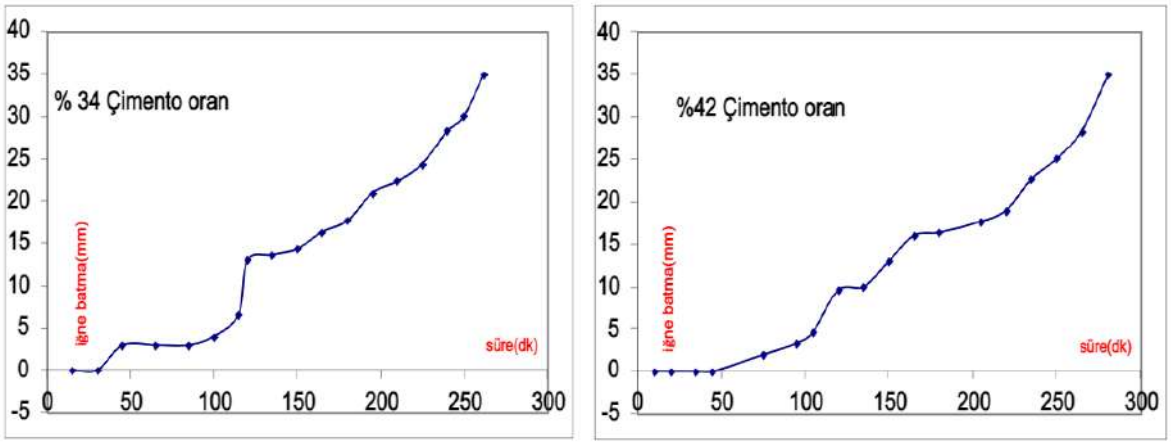
Tablo 8. Ağırlıkça %1,75 melamin sülfonat bazlı süper akışkanlaştırıcı katkılı KYH örneklerinin analiz bulguları

Karışım Kodu	Toz Yoğunluk (kg/m^3)	Yaş Yoğunluk (kg/m^3)	Yayılma Değeri (mm)	Sertleşmiş BHA, 7d (kg/m^3)	Sertleşmiş BHA, 28d (kg/m^3)	Basınç Dayanımı (7.gün) (N/mm^2)	Basınç Dayanımı (28.gün) (N/mm^2)	Su Emme (%)	Görünür Gözeneklilik (%)
MSH2-1	1140	2126	16	2249	2200	24,50	30,50	3,95	8,42
MSH2-2	1426	2047	24	2130	2080	21,25	37,50	3,88	7,84
MSH2-3	1349	2052	26	2100	2056	28,00	33,60	3,70	7,44
MSH2-4	1345	1987	27	1760	2015	24,50	43,50	3,73	7,22
MSH2-5	1352	1992	29	2088	2018	24,50	48,50	3,45	6,84

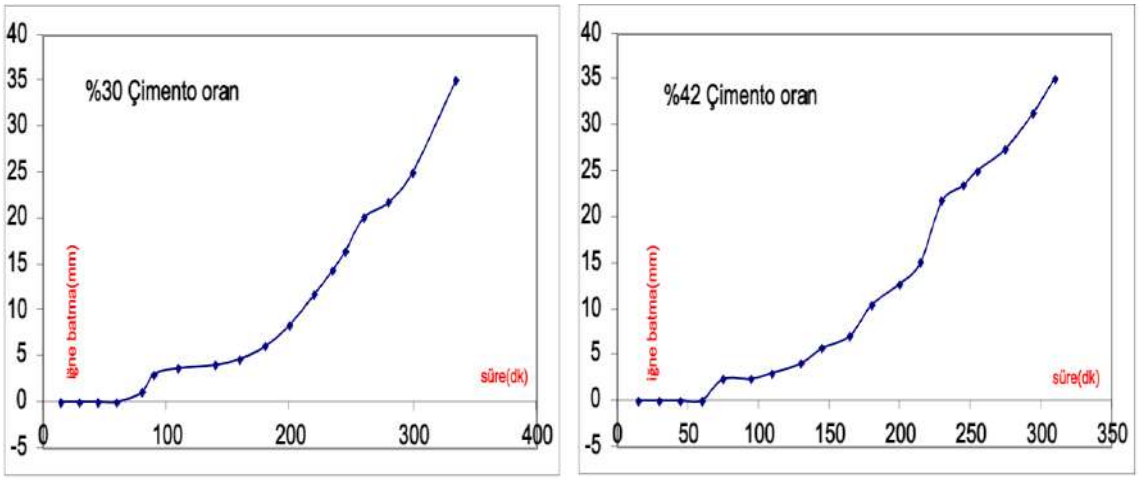
Çalışma kapsamında hazırlanan tüm KYH örneklerinin yaş kıvamda Vicat İğne yöntemi kullanılarak zamana bağlı priz alma süresi tayini testleri ayrı ayrı yapılmıştır. Elde edilen bulgular, her bir katkı türü için zamana bağlı iğne batma yükseklik değerleri ilişkisi grafiksel olarak analiz edilmiştir. Şekil 1 - Şekil 4'te Polikarboksilat esaslı ve Melamin sülfonat bazlı süper akışkanlaştırıcı katkılı harç örneklerine ilişkin bazı bulgular priz alma olgusunu temsilen grafiksel olarak verilmiştir.



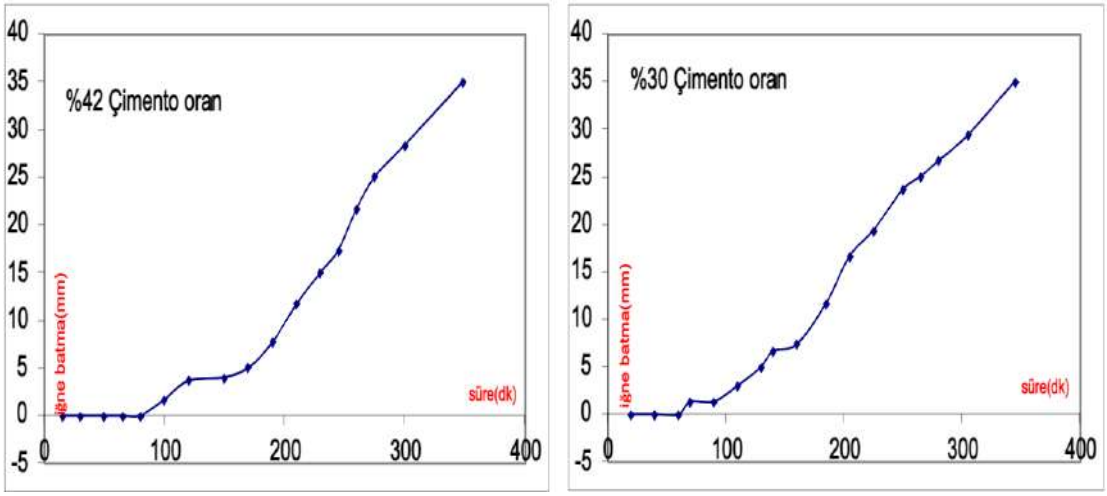
Şekil 1.%0.25 Polikarboksilat süper akışkanlaştırıcı katkılı KYH örneklerinin priz alma analiz bulguları



Şekil 2.%0.35 Polikarboksilat süper akışkanlaştırıcı katkılı KYH örneklerinin priz alma analiz bulguları



Şekil 3.%1.25 Melamin sülfonat süper akışkanlaştırıcı katkılı KYH örneklerinin priz alma analiz bulguları



Şekil 4.%1.75 Melamin sülfonat süper akışkanlaştırıcı katkılı KYH örneklerinin priz alma analiz bulguları

Şekil 1 - Şekil 4 irdelendiğinde görüleceği üzere, polikarboksilat katkılı harçların priz alma süreleri melamin sülfonat katkılı harçlara göre daha kısa zaman aralığında oluştuğu görülmektedir. Bununla birlikte, her iki katkı türü için genel bir eğilim olarak, harç kombinasyonunda akışkanlaştırıcı katkı oranı arttıkça, harcın priz alma süresinin uzadığı da görülmektedir. Yapılan bir diğer irdeleme de ise polikarboksilat katkılı harçların ilk priz sürelerinin yaklaşık 100±10 dakika gibi bir sürede oluştuğu, nihai priz sürelerinin ise yaklaşık 280±30 dakika gibi bir sürede oluştuğu değerlendirilmiştir. Melamin sülfonat katkılı harçların ilk priz sürelerinin ise yaklaşık 150±10 dakika gibi bir sürede oluştuğu, nihai priz sürelerinin ise yaklaşık 300±30 dakika gibi bir sürede oluştuğu değerlendirilmiştir. KYH test örneklerinin mekanik özellikleri TS EN 13892-2 standardında öngörülen prensiplere göre

basınç dayanım parametreleri irdelenmiştir. Her iki katkı türü için 7 günlük ve 28 günlük basınç dayanım analizleri yapılmıştır. Polikarboksilat katkılı harçların 7 günlük basınç dayanım değerleri 30,1 N/mm^2 - 51,35 N/mm^2 arasında değişmektedir. 28 günlük basınç değerleri ise 40,13 N/mm^2 - 64,30 N/mm^2 arasında değişmektedir. Melamin sülfonat katkılı karışımlarda ise 7 günlük basınç değerleri 15 N/mm^2 ve 28 N/mm^2, 28 gün priz sonrası sertleşmiş harç örneklerinde ise 21,50 N/mm^2 ve 48,50 N/mm^2 arasında değişmektedir. Ağırlıkça %0,25 polikarboksilat katkılı harçlarda çimento oranı arttıkça, artan akışkanlaştırıcı oranının da etkisiyle özellikle 7 günlük örneklerde genel bir dayanım artış eğiliminin olduğu görülmektedir. Bununla birlikte, ağırlıkça %0,35 polikarboksilat katkı içeren harçlarda ise %42 çimento kullanım oranına kadar dayanım artış eğilimi oluştuğu, ancak %42 çimento kullanım oranından sonra basınç dayanım değerinin önemli ölçüde düştüğü görülmektedir. Bu da karşımda yer alan polikarboksilat esaslı katkının harç kombinasyonunda optimum bir kullanım oranı oluşturduğunu temsil etmektedir. Benzer olgu, melamin sülfonat esaslı katkı açısından irdelendiğinde ise her iki katkı kullanım oranlı (%1,25 ve %1,75) 7 günlük test örneklerinin dayanım değerlerinde çimento ve katkı oran değişimlerine bağlı düzenli sayılabilecek bir dayanım değişimi belirlenmemiştir. Ancak, ağırlıkça %1,25 katkı kullanım oranlı örneklerin 28 günlük dayanım değerlerinde polikarboksilat katkılı harçlarda elde edildiğine benzer bir durum %42 çimento kullanım oranına kadar dayanım artış eğiliminin oluştuğu belirlenmiştir. Diğer taraftan ağırlıkça %1,75 melamin sülfonat bazlı katkı kullanım oranlı örneklerin 28 günlük dayanım değerlerinde artan çimento oranına bağlı olarak dayanım değerlerinin de artış eğilimi gösterdiği belirlenmiştir.

Tüm KYH örneklerinin atmosfer ortam koşullarında su emme oranları test örneklerinin test öncesi ve test sonrası ağırlık değişimlerinin kaydedilmesine bağlı olarak yapılan irdelemeyle belirlenmiştir. Bu bağlamda, polikarboksilat esaslı süper akışkanlaştırıcı katkılı harçlarda her iki katkı oranında su emme oranı %3,81 - %5,07 aralığında değişmektedir. Melamin sülfonat bazlı süper akışkanlaştırıcı katkılı karışımlarda ise su emme oranı %6,84 - %9,10 aralığında değişmektedir. Her iki tür akışkanlaştırıcı kullanımında çimento oranı arttıkça test örneklerinin su emme oranlarının genel bir eğilimle azaldığı görülmüştür. Bunda etken olan faktör, çimento oranının artması süper akışkanlaştırıcı katkı kullanım oranını artırmakta ve harcın yayılma potansiyelinin iyileşmesine bağlı olarak harç matrisinin daha kompakt ve daha gözenekliliği düşük bir form kazanması, su emme kabiliyetini düşürdüğü düşünülmektedir. Bir diğer bulgu ise melamin sülfonat bazlı süper akışkanlaştırıcı katkılı harçların polikarboksilat esaslı katkı içeren test örneklerinin su emme oranlarına kıyasla daha düşük oranlarda su emme kabiliyeti oluşturduğu belirlenmiştir. Diğer bir değişle, uygun bir katkı oranı kullanımında su emme oranı görece daha düşük harç kombinasyonlarının melamin sülfonat bazlı katkı kullanımıyla daha etkin bir sonuç elde edilebileceği düşünülmektedir.

4. Sonuçlar

Bu çalışmada, farklı tür ve kullanım oranlarında akışkanlaştırıcı kullanımlı çimento esaslı tesviye şapı harçları geliştirilmiştir. Çalışma bulgularına göre,

1. Kıvam analizleri irdelendiğinde düşük oranlarda dahi polikarboksilat esaslı katkı kullanımının melamin sülfonat esaslı katkı kullanımına göre daha fazla akıcılık ve kendinden yerleşme/yayılma özelliği kazandırmıştır.

2.Basınç değerlerinin değişimi bağlamında optimum çimento oranı polikarboksilat esaslı katkılı harçlarda ağırlıkça %42, melamin sülfonat katkılı karışımlarda ise ağırlıkça %38 dir.

3. Polikarboksilat katkılı harçlar düşük su/çimento oranına bağlı olarak melamin sülfonat katkılı karışımlara göre daha yüksek dayanım sağlamıştır.

4.Bütün harç karışımlarında çimento oranı artışına bağlı olarak dayanım artmıştır. Ayrıca harçların TS EN 13892-2 standardında öngörülen basınç dayanımı kriterlerini de sağladığı tespit edilmiştir.

5.Polikarboksilat katkısının melamin sülfonat katkısına göre harçların gözenekliliğini arttırdığı ve doğal olarak sertleşmiş numunelerin su emme yüzdesini artırdığı görülmüştür.

Referanslar

[1] A. Anderberg, Moisture properties of selflevelling flooring compounds. Division of Building Materials, Lund Institute of Technology, LTH, Lund University, TVBM-3120 Licentiate Thesis, ISSN 0348-7911 TVBM, 2004.

[2] TS EN 13813, Şap malzemeleri ve zemine uygulanan şaplar - Şap malzemeleri - Özellikler ve gerekler, TSE, s31, Ankara, 2004.

[3] A. Anderberg and L. Wadso, Drying and Hydration of Cement Based Self-Leveling Flooring Compounds, Drying Technology, 25(12), 1995-2003, 2007. https://doi.org/10.1080/07373930701728372.

[4] S. E. Klemenc, Self Levelers, Concrete Decor Magazine, https://www.concretedecor.net/author/stace yklemenc/page/18/, Accessed 18 June 2022.

[5] A. Padilla, I. Panama, A. Toledo and A. Flores, Development of Low Weight Self-leveling Mortars, VII International Congress of Engineering Physics, IOP Publishing, Journal of Physics: Conference Series 582, 012030, 2015. https://doi.org/10.1088/1742- 6596/582/1/012030.

[6] A. De Gasparo, M. Herwegh, R. Zurbriggen and K. Scrivener, Quantitative Distribution Patterns of Additives in Self-leveling Flooring Compounds (underlayments) as Function of Application, Formulation and Climatic Conditions, Cement and Concrete Research, 39(4), 313-323, 2009. https://doi.org/10.1016/j.cemconres.2008.12.009.

[7] L. Evangelista and J. de Brito, Mechanical Behaviour of Concrete Made with Fine Recycled Concrete Aggregates, Cement and Concrete Composites, 29(5), 397-401, 2007. https://doi.org/10.1016/ j.cemconcomp.2006.12.004

[8] A. İlgün, İ. Y. Türker, A. Müsevitoğlu, M. T. Çöğürcü, Katkı Malzemelerinin Fazla Kullanılmasının Betona Etkisi, KMÜ Mühendislik ve Doğa Bilimleri Dergisi https://dergipark.org.tr/tr/pub/kmujens 2(1), 31-39, (2020

[9] TS EN 934-2, Kimyasal katkılar- Beton, harç ve şerbet için- Bölüm 2: Beton katkıları- Tarifler ve özellikler, uygunluk, işaretleme ve etiketleme

[10] H. Yildirim, Betonda Kullanılan Kimyasal Akışkanlaştırıcı Katkılar ve Özellikleri, İ.T.Ü. İnşaat Fakültesi, CemenTürk Dergisi, 2018

[11] S. Türkel, B. Felekoğlu, Aşırı Dozda Akışkanlaştırıcı Kimyasal Katkı Kullanımının Taze ve Sertleşmiş Betonun Bazı Özellikleri Üzerine Etkisi, DEU Mühendislik Fakültesi Fen ve Mühendislik Dergisi, 6(1), 77-89, 2004.

[12] TS EN 13813, Şap malzemeleri ve zemine uygulanan şaplar- Şap malzemeleri- Özellikler ve gerekler, TSE, s31, Ankara, 2004.

Production of New Generation Packaging Materials with Utilization of Food Wastes

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Abstract

Food packaging is considered as important as food production due to being determinant on the quality and safety of food, in addition to informing customers about the product details (shelf life, ingredients, presence of allergens, etc.). Hence, packaging technology has also been progressing together with food production techniques. Recently, environmentalist approaches have pushed the researchers to green technologies and materials within the production of innovative food packages. In this frame, selection of green and renewable materials can be considered as the first step for such kind of a production. Food wastes and/or by-products are claimed to be great choice for both waste management and reduction of cost. For this purpose, there exist a wide variety of food wastes that can be originated from fruit and vegetables (peels, seeds, hulls, juice, etc.), whey, molasses and so on. Production methods can also vary, such as being based on a chemical (e.g., production of chitosan) or biotechnological process (e.g., bacterial cellulose production as a packaging material ingredient). As a result, organic based packaging materials are obtained and that kind of production has also been investigated in the concept of "bioplastics". Production of bioplastic packaging materials generally includes particular steps that can be aligned as pre-treatment of the food waste, main production step (extraction, alkaline treatment, etc.) via a selected method and the addition of a plasticizer to form an appropriate film. In biotechnological production applications, food wastes and by-products are generally utilized as a carbon source (substrate) with specific additives and the formation of necessary conditions for a microbial process, while parameters of the process, yield and purity of the product depend on the production itself. These packaging materials are mostly claimed to be promising alternatives with adequate physical and thermo-mechanical properties, as well as some extra functions such as gaining antimicrobial, antioxidant character with good gas barrier properties for a wide spectrum of food products. This study aims to present a general look on those new generation packaging materials with utilization of food wastes.

Keywords: Food wastes, bioplastics, packaging materials, green technologies

Introduction

The expansion of the food packaging industry has helped to advance the evolution of the food system, but it has also led to significant environmental problems. Petroleum-based polymeric packaging materials make up a significant amount of all materials used in packaging, although these materials are often non-degradable and only about 10% of them get recycled [1]. On the other hand, their usage causes the release of toxic gases such as carbon dioxide and methane, and these greenhouse gases seriously affect climate change worldwide [2]. In addition, these discarded plastics harm the environment through the soil and oceans [3]. In fact, these plastics can have a negative impact not only on aquatic ecosystems, but also on human health [4]. Leslie et al. (2022) detected the presence of microplastics in human blood and reported the mean of the total measurable concentration of plastic particles in blood as 1.6 μg/ml [5]. In recent years, alternative methods have been urgently needed to reduce the potentially harmful effects of plastic-based materials on human and environmental health [6]. Therefore, biodegradable plastics, also known as "bio-based polymers" or "bioplastics", have been proposed as a potential solution to reduce the harmful effects of petrochemical plastics on the environment and human health [4].

Bioplastic is known as a natural polymeric material that has been extensively developed over the past two decades due to its good biocompatibility, biodegradability and material properties. In recent years, bioplastic production has been one of the most active study fields in the literature. Bioplastics can be used in the packaging industry as well as in solvents, chemical media, spray materials, appliance materials, electronic, agricultural, and automotive applications. The interlinking of biotechnological

processes in the manufacturing of bioplastics is an important strategy designed to optimize the utilization of food waste and increase the potential revenue of the entire bioprocessing chain [7]. This review focuses on sustainable and eco-friendly packaging concept with, green and renewable materials (including food wastes) as new packaging approaches.

Utilization of Food Wastes in Food Packaging

Food waste is the term used to describe the loss of food quality and quantity along the supply chain process during the postharvest and processing stages of a product. The fruit by-products from the jam, juice, and jelly industries (apples, citrus, bananas, peaches, mangoes, blueberries, pears) and vegetable waste (potatoes, carrots tomatoes, fennel, cassava, or artichokes) are the food wastes that the most prevalent industries produce in significant quantities [8]. Approximately 50% of the fresh fruits and vegetables are wasted or lost from post-harvesting to processing, storage and the consumer-end. The best way to valorize these wastes is claimed to produce bioplastics to be used as novel food packaging materials [1; 8].

Fruit and vegetable wastes have special qualities that make them useful in food packaging, including extending food shelf life, maintaining food quality biologically and visually, decreasing water and water activity, enhancing antioxidant capacity, enhancing nutrients, and reducing lipid oxidation [8]. Figure 1 shows the effects of fruit and vegetable by-products when used in food packaging.

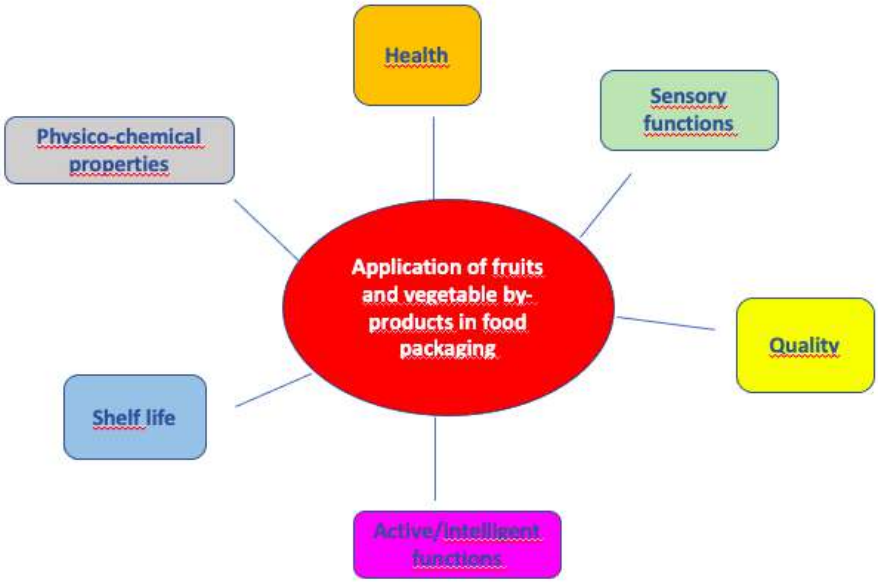

Figure 1. The effects of fruit and vegetable by-products when used in food packaging [8]

Some of the biodegradable packaging films which have been manufactured by using food and food waste-derived bioactive compounds, also gain active and intelligent character by providing visual quality evaluation. Moreover, food derived natural pigments, bioactive compounds, can act as indicator of quality and freshness of the food stuff such as meat, milk, seafood, etc. [9]. The research of Zhang et al. (2023), which also occurs in Table 1 can be a good example of such a production. In that research, pectin, cellulose and lignin from citrus fruits' peels were used and obtained bioplastic packaging film gained antioxidant character in addition to its successful mechanical properties [10].

On the other hand, production of bioplastics from food wastes contains basic steps that start with the collection and pre-treatment of wastes, the addition of process aids if needed (such as glycerol as a plasticizer), blending of the mixture to get the film formation solution and finally obtaining the film via a suitable technique (eg. coating, extrusion, casting, etc.). The procedure of this production for laboratory-scale is shown on the Figure 2.

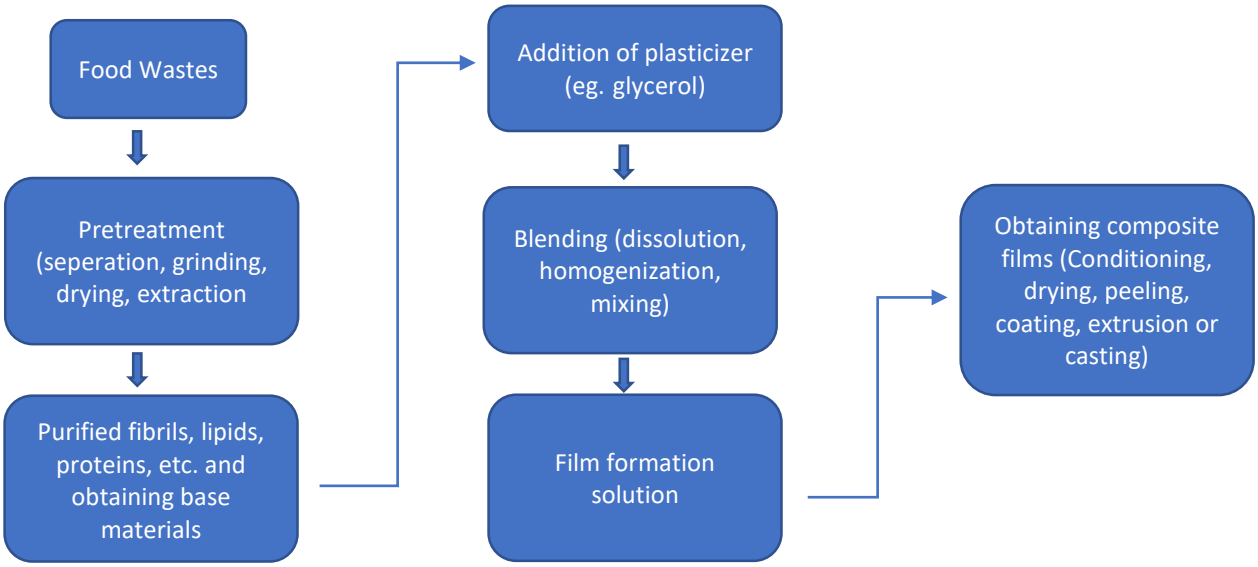

Figure 2. The conventional method to fabricate biodegradable films with the usage of food wastes in lab-scale [1; 11]

As the bioplastics are produced, the process contributes to a circular economy approach in addition to green and sustainable production strategies. However, reducing the production costs of bioplastics and optimization of each process in itself seem to take some more time. Up to now, the usage of synthetic plastics has not been left. Nevertheless, recent studies are found to be promising with enhanced food waste valorization techniques implemented on a large scale for waste management and bioplastic production. Some of these promising studies are shown on Table 1.

Table 1. Examples of several novel packaging materials produced from food wastes

Bioplastic Packaging Film	Explanation	Reference
Cellulose and fatty acids based bioplastic films from coffee grounds (with apple pectin)	• Mechanical performances are easily tuned by exposure to UV irradiation, • A variety of materials with controlled behavior can be obtained	[12]
Protein based films from soybeans waste	• Good water absorption capacity, • Good thermal and tensile strength • Excellent bio-based packaging material	[13]
Fatty acid based bioplastic films from tomato pomace	• The rigidity, hardness, wettability, and water uptake depend on the degree of polymerization • So, mechanical properties are adjustable	[14]
Pectin from banana peels	• Good water resistance and mechanical properties	[15]
Lignocellulosic bioplastic from agricultural waste (corncob and wheat straw)	• Good mechanical properties, • Good ultraviolet resistance, • Water stability	[16]
Pectin, cellulose and lignin from citrus fruits' peels	• Excellent water stability, • Good mechanical properties, • Water vapor barrier properties, • Antioxidant activity	[10]

Table 1 shows different kinds of productions from different food wastes that derive from lignocellulosic, protein based, fatty acid based or carbonhydrate based (pectin) materials. Obtained packaging films seem to have good properties that can substitute conventional plastics. However, some of them such as PHB could have both advantageous and disadvantageous characteristics such as excellent physical characteristics, great blockage against gases, and high crystallinity. But, its brittle, fragile and thermally instable nature are the main limitations to their applicability in large-scale

applications. These drawbacks are claimed to be eliminated using chemical grafting, polymer blending and introduction of co-polymers. [17]. However, PHA seems to be more trouble-free with its good barrier (to oxygen, water vapor and fat/odor) properties as well as satisfactory physico-chemical properties that resulting in a big potential to be used in various fields including food packaging [7]. On the other hand, bacterial cellulose (BC) is claimed to be a good component of packaging film materials. BC production by using food wastes is a good example of biotechnological processes to obtain raw material for bioplastic production. Several agro-wastes such as pineapple waste, citrus peel waste, extracted date syrup or household food wastes can be valorized for BC production [18; 19].

Future Trends and Conclusions

Growing concerns related to the usage of plastics due to serious environmental problems and its effects on human health have led to search for green and new alternatives. Bioplastics seem to be a promising alternative for this purpose and applicable to the food industry. Thermo-mechanical properties of bioplastic packaging materials have been found sufficient to substitute for the usage of traditional plastic packaging materials while also open to progress depending on the process. However, cost-effectiveness is the main aspect that limits the production and usage of bioplastics. Because production costs can be approximately 5-10 times higher than petroleum derived plastics. To reduce the production costs of bioplastics, cheap and abundant raw materials (such as food wastes and by-products) can efficiently be explored. Now, there have been an urgent need for more and optimized food waste valorization techniques implemented on large scale for waste management and bioplastic production, but future research activities are directed to genetic engineering, waste pre-treatment processes, biorefinery platform, sustainable recycling routes for bio-based materials. Once the production technologies become more feasible, usage of bioplastic packaging materials is expected to be dominant with extra advantages such as waste management and circular economy approach.

References

[1] Zhang H, Sablani S. Biodegradable packaging reinforced with plant-based food waste and by-products. Current Opinion in Food Science 2021; (42):61–68.

[2] Barker T. (2010). In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment, Report of the Intergovernmental Panel on Climate Change. 2010, USA: Cambridge University Press.

[3] Smith M, Love DC, Rochman CM, Neff RA. Microplastics in seafood and the implications for human health. Curr Environ Health Rep 2018; (5):375-386.

[4] Ali SS, Abdelkarim EA, Elsamahy T, Al-Tohamy R, Li F, Kornaros M, Zuorro A, Zhu D, Sun J. Bioplastic production in terms of life cycle assessment: A state-of-the- art review. Environmental Science and Ecotechnology 2023; (15): 100254.

[5] Leslie HA, van Velzen MJM, Brandsma SH, Vethaak AD, Garcia-Vallejo JJ, Lamoree MH. Discovery and quantification of plastic particle pollution in human blood. Environment International 2022; (163), Article 107199.

[6] Yin W, Qiu C, Ji H, Li X, Sang S, McClements DJ, Jiao A, Wang J, Jin Z. Recent advances in biomolecule-based films and coatings for active and smart food packaging applications. Food Bioscience 2023; (52): 102378.

[7] Tsang YF, Kumar V, Samadar P, Yang Y, Lee J, Ok YS, Song H, Kim KH, Kwon EE, Jeon YJ. Production

[8] Karimi Sani I, Masoudpour-Behabadi M, Alizadeh Sani M, Motalebinejad H, Juma ASM, Asdagh A, Eghbaljoo H, Khodaei SM, Rhim J-M, Mohammadi F. Value-added utilization of fruit and vegetable processing by-products for the manufacture of biodegradable food packaging films. Food Chemistry 2023; (405): 134964.

[9] Bhargava N, Sharanagat VS, Mor RS, Kumar K. Active and intelligent biodegradable packaging films using food and food waste-derived bioactive compounds: A review. Trends in Food Science & Technology 2020; (105): 385–401.

[10] Zhang S, Fu Q, Li H, Wu P, Waterhouse GIN, Li Y, Ai S. A pectocellulosic bioplastic from fruit processing waste: robust, biodegradable, and recyclable. Chemical Engineering Journal 2023; (463): 142452.

[11] Imam SH, Glenn GM, Chiellini E. Utilization of biobased polymers in food packaging: assessment of materials, production and commercialization. Emerging food packaging technologies Woodhead Publishing Series in Food Science, Technology and Nutrition 2012; 435-468.

[12] Cataldo VA, Cavallaro G, Lazzara G, Milioto S, Parisi F. Coffee grounds as filler for pectin: green composites with competitive performances dependent on the UV irradiation. Carbohydr. Polym. 2017; (170): 198-205.

[13] Muhammad A, Rashidi A, Roslan A, Idris S. Development of bio based plastic materials for packaging from soybeans waste. AIP Conf. Proc. 2017; 1885(1): 020230 https://doi.org/10.1063/1.5002424.

[14] Heredia-Guerrero JA, Caputo G, Guzman-Puyol S, Tedeschi G, Heredia A, Ceseracciu L, Athanassiou A. Sustainable polycondensation of multifunctional fatty acids from tomato pomace agro-waste catalyzed by tin (II) 2-ethylhexanoate. Materials Today Sustainability. 2018; (3–4): 100004.

[15] Chodijah S, Husaini A, Zaman M and Hilwatulisan. Extraction of Pectin from Banana Peels (Musa Paradiasica Fomatypica) for Biodegradable Plastic Films. 2nd Forum in Research, Science, and Technology, IOP Conf. Series: Journal of Physics: Conf. Series 2019; (1167): 012061 doi:10.1088/1742-6596/1167/1/012061.

[16] Shen J, Hu F, Chen Y, Gan M, Xie Y, Feng Q. Direct dissolution of unbleached pulp from agricultural wastes in cold organic alkali/urea for construction of bioplastic. Industrial Crops & Products 2023; (196): 116532.

[17] Usmani Z, Sharma M, Gaffey J, Sharma M, Dewhurst RJ, Moreau B, Newbold J, Clark W, Thakur VK, Gupta VK. Valorization of dairy waste and by-products through microbial bioprocesses. Bioresource Technology 2022; (346): 126444.

[18] Chua GK, Mahadi NIF and Tan FHY. Bacterial Cellulose Production from Agro-Industrial and Food Wastes. Environmental and Microbial Biotechnology book series (EMB), Bio-valorization of Waste 2021; 169–186.

[19] Khan SB and Kamal T. (2021). Bacterial Cellulose Synthesis, Production, and Applications. First edition published 2022 by CRC Press 6000 Broken Sound Parkway NW, Suite 300, Boca Raton, FL 33487–2742.

Benefits of Probiotic Containing Foods for the Prevention of Enteric Cancer: A Review

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Abstract

Probiotics that could act as cancer preventive agents, one of the representation of new novel therapeutic options and the beneficial in the prevention and alleviation of symptoms of colon cancer has been proven. The development, progression and treatment of colorectal cancer could be possible by using probiotics that have the potential significantly on it. Moreover, there are different strains of probiotics bacteria which possess varying responses towards the prevention of colorectal cancer. The consumption of prebiotics (special form of dietary fiber that induces the growth of favourable bacteria) and probiotics is the main attention has been focused on to decrease cancer risk through diet variations. The cultured milk, yogurt and other fermented dairy products and foods which contain probiotics have been proven by some recent reports that demonstrated there is an inverse association between cancer risk and them. In addition, the probiotic bacteria in association with prebiotic effectively enhances the humoral immune response has also been shown when that be on an oral administration. The anticancer activity of probiotics obtains by various mechanisms such as augmentation of natural killer cell activity, modulation of host immune response through macrophages (induction of ILs) and restraint of the composition of indigenous microbiota and their metabolic activity are important. Moreover, the enhanced activity of NK cells was also observed in symbiotic association of probiotics with prebiotics (indigestible dietary fiber/carbohydrate). Usage of probiotic nutritional intervention pre and post treatment may provide protection for healthy cells and tissues.

Keywords: Probiotics, foods, health benefits, enteric cancer

1. Introduction

Probiotics are defined as live microorganisms that confer a health benefit to the host when ingested in adequate amounts. Also, Probiotic knows as a phrase of the modern era, denotation “for life” and is in use to name bacterial association with beneficial effects on human and animal health (Bagchi, 2014). The Association of Modifiable Health has established that at least one half of all cancers may have dietary components, which indicates that nutritional factors play a major role in cancer treatment. Hence, many dietary components and natural health products have attracted the attention of scientists for the development of natural therapeutics. One such treatment is probiotics, non-pathogenic microorganisms (living in host), which protect and benefit the host against various infections including cancer (Daniluk, 2012). There are many health benefits offered by probiotics to the host: improved digestion, immunity and health. However, it is important to realize that each probiotic species is different and thus has different abilities and effects on human health. Each probiotic species has its own health effects. The organisms that are best studied and generally regarded as probiotics are species of the bacteria *Bifidobacterium*, *Lactobacillus*, and *Streptococcus*, and also including yeast such as *Saccharomyces boulardii*. While knowledge about the beneficial effects of the probiotic organisms and the foods that harbor them was in existence for quite some time, the interest in probiotics has increased recently with the pressing need to find alternative treatment regimens for various ailments and conditions that afflict humans. The increased awareness about lifestyle related diseases has also been one of the reasons for the interest in probiotics and probiotic based food supplementation.

1.1. Prebiotic

Prebiotic are defined as “non-digestible food ingredients that beneficially affect the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon, and thus improve host health”. Further exploration of probiotics have led to the development of

prebiotics, which are certain nutrients that modify the gut microbial flora although not easily digested by humans but have a selective role in stimulation of growth or activity of beneficial bacterial species in the gut (Thomas,2016). Some of the common known prebiotics includes bifidogenic properties of insulin, oligo-fructose, and fructo-oligosaccharides (FOS) (Hutkins et al., 2016) synthetically produced from sucrose, as well as galactose containing and xylose-containing oligosaccharides

1.2. Synbiotics

Synbiotics the combination of prebiotic and probiotics are termed as synbiotics. It is being further classified as synergistic and complementary synbiotics. Development in microbial research has led to formation of synbiotics which is a fusion of probiotics and prebiotics products and helps in enhancing the survival and the implantation of live microbial dietary supplements in the gut (Roberfroid et al., 2010). The synergistic benefits are more efficiently promoted when both the probiotic and prebiotic work together in the living system.

2. Probiotic Fortified by Food

The most popular functional food products on the market are those designed for improvement of gut health, particularly those that contain probiotics (Siró et al., 2008). In the days before antibacterial and food processing, humans ate lots of foods that contained microbes. Some of these microbes were unhealthy; modern processing techniques that limit our exposure to these harmful microbes are beneficial to our health. However, some of the bacteria and yeasts we used to eat in our foods were good for us. Sauerkraut, kimchi, kefir, kvass, miso, beer, wine and tamari are all foods that are made with the help of bacteria and yeast. The most common source in your diet of probiotics is likely yogurt and cheese. New probiotic-rich foods have been emerging on the market since 2000, including probiotic chocolate bars, cereals, milks and more. To date, the best way to get high dosages of probiotics into your gastrointestinal tract is through probiotic supplementation.

2.1. Dairy products

Dairy products constitute the major group of products able to carry and deliver probiotic bacteria, and among them, fermented milks and cheeses are the most consumed around the world. In addition, some dairy products, especially fermented milks and cheeses, due to some of their characteristics such as pH and buffer capacity, their dense matrix, and their fat content offer additinal protection to these microorganisms in their passage through the GIT, in particular against the acidic environment of the stomach (Souza and Saad, 2009).

2.2. Fruit juices

Fruit juices in several reports, fruit drinks have been indicated as good probiotic carriers if some care is taken relating to organoleptic characteristics and pH (Champagne and Gardner, 2011). Fruits and vegetables are in general considered as potential matrices because they are rich in nutrients such as vitamins, dietary fibers, sugars, minerals, and polyphenols known by its antioxidant properties. There are attempts have been reported to increase storage stability of Bifidobacterium strains in low pH fruit juice such as the use of ultraviolet (UV) mutagenesis combined with a stress step in low pH to generate acid-resistant strains (Saarela et al., 2009). Champagne and Gardiner (2011) performed some studies related to GIT resistance. According to these authors, the tested strains in a commercial juice were evaluated for their survival to the exposure to simulated GIT stresses after 35 days of storage at 4°C. Their viability in presence of 0.3% bile salts and pancreatic enzymes was not affected by the storage, but some susceptibility was observed to exposition at simulated gastric stress. Developed potentially symbiotic fresh-cut apple wedges by applying probiotic *L. rhamnosus GG* and prebiotics such as oligofructose and inulin. The wedges were dipped in probiotic solution, and the prebiotic carrier used was alginate assuring a homogeneous layer on fruit surface. Organoleptic properties were almost not changed by applying the functional ingredients, assuring similar quality to apple slices currently available. All samples attained ca. 10^8 cfu/g over the test period, which is sufficient for a probiotic effect.

2.3. Ice cream

Ice cream and frozen desserts based on dairy or fruit pulp or juice are another group of food products that have demonstrated potential as probiotic culture carrier for the consumers. Due to the lower storage temperatures, the ice cream is considered favorable for viability of probiotic strains, provided that damage by freezing and thawing, mechanical stresses of mixing and by oxygen incorporation during ice cream manufacture is minimized, as they can lead to decrease of probiotic

viable cells at the moment of consumption (Cruz et al., 2009a). As in general ice cream is a well accepted and desirable food product especially for children, it has a great potential for delivering probiotics. A review on ice cream as a probiotic carrier was published by Cruz et al (2009a). More recent studies on probiotic ice cream focus on the use of prebiotic compounds such as inulin and starch and microencapsulated cells (Homayouni et al., 2008). The addition of inulin improved viscosity and stimulated the growth of *L. acidophilus* and *B. lactis* resulting in higher viability in ice cream with no effect on its sensory properties (Akin et al., 2007). According to Homayouni et al (2008), encapsulation increased significantly the survival rate of probiotic bacteria in the ice cream over storage for 180 days at –20°C.

2.4. Soybean products

Among plan materials, soybean has been quite explored as matrix for probiotic delivery. As a soybean probiotic product (fermented soybean), Natto is normally consumed either hot or cold. In this example, it is sold as a snack with dried soybeans coated with a ine white powder of Bacillus subtilis var. Natto, the active ingredient required for the taste and texture of Natto. However, the health benefits associated with Natto imply the consumption of soybeans and bacteria, rather than just the bacterium. Bc. subtilis var. Natto carries as many as 108 viable spores per gram of product, and for decades, health benefits have been associated with consumption of Natto including stimulation of the immune system. Another fermented soybean probiotic product was studied by Cho et al (2006), in which they attained the fermentation of soybean fermented food cheonggukjang by a potential probiotic *Bc. subtilis* CS90. They reported that this strain induced changes in 25 phytochemical contents, including isoflavones, flavonols, and phenolic acids during the fermentation, increasing phenolic compounds and consequently antioxidant activity. The final probiotic cheonggukjang extract may be used as a basis for possible commercial production of functional foods in the future. Another soy-based product, soy low-fat frozen dessert, similar to ice cream, was developed and proved to be a suitable product for the delivery of bacterial probiotics with good sensory appeal. They incorporated several probiotic strains (*L. acidophilus* MJLA1, *B. lactis, L. rhamnosus*, *and L. paracasei ssp. paracasei*), which grow well in this matrix.

3. Health Potential of Probiotics

Probiotics may play a beneficial role on human health by interacting with the gut microbiome and impacting on host response; it is less clear whether the observed human health benefits are actually mediated by the microbiome changes (Sanders, 2011). The mechanisms of action whereby probiotics may promote such health-promoting effects include competitive exclusion of pathogenic bacteria, either directly (inhibition or competition by probiotic strain) or indirectly (probiotic influence on endogenous commensal microbiota) ; strengthening of epithelial barrier function by modulating signaling pathways that may promote increased mucus production, defensins generation or tight junction function (Anderson et al., 2010), and apoptosis prevention, modulation of the host immune system. Noticeably, probiotic microorganisms do not act exclusively in the large intestine by affecting the intestinal flora but also mediate some of the abovementioned mechanisms (immunological modulation or provision of bioactive metabolites) in other organs. In particular, some of these interactions can be influenced by the *in situ* SCFA milieu, which may affect or even mediate some of the beneficial effects of probiotics. Concerning the improvement of endogenous microbiota, the colonization by probiotic bacteria involves, in first place, the adhesion of these bacteria to in situ cell receptors allowing for the competition for the sites of adhesion and for nutrients, reducing number of available receptors as well as accessible nutrients to be used by pathogenic bacteria. During their colonization and through their growth and metabolism, they can release antimicrobial substances, including bacteriocines—natural antimicrobial substances (generally of proteinaceous nature that can have a lipid or carbohydrate moiety) or organic acids (namely lactic and acetic acids, hydrogen peroxide, among others) that consequently decrease the local pH. During their permanence in the gut, they can improve epithelial and tissue integrity and functionality, mainly through the production of low amounts of nitric oxide (NO) synthesis, enhancement of mucus production, improvement of gut epithelia cell proliferation, inhibition of carcinogenic substances production or elimination through detoxification, and generation of nutrients, namely production of short fatty acids and vitamins.

4. Probiotic in Cancer Treatment and Management

Several experimental studies suggest the efficacy of probiotics in cancer prevention and treatment in humans and murine models (Rafter ,2002). Baldwin et al (2010) reported that Lactobacillus acidophilus and Lactobacillus casei were able to increase apoptosis induction in colorectal carcinoma

cell line (LS 513), suggesting that these probiotic bacteria may possess anticancer activity. Propionibacterium freudenreichii was shown to induce the death of human colon and gastric cancer cell lines through the secretion of short chain fatty acids (SCFA) into the culture media. Probiotic Lactobacillus spp. induced selective cytotoxic, pro-apoptotic effects on leukemia and colon cancer cell lines, as well as anti-inflammatory effects on macrophage cells at the molecular level. Shyu et al (2014) reported that Lactobacillus spp. from dairy products secreted metabolites with cytotoxic and anti-inflammatory effects and they strongly suggest that the increased cytotoxicity for HT-29 and HCT116 cells may be associated with an upregulation of the early apoptosis gene markers cfos and cjun. Some probiotic strains have been reported to influence haematological cancers such as Lactobacillus reuteri, which enhanced TNF-induced apoptosis in human chronic myeloid leukaemia derived cells (Iyer et al., 2008). Le *et al*,(2005) demonstrated that the symbiotic association between prebiotic and probiotic considerably assists the apoptotic response to a genotoxic carcinogen. There exists encouraging evidence that specific probiotics (Lactobacillus) are valuable in the prevention and treatment of cancer through the increased production of cytokines (IL-2 and IL- 12), antioxidants (SOD, CAT, GSH) and anti-angiogenic factors, in addition to decreasing DNA damage, inflammation, tumour size, cancer specific proteins, polyamine contents and pro carcinogenic enzymes. Since microbiota is involved in the genesis of GI cancers, its beneficial manipulation may have cancer-preventive/therapeutic effects. Most studies have been performed in CRC, but other cancer locations (like stomach and oesophagus) have begun to be explored as well. There is a growing interest in the genetic manipulation of PRO, designed to act as a delivery system for anti-proliferative or proapoptotic factors (IL-10, TGF-b, superoxide dismutase, catalase, SCFA) in the GI tract. Several attributes of probiotic bacteria have been used successfully in the treatment of acute diarrhoea, inflammatory bowel disease (IBD) and other intestinal disorders. In addition to the regulation of intestinal epithelial homeostasis and immune responses, certain probiotics have been reported to have anticancer activity through different mechanisms (Daniluk, 2012). Experimental studies demonstrated that probiotics exert anticancer activity through immune-modulatory effects on cancer cells through macrophages, natural killer cells and T-cells (Shida and Namoto, 2013). A population-based case control study showed an inverse association between beverages containing *L. casei Shirota* (LcS) consumption and breast cancer occurrence (Toi et al., 2013). The ingestion of Lc. S probiotics significantly prevents the recurrence of bladder cancer. Various mechanisms of the anticancer activity of probiotics such as augmentation of natural killer cell activity, modulation of host immune response through macrophages (induction of ILs) and restraint of the composition of indigenous microbiota and their metabolic activity are important. Natural killer cells are crucial for immune surveillance against cancer and infectious diseases, and higher natural killer cell activity has been reported to be associated with a lower risk of cancer development (Shida and Namoto, 2013). Oxidative DNA damage induction is a preliminary step during carcinogenesis of some drug induced cancers. It has been suggested that probiotics could be efficacious in the reduction of oxidative DNA damage caused by carcinogenic chemical agents in vitro and in vivo (Zhang et al., 2013). However, this treatment had not been effective in cancer prevention but the concept of antioxidant activity of probiotics was developed since both milk and milk containing LAB were shown to exert anticancer and antioxidant activity (Kim et al., 2007). Data from experimental studies indicate that oral administration of certain types of LAB strains and their metabolic products reduced the risk of ROS accumulation and also degraded superoxide anions and hydrogen peroxides (Liu .et al., 2011). Metabolites of probiotic bacteria, such as butyrate, a short chain fatty acid (SCFA), are important therapeutic compounds against cancer. Butyrate is one energy source for the colonocytes and has been used in the regulation of apoptotic cellular proliferation and differentiation. Sodium butyrate induces anti-proliferative activity on many cancer cell types especially on colon cancer (Waldecker, 2008). Archer & Hodin (1999), hypothesised that butyrate affects gene expression in a process involving phosphorylation and acylation of histone proteins. Regimen-induced complications are most widely treated by alterations in diet especially the introduction of probiotic food. Usage of probiotic nutritional intervention pre and post treatment may provide protection for healthy cells and tissues (Chitapanarux et al., 2010). The protective role of probiotic bacteria against diarrhoea and mucositis may be due to the improved immune status of the gut (Rao, Samak, 2013). Previous studies also explain that these probiotic bacteria may compete with pathogenic bacteria for binding on epithelial cells (Chitapanarux et al., 2010).

5. Conclusion

Probiotics have become very important in food products because of their useful effects on the host health. Numerous in vitro studies and animal models show positive effects of probiotics fortified foods on gastrointestinal cancers by various mechanisms, including anti-carcinogenic effects, anti-mutagenic

properties, modification of differentiation process in tumor cells, production of short chain fatty acids, alteration of tumor gene-expressions, activation of the host's immune system, inhibition of the bacteria that convert pro-carcinogens to carcinogens, alteration of colonic motility and transit time, as well as reduction of intestinal pH to reduce microbial activity.

References

Akin M. B., Akin, M. S. and Kirmaci, Z, 2007. Effects of inulin and sugar levels on the viability of yogurt and probiotic bacteria and the physical and sensory characteristics in probiotic ice-cream. Food Chem., 104, 93–99.

Anderson, R. C., Cookson, A. L., McNabb, W. C., Park, Z., McCann, M. J., Kelly, W. J., & Roy, N. C. (2010). Lactobacillus plantarum MB452 enhances the function of the intestinal barrier by increasing the expression levels of genes involved in tight junction formation. BMC Microbiology, 10, 316.

Archer SY, Hodin A,1999. Histone acetylation and cancer. Curr Opin Genet Dev;9:171e4.

Bagchi T. Traditional food & modern lifestyle: impact of probiotics. Indian J Med Res 2014;140(3):333e5.

Champagne, C.P., R.P. Ross, M. Saarela, K.F. Hansen and D. Charalampopoulos. 2011. Recommendations for the viability assessment of probiotics as concentrated cultures and in food matrices. International journal of food microbiology 149(3): 185–193

Chitapanarux I, Chitapanarux T, Traisathit P, Kudumpee S, Tharavichitkul E, Lorvidhaya V., 2010. Randomized controlled trial of live Lactobacillus acidophilus plus Bifidobacteriumbifidum in prophylaxis of diarrhea during radiotherapy in cervical cancer patients. Radiat Oncol ;5:31.

Cho, H. J., Kim, E. J., Lim, S. S., Kim, M. K., Sung, M. K., Kim, J. S., & Park, J. H. (2006). Trans-10,cis-12, not cis-9,trans-11, conjugated linoleic acid inhibits G1-S progression in HT-29 human colon cancer cells. The Journal of Nutrition, 136(4), 893– 898

Cruz, A. G., Buriti, F.C. A., Souza, C. H. B., Faria, J. A. F. and Saad, S. M. I. 2009a. Probiotic cheese: health beneits, technological and stability aspects. Trends Food Sci. Technol., 20, 344–354.

Daniluk U., 2012. Probiotics the new approach for Cancer prevention and/or potentialization of Anti-Cancer treatment? J Clin Exp Oncol ;1:2

Homayouni, A., Azizi A., Ehsai M. R., Yarmand M. S. and Razavi S. H., 2008. Effect of microencapsulation and resistant starch on the probiotic survival and sensory properties of synbiotic ice cream. Food Chem., 111, 50–55.

Hutkins RW, Krumbeck JA, Bindels LB, Cani PD, Fahey G, Goh YJ, et al. Prebiotics: why definitions matter. Curr Opin Biotechnol 2016;37:1e13

Iyer C, Kosters A, Sethi G, Kunnumakkara AB, Aggarwal BB, Versalovic J.,2008. Probiotic Lactobacillus reuteri promotes TNF-induced apoptosis in human myeloid leukemia-derived cells by modulation of NF-kappa B and MAPK signalling. Cell Microbiol ;10:1442e52.

Kim JE, Kim JY, Lee KW, Lee HJ., 2007. Cancer chemopreventive effects of lactic acid bacteria. J Microbiol Biotechnol ;17:1227e35.

Le LRK, Brown IL, Hu Y, Bird AR, Jackson M, Esterman A, et al. A symbiotic combination of resistant starch and Bifidobacterium lactis facilitates apoptotic deletion of carcinogen-damaged cells in rat colon. J Nutr 2005;135: 996e1001

Liu CT, Chu FJ, Chou CC, Yu RC., 2011. Antiproliferative and anticytotoxic effects of cell fractions and exopolysaccharides from Lactobacillus casei 01. Mutat Res ;721:157e62.

Rafter J, 2002. Lactic acid bacteria and cancer: mechanistic perspective. Br J Nutr ;88:S89e94.

Roberfroid M, Gibson GR, Hoyles L, McCartney AL, Rastall R, Rowland I, et al. Prebiotic effects: metabolic and health benefits. Br J Nutr 2010;104(2):S1e63

Sanders, M. E. (2011). Impact of probiotics on colonizing microbiota of the gut. Journal of Clinical Gastroenterology, 45(Suppl.), S115–S119

Saarela, M., H. Alakomi, A. Puhakka and J. Matto. 2009. Effect of the fermentation pH on the storage stability of Lactobacillus rhamnosus preparations and suitability of in vitro analyses of cell physiological functions to predict it. Journal of applied microbiology 106: 1204–1212

Shida K, Namoto M, 2013. Probiotics as efficient immunopotentiators: translational role in cancer prevention. Indian J Med Res ;138:808e14

Shyu PT, Oyong GG, Cabrera EC. Cytotoxicity of probiotics from Philippine commercial dairy products on cancer cells and the effect on expression of cfos and cjun early apoptotic-promoting genes and Interleukin-1 b and Tumor Necrosis Factor-a pro-inflammatory cytokine genes. Biomed Res Int 2014;2014:491740.

Siró, I., Kápolna, E., Kápolna, B., and Lgasi, A., 2008. Functional food. Product development, marketing and consumer acceptance – A Review. Appetite, 51, 456–467.

Sousa, C. H. B. and Saad, S. M. I., 2009. Viability of Lactobacillus acidophilus La-5 added solely or in co-culture with a yoghurt starter and implications on physic-chemical and related properties on Minas fresh cheese during storage. LWT-Food Sci. Technol., 42, 633–640.

Thomas LV. Probiotics-the journey continues. Int J Dairy Tech 2016;69:1e12

Toi M, Hirota S, Tomotaki A, Sato N, Hozumi Y, Anan K, 2013. Probiotic beverage with soy isoflavone consumption for breast Cancer prevention: a case-control study. Curr Nutr Food Sci ;9(3):194e200

Waldecker M, Kautenburger T, Daumann H, Busch C, Schrenk D, 2008. Inhibition of histone-deacetylase activity by short chain fatty acids and some polyphenol metabolites formed in the colon. J Nutr Biochem 2008;19:587e93.

Zhang M, Wang F, Jiang L, Liu R, Zhang L, Lei X, 2013. Lactobacillus salivarius REN inhibits rat oral cancer induced by 4-nitroquioline 1-oxide. Cancer Prev Res (Phila) ;6(7):686e94.

The Plant-Based Enzymes Used in Coagulation of Milk for Cheese Production

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Abstract

Dairy products have a quite important for the food industry. Cheese, which has more than a thousand varieties, takes it in the first place among dairy products. Coagulation of milk is the most important step in cheese production. A considerable part of the cheese produced in the world is obtained as a result of coagulation of milk with enzymes. The rennets used to provide milk coagulation in cheese production can be obtained from different animal, plant-based and microbial sources. Coagulant enzymes obtained from different sources are called rennet obtained from animal sources. The increase in the amount of cheese production also increases the need for rennet. Due to reasons such as increasing cheese production and consumption around the world, difficult calf rennet supply (expensive and scarce), religious reasons, prohibition of rennet obtained from recombinant calf rennet in some countries, vegetarian preferences of consumers, some diseases that can be transmitted from animals, attitudes towards genetically modified foods have led to the need for alternative coagulants in cheese production. This situation has led to studies on the production of alternative coagulant enzymes of microbial, plant-based and recombinant origin that can be used instead of calf rennet. Enzymes obtained from different parts of plants (such as roots, stems, leaves, flowers, seeds and fruits) by different extraction methods can be used to coagulate milk. Although coagulant enzymes of plant-based origin are used in the production of traditional cheese varieties in many different countries, they are not used in general areas due to their high proteolytic activities, degradation in coagulum qualities, decrease in yield, and negative effects on sensory properties such as bitter taste formation. In this review, the most commonly used plant-based enzymes used in coagulation of cheese milk and their effects on the final product properties are mentioned.

Keywords: Plant-based enzymes, cheese, coagulation

Introduction

Dairy products have a quite important for the food industry. Cheese, which is one of the most common and widely consumed and has more than a thousand varieties, takes its in the first place among dairy products. Coagulation of milk is the most important step in cheese production for the development of cheese texture and flavour [1,3]. Coagulation of milk is carried out with different enzymes or acids. Proteolytic enzymes that are effective in the coagulation process are obtained from different sources such as plants, animals and microorganisms [2]. Milk-clotting proteases are essential enzymes for cheesemaking [4]. Rennet, which is an enzyme of animal origin, is extracted from the abomasum of the newborn ruminants is commonly used in the worldwide [2,4]. It contains a high amount of chymosin, an aspartic protease that can hydrolyze a specific k-kazein bond, thus causing the coagulation of milk during cheesemaking [4]. However, due to the worldwide increase in cheese production, the fact that calf rennet is expensive and scarce in some countries, the products obtained using this enzyme do not comply with vegetarian dietary habits and some religious restrictions, have led to the search for alternative enzymes for coagulation of milk as appropriate substitutes for animal rennet [2,4]. For this reason plant-based coagulants have gained importance as an alternative to animal rennet in recent days. Milk to be used in cheese making, it can coagulate with proteolytic enzymes in different parts of plants such as roots, stems, leaves, flowers, seeds and fruits. These plants include fig, wild artichoke, sodom apple, ginger, wild papaya, desert date palm, golden berry, curd/hereme grass, agar grass, chickpea etc. [3]. In this review, the most commonly used plant-based enzymes used in coagulation of cheese milk and their effects on the final product properties are mentioned.

Calf Rennet

Milk coagulating enzymes are important active agents used in the cheese industry. In addition to providing coagulation, they are also effective on the texture and aroma of cheese. The most widely used coagulating agent in the cheese industry is calf rennet obtained from fourth stomach of suckling calves [5]. Calf rennet is a traditional milk coagulating enzyme used in the cheese industry. The major portion consists of chymosin (EC 3.4.23.4), which hydrolyzes the specific k-casein during cheese production, thereby coagulating the milk, and small portion of pepsin (EC 3.4.23.1); while this proportion is inverted when it was extracted from adult animals [2,4,6]. It has a high milk coagulation activity (MCA)/proteolitic activity (PA) ratio and high heat sensitivity, leading to great cheese yield. Calf rennet hydrolyzes the Phe105-Met106 site of κ-casein in casein. However, the calf rennet supply has decreased because of the limited availability of calf abomasum. Therefore, it is necessary to search for calf rennet substitutes [5].

Plant-Based Coagulants

Coagulating enzymes such as rennet of plant-based origin; bromelin, ricin, papain and ficin are obtained from the roots, seeds, leaves, flowers and stems of plants using different methods. The fact that their coagulation abilities are lower than their proteolytic activities [1]. Too high proteolytic activity causes a decrease in curd firmness, a slowdown in whey separation, a decrease in yield, and cheese defects such as bitter taste formation [7]. This limits the use of plant-based rennets in cheese production. Plant-based rennets with high proteolytic activity cause decreased productivity, formation of problematic clots and bitter taste during the ripening period of cheese. Animal and microbial enzymes used in cheese production provide higher quality products and also more economical and practical than plant origin enzymes. Despite these positive aspects of animal-derived coagulants, genetic changes and religious restrictions lead cheese producers to plant-based coagulants. However, plant-based coagulants are not preferred except for cheese production, which requires mastery in small-scale enterprises and farms [1].

Milk can be coagulated through enzymes naturally found in some plants that have the ability to coagulate milk. These plant-based enzymes are obtained by using parts of plants such as roots, stems, leaves, seeds, flowers or by extracting them from certain parts. Some plants have strong proteolytic activity. For this reason, there may be a bitter taste formation and a decrease in the clot yield. Thus plant selection, amount of use and fermentation time are important for process efficiency. The most important difference that distinguishes among the plant-based enzymes from other enzymes is that the optimum pH and temperature values of plant-based enzymes are high, and therefore they effectively coagulate milk that undergoes high temperature treatment [2].

Cynara cardunculus, *Solanum dubium*, *Calotropis procera*, *Carica papaya*, *Ficus carica*, *Albizia julibrissin*, *Zingiber officinale* are the most commonly used plant-based coagulants in cheese production.

Fig (*Ficus carica*)

Figs contain two groups of proteolytic enzymes. The first group has high coagulation activity but low proteolysis, while the second group has high proteolytic activity. For the production of curd from the fig, the leaf, branch tips or the juice obtained from the fruit of the fig are used [2].

It is known that plant extracts have been used as coagulants in cheese making since ancient times, and the first proteolytic enzyme used in cheese production was ficin, which was crystallized from fig milk. Although the use of herbal coagulants dates back to ancient times, their use is limited until now due to their high proteolytic activities, except for a few varieties. Extracted from the fig tree, ficin is the first plant-derived enzyme used in cheese making and is known to cause bitterness in cheeses due to its high proteolytic activity [7].

Albizia julibrissin

Albizia julibrissin seeds are known to have milk coagulating proteolytic enzymes that do not develop any bitterness until 3 months after cheese ripening. In a study examining the milk coagulation activity of Albizia lebbeck and Helianthus annus seed extracts, it was determined that sunflower seed extract was 15 times less than the specific coagulation activity of Albizia seed extract. As a result, Albizia seeds, which are more active than the sunflower enzyme, are also a suitable substitute for animal rennets [8]. Unfortunately, some plant coagulant enzymes are considered inappropriate because of their high proteolytic activity, forming short peptides and playing a role in the production of bitter-tasting cheese. However, studies showed that some milk coagulating enzymes such as *Cynara cardunculus* flowers, has been used in several areas of Portugal and Spain for years. After 3 months of ripening, bitterness did not acquire in cheeses produced using *Albizia julibrissin* seed extracts [6,8].

Zingiber officinale

Zingibain is a cysteine protease enzyme derived from the rhizome of Zingiber officinale Roscoe, capable of coagulating milk [10]. Compared to calf rennet and papain, it shows higher milk coagulant activity. In the dairy industry, it can be used instead of or in addition to calf rennet to coagulate milk [11, 12, 13].

Hailu et al. (2014) [14] compared the quality characteristics of soft cheese made using ginger raw extract and cheese prepared using camel chymosin. Cheese produced with ginger showed less acidity and ash content. They determined that the total dry matter and protein content was less than the cheese produced with camel chymosin. They stated that ginger can be used to coagulate camel milk and thus to make cheese from camel milk.

Carica papaya

The use of papain in cheese production is quite common in Indonesia. The latex of the raw fruits of papaya (*Carica papaya* L.) has strong milk coagulation activity. Papain, a proteolytic enzyme isolated from papaya latex, has the ability to break down polypeptides, which are organic molecules made up of amino acids [3].

Liburdi et al. (2019) [15] examined the extracts of *Cynara cardunculus*, *Carica papaya* and *Ficus carica*, which are claimed as milk coagulants. Coagulation activities were measured in cattle, buffalo, goat and sheep milk. As a result of the study, *Cynara cardunculus* proved to be the most suitable milk coagulation enzyme for cheese production. Ficus carica latex has only been seen as a promising alternative coagulant at higher temperatures.

***Calotropis procera* (Sodom apple)**

Calotropis procera, which is also known as the sodom apple, is a plant belonging to the *Asclepiadaceae* family. It has been used over the years for its unique medicinal properties. It is known that the latex of *Calotropis procera* extract has a wound-healing, anti-inflammatory, and protective effect against skin infections [16]. Sodom apples are available in tropical and subtropical areas growing naturally [17]. *Calotropis procera* is also used as a coagulant in the production of traditional cheese in some African countries such as Benin and Nigeria, which is called “Wagashi” cheese [12,16,18,19]. Extracts of *C. procera* has been reported to contain rennet enzymes called calotropin that coagulates cow milk. In addition, it has been determined that the cheese produced using the extract obtained from *Calotropis procera* leaves is harder and gummy [12,18]. Aïsso et al. [20] reported that all parts of *Calotropis procera* (leaf, stem, fruit and latex) have coagulation activity in milk casein and that the fruit is more effective than the leaves and stems.

Solanum dubium

Solanum dubium is a well-known wild plant found in most regions of the Sudan. It is the quite often used for milk coagulation especially in rural areas. Enzymes produced from the wild *Solanum dubium* plant grown in a large area in Sudan are generally used as milk coagulants in rural areas. In the study of Abdalla et al., (2010) [21] it was determined that the seeds of the *Solanum dubium* plant have high coagulation activity and a short coagulation time when extracted with water.

Cynara cardunculus

Cynara cardunculus L., known locally as wild artichoke in our country, is a wild plant with a large head and purple flowers. This plant is found on the coasts of the Mediterranean region, in Portugal, North Africa, and in the south of Spain. It grows in Turkey, especially in the Aegean and Mediterranean Regions [7]. Enzymes obtained from this plant and called "Cardoon" have been used for over 2000 years in several areas of Portugal and Spain for the production of various traditional cheeses with a creamy soft texture and distinctive taste [6,7]. This type of cheese has been designated and protected as a Protected Designation of Origin (POD) by the European Union due to its unique characteristics. The flower of the *Cynara* spp. plant contains high levels of proteolytic enzymes. This situation can cause a soft and oily texture in cheese, but partially softening and loss of shape and textural defects [7]. Cardoons contain cardosin, a protease enzyme that has high milk-clotting activity [10]. "Cardosin A" and "Cardosin B" coagulants obtained from the neck and stigma of *Cynara cardunculus* L. flowers are aspartic proteases such as chymosin. While the enzyme Cardosin A shows chymosin-like properties and activity, the enzyme defined as "Cardosin B" is similar to pepsin. Cardosin B is more proteolytic than Cardosin A and both enzymes affect the Phe105-Met106 bond of k-casein. The enzyme shows maximum activity at pH 5.12 [7]. These rennets are capable of preserving the distinct and native flavours of traditional cheeses [10].

Table 1: Cheeses made with *Cynara* L. in the Iberian Peninsula [22]

Country	*Cheese*	*Type of Milk*
Portugal	Serra da Estrela	Ewe
	Serpa	Ewe
	Azeitão	Ewe
	Nisa	Ewe
	Castelo Branco	Ewe
	Évora	Ewe
Spain	Casar de Cáceres	Ewe
	Torta del Casar	Ewe
	La Serena	Ewe
	Los Pedroches	Ewe
	Los Ibores	Goat
	Flor de Guía	Ewe and Goat

Conclusion

Coagulation of milk is one of the most important step in cheese production. For this aim, first and most frequently used rennets are coagulants of animal origin. However, increase cheese production in the worldwide, ethical issues and religious restrictions on the use of animal-derived rennet, not suitable for vegetarian dietary habits have increased the interest in plant-derived coagulants. Plant-based coagulants have been used in cheese production since ancient times. The strong proteolytic effect of plant-based coagulant enzymes affects the texture, taste and yield of cheese. While high proteolytic activity causes the formation of bitter taste in cheese, it accelerates the formation of clots. Plant-derived coagulants show low efficiency in the production of hard cheese, they give successful results in the production of soft textured cheeses. So, every enzyme can't be used for cheese making. However, if it is aimed to produce a soft cheese, these plant-based enzymes can be used. In order to obtain cheese in the desired structure, it is recommended to continue to carry out more enzyme studies in the future and to make experiments using different milks.

References

[1] Kaya O. Elazığ ilinde satışa sunulan hayvansal peynir mayalarının bazı kalite özelliklerinin incelenmesi [MSc Thesis]. Elazığ, Türkiye; Fırat Üniversitesi; 2018.

[2] Say D, Güzeler N. Süt pıhtılaştırılmasında kullanılan bitkisel enzimler. Nevşehir Bilim ve Teknoloji Dergisi TARGİD Özel Sayı 2016;253-261.

[3] Rana MS, Hoque MR, Rahman MO, Habib R, Siddiki MSR. Papaya (*Carica papaya*) latex- an alternative to rennet for cottage cheese preparation. Journal of Advanced Veterinary and Animal Research 2017;4(3):249-254.

[4] Nicosia FD, Puglisi I, Pino A, Baglieri A, Cava RL, Caggia C, Carvalho AF, Randazzo CL. An Easy and Cheap Kiwi-Based Preparation as Vegetable Milk Coagulant: Preliminary Study at the Laboratory Scale. Foods 2022, 11, 2255.

[5] Liu X, Wu Y, Guan R, Jia G, Ma Y, Zhang Y. Advances in research on calf rennet substitutes and their effects on cheese quality. Food Research International 149 (2021) 110704.

[6] Abdeen EMM, Ibrahim OA, Kholif AMM. Utility of *Moringa oleifera* waste as a coagulant in goat soft cheese production. Heliyon 7 (2021) e07536

[7] Eroğlu E, Özcan T. Sütün Enzimatik Koagülasyonu ve Peynir Üretiminde Bitkisel Pıhtılaştırıcılar. Journal of Agricultural Faculty of Bursa Uludag University 2018;32 (2), 201-214.

[8] Egito AS, Girardet JM, Laguna LE, Poirson C, Mollé D, Miclo L, Humbert G, Gaillard JL. Milk-Clotting Activity of Enzyme Extracts from Sunflower and Albizia Seeds and Specific Hydrolysis of Bovine κ-Casein. International Dairy Journal, 17 (7), 816– 825, 2007.

[9] Darwish MS. Influence of Plant Based Coagulant (Enzyme Extracts from Albizia and Sunflower Seeds) on Quality of Domiati Cheese. J. Food and Dairy Sci., Mansoura Univ. 2016; Vol. 7 (12): 501- 506.

[10] Bathmanathan R, Yahya YAC, Yusoff MM, Vejayan J. Utilizing Coagulant Plants in the Development of Functional Dairy Foods and Beverages: A Mini Review. Journal of Biological Sciences 2019;19 (3): 259-271.

[11] Hashim MM, Mingsheng D, Iqbal MF, Xiaohong C. Ginger Rhizome as a Potential Source of Milk Coagulating Cysteine Protease. Phytochemistry, 72 (6), 458-464, 2011.

[12] Mazorra-Manzano MA, Perea-Gutiérrez TC, Lugo-Sánchez ME, Ramirez-Suarez JC, Torres-Llanez AF, González-Córdova, Vallejo-Cordoba. Comparison of the Milk-Clotting Properties of Three Plant Extracts. Food Chemistry, 141(3), 1902-1907, 2013.

[13] Gagaoua M, Hoggas N, Hafid K. Three Phase Partitioning of Zingibain, a Milk-Clotting Enzyme from *Zingiber officinale* Roscoe Rhizomes. International Journal of Biological Macromolecules, 73, 245-252, 2015.

[14] Hailu Y, Seifu E, Yilma Z. Physicochemical Properties and Consumer Acceptability of Soft Unripened Cheese Made from Camel Milk Using Crude Extract of Ginger (*Zingiber officinale*) as Coagulant. African Journal of Food Science, 8 (2), 87-91, 2014.

[15] Liburdi K, Boselli C, Giangolini G, Amatiste S, Esti M. An Evaluation of the Clotting Properties of Three Plant Rennets in the Milks of Different Animal Species. Foods 2019, 8, 600

[16] Anihouvi ELPS. Bazı probiyotik bakterilerin Wagashi (Peulh) peyniri üretiminde destek kültür olarak kullanımı [MSc Thesis]. İzmir, Türkiye; Ege Üniversitesi; 2021.

[17] Waweru CM, Muthamia JM, Otaye DO. Potential of Sodom Apple (*Solanum incanum* L.) Fruit Extracts in the Management of Chilli Root Knot Disease in Nakuru County, Kenya. Advances in Agriculture 2017.

[18] Pontual EV, Carvalho BEA, Bezerra RS, Coelho LCBB, Napoleao TH, Paiva PMG. Caseinolytic and Milk-Clotting Activities from *Moringa oleifera* Flowers. Food Chemistry, 135 (3), 1848-1854, 2012.

[19] Chikpah SK, Teye M, Annor JAF, Teye GA. Potentials of Sodom apple (*Calotropis procera*) extract as a coagulant to substitute Alum in soy cheese production in Ghana. Elixir Food Science 79 (2015) 30166-30170.

[20] Aïsso RCB, Aïssi V, Youssao AKI, Soumanou MM. Caractéristiques physico-chimiques du fromage Peulh produit dans les conditions optimales de coagulation à partir du lait de deux races de vaches du Bénin. « Nature & Technologie ». B- Sciences Agronomiques et Biologiques 2016;37-43.

[21] Abdalla MOM, Ali DAA, Mohamed BE. Extraction, Milk Clotting Activity Measurements and Purification of *Solanum dubium* Fresen (Gubbain) for Cheesemaking. World Journal of Dairy and Food Sciences 2010;5 (2): 152-159.

[22] Roseiro LB, Barbosa M, Ames JM, Wilbey RA. Cheesemaking with vegetable coagulants—the use of *Cynara* L. for the production of ovine milk cheeses. International Journal of Dairy Technology 2003; Vol 56, No 2 May.

Investigation of Waste Grape Pulp for Healthy, Functional Beverage Production

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Abstract

Turkey, where different ecologies coexist, has great potential in fruit and vegetable production. Turkey, which has suitable climate and soil conditions, offers wide opportunities, especially in the field of viticulture and is an important center in the world with its rich grape gene potential. Grapes, which are rich in bioactive components, have an important place in the country's economy and social life for reasons such as providing raw materials to the food industry sector, creating employment opportunities, and having a high export potential, as well as being a valuable nutrient. Nowadays, with the developing understanding of conscious nutrition, the demand for fruit juice and similar products is gradually increasing as consumers turn towards natural and health-beneficial products. The grape, rich in various organic acids, vitamins and minerals and bioactive compounds with natural antioxidant properties has taken its place in the food industry for different purposes. Grape juice, must, molasses and grape pulp produced after wine production is an important food waste. The grape pulp contains 10%-30% of the crushed grape mass and other value-added components such as unfermented sugars, polyphenols, colors, alcohol, and tannins. These compounds should be recovered using acceptable, eco-friendly techniques without compromising the stability or quality of the product. The recovery of useful substances from food waste is a new development in the food industry. Thus, it is achieved to obtain high value-added products. This study, it was aimed to investigate the production of a new functional beverage with high phenolic content by drying the waste grape pulp formed after pressing purple grapes.

Keywords: Grape pulp, waste, resveratrol, sustainability

Introduction

Nowadays, with the interest in healthy nutrition and the increase in the world population, it is becoming more difficult for every individual to access safe food. Adequate nutrition is not only a question of survival, but also closely linked to the environment and its balance. Food production covers about 40% of global land area and is responsible for 30% of greenhouse gas emissions and 70% of freshwater use. Providing a sustainable diet for the world's growing population is extremely challenging. In terms of food security and sustainability, the processing, transportation and utilization of food waste and by-products are crucial as they have a significant impact on how the world is balanced when producing food (Fardet and Rock, 2020). Diets around the world link human health and environmental sustainability. Hence the need to provide a healthy and sustainable diet for the growing world population. The processing, transportation, waste, and by-product utilization of food, which has a great impact on the world balance for its production, is very critical for food security and sustainability. The increase in food processing has greatly contributed to the increase in agro-industrial waste. Agro-industrial waste is generated at all stages of the cycle, starting from agricultural production, industrial production, processing, and distribution. About 42% of waste from domestic activities, about 39% of industrial waste and about 20% of waste is generated during distribution (Kumar et al., 2017). For the welfare of the future, it is important to update all food systems from producer to consumer in a way that can contribute to sustainability.

Fruits and vegetables, which have an important place in our diet, contain many important nutrients such as vitamins, minerals, phenolic compounds, organic acids, food fibers (Samtiya et al., 2021). Various structural components known as polyphenols, found mostly in fruits and vegetables, are important for human nutrition and health. For the prevention of overpowering free radicals, the presence of phenolic substances shows a strong antioxidant effect (Hussain et al., 2022). The skins of fruits such

as grapes, strawberries and raspberries are particularly rich in phenolic compounds, making them excellent sources of nutrients. Due to their antioxidant properties, polyphenols, which are secondary metabolites often found in plants and include phenolic acids, flavonoids, procyanidins and tannins, have been shown to have protective or therapeutic effects on several degenerative and aging-related diseases, including cancer and cardiovascular diseases (Rudrapal et al., 2022)

Grapes, one of the agricultural products of our country, are processed for grape juice and wine, resulting in about 10-20% of the waste (Demirkol ve Tarakçı, 2018). These wastes, which have nutritional value, have taken their place in agricultural areas, feed industry, human nutrition, pharmaceutical and cosmetic industry, and their importance is increasing day by day. Many clinical and research studies have been conducted on the Mediterranean diet model due to the positive effects of grapes and grape pulp on human health. In Muslim Mediterranean countries where alcoholic beverages are not consumed, it was aimed to investigate a product rich in polyphenols and beverages rich in bioactive components as an alternative to wine, which has an important place in this diet. In this study, a new functional beverage with high phenolic content was produced by drying the waste grape pulp formed after pressing purple grapes.

Grape and grape pulp

Grape (*Vitis vinifera L.)* is considered one of the most widespread cultivated plants in the world because it is not very selective in terms of climate and soil requirements, easy to propagate and can be utilized in different ways. In the grape evaluation report, which includes Turkey's grape production data for the last 5 years, it is seen that Manisa has the largest grape production area and amount (Republic of Turkey Ministry of Agriculture and Forestry, 2021).

These wastes with nutritional value have taken their place in agriculture, feed industry, human nutrition, pharmaceutical and cosmetic industry, and their importance is increasing day by day. The main phenolic compounds found in grape pulp are known as anthocyanins, catechins, flavanols, flavonols, glycosides, phenolic acids, and stilbenes (Bao et al., 2020). Figure 1 shows the main phenolic compounds in grape pulp. Grape pulp consists of two different types of residues: seedless pulp (containing pulp, skins, and stems) and pulp containing seeds. The chemical composition of grape pulp is shown in Table 1.

The resulting grape pulp causes an important disposal problem for the viticulture industry. On the other hand, it attracts a lot of attention in the literature as it creates economic recycling output due to the phenolic compounds it contains. Therefore, the use of pulp in alternative fields has been investigated for many years (Barba et al., 2016; Sevindik and Selli, 2016). It is reported that metabolites obtained from grape pulp are rich in phenolic compounds with many health-related physiological properties such as anti-allergic, antibacterial, anticarcinogenic, anti-inflammatory, antioxidant and cardioprotective effects (Demirkol and Tarakçı, 2018). However, it is also reported to cause serious environmental damage if the pulp is thrown into the environment or burned outdoors (Lavelli et al., 2017; Drevelegka and Goula, 2020).

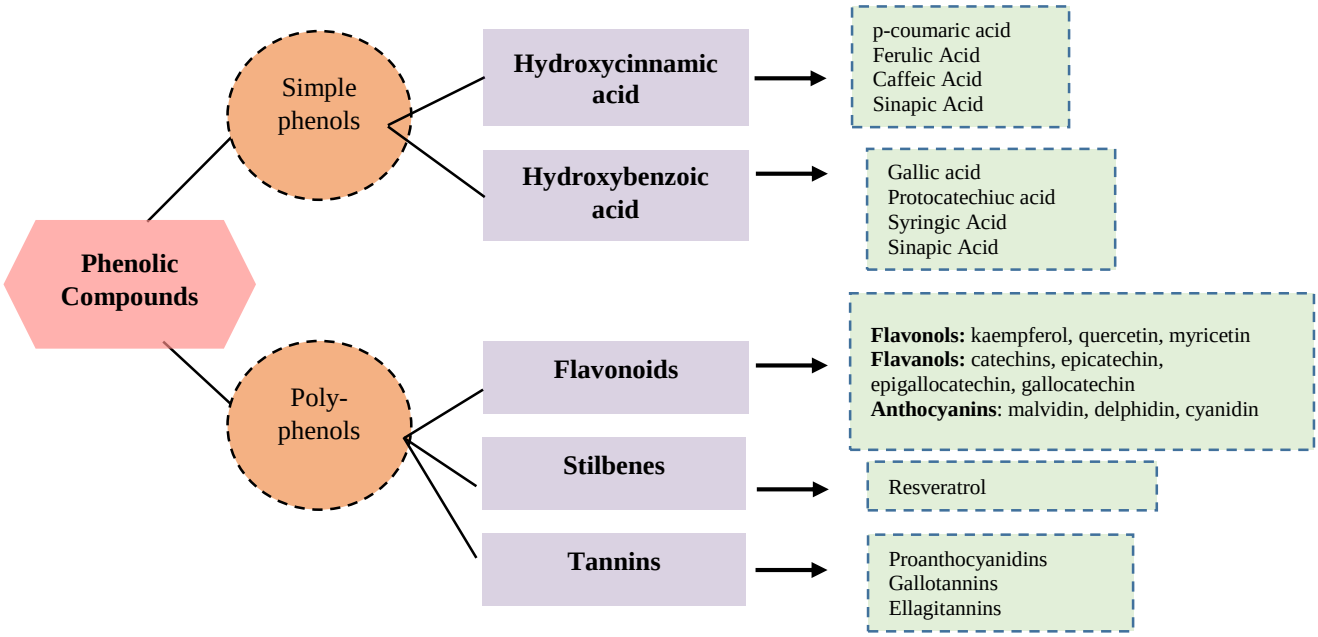

Figure 1. Major phenolic compounds in grape pulp (Sirohi et al., 2020).

Table 1. Chemical composition of grape pulp (dry basis) (Sirohi et al., 2020).

Moisture content (g/100 g)	3.33–7.55
Ash (g/100 g)	3.25–5.07
Total Lipids (g/100 g)	8.16–11.09
Protein (g/100 g)	8.49–10.32
Pectin (g/100 g)	3.68–29.20
Total Sugar (g/100 g)	3.68–29.20
Total dietary fibre (g/100 g)	19–38
Catechin (mg/100 g)	150.16
Total phenolics (mg GAE/100 g)	0.68–0.75
Anthocyanin (mg/100 g)	84.4–131

Functional Beverage Production from Grape Pulp

Grape pulp of Royal grapes (*Vitis Vinifera Linne Subsp. Vinifera*) was obtained from Manisa Viticulture Research Institute in September 2022. These products are the pulp left over after pressing of purple grapes processed into juice and used as waste. The supplied pulp was shade dried, ground for a more efficient extraction process and then sieved to obtain uniform sizes. In addition, for the sweetening of the product, it was aimed to obtain a low-calorie and naturally sweetened beverage by using stevia leaves, which have been shown to increase insulin sensitivity and can be used in diabetic products. In the light of this information, the targeted grape pulp drink was produced by infusion method at 80 °C by mixing waste dried grape pulp and sweetener stevia in certain amounts (Figure 2).

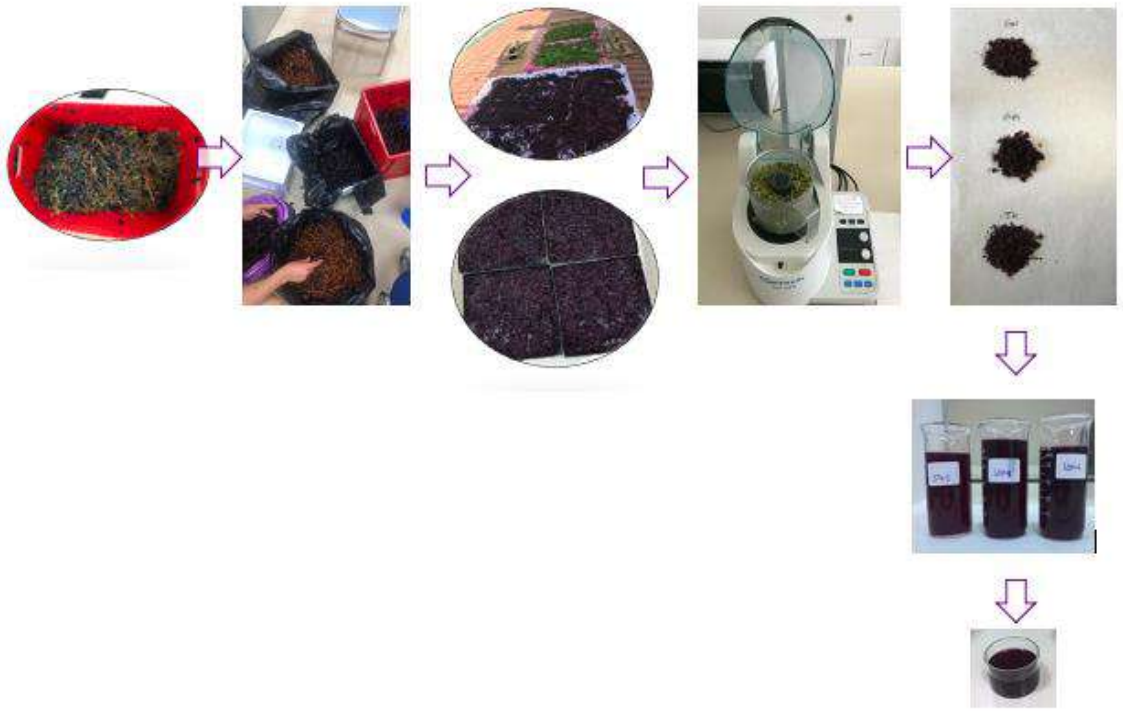

Figure 2. Flow chart of beverage produced from grape pulp

Effects on Health

Grapes are rich in polyphenols. There are many clinical studies showing that these polyphenols play an important role in preventing or reducing neurodegenerative disorders (Zhao et al., 2020). Grape products have anticarcinogenic effects by preventing DNA damage due to oxidation in plasma with the potential antioxidant effect of flavonoid compounds they contain (Aşçı, 2020). Resveratrol, known as the most active stilbene in terms of its biological activity, is the polyphenol whose health benefits have been investigated the most in in-vivo studies (Kersh et al., 2023). Resveratrol has been reported to inhibit tumor formation in different cancer types by showing anti-mutagenic activity. In addition, studies have shown that resveratrol taken with the consumption of grape products prevents many diseases such as virus development, bad cholesterol, high blood pressure, heart attack risk, Alzheimer's, Parkinson's, dementia, neurodegeneration. Grape seeds contain about 35% fiber, 29% extractable phenolic compounds, proteins (11%), minerals (3%) and water (7%). Grapes contain different polyphenols and may prevent inflammation by reducing Nitric oxide (NO) inactivation through antioxidative enzymes. Grape seed extract, which is rich in proanthocyanins, has been proven to be beneficial against many diseases such as inflammation, cardiovascular diseases, hypertension, diabetes, cancer, peptic ulcer and microbial infections by different and various studies (Aşçı, 2020).

Despite diets high in saturated fat, it has been discovered that the low incidence of heart disease among people in Southern France is associated with high red wine consumption. This phenomenon is known as the "French paradox" and is attributed to the significant amount of resveratrol (0.1-14.3 mg/L) found in red wine (Ross, 2023). In Muslim Mediterranean countries where alcoholic beverages are not consumed, the production of a non-alcoholic product rich in bioactive components such as polyphenols, which have an important place in the diet, is very important for health.

Conclusions

In recent years, natural and healthy nutrition has become increasingly widespread and important. Grapes and grape products are among the foods that should be included in the daily eating habits of people of all age groups and should be consumed due to their rich nutritional content and phenolic substances, disease-protective and anti-aging properties. A significant amount of grape pulp is produced worldwide, but unfortunately it cannot be transformed into a value-added product. Moreover, its disposal into the environment creates serious pollution and raises concerns. Given its rich composition, it could potentially be transformed into value-added products and make a significant contribution to the

sustainability of the food industry from producer to consumer for the well-being of people and the planet. In line with these objectives, a new functional beverage with high phenolic content was obtained by drying and utilizing grape pulp, which is considered as waste.

References

Aşçı, Aras Ö. 2020. Sağlıklı Yaşamda Üzüm ve Üzüm Ürünleri. Bilge International Journal of Science and Technology Research, 22-32.

Bao, Y., Reddivari, L., Huang, J. Y. 2020. "Enhancement of phenolic compounds extraction from grape pulp by high voltage atmospheric cold plasma", LWT, 133, 109970.

Barba, F. J., Zhu, Z., Koubaa, M., Sant'Ana, A. S., Orlien, V. 2016. "Green alternative methods for the extraction of antioxidant bioactive compounds from winery wastes and by-products: A review". Trends in Food Science & Technology, 49: 96-109.

Demirkol, M., Tarakci, Z. 2018. "Effect of grape (Vitis labrusca L.) pulp dried by different methods on physicochemical, microbiological and bioactive properties of yoghurt", LWT-Food Science and Technology, 97, 770-777.

Drevelegka, I., Goula, A. M. 2020. "Recovery of grape pulp phenolic compounds through optimized extraction and adsorption processes", Chemical Engineering and Processing-Process Intensification, 149, 107845.

Fardet, A., & Rock, E. 2020. Ultra-processed foods and food system sustainability: what are the links?. Sustainability, 12(15), 6280.

Hussain, T., Kalhoro, D. H., & Yin, Y. 2023. Identification of nutritional composition and antioxidant activities of fruit peels as a potential source of nutraceuticals. Frontiers in Nutrition, 9, 1065698.

Kersh, D. M. E., Hammad, G., Donia, M. S., & Farag, M. A. 2023. A comprehensive review on grape juice beverage in context to its processing and composition with future perspectives to maximize its value. Food and Bioprocess Technology, 16(1), 1-23.

Kumar, K., Yadav, A.N., Kumar, V., Vyas, P., Dhaliwal, H.S., 2017. Food waste: a potential bioresource for extraction of nutraceuticals and bioactive compounds. Bioresources and Bioprocessing 4 (1), 18.

Lavelli, V., Harsha, P. S. C. S., Laureati, M., Pagliarini, E. 2017. "Degradation kinetics of encapsulated grape skin phenolics and micronized grape skins in various water activity environments and criteria to develop wide-ranging and tailor-made food applications", Innovative food science and emerging Technologies, 39, 156-164.

Ross, S. M. 2023. Resveratrol: The Anti-inflammatory Effects of a Phytochemical Compound on Pneumonia, Respiratory Syncytial Virus, and Severe Acute Respiratory Syndrome (SARS-CoV-2). Holistic Nursing Practice, 37(2), 110-112.

Rudrapal, M., Khairnar, S. J., Khan, J., Dukhyil, A. B., Ansari, M. A., Alomary, M. N., ... & Devi, R. (2022). Dietary polyphenols and their role in oxidative stress-induced human diseases: insights into protective effects, antioxidant potentials and mechanism (s) of action. Frontiers in pharmacology, 13, 283.

Samtiya, M., Aluko, R. E., Dhewa, T., & Moreno-Rojas, J. M. 2021. Potential health benefits of plant food-derived bioactive components: An overview. Foods, 10(4), 839.

Sevindik, O., Selli, S. 2016. "Üzüm Çekirdeklerinin Temel Biyoaktif Bileşenleri", Çukurova Tarım ve Gıda Bilimleri Dergisi, 31(2), 9-16.

Sirohi, R., Tarafdar, A., Singh, S., Negi, T., Gaur, V. K., Gnansounou, E., & Bharathiraja, B. 2020. Green processing and biotechnological potential of grape pulp: Current trends and opportunities for sustainable biorefinery. Bioresource Technology, 314, 123771.

Republic of Türkiye Ministry of Agriculture and Forestry. 2020. "Grape Evaluation Report". Last accessed: 23 November 2021.

Zhao, D., Simon, J. E. and Wu, Q., 2020. A critical review on grape polyphenols for neuroprotection: Strategies to enhance bioefficacy, Critical Reviews in Food Science and Nutrition, 60:4, 597-625.

Değerli Bir Atık Olan Peynir Altı Suyunun Probiyotik Fermente İçecek Üretiminde Kullanımı

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Özet

Türk Gıda Kodeksi peynir tebliğine göre peynir altı suyu; pıhtı kesimi sonrasında pıhtıdan ayrılan ve teleme dışında kalan yeşilimsi sarı renkteki sıvı olarak tanımlanmaktadır. Peynir altı suyu, peynir prosesinin ana yan ürünüdür. Peynir altı suyu yüksek oksijen ihtiyacına sahiptir bu yüzden su kaynaklarına atıldığında çözünmüş oksijeni azaltır ve çevre için risk oluşturur. Peynir altı suyu, farklı düzeylerde laktoz, serum proteinleri (albümin, globülin), vitaminler, mineraller, laktoferrin, laktoperoksidaz gibi minör bileşenler, yüksek amino asit (lösin, izolösin ve valin) içeriğine sahiptir. Peynir altı suyu zengin kuru madde içeriği ile insan sağlığı ve beslenmesi açısından biyolojik değeri yüksek bir atıktır. Peynir altı suyunun gıda ürünlerinde kullanımı, besin değeri zengin gıdaların üretilmesi açısından inovatif, ayrıca atık su arıtma maliyetlerinin düşürülmesine katkı sağlaması ve yanlış bertaraf edilmesinden kaynaklı çevresel zararın azaltılması yönünden büyük ekonomik ve ekolojik değere sahiptir. Muhafaza, taşıma ve depolama kolaylıklarında dolayı peynir altı suyu tozu üretimi ve kullanımı yaygın olarak tercih edilmektedir. Gıda endüstrisinde yoğurtlar, dondurmalar, kekler, şekerlemeler, bebek mamaları, soslar, fırıncılık ürünleri, et ürünleri, çorbalar ve çeşitli içeceklerin gibi gıdaların üretimde kullanılmaktadır. Bunlarla birlikte peynir altı suyu tozundan yemlerle karıştırılarak hayvan beslenmesinde de yararlanılmaktadır. Son yıllarda peynir altı suyunun tek olarak kullanıldığı veya süt, meyve suyu, meyve pulpları vb. ile karıştırılarak ve aynı zamanda probiyotik bakteri ve/veya maya ilaveli birçok inovatif ürün geliştirilmektedir. Özellikle probiyotik mikroorganizmaların büyümesi ve canlılığı için uygun bir besin matrisi sunduğu için fermente peynir altı suyu içecekler ile ilgili araştırmalar artış göstermiştir. Probiyotik fermente peynir altı suyu içeceklerinin, kandaki kolesterol seviyesini düşürücü, laktoz metabolizmasını düzenleyici, kan basıncını düşürücü, antikanserojenik özellikleri ve immun sistem teşviki gibi insan sağlığına olumlu etkiler gösterdiği uzun zamandır bilimsel çalışmalara konu edilmiş ve halen bu konularda çalışmalara devam edilmektedir.

Bu çalışmada peynir altı suyu ve farklı probiyotik kültürler kullanılarak üretilen fermente içecekler ile ilgili araştırmalar ürünlerin kalite özellikleri ve insan sağlığına etkileri kapsamında derlenmiştir.

Anahtar kelimeler: Peynir altı suyu, probiyotikler, fermente içecek

Giriş

Gıda endüstrisinde besin açısından zengin bileşenlere sahip ve tüketiciler tarafından sevilerek tercih edilen büyük bir fonksiyonel gıda grubu geliştirilmiştir. Fonksiyonel gıda grubunda süt ve süt ürünlerinin payı daha büyüktür. Bu nedenle sağlık ve beslenme özellikleri açısından zenginleştirilip inovatif ürünler geliştirilmekte ve çalışmalar devam etmektedir [1,2]. Peynir üretiminin bir yan ürünü olan peynir altı suyu genellikle ya atık olarak bertaraf edilmekte ya da hayvan beslenmesinde kullanılmaktadır. Ancak peynir altı suyunun ilk olarak sahip olduğu zengin besin değerinden ve yüksek ekonomik değerinden dolayı hem kendisi hem de peynir altı suyu içeren gıdalar bu yeni ürünler arasında kendine önemli bir yer edinmiştir[1]. Fonksiyonel gıdaların önemli ve hızla büyüyen kategorilerinin başında probiyotik içeren gıdalar bulunmaktadır. Probiyotikler yeterli miktarda uygulandığında konakçıya sağlık yararları sağlayan canlı mikroorganizmalardır [3]. Probiyotik gıdalar, antimikrobiyal aktivite, hipokolesterolemik aktivite, gastrointestinal denge ve antikanserojen aktivite gibi terapötik özelliklere sahip mikroorganizmalar içeren gıdalar olarak tanımlanmaktadır [4]. Fermente süt ürünleri fonksiyonel içeceklerin başında yer almaktadır. Bununla birlikte peynir altı suyunun sahip olduğu mevcut besin değerini probiyotik mikroorganizmalarla birlikte geliştirerek yapılan pek çok çalışma bulunmaktadır. Bu makalede yapılan çalışmalara örnekler göstererek, peynir

altı suyu ile üretilmiş fermente içeceklerin insan sağlığına etkisi ve gösterdikleri kalite özellikleri incelenmiştir.

Peynir altı suyu bileşimi ve özellikleri

Peynir altı suyunun bileşimi sütün kaynağına, üretilen peynir türlerine (peynir mayası veya asit pıhtılaşması) ve genel olarak süt bileşimini etkileyen cins, mevsimsel döngüler, yem ve laktasyon fazı gibi faktörlere bağlıdır[1]. Tatlı ve ekşi peynir altı suyu olarak ikiye ayrılmaktadır. Enzim kullanılarak pıhtılaştırma yapılırsa tatlı peynir altı suyu (min pH 6.3), asit kullanılarak pıhtılaştırma yapılırsa ekşi peynir altı suyu (pH 4.6) olarak sınıflandırmak mümkündür.

Tablo 1: Tatlı ve ekşi peynir altı suyunun bileşenleri [1]

Bileşenler	Tatlı peynir altı suyu (g/L)	Ekşi peynir altı suyu (g/L)
Toplam katı madde	63.0-70.0	63.0-70.0
Laktoz	46.0-52.0	44.0-46.0
Protein	6.0-10.0	6.0-8.0
Yağ	5.0	0.4
Laktat	2.0	6.4
Kül	5.0	8.0
Kalsiyum	0.4-0.6	1.2-1.6
Fosfat	1.0-3.0	2.0-4.5
Klorür	1.1	1.1

Peynir altı suyu, farklı düzeylerde laktoz, serum proteinleri (albümin, globülin), vitaminler, mineraller (kalsiyum, fosfor, magnezyum, çinko vs.), P2O5 ve K2O ihtiva etmektedir[5]. Bu bileşenlerin teknolojik olarak en önemlisi peynir altı suyu proteinleridir. Bu proteinler çok dallı zengin amino asitlerden ulaşan globüler proteinlerdir. Peynir altı suyu proteinlerinin ana bileşenleri β-laktoglobulindir (β-Lg) (%50), ve bunu sırasıyla α-laktalbumin (α-La) (%20), immunoglobulinler (Ig) (%10), sığır serum albumini (BSA) (%10), laktoferrin (LF) (%0,3) ve laktoperoksidaz (LP) (%0,3) gibi proteinler takip etmektedir[6]. β-Laktoglobulin (β-Lg), peynir altı suyu proteinlerinde en yüksek oranda bulunan proteindir. Bu protein glutatyon sentezlenmesinde büyük önem taşımakta, yağ asidi ve lipid bağlayıcı olarak görev yapmakta, yapısındaki sistein amino asidi sayesinde kas gelişiminde görev almaktadır[7], [8]. α-Laktalbumin (α- La), peynir altı suyunda en fazla bulunan ikinci proteindir. Yeni doğanlar için enerji kaynağı olarak kullanılmakta ve laktozun biyosentezi için bir ko-enzim görevi görmektedir. Anne sütündeki temel proteine yapı ve kompozisyon açısından benzediği için bebek mamaların yapımında saf α-laktalbumin kullanılmaktadır[9]. Sığır serum albumini (BSA), kan akışı ile süte geçmekte ve serbest yağ asitlerini ve lipitleri bağlayabilme özelliği göstermektedir[7]. İmmunoglobulinler (Ig), peynir altı suyunda bulunan proteinlerin en küçük fraksiyonudur. IgG1, IgG2, IgA ve IgM gibi çeşitleri bulunmaktadır ve minör bileşenler olarak adlandırılan PAS proteinlerinin bu grubu, bebekler için pasif bağışıklığı sağlamakta iken yetişkinlerde bağışıklık sistemini güçlendirmektedir[10].

Laktoz ise peynir altı suyu kuru maddesinin ana bileşenidir (yaklaşık %70) ve çok önemli bir enerji kaynağıdır. Laktozun bazı yararlı etkileri sindirim sisteminde peristaltik aktivitelerin stimülasyonu, bağırsakta patojenlerin büyümesini ve gelişmesini engelleyerek hafif asit reaksiyonun kurulması olarak sıralanabilir[1]. Peynir altı suyunda riboflavin, folik asit ve kobalamin önemli miktarlarda bulunur ve peynir altı suyu proteinlerine bağlı durumdadırlar. Peynir altı suyu sütten daha yüksek miktarda riboflavin içermektedir. Bunun nedeni, peynir üretiminde kullanılan bazı laktik asit bakterilerinin aktiviteleri nedeniyle riboflavin içeriğinde artış meydana gelebilmektedir. Oldukça yüksek riboflavin içeriğinden dolayı, peynir altı suyu karakteristik sarı-yeşil renge sahiptir[5].

Peynir altı suyunun değerlendirilmesi

Türkiye'de yılda yaklaşık 23,2 milyon ton çiğ süt üretilmektedir[11]. Üretilen bu sütün yaklaşık % 20'sinin peynire işlendiği kabul edilirse, Türkiye'de yılda yaklaşık 4,64 milyon ton sütün peynire işlendiği sonucu elde edilmektedir. Normalde peynire işlenen sütün yaklaşık %80'i peynir altı suyu olarak ayrılmakta ve yine yılda yaklaşık 3,71 milyon ton olarak ortaya çıkan peynir altı suyu büyük

ölçüde atık olarak kalmaktadır. Bu değerli atığın direkt olarak çevreye deşarj edilmesi yasak olduğu ve ayrıca pek çok yönden değerli bir atık olduğu için geliştirilen teknolojilerle ekonomiye kazandırılması sağlanmıştır. Peynir altı suyu tozu (WP), peynir altı suyu protein konsantreleri (WPC), peynir altı suyu protein izolatları (WPI) ve toz laktoz gibi suyu alınmış peynir altı suyu ürünlerinin üretimi peynir altı suyunun arıtılmasına yönelik geleneksel çözümler arasındadır. Gelişen teknolojiyle birlikte ultrafiltrasyon, mikrofiltrasyon, ters osmoz, iyon değişimi, kurutma veya konsantre etme gibi işlemlerle peynir altı suyu bileşenlerinin her birinin tek tek izole edilmesi gibi farklı amaçlarla kullanılmaya başlanmıştır. İzole edilmiş peynir altı suyu proteinleri, gıda sistemlerinde emülgatör, jelleştirici ajan, su bağlayıcı ve köpürtücü/çırpıcı ajan olarak kullanımına olanak sağlayan fiziksel-kimyasal ve besleyici özelliklerinden dolayı gıda endüstrisinde kullanım alanına sahiptir. Çorbalar, salata sosları, işlenmiş et, süt ve unlu mamuller ve ricotta, lor gibi peynir altı suyu peynirleri, spesifik peynir altı suyu ürünleri, ayrıca fermente peynir altı suyu içecekleri gibi birçok farklı gıdada kullanılırlar [2,12,13].

Peynir altı suyu ve tozu ekmek ve fırın ürünlerinde besin değerini artırıcı bir katkı maddesi olarak kullanılabilmektedir. Yalnızca fazla miktarda kullanıldığında, yüksek miktarda laktoz içeriği ve mineral madde varlığı nedeniyle maya aktivitesini olumsuz yönde etkileyerek daha düşük hacimli ve tekstürel özellikleri zayıf bir ekmek elde edilmesine neden olmaktadır. Yapılan çalışmalarda, peynir altı suyunun %2 oranında ekmek üretiminde kullanımının, ekmeğin besin değerini artırdığı ve kalitatif özelliklerini geliştirdiği tespit edilmiştir[14].

Peynir altı suyu proteini kısmen et proteininin yerini alabilmekte ve soya proteini ve diğer bağlayıcı maddeler, lifler, modifiye nişasta ve hidrokolloidlerin yerine ikame maddesi olarak değerlendirilmektedir[15].Özellikle, şarküteri ürünlerinin örneğin; sosis, salam, mortadella ve surimi gibi üretiminde de önemli bir katkı maddesi olarak kullanılabilmektedir.

Peynir altı suyu ve ürünleri margarin yapımında, maya ve sirke üretiminde, limon asidi, B12 vitamini elde edilmesinde, laktoz, etil alkol ve biyogaz üretiminde, poliüretan köpük yapımında, tek hücre proteini ve tarımsal ilaçların üretiminde, boyalar ve çeşitli kimyasalların yapımında, sentetik deterjanlar, temizleme ajanlarının üretimi ve kozmetik sanayiinde kullanılabilmektedir[5].

Peynir altı suyundan içecek üretimi

Peynir altı suyu içecek sektöründe kullanılmaya 1970'lerde başlamıştır ve en eski peynir altı suyu içeceklerinden biri İsviçre'de üretilen Rivella'dır[9]. Günümüzde de yaygın olarak tatlı peynir altı suyu kullanılırken ürünlerin içilebilirliğini geliştirmek amacıyla çeşitli meyve suları, konsantreleri, pulpları, nektarları veya şurupları ilave edildiği çalışmalar yapılmaktadır[16–19]. En fazla turunçgil meyveleri tercih edilmiştir, bunu muz, mango, papaya gibi tropik meyveler ve elma, vişne, kavun, kayısı gibi meyveler ve üzümsü meyveler takip etmiştir. Çünkü bu içeceklerin istenmeyen pişmiş süt aroması ve taze peynir altı suyunun tuzlu-ekşi aromasının maskelenmesi acısından çok etkili olduğu ispatlanmıştır[20].

Araştırmacılar ürünün asitliğini düzenlemek için en çok sitrik asidin tercih edildiğini belirtmiştir[9]. Bazı araştırmacılar ürünü tatlandırmak için fruktoz veya enzimatik hidrolize laktoz kullanırken, bazıları ise doğal ve yapay tatlandırıcı kullandığını belirtmiştir[21]. Aynı zamanda elma, armut, şeftali, kayısı ve kiraz gibi birçok meyve konsantresi de uygulanmıştır. İyi bir demir ve antioksidan kaynağı olarak bilinen meyvelerin eklenmesinin çok faydalı olduğu kanıtlanmıştır.

Nedanovska ve ark. (2022), yapmış olduğu çalışmadapeynir altı suyu ve mango, ananas, tropik meyve aromalı içecekler şeker, extra şeker ve stevia ile tatlandırılarak 15 gün boyunca fizikokimyasal, duyusal ve mikrobiyolojik analizleri yapılmıştır. Ürünler arasında fizikokimyasal ve mikrobiyolojik olarak önemli bir fark görülmezken duyusal testlerde en çok tercih edilen stevia özlü ve tropik meyve aromalı ürün tercih edilmiştir. Sonuç olarak peynir altı suyu içeceklerin fonksiyonel olarak geliştirilip kalite özelliklerinin iyileştirilebileceği kanıtlanmıştır [22].

Meyvelerin yanı sıra çikolata, kakao, vanilya gibi diğer tatlandırıcılar, tahıllar (çoğunlukla pirinç, yulaf ve arpa), bal vb. eklendiği çalışmalar da bulunmaktadır. Özellikle tahılların eklenmesi sonucunda, alerjik popülasyonun ve çocuklar tarafından tüketilebilir hale getiren diyet liflerle, esansiyel yağ asitleri ile (yulaf ilavesi ile) ve hipoalerjenik proteinlerle güçlendirilmiş özellikte içeceğin üretilmesi sağlamaktadır. Hipoalerjenik bir içecek hazırlamak için patates izolatları veya soya proteinleri gibi diğer bitkisel protein kaynaklarının eklenmesinden de yararlanılabilir. Bu içeceklere şeker veya diğer tatlandırıcılar yerine balın eklenmesi, peynir altı suyunda doğal olarak bulunmayan vitaminler, mineraller ve fitokimyasallar gibi çok sayıda başka besin maddesi ile güçlendirilmesine neden olur [23].

Peynir altı suyu yüksek laktoz oranına (%70) sahip olduğu için alkollü içecek üretimi içinde uygun özelliktedir. Genel olarak düşük alkollü içeceklerin (≤ % 1.5) üretimi yapılırken laktozu fermente eden

Kluyveromyces marxianus mayasının fermentasyonuyla yüksek oranda alkol konsantrasyonuna sahip içecek üretebildiği belirtilmiştir. Peynir altı suyu kullanılarak üretilen peynir altı suyu birası, şarabı ve likörünün üretimi uluslararası pazarda tüketime sunulmuştur [24].

Peynir altı suyundan fermente içecek üretimi

Son yıllarda, peynir altı suyu içeceklerinin üretiminde probiyotik bakterilerden yararlanma olanakları üzerine araştırmalar yoğunlaşmış durumdadır. Probiyotik ürün tüketiminin sağlık açısından faydaları, spesifik probiyotik mikroorganizmaların üretim, depolama ve tüketim sırasındaki canlılığının yanı sıra gastrointestinal sistemden geçişine bağlıdır. Ürünlerde probiyotiklerin stabilitesini etkileyen en önemli faktörler: spesifik suş özellikleri, gıda matrisinin kimyasal bileşimi, asitlik, eşlik eden diğer bakteriler, saklama süresi ve koşullarıdır[25]. Bu özelliklerin çoğu, genel olarak gıdanın duyusal özelliklerini belirlemektedir. Duyusal çekicilik, tüketicinin gıda satın alma kararını temelinde verdiği en önemli faktördür. Bu nedenle, probiyotik gıdaları tasarlarken, probiyotik bakterilerin hayatta kalmasını iyileştirmek, ürün parametrelerini ayarlamak için sınırlı bir kapsam vardır. Bu yüzden yeni bir gıda üretimi için iyi teknolojik özelliklere sahip uygun bir probiyotik türün seçimine özel dikkat gösterilmelidir[26].

Peynir altı suyundaki yüksek laktoz seviyesi, bu yan ürünün kolayca fermente edilmesini ve atık bir üründen katma değerli bir içeceğe dönüştürülmesini sağlamaktadır[27]. Peynir altı suyu, *Lactobacillus acidophilus*, *Lactobacillus delbrueckii* ssp. *bulgaricus*, *Streptococcus thermophilus*, *Lactobacillus rhamnosus* ve *Bifidobacterium animalis* ssp. *lactis* gibi farklı suşlarla fermente edilmiştir. Yapılan çalışmalar sonucunda yoğurt kültürü ve *Streptococcus thermophilus* – *Bifidobacterium animalis* ssp. *lactis* gibi kombine kültürler ile fermantasyonların en iyi sonuçlar verdiği belirlenmiştir.[28]

Marek ve ark. (2017), yapmış olduğu çalışmada portakal, elma ve frenk üzümü peynir altı suyu içecekleri üretilmiş ve her biri Bifidobacterium *lactis, Lactobacillus acidophilus, Lactobacillus paracasei, Lactobacillus rhamnosus* probiyotik suşlardan biri ile aşılanmıştır ve 28 günlük depolama süresince mikrobiyolojik analizler canlı sayısı takibi gerçekleştirilmiştir. Sonuç olarak meyveli peynir altı suyu içeceklerinde yeterli sayıda canlı probiyotik hücre olduğunu, yani terapötik düzeyi sağladığını ancak meyve suyu bileşeninin, özellikle asitliği açısından dikkatli seçiminin, başarılı probiyotik meyveli peynir altı suyu içeceklerini tasarlamanın anahtarı olduğunu göstermiştir [3].

Güzeller ve Esmek 'in (2014), yapmış olduğu çalışmada beyaz peynir üretiminden arta kalan peynir altı suyu ve kefir kültürü kullanılarak içecek üretilmiştir. % 25 peynir altı suyu % 75 süt oranı ile üretilen içecek tercih edilmiş ve bu içeceğin depolamanın 1., 7., 14. Ve 21. günlerinde bazı fiziksel, kimyasal ve duyusal özellikleri incelenmiştir. Yapılan kimyasal ve duyusal analizler sonucu 48 saatlik inkübasyon tercih edilmiştir ve kefir taneleriyle fermantasyonu ile peynir altı suyundaki laktoz konsantrasyonu azalırken lezzet ve tekstüre katkı sağlayacak aroma bileşenleri oluşmuştur. İçeceğin üretimi sırasında meydana gelen laktik asit ve alkol fermantasyonları aracılığıyla da arzu edilen ferahlatıcı tat ve aroma ile duyusal özellikler sağlanmıştır [21].

Maity ve ark. (2008), yapmış olduğu çalışmada probiyotikli, sağlıklı fermente peynir altı suyu içeceği yapmak için, *Lactobacillus rhamnosus, Bifidobacterium bifidum* ve *Propionibacterium freudenreichii subsp. shermanii* kültürleri kullanılmıştır. Titre edilebilir asitlik ve duyusal özellikler, depolamanın ilk 7 günü boyunca önemli ölçüde değişmemiştir. 15 günlük depolama sonunda örneklerin asitliğinde hafif artış gözlemlenmiştir. Bununla birlikte 8 saat boyunca fermente edilmiş ve %4 inokulum karışık kültür (1:1:1) ile hazırlanan peynir altı suyu içeceği, 10 günlük depolama süresine kadar her bakteri popülasyonu 10^8 CFU/mL'den daha büyük sayılarda tutularak probiyotik kriterini karşılamıştır[29].

Ericka ve ark. (2015), yapmış olduğu çalışmada çikolatalı keçi peynirinden üretilen peynir altı suyu içeceği probiyotik *Bifidobacterium lactis* ile fermente edilmiştir. İçeceğe prebiyotik olarak inülin ve oligofruktoz eklenmiş içeceklerin fizikokimyasal parametreleri ve duyusal özellikleri değerlendirilmiştir. Sonuç olarak, keçi peyniri peynir altı suyunun ve inülin ile oligofruktoz kombinasyonun fonksiyonel olarak kullanılabileceği aynı zamanda yeterli probiyotik canlılığını sürdürmek ve viskozitesini ve duyusal özelliklerini iyileştirmek için probiyotik bir çikolatalı keçi sütü içeceğinin formüle edilebileceği kanıtlanmıştır[16].

Peynir altı suyunun insan sağlığı üzerine etkileri

Peynir altı suyu ve peynir altı suyundan elde edilen proteinlerin besinsel ve biyolojik özelliklerinin gelişen teknoloji ile daha iyi anlaşılması sağlanmış ve bu ürünlerin insan sağlığının korunması ve hastalıkların iyileştirilmesinde kullanılabileceği ortaya koyulmuştur. Peynir altı suyu proteinleri

oldukça yüksek bir biyolojik değere sahiptir. Lisin ve lösin aminoasitleri açısından oldukça zengin olan ve önemli miktarda metionin ve sistin aminoasitlerini içeren kıymetli bir protein özelliğindedir. Sistein konsantrasyonun yüksek olmasına bağlı olarak glutatiyon üretimini arttıran tek protein peynir altı suyu proteinidir. Glutatiyon, vücudun antioksidan ve bağışıklık savunma sistemlerinin ana maddesidir[30, 31].

Peynir altı suyu proteini, sahip olduğu mükemmel besin değerine ilave olarak, bağışıklığı güçlendirme, gastrointestinal hormon salgılanmasını uyarma, antimikrobiyal ve antiviral aktivite, tokluk tepkisi ve kas anabolizmi gibi diğer metabolik fonksiyonlar açısından da sağlık üzerinde önemli etkilere sahiptir. Peynir altı suyu proteinlerinin temel biyolojik aktiviteleri Tablo 2'de özetlenmiştir.

Tablo 2: Peynir altı suyu proteinlerinin biyolojik aktiviteleri ve peynir altı suyu proteini tüketiminin potansiyel faydaları

Protein	*Biyolojik aktivite (Biological activity)*
Tam peynir altı suyu proteini	Kanserin önlenmesi (ör., meme ve bağırsak kanseri, glutathion düzeyinin artırılması, tümör hücresinde zayıflama, HIV tedavisi, antimikrobiyal aktivite, doygunluk cevabının artması, plazma amino asitlerinde artış, kolesistokinin ve glukagon benzeri peptit miktarında artış
β-laktoglobulin	Retinol, palmitat, D vitamini, kolesterol, yağ asitleri ve trigliseritlerin taşıyıcısı, mideden geçiş sırasında dayanıklılık göstermesi, pasif bağışıklık gelişimi ve transferi, meme bezi metabolizmasının düzenlenmesi, antikanserojenik ve immünomodülatör aktivite
α-laktalbumin	Antikanserojenik aktivite, laktoz sentezi, kronik stres kaynaklı hastalıkların tedavisi
Sığır serum albumini	Lipitlerin sentezi, antimutajenik aktivite, antioksidan aktivite, antikanserojenik aktivite
İmmünoglobulinler	İmmünomodülatör aktivite, büyüme ve gelişme, pasif bağışıklık yoluyla hastalıklardan korunma, antibakteriyel aktivite, antifungal aktivite, opioid etkinliği, HIV tedavisi
laktoferrin	Antimikrobiyal etkinlik, antifungal aktivite, antiviral aktivite, antitrombotik aktivite, immünomodülatör aktivite, antiproliferatif aktivite
Laktoperoksidaz	Antimikrobiyal aktivite , antifungal aktivite, immünomodülatör aktivite

Sütte bulunan ve suda çözünen vitaminler, peynir altı suyuna geçmektedir. Riboflavin (B2), folik asit ve siyanokobalamin (B12), peynir altı suyunda önemli miktarlarda bulunan vitaminlerdir. Peynir altı suyu sütten daha yüksek miktarda riboflavin içermektedir. Bundan dolayı, karakteristik yeşilimsi sarı renge sahiptir[1].

Son yıllarda, peynir altı suyu içeceklerinin üretiminde probiyotik bakterilerden yararlanma olanakları üzerine araştırmalar yoğunlaşmış durumdadır. Hem probiyotik bakterilerin hem de nutrasötik bileşenlerin fermente peynir altı suyu içeceği üretiminde birlikte kullanımı terapatik/fonksiyonel potansiyeli artıracağından sağlık üzerinde olumlu etkiler yaratacağı açıktır[32].

Rosa ve ark. [33], gerçekleştirdiği çalışmada probiyotik peynir altı suyu içeceklerinin insan prostat kanser hücre dizilimdeki etkilerini gözlemlemişlerdir. Çalışmada 5 farklı peynir altı suyu üretimi yapılmış; geleneksel peynir altı suyu (probiyotik suş eklenmemiş), *Lactobacillus acidophilu, Lactobacillus acidophilus, Lactobacillus casei ve Bifidobacterium animali*s içeren peynir altı suyu içecekleri üretilmiştir. Sonuç olarak tüm numunelerin, kanser hücre hattına karşı sitotoksik aktiviteler sergiledikleri gözlemlenmiştir. Bunun yanı sıra bütün probiyotik suşlar kanser hücrelerin geniş apopoz indüksiyonuna neden olduğu tespit edilmiştir[33].

Suchkova ve ark. [34], gerçekleştirdiği çalışmada peynir altı suyunun yüksek biyolojik değeri nedeniyle, organizmada beyin, sinir ve sinir sisteminin normal işleyişini sağlayan çeşitli biyokatalitik reaksiyonlara katılan B12 vitamini gibi karmaşık yüksek moleküler maddelerin doğrudan mikrobiyolojik sentezi tekniklerinde besin ortamı olarak kullanılması amaçlanmıştır. Bu çalışma içinde B12 üreticisi olarak peynir altı suyundaki laktozu karbon kaynağı olarak kullanabilen ve doğrudan peynir altı suyunda gelişim gösterebilen *Propionibacterium shermanii* suşu tercih edilmiştir. Elde edilen sonuçlar ise propiyonik bakterilerin peynir altı suyuna dayalı ve B12 vitamini ile

zenginleştirilmiş fermente gıda ürünlerinin imalatının yoğunlaştırılması için kullanılabileceğini göstermiştir [34].

Sonuç

Peynir üretiminin bir yan ürünü olan peynir altı suyunun sahip olduğu kalite özellikleri ve besin değeri ile yüksek ekonomik değere sahip olduğu pek çok çalışmada kanıtlanmıştır. Son dönemlerin popüler beslenme alışkanlarından doğan fonksiyonel gıda kategorisi içinde oldukça uygun özelliklere sahip olduğu gözlemlenmiştir. İnsan sağlığı bakımından faydaları kanıtlanmış probiyotik bakterilerle zenginleştirilip, çeşitli aroma maddeleri ile albenisi arttırılan fermente peynir altı suyu içecekleri ilerleyen dönemlerde tüketici tarafından tercih edilecektir. Bununla birlikte bir atık olan peynir altı suyunun gıda endüstrisinde kullanımı ekonomik açıdan, gıda kayıplarının azaltılması açısından ve çevre kirliliği açısından büyük önem taşımaktadır.

Referanslar

[1] I. Jeličić, R. Božanić, and L. Tratnik, "Whey-based beverages-a new generation of diary products," Mljekarstvo 58 (3) 257-274, 2008.

[2] M. P. Ryan and G. Walsh, "The biotechnological potential of whey," *Reviews in Environmental Science and Biotechnology*, vol. 15, no. 3. Springer Netherlands, pp. 479–498, Sep. 01, 2016. doi: 10.1007/s11157-016-9402-1.

[3] M. Sady, D. Najgebauer-Lejko, and J. Domagała, "The suitability of different probiotic strains for the production of fruit-whey beverages," *Acta Sci Pol Technol Aliment*, vol. 16, no. 4, pp. 421–429, Dec. 2017, doi: 10.17306/J.AFS.2017.0515.

[4] A. R. Madureira, C. I. Pereira, K. Truszkowska, A. M. Gomes, M. E. Pintado, and F. X. Malcata, "Survival of probiotic bacteria in a whey cheese vector submitted to environmental conditions prevailing in the gastrointestinal tract," in *International Dairy Journal*, Jun. 2005, pp. 921–927. doi: 10.1016/j.idairyj.2004.08.025.

[5] A. Kavaz Yüksel *et al.*, "Peynir Altı Suyunun Çeşitli Özellikleri Ve Kullanım Olanakları Various Properties of Whey and Possibiliteis of Its Utilisation," KSÜ Mühendislik Bilimleri Dergisi, 22(3), 2019.

[6] C. Mollea, L. Marmo, and F. Bosco, "Valorisation of Cheese Whey, a By-Product from the Dairy Industry," in *Food Industry*, InTech, 2013. doi: 10.5772/53159.

[7] J. N. De Wit, "Nutritional and Functional Characteristics of Whey Proteins in Food Products," *J Dairy Sci*, vol. 81, no. 3, pp. 597–608, 1998, doi: 10.3168/jds.S0022-0302(98)75613-9.

[8] M. D. Pérez and M. Calvo, "Interaction of β-Lactoglobulin with Retinol and Fatty Acids and Its Role as a Possible Biological Function for This Protein: A Review," *J Dairy Sci*, vol. 78, no. 5, pp. 978–988, 1995, doi: 10.3168/jds.S0022-0302(95)76713-3.

[9] O. Yerlikaya *et al.*, "Peynir altı Suyunun Fonksiyonel Özellikleri ve Peynir altı Suyu Kullanılarak Üretilen Yeni Nesil Süt Ürünleri," GIDA (2010) 35(4):289-296, 2010.

[10] R. L. Walzem, C. J. Dillard, and J. B. German, "Whey components: Millennia of evolution create functionalities for mammalian nutrition: What we know and what we may be overlooking," *Crit Rev Food Sci Nutr*, vol. 42, no. 4, pp. 353–375, Aug. 2002, doi: 10.1080/10408690290825574.

[11] TÜİK, "TÜİK, (2022)Tarım Ürünleri Piyasaları Agricultural Products Markets," 2022. [Online]. Available: https://arastirma.tarimorman.gov.tr/tepge

[12] A. Kotoulas *et al.*, "Second cheese whey treatment using zeolite under continuous flow mode and its application on wheat growth," *Water (Switzerland)*, vol. 11, no. 5, May 2019, doi: 10.3390/w11050928.

[13] Carlos Pereira, Marta Henriques, David Gomes, Andrea Gomez-Zavaglia, and Graciela de Antoni, "Novel Functional Whey-Based Drinks with Great Potential in the Dairy Industry," May 2015.

[14] Mete Hasan, "Peynir Altı Suyunun Ekmekçilikte Değerlendirilmesi ve Ekonomik Önemi," Tekirdağ S.M.M.M. Odası Sosyal Bilimler Dergisi, Sayı 1,2012.

[15] M. K. Youssef and S. Barbut, "Effects of two types of soy protein isolates, native and preheated whey protein isolates on emulsified meat batters prepared at different protein levels," *Meat Sci*, vol. 87, no. 1, pp. 54–60, Jan. 2011, doi: 10.1016/j.meatsci.2010.09.002.

[16] E. O. D. da Silveira, J. H. Lopes Neto, L. A. da Silva, A. E. S. Raposo, M. Magnani, and H. R. Cardarelli, "The effects of inulin combined with oligofructose and goat cheese whey on the physicochemical properties and sensory acceptance of a probiotic chocolate goat dairy beverage," *LWT*, vol. 62, no. 1, pp. 445–451, Jun. 2015, doi: 10.1016/j.lwt.2014.09.056.

[17] T. S. AbdulAlim, A. F. Zayan, P. H. Campelo, and A. M. Bakry, "Development of new functional fermented product: mulberry-whey beverage," *Journal of Nutrition, Food Research and Technology*, vol. 1, no. 3, pp. 64–69, Oct. 2018, doi: 10.30881/jnfrt.00013.

[18] F. P. Souza *et al.*, "The addition of xyloligoosaccharide in strawberry-flavored whey beverage," *LWT*, vol. 109, pp. 118–122, Jul. 2019, doi: 10.1016/j.lwt.2019.03.093.

[19] S. Arsić, M. Bulatović, D. Zarić, G. Kokeza, J. Subić, and M. Rakin, "Functional fermented whey carrot beverage-qualitative, nutritive and techno-economic analysis," 2018.

[20] M. Djurić, M. Carić, S. Milanović, M. Tekić, and M. Panić, "Development of whey-based beverages," in *European Food Research and Technology*, Sep. 2004, pp. 321–328. doi: 10.1007/s00217-004-0950-1.

[21] E. M. E. Nuray Güzeller, "Production of Fermented Cheese Whey-Based Beverage Using Kefir Culture Some Properties and Effects of Storage Period," adana, 2014.

[22] E. Nedanovska, K. L. Jakopović, D. Daniloski, R. Vaskoska, T. Vasiljevic, and I. Barukčić, "Effect of storage time on the microbial, physicochemical and sensory characteristics of ovine whey-based fruit beverages," *Int J Food Sci Technol*, vol. 57, no. 8, pp. 5388–5398, Aug. 2022, doi: 10.1111/ijfs.15870.

[23] C. R. Shraddha RC and K. A. Nalawade T, "Whey Based Beverage: Its Functionality, Formulations, Health Benefits and Applications," *J Food Process Technol*, vol. 6, no. 10, 2015, doi: 10.4172/2157-7110.1000495.

[24] G. Dragone, S. I. Mussatto, J. M. Oliveira, and J. A. Teixeira, "Characterisation of volatile compounds in an alcoholic beverage produced by whey fermentation," *Food Chem*, vol. 112, no. 4, pp. 929–935, Feb. 2009, doi: 10.1016/j.foodchem.2008.07.005.

[25] R. Mahmoudi, H. Tajik, A. Ehsani, A. A. Farshid, P. Zare, and M. Hadian, "Effects of Mentha longifolia L. essential oil on viability and cellular ultrastructure of Lactobacillus casei during ripening of probiotic Feta cheese," *Int J Dairy Technol*, vol. 66, no. 1, pp. 77–82, Feb. 2013, doi: 10.1111/j.1471-0307.2012.00867.x.

[26] M. Saarela, "Probiotics as ingredients in functional beverages," in *Functional and Speciality Beverage Technology*, Elsevier Ltd., 2009, pp. 55–70. doi: 10.1533/9781845695569.1.55.

[27] B. H. Özer and H. A. Kirmaci, "Functional milks and dairy beverages," *International Journal of Dairy Technology*, vol. 63, no. 1. pp. 1–15, Feb. 2010. doi: 10.1111/j.1471-0307.2009.00547.x.

[28] K. E. Almeida, A. Y. Tamime, and M. N. Oliveira, "Acidification rates of probiotic bacteria in Minas frescal cheese whey," *LWT*, vol. 41, no. 2, pp. 311–316, 2008, doi: 10.1016/j.lwt.2007.02.021.

[29] R. K. A. K. Maity T.K., "Development of healthy whey drink with Lactobacillus rhamnosus, Bifidobacterium bifidum and Propionibacterium freudenreichii subsp. shermanii," 2008.

[30] By Dr. Paul J. Cribb, "U.S. WHEY PROTEINS IN SPORTS NUTRITION," *U.S. Dairy Export Council*, 2014.

[31] E. Ha and M. B. Zemel, "Functional properties of whey, whey components, and essential amino acids: Mechanisms underlying health benefits for active people (Review)," *Journal of Nutritional Biochemistry*, vol. 14, no. 5. Elsevier Inc., pp. 251–258, May 01, 2003. doi: 10.1016/S0955-2863(03)00030-5.

[32] Emine Seyhan, "Fonksiyonel Fermente Peyniraltı Suyu İçeceği Üretimi Üzerine Bir Araştırma," Yüksek lisans tezi, Abant İzzet Baysal Üniversitesi, 2012.

[33] L. S. Rosa *et al.*, "Antiproliferative and apoptotic effects of probiotic whey dairy beverages in human prostate cell lines," *Food Research International*, vol. 137, Nov. 2020, doi: 10.1016/j.foodres.2020.109450.

[34] B. S. D. B. E. Suchkova, "Effect of ultrasonic trestment on metabolic activity of Propionibacterium shermanii, cultivated in nutrient medium based on milk whey," 2014.

Investigation of Adulteration of Sugars in Pomegranate Concentrate

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Abstract

In this study, 58 pomegranate concentrate samples collected directly from the local producers were adulterated with 2 different corn syrup and beet sugar syrup at different rates as 5-50% (w/w). The spectra obtained by FTIR-ATR spectroscopy of authentic and adulterated samples were evaluated by PCA chemometric methods. PCA method was used to distinguish the authentic-adulterated samples, select the spectral region and data reduction. The PCA-loading plot shows the most effective wavenumber to distinguish authentic samples from adulterated ones, which was determined to be in the range of 1200-900 cm^{-1}. In the model created to distinguish the samples; it was found that PC1 and PC2 explained 83.1% of the total variance. Authentic and adulterated samples were successfully distinguished by PCA method. As a result, FTIR spectroscopy combined chemometric methods, can be used as a rapid and eco-friendly as alternative method for detection of in pomegranate concentrate.

Keywords: Adulteration, FT-IR, chemometrics, food fraud

Introduction

Pomegranate (*Punica granatum* L.) is one of the oldest fruits native to the Middle East [1]. The fruit is consumed fresh and can also be used as flavoring and coloring agent [2]. Pomegranate concentrates are concentrated syrup made by boiling of the pomegranate juice to a sticky form. This syrup is used as a delicious sauce for salads and vegetables in Mediterranean kitchen [3]. It has been reported that the levels of antioxidants have been found to be higher than in other natural juices and even in red wine [4]. The antioxidant, anti-carcinogenic, anti-mutagenic and anti-inflammatory effects and other health benefits of pomegranate are attributed to many phenolic compounds, including flavonoids, anthocyanin and other flavonoids and hydrolysable tannins, compounds with high antioxidant activity [5, 6, 7, 8]. Since the nutritional value and health benefit of pomegranate juice is an important factor that makes it preferable to some other juices, it makes it valuable [9]. Therefore, it is adulterated with low-cost sweeteners and red-colored juices to reduce production costs [3]. Despite this widely use, these methods are a slow and expensive techniques. Although traditional analytical methods are time-consuming and expensive techniques and cause destruction of samples [10]. FTIR spectroscopy is a method based on the principle of infrared spectroscopy, and its reveal unique infrared finger-print of a specific molecule [11]. There are many studies on FTIR-ATR spectroscopy can detection of adulteration: vegetable oil added to butter, different types of milk mixtures, different oils added to olive oil, lard added to vegetable oils, pork in different types of meat, corn syrup in foods with high sugar content such as honey and molasses example can be given [12-13-14-15-16-17-18].

PCA is a dimension reduction analysis that transforms data relating to a set of observations with a high probability of correlation into a series of uncorrelated linear components called principal component using orthogonal transformation to basis of correlation eigenvectors [19]. It provides the eigenvector and eigenvalues of the data matrix to be moved to a coordinate plane where the variables of the data set are represented in low-dimensions [20]. Therefore, there is a need to develop analytical methods, such as FTIR spectroscopy, that are fast, easy to use, cost-effective, eco-friendly, non-destructive to the sample to detect adulteration. Fourier Transform Infrared (FTIR) spectroscopy can be used as a method for the detection of adulteration in fruit juice concentrates.

In this study, the PCA method was used to visually distinguish the classification of authentic and adulterated samples. It was aimed to use detect the adulteration with corn syrups and beet sugar syrup added to pomegranate concentrate at different rates between 5-50%.

Material and Methods

Material

34 pomegranate concentrates were collected from small producers and cooperatives in different regions of Turkey. High fructose corn syrup (50% glucose + 45% fructose), glucose-fructose syrup (30% glucose + 10% fructose) and beet sugar syrup were used for adulteration of sample. The total water-soluble solids content of the authentic samples and sugar syrups were diluted in 50°Brix using distilled water. 6 randomly selected samples were adulterated with each 3 syrups, at the rate of 5, 10, 20, 30, 40, 50 % (w/w). Thus, 34 authentic and 108 adulterated samples, totally 142 samples were obtained for analysis. Before FT-IR analysis, samples were vortexed to ensure homogeneity.

Methods

FTIR-ATR measurements

FTIR spectra of authentic and adulterated pomegranate concentrate samples were recorded using FTIR-ATR spectrometer (Perkin Elmer Spectrum Two™, FTIR Spectrometer, United States) equipped with ATR and diffuse reflectance modulus, potassium bromide (KBr) coated diamond crystal and DGTS detector. The FTIR-ATR spectra of the samples were determined at a resolution of 4 cm^{-1}, in the range of 400-4000 cm^{-1} MIR wavenumbers. ATR crystal was cleaned with ethanol before each measurement. Triple measurements of each sample were obtained.

Principal Component Analysis (PCA)

The data collected from FTIR spectra of authentic and adulterated pomegranate concentrates (142 samples) evaluated using Principal Component Analysis (PCA) (SIMCA 14.1 software, Umetrics, Sweden). While creating models; pretreatment techniques were used to reduce spectrum noises, highlight spectrum differences, correct baseline. First Derivative (FD), Second Derivative (SD), Third Derivative (TD) Multiplicative Scattering Correction (MSC), Standard Normal Variable (SNV), Savitzky-Golay (SG), Row Center (RC) pretreatments and their combinations were used to the raw data set**.**

Results and Discussions

Spectral Region Analysis

The 4000-400 cm^{-1} range of the FTIR-ATR spectra of authentic pomegranate concentrate samples is shown in Figure 1-a. 1200-900 cm^{-1} fingerprint region (Figure 1-b), correspond to the absorption region of main sugars and organic acids of pomegranate concentrate. The characteristic bands of glucose have specific peaks at 902, 1036, 1150, 1360, and 1431, 1033 and 1150 cm^{-1}. These absorption bands corresponding to the glucose is the result of the stretching vibrations of C-O, C-H, C-O, C-C. The characteristic bands of fructose have specific peaks at 923, 978, 1065, 1250, 1346, and 1418, 1055 and 1065 cm^{-1}. The characteristic absorption bands of sucrose at wave number of 995 cm^{-1} and 925 cm^{-1} are observed.

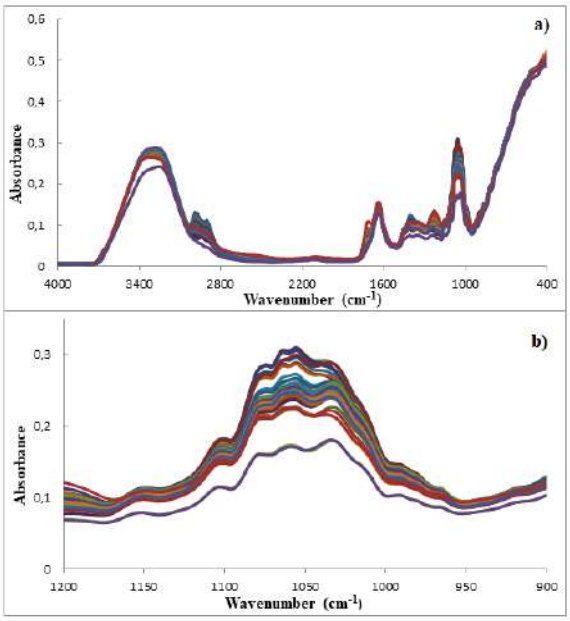

Figure 1: FTIR spectra of authentic pomegranate concentrate samples (a) 4000-400 cm^{-1} and (b) 1200-900 cm^{-1}

Principal Component Analysis

PCA model obtained by using the whole spectrum, the peaks that are effective in distinguish authentic and adulterated samples can be due to many components (organic acids, sugars, phenols, etc.) in the samples. According to the specific absorbance regions in the FTIR spectrum, models can be created and evaluated with these compound/compounds individually. The characteristic bands of glucose, fructose and sucrose are in the spectral range 1200-900 cm^{-1} [21]. In order to clearly distinguish authentic samples from adulterated ones, data in the carbohydrate region were selected. The PCA model was established with the raw data set. Then, by applying different pretreatment to the data in the spectral range of 1200-900 cm^{-1}, the second derivative-MSC-RC pretreated model was selected, which gave the best results. Both two and three-dimensional PCA graphs were obtained from the models applied to the spectral data. With these score charts, the ability to classify authentic and adulterated pomegranate concentrate samples at a 95% confidence interval was examined. In Figure 2, PCA graphs of the raw data set (a, b) and the second derivative-MSC-RC dataset (c, d) are given.

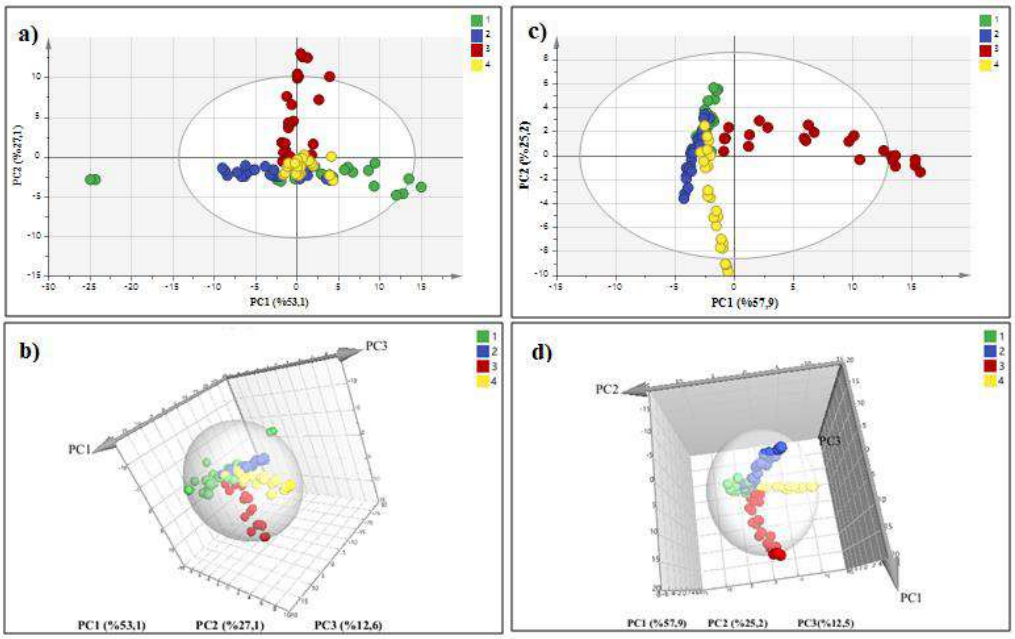

Figure 2: a-b**:** Score plots (a) and 3D scatter plots (b) obtained from raw data
c-d: Score plots (c) and 3D scatter plots (d) obtained from second derivative-SNV-RC pretreated data

Each sample is represented by a point on the PCA score plot. As a result of PCA analysis, it shows the distinguishing of authentic and adulterated samples with 3 different sugar syrups. In Figure 2, (1) the green points represent authentic samples, (2) blue: adulterated with high fructose syrup, (3) red: adulterated with glucose-fructose syrup, and (4) yellow: adulterated with beet sugar syrup. PCA score plots differentiated the sample groups according to the level of difference and similarity. In the score plot obtained with the raw data set, PC1 and PC2 explain 80.2% of the total variance (PC1: 53.1% and PC2: 27.1%) (Figure 2.a). In this model, 99.7% of the total variation is explained with the number of 6 principal components. Although it can be seen in Figure 2.a that adulterated samples are clearly distinguished, it is observed that different adulteration rates (5, 10, 20, 30, 40, and 50%) are slightly distinguished. Since sucrose is found in very little amount, it is seen more clearly that there is a decrease in the adulteration rate as the groups in the score plot of the samples adulterated with beet sugar syrup (red point) approach the origin. The samples furthest from the origin represent samples that are adulterated at 50% by weight, while the next group shows samples that are adulterated at 40% by weight. Thus, the rate of adulteration gradually decreases towards the origin. 5% adulteration rates are closer to authentic samples and also closer to each other in the score plot. As seen in Figure 2.a, one of the authentic samples is located in a quite different place from the other samples. Although it is observed as outlier data visually in the model created with raw data, the model can be improved by applying different pretreated to the data set. Pretreatment techniques can help to classify these two samples more accurately by highlighting the spectral differences and correcting the baseline and scattering.

In Figure 2.c, PC1 and PC2 values characterizing the data set with 2nd derivative-SNV-RC pretreatment are given. PC1 and PC2 (PC1: 57.9% and PC2: 25.2%) of the 2nd Derivative-MSC-RC model explained the maximum variance between samples with a value of 83.1%. In this model, 99.9%

of the total variation is explained with the number of 7 basic components. In Figure 2.d, the discrimination power in the 3D scatter plot model is observed more clearly. PCA results revealed a clear distinction between authentic and adulterated pomegranate concentrate samples. Differences between adulteration rates are observed more clearly in the pretreated PCA data set than in the raw dataset. As in the raw data set, a decrease is observed in the adulteration rate as the pomegranate concentrate samples adulterated with different syrups move away from authentic pomegranate concentrate. The reason for this is that authentic samples and samples with the lowest adulteration rate (5%) show more similarity. As the adulteration rate increases, authentic samples and adulterated samples show a clearer classification. The low rate of adulteration makes it very difficult to distinguish in models evaluated qualitatively. The outliers seen in the PCA score plot of the raw dataset were located between the pure samples in the 2nd derivative-SNV-RC pretreated model. These outliers were thus corrected by pretreatment techniques. Mishra et al. (2010), the first three basic components of PCA analysis used in the qualitative determination of Indian honey with added jaggery syrup explained 90% of the data [22]. These results can be compared with those obtained by other researchers. When the PCA score graph was examined in a study conducted with honey with jaggery syrup added, it was found that the concentration of jaggery syrup increased in the PC-1 axis and the wavenumber of honey with jaggery syrup added contained higher fructose compared to authentic honey [22].

Conclusion

On account of the increasing demand for pomegranate juice concentrate, in the market resort to many cheats to earn more profit. These cheats are adulteration with cheap commercial sweeteners and cheaper juices.. This method offers the detection of adulteration with sugar syrups by ATR-FTIR spectroscopy. The results have shown that distinguish the adulteration in pomegranate concentrate samples with values as low as 5% of sugar syrups are possible with high precision and accuracy. The results show that it has been quite successfully used both to grouping the authentic-adulterated pomegranate concentrate samples, and can be used as a promising simple, fast, non-destructive and eco-friendly alternative to wet chemical methods.

References

[1] Jarena J. Therapeutic applications of pomegranate (*Punica granatum* L.): a review. Alternative Medicine Review. 2008; 13(2):128-44.

[2] Maskan M. Production of pomegranate (*Punica granatum* L.) juice concentrate by various heating methods: colour degradation and kinetics. J Food Eng. 2006; 72(3):218-4.

[3] Uzaşçı S, Başkan S, Erim, FB. Biogenic amines in wines and pomegranate molasses—A non-ionic micellar electrokinetic chromatography assay with laser-induced fluorescence detection. Food Analytical Methods. 2012; 5:104-108.

[4] Ferrari G, Maresca P, Ciccarone R. The application of high hydrostatic pressure for the stabilization of functional foods: Pomegranate juice. J Food Eng. 2010; 100(2):245-253.

[5] Mphahlele RR, Fawole OA, Mokwena LM, Opara UL. Effect of extraction method on chemical, volatile composition and antioxidant properties of pomegranate juice. South African Journal of Botany. 2016; 103:135-144.

[6] Lydia DE, Khusro A, Immanuel P, Esmail GA, Al-Dhabi NA, Arasu MV. Photo-activated synthesis and characterization of gold nanoparticles from Punica granatum L. seed oil: An assessment on antioxidant and anticancer properties for functional yoghurt nutraceuticals. Journal of Photochemistry and Photobiology B: Biology. 2020; 206: 111868.

[7] Asgary S, Sahebkar A, Afshani MR, Keshvari M, Haghjooyjavanmard S, Rafieian-Kopaei M. Clinical evaluation of blood pressure lowering, endothelial function improving, hypolipidemic and anti-inflammatory effects of pomegranate juice in hypertensive subjects. Phytotherapy Research. 2014; 28(2):193-199.

[8] Viswanath M, Sridevi P, Bhagavan BVK, Kumar KR, Subbaramamma P. Toxicological, pharmacological and cellular properties of pomegranate (*Punica granatum* L.): a review. Journal of Pharmacognosy and Phytochemistry. 2019; *8*(2):172-176.

[9] Mirsaeedghazi H, Emam-Djomeh Z, Ahmadkhaniha R. Effect of frozen storage on the anthocyanins and phenolic components of pomegranate juice. Journal of Food science and Technology. 2014; 51:382-386.

[10] Lohumi S, Lee S, Lee H, Cho BK. A review of vibrational spectroscopic techniques for the detection of food authenticity and adulteration. Trends in Food Science & Technology. 2015; 46(1):85-98.

[11] Baudot C, Tan CM, Kong JC.FTIR spectroscopy as a tool for nano-material characterization. Infrared Physics & Technology. 2010; 53(6): 434-438.

[12] Rohman A, Che Man YB, Hashim P, Ismail A. FTIR spectroscopy combined with chemometrics for analysis of lard adulteration in some vegetable oils. Cyta-Journal of Food. 2011; 9(2): 96-101.

[13] Javidnia K, Parish M, Karimi S, Hemmateenejad B. Discrimination of edible oils and fats by combination of multivariate pattern recognition and FT-IR spectroscopy: A comparative study between different modeling methods. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy. 2013; 104: 175-181.

[14] Lerma-García MJ, Ramis-Ramos G, Herrero-Martínez JM, Simó-Alfonso EF. Authentication of extra virgin olive oils by Fourier-transform infrared spectroscopy. Food Chemistry.2010; 118(1): 78-83.

[15] Nicolaou N, Xu Y, Goodacre R. Fourier transform infrared spectroscopy and multivariate analysis for the detection and quantification of different milk species. Journal of Dairy Science. 2010; 93(12):5651-5660.

[16] Candoğan K, Altuntas EG, İğci N. Authentication and quality assessment of meat products by fourier-transform infrared (FTIR) spectroscopy. *Food Engineering Reviews*. 2021; 13:66-91.

[17] Rios-Corripio MA, Rojas-López M, Delgado-Macuil R. Analysis of adulteration in honey with standard sugar solutions and syrups using attenuated total reflectance-Fourier transform infrared spectroscopy and multivariate methods. CyTA-Journal of Food. 2012; 10(2): 119-122.

[18] Yaman N, Durakli Velioglu S. Use of attenuated total reflectance—Fourier transform infrared (ATR-FTIR) spectroscopy in combination with multivariate methods for the rapid determination of the adulteration of grape, carob and mulberry pekmez. Foods. 2019; 8(7): 231.

[19] Medina S, Perestrelo R, Silva P, Pereira JA, Câmara JS. Current trends and recent advances on food authenticity technologies and chemometric approaches. Trends in Food Science & Technology. 2019; 85: 163-176.

[20] Kambhatla N, Leen, TK. Dimension reduction by local principal component analysis. Neural Computation. 1997; 9(7):1493-1516.

[21] Dhaulaniya AS, Balan B, Yadav A, Jamwal R, Kelly S, Cannavan A, Singh DK. Development of an FTIR based chemometric model for the qualitative and quantitative evaluation of cane sugar as an added sugar adulterant in apple fruit juices. Food Additives & Contaminants: Part A. 2020; 37(4): 539-551.

[22] Mishra S, Kamboj U, Kaur H, Kapur P. Detection of jaggery syrup in honey using near-infrared spectroscopy. International Journal of Food Sciences and Nutrition. 2010; 61(3):306-315.

[23] Kumaravelu C, Gopal A. Detection and quantification of adulteration in honey through near infrared spectroscopy. International Journal of Food Properties. 2015; 18(9):1930-1935.

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Application of Spray Drying Process for Food Bioactive Compounds

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Abstract

In addition to the essential nutrients found in the structure of foods, some compounds that have positive effects on health are gradually taking their place in nutritional recommendations. Food-derived bioactive are known as these non-nutritional compounds and are secondary metabolites of plants consisting of vitamins, minerals, fatty acids, phytosterols, polyphenols, anthocyanins, carotenoids, probiotics, and bioactive peptides. There are difficulties in ensuring the stabilization of bioactive compounds that have positive effects on human health during production, product, and storage periods. Encapsulation techniques are used to preserve these compounds from decreased biological activity, interaction with environmental conditions, physicochemical and organoleptic adverse effects. Micro and/or nanoencapsulation are an effective method that increases the stabilization of bioactive food compounds and enables their use in food systems. Among encapsulation technologies, spray drying, which is cost-effective, is one of the most frequently used methods for micro- and nano-sized encapsulation of different bioactive compounds, especially for the encapsulation of heat-sensitive compounds. The aim of this study was to provide an overview of the micro/nanoencapsulation of food-derived bioactive compounds by spray drying with different encapsulation agents and to investigate oxidative stress, temperature effect, storage stability, bioavailability as well as the advantages and disadvantages of this method..

Keywords: Food bioactive compound, spray drying, encapsulation

Introduction

Food-derived bioactive compounds are defined as secondary metabolites of plants such as vitamins, minerals, fatty acids, phytosterols, polyphenols, anthocyanins, carotenoids, probiotics, and bioactive peptides that affect human health through their potential nutritional and pharmaceutical properties. These compounds have been widely used for thousands of years for medicinal, cosmetic, and preservative purposes. These valuable components are sensitive to environmental and processing conditions and need to be protected from reduced biological activity, interaction with environmental conditions, physicochemical instability, and adverse organoleptic changes [1,2]. Micro/nanoencapsulation has been a technology that serves to protect the bioactive compound by dispersing or entrapping it in a matrix of different carriers. Among micro/nanoencapsulation technologies, spray drying has been one of the major preservation and conservation processes based on the conversion of liquid into powder form [3]. The process starts with an appropriate extraction technique to obtain bioactive compounds or bioactive-rich fractions from medicinal and aromatic plants, vegetables, fruits and/or their seeds, bark, leaves, and roots. During the process, the solution containing the core and wall materials is sprayed into the drying chamber through a nozzle, while hot air circulates through the chamber and the pulverized capsules are collected in a suitable container. This technology is widely used in the food and pharmaceutical industries, especially for the encapsulation of heat-sensitive compounds, as it is more cost-effective than some of its counterparts [4, 5]. Our study aimed to provide an overview of micro/nanoencapsulation of food-derived bioactive compounds by spray drying with different encapsulation agents and to examine oxidative stress, temperature effect, storage stability, bioavailability as well as their advantages and disadvantages.

Spray Drying Technologies

Spray drying is a common preservation and conservation process based on the conversion of feed liquid into powder form by spraying it onto a hot drying medium [3]. The process starts with the extraction of bioactive compounds or bioactive-rich fractions from medicinal and aromatic plants, vegetables, fruits and/or their seeds, bark, leaves, and roots by a suitable method. Encapsulation in a

spray dryer involves heat and mass transfer simultaneously. The bioactive-rich fractions form the core or active substances. Spraying the solution containing the core and wall materials in fine droplets with equipment called an atomizer or nozzle is the first step to start the process. The liquid is sprayed into the drying chamber where it is exposed to circulating hot air. This circulating hot air and increased surface area can accelerate the evaporation of moisture from the droplets as the hot air circulates through the chamber and is pulverized. Finally, the dewatered and pulverized capsules are collected in a suitable container [6]. Figure 1 shows the schematic of the spray drying mechanism. The use of spray drying for encapsulation dates to the 1950s and has become one of the most widely used techniques for microencapsulation of functional food ingredients [7]. Although spray drying is a dehydration process, it has undergone rapid development due to its relatively low cost. Therefore, it has become a highly suitable technique for the encapsulation of bioactive compounds [5, 8]. This simple technology is widely used in the food and pharmaceutical industry, as it is both suitable for the encapsulation of heat-sensitive compounds and cost-effective [4, 5]. Spray drying has been reported to be 30 to 50 times more economical compared to other encapsulation techniques, especially freeze drying [9]. Another advantage of this process, which is often preferred especially for the encapsulation of flavors, lipids, and carotenoids, is the very short drying time (usually 15-30 s). A spray dryer can provide very fine powder (10-50 micrometers) or large size particles (2-3 mm) in good quality. However, choosing inappropriate operating conditions, such as high temperature, can cause thermal degradation of bioactive compounds, which can be a disadvantage [10, 11, 12]. There are some disadvantages such as difficult control of particle size and shape during the process and low encapsulation efficiency in laboratory scale production [13].

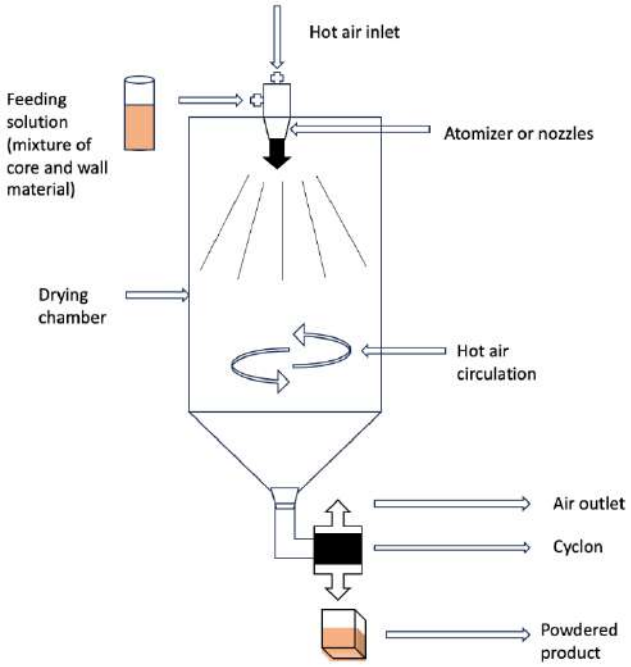

Figure 1. Schematic representation of spray-drying mechanism

Food-Derived Bioactive Compounds

A bioactive compound is a chemical component with biological activity. According to medical literature, a bioactive substance is defined as “affecting living tissue, causing a reaction or triggering a response in living tissue". It is widely believed that these compounds act as antioxidants, are chemo- and cardio-preventive and may even reduce the risk of or prevent some diseases. When the definition of food-derived bioactive compounds is considered, it is concluded that bioactive food ingredients correspond to components in foods or dietary supplements that are not essential to meet basic nutritional needs but may potentially have a positive effect on health status when consumed [14]. Food-derived bioactive compounds are primary or secondary metabolites of plants that affect human health through their potential nutritional and pharmaceutical properties. In general, fruits, vegetables, grains, and leaves contain bioactive components, but these are present in small amounts as part of foods, such as vitamins, minerals, fatty acids, phytosterols, polyphenols, anthocyanins, carotenoids, probiotics, and bioactive peptides. Despite their potential health effects, there are no recommended daily intake values for most bioactive components of foods, such as proteins, lipids, or vitamins [15, 27].

These compounds have been widely used for thousands of years for medicinal, cosmetic, and preservative purposes. However, these valuable components are sensitive to environmental and processing conditions and need to be protected from reduced biological activity, interaction with environmental conditions, physicochemical instability, and adverse organoleptic changes [1, 2, 15]. Most of these components are particularly unstable to oxygen, light, moisture, and heat, and above all to digestive fluids. Therefore, instability can mainly lead to unpleasant flavors and reduced shelf stability, sensory properties, and consumer acceptability of the fortified product. Furthermore, low solubility, uncontrolled release and poor bioavailability may occur due to sensitivity to digestive conditions [16]. Micro/nanoencapsulation has been a technology that serves to protect the bioactive component by dispersing or entrapping it in a matrix of different carriers. Among micro/nanoencapsulation technologies, spray drying has become one of the common preservation and conservation processes based on the conversion of liquid into powder form [3].

Selection of Coating Materials

The selection of encapsulation materials and encapsulation techniques suitable for the specific characteristics of each component are the two main aspects of the preparation of a suitable encapsulation system. Since the coating material greatly influences the encapsulation efficiency, it is expected to have several key properties such as [16, 17]:

- It should not react with the core material during the coating process and/or storage.
- It should have emulsion and dispersion properties and high emulsion stability.
- It should be able to coat the core material uniformly and protect it both during processing and storage.
- Rheological properties at high concentration and easy processing at high concentration.
- It must have mechanical strength.

Microencapsulation wall materials are classified into two categories: single-type wall materials (carbohydrates, proteins, or hydrophilic gums) and mixed-type wall materials. Traditional methods of selecting wall materials require trial-and-error procedures. After that, they should be evaluated for encapsulation efficiency, stability under different conditions, degree of protection, surface observation and morphology, among other considerations [18]. It is mainly classified as a protein, polysaccharide and lipid-based carrier and is often used in food applications. Gummies are excellent wall materials classified as polysaccharides with their functionality of non-toxicity, biocompatibility, biodegradability and safe for human consumption. Selecting the appropriate coating/wall materials during the encapsulation steps is one of the important criteria that directly affect encapsulation efficiency and stability. For this, carbohydrate-based wall materials such as gum, maltodextrin, or protein-based wall materials such as whey and casein are widely preferred good alternatives. Carbohydrate-based materials have some advantages such as low price, low viscosity, good solubility, and good oxidation resistance. Carbohydrate-based materials can be terminated by Maillard and polycondensation reactions. However, they have poor film formation, low emulsifying ability, and high porosity. Protein-based materials are generally preferred for their good solubility and emulsification, low cost despite their environmental friendliness, and unstable product quality. Proteins can be linked together by hydrophobic interaction and covalent disulfide cross-linking [19, 20]. It is also known that the microencapsulation efficiency can be increased by increasing the solid concentration of the wall solution. The criteria considered in the selection of wall material for spray dryer are solubility; molecular weight; glass/melt transition; crystallinity; spreadability; film-forming and emulsifying properties; and cost [11].

Application of Spray Drying in Food Bioactive Compounds

In microencapsulation technologies, the core material is surrounded by a capsule that surrounds it like a shell, protecting it from the external environment. This shell not only increases the stability of the bioactive ingredient in processing and storage but also facilitates these steps and transportation by converting from liquid to solid form. Minimizing the nutrient loss of ingredients is another advantage of encapsulation technologies. The enrichment of foods with bioactive ingredients is also becoming easier [21]. Meanwhile, there have been several reasons that have prompted researchers to investigate the microencapsulation of food bioactive compounds by spray drying.

Anthocyanins of Artemide type black rice were encapsulated by spray drying and maltodextrin (MD), gum arabic (GA) and MD/GA (50/50) were used as coating agents. Encapsulated and non-encapsulated powders were added to formulate model biscuits. It was concluded that the coating agents, especially GA, had a protective effect on polyphenols during baking. The data revealed that the enriched

biscuits showed significantly higher polyphenol, antioxidant capacity and anthocyanin content than the control biscuit [22].

Kaderides et al [23] used pomegranate peel extract as a source of phenolic compounds in cookie production. They revealed that phenol content in cookies with encapsulated and free extract decreased by 65% and 75% during baking, respectively. The antioxidant activity of cookies containing the encapsulated extract was significantly higher (90%) than the control biscuits (without extract) during storage. In particular, the color and odor of the cookies containing the encapsulated extract were found to be like the control cookies.

In a study aiming to determine the effect of dehumidified air spray drying of rapeseed honey and low temperature, it was emphasized that the honey powders obtained were characterized by high antioxidant activity and rich aroma. The studied properties did not deteriorate compared to pure honey before drying [24].

Another study investigated the encapsulation of Sacha Inchi (*Plukenetia volubilis* L.), a vegetable oil highly prone to oxidation, by spray drying. The oil capsules showed high oxidation stability and were resistant to pasteurization and sterilization processes used in the food industry [25].

In another study using a nanospray dryer to evaluate folic acid encapsulation, spray drying techniques were shown to lead to an improvement in folic acid stability. It was noted that the content of unencapsulated folic acid was greatly reduced, remaining only 1% after 15 days of storage, thus improving folic acid stability even in highly soluble resistant starch capsules [26].

Conclusion

Micro and nanoencapsulation technology are the most preferred process in the food and pharmaceutical industry, involving the incorporation of ingredients into small-sized wall materials. spray drying can mask undesirable taste and odor, control and in situ release, protect sensitive ingredients against process and storage conditions, reduce bioaccessibility and bioavailability by providing digestive fluids, etc. From an industrial point of view, spray drying technologies that offer high production rates at minimum cost are widely used. Especially fatty acids, essential oils, vitamins, antimicrobials, and probiotics can be successfully obtained by micro- or nanoencapsulation via spray drying.

References

[1] Akbarbaglu Z, Peighambardoust SH, Sarabandi K, Jafari SM. Spray drying encapsulation of bioactive compounds within protein-based carriers; different options and applications. Food Chemistry. 2021 Oct 15;359:129965.

[2] Munekata PE, Pateiro M, Rocchetti G, Dominguez R, Rocha JM, Lorenzo JM. Application of metabolomics to decipher the role of bioactive compounds in plant and animal foods. Current Opinion in Food Science. 2022 Aug 1;46:100851.

[3] Furuta T, Neoh TL. Microencapsulation of food bioactive components by spray drying: A review. Drying Technology. 2021 Sep 8;39(12):1800-31.

[4] Awuchi CG, Morya S, Dendegh TA, Okpala CO, Korzeniowska M. Nanoencapsulation of food bioactive constituents and its associated processes: A revisit. Bioresource Technology Reports. 2022 May 19:101088.

[5] Guía-García JL, Charles-Rodríguez AV, Reyes-Valdés MH, Ramírez-Godina F, Robledo-Olivo A, García-Osuna HT, Cerqueira MA, Flores-López ML. Micro and nanoencapsulation of bioactive compounds for agri-food applications: A review. Industrial Crops and Products. 2022 Oct 15;186:115198.

[6] Baltacioğlu C, Yetişen M, Duygu BO. Püskürtmeli Kurutma Tekniği ve Gıda Endüstrisinde Kullanımı: Gıda İşleme Teknolojisi. Journal of Agriculture, Food, Environment and Animal Sciences. 2021 Dec 15;2(2):163-89.

[7] Jafari SM, editor. Nanoencapsulation of food bioactive ingredients: Principles and applications. Academic Press; 2017 May 25.

[8] Piñón-Balderrama CI, Leyva-Porras C, Terán-Figueroa Y, Espinosa-Solís V, Álvarez-Salas C, Saavedra-Leos MZ. Encapsulation of active ingredients in food industry by spray-drying and nano spray-drying technologies. Processes. 2020 Jul 24;8(8):889.

[9] Bakry AM, Abbas S, Ali B, Majeed H, Abouelwafa MY, Mousa A, Liang L. Microencapsulation of oils: A comprehensive review of benefits, techniques, and applications. Comprehensive reviews in food science and food safety. 2016 Jan;15(1):143-82

[10] Bratovcic A, Suljagic J. Micro-and nano-encapsulation in food industry. Croatian journal of food science and technology. 2019 May 30;11(1):113-21

[11] Gharsallaoui A, Roudaut G, Chambin O, Voilley A, Saurel R. Applications of spray-drying in microencapsulation of food ingredients: An overview. Food research international. 2007 Nov 1;40(9):1107-21.

[12] Mudalip SA, Khatiman MN, Hashim NA, Man RC, Arshad ZI. A short review on encapsulation of bioactive compounds using different drying techniques. Materials Today: Proceedings. 2021 Jan 1;42:288-96.

[13] Samborska K, Boostani S, Geranpour M, Hosseini H, Dima C, Khoshnoudi-Nia S, Rostamabadi H, Falsafi SR, Shaddel R, Akbari-Alavijeh S, Jafari SM. Green biopolymers from by-products as wall materials for spray drying microencapsulation of phytochemicals. Trends in Food Science & Technology. 2021 Feb 1;108:297-325

[14] Walia, A., Gupta, A. K., & Sharma, V. (2019). Role of bioactive compounds in human health. *Acta Sci. Med. Sci*, *3*(9), 25-33.

[15] Gur, J., Mawuntu, M., & Martirosyan, D. (2018). FFC's advancement of functional food definition. *Functional Foods in Health and Disease*, *8*(7), 385-397

[16] Shishir MR, Xie L, Sun C, Zheng X, Chen W. Advances in micro and nano-encapsulation of bioactive compounds using biopolymer and lipid-based transporters. Trends in Food Science & Technology. 2018 Aug 1;78:34-60.

[17] Varhan E, Koç, M. Gida bileşenlerinin sprey soğutma yöntemi ile enkapsülasyonu. Food and Health. 2018 Apr 1;4(3):202-12.

[18] Poornima K, Sinthya R. Application of various encapsulation techniques in food industries. Matrix. 2017;10:400.

[19] Coimbra PP, Cardoso FD, Goncalves EC. Spray-drying wall materials: Relationship with bioactive compounds. Critical Reviews in Food Science and Nutrition. 2021 Sep 25;61(17):2809-26.

[20] Lu W, Yang X, Shen J, Li Z, Tan S, Liu W, Cheng Z. Choosing the appropriate wall materials for spray-drying microencapsulation of natural bioactive ingredients: Taking phenolic compounds as examples. Powder Technology. 2021 Dec 1;394:562-74.

[21] Bosnali S, Ocak ÖÖ. Gıda sanayiinde kullanılan uçucu yağların mikroenkapsülasyon uygulamaları. Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi. 2019 Dec 12;25(7):846-53.

[22] Papillo, V. A., Locatelli, M., Travaglia, F., Bordiga, M., Garino, C., Arlorio, M., & Coïsson, J. D. (2018). Spray-dried polyphenolic extract from Italian black rice (Oryza sativa L., var. Artemide) as new ingredient for bakery products. *Food Chemistry*, *269*, 603-609.

[23] Kaderides K, Mourtzinos I, Goula AM. Stability of pomegranate peel polyphenols encapsulated in orange juice industry by-product and their incorporation in cookies. Food Chemistry. 2020 Apr 25;310:125849.

[24] Samborska K, Jedlińska A, Wiktor A, Derewiaka D, Wołosiak R, Matwijczuk A, Jamróz W, Skwarczyńska-Maj K, Kiełczewski D, Błażowski Ł, Tułodziecki M. The effect of low-temperature spray drying with dehumidified air on phenolic compounds, antioxidant activity, and aroma compounds of rapeseed honey powders. Food and Bioprocess Technology. 2019 Jun 1;12:919-32.

[25] Sanchez-Reinoso Z, Gutiérrez LF. Effects of the emulsion composition on the physical properties and oxidative stability of sacha inchi (Plukenetia volubilis L.) oil microcapsules produced by spray drying. Food and Bioprocess Technology. 2017 Jul;10:1354-66.

[26] Pérez-Masiá R, López-Nicolás R, Periago MJ, Ros G, Lagaron JM, López-Rubio A. Encapsulation of folic acid in food hydrocolloids through nanospray drying and electrospraying for nutraceutical applications. Food chemistry. 2015 Feb 1;168:124-33.

[27] Câmara JS, Albuquerque BR, Aguiar J, Corrêa RC, Gonçalves JL, Granato D, Pereira JA, Barros L, Ferreira IC. Food bioactive compounds and emerging techniques for their extraction: Polyphenols as a case study. Foods. 2020 Dec 24;10(1):37

Hazır Yemek Sektöründe Sürdürülebilirlik

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Özet

Son on yılda sürdürülebilirlik kavramının hem bilim insanları tarafından araştırma konusu olarak hem de uygulamaya dönüştürülmesi alanında yapılan girişimler yoğunluk kazanmıştır. Gıda endüstrisi de sürdürülebilirlik endişesinin büyük bir paydaşı olarak söz konusu girişimlerin odak noktasında yer almaktadır. Günümüzde tüketicilerin de bir gıda materyalini satın alma veya bir yemeği tüketme davranışları üzerinde sürdürülebilir de etkili olmaya başlamıştır. Gıda firmalarının müşterilerine iyi bir tadın yanı sıra, daha az kimyasal katkı, çevre dostu gıda, sürdürülebilir menüler ve çevreye duyarlı girişimler sunmaları onları avantajlı konuma getirmeye başlamıştır. Dünya nüfusun ev dışı yemek tüketim alışkanlığında artan eğilim hazır yemek sektörünün gıda pazarındaki payını zamanla artırmaktadır. Bu sebeple hazır yemek sektörleri hem üretim hem de tüketim tarafında sürdürülebilirliği sağlamak için benzersiz bir konumda yer almaktadır. Bu çalışmada gıda sektörünün ana üretim ve tüketim kollarından birisi olan hazır yemek sektörünün faaliyetlerinin çevresel, sosyal ve ekonomik boyutları sürdürülebilirlik açısından incelenmiştir.

Anahtar kelimeler: Gıda, hazır yemek, sürdürülebilirlik

Giriş

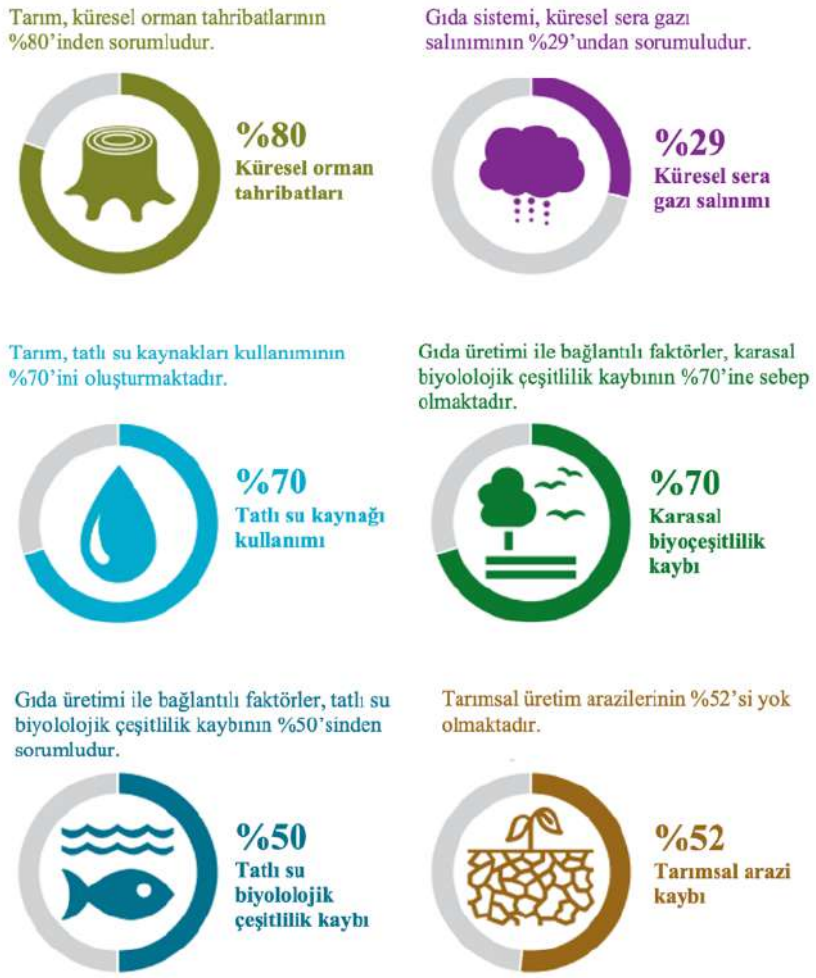
Gıda sektörü hammaddelerin yetiştirilmesi, işlenmesi, paketlenmesi ve dağıtımını içeren çok geniş bir ağdan oluşmaktadır. Bu geniş faaliyet alanı sektörün aynı zamanda fazla miktarlarda enerji tüketimi, sera gazı ve hava kirliği oluşturmasıyla küresel bazda önemli çevresel etkilere sahip olmasının temel sebebidir. Gıda sektörü yüksek oranda arazi kullanımı ile birlikte özellikle biyoçeşitliliğinin azalmasının, iklim değişikliğinin, su kıtlığının/kirliliğinin, toprak bozulmasının ve atık üretiminin önde gelen nedenlerinden birisi olarak görülmektedir [1]. Son on yılda sürdürülebilirlik kavramının hem bilim insanları tarafından araştırma konusu olarak hem de uygulamaya dönüştürülmesi alanında yapılan girişimler yoğunluk kazanmıştır. Gıda endüstrisi de sürdürülebilirlik endişesinin büyük bir paydaşı olarak söz konusu girişimlerin odak noktasında yer almaktadır [2]. Bununla birlikte sürdürülebilirlik, günümüzde tüketicilerin de bir gıda materyalini satın alma veya bir yemeği tüketme davranışları üzerinde etkili olmaya başlamıştır. Artan rekabet baskısı altında gıda firmalarının müşterilerine iyi bir tadın yanı sıra, daha az kimyasal katkı, çevre dostu gıda, sürdürülebilir menüler ve çevreye duyarlı girişimler sunmaları onları avantajlı konuma getirmeye başlamıştır [3]. Özellikle şehirler ve kentsel alanlarda ana gıda tedarik kanallarından birisi catering olarak da adlandırılan yemek hizmet sektörüdür. Yemek hizmet sektörü basit bir ifade ile ev dışında hazırlanan ve servis edilen yiyecek-içecek endüstrisini ifade etmektedir. Dünya nüfusunun ev dışı yemek tüketim alışkanlığında artan eğilim hazır yemek sektörünün gıda pazarındaki payını zamanla artırmaktadır. Bu sebeple hazır yemek sektörleri hem üretim hem de tüketim tarafında sürdürülebilirliği sağlamak için benzersiz bir konumda yer almaktadır. Bölgesel bazda sürdürülebilirlik kapsamı ile uygulanan yasal prosedürler mevcut olsa da yapılan çalışmalar kapsamlı adımların atılmasının gerekliliğini ve bunların yetersizliğini vurgulamaktadır [4,5]. Bu konuda izlenen stratejilerin başında satın alınan malzemelerin/menülerin değiştirilmesi gelmektedir. Araştırmalar menülerde et ve balık kullanılmasının sera gazı katkısının diğer bileşenlere kıyasla en büyük paya sahip olduğunu göstermiştir [6]. Sığır içeren bir ana yemeğin, ortalama bir vejetaryen yemekten 8-11 kat daha fazla çevresel etkiye sahip olduğu vurgulanmaktadır [7]. Bu çalışmada gıda sektörünün ana üretim ve tüketim kollarından birisi olan hazır yemek sektörünün faaliyetlerinin çevresel, sosyal ve ekonomik boyutları sürdürülebilirlik açısından incelenmiştir.

Sürdürülebilirlik

Son yıllarda artan çalışma sayısı ve bilgi birikimine rağmen sürdürülebilirlik kavramının kesin ve evrensel kabul edilen bir tanımının olmaması bu alanda yapılan çalışmaların önünde bir engel teşkil etmektedir. Sürdürülebilirliğin kullanıldığı disipline bağlı olarak çok sayıda tanımla karşılık bulması kavram karmaşasının en büyük etkeni durumundadır. Ancak araştırmacılar sürdürülebilirlik kavramını farklı disiplinlerde incelediklerinde yaygın kabul edilen tanımların denge, süreklilik, uyum ve fayda ortak noktasını içerdiklerini ortaya çıkarmıştır [8,9].

Gıda sektörü ve sürdürülebilirlik

Enerji, yiyecek ve su toplumlar için kritik öneme sahip olsa da bunlara erişimde topluluklar arasındaki ciddi farklılıklar nedeniyle söz konusu kaynakların varlığı daha kısıtlı hale gelmektedir. Birbiri ile yakından ilişkili bu 3 temel kaynağın efektif kullanımı artan popülasyonla birlikte zorunlu hale gelmiştir [10]. Tarım ve diğer gıda sistemi faaliyetleri, küresel sera gazı emisyonlarının üçte birinden sorumlu görülmektedir [11]. Ek olarak küresel tatlı su kaynaklarının yaklaşık %70'inin bu iki sektör tarafından tüketildiği bilinmektedir. Gıda sistemleri ve bu sistemlere hammadde tedarik kanalları biyoçeşitlilik kaybının ise %70'ine neden olmaktadır [12]. Gıda sisteminin yarattığı tahribat göz önüne alındığında, sürdürülebilirliğin gıda sektöründe sağlanması yüksek bir önem ve aciliyet gerektirmektedir. Gıda sürdürülebilirliği kavramı, çevre ve ekosistemler üzerinde nötr veya faydalı bir etkiye sahip olan üretim, dağıtım ve bertaraf sistemlerini kullanarak, bir bireyin veya bir popülasyonun beslenme gereksinimlerini karşılamak için yeterli gıdayı üretme veya tedarik etme yeteneğini içermektedir [13].



Şekil 1. Gıda üretiminin çevresel etkileri [12]

Şekil 2. Hazır yemek sektörü kuruluşlarından örnekler [5]

Catering olarak da adlandırılan yemek hizmet sektörü basit bir ifade ile ev dışında hazırlanan ve servis edilen yiyecek-içecek endüstrisini ifade etmektedir. Gelişen ve değişen yaşam tarzlarına paralel bir şekilde özellikle şehirler ve kentsel alanlarda ana gıda tedarik kanallarından birisi haline gelmiştir. Oldukça çeşitli işletmelerden oluşan yemek hizmeti sektörünü temelde iki ana kategoriye ayırmak mümkündür ve bu işletmelerden bazı örnekler Şekil 2'de gösterilmektedir. Kar amacı taşıyan özel veya ticari restoran, kafe, bar, fast food satış noktaları gibi tüketim alanları yemek hizmet sektörünün ana işletmelerini oluştururken; hastane, okul, bakım evi gibi kamusal ve kurumsal yerler de bu sektöre dahil edilmektedir [5].

Dünya nüfusun ev dışı yemek tüketim alışkanlığında artan eğilim hazır yemek sektörünün gıda pazarındaki payını zamanla artırmaktadır. Bu sebeple hazır yemek sektörleri hem üretim hem de tüketim tarafında sürdürülebilirliği sağlamak için benzersiz bir konumda yer almaktadır. Bölgesel bazda sürdürülebilirlik kapsamı ile uygulanan yasal prosedürler mevcut olsa da yapılan çalışmalar kapsamlı adımların atılmasının gerekliliğini ve bunların yetersizliğini vurgulamaktadır [4].

Hazır yemek sektörü ve sürdürülebilirlik

Hazır yemek sektöründe sürdürülebilirliğin incelenmesi amacı ile gerçekleştirilen çalışmalar incelendiğinde bu konudaki girişimlerin daha çok;

- geri dönüşüm (atık, su, yağ, kağıt, alüminyum),
- enerji tasarrufu,
- yerel ve organik ürünler kullanma,
- seçici toplama,
- menüde değişiklik yapma konularında yoğunlaştığını söylemek mümkündür.

Bu konuda izlenen stratejilerin başında satın alınan malzemelerin/menülerin değiştirilmesi gelmektedir. Yapılan bir çalışmada, ete dayalı menülerin vejetaryen versiyonları ile değiştirilmesinin karbon ayak izinde %32'lik azalma sağlayarak en etkili sürdürülebilirlik müdahalesi olduğu belirtilmiştir. Araştırmacılar daha yüksek çevresel üretim standartlarına sahip organik gıdaların satın alınmasının ise %11'lik azalma ile menü değişimini takip ettiğini belirtmişlerdir [14]. Sığır eti tüketiminin, kümes hayvanları ve balık gibi daha düşük çevresel etkiye sahip hayvansal ürünlere veya bitki proteinlerine dönüştürülmesinin çevresel açıdan yüksek fayda sağlayacağı düşünülmektedir [15]. Sığır eti, yaygın bitki proteinlerine göre 20 kat daha fazla toprağa ihtiyaç duyar ve yenilebilir proteinin gramı başına 20 kat daha fazla sera gazı emisyonu üretmektedir [16]. Humpenöder ve ark. [17], tarafından gerçekleştirilen çalışmada 2050 yılına kadar küresel olarak kişi başına düşen ruminant hayvan eti tüketiminin %20'sini mikrobiyal protein ile ikame etmenin gelecekteki küresel mera alanındaki

artışları dengelediği, ormansızlaşmayı ve ilgili CO_2 emisyonlarını kabaca yarıya indirirken aynı zamanda metan emisyonlarını da düşürdüğü vurgulanmaktadır. Araştırmalar menülerde et ve balık kullanılmasının sera gazı katkısının diğer bileşenlere kıyasla en büyük paya sahip olduğunu göstermiştir [6].

Servis araç gereçleri ve paketleme ürünleri hazır yemek sektöründe sürdürülebilirlik konusunda atılması gereken yeni adımları ve kapsamlı dönüşümleri içeren bir diğer konudur. Tüketim esnasında kullanılan servis araç gereçlerinin geri dönüştürülmüş, çevre dostu veya tüketim sonrası ürünlerden üretilenlerden seçilmesi önerilmektedir. Örnek bir uygulama olarak strafor materyal yerine biyolojik olarak parçalanabilecek veya geri dönüştürülebilir paket servis kapları kullanılması çevresel etki açısından yarar sağalacaktır. Atık dönüşümünün etkin sağlanması adına ise daha yüksek geri dönüşüm oranları sağlayan çöp toplama sistemlerinin iyileştirilmesi (geri dönüştürülebilir malzemelerin daha iyi ayrılması) ve her bir işletme/ dükkâna özel geri dönüşüm kutuları tedariği başlıca uygulanabilecek adımlar arasındadır. Bununla birlikte bireysel bazda bilinçlendirme önlemleri yoluyla tek kullanımlık plastik çatal-bıçak ve tabakların, içecek karıştırıcılarının ve içecek kaplarının tüketimin azaltılması da söz konusu atıkların azalması ve ayrıştırılması konusunda oldukça önemli bir yer tutmaktadır. Söz konusu atıklar gıda atıklarından oluşuyorsa bunların da çeşitli kompostlaştırma programları ile bertaraf edilmesi hem toprak verimi artırılması hem atık sorununun azaltılmasında etkili bir yol olmaktadır [18,19].

Hazır yemek sektöründe sürdürülebilirliği sağlamak için önde gelen stratejilerden bir diğeri "yerel" ve "mevsimlik" ürün tercihidir. Sera gazı salınımı ve enerji-zaman planlaması yerel tedarik zincirinin oluşturulmasında başlıca etmendir. Ancak yerel üretimin temini sadece bu amaçlarla sınırlı değildir. Aynı zamanda yerel üretici ve distribütörlerle çalışılması, şefler, diyetisyenler, çiftçiler gibi bölge halkının arasındaki ilişkileri de güçlendirerek, bölgesel kalkınmaya destek sağlar. Diğer bir taraftan üreticinin yerel gıdalara olan pozitif yaklaşımı, yerel olmayan yiyeceklerden daha lezzetli olduğuna, daha kaliteli olduğuna ve yerel ekonomiye yardımcı olduğuna inandıkları için yerel yiyecekleri satın aldıklarını ve restoranlarda yerel ürünlere olan talebi artırdığını göstermektedir. Bununla birlikte bir ürünün sadece yerel olduğu için diğer faktörler göz önüne alınmadan, yerel olmayana göre sürdürülebilir olduğunu düşünmek kesin doğru bir yargı değildir. Ancak "yerel ve mevsimlik" bir gıda ele alındığında sürdürülebilirliğin birçok şartını yerine getirdiği bilinmektedir. Kentsel bölgelerde daha fazla yerel ürün arzına bir alternatif olarak karşımıza çıkan kentsel tarım uygulamalarına ise tüm dünyada ilgi artmaktadır. Söz konusu uygulamada özellikle çatı çiftlikleri, çatı seraları ve bitki fabrikaları gibi kentsel binaların içindeki ve üzerindeki projelerde üretim yapılmaktadır [20,21].

Sonuç

Gıda sistemleri birincil hammadde temininden son ürünün tüketimini de içerecek şekilde çok kapsamlı alt faaliyet dallarına ayrılmaktadır. Bu kapsamlı faaliyet alanları ve günümüz dünyasının artan popülasyonu göz önüne alındığında özellikle enerji, su ve yiyecek kaynakları için rekabet eden birçok sektörün içerisinde gıda endüstrisi büyük bir paydaş olarak yerini almış durumdadır. Kısıtlı kaynakların yüksek oranda tüketiminden sorumlu olan gıda firmaları maliyet düşürme, imajını yenileme, müşteri taleplerini karşılama gibi çeşitli nedenlerden dolayı küresel sorunlara çözüm noktasında girişimlerde bulunmak ihtiyacındadır. Özellikle ev dışı yiyecek/ içecek tüketiminin olduğu her yerde var olan hazır yemek sektörü gıda sektörünün merkezi konumunda yer alması nedeni ile sürdürülebilirliğin sağlanmasında büyük rolü bulunmaktadır. Hazır yemek sektöründe bireysel ve lokal bazda alınabilecek önlemler ve bilinçlendirme eğitimlerinin yaygınlaştırılması, küresel sorunların azalmasında katkı sağlayacağı düşünülmektedir.

Referanslar

[1] Mistretta M, Caputo P, Cellura M, Cusenza MA. Energy and environmental life cycle assessment of an institutional catering service: An Italian case study. Science of the Total Environment. 2019 Mar 20;657:1150-60.

[2] Lehtinen U. Sustainability and local food procurement: a case study of Finnish public catering. British Food Journal. 2012 Aug 3.

[3] Kizildemir Ö, Kaderoğlu Gh. Yiyecek İçecek İşletmelerindeki Menü Tasarimlarinin Sürdürülebilirlik Kapsaminda Değerlendirilmesi. Journal of Tourism Intelligence and Smartness. 2021 Sep;4(2):296-322.

[4] Reisch L, Eberle U, Lorek S. Sustainable food consumption: an overview of contemporary issues and policies. Sustainability: Science, Practice and Policy. 2013 Oct 1;9(2):7-25.

[5] Takacs B, Borrion A. The use of life cycle-based approaches in the food service sector to improve sustainability: a systematic review. Sustainability. 2020 Apr 25;12(9):3504.

[6] Wickramasinghe KK, Rayner M, Goldacre M, Townsend N, Scarborough P. Contribution of healthy and unhealthy primary school meals to greenhouse gas emissions in England: linking nutritional data and greenhouse gas emission data of diets. European journal of clinical nutrition. 2016 Oct;70(10):1162-7.

[7] Calderón LA, Herrero M, Laca A, Díaz M. Environmental impact of a traditional cooked dish at four different manufacturing scales: from ready meal industry and catering company to traditional restaurant and homemade. The International Journal of Life Cycle Assessment. 2018 ;23:811-23.

[8] Pezzey J. Sustainability: an interdisciplinary guide. Environmental values. 1992 1;1(4):321-62.

[9] Salas-Zapata WA, Ortiz-Muñoz SM. Analysis of meanings of the concept of sustainability. Sustainable Development. 2019 Jan;27(1):153-61.

[10] Keskinen M, Sojamo S, Varis O. Enhancing security, sustainability and resilience in energy, food and water. Sustainability. 2019 Dec 17;11(24):7244.

[11] Crippa M, Solazzo E, Guizzardi D, Monforti-Ferrario F, Tubiello FN, Leip AJ. Food systems are responsible for a third of global anthropogenic GHG emissions. Nature Food. 2021 Mar;2(3):198-209.

[12] Almond R, Grooten M, Petersen T. Living PlanetReport 2020—Bending theCurve of Biodiversity Loss. World Wildlife Fund, Gland, 2020. Switzerland. (online) Available at: https://www.zsl.org/sites/default/files/LPR%202020%20Full%20report.pdf

[13] Young I, Collinson P, Antal L, Macbeth H. Towards A Cross-Dıscıplınary Approach To Food And Sustaınabılıty In The Twenty-Fırst Century. Food and Sustainability in the Twenty-First Century: Cross-Disciplinary Perspectives. 2019 Jun 6;9:11.

[14] Cerutti AK, Ardente F, Contu S, Donno D, Beccaro GL. Modelling, assessing, and ranking public procurement options for a climate-friendly catering service. The International Journal of Life Cycle Assessment. 2018 Jan;23:95-115.

[15] Ritchie H, Roser M. Environmental impacts of food production. Our world in data. 2020 Jan 15.

[16] Howard JA. Facing up to our converging climate and food system catastrophes. Advances in Food Security and Sustainability. 2022 Oct 13;7:1.

[17] Humpenöder F, Bodirsky BL, Weindl I, Lotze-Campen H, Linder T, Popp A. Projected environmental benefits of replacing beef with microbial protein. Nature. 2022 May 5;605(7908):90-6.

[18] Puri D, Kapoor B. Green Practices Initiative as a Sustainable Aspect for Food Industry. InEnvironmental Sustainability in the Food Industry 2022 Dec 7 (pp. 33-44). CRC Press.

[19] Dybka-Stępień K, Antolak H, Kmiotek M, Piechota D, Koziróg A. Disposable food packaging and serving materials—trends and biodegradability. Polymers. 2021 Oct 19;13(20):3606.

[20] Maynard DD, Vidigal MD, Farage P, Zandonadi RP, Nakano EY, Botelho RB. Environmental, social and economic sustainability indicators applied to food services: A systematic review. Sustainability. 2020 Feb 28;12(5):1804.

[21] Vargas AM, de Moura AP, Deliza R, Cunha LM. The role of local seasonal foods in enhancing sustainable food consumption: A systematic literature review. Foods. 2021 Sep 17;10(9):2206.

Dairy Protein vs. Plant Protein and Their Consumer Perception

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Abstract

Proteins are crucial macronutrient for human health. Animal, dairy, and some plant proteins are considered high-quality proteins that provide health and metabolic benefits based on the digestible levels of essential amino acids they contain. Animal protein is rich in many essential amino acids, but excessive animal protein intake greatly increases fat intake. Therefore, due to the improvement in people's living standards and increase in protein intake, the animal protein supply is not sufficient to meet the increasing demand of people. Technologically, milk proteins are the most important component of milk due to their unique properties that allow milk to be converted into a wide range of products such as cheese or yoghurt quite easily. It is widely accepted that dairy products are excellent sources of highly digestible essential amino acids. Nowadays, plant protein is preferred because has advantages such as it is an abundant source, cheap, easy to obtain, preferred by special consumer groups such as vegan/vegetarian, does not contain cholesterol and preventing diseases. In the last decades, the increasing interest of both producers and consumers in plant proteins and the decrease in animal protein intake and inclination to plant protein intake with the innovations in the markets emphasize the importance of these alternative sources. In this review, information is given about the importance of milk proteins and plant proteins and the role they play in consumer preference is mentioned.

Keywords: Dairy proteins, plant proteins

Introduction

The protein, originated from the Greek “proteios”, means primary. Protein is a crucial dietary macronutrient essential for life with a variety of metabolic and physiological functions, including regulation of appetite, food intake, body weight and body composition [1]. The recommended dietary allowance (RDA) of protein, which is important in human nutrition, is 0.8 g per kilogram of body weight (g/kg BW) for a healthy adult. The source of the recommended dietary allowance is as important as the amount. Proteins are divided into three according to their source of intake [2]. The Food and Agriculture Organization (FAO) projects that the world population will increase approximately 9,1 billion by 2050. Food production will have to increase by %70 to meet the demand for adequate nutrition [3]. This population growth indicates the potential insuffiency of conventional protein sources in the future, resulting in increased interest in unconventional proteins. Proteins are one of the most macronutrients of the human diet. Proteins are large biomolecules and macromolecules comprising one or more long chains of amino acid residues [4]. Protein is the material basis of all life and plays a significant role in sustaining the growth, metabolism and immun regulation of the body. According to the source of intake, protein can be divided into two categories. These are animal protein and plant protein. Plant protein has many advantages of abundant resources, being cheap and easy to obtain, having no cholesterol and it can prevent diseases. It is safe option, which can make up for the insufficient supply of animal protein [1]. In this review, information is given about the importance of dairy proteins and plant proteins and the role they play in consumer preference is mentioned.

Protein

Protein is a crucial macronutrient in human diet [4,5]. Proteins are fundamental to maintaining human body function and regulate various metabolic pathways such as immune system [1,5,6,7]. According to the source of intake, protein can be divided into two categories. These are animal protein and plant protein. Animal protein has a lot of essential amino acids. Due to the improvement of people’s living standards and the gradual increase in protein intake, the supply of animal protein is not enough to meet people’s growing demand. Plant protein has the advantages of abundant resources, being cheap

and easy to obtain, having no cholesterol, and it can prevent diseases. It is a green and safe food raw material, which can make up for the insufficient supply of animal protein [1].

The Recommended Daily Allowance (RDA) of protein is set at the minimum needed to prevent deficiency [8]. Recommended Daily Allowance (RDA) has been set at 0.8 g/kg of body weight for healty adults [6]. The nutritional value of dietary protein sources depends on their amino acid composition and bioavailability [5].

Protein Quality

A key factor in meeting the dietary needs of the world population is protein quality. Several methods have been used to evaluate the protein quality of foods, but newer technologies and understanding of protein requirements have led to significantly better methods [3]. The protein digestibility-corrected amino acid score (PDCAAS) has been used for more than two decades to evaluate protein quality in human foods [9]. According to the International Dairy Federation: "With respect to the quality of proteins, this is dependent on their ability to adequately meet the human requirements for indispensable amino acids. Amino acid requirements vary for specific age groups and physiological conditions". The consequences of inadequate protein intake to meet essential amino acid requirements are well known and include stunted growth, increased susceptibility to infection and diminished mental performance ranging from retardation to apathy [3].

In addition, protein is essential as it provides the body with amino acids that act as an important structural component of every cell in the human body. Essential amino acids are those that the body cannot synthesise on its own and must be retrieved from the diet such as histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine. Since adequate intake of essential amino acids is critical for good health, the quality of a protein can be expressed by its amino acid composition [10].

Dairy Proteins

Protein is an important component of milk as it largely determines its nutritional value and suitability for processing. Cow's milk contains approximately %3,4 protein on average [4]. Milk contains a mixture of proteins, each having unique attributes for nutritional, biological and food ingredient applications. The major proteins in milk are α-lactalbumin, β-lactoglobulin, immunoglobulin, bovine serum albumin and caseins: α-caseins, β-casein and κ-casein. In addition, minor but commercially important proteins are lactoferrin and lactoperoxidase [8].

The rising emergence of lactose intolerance, milk allergies, environmental concerns and different diet choices are leading toward a growing demand for dairy alternatives [11]. Casein and whey proteins are the two major classes of dairy protein and account for 80 and 20% of total milk protein [12,13]. Both proteins have emulsifying properties. Caseins are able to absorb water and whey proteins have better foaming properties [13]. Both casein and whey proteins are sources of many peptides with potential bioactive properties that provide health benefits [14]. Texture, flavour and colour changes result directly from the addition of dairy ingredients to food [13]. Proteins, especially dairy proteins are typically appealing ingredients for food applications since they can serve as gelling, emulsifying or foaming agents [15]. Dairy products are among the bacis ingredients for infant foods owing to their high-value proteins, vitamins, minerals and fats. However, prevelance of vegan dietary habits and increase of vegan products on the market parents' interest growing towards adopting vegan diets for their children [16].

Casein

Caseins make up %80 of the total protein in milk [13]. Casein can be broadly defined as the ingredient derived from "separating, washing and drying the coagulum of skimmilk and/or other products derived from milk". Two distinct products are produced depending on the method of coagulating the protein. Rennet casein is precipitated from milk using the rennet enzyme and acid casein is precipitated from milk by the development or addition of acid [3].

Whey

Whey is produced as a sidestream from cheese or casein manufacture [13]. The history of whey proteins, from a by-product of cheese production, used for feed or fertilizer, to the highly valued supplement, used by body builders and athletes, is well known and documented elsewhere. Whey proteins are highly functional with attributes that benefit many food systems. Their strong emulsification, heat stability, pleasant flavor, and structure are used in a variety of food systems to provide improved functionality and clean-label, cost-effective food systems. It is clear that whey proteins are key to this ingredient's wide range of nutritional and pharmaceutical benefits, from growth

and management of stunting, to strengthening seniors, improving body composition, and immune status. Globally, it is likely that the nutritional benefits of whey protein will continue to drive increased demand for whey proteins, while growth of the industry will be fueled by more cost-efficient sustainable production technologies [3].

Plant Proteins

Some of the raw materials, such as legumes and seeds have a protein content comparable to that of cow milk. Plant proteins often exhibit low quality, poor digestibility and an undesired limitation in essential amino acids [17].

Such diversity in nutrient composition adds significant complexity for consumers who intend to switch to plant-based animal alternatives for environmental reasons while still striving to balance their nutrient requirements. The protein content of plant ingredients offers wide versatility and may afford economic and environmental advantages. However, differences in the composition of a raw material pose significant challenges when formulating products to mimic the nutrient and sensory properties of animal proteins. Plant proteins require additional formulation to remove anti-nutritional components and enhance digestibility and nutrient density, taste, and functional properties from different plant sources. Plant-based foods are naturally lower in fat and cholesterol and higher in fiber content than foods of animal origin. Many plant-based products are positioned as higher in protein content, but the digestibility of plant-based foods can differ considerably. Moreover, many plant-protein products can have surprisingly high levels of fat or salt as producers formulate for sensory appeal without the use of animal-derived ingredients. This can result in higher intakes of saturated fat, salt, or sugar [18].

In addition a food with a high value correlates to a high supply of the essential amino acids. Animal sources typically possess a higher biological value than plant sources due to the plant source's lack of one or more of the essential amino acids. Plant proteins, when combined to provide for all of the essential amino acids, provide an excellent source for protein considering that they will likely result in a reduction in the intake of saturated fat and cholesterol [19].

Consumer Perception

With people's raise awareness of nutrition and health, high-nutrition and high protein products are more and more attractive to consumers [1]. Many healthcare professionals report confusion among consumers regarding the nutritional differences between plant-based and conventional animal products. From a nutritionist's perspective, many plant-based alternatives may have lower levels or quality of protein compared to traditional animal products [18].

The primary motivation for the development of plant-based products is to provide consumers with tasty and nutritious alternatives to conventional animal products. This shift to plant-based alternatives has been motivated by a desire to reduce the environmental impact of food supply and improve the sustainability of agricultural food production. While there is strong evidence to suggest that plant-based alternatives can have a significant positive influence on the environmental impact of food production, there are growing concerns regarding the nutritional profile of these products and their potential impact on overall diet quality [18].

Consumers value taste as the number one driver of food choice, followed by price, healthfulness, convenience and environmental sustainability. Many healthcare professionals report confusion among consumers regarding the nutritional differences between plant-based and conventional animal products. From a nutritionist's perspective, many plant-based alternatives lack nutrients such as iron, vitamin D, and B12, may have lower levels or quality of protein, and often have higher sodium and fat contents compared to traditional animal products [18].

To meet consumers' demands for improved satiating products, the food industry has designed a variety of protein-fortified foods. In addition, consumers believe that plant proteins are more sustainable than dairy proteins from the ecological point of view. Consumer perceptions are important to the food industry and authorities for the design of new products and communication about them. Expectations of satiation are beliefs about the extent to which a food is expected to deliver fullness. Satiation is determined by several intrinsic characteristics of foods such as the composition and sensory properties, as well as extrinsic factors related to consumer perceptions. Furthermore, in the case of protein-enriched product, the question arises as to whether satiety expectations are influenced by the type of added protein. Controversial evidence exists regarding the expected satiety of different protein sources (i.e., animal or plant). Studies conducted in the European population suggest that although plant proteins are seen as more sustainable, they are not the ones chosen by consumers to deliver fullness. Rather, the combination of a protein source and a conventional food carrier was found to be more acceptable [20].

Conclusion

Increase in population will eventually pressure on global resources for providing nutritious food products. Dairy protein has quite important for this situation. Caseins and whey proteins are unique to milk and dairy products. They supply proteins, calcium, and phosphate in high concentrations and provide adequate nutrients to the neonate. Several plant proteins sources such as wheat, rice, sorghum, millets, quinoa, soybean, pulses, seeds and nuts have been extensively explored and utilized as cost effective and sustainable sources of protein. Plants are relatively more abundant and cheaper than animal proteins but the direct use of plant-based proteins is still limited. Vegetable sources of protein also provide numerous other nutrients such as phytochemicals and fiber that are also highly regarded in the diet The conversion of plant-based proteins to animal proteins is inefficient. These unique nutritional and technological properties of dairy proteins are difficult to replace with plant proteins. Studies conducted in the European population suggest that although plant proteins are seen as more sustainable, they are not the ones chosen by consumers to deliver fullness. Rather, the combination of a protein source and a conventional food carrier was found to be more acceptable.

References

[1] Hu G, Liu J, Wang Y, Yang Z, Shao H. Applications of Plant Protein in the Dairy Industry. Foods 2022;11, 1067.

[2] Pasiakos SM, Agarwal S, Liebermann HR, Fulgoni VL. Sources and amounts of animal, dairy, and plant protein intake of US adults in 2007-2010. Nutrients. 2015, 7, 7058-7069.

[3] Lagrange V, Whitsett D, Burris C. Global Market for Dairy Proteins. Journal of Food Science 2015;Vol. 80, S1.

[4] Malecki J, Muszyński S, Sołowiej BG. Proteins in Food Systems-Bionanomaterials, Conventional and Unconventional Sources, Functional Properties, and Development Opportunities. Polymers 2021;13, 2506.

[5] Liu J, Klebach M, Visser M, Hofman Z. Amino Acid Availability of a Dairy and Vegetable Protein Blend Compared to Single Casein, Whey, Soy, and Pea Proteins: A Double-Blind, Cross-Over Trial. Nutrients 2019;11, 2613.

[6] Ferrari L, Panaite S, Bertazzo A, Visioli F. Animal- and Plant-Based Protein Sources: A Scoping Review of Human Health Outcomes and Environmental Impact. Nutrients 2022;14, 5115.

[7] Adhikari S, Schop M, Boer IJM, Huppertz T. Protein Quality in Perspective: A Review of Protein Quality Metrics and Their Applications. Nutrients 2022;14, 947.

[8] Etzel MR. Manufacture and Use of Dairy Protein Fractions. American Society for Nutritional Sciences 2004; 0022-3166/04.

[9] Mathai JK, Liu Y, Stein HH. Values for digestible indispensable amino acid scores (DIAAS) for some dairy and plant proteins may better describe protein quality than values calculated using the concept for protein digestibility-corrected amino acid scores (PDCAAS). British Journal of Nutrition 2017;117, 490–499.

[10] Chalupa-Krebzdak S, Long CJ, Bohrer BM. Nutrient density and nutritional value of milk and plant-based milk alternatives. International Dairy Journal 2018.

[11] Haas R, Schnepps A, Pichler A, Meixner O. Cow Milk versus Plant-Based Milk Substitutes: A Comparison of Product Image and Motivational Structure of Consumption. Sustainability 2019;11, 5046.

[12] Hoffman JR, Falvo MJ. PROTEIN – WHICH IS BEST? Journal of Sports Science and Medicine 2004;3, 118-130.

[13] Gallagher E, Kenny S, Arendt EK. Impact of dairy protein powders on biscuit quality. European Food Research and Technology 2005;221:237–243.

[14] Singh R, Rathod G, Meletharayil GH, Kapoor R, Sankarlal VM, Amamcharla JK. Invited review: Shelf-stable dairy protein beverages-Scientific and technological aspects. Journal of Dairy Science 2022;105:9327–9346.

[15] Tang Q, Roos YH, Miao S. Plant Protein versus Dairy Proteins: A pH-Dependency Investigation on Their Structure and Functional Properties. Foods 2023;12, 368.

[16] Gasparre N, Mefleh M, Boukid F. Nutritional Facts and Health/Nutrition Claims of Commercial Plant-Based Infant Foods: Where Do We Stand? Plants 2022;11, 2531.

[17] Tangyu M, Muller J, Bolten CJ, Wittmann C. Fermentation of plant-based milk alternatives for improved flavour and nutritional value. Applied Microbiology and Biotechnology 2019.

[18] Nolden AA, Forde CG. The Nutritional Quality of Plant-Based Foods. Sustainability 2023;15, 3324.

[19] Berrazaga I, Micard V, Gueugneau M, Walrand S. The Role of the Anabolic Properties of Plant- versus Animal-Based Protein Sources in Supporting Muscle Mass Maintenance: A Critical Review. Nutrients 2019;11, 1825.

[20] Curti CA, Lotufo-Haddad AM, Vinderola G, Ramon AN, Goldner MC, Antunes AEC. Satiety and consumers' perceptions: What opinions do Argentinian and Brazilian people have about yogurt fortified with dairy and legume proteins? Journal of Dairy Science 2022;105:8782–8791.

Alagöl Gölü Değişiminin Uzaktan Algılama ile Haritalanması

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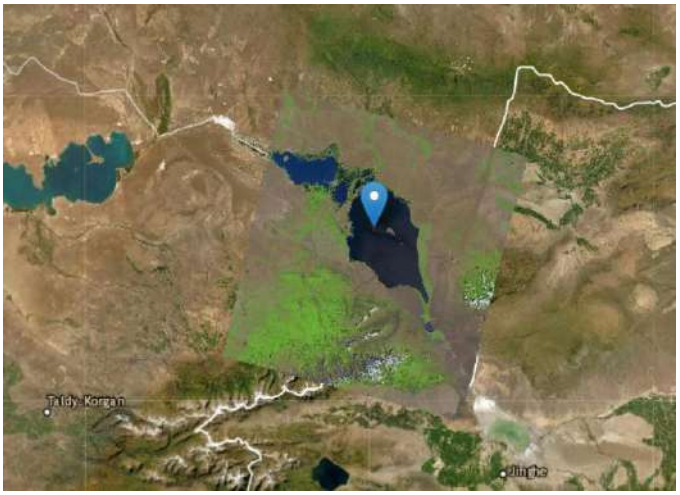
Özet

Bu çalışmanın temel amacı, Alagöl Gölü'nün kıyı şeridinin yıllar içindeki konumsal değişimlerini uzaktan algılama yaklaşımları kullanarak analiz etmektir. Bu amaç doğrultusunda üç adet Landsat 5 ve Landsat 8 uydu görüntüleri çalışmanın uygulama safhasında kullanılmıştır. Bu çalışmada Alagöl Gölü'nün alanındaki ve kıyı şeridindeki değişimin olası nedenleri araştırılmıştır. Gölün kıyı şeridi değişimleri, çok zamanlı uydu görüntüleri ve uzaktan algılama teknikleri kullanılarak belirlenmiştir. 1993, 2009 ve 2018 yıllarına ait Landsat 5 ve Landsat 8 uydu görüntüleri kullanılmıştır. Gerekli geometrik düzeltmeler yapıldıktan sonra, gölün kapladığı alan ve kıyı şeridinin belirlenmesi için kontrollü sınıflandırma yöntemleri veri setine uygulanmıştır. Sınıflandırma uygulamasının dışında ayrıca modifiye normalize fark su indeksi de kullanılmış ve elde edilen görüntüler daha sonra CBS ortamında sayısallaştırılmıştır. Son olarak 1993-2018 yıllarında gölün kıyı şeridi değişimleri tespit edilmiştir.

Anahtar Kelimeler: Uzaktan algılama, Kazakistan Alagöl, CBS

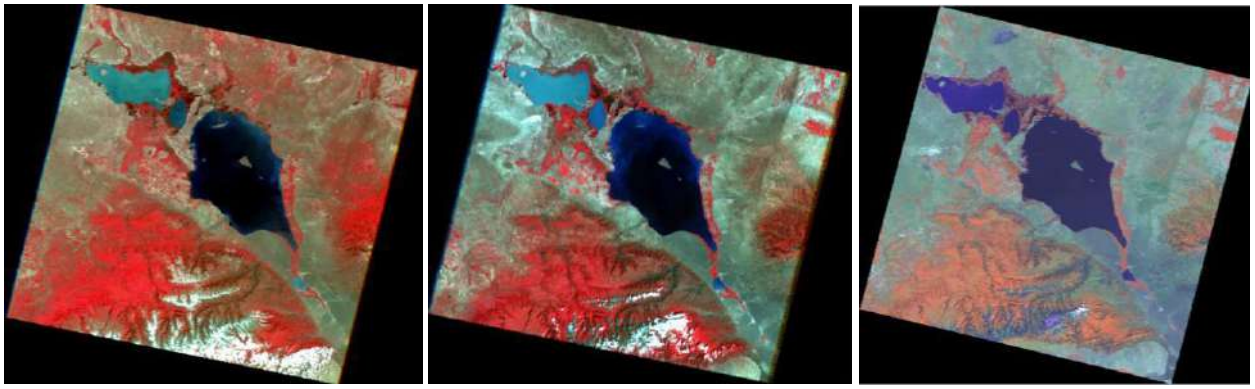
Giriş

Alagöl Gölü, Kazakistan'ın güneydoğusundaki Balkaş-Alagöl Nehri Havzası'nda bulunan en büyük hidrolojik olarak kapalı göllerden biridir (Şekil 1). Yaklaşık 490 km kıyısı olan Alagöl Gölü, tektonik hareketler, jeoloji ve rüzgâr dalga koşulları, artan turizm faaliyetleri, balıkçılık ve ulaşım gibi doğal ve insan kaynaklı faktörlerden dolayı çeşitli tehditlerle karşı karşıya kalmıştır [6]. Kazakça "Vahşi Göl" olarak adlandırılan Alagöl Gölü, Kazakistan'ın benzersiz bir su kaynağıdır. Büyüklük bakımından, bu ülkenin tüm iç suları arasında ikinci sırada yer almaktadır. Gün boyunca Alagöl suları gölgelerini birkaç kez değiştirir. Sabahları göl nazik bir turkuaz ile göze bayılıyor ve günün sonunda azure tonları hakim. Renk paleti değişikliği hava koşullarından etkilenir. Alagöl benzersizdir, çünkü tüm gezegende siyah renkte bir plaj olan tek su gövdesi. Kıyı çok yuvarlak çakıl ve çakıl taşlarından oluşur [8].



Şekil 1: Çalışma alanı

Balkaş'tan sonra Kazakistan'ın en büyük ikinci gölü olan Alagöl'e gelen turistler; balon turu, at binme, dağ yürüyüşü, rüzgar ve su sporları gibi aktiviteleri tercih ediyor. Alagöl, içerdiği 27 mineralle sağlık turizminin de gözdesi. Sabah güneşinde masmavi olan, gün batımında ise turkuaza dönüşen Alagöl'e Kazaklar "renkli göl" de diyor [7].



Şekil 2: 1993, 2009 ve 2018 yılları için Alagöl Gölü uydu görüntüleri

Bu çalışmada uzaktan algılama tekniklerinin veri setini oluşturan Landsat uydu görüntülerinden 1993, 2009 ve 2018 yıllarına ait veriler elde edilmiştir (Şekil 2). Söz konusu uydu görüntülerinin analizi için ERDAS IMAGINE adlı uzaktan algılama programı ile kontrollü sınıflandırma analizleri gerçekleştirilmiştir. Uydu Görüntülerine ait özellikler tablo 1'de verilmiştir (Tablo 1).

Tablo 1: Uygulamada kullanılan veri setine ait alım tarihleri

№	Alım Tarihi	Uydu	Uydu görüntüleri
1	14/06/1993	Landsat-5	LT05_L1TP_147028_19930614_20170118_01_T1
2	13/08/2009	Landsat-5	LT05_L1TP_147028_20090813_20161026_01_T1
3	21/07/2018	Landsat-8	LC08_L1TP_147028_20180721_20180731_01_T1

Bu çalışmanın amacı, Alagöl Gölü kıyı şeridinde 1993 – 2018 yılları arasında meydana gelen değişimin Landsat 5 ve Landsat 8 uydu verileri kullanılarak uzaktan algılama yaklaşımları ile belirlenmesidir. Uzaktan algılama analizlerinde 14 Haziran 1993 ve 13 Ağustos 2009 tarihlerine ait iki adet Landsat 5, 21 Temmuz 2018 tarihine ait bir adet Landsat 8 verisi kullanıldı. USGS'in (United States Geological Survey) internet adresi (http://earthexplorer.usgs.gov/) üzerinden elde edilen görüntüler kullanıcılara ham veri halinde sunulmaktadır [14]. Uydu görüntüleri web sitesinden indirilirken görüntünün bulutluluk oranının %20den az olmasına dikkat edilmiştir. Ayrıca, fenolojik (bitki büyüme döngüsü) ve hidrolojik (su hareketleri) etkileri en aza indirmek amacıyla tüm uydu görüntüleri aynı mevsimlerde seçildi.

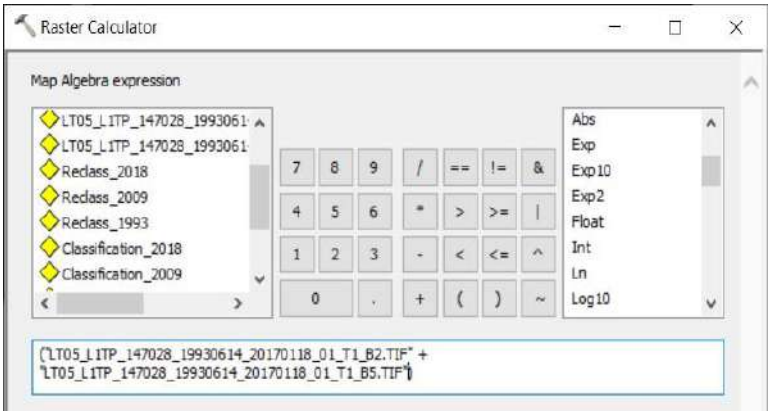
Yöntem

Kullanılan uzaktan algılama algoritmaları, en çok benzerlik sınıflandırması ve modifiye normalize fark su indeksidir. Sınıflandırma işleminde asıl amaç, yeryüzünde benzer spektral özelliğe sahip verilerin aynı grup altında toplanması ve ayırt edilebilirliğin artırılmasıdır [10]. Bu uygulamalar ile sonuçlar ayrıca karşılaştırılmış ve uzaktan algılama yöntemlerinin bu tür araştırmalarda ne kadar etkili olduğu görülmüştür. Modifiye Normalize Fark Su İndeksi (MNDWI) tarafından uydu görüntülerindeki akışkan suyu daha kesin ve net olarak saptamak için bantların orantılanmasını önermiştir. Veri setindeki uydu görüntülerine uygulanan MNDWI için eşik değerler -1 ve +1 arasında yer almaktadır. NDWI'ın farklı bantların kombinasyonu ile nasıl hesaplanacağı aşağıda gösterilmiştir [9].

$$MNDWI = (Band\ 2 - Band\ 5)/(Band\ 2 + Band\ 5) \quad (1)$$

$$MNDWI = (Band\ 3 - Band\ 6)/(Band\ 3 + Band\ 6) \quad (2)$$

Modifiye Normalize Fark Su İndeksi (MNDWI), farklı spektral bantlara (yeşil ve orta kızılötesi) dayanmaktadır. Landsat 5 (TM) ve 7 (ETM+) için bant 2 (yeşil) ve bant 5 (orta kızılötesi) spektral kanalları kullanılmaktadır: MNDWI = bant 2 (G) - bant 5 (MIR) / bant 2 (G) + bant 5 (MIR). Landsat 8 (OLI TIRS) için ise bant 3 (yeşil) ve bant 6 (orta kızılötesi) kullanılmaktadır: MNDWI = bant 3 (G) - bant 6 (MIR) / bant 3 (G) + bant 6 (MIR). Yapılan çalışmalar; MNDWI indeksinin yapılaşmanın yoğun olduğu bir bölgede, suyun özelliklerinin güçlendirilmesinde ve ortaya çıkarılmasında NDWI indeksine göre daha iyi sonuçlar verdiğini göstermiştir [9].



Şekil 3: MNDWI indeksinin hesaplanması işlemleri

Bulgular

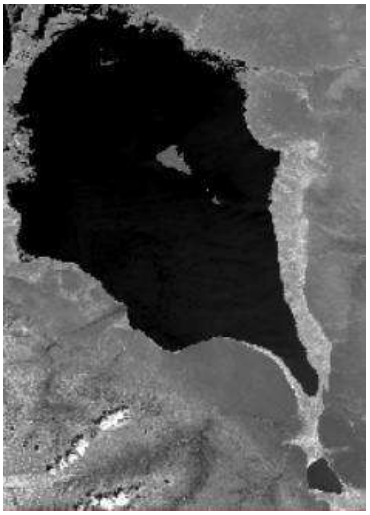
Elde edilen MNDWI spektral indeks görüntüleri, Coğrafi Bilgi Sistemleri (CBS) yardımıyla yıllara göre elle sayısallaştırıldı. Bu işlem, görüntülerdeki su alanlarını belirlemek ve değişimleri analiz etmek için kullanılan bir yöntemdir. CBS, coğrafi verilerin toplanması, yönetimi, analizi ve sunumu için kullanılan bir teknolojidir. Elle sayısallaştırma süreci, uydu görüntülerinin üzerinde belirli bir eşik değeri kullanarak su ve karaları ayırt etmek ve bu bölgeleri sayısal değerlere dönüştürmek anlamına gelir. Bu şekilde, her yıl için su alanlarının büyüklüğü ve konumu sayısal olarak temsil edilir ve değişiklikler gözlemlenebilir hale gelir.

Tablo 2: Landsat 8 uydusu bant özellikleri

Bant Numarası	Bant Gen. (µm)	Çözünürlük (m)	Açıklaması
Bant 1	0.43-0.45	30	Kıyı Aerosol
Bant 2	0.45-0.51	30	Mavi
Bant 3	0.53-0.59	30	Yeşil
Bant 4	0.64-0.67	30	Kırmızı
Bant 5	085.-0.88	30	Yakın Kızılötesi -NIR
Bant 6	1.57-1.65	30	Orta Kızılötesi – SWIR 1
Bant 7	2.11-2.29	30	Orta Kızılötesi – SWIR 2
Bant 8	0.50-0.68	15	Pankromatik
Bant 9	1.36 -1.38	30	Sirrus
Bant 10	10.60 – 11.19	100 (30)	Termal Kızılötesi – TIRS 1
Bant 11	11.5-12.51	100 (30)	Termal Kızılötesi – TIRS 2

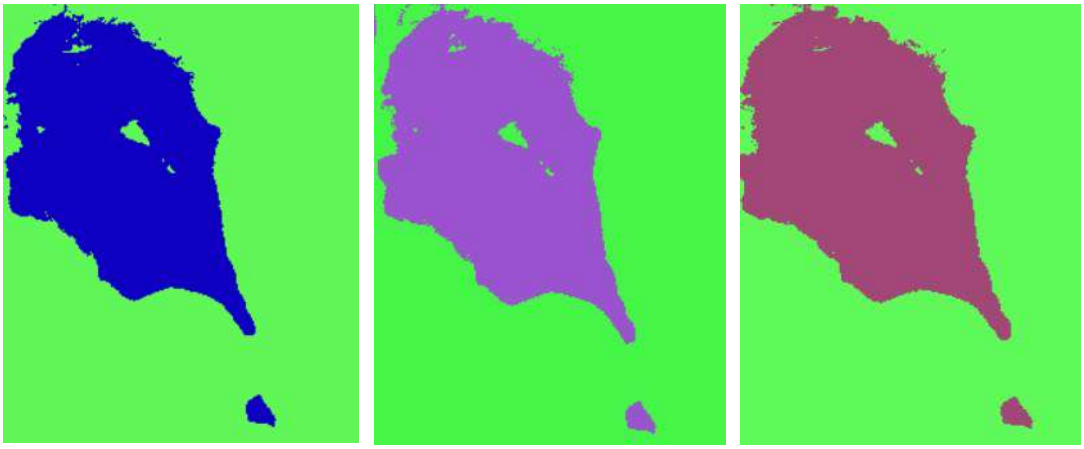
11 Şubat 2013 yılında fırlatılan Landsat 8 uydu algılayıcısı Operasyonel Yer Görüntüleyicisi (OLI) ve termal bantları içeren (TIRs) algılayıcılarına sahiptir. OLI bantları daha önceki geleneksel bandların yanında kıyı/aerosol çalışmaları için derin mavi bant (Bant 1), Sirrus bulutlarının tespiti için kısa dalga kızılötesi bant (Bant 9) ve bir de kalite değerlendirme bandı (Quality Assessment/ QA) olarak adlandırılan 3 yeni bant içermektedir [4]. Bu bantlar Landsat 7 ETM+ ve Landsat 5 TM ile karşılaştırıldığında doğrudan eşdeğeri yoktur ve çalışmada Bant 9 ve QA kullanılmamıştır. OLI bantları Landsat 7 ETM+ ve Landsat 5 TM gibi mekânsal çözünürlüğü 30 m ancak spektral olarak daha dar ve farklı spektral aralıkları kapsar (Tablo 2). Isıl Kızılötesi Algılayıcılar (TIRs) ise bant 10 ve bant 11 olmak üzere iki adet ısıl banda sahiptir. Landsat 8 OLI & TIRS, Landsat 7 ETM+ ve Landsat 5 TM'e kıyasla daha dar spektral bantlara, gelişmiş kalibrasyonu ve sinyal gürültü karakteristiği ile 8 bit radyometrik çözünürlükten daha yüksek çözünürlüğe sahiptir [5].

Çalışmada, farklı tarihlerde kapladıkları su yüzeyi alanlarının belirlenmesinde MNDWI *(Modified Normalized Difference Water Index)* indeksi kullanıldı. Bu indeks, Şekil 4'ten açıkça anlaşılacağı gibi, açık su yüzeylerini öne çıkartmaktadır. Buna karşın, yerleşim alanlarından, bitki örtüsünden ve topraktan gelen gürültüyü maskelemektedir [10].



Şekil 4: (MNDWI) algoritmasının Alagöl Gölüne uygulanması

Bu çalışmada, Landsat uydu görüntülerini kullanarak kıyı-alan değişim analizi yapılmaktadır. İlk olarak, kullanıcı tarafından belirlenen eğitim verileriyle kontrollü sınıflandırma yöntemiyle göl yüzeyi hesaplanmaktadır. Bu yöntemde, farklı sınıflandırma algoritmaları kullanılarak belirli sınıf sayısında bir sınıflandırma işlemi gerçekleştirilir. Daha sonra, zamansal değişim analizi için aradaki süre içinde değişen arazi büyüklüğü miktarı hesaplanır. Uzaktan algılama, farklı zamanlarda elde edilen uydu görüntüleri aracılığıyla değişim belirleme çalışmaları yapmak için etkili bir yöntemdir. Bu şekilde, çalışılan alandaki geçmişten günümüze bilgi sağlanabilir ve gelecek planlamaları için önemli bir rol oynar. Görüntü işleme adımlarından geçirilen ve bilgi çıkarımı yapılan görüntüler, zamansal olarak karşılaştırılarak alandaki değişimler gözlemlenebilir. Uzaktan algılanmış görüntülerde, sınıflandırılan piksellerden elde edilen alan hesaplamaları karşılaştırılır ve bu değerler yorumlanarak değişim analizi gerçekleştirilir.



Şekil 5: Alagöl Gölü için 1993, 2009 ve 2018 yıllarına ait vektör sınıflandırması sonuçları

1993, 2009 ve 2018 yıllarına ait Alagöl gölü uygulaması için vektör sınıflandırması sonuçlarına odaklanalım (Şekil 5). Vektör sınıflandırma, bir görüntüdeki pikselleri belirli sınıflara atayan bir sınıflandırma yöntemidir. Bu yöntemde, belirli özelliklere dayalı olarak piksellerin sınıflara ait olduğu olasılıklar hesaplanır ve en yüksek olasılığa sahip olan sınıfa atanırlar. 1993, 2009 ve 2018 yıllarına ait vektör sınıflandırma sonuçları, gölün kıyı şeridi ve diğer alanlar arasındaki ayrımı sağlar. Bu sonuçlar sayesinde her yıl için göl yüzeyinin sınıflandırılmış haritası elde edilir. Sınıflandırma sonuçları, farklı renkler veya etiketler kullanılarak görsel olarak temsil edilebilir. Örneğin, sınıflandırma sonuçlarına göre göl yüzeyi mavi renkle temsil edilebilirken, kara alanlar yeşil renkle veya farklı bir etiketle gösterilebilir.

Bu şekilde, her yıl için göl yüzeyinin sınıflandırılmış haritaları elde edilir ve bu haritalar aracılığıyla zaman içinde gölün alanında meydana gelen değişimler gözlemlenebilir.

Vektör sınıflandırması sonuçları, Alagöl gölü uygulamasında belirli bir yıl veya zaman dilimine ait göl yüzeyinin sınıflandırılmış haritasını sağlar. Bu haritalar, gölün alanında meydana gelen değişiklikleri incelemek, su alanının büyüklüğünü ve konumunu belirlemek, doğal veya insan kaynaklı etkileri analiz etmek gibi amaçlarla kullanılabilir.

Analiz sonucunda 25 yılda göl alanının ne kadar genişlemiş ya da daralmış, küçülmüş olduğunu görebileceğiz.

Tablo 3. Sınıflandırma sonuçlarına ait alan ve % değişimi

Yıllar	**Su alanı**
1993	2771,18 km²
1993-2009 Alan Değişimi	94,28 km²
1993-2009 % Değişimi	%3,4
2009	2865,46 km²
2009-2018 Alan Değişimi	35,1 km²
2009-2018 % Değişimi	%1,2
2018	2900,56 km²

Tüm uzaktan algılama ve CBS tabanlı veri işleme yöntemleri sonucu Alagöl Gölü su yüzey alanında 1993 yılından 2018 yılına kadar 129,38 km²'ye %4,67 yükselmiştir (Tablo 3).

Şekil 6. Alagöl Gölü'nde 1993 ile 2018 yılları arasında alansal değişim

Sonuç

Bu çalışma, MNDWI yöntemi ve sınıflandırma yöntemlerinin kullanılarak su alanlarının diğer alanlardan kolaylıkla tespit edilmesi, alanlarının hesaplanması ve farklı yöntemlerin sonuçlarının karşılaştırılması üzerine odaklanmaktadır. Ayrıca Alagöl Gölü'nün alanındaki ve kıyı şeridindeki değişimin olası nedenlerini araştırmaktadır. Bu amaçla, çok zamanlı uydu görüntüleri ve uzaktan algılama teknikleri kullanılarak gölün kıyı şeridi değişimleri belirlenmiştir. 1993, 2009 ve 2018 yıllarına ait Landsat 5 ve Landsat 8 uydu görüntüleri kullanılmış ve geometrik düzeltmeler yapılmıştır. Kontrollü sınıflandırma yöntemleri ve modifiye normalize fark su indeksi kullanılarak gölün kapladığı alan ve kıyı şeridi belirlenmiş ve elde edilen veriler CBS ortamında sayısallaştırılmıştır. Sonuç olarak, 1993-2018 yılları arasında gölün kıyı şeridi değişimleri tespit edilmiştir (Şekil 6). Bu çalışma, göl ve çevresindeki ekolojik etkiler, iklim, bitki örtüsü, rekreasyon faaliyetleri ve planlaması gibi konularda uzaktan algılamanın önemli veriler sağladığını ortaya koymaktadır.

Referanslar

[1] Bahadır, M., (2012). Eber ve Akşehir Göllerinin Bütünleşik Kıyı Alanları Yönetimi, Coğrafi Bilimler Dergisi, CBD 10 (1), s. 63- 89.

[2] Bahadır, M., (2012). Kovada Gölü'nde Seviye Değişimlerinin İstatistiksel Analizi, Turkish

Studies - International Periodical For The Languages, Terature And History of Turkish or Turkic. Volume 7/3, 2012, 441-452, Ankara-Turkey. http://dx.doi.org/10.7827/TurkishStudies.2465.

[3] Dube, T., Mutanga, O., 2015. 'Evaluating the utility of the medium-spatial resolution Landsat 8 multispectral sensor in quantifying aboveground biomass in uMgeni catchment, South Africa' ISPRS Journal of Photogrammetry and Remote Sensing, 101, pp. 36–46

[4] Ergene, E. M., 2016. LANDSAT 8 Uydu Görüntüsü Kullanilarak Yeryüzü Sicakliklarinin Uzaktan Algilama Tekniği İle Belirlenmesi : İstanbul Örneği, İTÜ FBE Yüksek Lisans Tezi

[5] Hilal Özçalık, Ahmet Tarık Torun, Süleyman Sefa Bilgilioğlu (2020) Landsat uydu görüntüleri kullanılarak Mogan Gölü'nün su yüzeyi ve arazi örtü değişiminin belirlenmesi. Türkiye Uzaktan Algılama Dergisi– 2020; 2(2); 77-84

[6] https://unansea.com/alakol-goelue-kazakistan-alakol-goelue-rekreasyon/

[7] Gülçin, D. (2018). Arazi Kullanımlarının Sınıflandırılmasında Piksel ve Obje Tabanlı Sınıflandırmanın Karşılaştırılması. Adnan Menderes Üniversitesi Dergisi, 42-49.

[8] McFeeters, S., (1996). The use of normalized difference water index (NDWI) in the delineation of open water features. International Journal of Remote Sensing, Vol. 17, No. 7: 1425-1432.

[9] Mehmet Ali AKGÜL, Mahmut ÇETİN (2017) Baraj gölü su kotunun Landsat 8 uydu görüntüleri kullanılarak tahmin edilmesi. DÜMF Mühendislik Dergisi 9:1 (2018) : 493-502

[10] Modification of Normalised Difference Water Index (NDWI) to Enhance Open Water Features in Remotely Sensed Imagery. International Journal of Remote Sensing 27, No. 14: 3025-3033.

[11] Özdemir M. A., ve Bahadır, M., (2010). Uzaktan Algılama İle Acıgöl Havzası'nda Arazi Kullanımının Zamansal Değişim Analizi (1975-2005), The Journal of International Social Research Volume: 3 Issue: 12 Summer.

[12] Torun, A. T., Ekercin, S., Gezgin, C., (2017). Ysa ile optimize edilmiş yapay arı koloni algoritmasının landsat uydu görüntülerinin sınıflandırılmasında kullanılabilirliğinin araştırılması. Afyon Kocatepe Üniversitesi Fen ve Mühendislik Bilimleri Dergisi, 17(4), 86-93.

[13] Torun, A. T., & Gündüz, H. İ. (2020). Comparison of Different Classification Algorithms for The Detection Of Changes On Water Bodies; Karakaya Dam Lake. Turkish Journal of Geosciences, 1(1), 26-33.

[14] USGS (United States Geological Survey. EarthExplorer-Home: https://earthexplorer.usgs.gov/

[15] Xu, H., (2006). Modification of Normalised Difference Water Index (NDWI) to Enhance Open Water Features in Remotely Sensed Imagery. International Journal of Remote Sensing 27, No. 14: 3025-3033.

[16] Xu, H., 2008. A new index for delineating built-up land features in satellite imagery. International Journal of Remote Sensing, 29, pp.4269–4276.

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Impact of Foreign Direct Investment on Poverty in Ghana: A Johansen Co-integration Analysis

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Abstract

In the past years, Ghana has witnessed a significant increase in Foreign Direct Investment which is expected to translate into transformative growth that reduces poverty and inequality; however, the country's poverty and income inequality profile remain high. Foreign direct investment (FDI) and poverty research are important because FDI can have both positive and negative effects on poverty levels in host countries [1]. The positives imply that FDI can bring in capital, technology, and job opportunities, which can help reduce poverty by boosting economic growth and raising people's living standards. On the other hand, FDI can displace local businesses, exacerbate income inequality, and have environmental consequences that harm the poorest members of society. Understanding the relationship between FDI and poverty can assist policymakers and businesses in making informed decisions that promote inclusive and sustainable economic growth and reduce poverty. This study investigates the impact of FDI on poverty in Ghana using a 29-year data set from (1990 to 2018). Analysis was done using the Johansen Cointegration technique. The literature informed the variables used for this study. The Gini coefficient (which serves as a proxy for poverty and its parts of the FGT poverty indices family), foreign direct investment (FDI), GDP per Capita, exchange rate, trade openness, and inflation rate were all cointegrated. The results of the study showed that FDI, GDP per capita, inflation rate, and exchange rate widen the income inequality gap, hence, increasing the poverty incidence. In contrast, an increase in trade openness reduces the Gini coefficient implying a reduction in income inequality and poverty.

Keywords: Foreign direct investment, poverty, Gini coefficient, income inequality

Introduction

As a pervasive global issue with various causes and effects, poverty affects everyone regardless of geographic location, and for a considerable amount of time now, governments and international organizations have aimed at discovering practical methods that can assist in tackling poverty while ensuring sustainability. In this context, Foreign Direct Investment (FDI) has garnered significant attention as a promising catalyst for improving the economy and alleviating poverty levels. Foreign direct investment (FDI) refers to the investment made by individuals or companies from one country into business interests located in another, FDI has become an increasingly important factor in economic development and growth, with many countries actively seeking FDI to stimulate their economies and enhance the quality of human resources [1]. At the same time, poverty continues to be a significant global challenge, affecting millions of people worldwide.

The existing research regarding the effects of FDI on poverty evidences a complex relationship resulting from varied outcomes, and some studies indicate that foreign direct investments (FDIs) may be helpful in terms of reducing poverty by creating jobs leading to higher wages resulting in improved livelihoods for people. [2] argue that FDI can positively affect economic growth and social welfare through increased financial resources for technological progress resulting from enhanced human capital. However, many studies have pointed out challenges and roadblocks associated with FDI as a tool for alleviating poverty, including the issue of income inequality and the depletion of resources, which significantly affect society. Moreover, dependence on foreign firms and inadequate spill-over effects for technological advancements within domestic industries are subjects that need addressing, and investigations carried out by [3] imply that the positive impacts of FDI in alleviating poverty, differ based on individual contextual settings, including host country specificities like the institutional environment or absorptive capacity.

Global FDI has increased for the past two decades until the COVID-19 pandemic hit the world [4]. Since the Covid-19 pandemic, the United Nations Conference on Trade and Development (UNCTAD) projected a damaging decline in FDI flows; this is expected to significantly impact developing nations. Foreign direct investment (FDI) contributes to economic growth in developing countries in numerous ways: breaking the vicious cycle of poverty, creating employment, technological and innovation pooling and sharing, and forging and promoting political stability. Over the past decades, the patterns in global FDI flows and the distribution of their related effects across the world's regions have been the focus of empirical decisions [4]. In 2018, global foreign direct investment (FDI) declined by 13 percent to $1.3 trillion. The decline–the third consecutive year of FDI decline–was mainly due to the large-scale repatriation of accumulated foreign earnings by US multinationals in the first two quarters of 2018, following tax reforms enacted at the end of 2017 [5]. The year 2020 had great expectations, with advanced and emerging economies adopting the idea of Industry 4.0, a mantra for the Fourth Industrial Revolution [6]. Despite the persistent slide in global FDI flows, Africa has enjoyed some of the highest global returns on foreign direct investment (FDI) in the global investment sphere [7]. Africa stood in sharp contrast compared to developed economies, whose FDI inflows dropped by 27% (their lowest level since 2004) [8]. A logical explanation could be attributed to the changes in the type of FDI inflow from resource-seeking to skills and technology-driven FDI, which most Sub-Saharan African countries lack.

In 2020, Ghana was optimistic about attracting more FDI inflows owing to the prospects and benefits of the government's efforts to strengthen the local market climate and implement the African Continental Free Trade Area (AfCFTA) in May 2019. The AfCFTA is expected to raise intra-African trade to 25% by 2040 [9]. However, during the second quarter of 2020, FDI flows to Ghana deviated from the projected global decline pattern, resulting in a substantial increase in FDI inflows for the year's first half [4]. In the first half of 2020, gross investments amounted to US$869.47 million, with a total FDI value of US$785.62 million [9]. The general trading sector reported an enormous value of US$246.05 million in terms of the estimated cost of investments. This was followed by the mining and manufacturing industries, with projected costs of US$231.02 million and US$170.67 million, respectively [9].

Poverty is a state or situation in which the financial resources and necessities for a basic standard of living are lacking for an individual or a society. Poverty means that the income level from work is so poor that it is difficult to meet basic human needs. Poverty-stricken individuals and families may lack adequate housing, clean water, nutritious food, and medical care. Each nation may have a threshold of its own that defines how many people live in poverty [11,12]. Poverty's social and economic effects profoundly hinder progress toward equality and inclusion by exacerbating already present disparities and hampering socio-mobility. Intersecting factors like gender disparities, unfairness, and limited access to resources or opportunities often exacerbate marginalization in terms of poverty. Overcoming poverty is made even harder for individuals and communities due to this further complicating matters [13].

The [14] describes poverty in absolute terms. The bank describes extreme poverty as living on less than US$1.90 a day and moderate poverty as living on less than $3.10 daily. In 2008, 1.4 billion people were reported to have consumption levels below US$1.25 per day, and 2.7 billion lived on less than US$2 per day. Poverty in Ghana is multidimensional, and cuts across different parts of Ghanaian society. The Ghana Statistical Service, in its 2020 multidimensional report, considers multidimensional poverty as the widely divergent deprivations faced by poor people in Ghana. Multidimensionally poor are often considered as those who lack education, adequate health and nutrition, suitable housing, and safe water; these are examples of their drawbacks to a meaningful standard of living. These deprivations indicate many poor people's living conditions and their challenges in seeking and achieving practical skills [15].

The multidimensional poverty (MP) report of Ghana prepared by[15] revealed that 45.6 percent of Ghana's population is multidimensionally poor. The indicators that contributed most to multidimensional poverty in Ghana are lack of health insurance coverage, under-nutrition, school lag, and households with non-educational qualifications. The report also showed that the intensity of poverty is 51.7 percent, meaning that poor people experience, on average, more than half of the weighted deprivations (thus, the 12 indicators which were used for study and categorized under education, health and nutrition, housing, and safe water). The multidimensional poverty index (MPI), which is the product of the incidence and intensity of poverty, is 0.236. Ghana managed to reduce its incidence of MP from 55 percent in 2011 to 46 percent in 2017, thus, a nine percentage points decrease. The intensity of poverty also fell from 54.2% in 2011 to 51.7% in 2017, reflecting a slight improvement. The MPI dropped from 0.298 in 2011 to 0.236 in 2017, showing a 0.062 reduction. The differences in incidence and intensity of MP are statistically significant, suggesting significant progress in reducing multidimensional poverty over time in the Country [15].

From a theoretical perspective, economic theories[1] have been put forward to understand the main determinants of economic growth and how that growth translates into prosperity. Robert Solow pioneered the modern understanding of the growth-development model; he demonstrated around the 19th century that a sustained rise in capital spending would temporarily increase the rate of growth, which explains the difference in growth rates between countries. Most FDI theories[2] focus more on the relationship between the investment made by multinational companies and the economic growth of the host countries. Most of the analyses try to emphasize the transfer of technology, skills, and impact on the macroeconomic indicators of the host countries. For this study, we are mostly interested in exploring poverty via the lens of spatial disparity and how FDI exacerbates poverty in Ghana.

The geographical disparity is old literature that clarifies the root causes and factors exacerbating poverty. It explains the dichotomy of developed and less developed economies. The theory suggested by [16] drew attention to the fact that in many places, individuals, institutions, and cultures lacked the objective tools needed to produce well-being and wealth and the power to demand redistribution [17].

As Bradshaw [18] pointed out, "Space is not a background for capitalism, but rather is restructured and contributes to the system's survival." The geography of poverty is thus a spatial representation of the capitalist system [18]. That poverty is most acute in some areas is an old observation and an abundance of reasons in the development literature why regions lack the economic foundation to compete. Recent explanations include disinvestment, proximity to natural resources, density, innovation diffusion, and other factors. To fully grasp the impact of FDI on poverty reduction initiatives in developing countries requires an understanding of geographical disparity theory's relevance, and this assists us in recognizing why these outcomes are distinct across different areas. Therefore, a comprehensive analysis incorporating geographical disparity theory alongside other relevant frameworks and factors is necessary to gain a more nuanced understanding of the relationship between FDI, poverty, and regional disparities in developing countries. Ghana's economic indicators are being analyzed in relation to the impact of FDI and poverty for a better understanding of these issues.

Empirically, [19] used time series data for Portugal between 1973 and 2016 to investigate how inward foreign direct investment (FDI) contributes to income inequality and poverty. Their results stipulated that increased inward FDI flow is associated with less unequal income distribution and lower poverty rates. Further, they posited that more unequal income distributions significantly and negatively impact inward FDI in the long run. They concluded that, among other things, human capital is a crucial determinant in mitigating income inequality and circumventing poverty, indirectly contributing to fostering additional FDI inflows.

[20] studies the impacts of Foreign Direct Investment (FDI) in the mining sector on rural poverty in Ghana. Using qualitative research techniques and New Institutionalist and Marxist theoretical perspectives, the study noted that large-scale mining activities in Ghana have intensified with an increase in foreign capital involvement within the mining industry. This he attributed to the mining sector reforms in 1986. He further posited that mining could potentially reduce rural poverty through revenue generation, employment creation, and Corporate Social Responsibility (CSR). However, he acknowledges that weak institutional capacity, ineffective and corrupt mining support institutions, capital-intensiveness of mining activities, and limited scope of CSR, have thwarted the ability of mining to reduce poverty in mining communities in Ghana.

[21] investigated the influencing factors of poverty in Pakistan and discussed the theoretical linkages between poverty and its main macroeconomic variables. They applied the Johansen co-integration technique with multi-diagnostics tests. The results of their study showed that all these variables (agricultural ratio to gross domestic product (GDP), the ratio of Foreign Direct Investment (FDI) to GDP, the ratio of primary education, the ratio of the domestic credit to the private sector and military expenditure as a percentage of GDP) had a significant effect on poverty. They explained that an increase in agricultural output leads to decreased poverty. The result posited that education enrollment significantly negatively impacted poverty in the long run. More so, domestic credit had a significant negative impact on poverty; however, military expenditure had a significant positive impact on poverty in Pakistan.

[22] made an extensive collection of literature that explains the linkages of the benefits of FDI for poverty reduction. They posited some benefits of FDI for poverty reduction, including increased

[1] Solow (1956): Solow Growth Model; Growth driven knowledge spillover and technological progress Romer (1986); Growth driven human capital Lucas (1988); Growth based on new knowledge (Romer, 1990, Grossman and Helpman, 1991); Growth based on innovation (Aghion and Howitt, 1992); Growth driven by public infrastructure (Barro, 1990).

[2] Vernon (1966): Production life Cycle; Itagaki (1981) and Cushman (1985): TheTheory of Exchange Rates on Imperfect Capital Markets; Buckley and Casson (1976), Hennart (1982) and Casson (1983): The Internalisation Theory; (Dunning,1973,1980,1988): The Eclectic Paradigm (O-L-I).

investment capital essential for economic growth and employment opportunities. However, they agree that the effect of FDI on poverty in the host country is not a simple relationship but varies depending on several factors. [17] integrated the understanding of linkages and spillovers into sectoral poverty analysis – FDI inflows nexus debate, foreign direct investment inflows, increased external earnings, trade openness, overall market size, favorable exchange rate, low external debt, increased foreign aid, and technology would significantly reduce poverty in a country. On the contrary, the lack of these economic indicators would lead to significant regional poverty.

A key finding from our understanding of the trends of FDI and Poverty and inequality in Ghana informs that FDI inflow into Ghana has not been pro-poor. The sectoral distribution of the inflow of Foreign Direct Investment to Ghana shows that most FDI was not targeted at sectors of the economy that could have reduced the MPI. The service sector recorded the highest growth share, followed by the manufacturing and export sectors [15]. The impact of FDI in the service industry on reducing poverty is a complex issue with both positives and negatives. Still, FDI can help drive economic expansion and expand opportunities for employment by investing in the services sector. However, its capacity for reducing poverty directly can sometimes be limited. Researchers such as [23] have shown that FDI benefits the manufacturing sector when invested in financial services but negatively impacts it when invested in trade services. The impact of FDI in the service sector on reducing poverty is context-dependent and involves a complex relationship. The Ghanaian economy is primarily driven jointly by the informal and agricultural sectors, which employ about 70 percent of the population, more than half of 45.6 percent of Ghana's multidimensionally poor population are equally domiciled in these sectors. Intuitively, these are the sector where FDI can indeed be pro-poor. However, the agricultural sector of Ghana has benefitted from as low as 1.% in FDI inflow [15].

The effect of foreign direct investment (FDI) on poverty remains uncertain. It requires more comprehensive research for us to gain a clear picture of this relationship. Still, in undertaking this study, our aim is not only to enhance but also to contribute new perspectives on the link that exists between FDI and poverty reduction. This study is unique in that it considers contextual factors and country-specific characteristics of Ghana, this study seeks to provide valuable insights into the role of FDI in poverty reduction through a comprehensive analysis that integrates theoretical frameworks, empirical evidence, and robust methodologies, this study seeks to contribute to the existing literature on the relationship between FDI and poverty. The research will explore the mechanisms through which FDI affects poverty levels, considering contextual factors such as the institutional environment, sectoral composition, and absorptive capacity of recipient countries. The findings of this research will inform evidence-based policy-making and contribute to poverty alleviation efforts.

Methodology

The variables to be employed for this study include the Gini coefficient (serving as a proxy for poverty), Gross Domestic Product per Capita (GDPC), Foreign Direct Investment (FDI), the Exchange rate (EXC), Inflation rate (INF), and Trade Openness (TOP). The log of these variables was taken to have a common base for better analysis. From the log form, the econometric model below was constructed. The model employed was a modification of [21] model.

$$lngini_t = \beta_0 + \beta_1 lnfdi_t + \beta_2 lngdpc_t + \beta_3 lnexc_t + \beta_3 lntop_t + \beta_4 lninf_t + \mu_t$$

where: $Lngini_t$: log of Gini coefficient (serving as a proxy for poverty), $Lnfdi_t$: the log of net inflow of FDI as a percentage of GDP, $Lngdpc_t$: the log of GDP per Capita, $Lnexc_t$: the log of the exchange rate, $Lntop_t$: the log of trade openness (which is the ratio sum of export and import over GDP), $Lninf_t$: the log of inflation rate (consumer price inflation), β_0 is the intercept of the model. β_1, β_2, β_3, β_4, and β_5 are the coefficients of the variables. μ_t is the error term. The data used for the analysis is a 29-year data series covering 1990 to 2018. Most data were collected from the World Bank's World Development Indicators (WDI), International Monetary Fund (IMF), UNCTAD, and Ghana Statistical Service.

Unit root test

A test for co-integration among variables is primarily required in the above model. The Augmented [24] unit root test technique was used to check for the unit root of the variables. The ADF test is an auxiliary regression developed by [24] to check the existence of a unit root for each variable of a model.

$$\Delta Y_t = \alpha + \delta_t + \beta Y_{t-1} + \sum_{i=1}^{k} \gamma \Delta Y_{t-1} + \mu_t$$

The aforementioned auxiliary regression tests for the possible presence of a unit root in Yt. The variable ΔYt−1, indicates the lagged first differences and shows the serial correlation errors, and α, δ, β *and* γ are the parameters of the equation which are to be estimated. The null and alternative hypotheses for the above equation can be written as: Ho: β=0, Hε: β<0. The t-statistics criterion is commonly used to test the null hypothesis. According to this approach, the null hypothesis (β=0) cannot be rejected if the t-statistics are lower than the critical values.

Co-integration and long-run model

To understand the long-term relationship between variables, the Johansen Co-integration test is designed for non-stationary variables. [25] introduced the co-integration method, and the fundamental purpose of this test was to protect losses from long-run data information that occurs due to the time series. The linear combination of variables is I (1) and I (0), so variables are said to be cointegrated and require data from time series to be non-stationary at the first difference and stationary levels. For the above model, the Johansen co-integration test was employed. The co-integration of two or more series means they have a long relationship. The co-integration analysis captures the dynamic relationship among the variables. Assume that the process Y_t is defined by an unrestricted vector autoregressive system of order (n×1).

$$Y_t = \pi_1 Y_{t-1} + \pi_2 Y_{t-2} + \ldots + \pi_k Y_{t-k} + \mu_t \quad (1)$$

where, Y_t = (n×1) vector, of I (1) variables π_1 = (n×n) matrix of unknown parameters, to be estimated (I = 1, 2, 3 … k) μ_t. The independent variables and identically distributed (n×1) vector of error terms (1, 2, 3 …. m) observations. Using $\Delta = (I - L)$ where L is the lags operator. The above equation can be transformed into the error correction form below:

$$\Delta Y_{t-1} = \sum_{i=1}^{k-1} \Gamma_i \Delta Y_{t-1} + \pi Y_{t-k} + \mu_t \quad (2)$$

where, ΔX_t is an I (0) vector. I is an (n×n) identity matrix.

$$\Gamma_i = \sum_{i=1}^{k-1} \pi_{i-I}, \text{ i=1, 2…..k-1, and} \quad (3)$$

$$\pi = \sum_{j=1}^{k-1} \pi_{j-1} \quad (4)$$

The fourth equation is a vector error correction equation.

Johansen's approach, along with the independent errors, is an estimator of the co-integration vector, the autoregressive process. The vector (n x n) can also be seen as the multiple of α and β, two (n x r) of each rank, where α indicates the integration of r co and β shows the elements of weighting and thus the above equation is written as:

$$\Delta X_t = \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-1} + (\beta\alpha) X_{t-k} + \mu_t \quad (5)$$

Here the hypothesis of r co-integration relation among the element of Y_t. The null hypothesis of no co-integration relations (r=0) means that π=0; thus, the co-integration test is the estimations of π are significantly different from 0 and test for the number of co-integrations. On the other hand, when there is no co-integration relation, where $0 \leq \Gamma < n$. If there is no cointegration relation, then the linear combination variables are stationary. The order of Γ is estimated using likelihood ratio (LR) trace test statistics suggested by [26].

$$\lambda_{trace(q,n)} = -T \sum_{i=q+1}^{k} \ln(1 - \lambda_i) \quad (6)$$

For Γ =0, 1, 2 …k−1. T represents the number of observations used for estimation is i[th] largest estimated Eigenvalue.

$$\lambda_{max(q,q+1)} = -Tln(1 - \lambda_{q+1}) \quad (7)$$

Trace statistics reject the null hypothesis of co-integration among the variables ($\Gamma = 0$) does not reject the null hypothesis, that there is one cointegrating relation between the variable ($\Gamma \leq 1$).

Data Analysis and Result

The augmented Dickey-Fuller test was estimated to verify the stationarity variables at the level as well as at the first difference, and the results of the ADF test are listed below:

Table 1. Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Year	27	2003	7.937	1990	2016
lnGINI	27	1.625	.013	1.603	1.64
lnRGDP	27	.69	.172	.338	1.148
lnGFCF	27	1.307	.122	1.071	1.466
lnTOP	27	-.135	.117	-.372	.065
lnINF	27	1.459	.614	.335	2.315
lnUMP	27	.793	.106	.665	1.015
lnFDI	27	.41	.451	-.6	.976
lnEXC	27	.301	.621	-.592	1.487
lnHUC	27	.332	.031	.273	.386

Table 2. Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)
(1) lnGINI	1.000					
(2) lnFDI	0.784*	1.000				
	(0.000)					
(3) lnRGDP	0.331	0.288	1.000			
	(0.092)	(0.145)				
(4) lnEXC	-0.972*	-0.769*	-0.209	1.000		
	(0.000)	(0.000)	(0.296)			
(5) lnTOP	0.415*	0.355	0.182	-0.557*	1.000	
	(0.032)	(0.069)	(0.362)	(0.003)		
(6) lnINF	0.989*	0.785*	0.280	-0.991*	0.496*	1.000
	(0.000)	(0.000)	(0.157)	(0.000)	(0.008)	

**** p<0.01, ** p<0.05, * p<0.1*

Table:3 Augmented Dickey-Fuller test

Variables	Level		1ST difference		Order level
	Constant	Trends	Constant	Trends	
lngini	-2.862*	1.625	-2.577	-3.323*	I (1)
lnfdi	-2.340	-2.619	-4.240***	-4.279**	I (1)
lngdpc	-2.759*	-3.888**	-6.340***	-6.225***	I (0)
lnexc	-1.846	-1.458	-3.571**	-3.892**	I (1)
lntop	-2.346	-1.919	-4.665***	-5.526***	I (1)
lninf	-2.754*	-4.637**	-2.586	-3.133	I (0)

**** p<0.01, ** p<0.05, * p<0.1*

The critical values at 1%, 5%, and 10% are -4.339, -3.587, and -3.229, respectively. The values of the variables are greater in absolute terms than the critical values and stationary at the first difference level except for lninf (inflation) whose variable was stationary at level. Thus, *lngini*, *lnfdi*, *lngdpc*, *lnexc, and lntop* are integrated of the order I (1) level. The *lninf* is integrated of order I (0) level.

Cointegration and Short-Run Model

The co-integration technique helps to determine the existence of an equilibrium relationship between the variables employed [27]. All variables included in the analysis were integrated; hence, the cointegrated relationship between the variables was tested. With a maximum lag of 1, Akaike Information Criterion, the lag length of unrestricted VAR model, the Johansen co-integration test was conducted.

The Trace and Maximum Eigen statistics are the two test statistics for co-integration vectors. The number of cointegrated equations in the model is given in both tests. The null hypothesis cannot be rejected if the t-statistics are greater than the 0.5 critical values. This means there is no co-integration among the values, and an unrestricted VAR model should be conducted. However, when the t-statistics is less than 0.5 critical values, reject the null hypothesis, and the VECM (Vector Error Correction Model) is conducted.

If there is no co-integration among variables, then there is a long-run relationship on the averages between the variable, ceteris paribus. If there is co-integration among the variables, it indicates a short-run relationship between the variables on average, ceteris paribus.

Table 4 shows the Trace and Max Eigen statistics results after running the Johansen Co-integration test. Table three provides the normalized co-integration results.

Table 4. Johansen Cointegration test result

Trace Statistics				Max-Eigen Statistics			
H0	Trace	CV (95%)	Prob.	H0	Max-Eigen	CV (95%)	Prob.
r = 0*	127.2030	95.75366	0.0001	r = 0*	44.29362	40.07757	0.0158
r = 1*	82.90939	69.81889	0.0032	r = 1	30.95226	33.87687	0.1074
r = 2*	51.95713	47.85612	0.0196	r = 2	22.55296	27.58434	0.1934
r = 3	29.40418	29.79707	0.0554	r = 3	15.27665	21.13162	0.2700
r = 4	14.12753	15.49471	0.0795	r = 4	13.88805	14.26460	0.0572
r = 5	0.239482	3.841465	0.6246	r = 5	0.239482	3.841465	0.6246

*The trace statistics showed that there are 3 cointegrated equations at the 0.5 level of significance. The Maximum Eigenvalue indicates only 1 cointegrated equation at the 0.5 level of significance.

From the above table, the Max-Eigen statistic results show that there is only one co-integration equation at none (r = 0), which means that the null hypothesis is rejected, suggesting a short-run relationship among the variables on average, ceteris paribus. Therefore, the VECM model should be conducted. However, with the trace statistics, there are three cointegrated equations and three non-cointegrated equations. At this point, the null hypothesis cannot be rejected or accepted, and both the unrestricted VAR and VECM models should be run.

Table 5. Normalized co-integration results from the Johansen Co-integration for the long-run relationship

	Dependent variable: lngini				
	Lnfdi	lngdpc	Lnexc	lntop	lninf
Coefficients	-0.003884	0.008811	-0.028608	0.052802	0.008004
Standard Error	0.00028	0.00090	0.00042	0.00193	0.00048

**** p<0.01, ** p<0.05, * p<0.1*

From the results above, FDI and exchange rate positively impact (reduces) gini coefficient in the long run by 0.3% and 2.8% respectively on average, *ceteris paribus*. This result is in tandem with the works of [28] and [29] in which they employed the VAR method in exploring the impact of FDI on poverty reduction. They found similar results where FDI reduce poverty in the long run. Howerver, GDP per capita, trade openness, and inflation harm (increase) gini coefficient by 0.8%, 5.2% and 0.8% respectively, on average, *ceteris paribus*. The VECM model was estimated, and the long and short-run relationship results are provided in Tables 6 and 7.

Table 6. Vector Error Correction Model results based on Johansen Co-integration (Long run results)

	Dependent variable: lngini				
	Lnfdi (-1)	lngdpc (-1)	lnexc (-1)	lntop (-1)	lninf (-1)
Coefficients	-0.011256	0.030063	-0.033955	0.091459	0.017083
St. Errors	0.00173	0.00514	0.00249	0.01083	0.00306
T Statistics	-6.51926**	5.85162	-13.6162**	8.44454**	5.57604*

**** p<0.01, ** p<0.05, * p<0.1*

From the table above, the long effects results are presented. In the long run, FDI is statistically significant and reduces income inequality by 1.125% ceteris paribus, hence reducing poverty levels per the arguments of the FGT poverty measurement. This results in line with the works of [28,29,30,31]. They all found FDI to harm poverty in the long run. Similarly, the exchange rate (exc) hurts Gini coefficient. Thus, it reduces inequality and hence poverty. This could link to the impact of FDI. This is more of an indirect impact through the positives of FDI inflows – more net inflows, economic growth and stable financial systems. However, inflation (lninf) and trade oppeness (lntop) are significant and positive relationship with gini coefficient in the long run. In the long run, inflation increases and trade oppeness increases poverty by 1.7% and 9.1% respectively, ceteris paribus. GDP per capita was insignificant but has increases gini coefficient by 3% in the long run.

Table 7. Vector Error Correction Model results based on Johansen Co-integration (Short-run result)

	Dependent variable: lngini						
	ConintEq1	Constant	lnfdi (-1)	lngdpc (-1)	lnexc (-1)	lntop (-1)	lninf (-1)
Coefficient	-1.1565	-0.0126	0.0102	0.0502	0.1022	-0.0079	0.0127
St. Errors	0.9942	0.0093	0.0153	0.0999	0.0861	0.0992	0.0158
T Stats	1.1632	-1.3555	0.6651***	0.5028**	1.1876*	-0.0796**	-0.8027**

R^2 = 0.194010

F stats = 0.653356

**** p<0.01, ** p<0.05, * p<0.1*

The VECM short-run results stipulate that FDI, GDP per capita, exchange rate, and inflation positively correlate with gini coefficient and statistically significant in the short-run. However, trade openness has a negative relationship with gini coefficient and statistically significant in the short-run. The cointegration equation (CointEq) shows that the previous year's deviation from long-run equilibrium is corrected at a speed of 115.6%. Thus, it show the speed of adjustment in the long run from the short run. In the long run, the variabeles will be at equilibrium with a 115.6% speed of adjustment.

The results show that a percentage change in FDI will lead to a 1.02% increase in the Gini coefficient in the short run. In effect, the net inflows of FDI widen the income inequality gap in the short run, hence pushing more people to fall below the safety net. This could be attributed to two issues. First, the kind of inflows which are brought into Ghana. Most of the inflow is not employment generative. They rather complement existing employment systems and industry less employment is created. Additionally, most of these inflows come from purchases within the financial sector, which crowds out domestic bond purchases. Second, the inflows are mostly targeted to areas where most Ghanaians are not participating. Thus. Per the demographics of Ghana, most people work within the informal sector and in the agricultural sector. However, according to the [9], most of the investments are in the service and oil and gas sectors. These findings are consistent with the works [22,32,33].

The result also postulates that GDP per capita, exchange rate, and inflation positively impacts gini coefficient by 5.02%, 10.22%, and 1.27% respectively. [22,28] also had similar results. Therefore, there is a need to stream policies that will ensure that the distribution of resources are Pareto optimal. In this regard, growth in per capita income will mean that more people will join the middle class of income earners.

Moreover, some diagnostics tests were conducted to test for heteroscedasticity and autocorrelation. The Breusch-Pagan LM test was conducted to ascertain the heteroscedasticity, and the Durbin Watson Autocorrelation test was conducted. The results are shown in Tables 8 and 9, respectively.

Table 8. Heteroscedasticity test result

Chi-Square	Degree of freedom	Prob
292.8969	294	0.5072
*No heteroscedasticity		

From the above results, the p-value is greater than the 1%, 5%, and 10% significance levels. The null hypothesis of no homoscedasticity is rejected. Therefore, there is no heteroscedasticity in the module. This implies that the model is homoscedastic.

Table 9. Autocorrelation test result

Lags	LRE*stat	d/f	Prob	RaoFstat	d/f	Prob
1	25.96665	36	0.8914	0.636670	(36, 37.9)	0.9117
2	26.96424	36	0.8620	0.667650	(36, 37.9)	0.8869

Null hypothesis: There is no serial correlation at lag h

From the autocorrelation LM diagnostics test above, the p values for the lags (1 and 2) are higher than the 5% significance level, which means there is no autocorrelation. Thus, the null hypothesis of no serial correlation cannot be rejected. This implies that the variables within the model are not serially correlated and are independent of each other.

Discussions, Conclusion, and Policy Implication

Poverty has been a nebulous and contentious phenomenon whose accurate quantification is daunting. While [34] argues that poverty is linked with an individual's capability to choose a life that he or she has a reason to value, [35] views poverty as the lack of ability to in a particular way of life. [36] opined that most research on income inequality and poverty explains the difference in income and consumption between people by focusing on the differences in individual household characteristics.

The analysis results indicate that FDI does not reduce the inequality gap; instead, it increases the gap by 1.02%. This can be attributed to the fact that the inflows of FDI into Ghana for the past years have been in the economy's service sector. It is worth noting that the informal and agricultural sectors of the Ghanaian economy are the most significant contributors to job creation in Ghana. These two sectors provide a living for the majority of the middle and lower classes, who are often poor. Over the years, the share of agriculture to GDP and employment is declining, meaning more people are becoming poorer. The Ghana Investment Promotion Center's 2020 2nd quarter report shows evidence of this. The report stipulated that in terms of sectoral distribution of investment cost and FDI value, the general

trading sector recorded an immense value of US$246.05 million. This was followed by the mining exploration and manufacturing sectors, with an estimated cost of US$231.02 million and US$170.67 million, respectively. The figure below shows the sectoral distribution of FDI value and the estimated cost in US dollars.

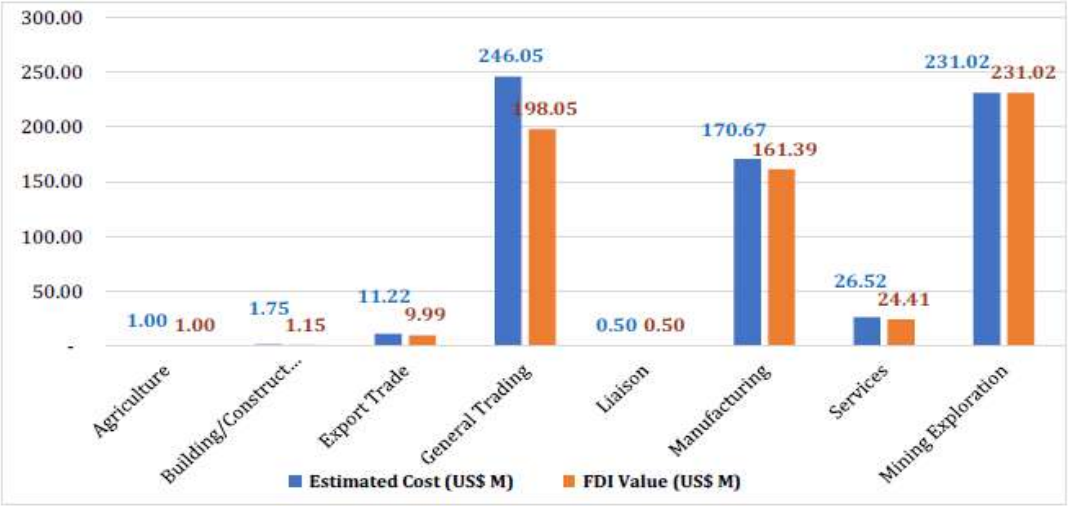

Figure 1. Sectoral distribution of FDI value and estimated cost in us dollars [15]

This accounts for the high multidimensional poverty in Ghana. The inequality gap between cities and villages and within cities is very high. As most cities become urbanized, inequality and urban poverty increase, increasing multidimensional poverty indices. The situation is worse in the rural part of Ghana, where the primary source of income is farming. This is because most of the FDI inflows remain within the cities, and the figure above demonstrates the abysmal performance of the agricultural sector in attracting FDI.

According to [15], 45.6% of 30 million Ghanaians are multidimensionally poor. This is a staggering 13.68 million Ghanaians who are multidimensionally poor. It is essential to state that the current government policy of one district, one factory (1D1F), and planting for food and jobs have attracted more FDI into the country concerning the former policy; most of these are in the manufacturing and mining sectors. In contrast, local investments are instead increasing in the latter policy.

As expected, inflation also increases the inequality gap, thereby making the poor poorer. When prices of goods and services increase without a parallel increase in income, more people will be pushed to live below the lifeline threshold. Therefore, the result of the study is consistent in that a percentage increase in the inflation rate creates a 1.27% increase in inequality (Gini coefficient); hence, the poverty index rises. When people are unable to afford a life they value due to increases in the inflation rate, it renders the individual incapable of living a life he or she values. This was what Sen was concerned about.

Similarly, the exchange rate is in sync with the inflation rate within a country. When a state's currency performs poorly against the primary trading currency, it leads to price hikes, especially in import-dependent countries. Ghana's import has been exceeding its exports for some time now, and anytime the Ghana cedis (GHS) performs poorly against the major trading currencies such as dollars, pounds, and euro, the prices of imported goods, especially rice, cooking oil, chicken, and other basic needs items goes up. This increases the number of people living below the World Bank safety net of US 2 dollars.

However, the inequality gap is reduced by 0.79 percent when trade openness increases by 1%. This could be attributed to the integration of trade within the Economic Community of West African States (ECOWAS) economic bloc. Whiles major cooperation and big business are taking advantage of this, middle- and low-level-income earners also increase their income through intercountry trading. Most traders in Ghana at the middle and low-income levels take advantage of the duty-free port in Togo to import their trading items. Others move to Nigeria to buy goods. Some provide service within the border towns or even move to other neighboring countries to establish a business where they enjoy some tax weaves and economic advantages.

Conclusion and Policy Implication

This study investigates the impact of FDI on poverty in Ghana using a 29-year data set (1990 - 2018). A Johansen Co-integration technique was employed to estimate the impact of FDI, and some diagnostics tests were conducted. The study concludes that FDI, GDP per capita, inflation rate, and exchange rate increase the Gini coefficient, increasing income inequality and poverty. In contrast, trade openness reduces the Gini coefficient, implying a reduction in income inequality and poverty.

The finding of this study that FDI does not reduce poverty is in tandem with the findings of [20,38]. With this backdrop, the following policy recommendations are suggested to policymakers:

1. FDI inflows need to be targeted toward sectors that involve a majority of middle and low-income earners.
2. Through the GIPC, the government can incentivize investors whose targets are the informal and agricultural sectors. This is because a majority of the poor people work within these sectors.
3. The 1D1F policy should be intensified as it can potentially revolutionize the agricultural and manufacturing sectors. This can reduce our import dependency. This project's expansion and sustainability plan should be a priority for the government. More jobs will be provided, and more livelihoods will be transformed as their earnings increase if the policy is sustained and appropriately planned. Additionally, for 1D1F to thrive skillfully, governments should commit to providing basic infrastructures like electricity, water, roads, hospitals, and good internet services. This infrastructure has a high potential of attracting FDI into Ghana. Moreover, the government should improve the institutional mechanism for a transparent business environment. This will enhance the ease of doing business in Ghana.
4. The inflation rate has been one of the bottlenecks in reducing income inequality and poverty. There is the need to maintain consistent single-digit inflation while frantic efforts should be made to reduce it further. This has a high potential of making people live a life they value and making their life better. It also suggests that investors' stability leads to steady economic growth and is thus worth an important focus point. Likewise, a stable currency exchange regime signals the robustness of the Ghanaian economy. The currency's stability against major foreign currencies was positive throughout 2020 despite the pandemic, and it is imperative to keep this robust performance consistent. This provides confidence as well as reduces negative speculations. More so, the stability of currency reduces price hikes, reducing the cost of living over time and improving the standard of living.

References

[1] Wang X, Xu Z, Qin Y, Skare M. Foreign direct investment and economic growth: a dynamic study of measurement approaches and results. Economic research-Ekonomska istraživanja. 2022 Dec 31;35(1):1011-34.

[2] Agya Adi AT, Friday Ogbole OG. Foreign direct investment in China: It's sectoral and aggregate impact on Economic growth. MPRA. 2013.Online at https://mpra.ub.uni-muenchen.de/62166/

[3] Muhammad B, Khan MK, Khan MI, Khan S. Impact of foreign direct investment, natural resources, renewable energy consumption, and economic growth on environmental degradation: evidence from BRICS, developing, developed and global countries. Environmental Science and Pollution Research. 2021 May;28:21789-98.

[4] Unctad. World investment report 2021: Investing in sustainable recovery. UN; 2021. https://unctad.org/system/files/official-document/wir2021_en.pdf

[5] Unctad. World investment report 2018: Investing in new industrial policies. UN; 2018. https://unctad.org/system/files/official-document/wir2018_en.pdf

[6] Giroud A, Ivarsson I. World Investment Report 2020: International production beyond the pandemic: United Nations Conference on Trade and Development, Geneva and New York, 2020, 247 pp. ISBN: 978-9211129854. https://unctad.org/system/files/official-document/wir2020_en.pdf

[7] Unctad. World Economic Situation Prospects: Investing in Sustainable Recovery. UN; 2019. https://www.un.org/development/desa/dpad/wpcontent/uploads/sites/45/WESP2019_BOOK-web.pdf

[8] Giroud A, Ivarsson I. World Investment Report 2020: International production beyond the pandemic: United Nations Conference on Trade and Development, Geneva and New York, 2020, 247 pp. ISBN: 978-9211129854.

[9] [9] Ghana Investment Promotion Center. Quarterly Investment Report: Second Quarter Report April-June 2020. https://www.gipcghana.com/press-and-media/downloads/reports.html obtained on 2 December 2020.

[10] Oyebamiji, O. A. Child labour, productivity and poverty in Osunstate, Nigeria. International Students Science Conference, p. 5, 2017, İzmir, Turkey.

[11] Milanovic B. Global inequality: A new approach for the age of globalization. Harvard University Press; 2016 Apr 11.

[12] Kyzyma I. How poor are the poor? Looking beyond the binary measure of income poverty. The Journal of Economic Inequality. 2020 Dec;18(4):525-49.

[13] Gweshengwe B, Hassan NH. Defining the characteristics of poverty and their implications for poverty analysis. Cogent Social Sciences. 2020 Jan 1;6(1):1768669.

[14] World Bank. Poverty and shared prosperity 2020: Reversals of fortune. The World Bank; 2020 Nov 19.

[15] Mensah F, Agyaho JF, Kofinti RE, Sebu J. Multidimensional Poverty-Ghana. Ghana Statistical Service; 2020.

[16] Shaw KL. An empirical analysis of risk aversion and income growth. Journal of Labor Economics. 1996 Oct 1;14(4):626-53.

[17] Anigbogu TU, Edoko TD, Okoli IM. Foreign direct investment and poverty reduction in Nigeria. International Journal of Business and Management Invention. 2016 Jun;5(6):19-28.

[18] Bradshaw TK. Theories of poverty and anti-poverty programs in community development. Community Development. 2007 Mar 1;38(1):7-25.

[19] Teixeira AA, Loureiro AS. FDI, income inequality and poverty: a time series analysis of Portugal, 1973–2016. Portuguese Economic Journal. 2019 Oct;18(3):203-49.

[20] Adu G. Impacts of foreign direct investment (FDI) on rural poverty in developing countries: The case of mining FDI in Ghana. Major Papers. 2018 Jun. 19.

[21] Akhtar R, Hongman Lİ, Amjad AL. Influencing factors of poverty in Pakistan: Time series analysis. International Journal of Economics and Financial Issues. 2017 Jan 6;7(2):215-22.

[22] Magombeyi MT, Odhiambo NM. Foreign direct investment and poverty reduction. Comparative Economic Research. Central and Eastern Europe. 2017;20(2):73-89.

[23] Doytch N, Uctum M. Spillovers from foreign direct investment in services: Evidence at sub-sectoral level for the Asia-Pacific. Journal of Asian Economics. 2019 Feb 1;60:33-44.

[24] Dickey DA, Fuller WA. Distribution of the estimators for autoregressive time series with a unit root. Journal of the American statistical association. 1979 Jun 1;74(366a):427-31.

[25] Engle RF, Granger CW. Co-integration and error correction: representation, estimation, and testing. Econometrica: journal of the Econometric Society. 1987 Mar 1:251-76.

[26] MacKinnon JG, Haug AA, Michelis L. Numerical distribution functions of likelihood ratio tests for cointegration. Journal of applied Econometrics. 1999 Sep;14(5):563-77.

[27] Dolado JJ, Jenkinson T, Sosvilla-Rivero S. Cointegration and unit roots. Journal of economic surveys. 1990 Sep;4(3):249-73.

[28] Rochman F, Sylviana W. Analysis of foreign direct investment (FDI) impact on poverty in Indonesia 2010 until 2014. PalArch's Journal of Archaeology of Egypt/Egyptology. 2020 Dec 8;17(3):1519-28.

[29] Anetor FO, Esho E, Verhoef G. The impact of foreign direct investment, foreign aid and trade on poverty reduction: Evidence from Sub-Saharan African countries. Cogent Economics & Finance. 2020 Jan 1;8(1):1737347.

[30] Hoa NT, Hemmer HR. Contribution of Foreign Direct Investment to Poverty Reduction: the case of Vietnam in the 1990s. Discussion Papers in Development Economics, Institute for Development Economics. 2002.

[31] Kedir R. The Impact Of Foreign Direct Investment On Poverty Reduction In Ethiopia: Cointegrated Var Approach. Adis Ababa University. 2012 Dec.

[32] Arabyat YA. The impact of foreign direct investment on poverty reduction in the developing countries. International Finance and Banking. 2017;4(2):92-111.

[33] Israel AO. Impact of foreign direct investment on poverty reduction in Nigeria (1980–2009). Journal of Economics and Sustainable Development. 2014;5(20):34-45.

[34] Sen A. Development as freedom. Oxford Paperbacks; 2001 Jan 18.

[35] Levine DP, Rizvi SA. Poverty, work, and freedom: Political economy and the moral order. Cambridge University Press; 2005 Jun 30.

[36] Bigman D, Fofack H. Geographical targeting for poverty alleviation: An introduction to the special issue. The World Bank Economic Review. 2000 Jan 1;14(1):129-45.

[37] Spicker P. Social policy: Theory and practice. Bristol: Policy Press; 2014 Mar 20.

[38] Ogunniyi MB, Igberi CO. The impact of foreign direct investment on poverty reduction in Nigeria. Journal of Economics and Sustainable Development. 2014;5(14):78-83.

Industry 4.0 Based Digital Supply Chain Business Analysis

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Abstract

Industry 4.0 is a period in which advanced digital technologies are integrated into production processes. In this period, technologies such as automation, data analysis, artificial intelligence and the internet of things are used to increase the efficiency of enterprises, optimize their operational processes and gain competitive advantage. In today's rapidly developing technology, the business world is constantly changing and transforming. Industry 4.0 is the most obvious example of this transformation. Industry 4.0 is a period in which advanced digital technologies are integrated into production processes and includes the use of technologies such as automation, data analysis, artificial intelligence and the internet of things. However, business analysis is of great importance in order to understand the value these technologies provide to businesses and to use them in the best way. Business analysis enables businesses to analyze data, evaluate their processes, improve them and determine their future strategies. Industry 4.0 offers new opportunities for business analysis. In particular, the increase in the amount of data in production processes and the use of advanced digital technologies have made the role of business analysis even more important. With Industry 4.0, business analysis has become a basic tool used to increase the efficiency of enterprises, optimize their operational processes and gain competitive advantage. With data analysis and business intelligence techniques, businesses can analyze their production processes, evaluate productivity levels, detect errors and identify opportunities for improvement. While automation and artificial intelligence help businesses optimize their processes and increase efficiency, business analysis can analyze the performance of these technologies and identify areas for improvement in processes. These factors have caused businesses to review their supply chain strategies. Therefore, businesses that want to remain competitive must manage their supply chains effectively and efficiently. For this, real-time information sharing and coordination between supply chain partners should be ensured. Activities such as organizing purchasing, production and distribution processes, stock management, improving supplier relations, receiving customer feedback quickly and responding to demands effectively and efficiently will be possible with the digitalization of the traditional supply chain. In this study, it is aimed to explain the general structure of the digital supply chain, which facilitates and makes the supply chain activities of the enterprises efficient. For this purpose, a general literature review has been made about the general structure of the digital supply chain, its relationship with industry 4.0, the transformation from the traditional supply chain to the digital supply chain, the characteristics of the digital supply chain, combining these basic elements with business analysis, its basic characteristics and benefits. In addition, the importance of the Internet of Things and cloud computing in the digital supply chain processes is also examined in this study.

Keywords: Industry 4.0; digital supply chain; internet of things; cloud computing, business analysis

Introduction

Industry 4.0 is a transformation movement in which digital technologies are widely used in production processes. This transformation takes place with the integration of technologies such as automation, data analytics, artificial intelligence, and the internet of things. One of the main goals of Industry 4.0 is to make production processes smarter, more flexible and efficient. Digital supply chains are chains where supply chain processes are integrated with digital technologies and managed through digital platforms. In these chains, real-time data sharing, collaboration and coordination between supply chain partners is ensured. By accelerating the flow of information between digital supply chains, suppliers, manufacturers, distributors and customers, it enables processes such as faster decision making, stock management, production planning and supplier relations to be managed more effectively. The relationship between Industry 4.0 and digital supply chains emerges through the use of digital technologies it provides in supply chain processes. Digital supply chains make supply chain

management more efficient, flexible and competitive with features such as automated data collection, real-time monitoring, analytics and AI-powered decision making. In this way, businesses can have advantages such as better stock management, faster procurement processes, more effective production planning.

While Industry 4.0 supports the development of digital supply chains, digital supply chains also play an important role in achieving the goals of Industry 4.0. While Industry 4.0 aims to transform the production processes of enterprises with digital technologies, making them more efficient, flexible and smart, business analysis is also important in this process [1]. Business analysis is the process of understanding the current processes of businesses, improving them and determining their future goals [2]. The relationship between Industry 4.0 and business analysis emerges as follows: Industry 4.0 technologies collect and analyze large amounts of data obtained from production processes and provide valuable information to businesses. Business analysis, on the other hand, makes sense of this data and guides the decision-making processes of enterprises. It collects large amounts of data from production processes with features such as Industry 4.0 technologies, automation, sensors, data analytics, and artificial intelligence. This data is analyzed by business analytics methods and provides businesses with valuable information in areas such as operational efficiency, quality control, production planning, inventory management. By examining this data in-depth, business analysis identifies trends, patterns and problems and provides businesses with the necessary information to make the right decisions. When Industry 4.0, business analysis and digital supply chain come together, it allows businesses to manage their supply chain processes more efficiently, flexibly and smartly. The data collected with Industry 4.0 technologies are analyzed with business analysis methods, and problems in the supply chain processes are identified and improvements are made [3]. In this process, real-time data sharing and coordination are key elements of the digital supply chain. While Industry 4.0 technologies provide large amounts of data to businesses, business analysis and digital supply chain make it possible to make sense of this data, improve processes and provide effective cooperation between supply chain partners.

The combination of these three concepts enables businesses to be more competitive, efficient and customer-oriented. In the first part of my work, I will discuss Industry 4.0, in the second part, supply chains and their details, in the third part, business analysis and integration, and in the last part, the combination and interpretation of these three concepts.

Industry 4.0 and Its Functions

Industry 4.0 or the Fourth Industrial Revolution is a period that emerged with the spread of digital technologies and automation in the production sector. In this period, while production processes become smarter, more efficient and connected, the competitiveness of enterprises increases. The key features of Industry 4.0 are:

Digitization: One of the most important features of Industry 4.0 is the extensive use of digital technologies in production processes. These technologies include big data analytics, artificial intelligence, internet of things (IoT), cloud computing and cyber-physical systems. In this way, production processes become more efficient, flexible and customizable.

Internet of Things (IoT): In Industry 4.0, devices and equipment used in production processes can communicate with each other by connecting to the Internet. In this way, real-time data can be collected, equipment status can be monitored, and businesses can make faster and more informed decisions [4].

Cyber-Physical Systems: In Industry 4.0, physical production systems are integrated with digital systems. This enables real-time data exchange between production lines, machines and products. Production processes are more automated and require less human intervention.

Data Analytics and Artificial Intelligence: Big data collected in Industry 4.0 is transformed into meaningful information by processing with analytical algorithms and artificial intelligence techniques. This information can be used for purposes such as optimizing production processes, detecting errors and malfunctions, and making demand forecasts. Because artificial intelligence also has the ability to learn, it can constantly improve itself to achieve better results.

Human-Machine Collaboration: In Industry 4.0, a closer collaboration between humans and machines is achieved. People can make more informed decisions by interpreting the analytical results that machines provide data. At the same time, machines become smarter to assist humans and take on repetitive tasks.

While Industry 4.0 offers businesses the opportunity to be more flexible, efficient and competitive, it also brings new challenges and transformations. In order to adapt to this period, businesses need to develop digitalization strategies and adapt their employees to these new technologies.

Digital Supply Chain

Digital supply chain is a supply chain management approach optimized by the use of digital technologies in traditional supply chain processes. These digital technologies provide businesses with greater visibility, flexibility and efficiency. The different variants of the digital supply chain are described below [5]:

Digital Integrated Supply Chain: This type of digital supply chain refers to a structure where all supply chain processes are managed on an integrated digital platform. This platform facilitates data sharing between suppliers, manufacturers, distributors and customers. Thus, processes such as stock levels, demand forecasts, logistics and inventory management can be managed more effectively.

Digital Demand and Forecast Management: In the digital supply chain, demand and forecast management is of great importance in order to meet customer demands accurately and on time. This diversity aims to predict future demands and optimize stock levels accordingly, using big data analytics, artificial intelligence and machine learning techniques. Thus, it is possible to adapt to changes in demand more quickly and flexibly.

Digital Logistics and Transportation Management: In the digital supply chain, logistics and transportation processes are optimized with digital technologies. Technologies such as GPS, smart tags and tracking systems make it easy to track and manage shipping processes. At the same time, route planning, vehicle usage and delivery times can be optimized with data analytics and optimization algorithms.

Digital Stock Management: Inventory management in the digital supply chain relies on real-time data collection and analysis. For this, technologies such as RFID tags, sensors and smart inventory systems are used. In this way, stock levels, storage space usage, material consumption and ordering processes are optimized.

Digital Supplier Relationship Management: In the digital supply chain, supplier relationship management is carried out through digital platforms. Data sharing with suppliers is facilitated, orders and payments are automated, and collaboration and communication processes are improved. Thus, closer cooperation with suppliers can be established and supply chain performance can be increased.

These are some of the different variants of the digital supply chain. Businesses can optimize their supply chain processes and gain competitive advantage by adopting one or more of these different types of digital supply chains according to their needs and goals.

Business Analysis

Business analysis is a method used to understand, analyze and describe an organization's business requirements and processes. Business analysis aims to create an effective business process that supports the goals, strategies and operations of businesses. Business analysis is used to identify the needs and goals of a project or business. This process is done to evaluate the current situation of the business, to identify future goals and to define the steps needed to achieve these goals. Business analysis provides to understand the needs of the business by using different methods and techniques. In this process, elements such as business processes, data and information requirements, organizational structure, job roles and responsibilities, technological requirements are taken into account. Business analysis also includes interacting with business stakeholders, understanding their needs and expectations, and suggesting appropriate solutions to improve business processes. Different techniques and tools can be used in business analysis [6]. These include methods such as interviews, surveys, observation, documentation review, business process mapping, data analysis, prototyping and testing. These techniques are used to understand the current state of the business, identify requirements, improve processes and develop solutions.

Relationship between Industry 4.0, Digital Supply Chain and Business Analysis

While Industry 4.0 refers to a period in which digital technologies and automation become widespread in the production sector, digital supply chain is an approach in which supply chain processes are optimized with digital technologies in this period. Business analysis, on the other hand, is a discipline that aims to identify improvement and transformation opportunities by analyzing business processes of enterprises. There is a relationship between these three concepts as follows: One of the main features of Industry 4.0 is digitalization. In this period, businesses take various digital measures to optimize their production processes and supply chain management using digital technologies. These measures create the digital supply chain and support the achievement of the goals of Industry 4.0. Digital supply chain refers to the use of digital technologies in supply chain processes. These technologies include big data analytics, artificial intelligence, internet of things (IoT), cloud computing and automatic recognition systems. The digital supply chain gives businesses greater visibility, flexibility and efficiency.

Businesses can benefit from the opportunities brought by Industry 4.0 by developing digitalization strategies in their supply chain processes. Business analysis aims to identify improvement and transformation opportunities by analyzing business processes of businesses. In this analysis process, businesses evaluate their current situation, document their processes, collect and analyze data. Business analysis is an important tool for digital supply chain management because it allows businesses to understand their current processes and identify their digital transformation potential. The business analysis process supports the integration and application of digital technologies into supply chain processes [7]. In this way, Industry 4.0, digital supply chain and business analysis are complementary concepts. Using the business analysis process, businesses can examine their supply chain processes, identify digital supply chain technologies and apply these technologies in line with Industry 4.0 goals. Business analysis provides a strategic approach for successful digital supply chain adoption and businesses gaining competitive advantage.

Conclusion

As a result, Industry 4.0, digital supply chain and business analysis are concepts that complement and work together. Industry 4.0 is a period that emerged with the spread of digital technologies in the production sector. In this period, businesses aim to optimize their production processes and supply chain management by using digital technologies. Digital supply chain is an approach in which supply chain processes are optimized with digital technologies in this period. The digital supply chain provides businesses with greater visibility, flexibility and efficiency. Business analysis aims to identify opportunities for improvement and transformation by analyzing business processes of businesses. The business analysis process allows businesses to assess their current status, document their processes, and collect and analyze data. Business analysis is an important tool for digital supply chain management because it allows businesses to understand their current processes and identify their digital transformation potential. The relationship between these three concepts is that businesses adopt digital supply chain processes to take advantage of the opportunities brought by Industry 4.0 and use the business analysis process manage the transformation. Business analysis helps businesses identify digital supply chain technologies by assessing their current situation. Adopting and applying these technologies enables businesses to be more efficient, flexible and competitive. Ultimately, Industry 4.0, digital supply chain and business analysis work together to provide businesses with a roadmap for digital transformation. By using these concepts together, businesses can optimize their supply chain processes, gain competitive advantage and successfully adapt to Industry 4.0.

References

[1] Bhargava, B., Ranchal, R., & Othmane, L. B. (2013, February). Secure information sharing in digital supply chains. In Advance Computing Conference (IACC) (pp. 1636-1640).

[2] Büyüközkan, G., & Göçer, F. (2018). An extension of ARAS methodology under ınterval valued ıntuitionistic fuzzy environment for digital supply chain. Applied Soft Computing, 69, 634-654.

[3] Raj, S., & Sharma, A. (2014). Supply chain management in the cloud. Accenture Global Management Consulting, 1-12.

[4] Roßmann, B., Canzaniello, A., von der Gracht, H., & Hartmann, E. (2018). The future and social impact of big data analytics in supply chain management: results from a Delphi study. Technological Forecasting and Social Change, 130, 135-149.

[5] Hanifan, G., Sharma, A., & Newberry, C. (2014). The digital supply network: a new paradigm for supply chain management. Accenture Global Management Consulting, 1-8.

[6] Korpela, K., Hallikas, J., & Dahlberg, T. (2017, January). Digital supply chain transformation toward blockchain integration. In proceedings of the 50th Hawaii international conference on system sciences.

[7] Obal, M., & Lancioni, R. A. (2013). Maximizing buyer–supplier relationships in the digital era: concept and research agenda. Industrial Marketing Management, 42(6), 851-854.

A New Method for Elliptic Partial Differential Equations

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Abstract

The study proposes a matrix method based on collocation points and Taylor polynomials for approximating the solution of elliptic partial differential equations. This method reduces the problem to solving a matrix equation with unknown Taylor coefficients, which are determined using the collocation points. The solution is then expressed in terms of Taylor polynomials. The technique is illustrated using a descriptive example, and the results are compared with a table and figure. The numerical calculations are performed using a program written in WOLFRAM MATHEMATICA 13.0.

Keywords: Partial differential equations, Taylor polynomials, boundary value problems, matrix - collocation method.

Introduction

Elliptic partial differential equations are important in modeling real-world problems in mathematics and engineering. The proposed method provides a promising approach for solving such equations, and its effectiveness can be further tested on more complex problems. In recent years for solving these equations, numerical methods have been developed. [1] and [2] studied one-dimensional moving boundary problem. We studied matrix approach to solving elliptic differential equations. [3] gave a method matrix approach to solving elliptic partial differential equations like us. Also elliptic PDEs are used for heat conduction. [5], [6], [8], [9],[10], [12],[13] and [14] worked about elliptic PDEs for heat conduction. To define the simplest kind of elliptic PDE, consider a real-valued function $u(x,y)$ of two independent real variables, x and y. A second-order, linear, constant-coefficient PDE for u takes the form

$$Au_{xx} + 2Bu_{xy} + Cu_{yy} + Du_x + Eu_y + Fu + G = 0 \tag{1}$$

and this PDE is classified as being elliptic if the coefficients satisfy the condition

$$B^2 - 4AC < 0$$

The elliptic partial differential equation we consider is the Laplace equation,

$$\nabla^2 u(x,t) = \frac{\partial^2 u(x,t)}{\partial t^2} + \frac{\partial^2 u(x,t)}{\partial x^2} = 0 \tag{2}$$

with the conditions

$$\left.\begin{aligned} &u(x,0) = g(x) \\ &u(0,t) = l(x) \\ &u(a,t) = h(x) \\ &u(x,b) = f(x) \quad 0 \le x \le b, \quad 0 \le x \le a \end{aligned}\right\} \tag{3}$$

where f, g, h, l are known functions and the function $u(x,t)$ is unknown.
By developing the Taylor collocation method, we will obtain the approximate solution of Eq.(2) in the truncated Taylor series form

$$u(x,t) \cong u_N(x,t) = \sum_{m=0}^{N} \sum_{n=0}^{N} a_{mn}\, x^m t^n \tag{4}$$

where $a_{mn}; m, n = 1, \ldots, N$ are the unknown Taylor coefficients

Fundamental Relations

To obtain the numerical solution of elliptic partial differential equation with Taylor Collocation Method, we first evaluate the Taylor coefficients of the unknown function. For convenience, the solution function (4) can be written in the matrix form

$$u(x,t) \cong u_N(x,t) = \mathbf{X}(x)\overline{\mathbf{X}(t)}\mathbf{A}, \tag{5}$$

where

$$\mathbf{X}(x) = \begin{bmatrix} 1 & x & \ldots & x^N \end{bmatrix}, \tag{6}$$

$$\overline{\mathbf{X}}(t) = diag\begin{bmatrix} \mathbf{X}(t) & \mathbf{X}(t) & \ldots & \mathbf{X}(t) \end{bmatrix}, \tag{7}$$

$$\mathbf{A} = \begin{bmatrix} A_0 & A_1 & \ldots & A_N \end{bmatrix}^T \tag{8}$$

$$\frac{\partial u}{\partial x} = \mathbf{X}(x)\mathbf{B}\overline{\mathbf{X}}(t)\mathbf{A} \tag{9}$$

$$\frac{\partial u}{\partial t} = \mathbf{X}(x)\,\overline{\mathbf{X}(t)}\,\overline{\mathbf{B}}\,\mathbf{A} \tag{10}$$

$$\frac{\partial^2 u}{\partial x^2} = \mathbf{X}(x)\mathbf{B}^2\,\overline{\mathbf{X}(t)}\,\mathbf{A} \tag{11}$$

$$\frac{\partial^2 u}{\partial t^2} = \mathbf{X}(x)\,\overline{\mathbf{X}(t)}\,\overline{\mathbf{B}}^2\mathbf{A}, \tag{12}$$

$$\mathbf{B} = \begin{bmatrix} 0 & 1 & 0 & \ldots & 0 \\ 0 & 0 & 2 & \ldots & 0 \\ \ldots & \ldots & \ldots & \ldots & 0 \\ 0 & 0 & 0 & \ldots & N \\ 0 & 0 & 0 & \ldots & 0 \end{bmatrix}, \qquad \overline{\mathbf{B}} = diag\begin{bmatrix} \mathbf{B} & \mathbf{B} & \ldots & \mathbf{B} \end{bmatrix} \tag{13}$$

Method of Solution

We are now ready to construct the fundamental matrix equation corresponding to (2). For this purpose, substituting the matrix relations (5) and (11)-(12), into (2) and simplifying, we obtain the fundamental matrix equation

$$\mathbf{X}(x)\,\overline{\mathbf{X}(t)}\overline{\mathbf{B}}^2\mathbf{A} + \mathbf{X}(x)\mathbf{B}^2\,\overline{\mathbf{X}(t)}\mathbf{A} = 0 \tag{14}$$

If we write as

$$\mathbf{W} = \left\{\mathbf{X}(x)\,\overline{\mathbf{X}(t)}\overline{\mathbf{B}}^2 + \mathbf{X}(x)\mathbf{B}^2\,\overline{\mathbf{X}(t)}\right\} \tag{15}$$

and we obtain,

$$\mathbf{W}(x,t)\mathbf{A}=0 \tag{16}$$

The standard collocation points used in matrix system are given, respectively, by

$$x_i=a+\frac{b-a}{N}i,\quad t_j=c+\frac{d-c}{N}j,\quad i,j=0,1,...,N, \tag{18}$$

We substitute the collocation points (18) into Eq. (15), then we can write

$$\mathbf{W}(x_i,t_j)=\left\{\mathbf{X}(x_i)\ \overline{\mathbf{X}(t_j)}\overline{\mathbf{B}}^{\,2}+\mathbf{X}(x_i)\mathbf{B}^2\ \ \overline{\mathbf{X}(t_j)}\right\} \tag{19}$$

We now ready to state the fundamental matrix equation of (2) as

$$\mathbf{WA}=\mathbf{0}\quad or\quad \left[\mathbf{W}\ \ ;\ \ \mathbf{0}\right] \tag{20}$$

where

$$\mathbf{W}(x_i,t_j)=\left[\mathbf{W}_0\quad \mathbf{W}_1\quad \dots\quad \mathbf{W}_N\right]^T,\quad \mathbf{A}_i=\left[a_{i0}\quad a_{i1}\quad \dots\quad a_{iN}\right]^T,\quad \mathbf{0}=\left[0\quad 0\quad \dots\quad 0\right]^T. \tag{21}$$

Matrix Representation of the Conditions

Let us define the matrix form of the initial conditions and boundary conditions

$$\left.\begin{array}{l} u(x,0)=g(x) \\ u(0,t)=l(x) \\ u(a,t)=h(x) \\ u(x,b)=f(x)\quad 0\le x\le b,\quad 0\le x\le a \end{array}\right\} \tag{22}$$

we can write

$$u(x_i,0)=\mathbf{X}(x_i)\ \overline{\mathbf{X}(0)}\ \mathbf{A}=\mathbf{G},\quad i=0,1,2,...,N \tag{23}$$

$$u(0,t_i)=\mathbf{X}(0)\ \overline{\mathbf{X}(t_i)}\ \mathbf{A}=\mathbf{L},\quad i=0,1,2,...,N \tag{24}$$

$$u(a,t_i)=\mathbf{X}(a)\ \overline{\mathbf{X}(t_i)}\ \mathbf{A}=\mathbf{H},\quad i=0,1,2,...,N \tag{25}$$

$$u(x_i,b)=\mathbf{X}(x_i)\ \overline{\mathbf{X}(b)}\ \mathbf{A}=\mathbf{F},\quad i=0,1,2,...,N \tag{26}$$

then

$$\mathbf{U_1A}=\mathbf{G}\quad or\quad \left[\mathbf{U_1}\ \ ;\ \ \mathbf{G}\right], \tag{27}$$

$$\mathbf{U_2A}=\mathbf{L}\quad or\quad \left[\mathbf{U_2}\ \ ;\ \ \mathbf{L}\right], \tag{28}$$

$$\mathbf{U_3A}=\mathbf{H}\quad or\quad \left[\mathbf{U_3}\ \ ;\ \ \mathbf{H}\right], \tag{29}$$

$$\mathbf{U}_4\mathbf{A}=\mathbf{F}\quad or\quad \left[\mathbf{U}_4\ \ ;\ \ \mathbf{F}\right] \tag{30}$$

Consequently, in order to find the Taylor coefficients $a_{mn};\ m,n=1,...,N$ related with approximate solution Eq.(4) of the problem (2) and(3) by replacing the row matrices(20) by the any rows of the matrix (27), (28),(29) and (30), we obtain augmented matrix

$$\left[\mathbf{W} \;;\; \mathbf{G}\right]=\begin{bmatrix} \mathbf{W} & ; & \mathbf{0} \\ \mathbf{U_1} & ; & \mathbf{G} \\ \mathbf{U_2} & ; & \mathbf{L} \\ \mathbf{U_3} & ; & \mathbf{H} \\ \mathbf{U_4} & ; & \mathbf{F} \end{bmatrix} \tag{31}$$

We can thus reach the coefficients matrix A by solving the system (31) only if the rank of this system yields $(N+1)^2$. Then, A produces a Taylor polynomial solution with the aid of (4).

Control of Solution via Residual Error Analysis

It is well known from [7] that the residual error analysis has presented highly effective tool to improve the approximate solutions of differential equations especially partial diffrential equations as Eq.(2) . Here, we aim to control the obtained solutions via an error analysis technique based on a residual function $R_N(x,t)$ in Ω. After inserting substituting the Taylor polynomial solution (4) into Eq. (2), a residual error function with respect to N is then obtained as

$$R_N(x,t) = L[u_N(x,t)] \tag{32}$$

where L is a linear operator.

$$R_N(x,t) = \frac{\partial^2 u_N(x,t)}{\partial^2 t^2} + \frac{\partial^2 u_N(x,t)}{\partial^2 x^2}. \tag{33}$$

with the initial conditions

$$\left.\begin{aligned} &u(x,0) = g(x) \\ &u(0,t) = l(x) \\ &u(a,t) = h(x) \\ &u(x,0) = f(x) \quad 0 \le t \le b, \quad 0 \le x \le a \end{aligned}\right\} \tag{34}$$

In additional the error function $e_N(x,t)$ is defined as follows

$$L[e_N(x,t)] = L[u(x,t)] - L[u_N(x,t)] = -R_N(x,t) \tag{35}$$

with the homogeneous conditions

$$\left.\begin{aligned} &e_n(x,0) = 0 \\ &e_n(0,t) = 0 \\ &e_n(a,t) = 0 \\ &e_n(x,b) = 0 \quad 0 \le t \le b, \quad 0 \le x \le a \end{aligned}\right\} \tag{36}$$

So the error problem can be written as

$$\frac{\partial^2 e_N(x,t)}{\partial^2 t^2} + \frac{\partial^2 e_N(x,t)}{\partial^2 x^2} = -R_N(x,t). \tag{37}$$

$$\left.\begin{aligned} &e_n(x,0) = 0 \\ &e_n(0,t) = 0 \\ &e_n(a,t) = 0 \\ &e_n(x,b) = 0 \quad 0 \le t \le b, \quad 0 \le x \le a \end{aligned}\right\} \tag{38}$$

Application

In this section we establish the matrix method by applying it to solve the general elliptic partial differential equations. The results of the example are reported in Table and Figure. As it is seen, Taylor polynomial solution method is of high accuracy. Also Table and Figure show the order of convergence of the scheme. It can be seen again the errors are decreasing as we rise N

Problem

We study the following problem [11].

Determine the steady-state heat distribution in a thin square metal plate with dimensions 0.5 m by 0.5 m . Two adjacent boundaries are held at $0\,^0C$, and the heat on the other boundaries increases linearly from $0\,^0C$ at one corner to $100\,^0C$ where the sides meet. Place the sides with the zero boundary conditions along the $x-$and $y-$axes. Then the problem is expressed as

$$\frac{\partial^2 u(x,t)}{\partial^2 t^2}+\frac{\partial^2 u(x,t)}{\partial^2 x^2}=0$$

with the conditions

$$\left.\begin{aligned} &u_t(x,0)=0\\ &u(0,t)=0\\ &u(0.5,t)=200y\\ &u(x,0.5)=200x \quad 0\le t\le 0.5, \quad 0\le x\le 0.5 \end{aligned}\right\}$$

The exact solution of this problem is

$$u_{ex}(x,t)=400xy.$$

By using the collocation points (18) for $N=5$ and using the (31) fundamental matrix equation the problem is solved and we obtain solution function. The results obtained are shown in Table 1. Also it can be seen absolute error function's graph in Figure 1.

$$\begin{aligned} u_5(x,t)= {} & 4.95173.10^{-14} - 4.63485.10^{-12}\,x + 6.25777.10^{-11}\,x^2 - 2.73285.10^{-10}x^3 + 4.83366.10^{-10}x^4 \\ & -0.00439602.10^{-10}\,x^5 - 4.0796.10^{-12}y - 0.0000219621\,xy + 0.00406018\,x^2y - 0.00250471\,x^3y \\ & +0.00575905\,x^4y - 0.00439602\,x^5y + 9.65895.10^{-11}\,y^2 - 0.000111792\,xy^2 - 0.00239098\,x^2y^2 \\ & 0.0199845\,x^3y^2 - 0.046892\,x^4y^2 + 0.0347623.x^5y^2 - 6.46968.10^{-10}\,y^3 + 0.00114322\,xy^3 \\ & -0.00567339\,x^2y^3 + 0.0027837\,x^3y^3 + 0.00980903\,x^4y^3 - 0.00365728.x^5y^3 + 1.67838.10^{-9}\text{-}y^4 \\ & -0.00503213\,xy^4 + 0.0266175\,x^2y^4 - 0.0314326\,x^3y^4 + 0.00372814\,x^4y^4 - 0.0141516\,x^5y^4 \\ & +1.47725.10^{-9}y^5 + 0.00728384\,xy^5 - 0.033334\,x^2y^5 + 0.0245961\,x^3y^5 + 0.0309171\,x^4y5 \\ & -0.0100881\,x^5y^5 \end{aligned}$$

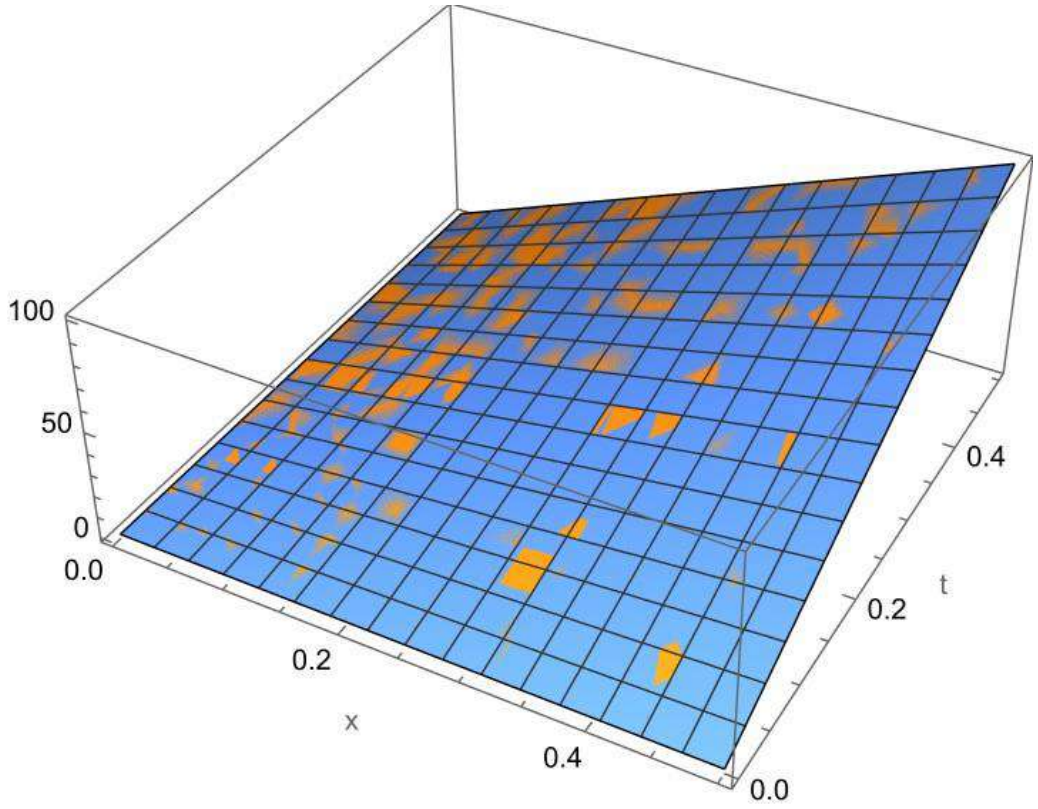

Figure 1: The approximate solution $u_{10}(x,t)$ compared with exact solution for the Problem

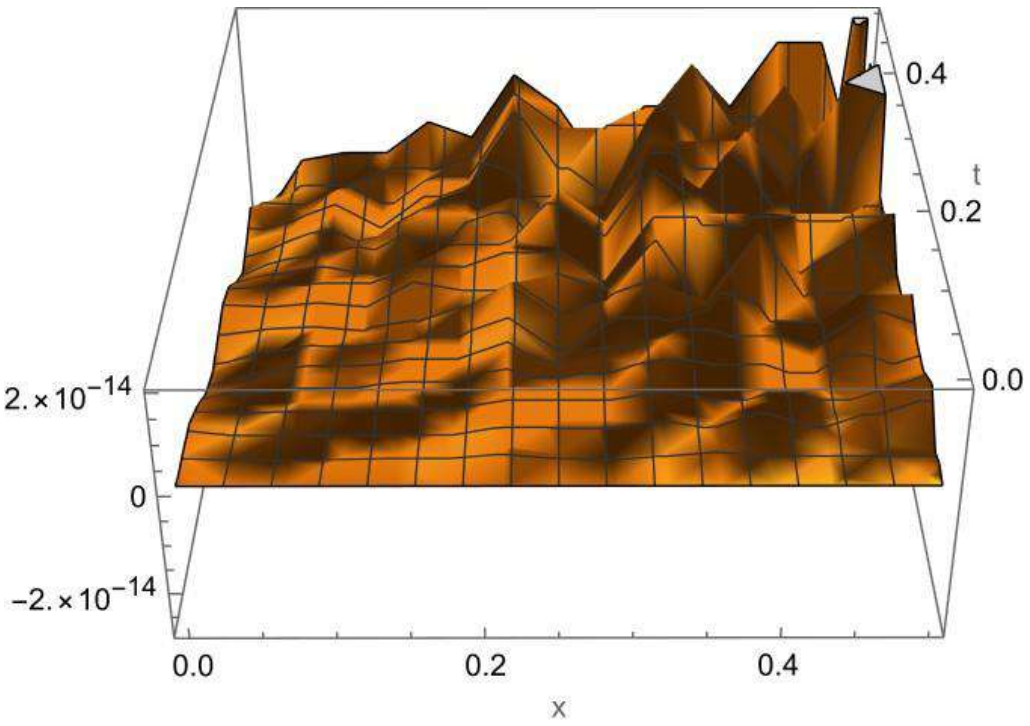

Figure 2: Graph of the absolute errors function of Problem for $N=10$

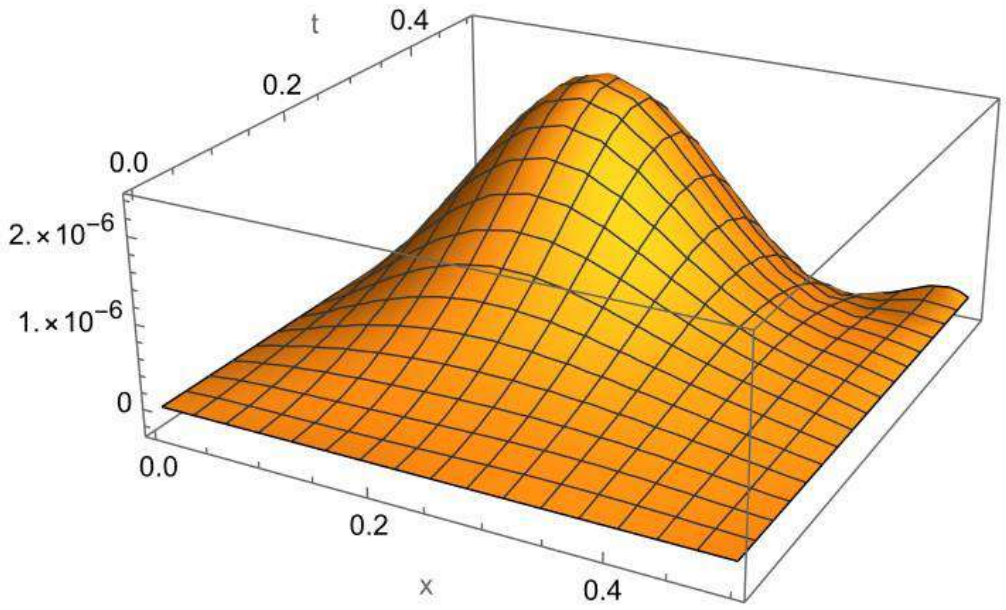

Figure 3: Graph of the absolute errors function of Problem for $N = 5$

As it is seen, Taylor polynomial solution method is of high accuracy. Also Table and Figure show the order of convergence of the scheme. It can be seen again the errors are decreasing as we increase N.

Conclusions

In this article, we present a new approach for solving elliptic differential equations using Taylor matrix-collocation techniques. Overall, our study demonstrates that the new approach with Taylor matrix collocation techniques is highly accurate, rapidly convergent, and easy to apply in various engineering problems, making it a good approximation for solving elliptic partial differential equations.

References

[1] Beattie B.A, Ochs K., 2022. Solving a One-Dimensional Moving Boundary Problem Based on Wave Digital Principles. https://doi.org/10.21203/rs.3.rs-2229820/v1

[2] Elmacı, D., Savaşaneril B., N., 2023. A New Computational Method to Solve the Boundary Value Problems Associated with Elliptic Partial Differential Equations. 8th International Congress on Life, Engineering, and Applied Sciences in a Changing World Proceedings Book, 168-179.

[3] Erdem Biçer K., Salih Yalçınbaş, 2016. A matrix approach to solving hyperbolic partial differential equations using Bernoulli polynomials. Filomat, Volume 30, Issue 4, Pages 993–1000.

[4] Ezgi Arkut, master's thesis, 2021.

[5] Gorguis A., Wai Kit Benny Chan W., K., B., 2008.Heat equation and its comparative solutions.Computers and Mathematics with Applications 55 (2008) 2973–2980.

[6] Hirpho, M., 2022. Numerical Solution of the Heat Transfer Equation Coupled with the Darcy Flow Using the Finite Element Method.Hindawi Abstract and Applied Analysis Volume 2022, Article ID 5108445, 9 pages. https://doi.org/10.1155/2022/5108445

[7] Kurt Bahşi, A., Yalçınbas, S. 2016. A new for the Nuymerical Solution of Telegraph Equaions by Using Fibonacci Polynomials. Math.Comput.Appl.21(2), 15

[8] Kurt, N 2008. Solution of the two-dimensional heat equation for a square in terms of elliptic functions. Journal of the Franklin Institute, 345(3): 303–317.

[9] Kurt, N., Sezer, M 2006. Solution of Dirichlet problem for a triangle region in terms of elliptic functions. Applied Mathematics and Computation, 182(1): 73–81.

[10] Kürkçü O., K., Sezer, M.2022. A new characteristic numerical approach with evolutionary residual error analysis to nonlinear boundary value problems occurring in heat and mass transfer

via combinatoric Mittag-Leffler polynomial. Numerical Heat Transfer, Part A: Applications, 82:9, 561-575. https://doi.org/10.1080/10407782.2022.2079838

[11] Richard L. Burden and J. Douglas Faires, Numerical Analysis. (Boston: Richard Stratton, 2011).

[12] Savaşaneril, N. B., Hacıoğlu, Z., 2018. Bernstein Series Approximation for Dirichlet Problem. Gazi University Journal of Science, 31(2): 544–553.

[13] Savasaneril N. B, and Delibas. H., Analytic solution for two-dimensional heat equation for an ellipse region NTMSCI 4, No. 1, 65-70 (2016)

[14] Vaidya N., V., Deshpande A., A., Pidurkar, S.,R., 2021. Solution of heat equation (Partial Differential Equation) by various methods.J. Phys.: Conf. Ser. 1913 012144.

A Review of an Eleventh Order of Chebyshev–Halley Type Method for Solving Nonlinear Equations

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Abstract

In this paper, we present a new eleventh order method for solving nonlinear equations numerically. This method is based on the methods of Chebyshev and Halley methods and requires five function evaluations (two function calculations, two first derivative calculations, and a second derivative calculation). Therefore, the efficiency index of this method is $\sqrt[5]{11} = 1{,}615$. The numerical comparisons made also show that the method of this article has good efficiency.

Keywords. Nonlinear equations; simple root; order of convergence; efficiency index

Introduction and Basic Definition

Today, nonlinear equations are widely used in solving problems of basic sciences and engineering sciences, surely this branch is one of the most practical branches of numerical analysis in mathematics. Solving equations, or in other words, determining the location of roots of equations, is finding α so that:

$$f(\alpha) = 0. \tag{1}$$

Because determining the location of zeros of functions has been an active field of study, various methods have been proposed to solve this problem. Finding the roots of non-linear equations using iterative methods is one of the research fields of scientists. In recent years, many cases of higher order iterative methods for solving nonlinear equations have been developed and analyzed. In this article, we present an eleventh order method whose efficiency index is $\sqrt[5]{11} = 1.615$.

Let $f: I \to R$ be a real function defined on the open interval I. Also, suppose that $I \in \alpha$ is a simple root of f. The most famous iterative method for solving the nonlinear equation $f(x) = 0$ is Newton's method. A method is known that has a second-order convergence in a sufficiently small neighborhood of α, and therefore, this method is used in solving many problems. In general, the relationship of Newton's method is as follows:

$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}. \tag{2}$$

In this article, we examine the structure of corrections of high-order methods on Halley and Chebyshev methods, and then we increase the efficiency of the method by removing the derivative of the function. The efficiency index of Newton's method is $\sqrt{2} = 1.414$.

Researchers have also proposed cubically convergent one-point methods. One such well-known scheme is the classical cubically convergent Chebyshev–Halley family [3] defined by

$$x_{n+1} = x_n - \left[1 + \frac{1}{2}\left(\frac{L_f(x_n)}{1 - \alpha L_f(x_n)}\right)\right]\frac{f(x_n)}{f'(x_n)}, \qquad \alpha \in R,$$

where

$$L_f(x_n) = \frac{f''(x_n)f(x_n)}{f'(x_n)^2}.$$

This family includes Chebyshev's method for ($\alpha = 0$), Halley's method for ($\alpha = \frac{1}{2}$) and super Halley method for ($\alpha = 1$). For more details, one may consult the references [4,5].

Definition 1. [1] let $f(x)$ be a real function with a simple root α and $\{x_n\}_{n\geq 0}$ be a sequence of real numbers, converging towards α. The convergence of the sequence is of order p, if there exists a constant real number C (called the asymptotic error constant) such that:

$$\lim_{n\to\infty} \frac{|x_{n+1}-\alpha|}{|x_n-\alpha|^n} = C.$$

For $p = 1, 2, 3$ we call the convergence linear, quadratic, and cubic, respectively. The larger p is, the faster the convergence speed will be.

Definition 2. [1] Let $e_n = x_n - \alpha$ be the error in the n-th iteration. In this case,

$$e_{n+1} = Ce_n^p + o(e_n^{p+1}). \tag{3}$$

is called the error equation. If we can obtain the error equation for any iterative method, then the value of p is its order of convergence and C is the asymptotic error constant.

Usually, the efficiency of a method is measured using the concept of efficiency index, defined as follows.

Definition 3. [1] The efficiency index of a method is given by

$$EI = p^{1/\beta}, \tag{4}$$

where p is the order of convergence and β is the whole number of function evaluations per iteration. Many multi-step higher-order convergent methods have been introduced in the recent past that use inverse, Hermite, and rational interpolations [10,11], [6,7]. In developing these methods, so far, the conjecture of Kung and Traub has remained the focus of attention. It states the following.

Conjecture 1. [8] An optimal iterative method without memory based on m function evaluations would achieve an optimal convergence order of 2^{m-1}. Hence, the efficiency index is $2^{(m-1)/m}$.

Sargolzaei and Soleymani [10] showed that, a four-step fourteenth-order convergent method to solve equation (1) as follows:

$$\begin{cases} y_n = x_n - \frac{f(x_n)}{f'(x_n)}, \\ z_n = y_n - \frac{f(x_n)}{f(x_n)-2f(y_n)}\frac{f(y_n)}{f'(x_n)}, \\ w_n = z_n - \left[\frac{f(x_n)+f(z_n)}{f(x_n)}\right]\frac{f[x_n,y_n]f(z_n)}{f[x_n,z_n]f[y_n,z_n]}, \\ x_{n+1} = w_n - \frac{f(w_n)}{2f[x_n,w_n]+f[z_n,w_n]-2f[x_n,z_n]+(z_n-w_n)f[z_n,x_n,x_n]} \end{cases} \tag{5}$$

in which,

$$\begin{cases} f[x_n, y_n] = \frac{f(x_n)-f(y_n)}{x_n-y_n}, \\ f[z_n, x_n, x_n] = \frac{f[z_n,x_n]-f'(x_n)}{z_n-x_n} \end{cases} \tag{6}$$

Each iteration of this method requires five function evaluations (four function calculations and one first derivative calculation). Therefore, the efficiency index of the above method is $\sqrt[5]{14} = 1.695$.

In the next section, we present an eleventh-order method for solving (1), which is based on the methods of Chebyshev and Halley [3]. For this purpose, we need the following theorem.

Theorem 1. [1] Suppose the methods $\emptyset_1(x)$ and $\emptyset_2(x)$ with convergence order m and n are available. In this case, the order of convergence of the method $\emptyset_3(x) = \emptyset_1(\emptyset_2(x))$ is equal to mn.

Main Results

In this section, we describe an eleventh-order algorithm, each iteration of which requires five function evaluations (two function calculations, two first derivative calculations, and one second derivative calculation). For this purpose, we consider the following four-order method [9]:

$$x_{n+1} = x_n - h(t_n)\frac{f(x_n)}{f'(x_n)} \tag{7}$$

in which

$$t_n = \frac{f(x_n)f''(y_n)}{2f'^2(x_n)}, \qquad y_n = x_n - \frac{f(x_n)}{3f'(x_n)}.$$

Here $h(t)$ is an arbitrary function with the following Taylor expansion.

$$h(t) = 1 + t + 2t^2 + mt^3 + O(t^4).$$

It is clear that the efficiency index of method (7) is equal to $\sqrt[3]{4} = 1.587$. According to theorem 1, the following two-step method will be an eight-order method:

$$\begin{cases} z_n = x_n - h(t_n)\frac{f(x_n)}{f'(x_n)} \\ \\ x_{n+1} = z_n - \frac{f(z_n)}{f'(z_n)} \end{cases} \tag{8}$$

Now define the following variables:

$$u = \frac{f(z)f''(y)}{f'^2(z)}, \qquad v = \frac{f(z)}{f'(z)f'(x)}a,$$
$$w = \frac{f''(y)f(z)f^2(x)}{\left(f'(z)f'(x)\right)^3}\left(-2f''^2(y) - \frac{f'^2(x)}{f(x)}\right)a,$$

in which

$$a = \left(f'(x) - f'(z)\right)\frac{f'(x)}{f(x)} - f''(y) - \frac{f''^2(y)f(x)}{2f'^2(x)}.$$

Let $G(u, v, w)$ is a three-variable function with the following conditions:

$$G(0,0,0) = 1, \qquad G_u(0,0,0) = \frac{1}{2},$$
$$G_v(0,0,0) = 2, \qquad G_w(0,0,0) = \frac{1}{2}.$$

Consider the following iterative method.

$$x_{n+1} = z_n - G(u_n, v_n, w_n)\frac{f(z_n)}{f'(z_n)}. \tag{9}$$

Theorem 2. Let $I \in \alpha$ be the simple root of the function f: $I \subseteq R \to R$. If the starting point x_0 is close enough to α, then the method (9) converges to the eleventh order and its error equation is:

$$e_{n+1} = \frac{-2}{81c_1^{10}}(3(-5+m)c_2^3 + 3c_1c_2c_3 - c_1^2c_4)^2$$
$$\times\left(18(-9+m)c_2^4 + 45c_1c_2^2c_3 - 18c_1^2c_2c_4 + c_1^2(-9c_3^2 + 5c_1c_5)\right)e_n^{11} + O(e_n^{12}),$$

where

$$e_n = x_n - \alpha \text{ and } c_k = \frac{f^k(\alpha)}{k!}, \text{ for } k = 1,2,\dots,5$$

Numerical Experiments

In this section, we discuss the numerical scale of methods (5), (7), (2) and (9). All computations have been performed using the programming package Mathematica in multiple precision arithmetic environment. For this purpose, we use the following test functions:

$f_1(x) = e^{x^2+7x-30} - 1,$ $\alpha = 3,$

$f_2(x) = x^2 - e^x - 3x + 2,$ $\alpha \approx 0.257530285439861,$

$f_3(x) = \sqrt{x^2 + 2x + 5} - 2\sin x - x^2 + 3,$ $\alpha \approx 2{,}331969765588396,$

$f_4(x) = \sin\frac{1}{x} - x,$ $\alpha \approx 0.897539461280487,$

$f_5(x) = 2\sin x + 1 - x,$ $\alpha \approx 2.380061273139339,$

$f_6(x) = e^{-x} + \cos x,$ $\alpha \approx 1.746139530408013,$

$f_7(x) = \cos^2 x - \frac{x}{5},$ $\alpha \approx 2.320204274495726.$

In the method (9) we have used the $G(u,v,w) = 1 + \frac{1}{2}u + 2v + \frac{1}{2}w$ function, which is clearly applied to the case. Numeric results are in Table 1. The numbers outside the parentheses indicate the number of repetitions and the numbers inside the parentheses indicate the number of correct (zero), $f(x_n)$ following this number of repetitions. This table shows that the results of method (9) are comparable with method (5).

Table 1. Numerical results after a certain number of repetitions

Function	Start point	Method (2)	Method (7)	Method (5)	Method (9)
f_1	1.3	(2)3	(12)3	(922)3	(143)3
f_2	0.9	(7)2	(13)2	(246)2	(101)2
f_3	2.5	(5)2	(25)2	(273)2	(177)2
f_4	2.0	(1)2	(9)2	(98)2	(62)2
f_5	4.1	(2)3	(15)3	(935)3	(387)3
f_6	1.0	(5)2	(12)2	(206)2	(89)2
f_7	2.1	(4)2	(12)2	(160)2	(77)2

Now we will solve the complete test examples up to the accuracy of 10,000 decimal with methods (5) and (9). The results of this comparison are summarized in Table 2. According to this table, we see that the method presented in this article is comparable to method (5) and in many cases it works even better than it.

Table 2. The results of the complete solution of the test examples

Function	Start point	Method (5)	Method (9)
f_1	3.1	(10000)4	(10000)5
f_2	0.9	(3463)3	(10000)4
f_3	2.5	(3845)3	(10000)4
f_4	2.0	(1382)3	(7537)4
f_5	4.1	(935)3	(4265)4
f_6	1.6	(4633)3	(10000)4
f_7	2.1	(2251)3	(9364)4

Conclusions

In this study, a general four-step iterative method has been given for solving nonlinear equations. An analytic proof of convergence order of this method was given which demonstrates that the method has an optimal convergence order eleventh. For this method, the number of function evaluations is five per full step, so the efficiency index is $\sqrt[5]{11} = 1.615$. Finally, the significant increase in the convergence speed of the proposed methods is attained without additional functional evaluations, which points to very high computationally efficiency.

References

[1] Traub JF. Iterative Methods for the Solution of Equations. New York: Chelsea Publishing Company; 1982.

[2] Sargolzaei P, Soleymani F. Accurate fourteenth-order methods for solving nonlinear equations, Numerical Algorithms. 2011; (58): 513–527.

[3] Argyros K, Munish Kansal, Vinay Kanwar, Sugandha Bajaj. Higher-order derivative-free families of Chebyshev–Halley type methods with or without memory for solving nonlinear equations. Applied mathematics and computation; 2017;(315): 224-245.

[4] Gutiérrez JM Hernández MA. An acceleration of Newton's method: Super-Halley method, Appl. Math. Comput. 2001; (117): 223–239.

[5] Amat S, Busquier S, Guttiérrez JM. Geometric constructions of iterative functions to solve nonlinear equations. J. Comput. Appl. Math.; 2003; (115): 197–205.

[6] Li X, Mu C, Ma J, Wang C. Sixteenth-order method for nonlinear equations. Appl. Math. and Comput.; 2010; 215: 3754–3758.

[7] Zafar F, Hussain N, Fatimah Z, Kharal A. Optimal Sixteenth Order Convergent Method Based on Quasi-Hermite Interpolation for Computing Roots. Hindawi Publishing Corporation; Volume 2014; Article ID 410410: 18 pages, 2014.

[8] Kung HT, Traub JF. Optimal order of one-point and multi-point iteration. J. Assoc. Comput. Math.; 1974; 21: 643–651.

[9] Sharma JR, Guha RK, Sharma R. Some variants of Hansen-Patrick method with third and fourth order convergence. Appl. Math. Comput.; 2009; 214: 171-177; applied, 2003.

[10] Sargolzaei P, Soleymani F. Accurate fourteenth-order methods for solving nonlinear equations, Numerical Algorithms. 2011; 58: 513–527.

[11] Sharma JR, Guha RK, Gupta P. Improved King's methods with optimal order of convergence based on rational approximations. Applied Mathematics Letters; 2013; 26: 473–480.

[12] Liu Z, Fang Q. A New Newton-Type Method with Third-Order for Solving Systems of Nonlinear Equations. Applied Mathematics and Physics; 2015; 28: Vol.3 No.10.

[13] Amat S, Busquier S, Plaza S. Iterative root-finding methods. 2004; (Unpublished report).

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Engineering Applications of Polynomial Matrix Method: A Review

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Abstract

The modeling of natural phenomena is based on ordinary and partial differential equations, which appear in all branches of science and engineering. For this reason, applied mathematicians and engineers have tried to develop new methods of solutions to these equations. One of the widely used numerical methods for the solution of ordinary and partial differential, integro-differential, and integral equations is the Polynomial Matrix Method (PMM). In this study, these methods are introduced first and then a brief history of the development of the method is given. Almost 30 polynomials used in this collocation approach are mentioned. Fundamental principle of the PMM is explained. Engineering applications such as in single and multi-degree of freedom systems, mechanical vibrations, heat equations, diffusion equation and others are reviewed.

Keywords: Engineering differential equations, polynomials, collocation, matrix method

Introduction

Ordinary and partial differential equations play a fundamental role in modeling various natural phenomena across different fields of research and engineering. Because of this, engineers and applied mathematicians have worked to create novel approaches to solving these equations.

The PMM is a matrix-based mathematical tool that is widely used for the solution of ordinary and partial differential, integro-differential, and integral equations. This is a collocation method where the objective is to determine a solution that solves the given equation at each of a set of domain locations known as collocation points in a finite-dimensional space of candidate solutions (typically, polynomials up to a specific degree). PMM represents a system in terms of a polynomial matrix and utilizes various operations such as matrix multiplication, polynomial division, and inversion to solve complex problems. PMM has become an increasingly popular method in recent years due to its ability to solve problems in a computationally efficient manner.

Collocation methods are called meshfree methods. Meshfree methods are numerical techniques used for solving problems in mathematics, engineering, and other related fields without the use of a fixed mesh or grid structure. Meshfree methods employ a set of scattered data points to represent the domain of interest and use local or global basis functions to interpolate the solution. These methods offer several advantages over traditional mesh-based methods, such as the ability to handle complex geometries and large deformations without the need for remeshing, and they often require fewer degrees of freedom, resulting in reduced computational costs. Examples of meshfree methods in mechanics include the smoothed particle hydrodynamics method, the element-free Galerkin method, the reproducing kernel particle method, collocation method and the radial basis function method.

These methods are used to establish a system of algebraic equations for the complete problem domain without using a predefined mesh. Alternatively, they employ easily generable meshes in a much more flexible approach. Meshfree methods basically adopt a set of nodes distributed within the problem domain as well as on the boundaries to represent the problem domain and its boundaries. The field functions are then approximated locally using these nodes [1]. The collocation methods are integration-free and have good flexibility. The disadvantage is that the smoothness requirement of the approximation functions is equal to that of the partial differential equations (PDEs), therefore the collocation methods demand direct approximation of the high order derivatives of the unknowns existing in the PDEs [2]. Xiang et al. [3] investigated the meshless global radial point collocation technique for solving three-dimensional partial differential equations using multiple radial basis functions. We looked at first, second, third, and fourth-order three-dimensional partial differential equations. The influence of various radial basis function shape parameters on numerical accuracy was investigated.

The primary objective of this paper is to provide a comprehensive review of the engineering applications of PMM. The fundamental concepts of PMM, the mathematical basis of the technique, and its applications in various engineering fields are covered. The paper focuses on the engineering applications of PMM in various systems.

Development of the Method

Kanwal and Liu [4] presented a Taylor expansion approach for solving integral equations in 1989. Later, Sezer developed this method for the Taylor polynomial solutions of, first, Volterra integral equations [5], and then, second-order linear differential equations with specified boundary conditions [6]. In the latter study [6], the method is also applied to the generalized Hermite, Laguerre, Legendre and Chebyshev differential equations. Sezer and Kaynak [7] modified the method to use Chebyshev polynomials. This technique was based on first taking the truncated Chebyshev series of the functions in equation and then substituting their matrix forms into the given equation. So that the equation reduced to a matrix equation, which corresponded to a system of linear algebraic equations with unknown Chebyshev coefficients.

In 2002, Karamete and Sezer [8] introduced a technique called the Taylor collocation method that utilized a matrix approach to solve linear integro-differential equations by truncating the Taylor series. This approach converted the integro-differential equation into a matrix equation representing a set of linear algebraic equations, with the Taylor coefficients being the unknowns. The effectiveness of this approach was demonstrated by applying it to various linear differential, integral, and integro-differential equations, and subsequently comparing the obtained results. In 2006, Gülsu and Sezer [9] presented a Taylor polynomial approximation for the solution of m^{th}-order linear differential-difference equations with variable coefficients under the mixed conditions about any point.

In the following years, there were studies applying various polynomial matrix approaches to solve a range of problems. Bülbül and Sezer [10] applied the Taylor matrix method to Duffing equation, Gökmen et al. [11] Taylor collocation approach to Lotka-Volterra predator-prey system, Jleli et al. [12] Legendre polynomials to a fractional model of pollution, Liu et al. [13] higher order polynomials to 2D and 3D elliptic partial differential equations with variable coefficients, Singh et al. [14] Bernoulli polynomials to two-dimensional hyperbolic telegraph equations with Dirichlet boundary conditions, Bahşı et al. [15] Jacobi polynomials to Volterra integro-differential equations.

Polynomials Used in Collocation Approach

A polynomial sequence is a series of polynomials in mathematics, where each polynomial's degree is represented by one of the nonnegative numbers 0, 1, 2, 3, ... These polynomials are used to approximate complex functions and solve numerical problems. In collocation methods, the differential equation is transformed into a system of algebraic equations by selecting specific collocation points at which the solution is required to satisfy the differential equation. The polynomial sequences used in collocation methods are typically orthogonal or nearly orthogonal.

The most widely used one in collocation method is the Taylor polynomials [4,5,8-10,16-19]. The Taylor polynomial can be used to approximate the function $f(x)$ near the point *a*, and the accuracy of the approximation improves as the degree of the polynomial increases. The Taylor polynomial can also be used to estimate the value of $f(x)$ at points near a, and this is known as the Taylor series expansion of $f(x)$ about *a*.

The nth degree Taylor polynomial of a function $f(x)$ about point *a* is given by:

$$P\_n(x) = f(a) + f'(a)(x-a) + \frac{f''(a)}{2!}(x-a)^2 + \ldots + \frac{f^{(n)}(a)}{n!}(x-a)^n$$

where $f(a), f'(a), \ldots, f^n(a)$ are the first *n* derivatives of $f(x)$ evaluated at $x = a$.

Other polynomial series used in collocation methods are Chebyshev polynomials [7,20,21], Chebyshev cardinal polynomials [22], Laguerre polynomials [23,24], Jacobi polynomials [15,25], Bessel polynomials [26,27], Legendre polynomials [28,29], Gegenbauer polynomials [30], Chelyshkov polynomials [31,32], Hermite polynomials [33,34], Bernoulli polynomials [14,35], hybrid Euler-Taylor polynomials [36], hybrid Taylor-Lucas polynomials [37], Pell polynomials [38], Touchard polynomials [39], Lucas polynomials [40], Morgan-Voyce polynomials [41], Bernstein polynomials [42-43], Boole polynomials [44], Dickson polynomials [45], orthoexponential polynomials [46-48], Fibonacci polynomials [49-50], Chebyshev-Lobatto polynomials [51], Boubaker polynomials [52], Bell polynomials [53,54], Lerch polynomials [55], Charlier polynomials [56], Lagrange polynomials [57-58], Genocchi polynomials [59].

The properties of polynomials generally depend on the interval over which they are defined. Chebyshev polynomials of the first kind are defined on the interval [-1, 1] and have the property that they oscillate between -1 and 1. Chebyshev polynomials of the second kind are also defined on the interval [-1, 1] and are non-negative for all values of x in that interval. Legendre polynomials are also defined on the interval [-1, 1] and have the property that they are orthogonal on that interval. They can be used to approximate functions defined on that interval. Laguerre polynomials are defined on the interval [0, ∞) and are used to solve differential equations in quantum mechanics and other fields. They have the property that they are orthogonal with respect to a weight function that is an exponential function. Hermite polynomials are defined on the interval (-∞, ∞) and are used to solve differential equations in quantum mechanics and statistical mechanics. They have the property that they are orthogonal with respect to a Gaussian weight function. Bernstein polynomials are defined on the interval [0, 1] and are used to approximate functions defined on that interval. They have the property that they are non-negative for all values of x in that interval. Jacobi polynomials are defined on the interval [-1, 1] with positive parameters α and β. They have the property that they are orthogonal on that interval with respect to a weight function. Jacobi polynomials arise in many applications in physics, engineering, and mathematics. Gegenbauer polynomials are defined on the interval [-1, 1] with a non-negative parameter λ. They have the property that they are orthogonal on that interval with respect to a certain weight function. Gegenbauer polynomials are used in the solution of differential equations and other applications. Bessel polynomials are defined on the interval [0, 1] and arise in the theory of Fourier analysis and orthogonal polynomials.

Taylor polynomials, on the other hand, are not defined on a specific interval, but rather are defined around a specific point. Given a function $f(x)$, the n[th] degree Taylor polynomial for $f(x)$ around the point *a* is a polynomial of degree *n* that approximates the function $f(x)$ near the point *a*. The properties of Taylor polynomials depend on the function being approximated and the specific point around which the approximation is being made. In general, the accuracy of the Taylor polynomial approximation improves as the degree of the polynomial increases and as the distance from the point of approximation to the point being approximated decreases. In addition, Taylor polynomials can be used to derive Taylor series, which are infinite series expansions of functions around specific points. These series can be used to approximate functions over a wider range of values, and their convergence properties depend on the specific function being approximated.

Therefore, the definition interval of a polynomial should be taken into consideration while choosing it to approximate the solution function of a differential equation.

Fundamental Principle of the Method

Consider an ordinary differential equation with variable coefficients

$$\sum_{k=0}^{m} P_k(x) y^{(k)}(x) = f(x)$$

with the mixed conditions

$$\sum_{k=0}^{m-1} \left[a_{ik} y^{(k)}(a) + b_{ik} y^{(k)}(b) \right] = \lambda_{ik}$$

where $P_k(x)$ and $f(x)$ are functions defined on $a \le x \le b$; the real coefficients a_{ik}, b_{ik} and λ_{ik} are suitable constants.

The solution for this equation is suggested in the following form of truncated Taylor series

$$y(x) = \sum_{n=0}^{N} \frac{y^{(n)}(c)}{n!} (x-c)^n$$

which is a Taylor polynomial of degree N at $x = c$, where $y^{(n)}(c)$ are the unknown coefficients to be determined. Also the solution function $y(x)$ can be written in the matrix form as

$$y(x) \cong \mathbf{X}(x)\mathbf{JY}$$

where

$$\mathbf{X}(x)=\begin{bmatrix}1 & x-c & (x-c)^2 & \cdots & (x-c)^N\end{bmatrix}$$

$$\mathbf{Y}=\begin{bmatrix}y_0 & y_1 & y_2 & \cdots & y_N\end{bmatrix}^T, y_n=y^{(n)}(c)$$

$$\mathbf{J}=\begin{bmatrix}\frac{1}{0!} & 0 & 0 & \cdots & 0\\ 0 & \frac{1}{1!} & 0 & \cdots & 0\\ 0 & 0 & \frac{1}{2!} & \cdots & 0\\ \vdots & \vdots & \vdots & \ddots & \vdots\\ 0 & 0 & 0 & \cdots & \frac{1}{N!}\end{bmatrix},$$

Here the matrix $\mathbf{X}(x)$ can be named as the Taylor basis matrix (or standard basis in the case of $c=0$).

Besides, if any of the above mentioned special polynomials $F_n(x), \quad n=0,1,\ldots,N$ can be written in terms of the powers of x, then they can be represented in the following matrix form

$$\begin{aligned}\mathbf{F}(x)&=\begin{bmatrix}F_0(x) & F_1(x) & \cdots & F_N(x)\end{bmatrix}\\ &=\mathbf{X}(x)\mathbf{M} \qquad (\text{in standard basis form})\end{aligned}$$

where $F(x)$ is the basis matrix of the special polynomials $F_n(x), \quad n=0,1,\ldots,N$ and $\mathbf{M}$ is the transformation matrix to the standard basis.

As a result, the matrix-collocation method is based on the operational matrix properties of the basis matrices $\mathbf{X}(x)$ and $\mathbf{F}(x)$, along with collocation points defined in the given interval.

Engineering Applications of the Method

The solution of differential equations is an essential tool for engineers in the design and analysis of systems in a wide range of fields to simulate real-world scenarios. The PMM is one of the efficient numerical methods and thus has numerous engineering applications in this respect. The development of computers has facilitated the widespread use and progress of numerical methods, and has revolutionized many fields of research and innovation by allowing complex mathematical problems to be solved more efficiently and accurately. The PMM, in particular, has been widely applied in engineering since its initial development. Its ability to solve polynomial matrix equations has made it a valuable tool in many areas of engineering. One of the key advantages of this method is its ability to handle multivariable systems, which are common in engineering applications. By representing the systems as polynomial matrices, engineers can use the PMM to solve complex problems involving multiple inputs and outputs. This method allows engineers to tackle complex problems that would be difficult or impossible to solve analytically, and have revolutionized many areas of engineering, from mechanics and heat problems to control systems and biomedical engineering.

Rao et al. [16] is known for being one of the pioneers in applying the PMM to mechanics. They attempted to develop an analytical solution to natural frequency analysis of laminated composite beams by higher-order mixed theory and compared their approach with the work of earlier researchers. Their contributions helped establish the use of PMM as a powerful numerical tool for solving various problems in engineering and mechanics, and laid the foundation for further developments in this field.

Single and multi-degree of freedom systems

An inspiring example of the application of this method is addressed by Kurt and Çevik [17,18]; they presented this novel and simple numerical method for the solution of single degree of freedom system in terms of Taylor polynomials in the matrix form. Particular and general solutions of the differential equation were determined and the method was demonstrated by a numerical application. The results were compared with those of the exact solution. Thereafter, several studies were conducted on the single degree of freedom system. Savasaneril employed the Laguerre [60] and Lucas [40] series solutions to the same system and validated the results by a numerical example. Similarly, two and degrees of freedom spring-mass systems were solved by Fibonacci [49] and Taylor [61] matrix approaches, respectively. Solution of the delayed single degree of freedom system equation was also performed by exponential matrix method [46]. Finally, Çayan et al. [62] applied the Taylor-splitting collocation method for free and forced oscillations of linear and nonlinear spring-dashpot-mass and related models.

Mechanical vibrations

It is known that the PMM has been utilized for analyzing various structures in the field of mechanical vibrations. Sepahvand et al. [63] introduced the concept and implementation of generalized polynomial chaos expansion to analyze stochastic free vibrations of orthotropic plates. Their study focused on investigating the effects of uncertainties in elasticity moduli on the stochastic behavior of orthotropic plates. To achieve this, the uncertain moduli, eigen-frequencies, and eigen-modes of the plates were approximated using truncated polynomial chaos expansions with arbitrary random basis. These expansions were then substituted in the governing differential equations to obtain the polynomial chaos coefficients of the eigen-frequencies and eigen-modes.

In another study [64], the solution of the higher order linear differential equation with variable coefficients, which is the transverse vibration equation of a beam subjected to axial loading, by the exponential matrix method was presented. The matrix forms of the exponential functions and their derivatives were constructed and the basic matrix equation was obtained by applying the order points to the sums of the matrix forms. This matrix equation corresponded to the algebraic linear equation system. This system of equations was solved by basic matrix operations. The residual and absolute errors of the obtained approximate solutions were examined. In order to demonstrate the effectiveness of the method, several numerical problems were given. Sınır and Çevik [65] employed the Taylor matrix method to simple and cantilever Euler-Bernoulli beams and solved the differential equation of elastic curve of the beam. The solution functions were obtained for each type of support and loading conditions. The Taylor polynomial matrix solutions were compared with the exact solution and the results from both methods were in good agreement.

Filippi et al. [66] presented a new class of refined beam theories for static and dynamic analysis of composite beams. The models are obtained by implementing higher-order expansions of Chebyshev polynomials for the three components of the displacement field over the beam cross-section. The governing equations were written in terms of fundamental nuclei, which are independent of the choice of the expansion order and the interpolating polynomials. Static and free vibration analysis of laminated beams and thin-walled boxes were performed. The results were compared with those available in the literature. For comparison, Taylor-like Expansion and Lagrange Expansion models, commercial codes, analytical and experimental data were exploited. The performances of refined beam models in terms of computational cost and accuracy in comparison to the reference solutions were assessed. The analysis performed pointed out the high level of accuracy reached by the refined beam models with lower computational costs than 2D and 3D Finite Elements.

In his study, Mukhtar [67] proposed the use of a generalized Taylor polynomials as a mesh-free method, for the analysis of axisymmetric plates and shells. Successful application of the method to several benchmark problems of axisymmetric plate and shell structures proved its robustness. The results were verified using the existing analytical solutions that are in most cases not suited to practical engineering calculations. In another study [68], Mukhtar analyzed the free vibration of orthotropic plates is using the differential transform method and the Taylor collocation method and used these methods to predict the frequency parameters and the effect of various factors ranging from geometric to material parameters. He employed the methods for the analysis of some cases whose analytical solutions were not readily available.

Çayan et al. [51] presented Taylor-matrix and Hermite-matrix collocation methods to obtain the modal vibration behavior of an Euler–Bernoulli beam. The methods provide approximate solutions in the truncated Taylor series and the truncated Hermite series by using Chebyshev–Lobatto collocation points and operational matrices. The approaches were applied to the well-known transverse vibration model of a simply-supported Euler–Bernoulli beam. The beam was assumed to be under the effect of external harmonic force with spatially varying amplitude. The proposed methods were compared with the exact solutions. Mode shapes of the first three fundamental frequencies are obtained for each approach. The convergence behaviors of transverse displacements and absolute errors are calculated for each mode. Based on the study, it was stated that the methods are remarkable, dependable, and accurate for approaching the model problems.

Longitudinal vibration of rods was analyzed in [19] using Taylor matrix method. Both free and forced vibrations of the system were studied; particular and general solutions were determined. The method was demonstrated by an illustrative example using symbolic computation. Comparison of the numerical solution of this study with the exact solution was quite good.

Heat equations

Savasaneril [69] developed Bernstein series matrix method for numerically solving the heat equation in 2-D. The method converted the heat equation to a matrix equation, which corresponded to a system

of linear algebraic equations. Error analysis was included to demonstrate the validity and applicability of the technique. The effectiveness of the method was illustrated for a cut ring region. In another similar study [70] Chebyshev collocation matrix method was employed to solve 2-D heat equation.

Pasban et al. [71] used the spectral collocation method for simulating the coupled three dimensional heat and mass transfer processes during convective drying of apple slices. Both the space and time variables were discretized based on the Jacobi Gauss Lobatto interpolation points. Also operational matrices of differentiation were implemented for approximating the derivative of the spatial and temporal variables. The model was validated against experimental data in a certain range of air temperatures and the results illustrated an agreement between the numerical predictions and experimental results, which confirmed robustness, computationally efficient and high accuracy of the proposed approach for predicting the simultaneous heat and mass transfer.

El-Gamel and El-Hady [72] adopted a fast collocation algorithm for solving the time fractional heat equation with the nonlocal condition. They employed orthogonal Jacobi polynomials as the basis. Numerical experiments were presented to illustrate the efficiency and accuracy of the proposed algorithm. Comparison was made with some other existing methods to confirm the reliability of the algorithm.

Diffusion equation

Zhou and Xu [73] presented a method based upon the second kind Chebyshev wavelets approximation for solving convection diffusion equations. Operational matrix of integration was derived and utilized to transform the equation to a system of algebraic equations by combining collocation method. Numerical examples were used to show good efficiency and precision of the method.

Yüzbaşı and Şahin [27] presented a numerical scheme for the approximate solutions of the one-dimensional parabolic convection–diffusion model problems, based on the Bessel collocation method used for some problems of ordinary differential equations. An error estimation technique was given, and to show the accuracy and the efficiency of the method, numerical examples were implemented for comparison by the other methods.

Heydari et al. [31] dealt with the distributed-order time fractional nonlinear diffusion-wave equations. The Chelyshkov polynomials were used to develop a spectral collocation method for these problems. After approximating the solution of the problem in terms of the Chelyshkov polynomials and employing the expressed matrices, solving the primary equations transformed into solving algebraic systems. Some numerical examples were presented to show the adequacy of the approach.

Zogheib and Tohidi [35] develop a matrix scheme for solving two-dimensional time-dependent diffusion equations with Dirichlet boundary conditions. They transformed these equations into equivalent integro partial differential equations which contain both of the initial and boundary conditions. All the existing known and unknown functions in the equations were approximated by Bernoulli polynomials. Two numerical examples were given to demonstrate the efficiency, accuracy, and versatility of the proposed method.

Singh et al. [74] suggested an efficient matrix approach by using Euler approximation for solving numerically the two-dimensional diffusion and telegraph equations subject to the Dirichlet boundary conditions. Several test examples were employed to confirm the accuracy and effectiveness of the method. Comparison of obtained numerical results was made with some earlier works.

Ali and Saleem [75] used Chebyshev polynomials for the simulation of two-dimensional mass transfer diffusion equation arising during the convective air drying processes of food products subject to Robin and Neumann boundary conditions. Some numerical examples were presented to confirm the numerical efficiency and theoretical justification of the proposed scheme. In order to further validate the accuracy of the numerical method, a comparison was made with the exact solution using different norms.

Deeb et al. [76] used the Proper Generalized Decomposition (PGD) method to solve non-linear diffusion equations and produce parametric solutions. To treat the non-linear functions, the non-linear terms were replaced by their Taylor series expansion up to an order *m*. This produced a new model, which they called the "developed equation". Numerical simulations were done for a non-linear diffusion equation with exponential diffusion coefficient as first trial, and with a magnetic diffusion coefficient as a second one.

Miscellaneous other applications

A Bessel polynomials collocation method was presented to solve modeling the pollution of a system of lakes by a system of differential equations [77]. Pollution model of a system of lakes was transformed into a matrix equation. The matrix equation corresponded to a system of linear equations with the

unknown Bessel coefficients. A numerical example was included to demonstrate the validity and applicability of the technique. The results showed the efficiency and accuracy of the present work.

The RLC circuit is a basic building block of the more complicated electrical circuits and networks. A simple numerical method was presented for the solution this problem in terms of Taylor polynomials in the matrix form [78]. Particular and general solutions of the related differential equation were determined by this method. The technique was illustrated by a numerical application and a quite good agreement was observed between the results of the present method and those of the exact method.

In another study [79], the approximate solutions of the HIV infection model of CD4+T were obtained by developing the Bessel collocation method. This model corresponded to a class of nonlinear ordinary differential equation systems. The reliability and efficiency of the proposed approach were demonstrated in the different time intervals by a numerical example.

Alijani et al. [80] developed and analyzed a new mathematical model for intravenous drug administration and the associated diffusion process. They used interval analysis to obtain a system of weakly singular Volterra integral equations over ordinary functions and the operational method based on Chebyshev polynomials for obtaining an approximate solution of the numerical form. Numerical solutions were estimated accurately by this approach.

The Duffing equation is a non-linear second-order differential equation that is commonly used in engineering to model a wide range of phenomena, including electrical circuits, mechanical systems, and acoustic oscillations. Bülbül and Sezer [10] suggested a numerical approach, based on an improved Taylor matrix method, for solving Duffing differential equation. The results showed the efficiency and the accuracy of the work.

Other examples of the application of PMM are numerical solutions of integro-differential equations and application of a population model with an improved Legendre method [81], numerical algorithm for solving system of Lane–Emden type equations arising in engineering [82], the dynamical behavior of a nonlinear mathematical model for cancers with tumor [83], adaptive approach for solving fourth-order partial differential equations with applications to engineering models [84], a new structural uncertainty analysis method based on polynomial expansions [85], a numerical method to treat fractional nonlinear terminal value problems with multiple delays appearing in biomathematics [86]. PMM is also applied to delayed Lotka–Volterra predator–prey system [11], fractional model of pollution [12], some nonlinear differential equations arising in physics and mechanics [29], damped wave equation [38], multi-term variable-order time-fractional diffusion-wave equation [87], nonlinear boundary value problems occurring in heat and mass transfer [88], nonlinear thin film flow problems [89], Legendre polynomial solution for modelling guided waves in anisotropic plates [90].

Conclusion

The PMM is a powerful mathematical tool that has proven effective for solving ordinary and partial differential, integro-differential, and integral equations. It represents a system in terms of a polynomial matrix and uses various operations such as matrix multiplication, polynomial division, and inversion to solve complex problems. PMM is a meshfree method that offers several advantages over traditional mesh-based methods, including the ability to handle complex geometries and large deformations without the need for remeshing and reduced computational costs. Collocation methods, which are integration-free and flexible, are commonly used with PMM. The use of polynomial sequences, such as the Taylor polynomials, in collocation methods has proven successful for approximating complex functions and solving numerical problems. PMM and collocation methods have a wide range of applications in engineering and other related fields, making them valuable tools for researchers and engineers alike.

References

[1] Liu, GR. Meshfree Methods, Moving Beyond the Finite Element Method. Boca Raton: CRC Press, Taylor & Francis Group; 2010.

[2] Wang X, Liu Y, Ouyang J. A meshfree collocation method based on moving Taylor polynomial approximation for high order partial differential equations. Engineering Analysis with Boundary Elements. 2020; 116: 77-92.

[3] Xiang S, Jin Y, Jiang S, Bi Z, Wang K. Meshless global radial point collocation method for three-dimensional partial differential equations. Engineering Analysis with Boundary Elements, 2011; 35: 289–297.

[4] Kanwal RP, Liu KC. A Taylor expansion approach for solving integral equations. Int. J. Mat. Educ. Sci. Technol. 1989; 20: 411-414.

[5] Sezer M. Taylor polynomial solutions of Volterra integral equations. Int. J. Mat. Educ. Sci. Technol. 1994; 25: 625-633.

[6] Sezer M. A method for the approximate solution of the second-order linear differential equations in terms of Taylor polynomials. Int. J. Mat. Educ. Sci. Technol. 1996; 27: 821-834.

[7] Sezer M, Kaynak M. Chebyshev polynomial solutions of linear differential equations. Int. J. Mat. Educ. Sci. Technol. 1996; 27(4): 607-618.

[8] Karamete A, Sezer M. A Taylor collocation method for the solution of linear integro-differential equations. International Journal of Computer Mathematics 2002; 79(9): 987–1000.

[9] Gülsu M, Sezer M. A Taylor polynomial approach for solving differential-difference equations. Journal of Computational and Applied Mathematics 2006; 186: 349–364.

[10] Bülbül B, Sezer M. Numerical solution of Duffing equation by using an improved Taylor matrix method. Journal of Applied Mathematics 2013; Volume 2013, Article ID 691614, 6 pages.

[11] Gökmen E, Işık OR, Sezer M. Taylor collocation approach for delayed Lotka–Volterra predator–prey system. Applied Mathematics and Computation 2015; 268: 671-684.

[12] Jleli M, Kirane M, Samet B. A numerical approach based on ln-shifted Legendre polynomials for solving a fractional model of pollution. Mathematical Methods in the Applied Sciences 2017; 40: 7356-7367.

[13] Liu G, Ma W, Ma H, Zhu L. A multiple-scale higher order polynomial collocation method for 2D and 3D elliptic partial differential equations with variable coefficients. Applied Mathematics and Computation 2018; 331: 430-444.

[14] Singh S, Patel VK, Singh VK, Tohidi E. Application of Bernoulli matrix method for solving two-dimensional hyperbolic telegraph equations with Dirichlet boundary conditions. Computers and Mathematics with Applications 2018; 75: 2280-2294.

[15] Bahşı M, Çevik M, Sezer M. Jacobi polynomial solutions of Volterra integro-differential equations with weakly singular kernel. New Trends in Mathematical Sciences 2018; 6(3): 24-38.

[16] Rao MK, Desai YM, Chitnis MR. Free vibrations of laminated beams using mixed theory. Composite Structures 2001; 52: 149-160.

[17] Kurt N, Çevik M. Polynomial solution of the single degree of freedom system by Taylor matrix method. Mechanics Research Communications 2008; 35: 530-536.

[18] Çevik M, Baykuş N. Tek serbestlik dereceli titreşim sisteminin taylor matris yöntem ile polinom çözümü. XVI. Ulusal Mekanik Kongresi Bildiriler Kitabı 427-431, 22-26 Haziran 2009, Kayseri.

[19] Çevik M. Application of Taylor matrix method to the solution of longitudinal vibration of rods. Mathematical and Computational Applications 2010; 15(3): 334-343.

[20] Atta AG, Abd-Elhameed WM, Moatimid GM, Youssri YH. A fast Galerkin approach for solving the fractional Rayleigh–Stokes problem via sixth-kind Chebyshev polynomials. Mathematics 2022; 10(1843): 16 pages.

[21] Ghimire BK, Li X, Chen CS, Lamichhane AR. Hybrid Chebyshev polynomial scheme for solving elliptic partial differential equations. Journal of Computational and Applied Mathematics 2020; 364(112324): 14 pages.

[22] Heydari HM, Razzaghi M, Rouzegar J. Chebyshev cardinal polynomials for delay distributed-order fractional fourth-order sub-diffusion equation. Chaos, Solitons and Fractals 2022; 162(112495): 7 pages.

[23] Savasaneril NB, Sezer M. Laguerre polynomial solution of high- order linear Fredholm integro-differential equations. New Trends in Mathematical Sciences 2016; 4(2): 273-284.

[24] Baykuş N, Çevik M, Sezer M. Laguerre polynomial solution of Fredholm integro-differential equations by a practical matrix method. ICAAA International Conference on Applied Analysis and Algebra Proceedings 2011, İstanbul.

[25] Bahşı MM, Bahşı AK, Çevik M, Sezer M. Improved Jacobi matrix method for the numerical solution of Fredholm integro-differential-difference equations. Mathematical Sciences 2016; 10: 83-93.

[26] Yüzbaşı Ş. Bessel collocation approach for solving continuous population models for single and interacting species. Applied Mathematical Modelling 2012; 36: 3787-3802.

[27] Yüzbaşı Ş, Şahin N. Numerical solutions of singularly perturbed one-dimensional parabolic convection–diffusion problems by the Bessel collocation method. Applied Mathematics and Computation 2013; 220: 305-315.

[28] Khan A, Naz H, Sarwar M, Shah K. Numerical analysis of some fractional order differential equations via Legendre spectral method. Fractals 2023; 31(2) 2340036: 13 pages.

[29] Demir DD, Çınardalı T, Kürkçü ÖK, Sezer M. The Legendre matrix-collocation approach for some nonlinear differential equations arising in physics and mechanics. European Journal of Science and Technology 2019; 15: 289-296.

[30] Mollaoğlu T, Sezer M. A numerical approach with residual error estimation for solution of high-order linear differential-difference equations by using Gegenbauer polynomials. CBU Journal of Science 2017; 13(1): 39-49.

[31] Heydari MH, Rashid S, Chu Y-M. Chelyshkov polynomials method for distributed-order time fractional nonlinear diffusion-wave equations. Results in Physics 2023; 47, 106344.

[32] Oğuz C, Sezer M, Oğuz AD. Chelyshkov collocation approach to solve the systems of linear functional differential equations. New Trends in Mathematical Sciences 2015; 3(4): 83-97.

[33] Yalçınbaş S, Aynıgül M, Sezer M. A collocation method using Hermite polynomials for approximate solution of pantograph equations. Journal of The Franklin Institute 2011; 348: 1128-1139.

[34] Gülsu M, Yalman H, Sezer M. A new Hermite collocation method for solving differential difference equations. Applications and Applied Mathematics: An International Journal (AAM) 2011; 6(1): 116-129.

[35] Zogheib B, Tohidi E. A new matrix method for solving two-dimensional time-dependent diffusion equations with Dirichlet boundary conditions. Applied Mathematics and Computation 2016; 291: 1-13.

[36] Balcı MA, Sezer M. Hybrid Euler-Taylor matrix method for solving of generalized linear Fredholm integro-differential difference equations. Applied Mathematics and Computation 2016; 291: 33-41.

[37] Bayku N, Sezer M. Hybrid Taylor-Lucas collocation method for numerical solution of high-order pantograph type delay differential equations with variables delays. Applied Mathematics and Information Sciences 2017; 11(6): 1795-1801.

[38] Çayan S, Çevik M, Sezer M. An approximate solution of 3D partial differential equation by the Pell matrix collocation method. 4th International Students Science Congress Proceedings 321-329, 18-19 September 2020, İzmir.

[39] Sabermahani S, Ordokhani Y. A computational method to solve fractional-order Fokker-Planck equations based on Touchard polynomials. Computational Mathematics and Computer Modeling with Applications 2022; 1(2): 65-73.

[40] Savaşaneril NB. Lucas polynomial solution of a single degree of freedom system. Scientific Research Communications 2023; 3(1): 1-10.

[41] Sirivastava HM, Adel W, Izadi M, El-Sayed AA. Solving some physics problems involving fractional-order differential equations with the Morgan-Voyce polynomials. Fractal and Fractional 2023; 7(301): 1-19.

[42] Shah K, Abdalla B, Abdeljawad T, Suwan I. An efficient matrix method for coupled systems of variable fractional order differential equations. Thermal Science 2023; 27(1): 195-210.

[43] Işık OR, Sezer M, Guney Z. Bernstein series solution of linear second-order partial differential equations with mixed conditions. Mathematical Methods in the Applied Sciences 2014; 37: 609-619.

[44] Biçer KE, Dağ HG. Numerical solutions of differential equations having cubic nonlinearity using Boole collocation method. Turkish Journal of Mathematics 2023; 47: 732-745.

[45] Kürkçü ÖK, Aslan E, Sezer M. A numerical approach with error estimation to solve general integro-differential-difference equations using Dickson polynomials. Applied Mathematics and Computation 2016; 276: 324-339.

[46] Çevik M, Bahşı MM, Sezer M. Solution of the delayed single degree of freedom system equation by exponential matrix method. Applied Mathematics and Computation 2014; 242: 444-453.

[47] Bahşı MM, Çevik M, Sezer M. Orthoexponential polynomial solutions of delay pantograph differential equations with residual error estimation. Applied Mathematics and Computation 2015; 271: 11-21.

[48] Yüzbaşı Ş, Sezer M. An exponential approach for the system of nonlinear delay integro-differential equations describing biological species living together. Neural Computing and Applications 2016; 27: 769-779.

[49] Kurt A, Yalçınbaş S, Sezer M. İki serbestlik dereceli kütle-yay sisteminin Fibonacci matris yöntemi ile serbest titreşim analizi. XVIII. Ulusal Mekanik Kongresi Bildiriler Kitabı 408-419, 26-30 Ağustos 2013, Manisa.

[50] Kurt A, Yalçınbaş S, Sezer M. Fibonacci collocation method for solving linear differential-difference equations. Mathematical and Computational Applications 2013; 18(3): 448-458.

[51] Çayan S, Özhan BB, Sezer M. Collocation approaches to the mathematical model of an Euler–Bernoulli beam vibrations. Mathematics and Computers in Simulation 2022; 197: 32-44.

[52] Aykutalp EZ, Sezer M. Boubaker collocation method for neutral functional-differential equations with proportional delays. 3rd International Students Science Congress Proceedings 335-343, 3-4 May 2019, İzmir.

[53] Yıldız G, Sezer M. Numerical solutions of Fredholm type integro-differential equations mixed delays by means of Bell matrix-collocation method. 3rd International Students Science Congress Proceedings 317-325, 3-4 May 2019, İzmir.

[54] Yıldız G, Sezer M. Truncated Bell series approach to solve systems of generalized delay differential equations with variable coefficients. Turkish Journal of Mathematics and Computer Science 2019; 11: 105-113.

[55] Çayan S, Sezer M. A novel study based on Lerch polynomials for approximate solutions of pure Neumann problem. International Journal of Applied and Computational Mathematics 2022; 8: 1-19.

[56] Kürkçü ÖK, Sezer M. Charlier series solutions of systems of first order delay differential equations with proportional and constant arguments. Scientific Research Communications 2022; 2(1): 1-11.

[57] Yüzbaşı Ş, Sezer M. On solutions of linear functional integral and integro-differential equations via Lagrange polynomials. Journal of Science and Arts 2021; 3(56): 707-720.

[58] Wang K, Wang Q. Lagrange collocation method for solving Volterra–Fredholm integral equations. Applied Mathematics and Computation 2013; 219: 10434-10440.

[59] Başar Ü, Sezer M. A combined numerical approach based upon Genocchi series for solution of functional integro-differential equations. 2nd International Students Science Congress Proceedings 78-82, 4-5 May 2018, İzmir.

[60] Savaşaneril NB. Laguerre series solutions of the delayed single degree-of-freedom oscillator excited by an external excitation and controlled by a control force. Journal of Computational and Theoretical Nanoscience 2018; 15: 606-610.

[61] Sınır S, Çevik M. Üç serbestlik dereceli kütle-yay sisteminin serbest titreşim analizi için Taylor matris yaklaşimi. XVIII. Ulusal Mekanik Kongresi Bildiriler Kitabı 581-588, 26-30 Ağustos 2013, Manisa.

[62] Çayan S, Özhan BB, Sezer M. A Taylor-splitting collocation approach and applications to linear and nonlinear engineering models. Chaos, Solitons and Fractals 2022; 164 (112683): 1-10.

[63] Sepahvand K, Marburg S, Hardtke H-J. Stochastic free vibration of orthotropic plates using generalized polynomial chaos expansion. Journal of Sound and Vibration 2012; 331: 167-179.

[64] Bahşı MM, Çevik M. Eksenel yüklemeye maruz değişken kesitli Euler-Bernoulli kirişinin üstel matris yöntemi ile enine titreşim analizi. XVIII. Ulusal Mekanik Kongresi Bildiriler Kitabı 94-104, 26-30 Ağustos 2013, Manisa.

[65] Sınır S, Çevik M. Taylor matrix solution of Euler-Bernoulli beam equation subjected to static loads. Proceedings of the Fourth International Conference on Mathematical and Computational Applications 382-389, 11-13 June 2013, Manisa.

[66] Filippi M, Pagani A, Petrolo M, Colonna G, Carrera E. Static and free vibration analysis of laminated beams by refined theory based on Chebyshev polynomials. Composite Structures 2015; 132: 1248-1259.

[67] Mukhtar FM. Generalized Taylor polynomials for axisymmetric plates and shells. Applied Mathematics and Computation 2016; 276: 182-199.

[68] Mukhtar FM. Free vibration analysis of orthotropic plates by differential transform and Taylor collocation methods based on a refined plate theory. Archive of Applied Mechanics 2017; 87: 15-40.

[69] Savaşaneril NB. Bernstein series solution of the heat equation in 2-D. New Trends in Mathematical Sciences 2017; 5(4): 220-231.

[70] Gumgum S, Kuru E, Savaşaneril NB. Chebyshev collocation method for the two-dimensional heat equation. Communication in Mathematical Modeling and Applications 2018; 3(2): 1-8.

[71] Pasban A, Sadrnia H, Mohebbi M, Shahidi SA. Spectral method for simulating 3D heat and mass transfer during drying of apple slices. Journal of Food Engineering 2017; 212: 201-212.

[72] El-Gamel M, El-Hady MA. A fast collocation algorithm for solving the time fractional heat equation. SeMA Journal 2021; 78: 501-513.

[73] Zhou F, Xu X. Numerical solution of the convection diffusion equations by the second kind Chebyshev wavelets. Applied Mathematics and Computation 2014; 247: 353-367.

[74] Singh S, Devi V, Tohidi E, Singh VK. An efficient matrix approach for two-dimensional diffusion and telegraph equations with Dirichlet boundary conditions. Physica A 2020; 545: 123784.

[75] Ali I, Saleem MT. Applications of orthogonal polynomials in simulations of mass transfer diffusion equation arising in food engineering. Symmetry 2023; 15(527): 15 pages.

[76] Deeb A, Kalaoun O, Belarbi R. Proper generalized decomposition using Taylor expansion for non-linear diffusion equations. Mathematics and Computers in Simulation 2023; 208: 71-94.

[77] Yüzbaşı Ş, Şahin N, Sezer M. A collocation approach to solving the model of pollution for a system of lakes. Mathematical and Computer Modelling 2012; 55: 330-341.

[78] Bahşı MM, Çevik M. Taylor matrix solution of the mathematical model of the RLC circuits. Mathematical and Computational Applications 2013; 18(3): 467-475.

[79] Yüzbaşı Ş. A numerical approach to solve the model for HIV infection of $CD4^{+}T$ cells. Applied Mathematical Modelling 2012; 36: 5876-5890.

[80] Alijani Z, Shiri B, Perfilieva I, Baleanu D. Numerical solution of a new mathematical model for intravenous drug administration. Evolutionary Intelligence 2012; 36: 5876-5890.

[81] Yüzbaşı Ş, Sezer M, Kemancı B. Numerical solutions of integro-differential equations and application of a population model with an improved Legendre method. Applied Mathematical Modelling 2013; 37: 2086-2101.

[82] Öztürk Y. An efficient numerical algorithm for solving system of Lane–Emden type equations arising in engineering. Nonlinear Engineering 2013; 8: 429-437.

[83] Khoei AA, Zakerzadeh M, Ayati M, Soleimani N. Developing and studying the dynamical behavior of a nonlinear mathematical model for cancers with tumor by considering immune system role. International Journal of Biomathematics 2021; 14(5): 2050056.

[84] Çayan S, Özhan BB, Sezer M. An adaptive approach for solving fourth-order partial differential equations: algorithm and applications to engineering models. Computational and Applied Mathematics 2022; 41(408): 17 pages.

[85] Zheng Y, Gu Y, Gao L, Wang Y, Qu J, Zhang C. A new structural uncertainty analysis method based on polynomial expansions. Applied Mathematics and Computation 2022; 427: 127122.

[86] Kürkçü ÖK. A streamlined numerical method to treat fractional nonlinear terminal value problems with multiple delays appearing in biomathematics. Computational and Applied Mathematics 2023; 41(74): 20 pages.

[87] Sadri K, Aminikhah H. A new efficient algorithm based on fifth-kind Chebyshev polynomials for solving multi-term variable-order time-fractional diffusion-wave equation. International Journal of Computer Mathematics 2022; 99(5): 966–992.

[88] Kürkçü ÖK, Sezer M. A new characteristic numerical approach with evolutionary residual error analysis to nonlinear boundary value problems occurring in heat and mass transfer via combinatoric Mittag-Leffler polynomial. Numerical Heat Transfer, Part A: Applications 2022; 82(9): 561–575.

[89] Ibraheem GH, Al-Jawary MA. The operational matrix of Legendre polynomials for solving nonlinear thin film flow problems. Alexandria Engineering Journal 2020; 59: 4027-4033.

[90] Zheng M, He C, Lu Y, Wu B. State-vector formalism and the Legendre polynomial solution for modelling guided waves in anisotropic plates. Journal of Sound and Vibration 2018; 412: 372-388.

Numerical Solutions of Hyperbolic Partial Differential Equations

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Abstract

Hyperbolic partial differential equations are frequently referenced in modeling real-world problems in mathematics and engineering. In this study, a matrix method based on collocation points and Taylor polynomials is presented to obtain the approximate solution of the hyperbolic partial differential equation. This technique reduces the solution of the mentioned hyperbolic partial differential equation under initial and boundary conditions to the solution of a matrix equation whose Taylor coefficients are unknown. Thus, the approximate solution is obtained in terms of Taylor polynomials. An example is provided to showcase the practical application of the technique. In addition, the numerical results obtained using these collocation points were compared with the table and figure. All numerical calculations were made on the computer using a program written in WOLFRAM MATHEMATICA 13.0.

Keywords: Partial differential equations, Taylor polynomials, boundary value problems, matrix - collocation method.

Introduction

Hyperbolic partial differential equation is a type of partial differential equation (PDE) that describes wave-like behavior in physical systems, such as sound waves or electromagnetic waves. In recent years for solving these equations, numerical methods have been developed. [1] and [2] studied one-dimensional moving boundary problem. We studied matrix approach to solving hyperbolic differential equations. [3] gives a method matrix approach to solving hyperbolic partial differential equations like us. Also hyperbolic PDEs are used for heat conduction. [5], [6], [8], [9], [10] and [12] and [13] worked about hyperbolic PDEs for heat conduction. To define the simplest kind of hyperbolic PDE, let us just consider a real-valued function $u(x, y)$ of two independent real variables, x and y. A second-order, linear, constant-coefficient PDE for u takes the form

$$Au_{xx} + 2Bu_{xy} + Cu_{yy} + Du_x + Eu_y + Fu + G = 0 \tag{1}$$

and this PDE is classified as being hyperbolic if the coefficients satisfy the condition

$$B^2 - 4AC > 0$$

In mathematics, a hyperbolic differential equation of order is a partial differential equation (PDE) that, roughly speaking, has a well-posed initial value problem for the first derivatives. . In this study, we introduce a Taylor collocation method based on matrix relations which has been used to find the approximate solution of hyperbolic partial differential equation.

$$\frac{\partial^2 u(x,t)}{\partial^2 t^2} = \alpha^2 \frac{\partial^2 u(x,t)}{\partial^2 x^2} \tag{2}$$

with the conditions

$$\left.\begin{aligned} &u_t(x,0) = g(x) \\ &u(0,t) = 0 \\ &u(a,t) = 0 \\ &u(x,0) = f(x) \quad t > 0, \quad 0 \le x \le a \end{aligned}\right\} \tag{3}$$

where *f* are known functions and the function $u(x,t)$ is unknown. By developing the Taylor collocation method, we will obtain the approximate solution of Eq. (2) in the truncated Taylor series form

$$u(x,t) \cong u_N(x,t) = \sum_{m=0}^{N} \sum_{n=0}^{N} a_{mn}\, x^m t^n \tag{4}$$

where $a_{mn}; m, n = 1, \ldots, N$ are the unknown Taylor coefficients.

Fundamental Relations

To obtain the numerical solution of hyperbolic partial differential equation with Taylor Collocation Method, we first evaluate the Taylor coefficients of the unknown function. For convenience, the solution function (4) can be written in the matrix form

$$u(x,t) \cong u_N(x,t) = \mathbf{X}(x)\overline{\mathbf{X}(t)}\,\mathbf{A} \tag{5}$$

where

$$\mathbf{X}(x) = \begin{bmatrix} 1 & x & \ldots & x^N \end{bmatrix}, \tag{6}$$

$$\overline{\mathbf{X}}(t) = diag\begin{bmatrix} \mathbf{X}(t) & \mathbf{X}(t) & \ldots & \mathbf{X}(t) \end{bmatrix}, \tag{7}$$

$$\mathbf{A} = \begin{bmatrix} A_0 & A_1 & \ldots & A_N \end{bmatrix}^T \tag{8}$$

$$\frac{\partial u}{\partial x} = \mathbf{X}(x)\mathbf{B}\overline{\mathbf{X}}(t)\,\mathbf{A} \tag{9}$$

$$\frac{\partial u}{\partial t} = \mathbf{X}(x)\,\overline{\mathbf{X}(t)}\,\overline{\mathbf{B}}\,\mathbf{A} \tag{10}$$

$$\frac{\partial^2 u}{\partial x^2} = \mathbf{X}(x)\mathbf{B}^2\,\overline{\mathbf{X}(t)}\,\mathbf{A} \tag{11}$$

$$\frac{\partial^2 u}{\partial t^2} = \mathbf{X}(x)\,\overline{\mathbf{X}(t)}\,\overline{\mathbf{B}}^2\mathbf{A}, \tag{12}$$

$$\mathbf{B} = \begin{bmatrix} 0 & 1 & 0 & \ldots & 0 \\ 0 & 0 & 2 & \ldots & 0 \\ \ldots & \ldots & \ldots & \ldots & 0 \\ 0 & 0 & 0 & \ldots & N \\ 0 & 0 & 0 & \ldots & 0 \end{bmatrix}, \qquad \overline{\mathbf{B}} = diag\begin{bmatrix} \mathbf{B} & \mathbf{B} & \ldots & \mathbf{B} \end{bmatrix} \tag{13}$$

Method of Solution

We are now ready to construct the fundamental matrix equation corresponding to (2). For this purpose, substituting the matrix relations (5) and (9)-(12), into (2) and simplifying, we obtain the fundamental matrix equation

$$\mathbf{X}(x)\ \overline{\mathbf{X}(t)}\,\overline{\mathbf{B}}^{\,2}\mathbf{A}-\alpha^2.\mathbf{X}(x)\mathbf{B}^2\ \ \overline{\mathbf{X}(t)}\mathbf{A}=0 \tag{14}$$

If we write as

$$\mathbf{W}=\left\{\mathbf{X}(x)\ \overline{\mathbf{X}(t)}\,\overline{\mathbf{B}}^{\,2}-\alpha^2.\mathbf{X}(x)\mathbf{B}^2\ \ \overline{\mathbf{X}(t)}\right\} \tag{15}$$

and we obtain,

$$\mathbf{W}(x,t)\mathbf{A}=0 \tag{16}$$

The standard collocation points used in matrix system are given, respectively, by

$$x_i=a+\frac{b-a}{N}i,\quad t_j=c+\frac{d-c}{N}j,\quad i,j=0,1,...,N, \tag{18}$$

We substitute the collocation points (14-15) into Eq. (12), then we can write

$$\mathbf{W}(x_i,t_j)=\left\{\mathbf{X}(x_i)\ \overline{\mathbf{X}(t_j)}\,\overline{\mathbf{B}}^{\,2}-\alpha^2.\mathbf{X}(x_i)\mathbf{B}^2\ \ \overline{\mathbf{X}(t_j)}\right\} \tag{19}$$

We now ready to state the fundamental matrix equation of (2) as

$$\mathbf{WA}=\mathbf{0}\quad or\quad \left[\mathbf{W}\ \ ;\ \ \mathbf{0}\right] \tag{20}$$

where

$$\mathbf{W}(x_i,t_j)=\left[\mathbf{W}_0\quad \mathbf{W}_1\quad \ldots\quad \mathbf{W}_N\right]^T,\quad \mathbf{A}_i=\left[a_{i0}\quad a_{i1}\quad \ldots\quad a_{iN}\right]^T,\quad \mathbf{0}=\left[0\quad 0\quad \ldots\quad 0\right]^T. \tag{21}$$

Matrix Representation of the Conditions

Let us define the matrix form of the initial conditions and boundary conditions

$$\left.\begin{aligned} &u_t(x,0)=0\\ &u(0,t)=0\\ &u(a,t)=0\\ &u(x,0)=f(x)\quad t>0,\quad 0\le x\le a\end{aligned}\right\} \tag{22}$$

$$u_t(x_i,0)=\mathbf{X}(x_i)\ \overline{\mathbf{X}(0)}\ \overline{\mathbf{B}}\,\mathbf{A}=0,\quad i=0,1,2,...,N \tag{23}$$

$$u(0,t_j)=\mathbf{X}(0)\ \overline{\mathbf{X}(t_j)}\ \mathbf{A}=0,\quad j=0,1,2,...,N \tag{24}$$

$$u(l,t_j)=\mathbf{X}(l)\ \overline{\mathbf{X}(t_j)}\ \mathbf{A}=0,\quad j=0,1,2,...,N \tag{25}$$

$$u(x_i,0)=\mathbf{X}(x_i)\ \overline{\mathbf{X}(0)}\ \mathbf{A}=\mathbf{F},\quad i=0,1,2,...,N \tag{26}$$

$$\mathbf{VA}=\mathbf{0}\quad or\quad \left[\mathbf{V}\ \ ;\ \ \mathbf{0}\right], \tag{27}$$

$$\mathbf{U_1A}=\mathbf{0}\quad or\quad \left[\mathbf{U_1}\ \ ;\ \ \mathbf{0}\right], \tag{28}$$

$$\mathbf{U_2 A = 0} \quad or \quad \left[\mathbf{U_2} \;\; ; \;\; \mathbf{0}\right], \tag{29}$$

$$\mathbf{U_3 A = 0} \quad or \quad \left[\mathbf{U_3} \;\; ; \;\; \mathbf{0}\right] \tag{30}$$

Consequently, in order to find the Taylor coefficients $a_{mn}; m,n = 1,...,N$ related with approximate solution Eq4) of the problem (2) and(3) by replacing the row matrices(20) by the any rows of the matrix (27), (28), (29) and (30), we obtain augmented matrix

$$\left[\mathbf{W} \;\; ; \;\; \mathbf{G}\right] = \begin{bmatrix} \mathbf{W} & ; & \mathbf{0} \\ \mathbf{V} & ; & \mathbf{0} \\ \mathbf{U_1} & ; & \mathbf{0} \\ \mathbf{U_2} & ; & \mathbf{0} \\ \mathbf{U_3} & ; & \mathbf{F} \end{bmatrix} \tag{31}$$

We can thus reach the coefficients matrix A by solving the system (31) only if the rank of this system yields $(N+1)^2$. Then, A produces a Taylor polynomial solution with the aid of (4).

Control of Solution via Residual Error Analysis

It is well known from [7] that the residual error analysis has presented highly effective tool to improve the approximate solutions of differential equations especially partial diffrential equations as Eq.(2) . Here, we aim to control the obtained solutions via an error analysis technique based on a residual function $R_N(x,t)$ in Ω. After inserting substituting the Taylor polynomial solution (4) into Eq. (2), a residual error function with respect to N is then obtained as

$$R_N(x,t) = L[u_N(x,t)] \tag{32}$$

where L is a linear operator.

$$R_N(x,t) = \frac{\partial^2 u_N(x,t)}{\partial^2 t^2} - \alpha^2 \frac{\partial^2 u_N(x,t)}{\partial^2 x^2}. \tag{33}$$

with the initial conditions

$$\left.\begin{aligned} &u_t(x,0) = 0 \\ &u(0,t) = 0 \\ &u(a,t) = 0 \\ &u(x,0) = f(x) \quad t > 0, \quad 0 \le x \le a \end{aligned}\right\} \tag{34}$$

In additional the error function $e_N(x,t)$ is defined as follows

$$L[e_N(x,t)] = L[u(x,t)] - L[u_N(x,t)] = -R_N(x,t) \tag{35}$$

with the homogeneous conditions

$$\left.\begin{aligned} &(e_n)_t(x,0) = 0 \\ &e_n(0,t) = 0 \\ &e_n(a,t) = 0 \\ &e_n(x,0) = f(x) \quad t > 0, \quad 0 \le x \le a \end{aligned}\right\} \tag{36}$$

So the error problem can be written as

$$\frac{\partial^2 e_N(x,t)}{\partial^2 t^2} - \alpha^2 \frac{\partial^2 e_N(x,t)}{\partial^2 x^2} = -R_N(x,t). \tag{37}$$

$$\left.\begin{aligned} &(e_n)_t(x,0) = 0 \\ &e_n(0,t) = 0 \\ &e_n(a,t) = 0 \\ &e_n(x,0) = f(x) \quad t > 0, \quad 0 \le x \le a \end{aligned}\right\} \tag{38}$$

Application

In this section we establish the matrix method by applying it to solve the general hyperbolic partial differential equations. The results of the example are reported in Table and Figure. As it is seen, Taylor polynomial solution method is of high accuracy. Also Table and Figure show the order of convergence of the scheme. It can be seen again the errors are decreasing as we rise N

Problem 1

We study the following problem [11].

The hyperbolic partial differential equation $(\alpha^2 = 1)$

$$\frac{\partial^2 u(x,t)}{\partial^2 t^2} = \frac{\partial^2 u(x,t)}{\partial^2 x^2}$$

with the conditions

$$\left.\begin{aligned} &u_t(x,0) = 0 \\ &u(0,t) = 0 \\ &u(l,t) = 0 \\ &u(x,0) = \sin(\pi x) \quad t > 0, \quad 0 \le x \le l \end{aligned}\right\}$$

The exact solution of this problem is

$$u_{ex}(x,t) = \sin(\pi x)\cos(\pi x).$$

By using the collocation points (16) for $N = 5$ and using the (27) fundamental matrix equation the problem is solved and we obtain solution function. The results obtained are shown in the table1. Also it can be seen absolute error function's graph in Figure 1.

$$\begin{aligned} u_5(x,t) = {} & 2.03723.10^{-15} + 3.11852\,x - 0.388089\,x^2 - 7.013322\,x^3 + 3.50661\,x^4 + 1.52795.10^{-12}\,x^5 - 2.07774.10^{-13}\,y \\ & -25.5201\,xy - 3.61195\,x^2y + 58.2641\,x^3y - 29.1321\,x^4y - 2.39101.10^{-11}\,x^5y + 1.3985.10^{-12}\,y^2 + 81.8083\,xy^2 \\ & +12.9535\,x^2y^2 - 189.524\,x^3y^2 + 94.7618\,x^4y^2 + 1.13268.10^{-10}x^5y^2 - 3.10895.10^{-12}y^3 - 126.051\,xy^3 \\ & -21.8908\,x^2y^3 + 295.885\,x^3y^3 - 147.942\,x^4y^3 - 2.26698.10^{-10}x^5y3 + 2.79863.10^{-12}y^4 + 93.1497\,xy^4 \\ & +17.4656\,x^2y^4 - 221.231\,x^3y^4 + 110.615\,x^4y^4 + 2.05649.10^{-10}\,x^5y^4 - 8.88243.10^{-13}y^5 - 26.5057\,xy^5 \\ & -5.30413\,x^2y^5 + 63.6196\,x^3y^5 - 31.8098\,x^4y^5 - 7.03148.10^{-11}\,x^5y^5 \end{aligned}$$

Table 1: The comparison of exact solution $u_{ex}(x,t)=\sin(\pi x)\cos(\pi x).$ and approximate solution $u_{20}(x,t)$ for $N=20$ Problem 1

	$t=0.2$		$t=0.5$		$t=1$	
x_i	$e_{ex}(x,t)$	$e_{20}(x,t)$	$e_{ex}(x,t)$	$e_{20}(x,t)$	$e_{ex}(x,t)$	$e_{20}(x,t)$
0	$6.13511.10^{-15}$	0	$5.32553.10^{-15}$	0	$1.90277.10^{-17}$	0
0.1	0.25	0.25	$6.13511.10^{-15}$	$1.89218.10^{-17}$	–0.309017	–0.309017
0.2	0.475528	0.475528	$3.66318.10^{-11}$	$3.59915.10^{-17}$	–0.587785	–0.587785
0.3	0.654508	0.654508	$7.8414.10^{-11}$	$4.9538.10^{-17}$	–0.809017	–0.809017
0.4	0.769421	0.769421	$9.13816.10^{-11}$	$5.82354.10^{-17}$	–0.951057	–0.951057
0.5	0.809017	0.809017	$4.58446.10^{-11}$	$6.12323.10^{-17}$	–1	–1
0.6	0.769421	0.769421	$-1.96982.10^{-11}$	$5.82354.10^{-17}$	–0.951057	–0.951057
0.7	0.654508	0.654508	$-4.53735.10^{-11}$	$4.9538.10^{-17}$	–0.809017	–0.809017
0.8	0.475528	0.475528	$-2.87762.10^{-11}$	$3.59915.10^{-17}$	–0.587785	–0.587785
0.9	0.25	0.25	$-8.14192.10^{-12}$	$1.89218.10^{-17}$	–0.309017	–0.309017
1.0	$-2.36105.10^{-15}$	0	$-3.799041.10^{-16}$	0	$1.86517.10^{-17}$	0

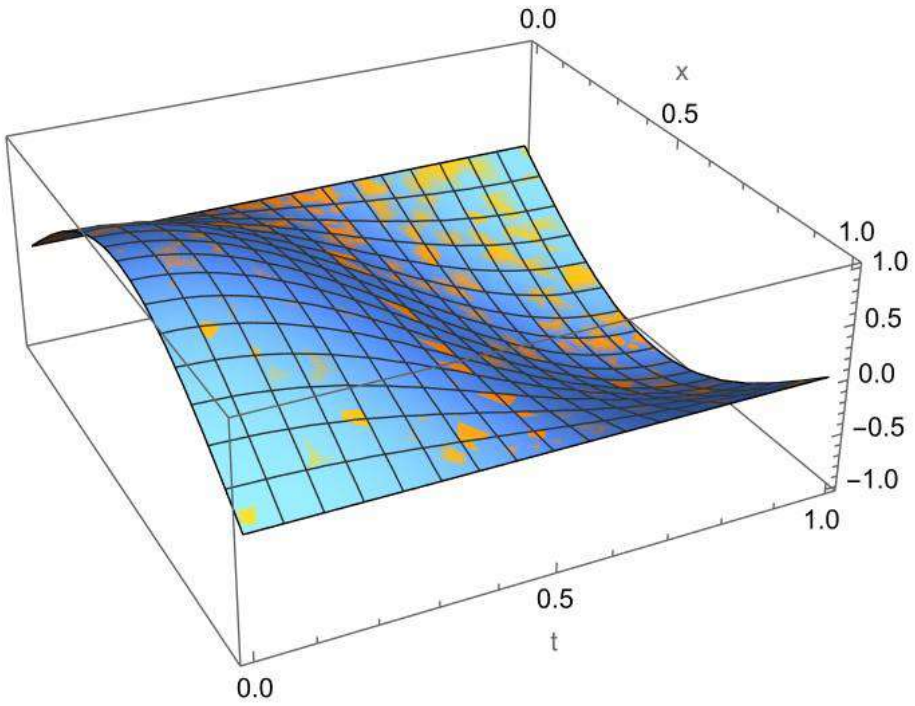

Figure 1: The approximate solution $u_{20}(x,t)$ compared with exact solution for Problem 1.

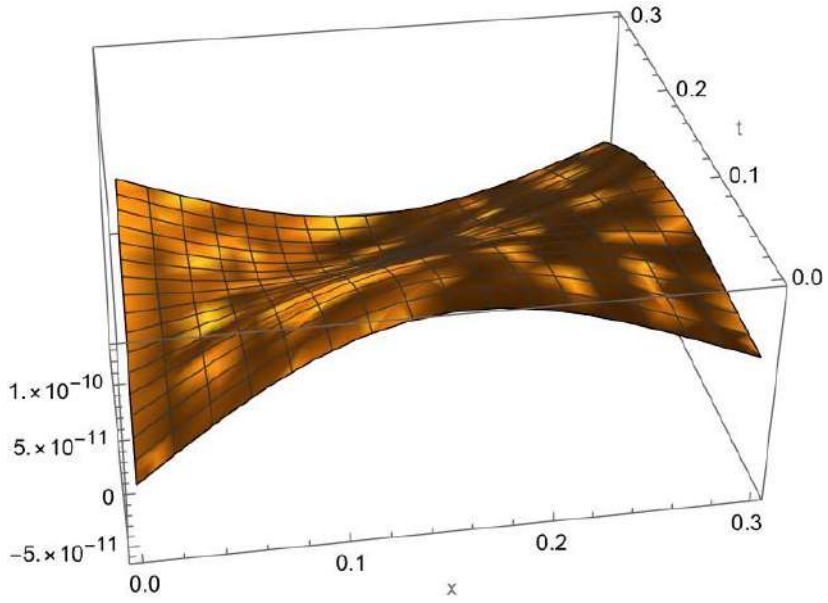

Figure 2: Graph of the absolute errors function of Problem 1 for N = 20.

Problem 2

We study the other following problem [11].

The hyperbolic partial differential equation $(\alpha^2 = 4)$

$$\frac{\partial^2 u(x,t)}{\partial^2 t^2} - 4\frac{\partial^2 u(x,t)}{\partial^2 x^2} = 0$$

with the conditions

$$\left.\begin{aligned} &u_t(x,0) = 0 \\ &u(0,t) = 0 \\ &u(l,t) = 0 \\ &u(x,0) = \sin(\pi x) \quad t > 0, \quad 0 \le x \le l \end{aligned}\right\}$$

The exact solution of this problem is

$$u_{ex}(x,t) = \sin(\pi x)\cos(2\pi x).$$

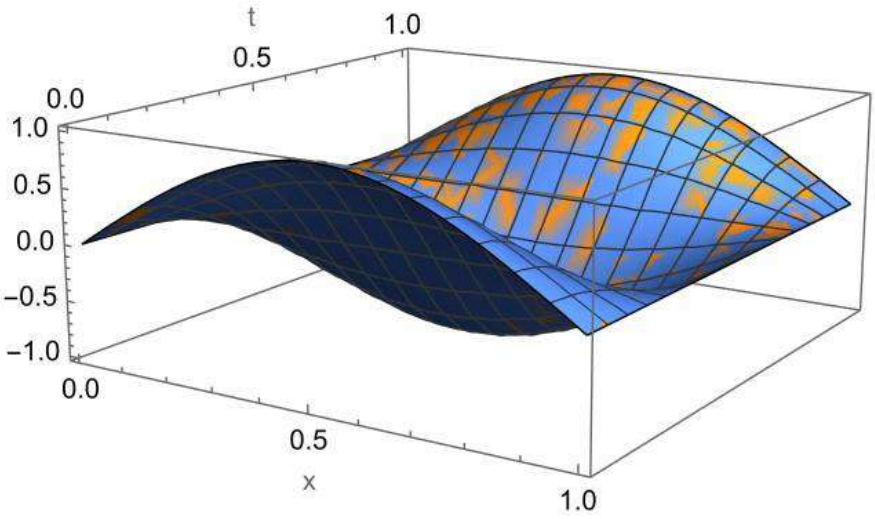

Figure 3: The approximate solution $u_{20}(x,t)$ compared with exact solution for Problem 2

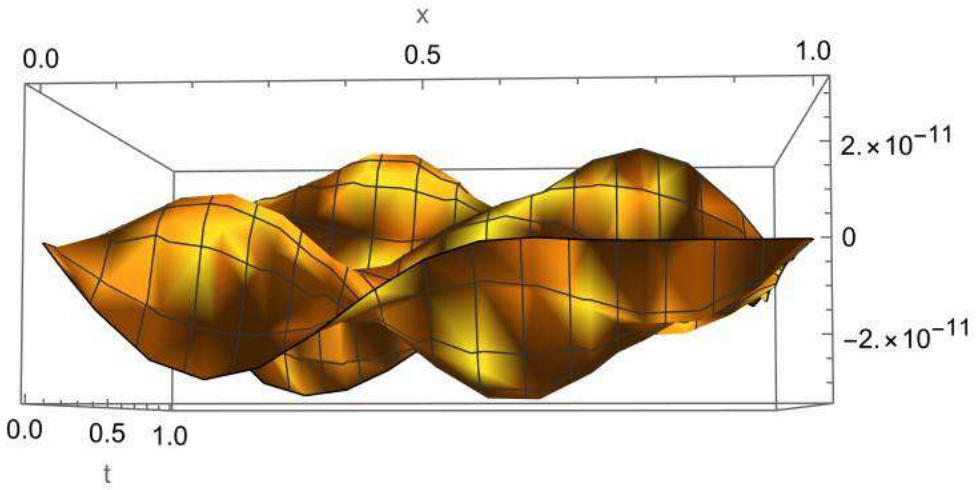

Figure 4: Graph of the absolute errors function of Problem 2 for N = 20

Conclusions

The article describes a new approach for solving hyperbolic partial differential equations using Taylor matrix-collocation techniques. The approach is shown to be efficient and accurate, yielding either exact solutions or high-accuracy approximations. The method is demonstrated through an illustrative example, and it is concluded that the approach is highly accurate, rapidly convergent, and easy to apply in various engineering problems. This new approach provides a good approximation for solving hyperbolic partial differential equations.

References

[1] Beattie B.A, Ochs K., 2022. Solving a One-Dimensional Moving Boundary Problem Based on Wave Digital Principles. https://doi.org/10.21203/rs.3.rs-2229820/v1

[2] Elmacı, D., Savaşaneril B., N., 2023. A New Computational Method to Solve the Boundary Value Problems Associated with Elliptic Partial Differential Equations. 8th International Congress on Life, Engineering, and Applied Sciences in a Changing World Proceedings Book, 168-179.

[3] Erdem Biçer K., Salih Yalçınbaş, 2016. A matrix approach to solving hyperbolic partial differential equations using Bernoulli polynomials. Filomat, Volume 30, Issue 4, Pages 993–1000.

[4] Ezgi Arkut, master's thesis, 2021.

[5] Gorguis A., Wai Kit Benny Chan W., K., B., 2008.Heat equation and its comparative solutions.Computers and Mathematics with Applications 55 (2008) 2973–2980.

[6] Hirpho, M., 2022. Numerical Solution of the Heat Transfer Equation Coupled with the Darcy Flow Using the Finite Element Method. Hindawi Abstract and Applied Analysis Volume 2022, Article ID 5108445, 9 pages. https://doi.org/10.1155/2022/5108445

[7] Kurt Bahşi, A., Yalçınbas, S. 2016. A new for the Nuymerical Solution of Telegraph Equaions by Using Fibonacci Polynomials. Math.Comput.Appl.21(2), 15

[8] Kurt, N 2008. Solution of the two-dimensional heat equation for a square in terms of elliptic functions. Journal of the Franklin Institute, 345(3): 303–317.

[9] Kurt, N., Sezer, M 2006. Solution of Dirichlet problem for a triangle region in terms of elliptic functions. Applied Mathematics and Computation, 182(1): 73–81.

[10] Kürkçü O., K., Sezer, M.2022. A new characteristic numerical approach with evolutionary residual error analysis to nonlinear boundary value problems occurring in heat and mass transfer via combinatoric Mittag-Leffler polynomial. Numerical Heat Transfer, Part A: Applications, 82:9, 561-575. https://doi.org/10.1080/10407782.2022.2079838

[11] Richard L. Burden and J. Douglas Faires, Numerical Analysis. (Boston: Richard Stratton, 2011).

[12] Savaşaneril, N. B., Hacıoğlu, Z., 2018. Bernstein Series Approximation for Dirichlet Problem. Gazi University Journal of Science, 31(2): 544–553.

[13] Savasaneril N. B, and Delibas. H., Analytic solution for two-dimensional heat equation for an ellipse region NTMSCI 4, No. 1, 65-70 (2016)

[14] Vaidya N., V., Deshpande A., A., Pidurkar, S.,R., 2021. Solution of heat equation (Partial Differential Equation) by various methods. J. Phys.: Conf. Ser. 1913 012144.

New Polygonal Numbers Identity by using Animation Proof Technique

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Abstract

Polygonal numbers are a special set of numbers that arise in geometry, specifically in the study of polygon shapes. These numbers have a rich history in mathematics and continue to be an area of active research and investigation in various mathematical disciplines. In this study, a brief introduction to the two-dimensional figurated numbers known as polygonal numbers is provided. Then a new polygonal numbers theorem about them is proved by using animation proof technique.

Keywords: Visual proof, animation proof technique, polygonal numbers.
MSC: 11A67, 11B75.

Introduction and Motivation

Proof has been used to understand almost everything since the beginning of mathematics in facilitating human life. "***Proof without words***" or "***visual proof***" is an effective visual method used to demonstrate mathematical concepts directly. It uses visual aids, such as diagrams or graphs, to prove the validity of a statement or theorem. These types of proofs can be useful in all areas of mathematics, including geometry and topology, where concepts and relationships can be difficult to grasp using only algebraic or symbolic notation.

Visual proofs been used for a very long time. Martin Gardner's article, which was published in the Scientific American in 1973, was the first to highlight the significance of "look – see" diagrams in modern history [1]. However, the earliest known "Proof without Words" in academic publications began in 1977 with J. Barry Love's article "Proof without Words: Cubes and Squares" [2]. Roger Nelsen also wrote a widely acclaimed book [3] in 1993, in which he compiled some examples of visual proofs. Following the publication of this book, two additional volumes [4] and [5] were released in 2000 and 2016. In his article titled "What makes a good Proof without Words?", Gerry Leversha, in 2021, explained how a good visual proof should be and what the standards are for it to be considered valid [6].

In classical civilizations such as ancient Greece, Rome, China, and 12th century India, many scientists, mathematicians, and philosophers used geometric shapes to represent operations with integers. These shapes were known as figurative numbers. It is one of the oldest concepts, combining numbers and shapes. Many renowned mathematicians, such as Pythagoras, Diophantus, Fibonacci, Euclid, Fermat and Euler, had studied figurative numbers. And many mathematicians continue to study them today. Basically, figurate numbers (such as polygonal numbers, platonic numbers, pyramidal numbers, polychoron numbers etc.) are numbers that can be represented by a regular and discrete geometric pattern of evenly spaced points [7]. Polygonal numbers are a form of two-dimensional figurate numbers.

Although the term *"**polygonal numbers**"* is not explicitly listed in the MSC System, it holds a significant place in the field of mathematics. Despite the common perception that polygonal numbers are not considered a pure mathematics subject, recent studies have shown that it is a topic of interest for many mathematics departments and researchers.

Additionally, polygonal numbers have a playful aspect that makes them a valuable addition to both pure mathematics and mathematics education. Various equalities related to polygonal numbers have been proved in many articles [8] and [9] Also Lagrange's Four Squares Theorem, Legendre's Three Squares Theorem, Gauss' Eureka Theorem, Cauchy's Polygonal Number Theorem, Fermat's Polygonal Number Theorem and many more theorems are associated with polygonal numbers [10].

Presently, the majority of academic journals are published in a hybrid (online and hardcopy) or fully online format. This trend has led to an increase in the number of digital journals with dynamic features and full-color illustrations. Typically, these journals are published as PDF files to facilitate viewing. With the latest version of Adobe Acrobat Reader [11], it is now possible to include moving images in

PDF files, and the LaTeX package "*animate*" supports the addition of animated shapes to pdf documents.

Consequently, with the development of technology, innovations are emerging in the field of mathematics, as in many other fields. Many academic journals have started to publish online issues instead of hard copies. Using animation visual proofs in articles can be a common result of these developments.

In this study, the animation proof technique is used by using moving images without changing the basic principles of visual proofs. The real motivation is to find a generalized formulation between sets of polygonal numbers, rather than making connections each other with examples by using animation proof technique.

Preliminaries

Definition 1: For $m=3,4,5,\ldots$ and $n\in\mathbb{N}$, some polygonal numbers formulas are as follows;

$S_m(n) := \dfrac{n\left((m-2)n-m+4\right)}{2}$; n-th m-gonal numbers

$\bar{S}_m(n) := S_m(-n) = \dfrac{n\left((m-2)n+m-4\right)}{2}$; n-th second m-gonal numbers

$CS_m(n) := \dfrac{mn^2-mn+2}{2}$; n-th centered m-gonal numbers

These are well-known polygonal numbers [7].

Example 1: For $n=1,2,3,4$ and $m=3,4,5,6$, some polygonal numbers and centered polygonal numbers are as follows [12];

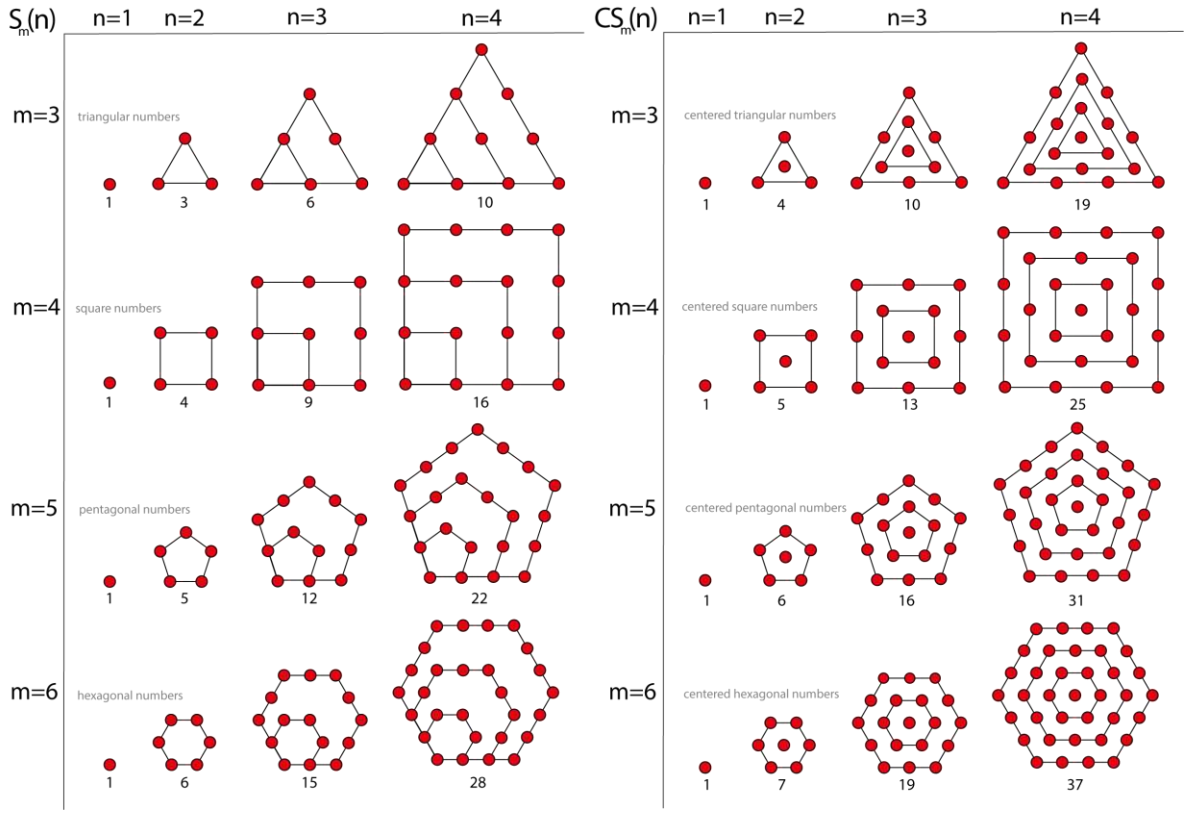


Figure 1: Polygonal numbers and centered polygonal numbers

- 3-gonal(triangular) numbers: $S_3(n)=\dfrac{n(n+1)}{2}$ [A000217, 13].
- 4-gonal(square) numbers: $S_4(n)=n^2$ [A000290, 13].

- 5-gonal(pentagonal) numbers: $S_5(n)=\dfrac{n(3n-1)}{2}$ [A000326, 13].
- 6-gonal(hexagonal) numbers: $S_6(n)=n(2n-1)$ [A000384, 13].
- Centered 3-gonal numbers: $CS_3(n)=\dfrac{3n(n-1)}{2}+1$ [A005448, 13].
- Centered 4-gonal numbers: $CS_4(n)=2n(n-1)+1$ [A001844, 13].
- Centered 5-gonal numbers: $CS_5(n)=\dfrac{5n(n-1)}{2}+1$ [A005891, 13].
- Centered 6-gonal numbers: $CS_6(n)=3n(n-1)+1$ [A003215, 13].

Main Theorem

In this section, the Animation Proof Technique is utilized to demonstrate the new polygonal numbers theorem through the use of moving images, while maintaining the fundamental principles of visual proofs.

Theorem 1: For $a=3,4,5,\ldots$, $b=3,4,5,\ldots$ and $n\in\mathbb{N}$ the following identity holds:

$$\underbrace{CS_a(n)}_{\substack{\text{centered}\\ \text{polygonal}\\ \text{numbers}}}-\underbrace{S_b(n)}_{\substack{\text{ordinary}\\ \text{polygonal}\\ \text{numbers}}}=\underbrace{\bar{S}_{(a-b+4)}(n-1)}_{\substack{\text{second}\\ \text{polygonal}\\ \text{numbers}}}.$$

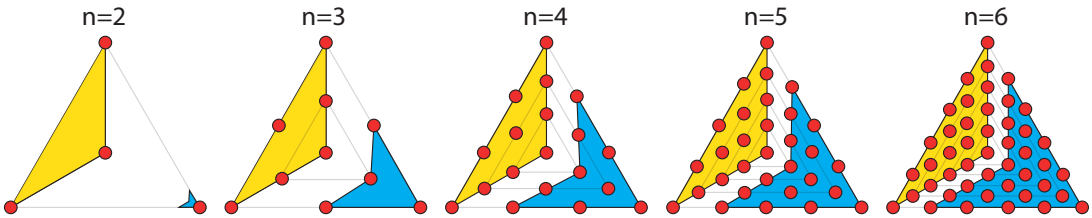
Proof.

$$\begin{aligned}
CS_a(n)-S_b(n)&=\frac{an^2-an+2}{2}-\frac{n((b-2)n-b+4)}{2}\\
&=\frac{an^2-an+2-n(bn-2n-b+4)}{2}\\
&=\frac{an^2-an+2-bn^2+2n^2+bn-4n}{2}\\
&=\frac{an^2-bn^2+2n^2-2n-an+bn-2n+2}{2}\\
&=\frac{(n-1)(an-bn+2n-2)}{2}\\
&=\frac{(n-1)((a-b+2)n-2+a-a+b-b)}{2}\\
&=\frac{(n-1)((a-b+2)n-(a-b+2)+a-b)}{2}\\
&=\frac{(n-1)((a-b+2)(n-1)+a-b)}{2}\\
&=\frac{(n-1)((a-b+4-2)(n-1)+a-b+4-4)}{2}\\
&=\bar{S}_{(a-b+4)}(n-1)
\end{aligned}$$

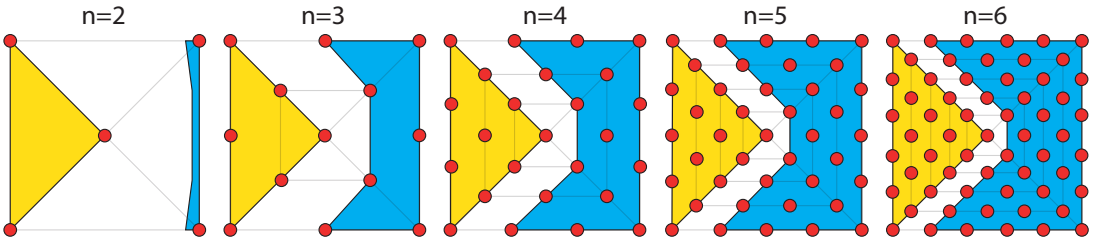
It can be understood from the theorem, when the polygonal numbers are subtracted from the centered polygonal numbers, the result gives the second polygonal numbers.

■

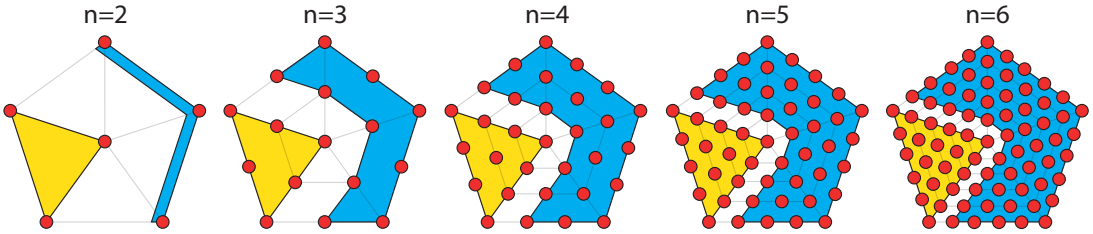
Visual Proof. Shapes may not be able to move in some PDF viewers. To ensure proper viewing, please use a compatible PDF viewer such as "Adobe Acrobat Reader".



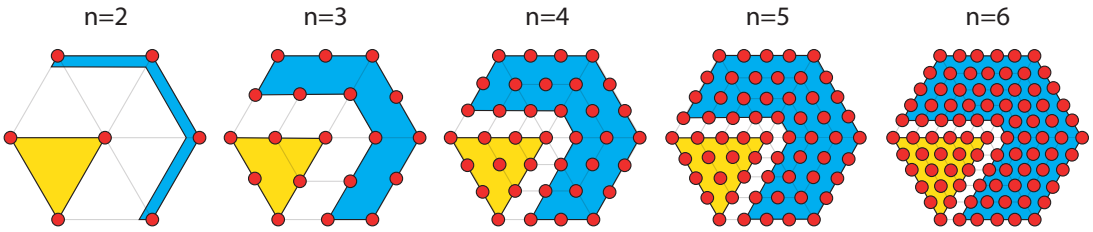
- $CS_3(n) - S_3(n) = \bar{S}_4(n-1)$ (c. triangular-triangular=s. square)



- $CS_4(n) - S_3(n) = \bar{S}_5(n-1)$ (c. square-triangular=s. pentagonal)
- $CS_4(n) - S_4(n) = \bar{S}_4(n-1)$ (c. square-square=s. square)



- $CS_5(n) - S_3(n) = \bar{S}_6(n-1)$ (c. pentagonal-triangular=s. hexagonal)
- $CS_5(n) - S_4(n) = \bar{S}_5(n-1)$ (c. pentagonal-square=s. pentagonal)
- $CS_5(n) - S_5(n) = \bar{S}_4(n-1)$ (c. pentagonal-pentagonal=s. square)



- $CS_6(n) - S_3(n) = \bar{S}_7(n-1)$ (c. hexagonal-triangular=s. heptagonal)
- $CS_6(n) - S_4(n) = \bar{S}_6(n-1)$ (c. hexagonal-square=s. hexagonal)
- $CS_6(n) - S_5(n) = \bar{S}_5(n-1)$ (c. hexagonal-pentagonal=s. pentagonal)
- $CS_6(n) - S_6(n) = \bar{S}_4(n-1)$ (c. hexagonal-hexagonal=s. square)

■

Conclusions

As a result, it can be seen that all second polygonal numbers can be expressed using polygonal numbers and centered polygonal numbers. The set of second polygonal numbers is defined for negative integers, and so it can be considered as a kind of extension of the ordinary polygonal numbers. The strong relationships between these numbers facilitate the proof of many theorems in different fields of mathematics. In addition, this study suggests that as technology advances, more visually engaging and dynamic proof techniques like the "animation proof technique" will become increasingly prevalent in new academic studies.

Gerry Leversha stresses the importance of using clear, simple, and effective images in visual proofs. Given the advancements in software technology, it is a positive development that moving images can now be included in article files published in digital media (such as PDFs) in addition to the traditional visual proofs. While this approach may not be a newly discovered method of proof, its benefits are undeniable.

References

[1] M. Gardner, Look-see'diagrams that offer visual proof of complex algebraic formulas, Mathematical Games column in. SciAm, 1973, 114-118.

[2] J. B. Love, Proof without words: Cubes and squares, Math. Mag. 50(2), 1977, 74.

[3] R. B. Nelsen, Proofs without Words: Exercises in Visual Thinking, MAA, 1993.

[4] R. B. Nelsen, Proofs without Words II: More Exercises in Visual Thinking, MAA 2000.

[5] R. B. Nelsen, Proofs without Words III: Further Exercises in Visual Thinking, MAA 2015.

[6] G. Leversha, What makes a good Proof without Words? Math. Gaz. 105(563), 2021, 271-281.

[7] E. Deza and M. M. Deza, Figurate numbers, World Scientific Publishing Co. Pte. Ltd., Singapore, 2012.

[8] G. Caglayan, Covering a triangular number with pentagonal numbers, Math. Intell. 42, 2020, 55.

[9] G. Caglayan, Proof Without Words: Centered Nonagonal Numbers are Triangular, Coll. Math. J. 51(5),2020, 371-371.

[10] O. Chipatala, Polygonal numbers, Kansas State University, 2016.

[11] Adobe Acrobat Reader, PDF viewer https://get.adobe.com/reader, 2023.

[12] U. Sarp, Visualising connections between types of polygonal number, Math. Gaz. 107(568), 2023, 56-64.

[13] OEIS,The On-Line Encyclopedia of Integer Sequences Foun. Inc. \url{http://oeis.org}, 2023.

Auxetic Thin-Walled Square Tubes Subjected to Oblique Loading

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Abstract

The use of auxetic structures with a negative Poisson's ratio in thin-walled tubes, which are widely used in many fields, is one of the topics discussed recently. This is because re-entrant auxetic tubes are generally more resistant to loads such as compression and impact than conventional honeycomb structures due to their high indentation resistance. However, there is limited information in the literature regarding the use of these structures on different sides of the thin-walled tube. In addition, there are few studies on how the compressive behavior of the re-entrant auxetic structure changes when subjected to an oblique load.

In this study, the effect of oblique loading on thin-walled square tubes with re-entrant and traditional honeycomb structures on the sides was investigated numerically. The side faces of the tubes were designed using auxetic re-entrant and conventional honeycomb cells with constant ligament properties. Four different types of square tubes were created with the designed re-entrant auxetic and conventional honeycomb side faces. These structures are; all side faces re-entrant (RRRR), all side faces honeycomb (HHHH), opposite side faces re-entrant-honeycomb (RHRH), and adjacent side faces re-entrant-honeycomb (RRHH). Oblique loads were applied to the edges and corners of these structures and their behavior was examined. The results showed that the use of different lattice structures on the thin-walled tubes significantly affected their behavior.

Keywords: Re-entrant square tubes, conventional honeycomb tubes, negative Poisson's ratio, oblique load, numerical analysis

Introduction

The use of auxetic structures in thin-walled tubes is widely used in many fields such as crush tubes [1], stents [2], and offshore tubular structures [3]. This is because auxetic tubes are generally more resistant to loads such as compression and impact than conventional honeycomb structures due to their high indentation resistance. Ren et al. studied foam-filled auxetic tubes for examination of the energy absorption performance under axial compression. It is shown that foam-filled auxetic tubes exhibit superior specific energy absorption compared with hollow auxetic tubes and non-auxetic foam-filled tubes [4]. Simpson et al. under quasi-static compressive loading, investigated the crashworthiness of thin-walled tubes filled with auxetic and conventional lattices. They compared lattice-filled auxetic tubes to empty and non-auxetic ones. They showed that the expansion of auxetic re-entrant structures further developed the crashworthiness execution by 64% compared with an empty tube [5]. Doudaran et al. investigated the effects of auxetic and non-auxetic structures in cylindrical tube walls on energy absorption capability. In quasi-static loading, they discovered that auxetic re-entrant structures have a greater peak force and force-crushing efficiency than non-auxetic structures [6]. Even though there are studies on auxetic and non-auxetic structures in tubes, the studies used together have not been found in the literature. In addition, there are few studies on how oblique load affects the re-entrant auxetic structure's compression behavior. It is important to determine this because not only the axial load acts under operating conditions. In this reason, the effect of oblique loading on thin-walled square tubes with re-entrant and traditional honeycomb structures on the side faces was investigated numerically. Four square tubes were created as re-entrant auxetic and conventional honeycomb side faces. 100N constant magnitude of force was applied to the edges and corners of the tubes and compression behavior was examined.

Materials and Methods

In this study, designs were created using auxetic re-entrant and traditional honeycomb cells. The parameters of the re-entrant and conventional honeycomb cell architectures, which are horizontal ligament length of H = 15 mm, re-entrant ligament length of L = 8.11 mm, ligament thickness of t = 3 mm, and re-entrant angle of = 60° given in Figure 1. The side surfaces of the tube were formed by repetitive design of unit auxetic and non-auxetic cells side by side. The cross-sectional geometry of each square tube taken into consideration for this investigation is 72 x 72 mm. In order to merge corner joints for the re-entrant and honeycomb lateral surface ligaments, these dimensions were selected. The 200 mm total tube length and 5 mm wall thickness are shown in Figure 1b. Four various types of square tubes were created. These include (a) all side faces re-entrant (RRRR), (b) all side faces honeycomb (HHHH), (c) opposite side faces re-entrant-honeycomb (RHRH), and (d) neighboring side faces re-entrant-honeycomb (RRHH), top view of the square tubes were depicted in Figure 2.

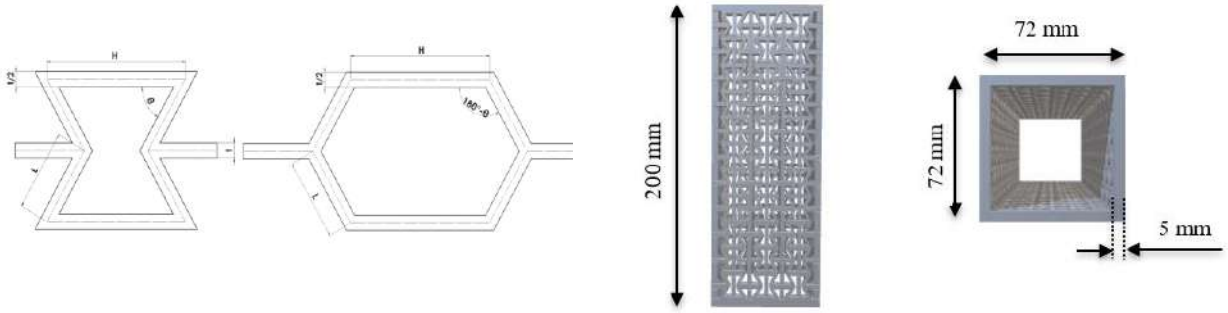


Figure 1. The unit cell parameters of a) re-entrant, b) honeycomb, and c) re-entrant tube parameters

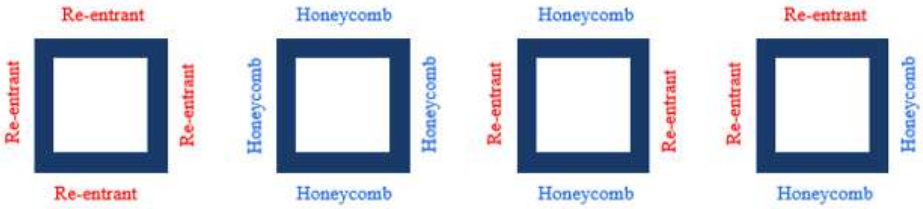


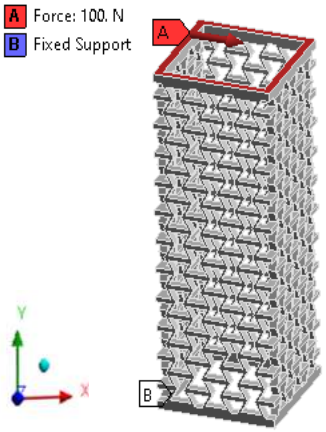
Figure 2. Square tubes with a) all side faces re-entrant (RRRR), b) all side faces honeycomb (HHHH), c) opposite side faces re-entrant-honeycomb (RHRH), and d) neighboring side faces re-entrant-honeycomb (RRHH)

Finite Element Modeling

In order to determine the compression performance of the auxetic re-entrant and conventional honeycomb tubes, the finite element models were created for the RRRR, RHRH, RRHH, and HHHH square tubes using ANSYS Workbench R19.2 software. The tube was considered as a solid element and the static analysis was carried out using 1mm mesh size that was determined with mesh convergence. The tube material was chosen as structural steel from the material library. The movement of the bottom surface of the square tube is restricted. The upper surface of the specimen was compressed by applying a force of constant magnitude as 100 N but at different angles from 0° to 180° according to y axis at xy and yz plane. Boundary conditions and magnitudes of force components according to angle were described in Figure 3. The applied force components are defined for the xy and yz planes as Eq.1 and Eq. 2.

$$F_{xy}= 100.[(\cos\theta)\ \mathbf{i}\text{-}(\sin\theta)\ \mathbf{j}+0\ \mathbf{k}] \quad \text{Eq. 1}$$

$$F_{zy}= 100.[0\ \mathbf{i}\text{-}(\sin\theta)\ \mathbf{j}+(\cos\theta)\ \mathbf{k}] \quad \text{Eq. 2}$$



Fxy= 100x[(cosθ)i-(sinθ)j+0k] Fzy= 100x[0i-(sinθ)j+(cosθ)k]

		Force x-y				Force y-z				
		xi	yj	zk		xi	yj	zk		
θ	0	100	0	0		0	0	100	θ	0
θ	15	96.6	-25.8	0		0	-25.8	96.6	θ	15
θ	30	86.6	-50	0		0	-50	86.6	θ	30
θ	45	70.71	-70.71	0		0	-70.71	70.71	θ	45
θ	60	50	-86.6	0		0	-86.6	50	θ	60
θ	75	25.8	-96.6	0		0	-96.6	25.8	θ	75
θ	90	0	-100	0		0	-100	0	θ	90
θ	105	-25.8	-96.6	0		0	-96.6	-25.8	θ	105
θ	120	-50	-86.6	0		0	-86.6	-50	θ	120
θ	135	-70.71	-70.71	0		0	-70.71	-70.71	θ	135
θ	150	-86.6	-50	0		0	-50	-86.6	θ	150
θ	165	-96.6	-25.8	0		0	-25.8	-96.6	θ	165
θ	180	-100	0	0		0	0	-100	θ	180

Figure 3. a) Description of the applied angle θ=0° applied in the xy plane and boundary conditions, b) magnitudes of force component according to angle

Result and Discussions

In this study, the equivalent stress caused in different types of thin-walled auxetic and non-auxetic tubes by the oblique load applied at an angle from 0 to 180 degrees in two different planes, xy and yz, and having a constant magnitude was investigated. These square tube types were all side faces re-entrant (RRRR), all side faces honeycomb (HHHH), opposite side faces re-entrant-honeycomb (RHRH), and neighboring side faces re-entrant-honeycomb (RRHH). The equivalent stress values obtained in Figure 4 and Figure 5 are graphically depicted. When the equivalent stress values caused by the forces applied in both the xy and yz planes are examined for the 90° angle, it is seen that the tube whose all side faces re-entrant (RRRR) has the lowest equivalent stress value as 2.283MPa, and the highest equivalent stress value is 7.420 MPa in the tube with all side faces honeycomb (HHHH). The equivalent stress values of tubes with opposite side face re-entrant-honeycomb (RHRH), and neighboring side faces re-entrant-honeycomb (RRHH) are 5.985MPa and 6.901MPa, respectively. When the force is applied at 0° angle, the equivalent stress values for RRRR, RHRH, RRHH, and HHHH tubes were found to be 16.495MPa, 36.630 MPa, 41.140 MPa, and 51.617 MPa, respectively. Although the equivalent stress difference between the tubes as increased the % change between RRRR and HHHH for each angle was examined, and it was seen that this ratio was 69% as a constant value. With the increase in the number of auxetic surfaces, there is a decrease in the equivalent stress values. For all tubes, the equivalent stress value was obtained as a minimum by applying the force in the axial -y direction. As the angle becomes perpendicular to the y-axis, the equivalent stress value increases because the force component will cause the moment.

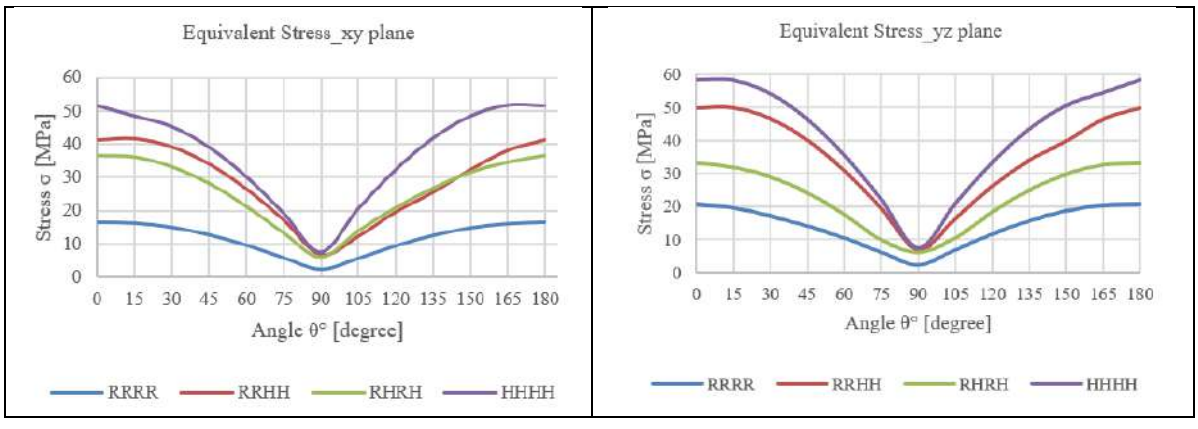
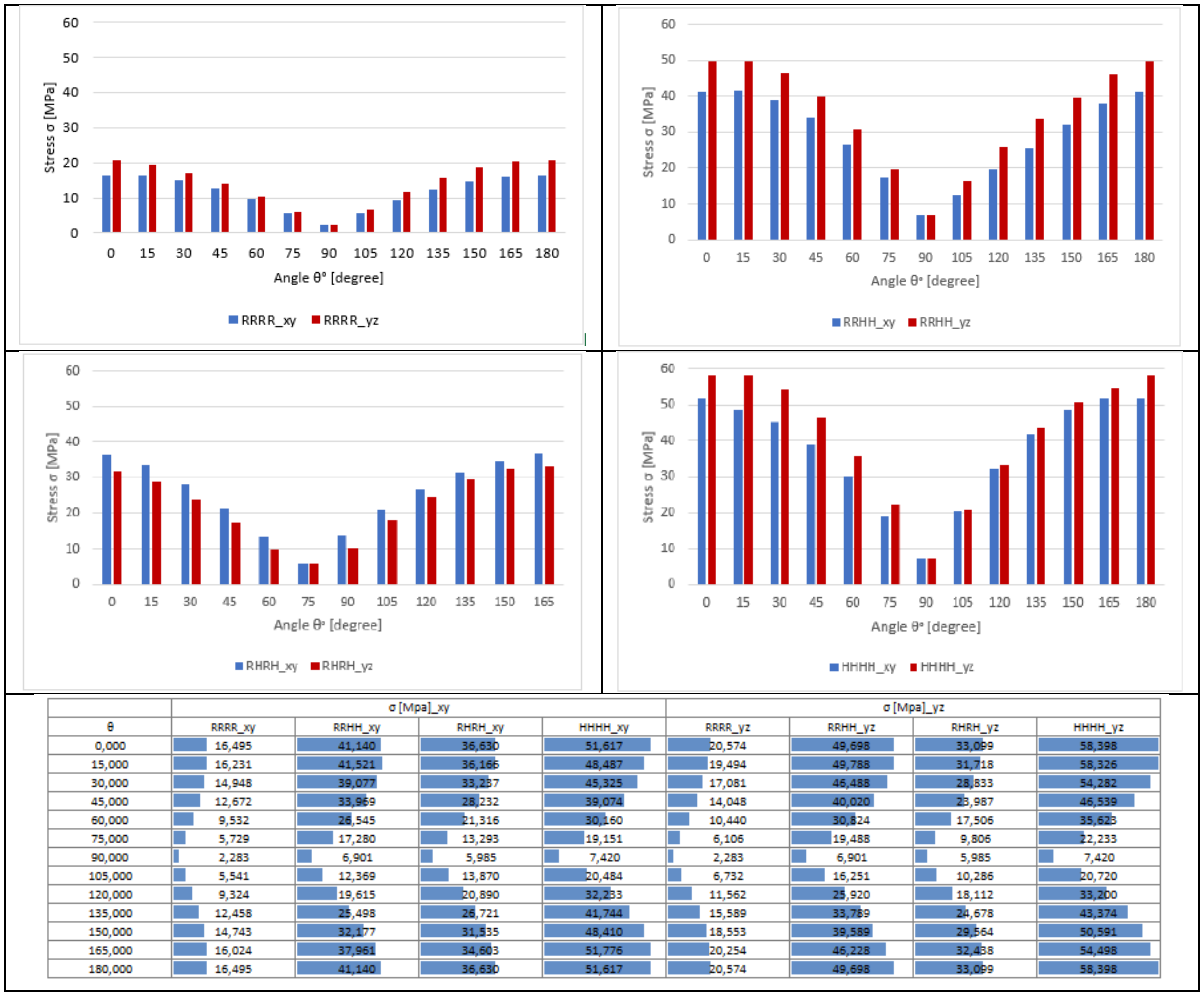


Figure 4. Equivalent stress magnitudes according to angles from 0° to 180° at a) xy plane b) yz plane

As seen in Figures 4 and 5, the use of re-entrant on the lateral surfaces is very important as it reduces the equivalent stress. However, since equivalent stress values of the RRHH and RHRH tubes are close to each other, where the reentrant surface is located is not as important as the surface number. In addition, when all the tubes were examined, it was seen that the equivalent stress values of the forces acting in the xy and yz planes in each tube were very close to each other for the same angle.



	σ [Mpa]_xy				σ [Mpa]_yz			
θ	RRRR_xy	RRHH_xy	RHRH_xy	HHHH_xy	RRRR_yz	RRHH_yz	RHRH_yz	HHHH_yz
0,000	16,495	41,140	36,630	51,617	20,574	49,698	33,099	58,398
15,000	16,231	41,521	36,166	48,487	19,494	49,788	31,718	58,326
30,000	14,948	39,077	33,287	45,325	17,081	46,488	28,333	54,282
45,000	12,672	33,959	28,232	39,074	14,048	40,020	23,987	46,539
60,000	9,532	26,545	21,316	30,160	10,440	30,824	17,506	35,623
75,000	5,729	17,280	13,293	19,151	6,106	19,488	9,806	22,233
90,000	2,283	6,901	5,985	7,420	2,283	6,901	5,985	7,420
105,000	5,541	12,369	13,870	20,484	6,732	16,251	10,286	20,720
120,000	9,324	19,615	20,890	32,233	11,562	25,920	18,112	33,200
135,000	12,458	25,498	26,721	41,744	15,589	33,789	24,678	43,374
150,000	14,743	32,177	31,535	48,410	18,553	39,589	29,564	50,591
165,000	16,024	37,961	34,603	51,776	20,254	46,228	32,438	54,498
180,000	16,495	41,140	36,630	51,617	20,574	49,698	33,099	58,398

Figure 5. Equivalent stresses a) (RRRR), b) (HHHH), c) (RHRH), and d) (RRHH)

Conclusion

The results showed that:

- The re-entrant structure considerably reduces the equivalent stress of the tube.
- The use of different lattice structures on the thin-walled tubes significantly affected compression behavior.
- If the force acts perpendicular to the pipe axis, the value of the equivalent stress increases because the force component causes the moment.

References

1. Hussain, N. N., Regalla, S. P., & Rao, Y. V. D. (2017). Low velocity impact characterization of glass fiber reinforced plastics for application of crash box. *Materials Today: Proceedings*, *4*(2), 3252-3262.
2. Bhullar, S. K., Ko, J., Cho, Y., & Jun, M. B. (2015). Fabrication and characterization of nonwoven auxetic polymer stent. *Polymer-Plastics Technology and Engineering*, *54*(15), 1553-1559.
3. Yu, Z., & Amdahl, J. (2018). A review of structural responses and design of offshore tubular structures subjected to ship impacts. *Ocean Engineering*, *154*, 177-203.
4. Ren, X., Zhang, Y., Han, C. Z., Han, D., Zhang, X. Y., Zhang, X. G., & Xie, Y. M. (2022). Mechanical properties of foam-filled auxetic circular tubes: Experimental and numerical study. Thin-Walled Structures, 170, 108584.
5. Simpson, J., & Kazancı, Z. (2020). Crushing investigation of crash boxes filled with honeycomb and re-entrant (auxetic) lattices. *Thin-Walled Structures*, *150*, 106676.
6. Doudaran, M. O., Ahmadi, H., & Liaghat, G. (2022). Crushing performance of auxetic tubes under quasi-static and impact loading. *Journal of the Brazilian Society of Mechanical Sciences and Engineering*, *44*(6), 230.

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Torque Vectoring on Front Wheel Drive Vehicle with Hub Motors

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Abstract

Nowadays electric vehicles (EVs) which are equivalent to fossil fuel vehicles and run on more environmentally friendly fuels, have become popular in the automotive industry. So EVs have very common use areas in that field. Driving stability and safety are also of great importance in these widely used vehicles. In this sense, torque vectoring (TV) appears as the most modern approach.TV control systems provide the distribution of torque to the wheels by the effect of the yaw moment. The application of torque vectoring in vehicles reduces power losses in the motor driver and the vehicle's power consumption. Using efficient torque vectoring algorithms for electric vehicles, this research describes existing and emerging vehicle technology related to yaw moment management and traction control. The article provides the allocation of wheel torques for a two-wheel drive all electric vehicle with individually controlled engines. Lateral dynamics and moment dynamics were used in the construction of this torque allocation. In addition, the lateral velocity and yaw rate of the vehicle related to the specified inputs were calculated from the nonlinear front wheel drive vehicle model which was designed by MATLAB. The reference yaw rate and the yaw rate, which is the output of the system, were compared and the error in between and the Proportional Integral Derivative (PID) controller were fed. The hub motor, which is widely used in electric vehicles and is easy to control, was used as the engine in the system. While increasing the control on this vehicle, the designed torque vectoring system also increased the stability and driving performance during turning.

Keywords: Torque vectoring, yaw rate, PID, front wheel drive, hub motors

Introduction

In the modern era, EV are comparable to fossil fuel vehicles and run on cleaner fuels, have gained popularity in the automotive industry. Hence, in that industry, EV use is widespread. In these frequently used cars, driving steadiness and safety are also of utmost importance. TV looks to be the most cutting-edge strategy in this regard. [1] TV control systems use the yaw moment's influence to distribute torque to the wheels. Vehicles' power consumption and motor driver power losses are both decreased by the use of TV. The use of hub motors in electric vehicles has facilitated the application of torque vectoring. The torque of each motor is adjusted with the application of torque vectoring, and its independent rotation is provided.

The main building block of the torque vectoring implementation is the yaw rate control. In this sense, it was used in the yaw rate control of the torque vector by integrating feedforward (FF) contribution and PID.[2] In this study, PID is combined with FF because it does not provide enough smoothness for yaw rate control. But FF is utilized to improve system performance even more during the transient phase. Additionally, FF is dependent on the estimated tire-road friction coefficient, which could cause problems with vehicle drivability in a continuously operating system and does not ensure robustness.

Canale et al. used second order sliding mode (SOSM) for yaw control [3]. A SOSM is a dynamic system's movement restricted to a specific subspace. The fundamental benefit of SOSM control is that in the event of a system with a relative degree of one it generates a continuous control action resulting in a reduction of the so-called chattering effect. In this study, which is based on the SOSM controller, the selected sliding variable is the error between the actual yaw rate and the reference yaw rate. Using the controller makes it possible to ensure that the error approaches zero in a finite time. Thus, when it comes to model uncertainties and disruptions, SOSM guarantees robust stability.

Goggia et al. used integrated sliding mode for torque vector distribution control [4]. This controller unlike the SOSM controller, a first-order low-pass filter is used to prevent high-frequency oscillations

and crackling to eliminate discontinuity in the control action. Selecting the time constant in the filter at the appropriate value prevents the display of significant oscillations that can be detected by passengers in the vehicle. The initial condition selection on the controller forces it to start from the first sampling moment in a sliding mode without any reaching phase transition. Thus, the convergence process coincides with the start time and the controller captures the reference value better.

Canale et al. used the model predictive controller (MPC) [5]. The controller uses a reference model to minimize the predicted difference between the future responses and the desired responses of the system.[5] The model is implemented as a difference equation, which is frequently generated from a model equation of a linear system or from a linearized equation of a non-linear system at equilibrium locations. When a nonlinear system is linearized, the problem arises because the linearized equation is only valid close to an equilibrium point, and in limit handling situations, the tires may be operating very far from their equilibrium. It is suggested that the linearization be done at general non-equilibrium locations to lessen this error, allowing MPC implementation to use an effective linear MPC algorithm.

A feedback control matrix was developed in the study using a gainfully timed linear–quadratic regulator (LQR) technique, accounting for steps in speed and lateral acceleration every two milliseconds [6]. The controller serves as a limiter as a result of the matrix mismatch, and the swift controller movement lowers the energy lost. As a result, the control power is cheap and control input cost matrix (R) can be arbitrarily selected to be modest in comparison to state cost matrix (Q). According to parameter incompatibility, the model shown high sensitivity when this control structure was used. It is possible to expand the control system with four integrators to remedy this condition.

In this study, the control of the yaw rate part was carried out with the PID controller and this PID controller was tuned and turned into a suitable controller for the system of front wheel drive vehicles. The main reason it is controlled by PID in operation is because the feedback controller provides strong stability, adequate damping and desired readiness.

As a result of these checks, the yaw rate coming out of the system has largely caught the reference yaw rate. After this step, torque distributions are provided for the right and left wheels.

Vehicle Model

In the study, the double track model of front-wheel drive vehicles was used. There is no traction force for the rear wheels as there is only the front wheel motor. The forces for the wheels were found according to the linear wheel model. As shown in Figure 1, the total moment on the M_z(z axis), the angle shown with r yaw rate, S(δ) is the steering angle that the steering wheel transfers to the wheels.

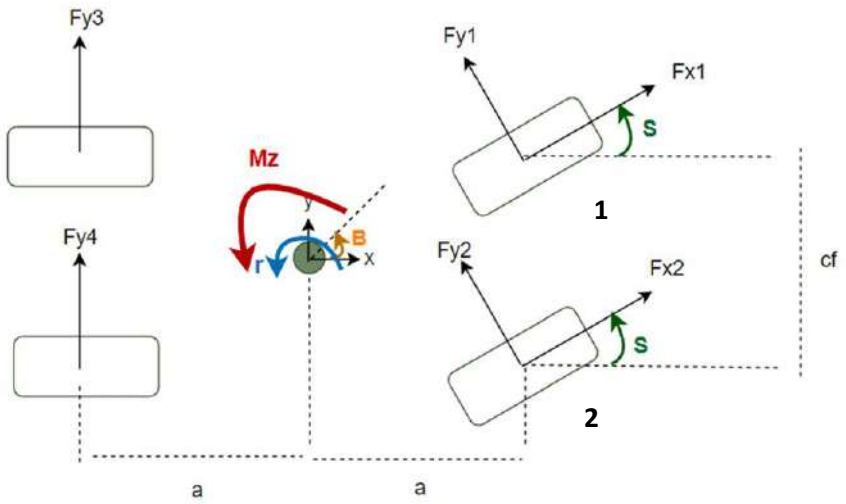

Figure 1. Double Track-Front Wheel Vehicle Model

In this project, a constant speed is intended hence the linear tire models (in Eq. 1) are used to determine the overall F_x. σ corresponds to slip ratio, α corresponds to slip angle and C_a corresponds to cornering stiffness about front and rear tire. Since the constant desired speed is assumed to be a known parameter, this simplification neglects the conversion of pedal pressures into a desired speed or force. In the system, steering angle and longitudinal speed are given as inputs. Outputs are lateral velocity, yaw rate and torques about each wheel.

$$Fx = C_{af} * \sigma \tag{1}$$

$$Fy = C_{\alpha f} * \alpha \tag{2}$$

For the model in which the dynamics of the vehicle for turns will be examined, the longitudinal dynamic has not been examined. Lateral dynamics and moment dynamics have been examined.

Looking at the moment dynamics:

$$J_z * \dot{r} = \left(-F_{x1}\cos\delta + F_{y1}\sin\delta + F_{x2}\cos\delta - F_{y2}\sin\delta\right)\frac{cf}{2} + \left(F_{x1}\sin\delta + F_{y1}\cos\delta + F_{x2}\sin\delta + F_{y2}\cos\delta - F_{y3} - F_{y4}\right)a \tag{3}$$

The distance indicated by a in the equation is the distance from the center of the vehicle to the front axle, c_f is the distance between the right and left wheels at the front and J_z is moment of inertia about z axis. In eq. 3, which makes use of the moment equation, the yaw rate produced by the system and required for rotation is found.

Looking at the lateral force dynamics:

$$F_{y1}\cos\delta + F_{y2}\cos\delta + F_{x1}\sin\delta + F_{x2}\sin\delta = m\left(\dot{V_y} + r * V_x\right) \tag{4}$$

When we examine the equation, F_x and F_y are found from the linear tire model. r and V_y(lateral velocity) appear as unknowns. By feeding the r found from the moment dynamics to this system, the velocity in the lateral plane (V_y) is found.

Control Design

In most cases, a vehicle control system's main goals are to increase the stability range of the vehicle and give the driver a regular driving experience under unforeseen driving circumstances. The motion of the vehicle can be largely controlled by correctly regulating the tire contact forces. As a result, the tire forces are used as the control actions in the suggested control methodology of this study.

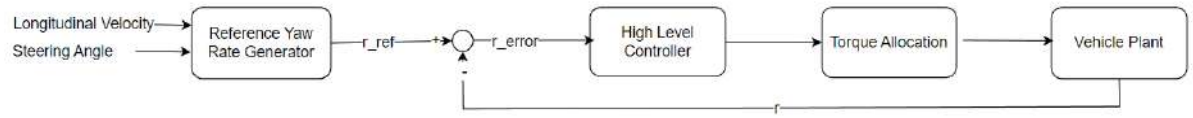

Figure 2. Controller structure

The vehicle model, which accepts input from the torque allocation and outputs the corresponding behavior of the car as measured in the variable r, is at the end of the control structure. This is the element of the feedback loop. In the reference yaw rate generator part, the reference yaw rate is calculated (eq. 5 [7]) depending on the steering angle and the longitudinal velocity. The difference between this reference value and the yaw rate obtained from the vehicle plant (the moment dynamics) is sent to the PID controller In Figure 2, the overall structure is displayed.

$$r_{desired} = \frac{V_x}{L + \frac{m * V_x * V_x * (a * C_{af} - a * C_{ar})}{2 * C_{af} * C_{ar} * L}} * \delta \tag{5}$$

Tracking with a short transient duration, fewer oscillations, robustness, and smoothness of the control law are desired properties of this controller.

Torque Allocation

The second block in Figure 2 is concerned with the distribution of torque; the optimizer is fed the required yaw moment and longitudinal drive/brake force, and it produces the values of the torques that the two motors must deliver to the wheels. If an online allocation without discretization is desired, the dynamics of this process must be significantly faster than the vehicle dynamics; of course, stability and resilience are also required.[8]

When energy saving wheel torque allocation is applied, eq. 6 and eq. 7 are found. In these equations, T_1 denotes net traction force for the first wheel. T_2 denotes net tarction force for the second wheel. There are torque commands sent to the wheels from the solution of two equations with two unknowns.

$$F_x * R = T_1 * cos\delta + T_2 * cos\delta \quad (6)$$

$$M_z * R = \left(-\frac{cf}{2} * cos\delta + a * sin\delta\right) T_1 + \left(\frac{cf}{2} * cos\delta + a * sin\delta\right) T_2 \quad (7)$$

Simulation Studies

The simulations and findings from the work described in the other chapters are presented in this chapter. Simulink, an integrated piece of software, was used to implement simulations while MATLAB was used for all calculations. All simulations are rough recreations of real events under certain simplifications, certain assumptions and referenced model parameters in Ghezzi's master's thesis [9].

The following assumptions are made: the vehicle is moving at a constant and known speed, all the vehicle characteristics involved are known or measurably accurate, and the delay caused by the control signal's travel time to the motors is disregarded.

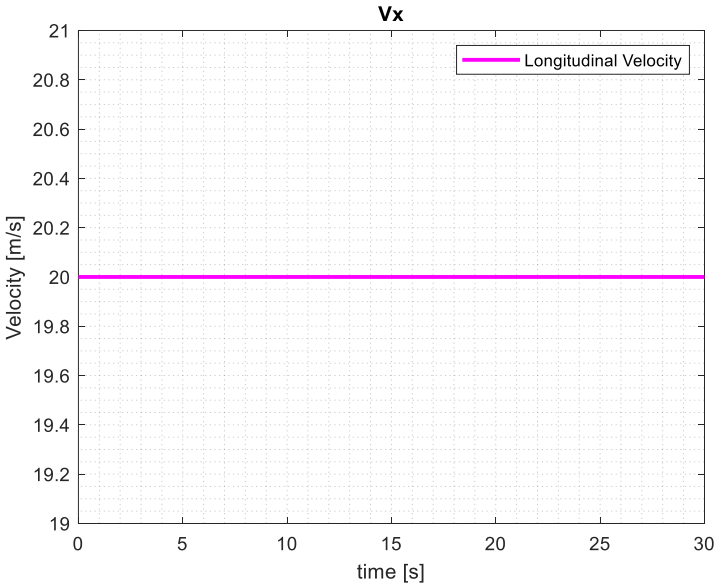

Figure 3. Vehicle longitudinal velocity

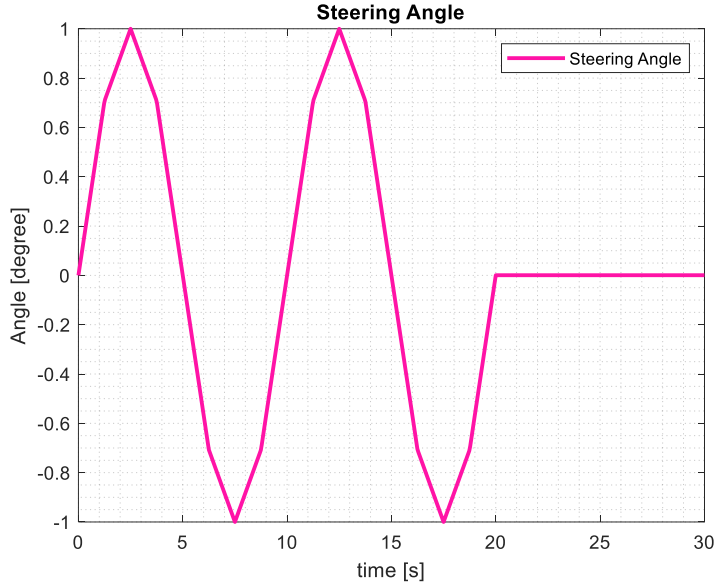

Figure 4. Steering angle input

The longitudinal speed is 20m/s as shown in Figure 3 and the steering angle as in Figure 4 are inputs applied to the vehicle. When the simulation is run based on these inputs, it is expected that the torque outputs of the wheels and the yaw rate will follow this input.

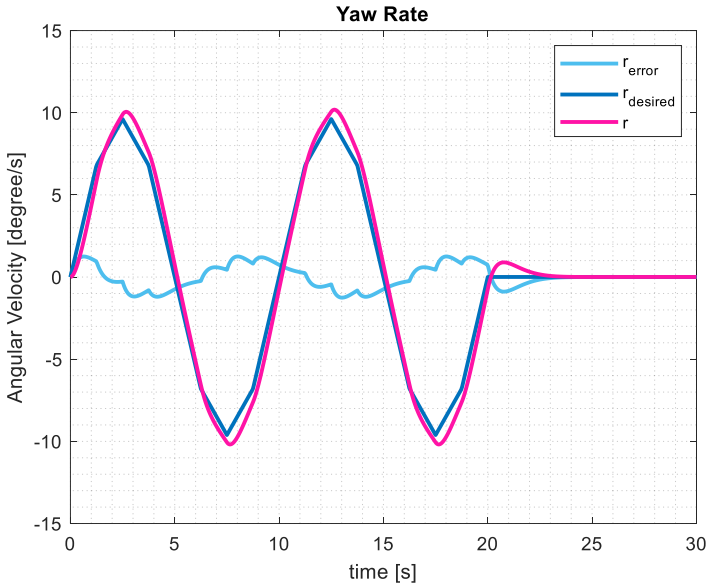

Figure 5. Yaw rate desired and actual demonstration

It is observed that the reference yaw rate and the yaw rate produced by the system catch each other with the PID controller and give an output similar to the steering angle in Figure 5. This output shows that the system provides the necessary stability when controlled by PID.

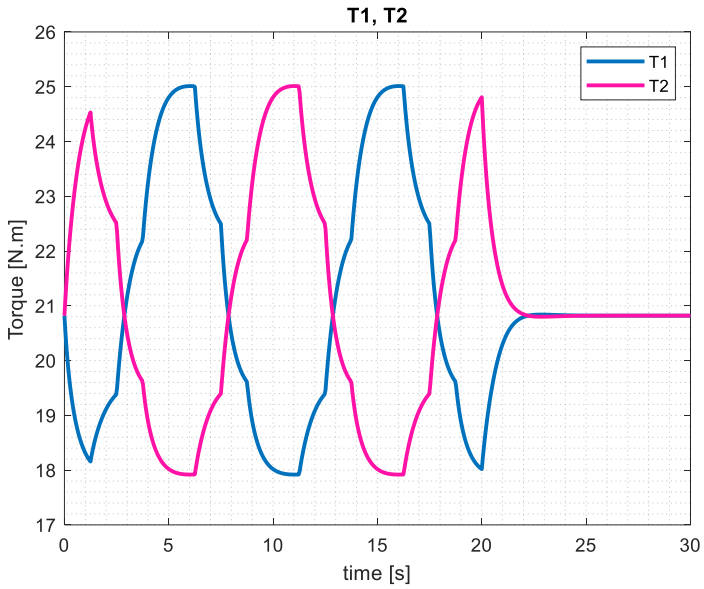

Figure 6. Torques distributed to the wheels

As can be seen in Figure 6, torques also give output similar to the steering angle.

When we examine the input angle, the wheels of the vehicle move at a constant longitudinal speed and steering wheel turned left to right successively. Considering this, when the vehicle maneuvers to the left, we consider the vehicle model specified in the second part and we expect the number two wheel to produce more torque in order to take the corner in the same radius. The main reason why the number two wheel produces more torque is that the second wheel (shown in Figure 1) is on the outside of the bend in the left turn in the base vehicle model, therefore, the distance traveled is more than the first wheel.

If we think with the same logic, this time the first wheel (shown in Figure 1) will stay on the outside of the corner, so it must produce more torque.

The steering angle given as input is reset after the 20th second, but there is a delay of approximately 2 to 3 seconds in the designed system. The reason for this delay is that the system dynamics of the vehicle is bulky.

At the time after the system delay, the torques settle to a constant value. The main reason for the torques to be fixed at another value, not zero, is that the longitudinal speed of the vehicle is constant, and the vehicle is in progress.

As can be seen from the graphic description, the system returns stable response with PID control.

Conclusions

In this study, the system of a front-wheel drive vehicle sends a separate torque command to each wheel according to the speed and steering angle of the vehicle, which provides vehicle dominance and power saving in corners. MATLAB-Simulink is used in the simulation and controller design procedure. Yaw rate and lateral vehicle speed are the most important parameters affecting the torque distribution. In order to obtain a more realistic approach, the dual-track vehicle model is used in a non-linear system instead of the single-track vehicle model. The purpose of the controller design is to send the torque command required for ideal turning to the system. It has been seen that yaw rate can be controlled with the torque command obtained as a result of the simulations. It has been seen that the PID control strategy can be used in torque vectoring applications against linear dynamics in the dual-track vehicle model.

References

[1] Knauder, B., Savitski, D., Theunissen, J., & De Novellis, L. (2014). Electric torque vectoring for electric vehicles. *ATZelektronik worldwide*, *9*(4), 50-55.

[2] De Novellis, L., Sorniotti, A., & Gruber, P. (2013). Optimal wheel torque distribution for a four-wheel-drive fully electric vehicle. *SAE International Journal of Passenger Cars-Mechanical Systems*, *6*(2013-01-0673), 128-136.

[3] Canale, M., Fagiano, L., Ferrara, A., & Vecchio, C. (2008). Vehicle yaw control via second-order sliding-mode technique. *IEEE Transactions on Industrial Electronics*, *55*(11), 3908-3916.

[4] Goggia, T., Sorniotti, A., De Novellis, L., & Ferrara, A. (2014, June). Torque-vectoring control in fully electric vehicles via integral sliding modes. In *2014 American control conference* (pp. 3918-3923). IEEE.

[5] Chang, S., & Gordon, T. J. (2007). Model-based predictive control of vehicle dynamics. *International Journal of Vehicle Autonomous Systems*, *5*(1-2), 3-27.

[6] Xiong, L., Yu, Z., Wang, Y., Yang, C., & Meng, Y. (2012). Vehicle dynamics control of four in-wheel motor drive electric vehicle using gain scheduling based on tyre cornering stiffness estimation. *Vehicle system dynamics*, *50*(6), 831-846.

[7] Rajamani, R. (2011). *Vehicle dynamics and control*. Springer Science & Business Media.

[8] Pennycott, A., De Novellis, L., Sabbatini, A., Gruber, P., & Sorniotti, A. (2014). Reducing the motor power losses of a four-wheel drive, fully electric vehicle via wheel torque allocation. *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, *228*(7), 830-839.

[9] Ghezzi, M. K. (2017). *Control of a four in-wheel motor drive electric vehicle* (Master's thesis, Universitat Politècnica de Catalunya).

Experimental Investigations on the Thermal Performance of an Office-Type Heat Recovery Ventilation System

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Abstract

Considering the global energy crises and climate change, the importance of energy recovery grows day by day. At this point, heat recovery ventilation (HRV) systems contribute energy saving by the help of heat exchange in between the cold and hot air streams. Furthermore, the Covid-19 pandemic shows us that ventilation is an inevitable part of heating, ventilation, air-conditioning and refrigeration (HVAC-R) systems to satisfy indoor air quality within the subregions of human-living constructions. In this experimental work, we use an industrial HRV system to examine the thermal performance under various air flow rates. The HRV unit mainly contains cold and hot stream fans, crossflow heat exchanger, air filter, and flow rate controller. The thermal scenarios are considered under winter climate conditions; therefore, temperature levels of the fresh and exhaust air streams are determined about 280K and 300K, respectively. In addition, thermal investigations are conducted with different mass flow rates. The temperatures are measured via thermocouples and collected by a precise multi-channel data logger. The results indicate that the investigated HRV system contribute both indoor air quality (complies with ASHRAE 62.1 standard) and reduction of air conditioning energy consumption.

Keywords: Heat recovery ventilation, indoor air quality, heat transfer

Introduction

Energy demand of the countries is sharply rising in parallel with the population, and today we commonly hear the energy crisis term due to strategic plans of nations. One of the primary energy concerns of European Union (EU) nations is the reduction of energy consumption in various end-use industries, particularly buildings [1]. EU member states aim to decrease overall energy consumption in buildings by improving building insulation and tightness [2,3]. In new and retrofitted buildings, depending on the insulation, compactness and air exchange, ventilation loads can account for 20-50% of the total air-conditioning demand to satisfy the indoor air quality parameters [4-6].

HVAC (Heating, Ventilation and Air Conditioning) systems are installed to provide ventilation, heating, cooling needs and also humidity control in buildings [7]. HVAC systems, whose primary purpose is to provide and maintain desired indoor air conditions, are reliable in long-term operations, and their maintenance is simple [8,9]. The main components of HVAC systems are the condenser, expansion valve, evaporator, compressor, and fans [10,11]. The importance of ventilation systems in the HVAC industry has raised due to the Covid 19 pandemic [12]. The main purpose of ventilation systems is to increase the indoor air quality of the environment and to provide comfortable ambient conditions for the people in the environment. Given the growing awareness of the health effects of poor indoor air quality, along with growing concerns about energy efficiency and environmental sustainability, the design and performance of ventilation systems has been a critical focus. Traditional ventilation systems work by exchanging indoor air with outdoor air to maintain air quality and remove moisture, odours, and pollutants [13]. However, this exchange of air can also result in a loss of heat, which can lead to increased energy consumption and costs. On the other hand, heat recovery ventilation (HRV) systems are designed to recover heat from the outgoing air and transfer it to the incoming air, thus these systems reduce the amount of heat lost during ventilation operation. HRV systems not only improve energy efficiency, but also help to maintain a consistent indoor temperature and air quality [14,15]. The HRV units basically include air-to-air heat exchanger(s), fan systems, filters and controllers [16]. The basic working principle of HRV units is to ensure heat exchange between the exhaust and clean air streams for transferring the heat energy in the air to the fresh air [17-19]. Heat recovery ventilation devices provide significant energy savings depending on the heating system and climatic conditions [20]. Fouih et al. [21] concluded that the adequacy of HRV systems in buildings with low energy consumption in

France varies according to the building type, heating loads, and ventilation device characteristics. Hamid et al. [19] studied on ventilation models in historical buildings and showed that HRV systems provide annual energy savings in the range of 24-39 kWh/m^2 in historical buildings. The results indicated that this energy-saving corresponds to 29-47% of the total energy consumption of offices. Evola et al. [22] investigated the energy demand of buildings located in different cities in Italy. The research outcomes provide that HRV systems' energy savings vary between 20% and 90% compared to traditional mechanical ventilation and natural ventilation systems, respectively. On the other hand, Logue et al. [23] documented that adding an HRV system to homes located in different regions of the USA increases the overall energy consumption due to the energy consumed by the fans.

In this experimental investigation, experiments have been carried out by operating an industrial HRV unit. The indoor air quality and personal comfort requirements of the investigated case are determined via ASHRAE 55[24] and ASHRAE 62.1[25] standards. The thermal scenario is selected as 280 K for the outdoor temperature and 300 K for the indoor temperature to ensure a 20 K temperature difference in winter conditions for observing the heat interaction among the cold and hot streams. One scenario has been investigated for same flow rates at the cold and hot sides. We used thermocouples and a data logger system to measure the instant measurement variations during the experiments. Temperature changes in the cold-hot air streams and heat transfer rates recovered by the HRV system have been documented in detail.

Method and Model

Ventilation Requirements

In this experimental investigation, we examine the thermal performance of an industrial HRV device to satisfy the indoor air quality requirements complying with the ASHRAE 62.1 standard. The investigated case is an educational office (62.5 m²) domain with 12 graduate students. First, the outdoor air inlet flow (V_{ot}) is calculated for to maintain the indoor air quality of the ventilated environment and to keep the domain at an adequate oxygen level. At this stage, the breathing zone outdoor airflow (V_{bz}) should be determined as follows:

$$V_{bz} = R_p \,.\, P_z + R_a \,.\, A_z \tag{1}$$

where, R_p is the outdoor airflow rate required per person, and R_a is the outdoor airflow rate required per unit area taken from the ASHRAE 62.1 an office space. Likewise, P_z is the number of people in the ventilation zone, and A_z is the net occupiable floor area of the ventilation zone. The zone outdoor airflow (V_{oz}) supplied to the ventilation zone by the supply air distribution system will be determined according to the following Equation.

$$V_{oz} = \frac{V_{bz}}{E_z} \tag{2}$$

E_z is the zone air distribution effectiveness taken from ASHRAE 62.1 standard. The outdoor air intake flow (V_{ot}) for single zone ventilation systems with one supply air stream shall be determined in accordance with the following equation:

$$V_{\mathbf{ot}} = V_{oz} \tag{3}$$

Next, the minimum primary airflow (V_{pz-min}) has been calculated to maintain the zone's indoor air quality. A safety factor of 1.5 is taken from the ASHRAE 62.1 standard, and the minimum primary airflow is obtained by:

$$V_{pz\text{-}min} = V_{oz} \,.\, 1{,}5 \tag{4}$$

After calculating the outdoor inlet flow and minimum primary air flow values, the average velocity and mass flow rates are calculated via the following equation set:

$$\dot{V} = V_{avg}.A_c \tag{5}$$

$$\dot{m} = \rho.V_{avg}.A_c \tag{6}$$

where A_{cs} is the cross-sectional area of the duct lines, ρ is the density of the air streams at specific temperature levels, $\dot{V}$ is the volumetric flow rate, and $\dot{m}$ corresponds to the mass flow rates. The total amount of heat transfer rates between the cold and hot streams are calculated by [26]:

$$\mathbf{Q} = \dot{m} \cdot c_p . \Delta T \quad (7)$$

In Eq. 7, Q is the heat transfer rate, c_p is the specific heat capacity of the streams, and ΔT is the temperature difference between the heat exchanger inlet and outlet. After these calculations, thermal efficiency of the supply and exhaust air streams is calculated according to the EN 308 [27] standard in which these part is called as the temperature ratio.

$$\eta_{t,eha} = \frac{t_{11} - \Delta t_{11} - t_{12} + \Delta t_{12}}{t_{11} + \Delta t_{11} - t_{21} - \Delta t_{21}} \quad (8)$$

$$\eta_{t,sup} = \frac{t_{22} - \Delta t_{22} - t_{21} + \Delta t_{21}}{t_{11} + \Delta t_{11} - t_{21} - \Delta t_{21}} \quad (9)$$

$$\eta_{t,epb} = \frac{\eta_{t,eha} + \eta_{t,sup}}{2} \quad (10)$$

Here, $\eta_{t,exh}$ is the exhaust side temperature ratio, $\eta_{t,sup}$ is the supply side temperature ratio, and $\eta_{t,mtr}$ is the mean temperature ratio. On the other hand, t_{11}, t_{12}, t_{21}, and t_{22} are the abbreviation of indoor air temperature, exhaust air temperature, outdoor air temperature, and supply air temperature, respectively. Likewise, Δt_{11}, Δt_{12}, Δt_{21}, and Δt_{22} are the correction factors of the formulas explained above, yet these parameters are negligible in our operations.

Thermal Experiments

A case study under winter climate conditions was selected to observe the thermal performance of the investigated heat recovery ventilation system. The HRV unit has two identical inlets and outlets (Fig. 1) for the supply and exhaust air streams.

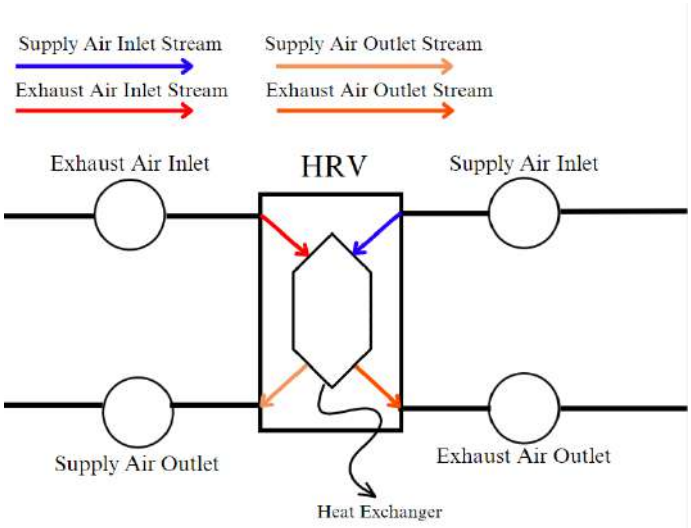

Figure 1. Schematic of the HRV unit and flow streams.

Diameter of the inlet/outlet sections is 125 mm. Note that the pipelines are made by thermally low conductive thermoplastics to eliminate the thermal losses as much as possible. Furthermore, the inlet-outlet lines of the HRV system (Fig. 2) are wrapped with polyurethane foam for thermal insulation.

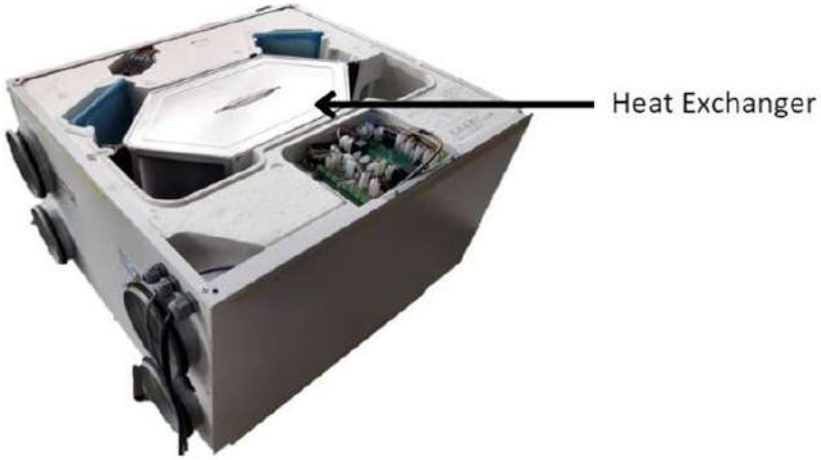

Figure 2. HRV system used in the experiments.

Inside the HRV device, a cross-counter plate type heat exchanger is placed to transfer the heat from exhaust air to fresh air streams. Figure 3 presents the utilized heat exchanger system. The heat exchanger used in the experiments is a plate type heat exchanger with 73 plates. The material of the plates is high-density polyethene and thermal conductivity ratio is 0.51 W/mK [28].

Figure 3. Counter-cross flow heat exchanger within the HRV system.

Fresh air at about 280 K is sucked with an insulated piping system so that the heat losses are assumed as negligible. During the experiment, 4 PVC pipes and three elbows have been used. The diameter of the pipes used in the experiment is 125 mm. On the other hand, TYPE-K (Ni-Cr) type thermocouples are used at the exhaust and supply air outlets to measure the temperature levels. The data logger basically calculates the operating logic of thermocouples by measuring the temperature according to the voltage difference that occurs in the temperature changes of different materials. IMC CS-7008-1 (Fig. 4) data logger was used to measure and log the experimental data.

Figure 4. Multichannel datalogger unit and connections.

Once connecting the data logger to the computer in an accurate way (see Fig. 5), required test settings were applied and defined into the software interface. Then, supply air inlet and exhaust air outlet graphics were created via the collected temperature data.

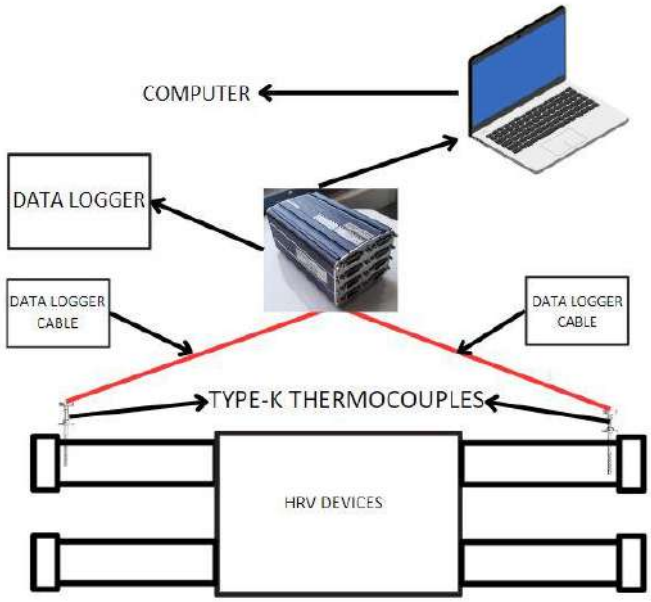

Figure 5. The experimental setup schematic

Centrifugal radial fans are used inside the heat recovery ventilation system to push the cold and hot streams, i.e., fresh and exhaust air flows. Figure 6 presents the radial fan system used during the experiments. Note that two identical centrifugal radial fans have been used in the experiments to control the volume flow rate level of the fresh and exhaust air streams. To find the mass flow rate of the fans, first we measured the average velocity with an anemometer. The measured average velocity level was then multiplied by the surface cross-section area and density. Calculation of the mass flow rate is crucial as the heat transfer rates of the cold and hot streams are directly depended on the mass flow rate level experienced at the fresh and exhaust air pipelines.

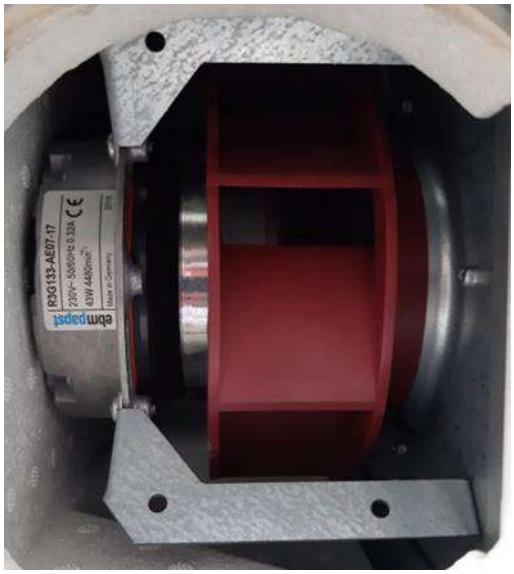

Figure 6. Radials fans in HVAC

Results and Discussion

In this section, the volumetric flow rates satisfying the indoor air quality requirements of the selected ventilation are calculated via Eq.1-4 that are taken from the ASHRAE 62.1 standard. Since the single zone R&D office space is considered in the study, the R_p and R_a values from the breathing zone chart in ASHRAE are taken as 2.5 L/s and 0.3 L/s per unit area, respectively. Then the mass flow rate is calculated by making the necessary measurements in the heat recovery ventilation device via Eq. 5,6. As a result of the measurement made with the anemometer, an average air velocity of 8,7 m/s was measured for the exhaust air outlet, while the level is about 8.1 m/s for the supply air outlet. Before calculating the mass flow rate, we need to calculate the volumetric flow, so we find the volumetric flow by multiplying it by the pipe's cross-sectional area. Finally, the volumetric flow rates are calculated as 440.9 m^3/h and 465.42 m^3/h for the exhaust air and supply air streams, respectively.

Table 1. Thermo physical properties and heat transfer rates of exhaust and supply air streams.

	Exhaust Air	**Supply Air**
$\mathbf{A_s}$ (m^2)	0.012272	0.012272
$\mathbf{V_{Mean}}$ (m/s)	8.7	8.1
$\dot{\boldsymbol{V}}$ (m^3/h)	440.908	465.420
ρ (kg/ m^3)	1.2109	1.2321
$\dot{\boldsymbol{m}}$ (kg/s)	0.129	0.122
$\mathbf{C_p}$ (J/Kg. K)	1007	1006.5
Δ**T** (K)	7.5	7.5
Q (W)	976.413	924.530

where, A_s is the heat transfer surface area, V_{mean} is the mean velocity measured at the fresh air and exhaust air pipelines, $\dot{\boldsymbol{V}}$ is the required volumetric flow rate satisfying the indoor air quality conditions, ρ is the density of the fluid streams, $\dot{\boldsymbol{m}}$ denotes the mass flow rate of each flow stream, $\mathbf{C_p}$ is the specific heat capacity at constant pressure, ΔT corresponds the temperature difference experienced between the inlet and outlet of the cold and hot air streams, and Q is the heat transfer rate of the exhaust and fresh air flows.

The fact that the supply air flow is higher than the exhaust air flow allows us to improve indoor air quality and keep humidity level at a desired level. The mass flow rate is obtained by multiplying the calculated volumetric flow values with the density corresponding to the average temperatures obtained as a result of the experiments. Mass flow rates for the supply and exhaust air outlets are 0.122 and 0.129

kg/s respectively. Then, the heat transfer rates are calculated for the exhaust and supply air streams to check the accuracy of the calculations/measurements and possible thermal losses.

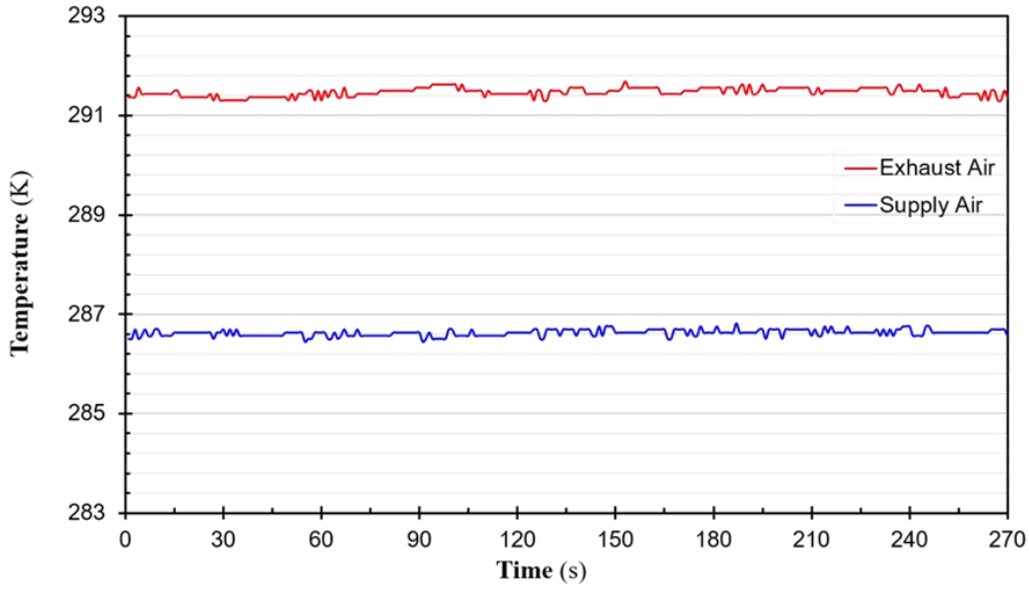

Figure 7. Steady state condition check for the temperature levels of each flow stream

Figure 8 shows that thermal results measured during the experiments. The red line in the graph represents the exhaust air, and the blue collared line corresponds to the fresh air streams. The results in the graph are obtained just after the system reaches to the steady state conditions (Fig. 7). An approximate temperature difference of 7.5 K was measured inside the heat exchanger for both exhaust air and supply air streams.

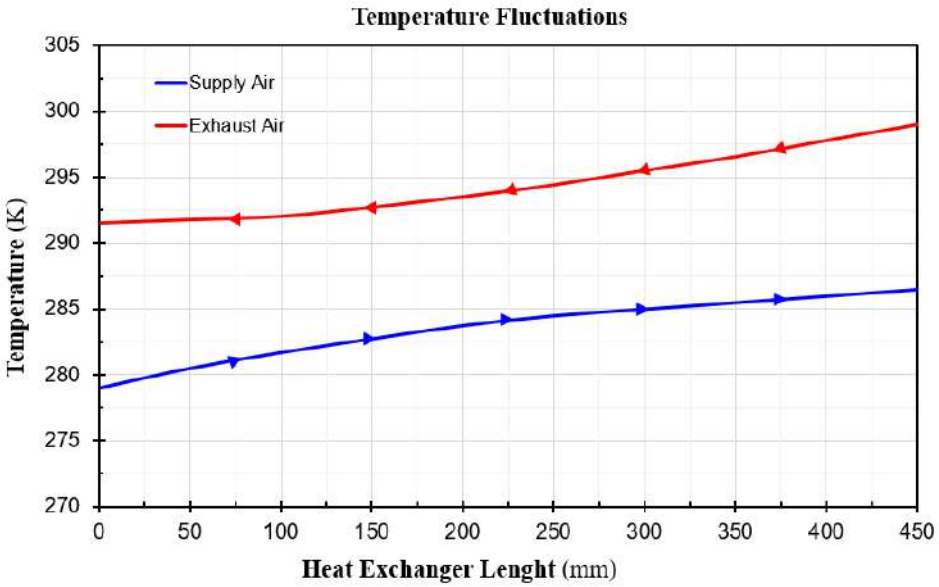

Figure 8. Temperature fluctuations in Heat Exchanger

The temperature, which was about 299 K at the exhaust air inlet, decreases to an average temperature level of 291.5 K at the exhaust air outlet. On the other hand, the supply air that is taken from the external environment to the interior was measured as about 279 K increased up to a mean temperature level of 286.5 K. The heat transfer rates calculated by using Eq. 7 are 976.41 W and 924.53 W for the exhaust and supply air, respectively. Note that we observed a thermal discrepancy of 5.31% among the cold and hot air streams. The discrepancy can be caused from the thermal losses experienced in the HRV unit and pipelines or uncertainties of the measurement devices [29]. Finally, we calculated the temperature ratio of the device according to Eq. 8-10, and the temperature ratio is of the investigated heat recovery ventilation system is 0.375.

Conclusion

In this work, experiments were carried out by operating an industrial heat recovery ventilation unit. While the ventilation process is running, the energy of the waste heat is recovered via a cross-counter plate type heat exchanger system placed within the HRV unit. The heat recovery process provides a reduction in the heating and cooling operations while satisfying the indoor air quality conditions. Main conclusions of the experimental investigation are given as follows:

- The exhaust and supply air volumetric flow rates ensuring the indoor air quality requirements (ASHRAE 62) are 440.9 m^3/h and 465.42 m^3/h for an R&D office with 12 researchers.
- Heat recovery process within the HRV unit heat exchanger system provides a 7.5K temperature increase at the cold fresh air stream. This temperature variation indicates the importance of heat recovery ventilation devices in air-conditioning energy consumption level.
- The heat transfer rates experienced within the HRV unit are 924.53 W and 976.41 W for the fresh and exhaust air streams, respectively.
- A thermal discrepancy of 5.31% was observed among the cold and hot air stream heat transfer levels. The physical reasons behind this discrepancy can be explained by uncertainties, thermal losses, and irreversibilities during the experiments.

References

[1] European Commission, EU-Directive 2010/31/EC of the European Parliament and of the council on the energy performance of buildings (recast); 19 May 2010

[2] C.A. Roulet, F.D. Heidt, F. Foradini, M.C. Pibiri, Real heat recovery with air handling units, Energy and Buildings (2001); 33; 495–502.

[3] A. Dodoo, L. Gustavsson, R. Sathre, Primary energy implications of ventilation heat recovery in residential buildings, Energy and Buildings (2011); 43;1566–1572.

[4] M. Orme, Estimates of the energy impact of ventilation and financial expenditures, Energy and Buildings (2001); 33(3); 199–205.

[5] M.W. Liddament, M. Orme, Energy and ventilation, Applied Thermal Engineering (1998); 18; (1998) 1101–1109.

[6] C.Simonson, Energy consumption and ventilation performance of naturally ventilated ecological house in a cold climate, Energy and Buildings (2005); 37; 23–35.

[7] M.Krarti, "Energy efficient systems and strategies for heating, ventilating, and air conditioning (HVAC) of buildings." *Journal of Green Building* (2008); 3; 44-55.

[8] N. Asim.; M. Badiei ; M.Mohammad ; H. Razali ; A. Rajabi; L. Chin Haw; M. Jameelah Ghazali, Sustainability of Heating, Ventilation and Air-Conditioning (HVAC) Systems in Buildings—An Overview. *Int. J. Environ. Res. Public Health* 2022; *19*; 1016.

[9] L.Lu, W.Cai, L. Xie, S.Li, Y.C.Soh ; "HVAC system optimization—in-building section." *Energy and Buildings* (2005); 37.1; 11-22.

[10] M.Trčka, and J.L.M. Hensen. "Overview of HVAC system simulation." *Automation in construction* (2010) ;19.2; 93-99.

[11] A.C.Hernandez III, N.Fumo. "A review of variable refrigerant flow HVAC system components for residential application." *International Journal of Refrigeration* (2020); 110; 47-57.

[12] M.Guo , P.Xu , T.Xiao , R. He , M.Dai , S.L. Miller. "Review and comparison of HVAC operation guidelines in different countries during the COVID-19 pandemic." *Building and environment* (2021); 187; 107368.

[13] K.W Cheong, K.Y Chong. "Development and application of an indoor air quality audit to an air-conditioned building in Singapore." *Building and Environment* (2001); 36.2; 181-188.

[14] P.M. Cuce, S.Riffat. "A comprehensive review of heat recovery systems for building applications." *Renewable and Sustainable Energy Reviews* (2015); 47; 665-682.

[15] R.M. Lazzarin ,A. Gasparella. Technical and economical analysis of heat recovery in building ventilation systems. *Applied thermal engineering* (1998); *18*(1-2); 47-67.

[16] M. Nasif, R. AL-Waked, G. Morrison , M. Behnia. "Membrane heat exchanger in HVAC energy recovery systems, systems energy analysis." *Energy and Buildings* (2010); 42.10; 1833-1840.

[17] E.Zender–Świercz. "A review of heat recovery in ventilation." *Energies* (2021); 14; 1759.

[18] A.Dodoo. "Primary energy and economic implications of ventilation heat recovery for a multi-family building in a Nordic climate." *Journal of Building Engineering* (2020); 31; 101391.

[19] A.A.Hamid, D.Johansson, H.Bagge. "Ventilation measures for heritage office buildings in temperate climate for improvement of energy performance and IEQ." *Energy and Buildings* (2020) ; 211; 109822.

[20] D. O'Connor, J.K.S. Calautit, B.R.Hughes. "A review of heat recovery technology for passive ventilation applications." *Renewable and Sustainable Energy Reviews* (2016); 54; 1481-1493.

[21] Y.E.Fouih, P.Stabat, P.Rivière, P.Hoang, V.Archambault. "Adequacy of air-to-air heat recovery ventilation system applied in low energy buildings." *Energy and Buildings* (2012) ; 54 29-39.

[22] G. Evola, A. Gagliano, L. Marletta, F. Nocera. "Controlled mechanical ventilation systems in residential buildings: Primary energy balances and financial issues." *Journal of Building Engineering* (2017); 11; 96-107.

[23] J.M. Logue, M.H. Sherman, I.S. Walker, B.C. Singer. "Energy impacts of envelope tightening and mechanical ventilation for the US residential sector." *Energy and Buildings* (2013); 65; 281-291

[24] American Society of Heating, Refrigerating and Air-Conditioning Engineers. (2017). ASHRAE Standard 55-2017. Thermal environmental conditions for human occupancy.

[25] American Society of Heating, Refrigerating and Air-Conditioning Engineers. (2019). ASHRAE Standard 62.1-2019. Ventilation for acceptable indoor air quality.

[26] Y.A.Cengel , A.J.Ghajar . *Heat and mass transfer: Fundamentals & applications*. McGraw-Hill Education. (2014) ; (5th edition)

[27] European Standard EN 308. Heat exchangers – test procedures for establishing performance of air to air and flue gases heat recovery devices. European committee for standardization; 1997.

[28] C-M.Ye, B-Q.Shentu, Z-X.Weng. "Thermal conductivity of high density polyethylene filled with graphite." *Journal of Applied Polymer Science* 101.6 (2006): 3806-3810.

[29] J.Fernández-Seara, R. Diz, F. J. Uhía, A.Dopazo, J.M. Ferro. "Experimental analysis of an air-to-air heat recovery unit for balanced ventilation systems in residential buildings." *Energy conversion and management*. (2011); 52; 635-640.

Quasi-Static Punch Shear Responses of Glass/Epoxy Composites Reinforced with Pinecone upon Immersion in Acidic and Basic Solutions

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Abstract

Nowadays, vehicles that are equivalent to fossil fuel vehicles and operate with more environmentally friendly approaches are becoming popular in the automotive industry. Electric vehicles (EV), which is one of these approaches, have very common usage areas in this field. Driving stability and safety are also of great importance in these widely used vehicles. In this sense, torque vectoring (TV) appears as the most modern approach. TV control systems provide the distribution of torque to the wheels by the effect of the yaw moment. The application of torque vectoring in vehicles reduces power losses in the motor driver and the vehicle's power consumption. Using efficient torque vectoring algorithms for electric vehicles, this research describes existing and emerging vehicle technology related to yaw moment management and traction control. The article provides the allocation of wheel torques for a two-wheel drive all electric vehicle with individually controlled engines. Lateral dynamics and moment dynamics were used in the construction of this torque allocation. In addition, the lateral velocity and yaw rate of the vehicle related to the specified inputs were calculated from the nonlinear front wheel drive vehicle model which design by MATLAB. The reference yaw rate and the yaw rate, which is the output of the system, were compared and the error was given to the PID controller as an input. Torque producer of the system is a hub motor, which is popular in electric vehicles and simple to control. While increasing the control on this vehicle, the designed torque vectoring system also increased the stability and driving performance during turning.

Keywords: Ageing, particle reinforced composites, bio-composites, glass fiber

Introduction

Fibre reinforced polymer-matrix composites (FRPMC) considered a high strength, lightweight alternative to traditional structural materials. Commonly, FRPMC would made out of reinforcing fibre (e.g. glass, carbon, hybrid fibres) which is the hardest, strongest and stiffest component, embedded in a continuous matrix (e.g. polyester, epoxy resins) [1]. Among many composites, glass fiber reinforced composites have been broadly preferred engineering materials. These composites have been found many applications in commercial and military areas such as aerospace, automobile, and marine structures [2, 3].

Acording to the studies in the literature, different fibers and different particle reinforcements were used together as reinforcement material in only limited amount of studies. In these studies, it was specified that particle reinforcements at different percentages, positively effects the mechanical properties of fiber reinforced composites [4].

Although, determining the mechanical properties of composites considered important, some studies consider impact loading as the most critical loading type. However, investigating low and high velocity impact reaction of composites is a complicated task, due to its different types of damage. Hence, using quasi-static punch-shear test which has the same failure mechanisms, seen as a better option by some researchers [5]. In their study, the researchers identified five stages that describe the ballistic levels of composites. These phases are classified as impact–contact and stress wave propagation, hydrostatic compression and local punch shear, shear plug formation under compression-shear, large deformation under tension-shear, and end of penetration. Additionally, they indicated that using the force-deformation information gained from the quasi-static punch shear test would allow for a better examination of these stages [6].

The vital topic of durability evaluations of fiber reinforced polymer composites has been the subject of numerous studies. Nevertheless, the long-term dependability of fiber reinforced polymer composites in practical applications can be ensured by these durability studies. In several studies, the strength of built fiber reinforced polymer structures is examined and tested in hydrothermal [7], seawater [8], chemical [9] and other environments before being employed in industrial applications.

In this investigation, glass fibers are reinforced with powdered pinecone. First, pre-aging quasi-static punch-shear experiments are conducted to evaluate the impact of chemical aging and particle reinforcement. Then experiments were repeated on specimens immersed in aging solutions at various aging stages.

Experimental Method

The Fibermak Company's F-1564 epoxy resin and F-3487 hardener are used to make composite materials. The hardener and epoxy resin are mixed in a 33:100 ratio. As the fiber reinforcing material, woven E-glass fiber laminates with a 500 g/m^2 areal density are used. In this investigation, particle reinforcing materials included pinecone particles with dimensions ranging from 10 to 40 m.

Pinecone shards are ground to sizes between 10 and 40 m as the first step in the production process. Following the size procedure, the particles are cleaned of contaminants using a 1.6mol.l-1 sodium hydroxide solution in a magnetic stirrer for 48 hours. The mixes are then allowed to dry for 96 hours before being employed to create composite materials.

The hand lay-up approach was chosen to create the composite plates used in this investigation. The weight ratio of the matrix material and fiber reinforcement used in the production process was chosen to be similar to the ratio used in the VARIM method. The epoxy resin and the particles are then combined in accordance with the determined amounts. First, epoxy and the particle combination were treated using a mechanical mixer at 250 rpm and an ultrasonic mixer for 30 minutes during the creation of the matrix-particle mixture. The hardener is then added to this mixture, and mechanical mixing was then repeated for a further 10 minutes. To guarantee a uniform particle distribution, the prepared matrix and particle mixture is evenly distributed to each fiber layer. The final step involved vacuuming and curing the produced woven composite laminates at 80°C for 8 hours. The pinecone particle ratios of 0, 1, 2, and 3 wt% are produced using the same method as described above.

Prior to the aging process and at time intervals of 3, 7 days (1 week), 14 days (2 weeks), 21 days (3 weeks), 28 weeks (4 weeks), and 96 weeks (12 weeks), the neat and particle reinforced composite plates were tested. TKA Pacific's water purifier machine provided the distilled water that was used in the aging solutions. Additionally, chemicals employed in acidic and basic aging solutions are HCl and NaOH. While the acidic solution was created by dilution of hydrochloric acid (HCl) to a concentration of 5% acid by weight in distilled water, the alkaline solution was created by dissolving sodium hydroxide (NaOH) into distilled water at a concentration of 10% by weight. Basic and acidic solutions have pH values of roughly 13.0 and 1.0, respectively.

Quasi-static perforation tests are performed at room temperature using the Shimadzu Autograph AG-X universal testing machine with crosshead speeds of 1, 10, and 20 mm/min to assess the penetrating behavior of the composites. The cross-head type used in the experiment is a hemispherical shaped head with a 12.7 mm diameter. The specimens for the quasi-static perforation tests are 100 x 100 mm in size. The samples are positioned between two plates that each have a 76 mm free section. The quasi-static perforation responses are assessed using maximum penetration forces of specimens.

Results and Discussion

The graphs and values in Table 1 and Figure 1 show the maximum penetration force (the quasi-static punch-shear strength) of particle-reinforced composites. Maximum penetration forces of each composite group rise as test speed increases, as shown in Figure 1. Additionally, maximum penetration forces of composites increase with increasing particle reinforcement ratios up to 2% particle ratio. Kılınc et al. concluded that when the ratio of the filler in the composite surpasses a specific number, some mechanical properties of composite, such as tensile strength, decrease. They expressed that the high concentrated filler in the composite had been poorly distributed, which was the cause of the current problem.

Table 1. Maximum Penetration Forces of quasi-static punch-shear tests

	0%	1%	2%	3%
1mm/min	1978	1862	2302	1566
10mm/min	2086	2226	2345	1949
20mm/min	2168	2293	2412	1991

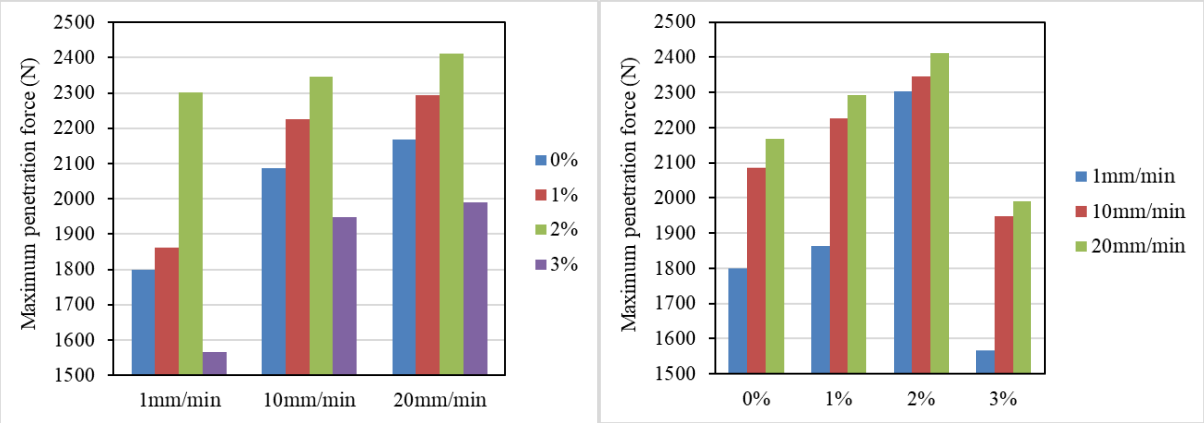


Figure 1. Maximum penetration forces of quasi-static punch-shear tests

For quasi-static punch-shear tests, the maximum penetration force point of composites is considered a crucial point in previous researches. Hence, Table 2 and Figure 2 provide absorbed energy graphs and results of quasi-static punch-shear testing at the maximum penetration force point and at end of test (total energy). Figure 2 shows that as test speed increases, the energy value of each composite group at the maximum penetration force point increases. Additionally, composites' absorbed energy at the time of maximum penetration force point increases in value up to 2% particle ratio. Table 2 and Figure 2 show that total absorbed energy value of each composite groups increases when test speed increases from 1 mm/min to 10 mm/min. However, unlike the 0% particle reinforced composite, the total absorbed energy values of the pinecone reinforced composites continued to increase with the increase of the test speed from 10mm/min to 20mm/min.

Table 2. Absorbed energy of quasi-static punch-shear tests at maximum penetration force and total

Absorbed energy (J)		0%	1%	2%	3%
Maximum penetration force	1mm/min	4.2	5.2	7.0	3.6
	10mm/min	5.5	6.2	7.3	4.9
	20mm/min	6.3	6.6	7.5	4.9
Total	1mm/min	12.3	14.4	14.4	12.9
	10mm/min	15.2	15.8	16.0	13.5
	20mm/min	14.9	16.6	16.9	14.6

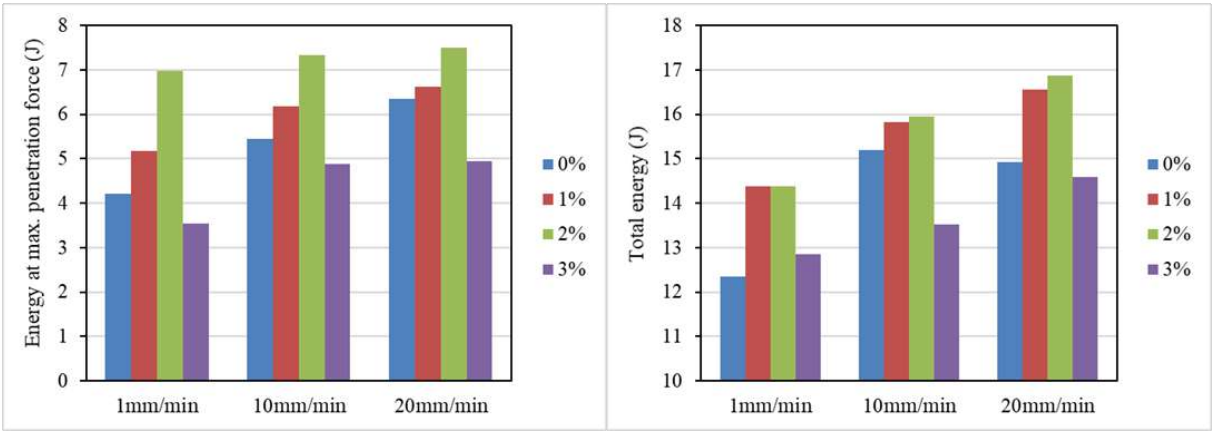
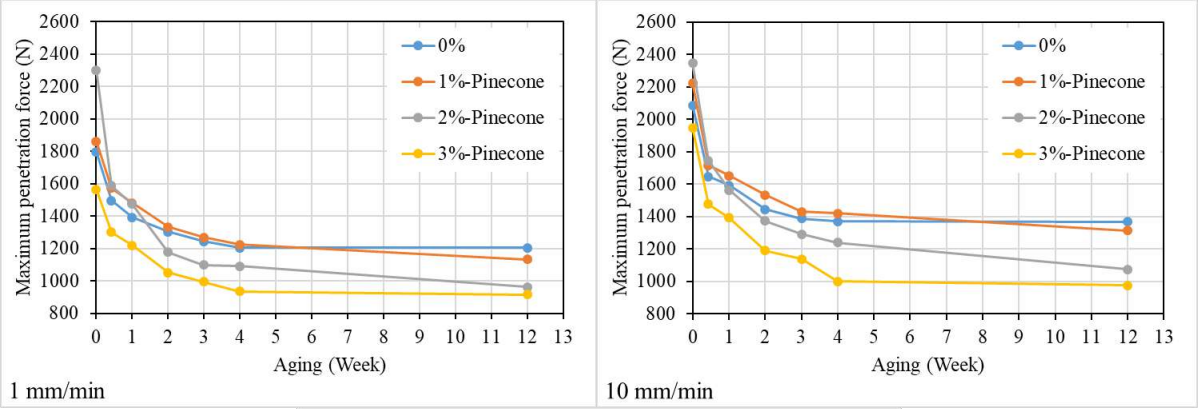


Figure 2. Absorbed energy of quasi-static punch-shear tests at maximum penetration force and total

The graphs and values in Table 3 and Figure 3 show the maximum penetration force of particle reinforced composites at different stages of acid aging. In 2% pinecone reinforced composite started to show similar strength with 1% pinecone reinforced composite with aging. By the second week of aging, the strength of 2% pinecone reinforced composites was lower than that of 0% particle reinforced composites. After the 4th week of aging, the strengths of all pine cone reinforced composites were lower than the 0% particle reinforced composite. 3% pinecone reinforced composites showed lower strength than 0% particle reinforced composites at all stages of aging.

Table 3. Maximum penetration forces of quasi-static punch-shear tests at acid ageing

		0%	1%	2%	3%
1mm/min	0 D	1798	1862	2302	1566
	3 D	1496	1574	1589	1302
	1 w	1392	1482	1474	1221
	2 w	1304	1333	1179	1051
	3 w	1245	1270	1098	995
	4 w	1204	1225	1091	936
	12 w	1204	1133	964	915
10mm/min	0 D	2086	2226	2345	1949
	3 D	1647	1715	1746	1476
	1 w	1593	1651	1562	1392
	2 w	1444	1533	1373	1189
	3 w	1387	1430	1290	1088
	4 w	1370	1419	1240	1001
	12 w	1368	1314	1073	975
20mm/min	0 D	2168	2293	2412	1991
	3 D	1663	1743	1997	1615
	1 w	1612	1664	1597	1544
	2 w	1522	1627	1440	1304
	3 w	1446	1544	1381	1233
	4 w	1423	1471	1323	1028
	12 w	1399	1366	1101	1019



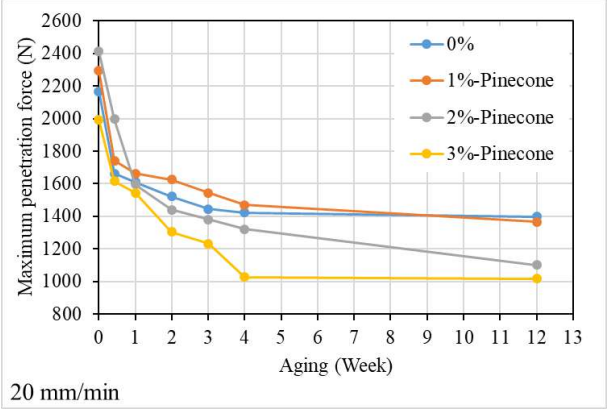


Figure 3. Graphs of maximum penetration force of quasi-static punch-shear test of pinecone powder reinforced composites aged in acidic solutions at 1mm/min, 10 mm/min and 20mm/min test speeds

The graphs and values in Table 4 and Figure 4 show the maximum penetration force of pinecone particle reinforced composites at different stages of base aging. Glass/epoxy composites show higher strength with 1% pinecone reinforcement at the first stages of base aging. After the second week of aging, the maximum penetration force of 1% pinecone reinforced composites was lower than that of 0% particle reinforced composites at all test speeds.

Table 4. Maximum penetration forces of quasi-static punch-shear tests at base ageing

	1mm/min		10mm/min		20mm/min	
	0%	1%	0%	1%	0%	1%
0 D	1798	1862	2086	2226	2168	2293
3 D	1591	1618	1851	1901	1897	1963
1 w	1534	1578	1779	1829	1829	1878
2 w	1526	1549	1742	1785	1814	1845
3 w	1497	1344	1712	1621	1768	1669
4 w	1487	1268	1681	1569	1721	1619
12 w	1401	1109	1534	1281	1619	1507

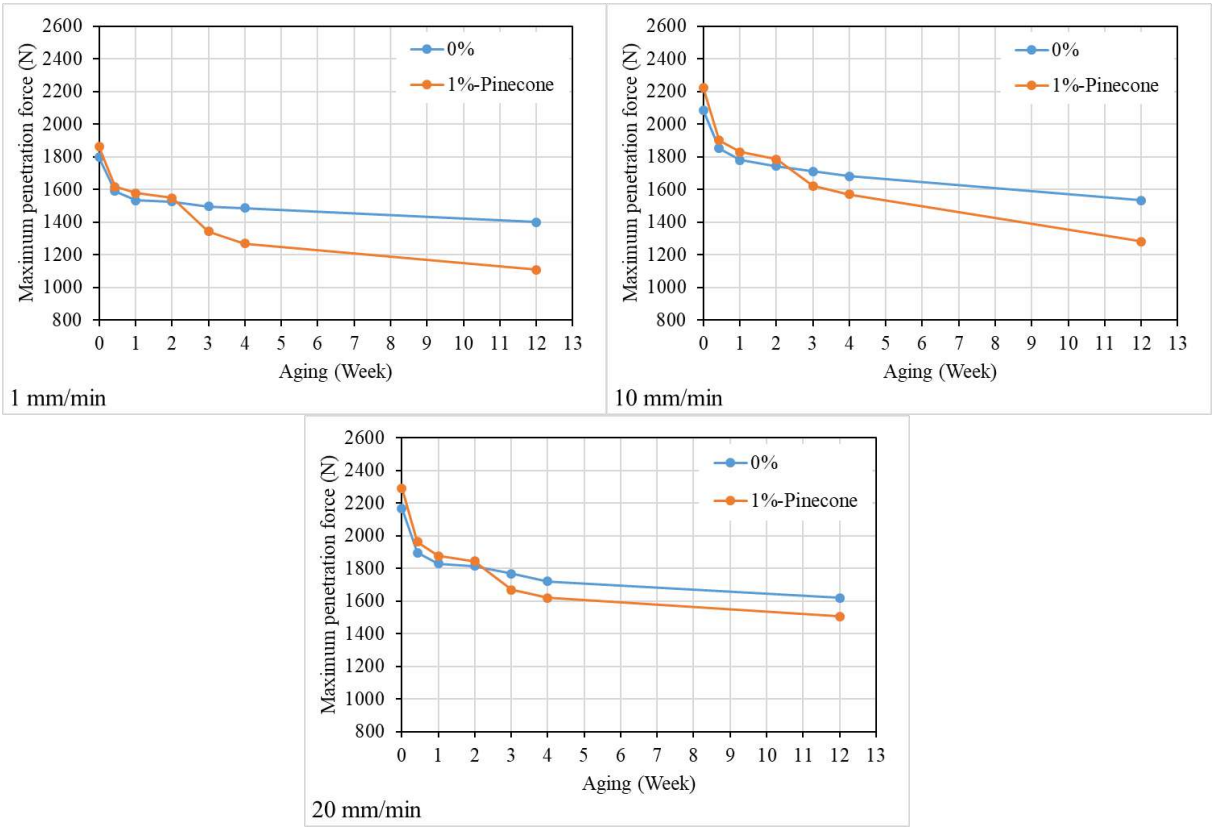


Figure 4. Graphs of maximum penetration force of quasi-static punch-shear test of pinecone powder reinforced composites aged in base solutions at 1mm/min, 10 mm/min and 20mm/min test speeds

Conclusions

In this study, the effect of different amounts of pinecone powder reinforcement on the quasi-static penetration behavior of glass fiber reinforced composites with aging was investigated experimentally. The quasi-static penetration tests were carried out at 1, 10 and 20 mm/minute cross-head speeds. The obtained conclusion can be summarized as:

- Maximum penetration force of composites increase along with particle reinforcement until 2% reinforcement at quasi-static punch-shear tests.
- Absorbed energy values of composites decrease at 3% particle ratio.
- 1% particle ratio can be defined as the most prominent pinecone ratio against acid aging.
- However, pinecone reinforcement made the glass/epoxy composite more susceptible to chemical aging at later stages of aging.

References

[1] Meng J and Wang Y. (2016) A Review on Artificial Aging Behaviors of Fiber Reinforced Polymer-matrix Composites. MATEC Web of Conferences 67: 06041.

[2] Abrate S. Impact on composite structures. Cambridge: Cambridge University Press, 1998.

[3] Reid SR and Zhou G. Impact behaviour of fibre-reinforced composite materials and structures. Cambridge, England: Elsevier, 2000.

[4] Singh, K., Kand, Rawat P. (2018) Mechanical behavior of glass/epoxy composite laminate with varying amount of MWCNTs under different loadings. Materials Research Express 5(5): 055012.

[5] Sadeghi, M., Pol, M.H. (2019) Investigation of behaviors of glass/epoxy laminate composites reinforced with carbon nanotubes under quasi-static punch shear loading. Journal of Sandwich Structures and Materials 21(4): 1535-1556.

[6] Gama B.A., & Gillespie J.W. Jr. (2008.) Punch Shear Based Penetration Model of Ballistic Impact of Thick-Section Composites. Composite Structures, 86, 356–369.

[7] K. Mayandi, N. Rajini, N. Ayrilmis, M.P.I. Devi, S. Siengchin, F. Mohammad, H.A. Al-Lohedan, An overview of endurance and ageing performance under various environmental conditions of hybrid polymer composites. Journal of materials research and technology, 2020; 9(6): 15962-15988.

[8] K. Mazur and S. Kuciel, Mechanical and Hydrothermal Aging Behaviour of Polyhydroxybutyrate-Co-Valerate (PHBV) Composites Reinforced by Natural Fibres. Molecules 2019, 24, 3538.

[9] A. Aslan, E. Salur, H. Duzcukoglu, O.S. Sahin, M. Ekrem, The effects of harsh aging environments on the properties of neat and MWCNT reinforced epoxy resins. Construction and Building Materials, 272 (2021), 121929.

Experimental Analysis of Auxetic Structures with Different Cell Parameters under Uniaxial Compression

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Abstract

The structures at varying operating conditions are exposed to loads that can lead to damage. One of the structural loads that cause damage is compression load. However, such loading causes different effects on auxetic structures having the negative Poisson's ratio. Since these structures contract under compressive loads, they exhibit higher indentation resistance than conventional cellular structures.

In this study, the effects of changing the ligament length and ligament angle in auxetic re-entrant structures under uniaxial compressive loading were experimentally investigated. The auxetic re-entrant structures were fabricated from PLA material by a three-dimensional printer using fused deposition method. The tests were performed under quasi-static uniaxial compression load and the test was continued until the indentation point. As a result of the tests, shrinkage of the cross-section was observed, and it was revealed that there is an inverse relationship between the ligament length and the maximum compressive load. In addition, it was clearly observed that the maximum compression load increased as the angle increased for the maximum ligament length.

Keywords: Auxetic structures, re-entrant, metamaterials, negative Poisson's ratio, compression load

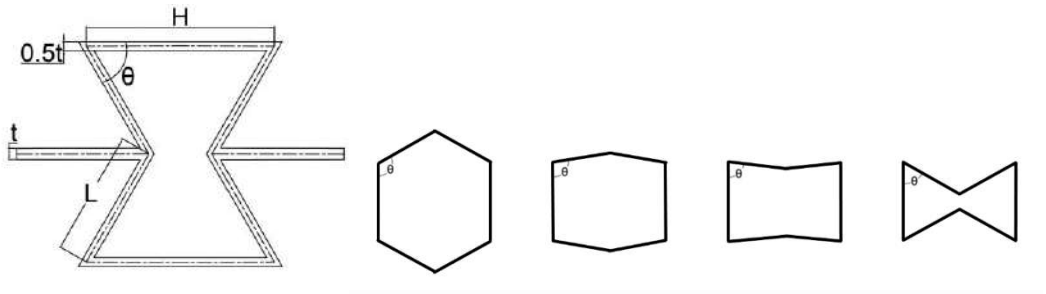
Introduction

Materials with negative Poisson's ratio expand with tensile force and contract with compression force in contrast to conventional materials [1]. Materials with such negative Poisson's ratio were named as 'auxetic' by Prof. Evans [2]. Auxetic materials have started to take place among the new designs due to extraordinary characteristics like impact resistance [3], fracture resistance [4], and especially compressive strength [5] because of higher indentation resistance. In compression tests, these materials exhibit shrinkage of the cross-section. So, this situation increases the indentation resistance. Li et al. examined auxetic and non-auxetic structures in terms of indentation and impact resistance. They reached the result that the auxetic reinforced composites are denser at the indentation point and therefore are more resistant to indentation [6]. However, one of the important variables that affect indentation resistance and compression stress is the size parameters of the auxetic cell. Auxetic structures that consist of cells with various special geometries offer options in the design. Thus, meeting the desired requirements can be achieved by changing the auxetic cell parameters. Dong et al. studied auxetic re-entrant structure with different wall thicknesses under quasi-static compression besides the deformation modes and the influence of the cell number. As a result of the experiments, they found that the cell-wall thickness showed a significant influence on deformation modes of reentrant honeycombs and the minimum cell number should be greater than four in order to investigate the compressive behavior of the re-entrant structure accurately. [7]. Wang et al proposed a novel periodic auxetic re-entrant honeycomb structure that is assembled with a new octagon honeycomb unit cell and investigated the mechanical performance of the structure under compressive loading both experimentally and numerically. The study shows that decreasing re-entrant angle and increasing the wall thickness of the structure leads to a better energy absorption capacity [8]. Luo et al. investigated the Poisson's ratio and energy absorption capacity of re-entrant honeycombs filled with slow recovery foam with numerical and experimental methods. They found that, the energy absorption capacity of slow recovery foam-filled re-entrant honeycombs increases with increasing cell wall thickness and decreasing cell angle [9]. As seen from the literature, cell parameters have important effects on the behavior of the auxetic structure. So, in this study, the effects of changing the ligament length and ligament angle in auxetic re-entrant structures under uniaxial compressive loading were experimentally investigated. As a result of the tests, it was revealed that there is an inverse relationship between the ligament length and the maximum

compressive load. In addition, it was clearly observed that the maximum compression load increased as the angle increased for the maximum ligament length.

Materials and Methods

Cell parameters have significantly important effect on the auxetic structures. Therefore, in this study, auxetic re-entrant structures with various ligament lengths and ligament angles were designed and produced. The effects of these cell parameters on the compression behavior of re-entrant cells were investigated experimentally. As seen in the picture, the angle change determined whether it was auxetic or non-auxetic. In order to provide the auxetic effect, the angle was chosen to be less than 90° degrees as shown in the Figure 1.



a) b)

Figure 1. a) Unit cell parameters and b) Description of the cell's transformation from honeycomb to auxetic form with angle change

For the purpose of this study, a specific type of cell structure called the two-dimensional re-entrant auxetic cell structure was chosen. The design of this structure was based on four variables, namely L, H, t, and θ, as illustrated in Figure 1. In this context, L refers to the length of the inclined ligament, H represents the length of the ligament, θ refers to the angle formed between the vertical and inclined ligaments, and t indicates the thickness of the ligament. A total of twenty-one unique auxetic re-entrant structures characterized by different ligament lengths as 5mm, 10mm, and 15mm and angles as 50°, 55°, 60°, 65°, 70°, 75°, and 80° degrees and H/L ratio was constant as 1.85. Additionally, ligament thickness (t) was 0.5 mm. The parameters defining the re-entrant auxetic cells are visually presented in the Figure 2.

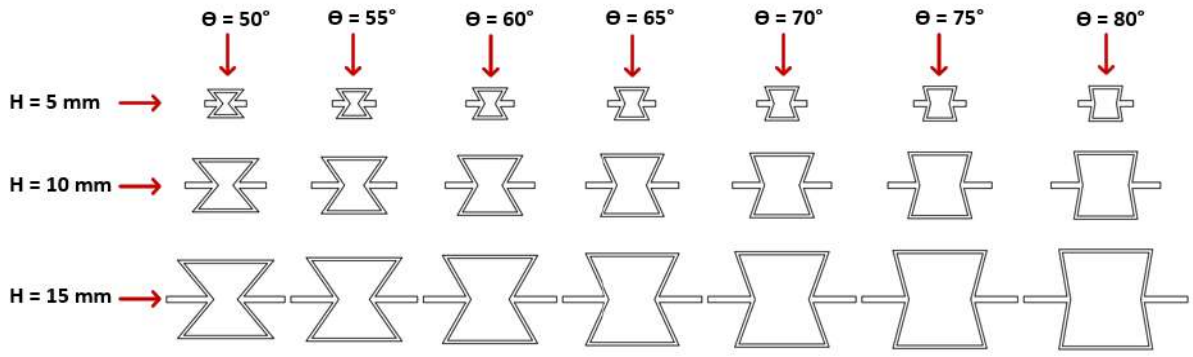


Figure 2. Auxetic cell shapes with varying ligament length and angle

Compression specimens were produced for each parameter. The dimensions of the compression specimens are 40mm x 50mm x 20mm as shown in Figure 3. The auxetic re-entrant cell constructions were symmetrically arranged inside a 40 mm × 40 mm square region to create the specimens. The 20 mm thickness of the compression specimens was designed to prevent any buckling behavior during the test. In addition, plates with a thickness of 5 mm were added to the top and bottom as indicated in the figure in order to prevent ligaments of the test specimens from crashing during the test.

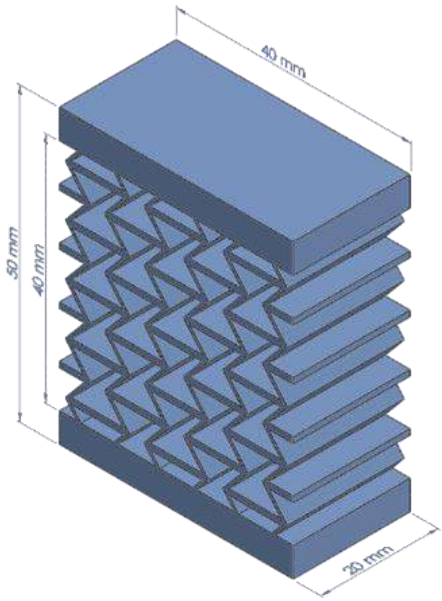


Figure 3. Compression specimens

Specimen Manufacturing

The auxetic re-entrant structures were manufactured from polylactic acid (PLA) plastic material utilizing 3D printing technology. Fused deposition modeling (FDM) was employed to create the specimens. The Creality Ender 3 V2 3D printer was used to manufacture all specimens. Esun PLA+ filament with a 1.75 mm diameter was employed as printing material. The suggested nozzle temperature and heating plate temperature for PLA material were 205-225°C and 60-75°C, respectively, in the product catalog [10]. The line infill pattern was used to create specimens with 100% infill density and 0.2 mm layer height. Furthermore, the manufacture of specimens laid horizontally on the device's plate required no support material. Testing was done in accordance with ASTM D638 [11] standard to look into the PLA's material characteristics. The modulus of elasticity and the tensile strength were determined as 2.85 GPa and 50.72. MPa, respectively, from the engineering stress-strain diagram. In addition, the Poisson's ratio for PLA material was obtained as $\nu = 0.37$. It has been observed that the mechanical properties are not much different from the values given by the manufacturer, but there is a slight decrease in the amount of strength and elongation due to 3D printing.

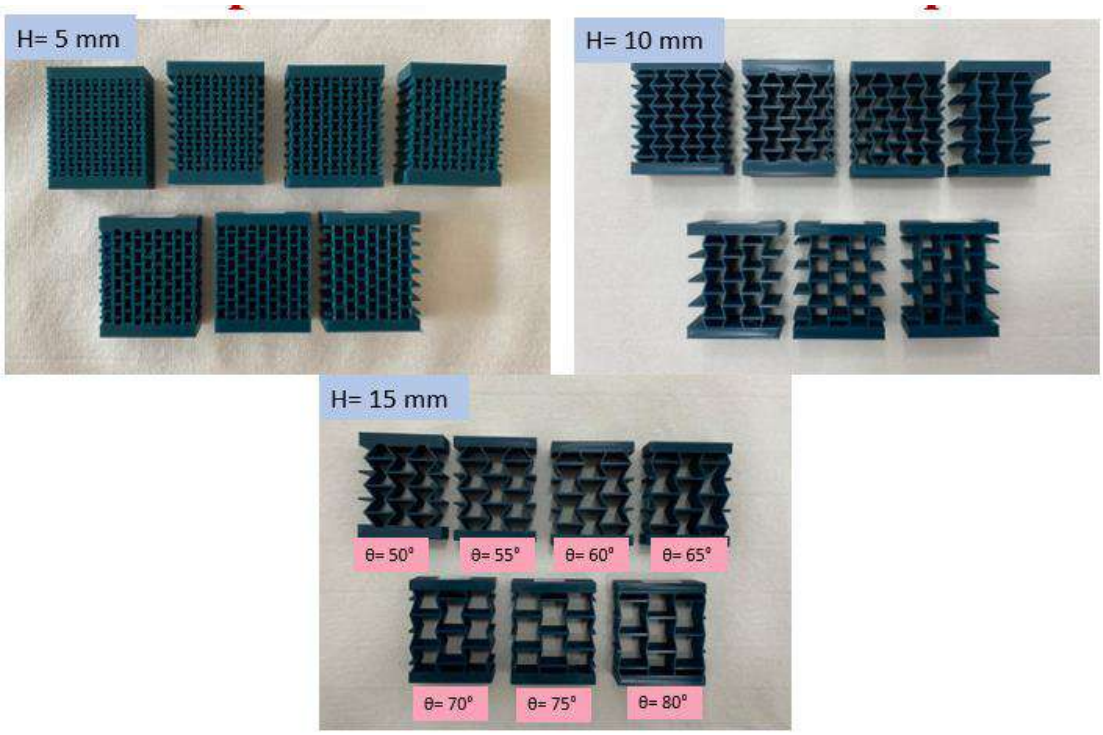
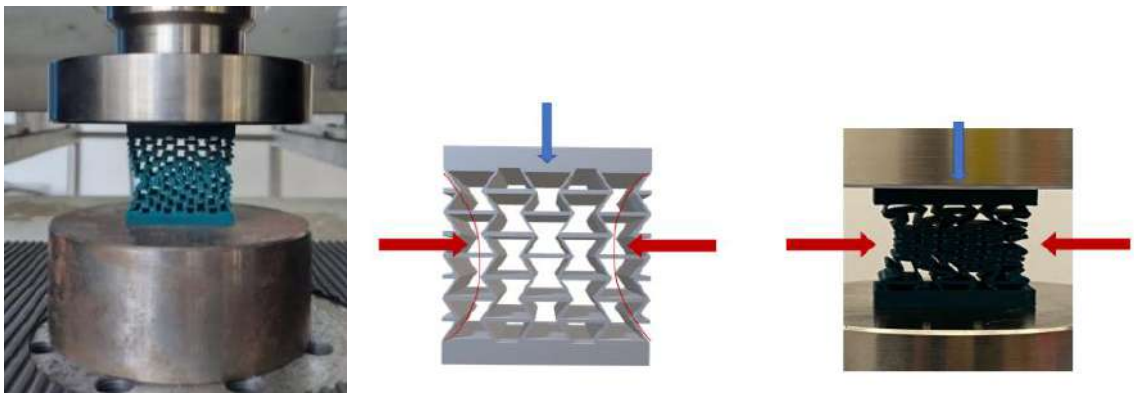


Figure 4. Manufactured specimens

Compression Test

Uniaxial compression tests of re-entrant auxetic specimens were carried out with the Shimadzu AG-IC 100kN universal test machines. The tests were performed under quasi-static uniaxial compression load at a constant speed of 1 mm/min and the test setup was given in Figure 5a. The test was continued until the indentation point. The auxetic effect is quite obvious as there is a narrowing the cross-section of the specimen under compression load as shown in the Figure 5b.



a) b)

Figure 5. a) test setup and b) failure of the specimen

Result and Discussions

The compressive force-displacement curves as a function of the changing ligament angle for specimens with a ligament length of 15 mm are shown in Figure 6. The compression force-displacement curves show linear behavior up to the yield point. This behavior is followed by the plateau region, where the force does not change but the displacement remains the same. The compression force-displacement curves exhibit non-linear behavior. Afterward, densification is observed with the closing of the spaces in the cellular structure, and a sudden increase in force occurs. Compression force-displacement diagrams for samples with different total ligament lengths (H) and ligament angles (θ) are shown in Figure 7. The yield point, plateau region, and densification can be clearly seen from the graphs created for each angle and ligament length.

From the graphs, it is clear that the ligament length directly affects the rigidity of the structure. The reduction in ligament length increases the density of the auxetic structure. This provides greater load-carrying capacity, densification, and rigidity. It was found that the stiffness increased as the length of the ligament decreased. For each constant ligament angle (θ), the amount of load carried by the specimen decreases as the total ligament length (H) increases. Because the increase in ligament length allows more deformation of the cells, resulting in a higher displacement value. As can be seen from the figures, high compression force at the constant angle value was realized at the ligament size of 5mm with the least length of the ligament. In addition, the increase in ligament length allows more deformation of the cells, resulting in higher displacement values. In addition, it was clearly observed that the maximum compression load increased as the angle increased for the maximum ligament length H=15mm. At H=15 mm, the force value is 174.8 N for the minimum angle of 50 degrees, while the force value for the maximum angle of 80 is 573.8 N. There is a huge decrease of -69.5% between these results.

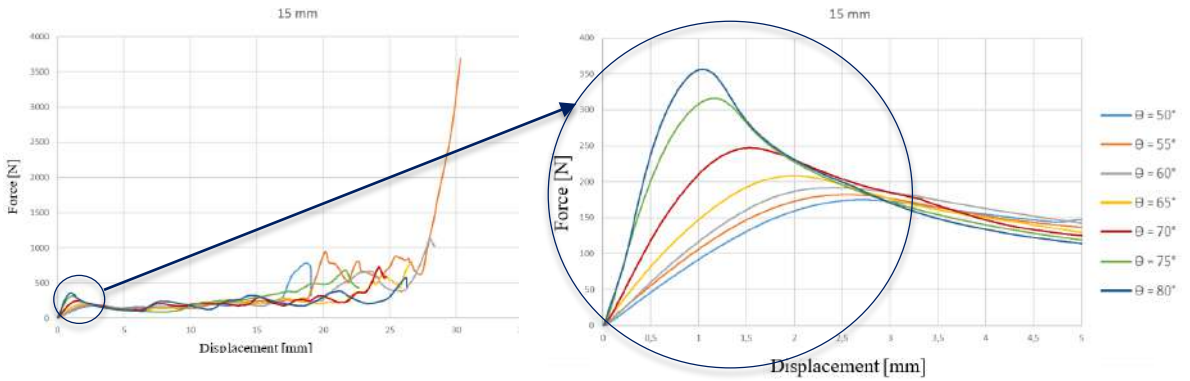


Figure 6. Force-displacement graph for H=15mm

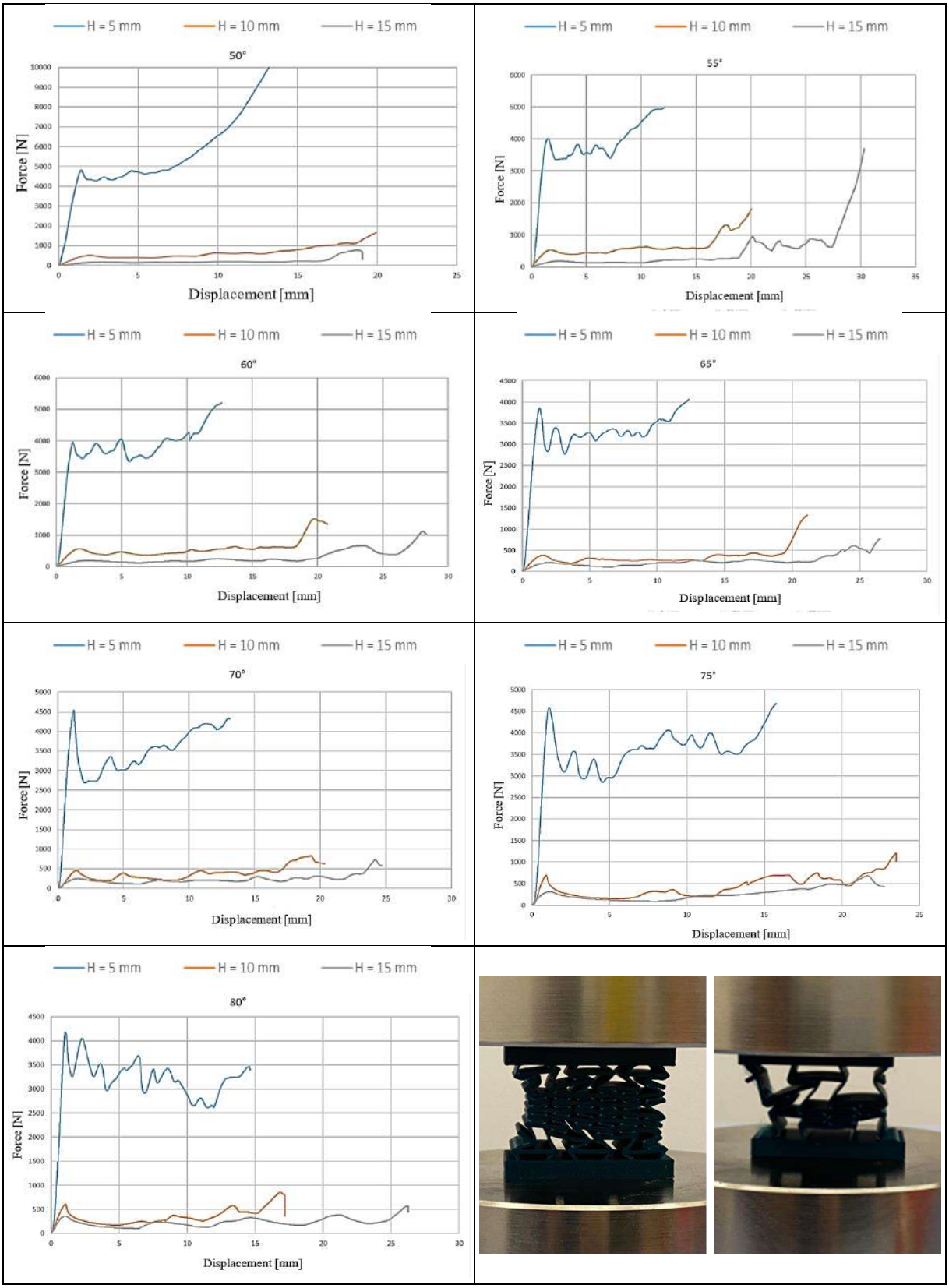


Figure 7. Force-displacement graph for varying ligament angles

Conclusion

As a result of the tests, shrinkage of the cross-section that causing the auxetic effect was observed. It was revealed that there is an inverse relationship between the ligament length and the maximum compressive load due to the rigidity and densification. In addition, it was clearly observed that the maximum compression load increased as the angle increased for the maximum ligament length H=15mm.

References

[1] Lim, T. C. (2015). *Auxetic materials and structures* (Vol. 11, pp. 383-387). Singapore: Springer.

[2] Evans, K. E., Nkansah, M. A., & Hutchinson, I. J. (1994). Auxetic foams: modelling negative Poisson's ratios. *Acta metallurgica et materialia*, *42*(4), 1289-1294.

[3] Bohara, R. P., Linforth, S., Nguyen, T., Ghazlan, A., & Ngo, T. (2023). Anti-blast and-impact performances of auxetic structures: A review of structures, materials, methods, and fabrications. *Engineering Structures*, *276*, 115377.

[4] Yang, S., Chalivendra, V. B., & Kim, Y. K. (2017). Fracture and impact characterization of novel auxetic Kevlar®/Epoxy laminated composites. *Composite Structures*, *168*, 120-129.

[5] Xue, Y., Wang, X., Wang, W., Zhong, X., & Han, F. (2018). Compressive property of Al-based auxetic lattice structures fabricated by 3-D printing combined with investment casting. *Materials Science and Engineering: A*, *722*, 255-262.

[6] Li, T., Liu, F., & Wang, L. (2020). Enhancing indentation and impact resistance in auxetic composite materials. *Composites Part B: Engineering*, *198*, 108229.

[7] Dong, Z., Li, Y., Zhao, T., Wu, W., Xiao, D., & Liang, J. (2019). Experimental and numerical studies on the compressive mechanical properties of the metallic auxetic reentrant honeycomb. *Materials & Design*, *182*, 108036

[8] Wang, S., Deng, C., Ojo, O., Akinrinlola, B., Kozub, J., & Wu, N. (2022). Design and modeling of a novel three dimensional auxetic reentrant honeycomb structure for energy absorption. *Composite Structures*, *280*, 114882.

[9] Luo, Hui Chen, et al. "Mechanical properties of foam-filled hexagonal and re-entrant honeycombs under uniaxial compression." *Composite Structures* 280 (2022): 114922.

[10] Esun PLA+ Product Details [Internet]. [Access date 20.06.2022]. https://www.esun3d.com/pla-pro-product/

[11] ASTM, D. (2002). 638-02a Standard test method for tensile properties of plastics. Philadelphia, PA: American Society for Testing and Material

Natural Fibers in Uganda Suitable for Sustainable Natural Fiber Reinforced Composites

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Abstract

The use of natural fibers in composite polymers has grown rapidly and has gained popularity in various areas. Most of these natural fibers can also be found in Uganda. Many sectors are currently shifting to "green technologies" that are environmentally friendly in order to reduce synthetic plastic wastes and pollutions. Natural fibers are at low-cost with high specific properties and low densities. Based on these factors, most developing countries already begun using natural fibers to produce good quality products that are effective and economical. Countries like Uganda are the future source of many known and many unknown natural fibers. One of the uses of natural fiber reinforced composites is the automotive industry; Uganda is a promising country in this sense.

In this study, we will review the natural fibers in Uganda suitable for natural fiber reinforced composites. These are, namely, mutuba tree (*ficus natalensis*), rice and coffee husk, cotton, *Sansevieria trifasciata*, banana fibers, sisal fibers, marsh grass and bamboo fibers. These plants are found in many other countries; however, a combined investigation is presented in our study. These fibers are mainly used in textiles, automotive industry, and lightweight items. Their future use as structural parts of low to medium strength are evaluated.

Keywords: Natural fibers, composite materials, jute, sisal, hemp, polymer

Introduction

Research on natural fiber composites has existed since the early 1900's but has not received much attention until late in the 1980's. Composites, were always primarily made from polymers, glasses, or metals. Currently natural fiber reinforced composites (NFRCs) are found in countless consumer products including boats, skis, agricultural machinery and cars. A major goal of natural fiber composites is to alleviate the need to use expensive materials such as glass fiber which has a relatively high density and is dependent on non-renewable sources. Natural fibers are fabricated from natural resources such as plants and animals, which are easily available, biodegradable, biocompatible and renewable.

In recent years, there has been a growing global interest in developing sustainable materials and technologies to address the environmental challenges we face today. Natural fibers have emerged as a promising alternative to traditional synthetic fibers due to their renewable and biodegradable nature. These fibers have gained significant attention for their potential applications in various industries, including automotive, construction, and packaging. The utilization of natural fibers as reinforcements in composite materials offers several advantages such as reduced environmental impact, improved mechanical properties, and cost-effectiveness.

Uganda, a country located in East Africa, is rich in natural resources and possesses a diverse range of plant species that produce abundant natural fibers. Despite this potential, the exploration and utilization of natural fibers in Uganda for the development of sustainable composites are still in their nascent stages. This presents a significant opportunity to harness the untapped potential of Ugandan natural fibers and foster sustainable economic growth while mitigating the environmental impact associated with traditional materials.

This paper aims to shed light on the natural fibers available in Uganda and their suitability for the production of natural fiber reinforced composites. We will explore the characteristics and properties of various indigenous natural fibers found in Uganda, mutuba tree (*ficus natalensis*) [1,2], rice and coffee husk [3], cotton [4,5], *Sansevieria trifasciata* [8] fibers, banana fibers [6,7,9], sisal fibers, marsh grass and bamboo fibers. Additionally, we will examine the current challenges and opportunities associated with the production and processing of these fibers, and how they can be overcome to facilitate their integration into sustainable composite materials.

Finally, we will discuss the potential benefits and implications of adopting natural fiber reinforced composites in Uganda, including environmental sustainability, economic growth, and employment opportunities. By elucidating the natural fibers available in Uganda and their potential for sustainable composite materials, this paper intends to provide valuable insights and a foundation for future research and industrial applications. It is hoped that the findings presented here will inspire further exploration, investment, and innovation in utilizing Uganda's natural resources to develop sustainable materials, thereby contributing to the global shift towards a more sustainable and environmentally conscious future.

Plants that produce natural fibers are divided into two depending on their utilization: primary, grown for their fibers; secondary, where the fibers are extracted from the waste product. Generally, relatively high mechanical strength and stiffness can be obtained by using plant fibers, but before that, they have to be conditioned mechanically and should undergo certain chemical treatments. Fiber selection as reinforcement in the composites basically dependent upon the application, where it's going to be implemented. Discover Natural Fibres Initiative reported that the world production of natural fibers was estimated at 33.7 million tons in 2022, compared with a preliminary 33.3 million tons in 2021 and 31.6 million in 2020.

Natural Fibers in Uganda: Characteristics and Properties

In this study, we focus on providing a comprehensive overview of the natural fibers available in Uganda. Information is given on Uganda's diverse natural fiber resources and their classification based on origin and properties. Key natural fibers are selected for further analysis based on their significance and potential for composite applications. The physical properties of the chosen fibers are then discussed.

Ficus Natalensis

Ficus natalensis, commonly known as the Natal fig or the wild fig, is a species of fig tree that is native to various regions in Africa, including Uganda [1]. It belongs to the *Moraceae* family, which includes other well-known fig species. *Ficus natalensis* is a medium to large-sized tree that can reach heights of up to 30 meters. It is commonly referred to as the Mutuba tree, but it also goes by other names such as the Uganda fig or the East African strangler fig. It has a distinctive growth habit, characterized by its aerial roots that descend from its branches and eventually reach the ground, giving it a unique appearance. These roots can eventually grow into new trunks, contributing to the tree's ability to "strangle" and overtake other host trees. The Mutuba tree holds significant cultural and economic importance in Uganda. It is considered a sacred tree among certain communities, and its leaves are used in traditional rituals and ceremonies. Additionally, the tree has multiple practical uses. The bark of the Mutuba tree is harvested for its fibers, which are then used to make bark cloth, a traditional fabric with a long history in Uganda. Bark cloth has cultural and ceremonial significance and is used for clothing, household items, and artistic purposes. The harvesting and production of bark cloth from the Mutuba tree are traditional practices that have been passed down through generations.

Figure 1: Barkcloth from *Ficus natalensis* [3]

Barkcloth is a nonwoven material produced through a series of pummeling processes from mutuba tree in Uganda [2]. The thermal conductivity of barkcloth is in the range of cotton fabrics rendering barkcloth from *Ficus natalensis*, a comfortable fabric. The lower value of thermal absorptivity of barkcloth compared to the value of cotton renders the fabric a warm feeling when in contact with the

skin. Barkcloth has a higher moisture vapor permeability compared to cotton and other fabrics, meaning its clothing comfort properties are reasonable. Thermal conductivity of barkcloth is 0.0357W/mK. This low level of thermal conductivity is attributed to the fabric structure being a natural nonwoven material with some pores arising from the fabric handling and rigorous manual production processes; the high porosity is a haven for entrapped air which lowers the thermal conductivity of the fabric. Barkcloth has thermal absorptivity of 81.4 Ws1/2/m2 K, which is lower than the values of reported for cotton by [5]. This gives a warm feel to barkcloth fabric when in contact with the skin.

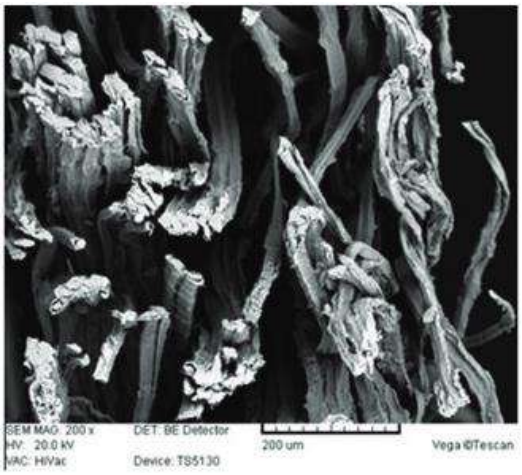

Figure 2: SEM morphology of transverse sections of bark cloth at magnification 200x [2]

Rice and Coffee Husk

Agricultural residues, particularly rice and coffee husks have vast applications in briquetting for domestic cooking applications, fiber reinforced plastics production, soil remediation and wastewater treatment [3]. In order to utilize agricultural wastes, in particular, rice and coffee husks, in briquette and biocomposites plastics development, several modifications may have to be done on the residues. One major modification that can be applied to these husks is carbonization, which produces liquid, gaseous and solid fuels [3]. Strength is a high impact factor when working with fiber-reinforced plastics development and briquettes production. Because of high bulk densities obtained for bio-chars, briquettes can be suitably produced [6]. This is because increased bulk density of residual biomass makes the materials obtained out of them compact and less humid, thus increasing the energy capacity of these materials to a level higher than that of less dense materials.

The results of [3] suggested that modification with NaOH greatly improved the cellulose content of the fibers. Alkali treatment with NaOH removed hemicellulose and lignin from the fibers. Biochemical contents of cellulose, lignin and hemicellulose have been used to predict develop a simple model relating bulk density and biochemical composition. The numerical bulk densities of rice and coffee husks varied between 112 kg/m^3–334 kg/m^3 while the analytical bulk densities ranged between 79 kg/m^3 and 301kg/m3. The Lignin and Cellulose contents increases with modification in distilled water and 3% NaOH is an indicator that moisture absorption by the rice and coffee husks will be reduced thus enhancing their potential usability in the production of briquettes and as fiber/fillers in polymer composites.

Cotton Fibers

Cotton is the most globally traded fiber in conventional textile use. Quality of cotton fiber is judged on many factors, such as staple length, maturity, fineness, cleanliness, stickiness and strength, to mention but a few. Cotton quality characteristics are of importance to farmers, traders, researchers, and cotton spinners. Cotton fiber properties are influenced by a number of factors, including; type of breed or species, farming and harvesting methods, environmental and climatic profiles, processing methods (such as ginning), storage and handling among others. These fiber characteristics have inherent effect on processing capabilities or requirements, yarn properties (such as evenness, strength and fineness) and fabric quality (such as dyeing quality, strength, and appearance) [7]. Three unique classes of cotton quality were drawn by AHC and k-means clustering [4]. It was upon the relativity in application and effectiveness of computation that one would opt for one method over the other. They asserted that AHC is a better method in view of the connectivity relationship that fixes an object to one class, for similar iterations, which is not true for k-means clustering. Using these methods together with the USDA standards, this selected batch of Uganda's cotton was classified as middling to good middling. They also

established that cotton yellowness and short fiber index closely account for much of the variability in cotton fiber quality, and that HVI quality parameters were less related, and were highly independent of each other. The highest correlation was found between cotton yellowness and short fiber index.

Sansevieria Trifasciata

Sansevieria trifasciata is a common perennial plant (see Figure 3) which freely grows and widely found in homes, parks, and woodlands. Rwawiire and Tomkova [8] studied the morphology using Scanning Electron Microscope and Fourier Transform Infrared; thermal properties using Thermogravimetric (TGA) and Differential Scanning Calorimetric (DSC) analyses; mechanical behavior through tensile tests of *Sansevieria trifasciata* fiber obtained from Butaleja in Eastern Uganda. Findings showed that the fiber has an irregular cross-sectional shape with lumens in the center, the fiber diameter was between 80 and 120 μm. TGA tests showed that the fiber was stable below 200°C with maximum cellulose decomposition temperature of 315°C. DSC showed that the fiber's crystallization temperature was 310.5°C and lignin decomposition temperature of 372.7°C. The surface functional groups were majorly of cellulose, hemicelluloses, and lignin in direct correlation with research elsewhere on natural fibers.

Figure 3: *Sansevieria trifasciata* plant (left) and its fibers (right)[8]

Banana Fibers

Uganda is one of the leading banana-producing countries globally, and the abundance of banana plants provides a sustainable and renewable source of fibers. The use of banana fibers not only offers economic benefits but also contributes to waste reduction and environmental sustainability. Banana fibers are obtained from the pseudostem or the outer sheath of the banana plant. The pseudostem consists of tightly overlapping leaf sheaths, and the fibers are extracted through a manual or mechanical process [9].

Banana fibers possess several notable characteristics that make them suitable for various applications. (i) Strength and durability: Banana fibers are known for their high tensile strength, which makes them comparable to other natural fibers such as jute and flax [6,7]. These fibers are robust and can withstand considerable stress and strain. (ii) Flexibility and fineness: Banana fibers exhibit excellent flexibility, allowing them to be spun into fine threads or yarns. The fineness of the fibers enables their use in textiles and weaving applications. (iii) Moisture absorption and breathability: Banana fibers have natural moisture-wicking properties and good breathability, making them suitable for textiles and garments. They can absorb and release moisture efficiently, ensuring comfort in clothing and other textile products. (iv) Eco-friendly and sustainable: Banana fibers are considered eco-friendly as they are derived from a renewable and widely available plant source. Utilizing banana fibers promotes sustainability by reducing reliance on synthetic materials and contributing to waste reduction in banana cultivation. Banana fibers find diverse applications in Uganda, including textiles and clothing, Handicrafts, Paper and packaging Construction materials.

Banana fibers (Figure 4) have found extensive use in composite materials, where they serve as reinforcement components. The incorporation of banana fibers into composite matrices offers several advantages, including improved mechanical properties, reduced environmental impact, and enhanced sustainability. The use of banana fibers in composite materials has gained attention in various industries, including automotive, construction, packaging, and consumer goods. In composite materials, banana fibers are typically combined with a matrix material, such as a polymer resin, to create a reinforced composite structure. The fibers provide reinforcement by enhancing the strength, stiffness, and impact resistance of the composite, while the matrix material holds the fibers together and provides structural integrity.

Figure 4: Banana fibers

Sisal Fibers

Sisal fibers are a type of natural fiber derived from the Agave sisalana plant, which is native to Mexico but now cultivated in various countries worldwide, including Uganda. Sisal fibers have gained popularity due to their strength, durability, and versatility, leading to a wide range of applications in different industries. In Uganda, sisal cultivation is mainly concentrated in the eastern and northeastern regions of the country. Sisal plants thrive in the country's favorable climatic conditions and are cultivated as a cash crop by small-scale farmers. The cultivation of sisal provides economic opportunities and income diversification for rural communities in Uganda.

The fibers obtained from the sisal plant (Figure 5) have several notable characteristics that make them suitable for various applications: Strength and durability, Natural abrasion resistance, Moisture absorption, Heat resistance. The utilization of sisal fibers in Uganda includes agriculture and horticulture, handicrafts and home décor, geotextiles and erosion control, automotive and transportation. Efforts are being made to promote sisal cultivation and fiber utilization in Uganda, both for domestic consumption and for export markets. By harnessing the potential of sisal fibers, Uganda can leverage this sustainable and versatile resource to support local industries, generate income, and contribute to sustainable economic development [3,8].

Figure 5: Agave sisalana plant (left) and sisal fibers (right)

Marsh Grass

In Uganda, the diverse wetland areas, including the extensive swamps and marshes found in regions such as the Albertine Rift Valley, provide habitats for different types of marsh grasses (Figure 6). These grasses can vary in species composition, with common examples including species of Papyrus (*Cyperus papyrus*) and various sedges (*Cyperaceae* family).

Papyrus (*Cyperus papyrus*) is a notable wetland grass that grows in dense stands and forms tall, thick stems with long, umbrella-like clusters of thread-like leaves. Papyrus wetlands are found in Uganda's marshy areas, particularly along the shores of Lake Victoria and other freshwater bodies. Papyrus wetlands provide valuable ecological services, including water filtration, wildlife habitat, and support for traditional crafts such as papyrus mat and basket weaving.

It is important to note that the specific species composition and characteristics of marsh grasses in Uganda may vary depending on the location and type of wetland. Wetland ecosystems in Uganda are subject to conservation efforts and management practices to protect their ecological integrity and the services they provide. [10]

Figure 6: Marsh grass (left) and mats made from boiled papyrus (right)

Bamboo Fibers

Bamboo belongs to the grass family (*Poaceae*) and is known for its rapid growth and versatility. It is widely distributed across various regions of the world, including Africa. In Uganda, bamboo can be found in different parts of the country, particularly in the western and central regions. There are several species of bamboo that are native to Uganda, including *Bambusa vulgaris* and *Oxytenanthera abyssinica*. These species are well-adapted to the local climate and can thrive in Uganda's diverse ecosystems. Bamboo is valued for its numerous uses and benefits. It is a versatile plant with various applications, including construction, furniture making, handicrafts, and even as a food source. The fast growth rate of bamboo, along with its strength and durability, makes it an attractive alternative to traditional timber for various purposes. Bamboo fibers are derived from the stalks of bamboo plants and have gained popularity as a sustainable and eco-friendly alternative to traditional fibers such as cotton and synthetic materials. The fibers can be extracted from bamboo through mechanical or chemical processes and then processed into various forms for different applications. Bamboo fibers have several desirable characteristics that make them suitable for various uses; such as, softness, breathability, antimicrobial properties, strength and durability, sustainable and eco-friendly.

Bamboo fibers are utilized in various products, including textiles, clothing and composite materials. Bamboo fibers can be incorporated into composite materials, such as bamboo fiber-reinforced plastics or composites used in construction, furniture, and automotive industries. The high strength and durability of bamboo fibers make them valuable in reinforcing these material. [3,6]

Conclusion

The research on natural fiber composites has gained significant attention in recent years due to the growing global interest in developing sustainable materials. Natural fibers derived from plants offer a renewable and biodegradable alternative to traditional synthetic fibers. This research focused specifically on the natural fibers available in Uganda and their suitability for the production of natural fiber reinforced composites. The paper highlighted various indigenous natural fibers found in Uganda,

such as Mutuba tree (*Ficus natalensis*), rice and coffee husk, cotton, *Sansevieria Trifasciata* fibers, banana fibers, sisal fibers, marsh grass, and bamboo fibers. The characteristics and properties of these fibers are explored, along with the current challenges and opportunities associated with their production and processing. The potential benefits of adopting natural fiber reinforced composites in Uganda are discussed, including environmental sustainability, economic growth, and employment opportunities.

The findings presented in this paper aim to provide valuable insights and a foundation for future research and industrial applications. It is hoped that the exploration and utilization of natural fibers in Uganda will inspire further investment, innovation, and sustainable economic growth. By leveraging the diverse range of natural resources in Uganda, the country can pave the way for a more sustainable and environmentally conscious future.

References

[1] Rwawiire, S., Tomkova, B. (2014). Thermo-physiological and comfort properties of Ugandan barkcloth from *Ficus natalensis*. The Journal of the Textile Institute, 105(6), 648–653.

[2] Rwawiire, S., Luggya, G.W., Tomkova, B. (2013) Morphology, Thermal, and Mechanical Characterization of Bark Cloth from *Ficus natalensis*. ISRN Textiles, 2013, Article ID 925198, 8 pages

[3] Yiga, V. A., Lubwama, M., Olupot, P. W. (2019). Effect of Alkaline Surface Modification and Carbonization on Biochemical Properties of Rice and Coffee Husks for Use in Briquettes and Fiber-Reinforced Plastics. Journal of Natural Fibers, 1–10.

[4] Kamalha, E., Kiberu, J., Nibikora, I., Mwasiagi, J. I., Omollo, E. (2017). Clustering and Classification of Cotton Lint Using Principle Component Analysis, Agglomerative Hierarchical Clustering, and K-Means Clustering. Journal of Natural Fibers, 15(3), 425–435.0

[5] Chidambaram, P., Govindan, R., Venkatraman, K. C. (2012). Study of thermal comfort properties of cotton/regenerated bamboo knitted fabrics. African Journal of Basic & Applied Sciences, 4, 60–66.

[6] Menya, E., P. W. Olupot, H. Storz, M. Lubwama, Y. Kiros. 2018. Characterization and alkaline pretreatment of rice husk varieties in Uganda for potential utilization as precursors in the production of activated carbon and other value-added products. Waste Management 81:104–16. doi:10.1016/j.wasman.2018.09.050.

[7] Judith, M. B., H. G. Davidonis. 2000. Quantitation of fiber quality and the cotton production-processing interface: A physiologist's perspective. The Journal of Cotton Science 4:34–64.

[8] Rwawiire, S., Tomkova, B. (2015). Morphological, thermal, and mechanical characterization of *Sansevieria trifasciata* fibers. Journal of Natural Fibers, 12(3), 201–210.

[9] Yusuf, A. A., Inambao, F. L. (2020). Characterization of Ugandan biomass wastes as the potential candidates towards bioenergy production. Renewable and Sustainable Energy Reviews, 117, 109477. doi:10.1016/j.rser.2019.109477

[10] Kakuba S.J., Kanyamurwa J.M. 2021. Management of wetlands and livelihood opportunities in Kinawataka wetland, Kampala-Uganda. Environmental Challenges, 2, Article ID 100021, 12 pages.

Compression after Impact Behavior of S2-Glass Reinforced Composite Plates at Low Temperatures

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Abstract

Composite materials are used in a wide variety of applications due to their durability, high mechanical strength and low weight. As a result, they have application in several industrial areas. The automotive, marine and aerospace industries are a few of these sectors. Glass fibers are the most often implemented reinforcement material in composites because of their lower cost and greater strength compared to other types of fibers. They can be employed with ease in the aircraft industry due to their high degree of thermal resistance. These aspects have led to many researchers on S2-glass composites. There are gaps in the literature despite the fact that there have been numerous studies on this topic.

In this study, the vacuum assisted resin infusion method (VARIM) was used to manufacture S2-glass/epoxy composites with 18 layers. Firstly, pre-curing was carried out during the production process at 50 °C for 30 minutes, followed by an 8-hour curing process at 80 °C. After production, the composite material was cut into 100 mm x 150 mm sized specimens. Impact test was performed at room temperature with the Ceast 9350 Fractovis Plus impact test machine for different impact energies. Then, Compression after impact (CAI) tests were conducted at low temperatures for impacted and unimpacted specimens to assess influence of impact damage on the residual compressive strengths of the composite plates by Universal Shimadzu testing machine according to Boeing CAI fixture (ASTM D 7137). Impact behavior and the effect of low temperature on the CAI strength of S2-glass/epoxy composite plate were investigated.

Keywords: S2-glass, laminated composite, compression after impact, low velocity impact

Introduction

In this study, S2 glass/epoxy laminated composite were produced by using the vacuum assisted resin infusion method (VARIM). 18-layer S2 glass composites were used to investigate the effect of temperature and impact on compression-after impact (CAI) strength of composites. Impact tests were conduct by using Ceast 9350 Fractovis Plus impact test machine at 30J, 40J and 50J impact energies at room temperature. In order to determine the effect of the impact damage on the residual compressive strength of the specimen, Compression-after impact (CAI) tests were carried out by using Universal Shimadzu testing machine with Boeing CAI fixture (ASTM D 7137) for impacted and unimpacted specimens. CAI strength of composites decreases with increase of impact energy.

Composite materials are used in a wide variety of applications due to their durability, high mechanical strength and low weight. As a result, they have application in several industrial areas. The automotive, marine and aerospace industries are a few of these sectors. Glass fibers are the most often implemented reinforcement material in composites because of their lower cost and greater strength compared to other types of fibers. They can be employed with ease in the aircraft industry due to their high degree of thermal resistance. These aspects have led to many researchers on S2-glass composites. There are gaps in the literature despite the fact that there have been numerous studies on this topic [1-3].

It is certain that these materials will be subjected to impacts at low velocities and various temperatures until the end of their usage. As a result of exposure to this low velocity impact and temperature, theoretically calculated material properties may change. Several researches on the low velocity impact behavior of polymer composite structures were conducted at room temperature. Those researches focused on alterations of maximum contact force, maximum deflection, contact time, absorbed energy and damage area in low velocity impact tests of E-glass/epoxy laminated composites. In addition, researches were evaluated low velocity impact reactions in regard to impact energy, impactor mass, impact velocity and specimen dimensions [1-3].

The compression after impact test is used for evaluating the composite material's remaining compressive strength upon impact loading. Due to the numerous applications where compressive strength of composite materials is crucial, researchers have conducted several investigations. Several researchers used numerical and experimental methods to study CAI and low velocity impact behavior of laminated composites. [4-9] In one of these studies, in which composites made of glass knitted fabrics were used for experiments, Alpyildiz et al. [10] looked at the results of the samples for impact, compression, tensile and CAI tests. At low and high temperatures, low velocity impact tests were applied to two glass/epoxy composite plates by various impact energies by Aktas et al. [3]. In order to determine importance of laminate orientation on CAI strength and CAI damage mechanism of composites, two distinct laminate orientations were examined.

In this study, vacuum assisted resin infusion method (VARIM) was used to manufacture S2 glass/epoxy composites. The composite specimens underwent impact testing initially, followed by CAI testing. The effects of the impact energy and temperature on CAI strength were investigated experimentally.

Method

Firstly, the manufacturing plate covered with mold release film to prevent the epoxy from sticking to the plate and all edges of release film covered with vacuum paste. Afterward, 18-layer S2 glass fibers laid on the release film and peel ply placed on S2 glasses in order to free S2 composite plate from manufacturing assistants at the end of process. A resin dispenser placed on the peel ply to distribute the resin well, followed by the spiral pipes were placed and all layup covered with a vacuum bag. After opening the vacuum and drawing the air inside, leak check done. The epoxy and hardener mixture is applied with a hardener/epoxy ratio of 1/3 if there is no leakage following the control. In production process, pre-curing established at 50 °C for 30 minutes and then curing process applied at 80 °C for 8 hours. Resin and hardener used in study along with composite manufacturing system given in Figure 1.

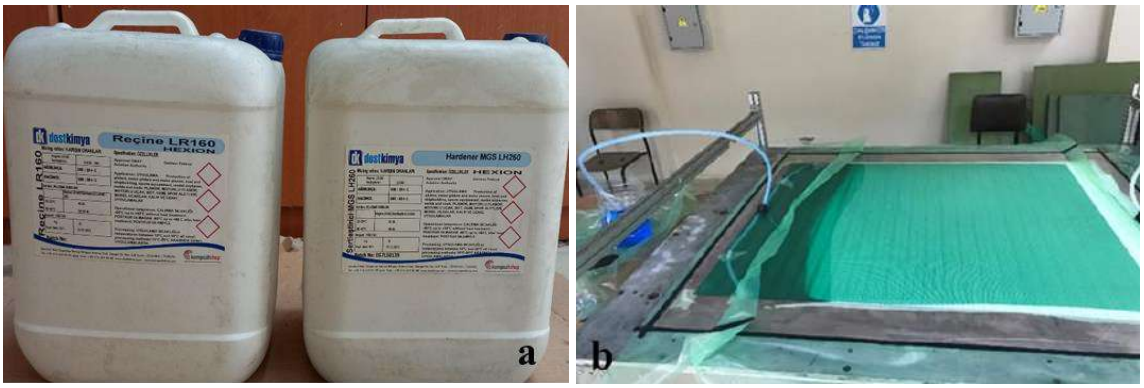

Figure 1. a) Composite resin and hardener, b) Composite manufacturing system

Figure 2. a) Low velocity impact device, b) CAI test setup

The specimens were cut at dimensions of 100x150mm. Firstly, impact tests were carried out by Ceast 9350 Fractovis Plus impact test machine at 30J, 40J and 50J impact energies for different thicknesses. After that, the CAI tests were applied to composite specimens at -25°C. Low velocity impact device and compression after impact (CAI) test setup used in study given in Figure 2.

Results

In order to compare impact behavior of this composite, contact force – time diagrams of the specimens were given in Figure 3. Figure shows that the elastic bending of the composite material similar to the first monotonous increase with the impact event. For all energies, the linear portions of graphs in the loading case are nearly the same. Up until a particular force amount, this rise persists in the form of minor oscillations. The matrix damage occurs once force reaches its maximum value. The large decrease in force up until the maximum force is reached is due to propagated damage to the composite material. The breaking of the fibers occurs at this point. After maximum force value, impactor starts to move opposite direction. Test concludes with force reaching zero. Due to an increase in test speed, contact time increases due to an increase in impact energy.

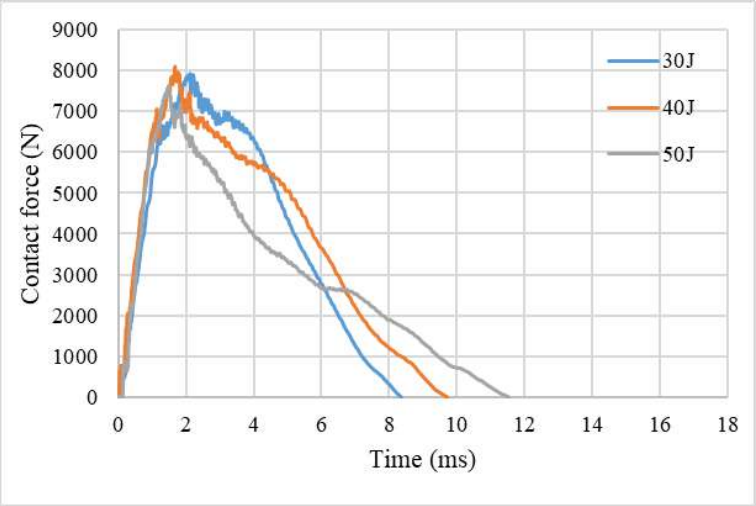

Figure 3. Contact force-time graphs according to the impact energy

Energy – time diagrams of the specimens are given in Figure 4. In energy – time diagrams, the rebounding case was observed at all impact energy levels. Absorbed energy level change significantly with the increase of impact energy.

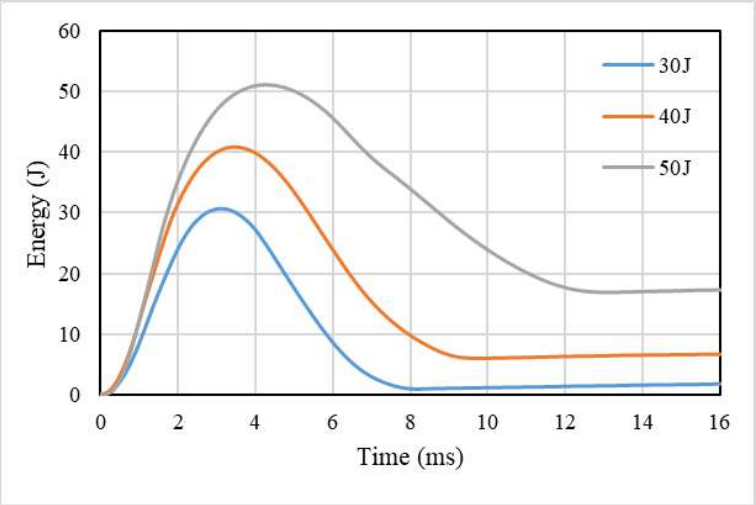

Figure 4. Energy-time graphs according to the impact energy

The specimens with 100 mm x150 mm dimensions were subjected to CAI tests at -25 °C with at least five test repetitions. Figure 5 shows the compression force-displacement graphs of the composite material after impact loading at all energy values at -25 °C. Due to local fiber breakages, sudden decreases in compression forces are observed in graphs. It is seen that the specimen with the highest compression resistance is the specimen that has not been subjected to impact damage (0J).

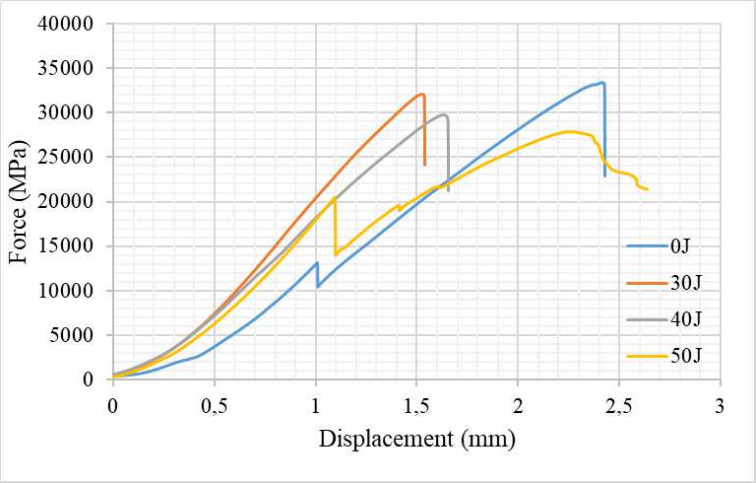

Figure 5. Force-displacement graphs of specimens

To investigate CAI behaviors better, maximum CAI forces and CAI strengths diagrams of composites were given in Figure 6. CAI force and CAI strength values of specimens were given in Table 1. CAI strength of specimens decreases with the increase of impact energy [6]. This can be explained by the simple reason that when impact energy increases, more impact damage is induced by absorbed energy, which causes the specimen's compressive strength to drop.

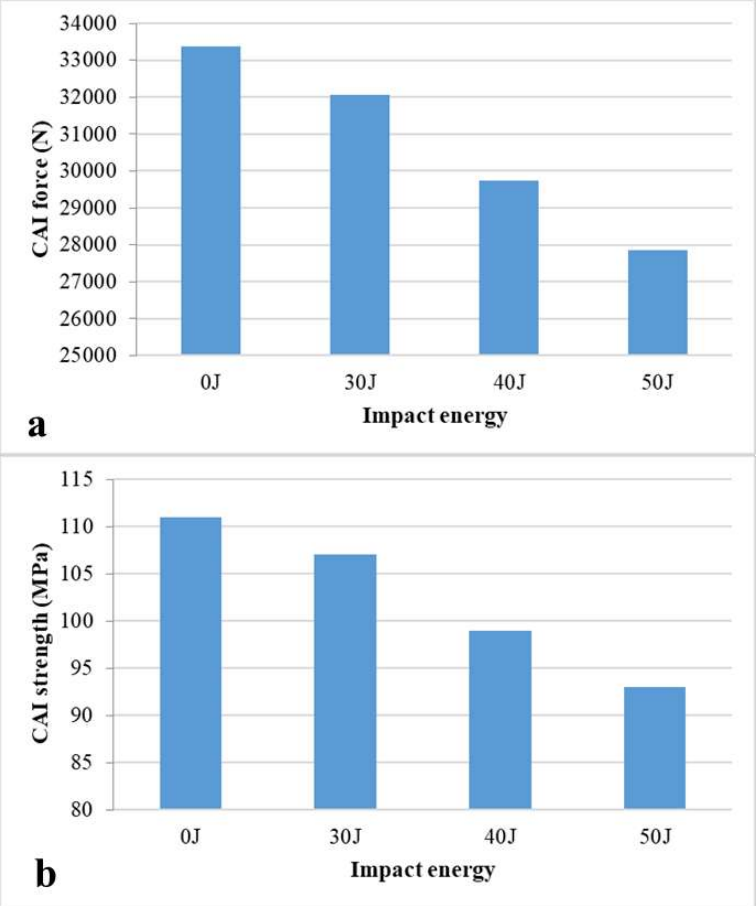

Figure 6. a) CAI forces and b) CAI strengths diagrams of specimens according to the impact energy

Table 2. CAI forces and CAI strengths

Specimen	CAI force (N)	CAI strength (MPa)
0J	33387	111
30J	32066	107
40J	29742	99
50J	27866	93

Conclusion

In this study, the effect of impact energies on compression after impact behavior of S2-glass composites was investigated at -25°C. CAI tests were conducted to undamaged and damaged specimens. From obtained results, the following conclusions were drawn:

- Contact time of specimens extended with increase of impact energy.
- All impact test specimens showed rebounding case according to the energy-time curves.
- Undamaged specimens showed the highest CAI strength. CAI strength decreases by increase of impact energy.

References

[1] R. Karakuzu, E. Erbil, M. Aktas, Impact characterization of glass/epoxy composite plates: An experimental and numerical study. Composites: Part B Engineering 2010; 41: 388-395.

[2] Z. Aslan, R. Karakuzu, B. Okutan, The response of laminated composite plates under low-velocity impact loading. Composite Structures 2003; 59: 119-127.

[3] M. Aktas, C. Atas, B.M. Icten, R. Karakuzu, An experimental investigation of the impact response of composite laminates. Composite Structures 2009; 87: 307-313.

[4] H. Tuo, Z. Lu, X. Ma, C. Zhang, S. Chen, An experimental and numerical investigation on low-velocity impact damage and compression-after-impact behavior of composite laminates. Composites: Part B Engineering 2019; 167: 329-341.

[5] X.C. Sun, S.R. Hallett, Failure mechanisms and damage evolution of laminated composites under compression after impact (CAI): Experimental and numerical study. Composites: Part A 2018; 104: 41-59.

[6] B. Yang, Y. Chen, J. Lee, K. Fu, Y. Li, In-plane compression response of woven CFRP composite after low-velocity impact: Modelling and experiment. Thin-Walled Structures 2021; 158: 107186.

[7] H. Liu, B.G. Falzon, W. Tan, Predicting the Compression-After-Impact (CAI) strength of damage-tolerant hybrid unidirectional/woven carbon-fibre reinforced composite laminates. Composites: Part A 2018: 105: 189-202.

[8] G. Han, Z. Guan, X. Li, S. Du, Failure analysis of carbon fiber reinforced composite subjected to low velocity impact and compression after impact. Journal of Reinforced Plastics and Composites 2016; 35(9): 727-746.

[9] E. Selver, H.H. Dalfi, H. Yousaf, Investigation of the impact and post-impact behaviour of glass and glass/natural fibre hybrid composites made with various stacking sequences: Experimental and theoretical analysis. Journal of Industrial Textiles 2022; 51(8): 1264–1294.

[10] T. Alpyildiz, B.M. Icten, R. Karakuzu, A. Kurbak, The effect of tuck stitches on the mechanical performance of knitted fabric reinforced composites. Composite Structures 2009; 89: 391-398.

Dynamic Compressive Behavior of Glass/Epoxy Composites Using Split Hopkinson Pressure Bar

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Abstract

In this study, E-glass/epoxy composites were subjected to Split Hopkinson Pressure Bar (SHPB) tests to obtain the compressive properties of composite under the different strain rate values. Composite materials were manufactured by vacuum assisted resin infusion moulding (VARIM) method. Then cylindrical SHPB specimens with 6 mm diameter and 6 mm height were obtained by cutting the composite with water jet through the thickness. E-glass/epoxy specimen was connected to the SHPB test apparatus. The variation of strain according to time was obtained by using axial strain-gage. Then compressive stresses were calculated by using strain values, the modulus of elasticity and the area of the pressure bar, and the area of specimen. The variations of engineering stress according to the engineering strain and time, and engineering strain rate vs time were obtained under different velocities or strain rates. The results shows that velocity or strain rate has a significant effect on compressive properties of E-glass/epoxy composite.

Keywords: E-glass fabric; VARIM; composite materials, Split Hopkinson pressure bar test

Introduction

The resistance of composite materials to the high velocity impact is based on thickness and fiber type that used in the several applications such as aerospace protective structures and defense. In the aeronautical sector, impacts usually include hail collision and bird strikes. However, in the case of applications military, the impactors such as projectiles and missiles were used in the high-velocity impact. Song et al. [1] conducted the validation, modelling and experimental studies of titanium alloy. The ballistic performance was explained for Tie 5322 target with thickness of 7 mm then by using the ballistic test results. The split Hopkinson pressure bar was used in experimental test. The fracture strain of material decreases with the strain rate increases. Khoramishad et al. [2] studied the effect of multi-walled carbon nanotubes on fiber-metal behavior of laminates subjected to high velocity impact tests. They used different weight percentages of carbon nanotubes from 0.25 to 1 at production of specimens. The results show that the addition of carbon nanotubes improved adhesion of resin-fiber and reduced matrix cracking and delamination in the manufactured composite materials. Sarwar et al. [3] obtained the properties of composite such as torsion, Rockwell hardness, compression, tension and three-point bending behaviors of multiple layered sandwich composite Kevlar and flax fibers. Results showed that stiffness and strength of composites materials were improved by using hybrid materials. Chatterjee et al. [4] manufactured the panels of sandwich composite using glass and Kevlar fabric as a hybrid face sheet. The process of vacuum assisted resin infusion molding (VARIM) technique was used to fabricate the sandwich composites. The high velocity impact test was conducted by bullets with 175 m/s velocity. The damage morphologies were investigated and fiber failure, delamination and shear plugging causes dissipation of energy in the sandwich composite materials. Tao et al. [5] studied energy absorption and impact behavior of different configurations of sandwich composite under the high velocity impact from 50 to 220 m/s by using gas gun. They evaluated performance of energy absorption of the sandwich composites by considering the effect thickness on the sandwich panels. Nugroho et al. [6] discussed the hybrid panels by using woven aramid fabric with platinum teak veneer in order to manufacture the plate of laminate. Epoxy as adhesive was used to join the laminated of aramid fabric. All the samples were subjected to ballistics tests at distance of 5 m by using 9 mm Luger ammunition according to the NIJ 0108.01. The result shows that the stabilization of the resin in the ballistic test has an effect on the absorption energy.

The main objective of this study is to obtain the compressive properties of E-glass/epoxy composite under the different strain rate values by Split Hopkinson pressure bar device.

Experimental Details

Materials

E-glass fabric was used to prepare specimens of polymer composite as shown in (Figure 1). The Areal density, weave style and number of layers for reinforcement can be seen in the Table 1. Epoxy resin (F-1564) with hardener (F-3487) were used to fabricate the composites materials as depicted in Figure 2 and the ratio of the resin and hardener was 3/1. Table 2 shows the used weight of epoxy and hardener in composite materials.

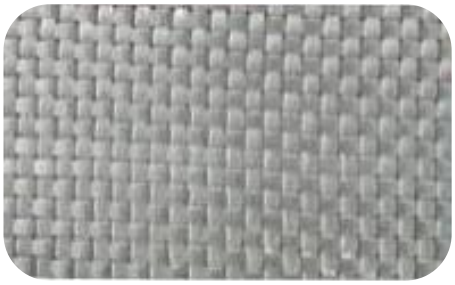


Figure 1. E-glass fabric

Table 1. Properties of E-glass fabric

Areal density (g/m^2)	Weave style	Number of layers
500	Woven	17

Figure 2. Matrix materials

Table 2. Weight of epoxy and hardener

Weight of Epoxy	Weight of Hardener	Total Weight
975 g	325 g	1300 g

Composite Fabrication Method

The laminated composite material was manufactured by vacuum assisted resin infusion moulding technique (VARIM) as illustrated in Figure 3. The surface of mold was covered by release film in order to save the surface during infusion the resin and hardener on the molding process at manufacturing. After that, E-glass fabric was put over the release film. The complete impregnation of the dry fabrics was achieved by using the peel ply and liquid resin distribution medium which placed on the dry fabrics. Finally, vacuum bag was used over all the surface of mold to obtain of the closed system. After that, the liquid resin and hardener are permeated to the dry fabrics by using the vacuum.

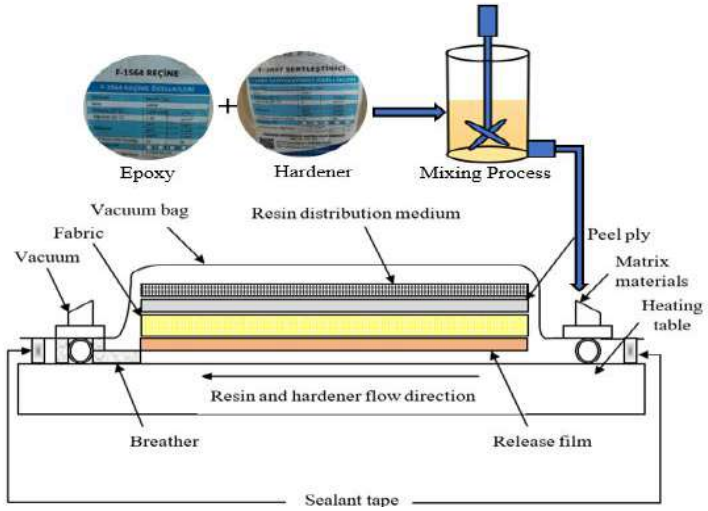


Figure 3. A schematic view of vacuum assisted resin infusion moulding technique

Waterjet cutting machine was used to achieve the specimens of E-glass as shown in Figure 4. Table 3 shows final height and diameter of specimen while the Figure 5 demonstrates specimen 500 (g/m^2) of E-glass which consists of 17 layers.

Figure 4. Waterjet cutting machine

Table 3. Final Height and Diameter of Specimen

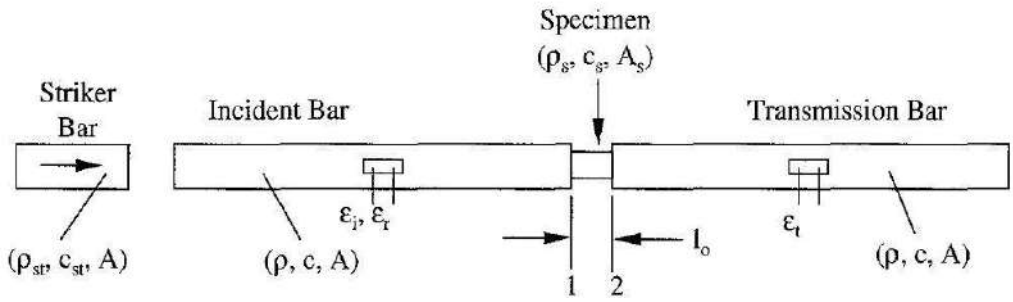
Types of specimens	Height mm	Diameter mm
E-glass	6	6

Figure 5. E-glass specimens cut by water jet

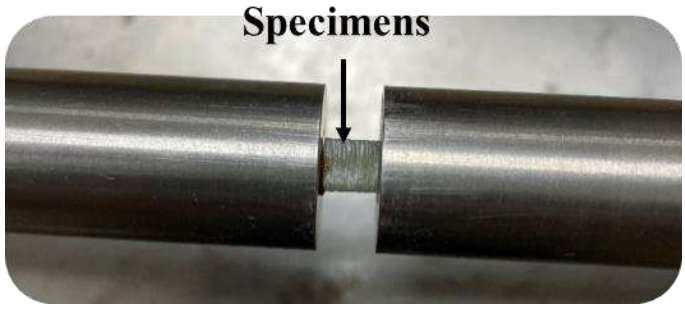
Split Hopkinson Pressure Bar Tests

The experimental tests of high strain rate are implemented by using Split Hopkinson device [7] which available at Impact Mechanics Lab, Applied Mechanics, Mechanical Engineering Department in the Erciyes University/Kayseri/Türkiye. In this study, the experimental investigation was carried out on E-glass/epoxy specimen of composite laminates with diameter of 6 mm and height of 6 mm under high strain rate loading. The compression Split Hopkinson bat test includes striker, input and output bars. Input and output bars are equal length and diameter. The tested circular specimen was inserted between

the input and output bars as shown in Figure 6. Test pressure, corresponding striker bar velocity and measured maximum strain rate values were given in Table 4.



(a)



(b)

Figure 6. (a) A schematic view of Split Hopkinson Pressure Bar Test, (b) E-glass/epoxy specimen connected to the SHPB test apparatus

Table 4. Test properties

Pressure	Striker bar velocity	Maximum strain rate
5 psi (34.47 kPa)	8.2 m/s	1700 1/s
10 psi (68.95 kPa)	13.4 m/s	3000 1/s
15 psi (103.42 kPa)	17.8 m/s	4000 1/s

Specimens were subjected to an axial compression as impact between input and output bars by striker bar which caused to obtain the stress pulse at impact. The pulse propagates of the striker bar to specimen, which consist of reflected and transmitted waves. The reflected wave propagates back on along the striker bar however the transmitted wave moves to specimen. The stress σ_s (t), strain ε_s (t) and strain rate $\acute{\varepsilon}_s$ (t) for the specimen with time were calculated as below [8]:

$$\sigma_s(t) = \frac{EA}{A_S}\,\varepsilon_t(t) \quad (1)$$

$$\varepsilon_s(t) = -\frac{2\,C0}{L_0}\int_0^t \left(\varepsilon_i(t) - \varepsilon_t(t)\right) dt \quad (2)$$

$$\acute{\varepsilon}_s(t) = -\frac{2\,C0}{L_0}\left(\varepsilon_i(t) - \varepsilon_t(t)\right) \quad (3)$$

where E is the Young's modulus, A is the cross-section area of transmitted bar, A_s is the cross-section area of the specimen, $c_0 = \sqrt{E/\rho}$, is the wave velocity of the striker bar, ρ is mass density of bar, L_0 is the specimen length, ε_i (t) is the incident pulse and ε_t (t) is the transmitted pulse.

Results and Discussion

The strain rate – time curves of the E-glass/epoxy specimen under different velocity impact were shown in Figure 7. The strain rate initially increases linearly. Then, it shows a fluctuating behavior with time. The strain rate sharply decreased with small increases of the time. Strain rate increases by increase of velocity. However, the contact duration reduces with increasing the velocity.

Engineering stress versus time diagrams of E-glass/epoxy specimens were given in Figure 8 according to the various velocities of striker bar. Engineering stress increases linearly. After that slops of curves decreases because of the damages. The maximum engineering stress reduces by increasing velocity from 8.2 m/s to 13.44 m/s then increases under velocity of 17.8 m/s. After the maximum stress, the maximum engineering stress reduces with time. The time reduces with increasing velocity as shown in Table 5.

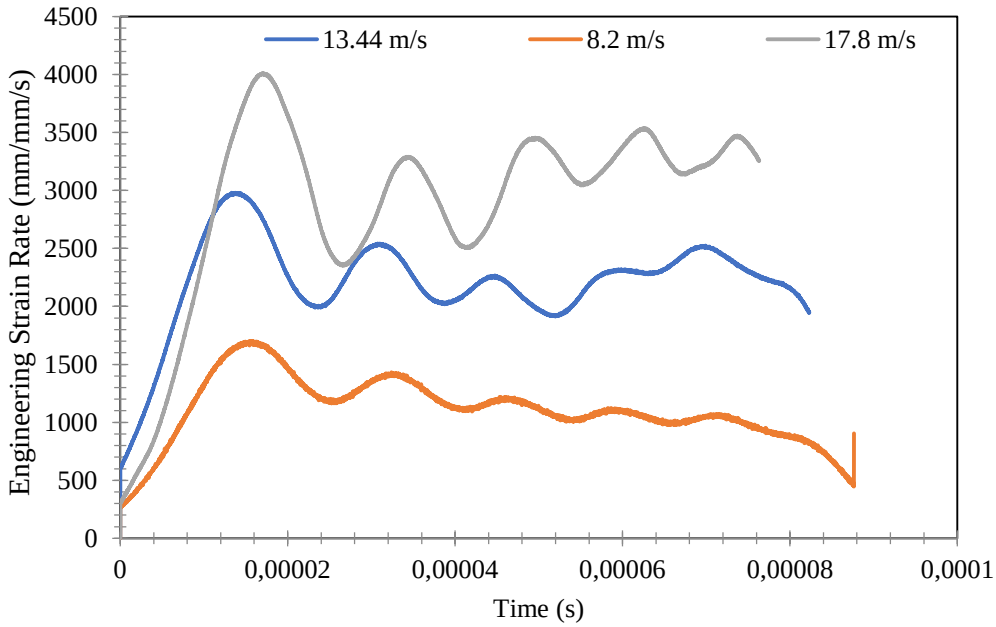


Figure 7. The strain rate versus time curves

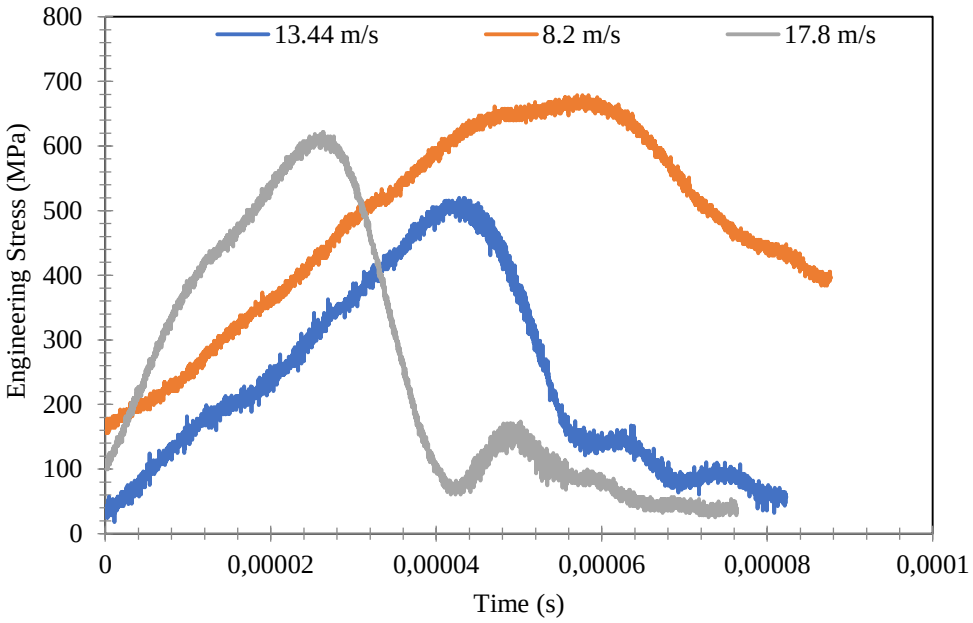


Figure 8. Stress versus time curves

The tests were conducted by gradually increasing the velocity impact from 8.2 m/s to 17.8 m/s. The engineering stress-engineering strain curves are shown in Figure 9. The stress increases linearly with strain after that becomes nonlinear after deformation an damage of specimen [8]. Maximum engineering stress and engineering strain at maximum stress were given for various velocities in Table 5.

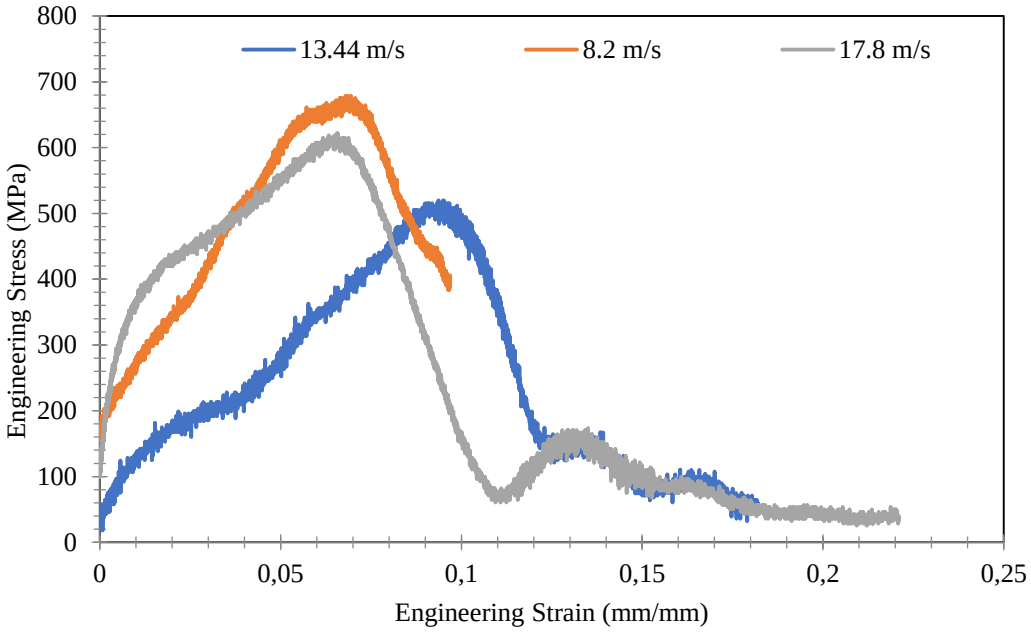


Figure 9. Engineering Stress versus Engineering Strain Curves

Table 5. Maximum stress, strain at maximum stress and time at maximum stress for various velocities

Velocity of striker bar (m/s)	Maximum stress (MPa)	Strain at maximum stress (mm/mm)	Time at maximum stress (s)
8.2	678.77	0.06867	5.77×10^{-5}
13.4	519.89	0.09367	4.27×10^{-5}
17.8	621.89	0.06579	2.64×10^{-5}

Figure 10 gives maximum stress variation according to the velocity. It is seen from figure that maximum stress occurs at 8.2 m/s velocity while minimum stress exists at 13.44 m/s. Variation of strain is similar to stress variation. The maximum engineering strain values increases by increase of striker bar velocity as shown in Figure 11.

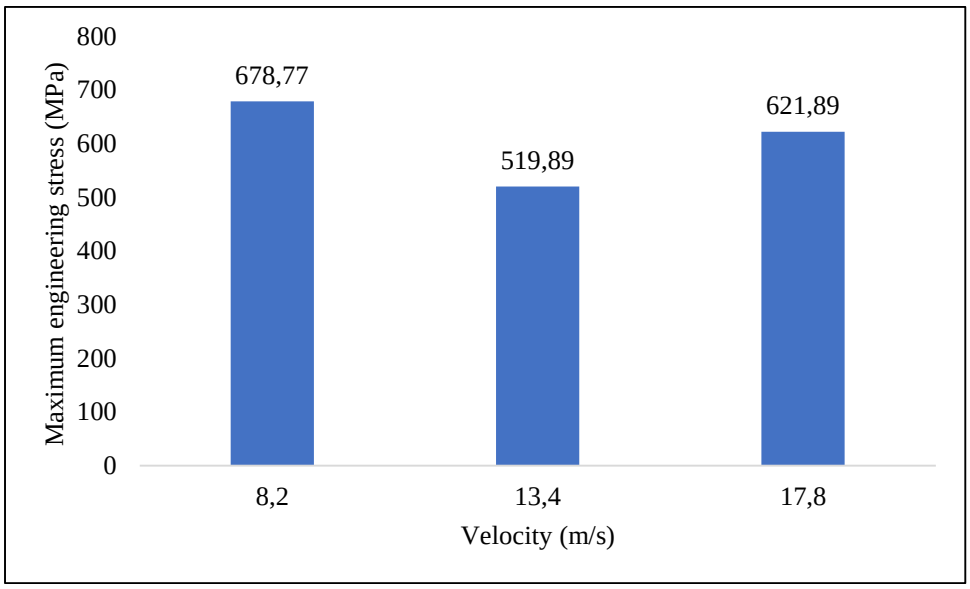


Figure 10. Maximum engineering stress with velocity

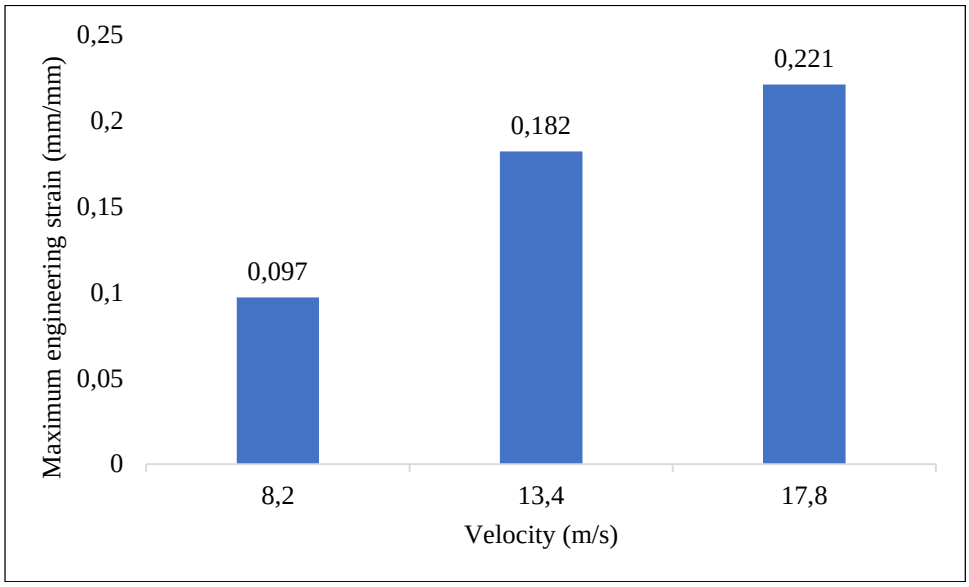


Figure 11. Maximum engineering strain with velocity

The failure and damage of specimens were given in Figure 12. Damage increases by increase of velocity and the specimens were divided into multiple fragments.

Figure 12. Damages of specimens

Conclusion

In this study, dynamic compression behaviors of E-glass/epoxy composite were investigated by SHPB tests. In the test, three different bar velocities were used. Strain rate-time, stress-time, stress-strain curves were obtained. It is concluded from obtained results that strain rate or bar velocity has significant effect on engineering stress, engineering strain, damages of composite materials and time.

References

[1] P. Song *et al.*, "The constitutive behavior of Ti–5Al–3V–2Cr–2Fe under high-velocity impact: Experimental, modeling, and validation," *J. Alloys Compd.*, vol. 811, p. 151946, 2019, doi: 10.1016/j.jallcom.2019.151946.

[2] H. Khoramishad, H. Alikhani, and S. Dariushi, "An experimental study on the effect of adding multi-walled carbon nanotubes on high-velocity impact behavior of fiber metal laminates," *Compos. Struct.*, vol. 201, no. May, pp. 561–569, 2018, doi: 10.1016/j.compstruct.2018.06.085.

[3] A. Sarwar, Z. Mahboob, R. Zdero, and H. Bougherara, "Mechanical characterization of a new Kevlar/Flax/epoxy hybrid composite in a sandwich structure," *Polym. Test.*, vol. 90, no. May, p. 106680, 2020, doi: 10.1016/j.polymertesting.2020.106680.

[4] V. A. Chatterjee, S. K. Verma, D. Bhattacharjee, I. Biswas, and S. Neogi, "Manufacturing of dilatant fluid embodied Kevlar-Glass-hybrid-3D-fabric sandwich composite panels for the enhancement of ballistic impact resistance," *Chem. Eng. J.*, vol. 406, no. July 2020, p. 127102, 2021, doi: 10.1016/j.cej.2020.127102.

[5] Q. Tao *et al.*, "Energy absorption and impact behavior of composite sandwich panels under high-velocity spherical projectile," *Int. J. Impact Eng.*, vol. 162, no. November 2021, p. 104143, 2022, doi: 10.1016/j.ijimpeng.2021.104143.

[6] A. Nugroho, Triastuti, S. Sufiandi, and A. Z. Syahrial, "Energy absorption of densified veneer-aramid hybrid composites subjected to ballistic impact," *Heliyon*, vol. 8, no. 8, 2022, doi: 10.1016/j.heliyon.2022.e10271.

[7] R. Kapoor, L. Pangeni, A. K. Bandaru, S. Ahmad, and N. Bhatnagar, "High strain rate compression response of woven Kevlar reinforced polypropylene composites," *Compos. Part B Eng.*, vol. 89, pp. 374–382, 2016, doi: 10.1016/j.compositesb.2015.11.044.

[8] K. Shaker, A. Jabbar, M. Karahan, N. Karahan, and Y. Nawab, "Study of dynamic compressive behaviour of aramid and ultrahigh molecular weight polyethylene composites using Split Hopkinson Pressure Bar," *J. Compos. Mater.*, vol. 51, no. 1, pp. 81–94, 2017, doi: 10.1177/0021998316635241.

A Case Study on PV-Aided Net Zero-Energy Building: the Daycare in IKCU

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Abstract

At the core of our growing societies, energy supply stands as one of the major concerns today, and it will be an inevitable challenge for our near future. As the nations are looking to find solutions for the transition from fossil fuels – depleting at a high rate – to alternative energy sources, solar energy through PV cells is getting attention as an affordable and easily implemented option especially for power supply in commercial and residential buildings. This work consists in analyzing the possibility to cover the entire energy needs of a building via PV solar cells for the case of a constructed daycare. In this case study, HVAC energy requirement has been calculated by the TS825 standard. The standard specifies a method for calculating the net heating/ventilation energy need and provides the rules for calculating the maximum allowable temperature in buildings. First, dimensions of the investigated building are taken and characteristics affecting the thermal insulation are assessed. Then, other energy needs, mainly lighting and electrical devices, are computed in the analysis as internal electricity needs. The scope of this work extends to the assessment of indoor air quality for occupants of building, which is an important aspect in our case study where the occupants are children. ASHRAE standards 62.1 is utilized for this purpose. The standard specifies minimum ventilation rates and other measures intended to provide acceptable indoor air quality to human occupants and that minimizes adverse health effects. The results are obtained for monthly varying solar exposition in the specified area where the building is located to provide supply for the determined energy demand via solar energy. Finally, monocrystalline PV panel system has been proposed with proper orientation and adequate power potential. Based on the obtained results, as well as the economical aspect, inferences and suggestions are made for improvement.

Keywords: Photovoltaic panels, power generation, zero-energy building

Introduction

As the world population continues growing, energy demand due to industrial and human-based activities increases in parallel [1]. Usage of renewable energy sources has become an attractive alternative to conventional energy sources to meet the growing energy demand while reducing greenhouse gas emissions [2]. One of the most promising renewable energy sources is solar or radiant energy which can be harvested via photovoltaic (PV) panels [3]. Recent progress in efficiency of PV panels has allowed the rise of concepts like zero and net-zero energy buildings.

A zero-energy building is a construction that generates adequate energy for annual energy consumption. Such buildings are designed to reduce energy consumption to a minimum and produce the remaining energy using renewable sources [4]. The concept of zero energy buildings has gained increasing popularity due to the growing concerns on sustainable environment and energy-efficient buildings. PV panel systems are commonly used in zero energy buildings to generate renewable energy-based electricity. PV panels convert sunlight into electricity without any harmful emissions. The size and capacity of the PV systems depend on the building's energy demand and the available solar irradiation. PV-aided zero energy buildings have been researched extensively in recent years [5].

In western countries, the main factor affecting the total energy demand in buildings is the heating, ventilation, air conditioning and refrigeration (HVAC-R) units. A review of energy consumption in buildings across developed countries by Firth et al. in 2016 documented that space heating accounted for the largest proportion of energy consumption in both residential and commercial buildings [6]. The authors note that this is due to a combination of factors, including the climate conditions and building design. This fact is better illustrated in Fig. 1 by a pie chart from the National Academies of Sciences of the US [7].

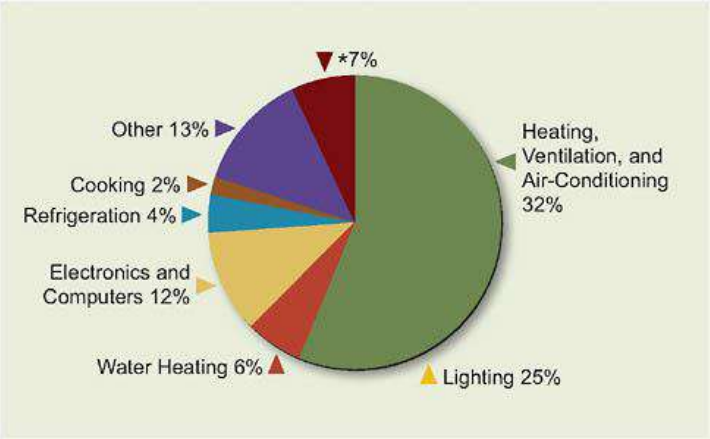

Figure 1: Energy use in U.S. commercial buildings [7]

At this point Turkish Standard TS825, that is a technical norm developed by the Turkish Standards Institution (TSE), provides a guideline for the calculation of energy requirement in the residential/commercial buildings. The title of the standard is "Energy Performance of Buildings - Calculation of Energy Use for Heating and Cooling" [8]. In Türkiye, it is estimated that buildings that obey the TS825 regulations for insulation can save up to 60% of the energy used for heating purpose. As energy represents a major issue today in the world and especially in the country, TS825 has become a mandatory norm for all new buildings as of 14th June 2000. The purpose of TS825 is to provide a standardized method for assessing the energy performance of buildings, particularly with respect to heating, heat gains and heat losses. The standard allows engineers and designers to determine the energy performance of buildings using a range of parameters, including the building placement, wall specifications, ceiling layers, floor type and layers, window types and area, door type, indoor and outdoor temperature level for each month, heating and cooling systems, ventilation system and type, and solar heat gains. We mainly utilized from this standard and the methodology within it to determine the monthly and annual heating energy requirement for the building considered in our case study, i.e., the daycare (nursery) at Izmir Katip Celebi University. In that calculation method, TS825 mainly takes into consideration: building properties such as construction materials, insulation, heat losses through conduction convection and ventilation; as well as heat gains from internal sources and solar radiation, to determine the heating energy need for the building. Other factors considered when calculating the energy need in our work are the energy needs for cooking, lighting, refrigeration, electronic devices, and water heating. Their values are relatively constant, and they are taken as monthly and yearly average. The calculation provides an accurate estimation of the total energy demand of the building. The procedure is detailed in section 2. Our assumption is that under TS825 specified conditions, PV-panels will provide 100% of the energy needs for the daycare in our case study, making it a net zero-energy building.

Next, indoor air quality and personal comfort conditions have been considered while calculating the total energy consumption of the investigated domain. ASHRAE 62.1 standard [9] is used for ventilation rates and indoor air quality requirements. This standard provides guidelines for the assessment of indoor air quality of occupants in various spaces. In a daycare, where the occupants are kids/children, this standard is crucial in achieving a viable zero energy building and ensuring the health and safety of kids. Furthermore, ASHRAE 55 is utilized for the determination of personal comfort conditions especially for the ventilation speed point of view [10].

In this case study, we investigate usage of PV panels for the daycare building at Izmir Katip Çelebi University to cover all the energy requirement in an annual period. First, the monthly and annual heating energy loads of the selected nursery are calculated via TS825 standard. Next, energy consumption due to the electronic appliances, lighting and specific devices are determined to obtain total energy requirement of the investigated building. PV panel type and total number of PV panels have been determined according to the maximum energy requirement case experienced in January. Furthermore, a detailed cost analysis has been performed to compare the investment cost of possible PV solutions.

Methods

The first step in our work is to measure the building properties needed at all calculation stages of the TS825. They include mainly: measurements of dimensions, heat losing surfaces, area of each component considered in calculations, and total window and door areas in each direction. The data are presented in Table 1.

Table 1. Main dimensions and specifications of the investigated building

Building dimensions (m)		Layer/wall areas (m^2)		Gross volume (m^3)	Window area (m^2)		Door area (m^2)		Internal Temp. (ºC)
Length	18,9	Reinforced Concrete	53,4	1791	North	20,6	North	0	20
Width	25,5	External Wall	202,5		East	16,3	East	5,9	
Height	3,7	Ceiling	484,1		West	13,0	West	0	
Floor Height	3	Floor	484,2		South	15,6	South	1,9	
		Total Area	1297,6		Total	65,5	Total	7,9	
		Net Usage	573,3						

The heating energy need for the building, as stated in the previous sections, is the main factor affecting the total energy demand. That value was calculated according to the systematic calculation method using the TS825 with the data listed in Table 1. The calculation steps contain: calculation of heat loss of the building (through conduction, convection), calculation of heat gain of the building (internal and solar gains), and lastly, calculation of the heating energy need using the obtained data. In order to determine the specific heat loss of the building, we initially focused on the heat loss through conduction and convection. Then we calculate the heat loss through ventilation, and we add the two values to get the total heat loss value as shown in Eq. (1).

$$H = H_T + H_V \tag{1}$$

where, H is the total specific heat loss, H_T is the heat loss through conduction and convection heat transfer mechanisms, and H_V denotes the heat loss through ventilation. First, we calculate the thermal permeability resistance (R) values of each building components via Eq. (2) to determine the H_T.

$$R = \frac{d}{\lambda} \tag{2}$$

where, R corresponds to the thermal permeability resistance (m^2.K/W), d is the thickness of the building component, and λ is the thermal conductivity of the components (W/mK). Note that the thermal conductivity values are provided in Annex E of the TS825 [8]. R-value calculation for multi-layered building components is made by simply adding the R-values of each structural element (layer) of the component. Utilizing the R-values previously calculated, we derive the total thermal performance coefficient (U), from the inverse function of total thermal permeability resistance (1/U) formula, for each component, as shown Eqs. (3) and (4).

$$\frac{1}{U} = R_i + R + R_e \tag{3}$$

$$U = \frac{1}{R_i + R + R_e} \tag{4}$$

In equations (3) and (4), R_i and R_e are the surface thermal transmission resistance of the inner and outer surfaces, respectively. R_i and R_e values are provided in TS825 standard for various building scenarios. The heat loss by conduction and convection (H_T) value is then calculated by summing up the products of each component's total thermal performance coefficient (U) by its specific area (A), and adding to it the heat loss transmitted through the thermal bridges, as shown in equation (5)

$$H_T = \sum AU + \sum Ul \tag{5}$$

In the case of our building that doesn't contain thermal bridges, the term (∑Ul) is ignored from equation (5) which can then be developed for each component, giving us equation (6).

$$\sum \text{AU} = U_D A_D + U_p A_p + U_k A_k + 0.8\, U_T A_T + 0.5\, U_t A_t + U_d A_d + 0.5 U_{ds} A_{ds} \quad (6)$$

where:

U_D = Thermal permeability coefficient of the outer wall (W/m^{2}K),
U_P = The thermal transmittance coefficient of the window (W/ m^{2}K),
U_k = Thermal permeability coefficient of the outer door (W/ m^{2}K),
U_T = Thermal permeability coefficient of the ceiling (W m^{2}K),
U_t = Thermal permeability coefficient of the base/floor on the ground (W/ m^{2}K),
U_d = Thermal permeability coefficient of the sole in contact with the outside air
U_{ds} = The coefficient of thermal permeability of the building elements in contact with the indoor environments at low temperatures (m^{2}K),
A_D = Area of the outer wall (m^2),
A_P = Area of the window (m^2),
A_k = The area of the outer door (m^2),
A_T = Ceiling area (m^2),
A_t = Floor-to-floor/floor area (m^2),
A_d = Area of floor/floor in contact with outside air (m^2),
A_{ds} = Area of building elements in contact with indoor environments at low temperatures (m^2).

The calculation of heat loss by ventilation, H_V includes both natural and mechanical ventilations affecting to the building. In the case of the daycare building of our study, since there is no mechanical ventilation, only natural ventilation is considered and calculated as follows:

$$H_V = \rho.c.V^1 = \rho.c.n_h\, V_h = 0.33\, n_h.V_h \quad (7)$$

where, ρ is the unit volume mass of air, c is the specific heat capacity, V^1 corresponds to air exchange rate by volume, n_h is the air exchange rate, and V_h denotes the ventilated volume. As density and specific heat capacity of the air slightly change (depending on temperature and pressure), their variations are neglected in the equation, and values are taken at 20 °C and 100 kPa. The enthalpy increase between the incoming and outgoing air is also neglected.

Heat gains need to be calculated to determine the monthly and annual energy demand of the building. Heat gain term refers to the amount of heat that enters the building through various sources such as solar radiation, appliances, lighting, and occupants. In this study, we calculate total heat gains as the sum of internal and solar gains. Average monthly internal heat gains ($\phi_{i,\ month}$) include metabolic heat gains from humans, heat gains from the hot water system, heat gains from cooking, heat gains caused by the lighting system, heat gains from various electrical devices used in buildings. These values are taken as the average and considered constant throughout the year. For our building category (school), internal heat gain can be calculated via:

$$\phi_{i,\ month} \leq 5 \text{ x } A_n \text{ (W)} \quad (8)$$

Here, A_n is the usage area of the building that can be obtained as follows:

$$A_n = 0{,}32 \text{ x } V_{gross} \quad (9)$$

V_{gross} is the heated gross volume of the building. On the other hand, the monthly solar gain ($\phi_{S,\ month}$) refers to the amount of energy gained by solar radiation from sunlight through the windows. The gains from passive solar energy systems are neglected in this work. The average solar gain is calculated using equation (10).

$$\phi_{S,\ month} = \Sigma\, r_{i,\ month} \text{ x } g_{i,\ month} \text{ x } I_{i,\ month} \text{ x } A_i \quad (10)$$

where, $r_{i,\ month}$ is the monthly average shading factor of transparent surfaces in "i" direction, $g_{i,\ month}$ denotes the solar energy transmission factor of transparent elements in "i" direction, $I_{i,\ month}$ is the monthly average solar radiation intensity on vertical surfaces in the "i" direction, and A_i is the total window area in the

"i" direction. While $r_{i,\,month}$ and $I_{i,\,month}$ values are provided by the TS825, $g_{i,\,month}$ is calculated with the help of Eq. (11).

$$g_{i,ay} = F_w . g_{\perp} \tag{11}$$

Here, F_w is the correction factor for glasses and $g_{\perp}$ denotes the solar energy transmission factor for the beam perpendicular to the surface measured under laboratory conditions. It is not always appropriate to consider the sum of the internal gains and solar energy gains as useful energy in terms of reducing the heating energy need. Because in times of high heat gains, the gains may be more than the instantaneous losses, or the gains may come when heating is not needed. The indoor temperature control system is not perfect, and some heat is stored in the building elements. Therefore, internal gains and solar gains are reduced by a utilization factor (η) that is the magnitude of this factor depends on the relative size of the gains and losses and the thermal mass of the building. The calculation of (η) is made using equations (9) and (10):

$$\eta_{month} = 1 - e^{(-1/KKO_{month})} \tag{12}$$

where KKO_{month} is the gain/loss ratio, and it is calculated as follows:

$$KKO_{month} = (\phi_{i,month} + \phi_{s,month}) / H(\theta_{i,month} - \theta_{e,month}) \tag{13}$$

Here, ϕ and θ are the abbreviation of heat gains and temperature levels. Note that, when the KKO_{month} value is 2.5 or above, it is considered that there is no heat loss for that month. The monthly average internal and external temperatures, $\theta_{i,ay}$ and $\theta_{e,ay}$ are provided by TS825 in Annex B, section 1 and 2 respectively. With the help of the parameters calculated in the previous steps, we finally obtain the annual heating energy need for our building adding up the monthly heating energy need values for our building according to equations (14) and (15).

$$Q_{year} = \sum Q_{month} \tag{14}$$

$$Q_{month} = [H(\theta_{i,month} - \theta_{e,month}) - \eta(\phi_{i,month} + \phi_{s,month})].t \tag{15}$$

where, Q_{year} and Q_{month} are the annual and monthly heating energy need of the investigated building, t is the time in the unit of seconds. The energy demand other than heating energy has been considered for the electrical devices used in the daycare. Main equipment list contain computer, washing Machine (A++), camera system, fridge (A++), deep-freeze (A+, 102L), microwave (A++), oven, fume hood and kettle. The annual energy requirement for these devices was calculated according to the number of devices, the power they consume and their respective daily working hours.

It is important to mention that the building investigated in our study lacks insulation in its components. Insulation represents a major parameter in the calculation method of TS825. The use of insulation material in the building components is recommended because it has a significant impact on the heat loss of the building by conduction, resulting in lower energy need [8]. Since the investigated daycare does not have any insulation material in its walls and other building components, we have conducted separate calculations for the heat loss through conduction and convection, assuming cases in which insulation materials are used for the walls and ceiling. The insulation material used for this purpose were selected according to the recommendations from TS825. This step is conducted for comparison purpose to analyze the impact of using insulation material.

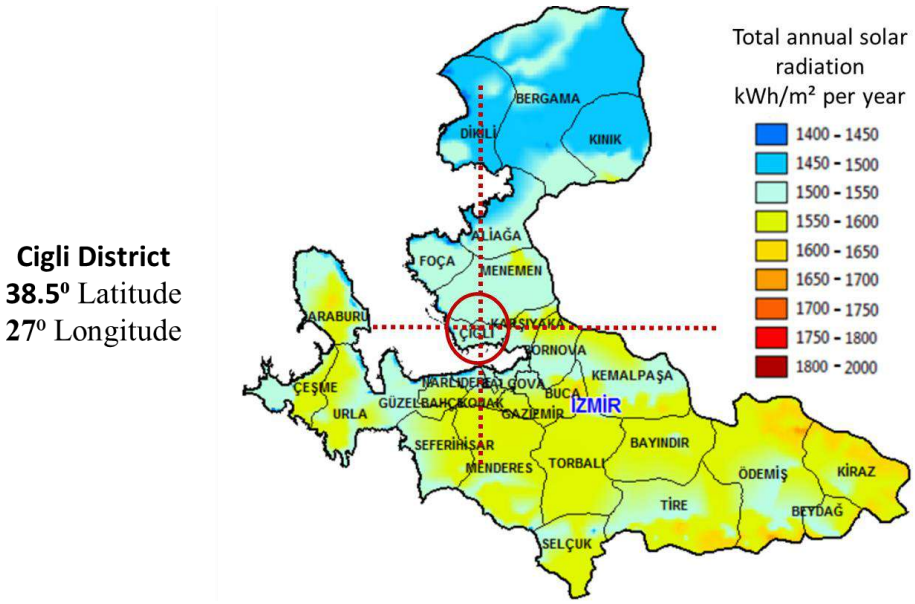

Figure 2. Solar irradiation map and latitude of Çiğli district [11]

Once the energy demand of the selected building has been calculated for monthly and annual periods, PV panel type and required number of PV panels were investigated. Figure 2 presents the solar irradiation map of Çiğli district. Furthermore, latitude of the selected building is a crucial parameter for PV system design as tilt angle of the PV panels is directly depended on the latitude. We utilize from a simplified equation set to calculate the optimal tilt angle (β) of each season:

$$\begin{cases} \text{During summer:} & \beta = (0.9 \times \text{Latitude}) - 23.5^0 \\ \text{For spring and autumn months:} & \beta = \text{Latitude} \pm 2.5^0 \\ \text{During winter:} & \beta = (0.9 \times \text{Latitude}) + 29^0 \end{cases} \quad (16)$$

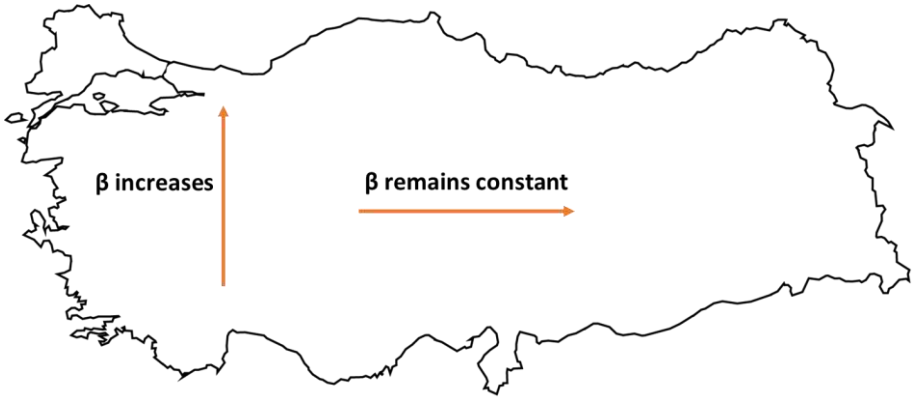

Figure 3. Effects of latitude and longitude on PV panel tilt angle

PV panel orientation should be altered according to the PV panel tilt angle calculations. In most of the PV panel applications in our country, tilt angle is kept constant. In this case, an optimal angle value should be determined for annual radiant harvesting. Note that tilt angle only varies with latitude (Fig. 3). We may sum winter, summer, spring, autumn tilt angles and divide by four to find an approximate annual tilt angle. Another simplified equation can also be utilized for annually constant tilt angles:

$$\beta = (0.87 \times \text{Latitude}) + 3.1^0 \quad (17)$$

Results and Discussion

The results of our work using the methods described in section 2, are reported in this section. Parameters and properties used at each calculation step are described in tables and values found are reported. As mentioned in the first section, the energy need for heating purpose in the building (H), is the dominant factor when determining the total energy need. It is defined in section 2 as the sum of heat

loss through conduction and convection (H_T), and heat loss through ventilation. (H_v). Table 2 describes the calculation of (H_T).

Table 2. Building heat loss through conduction and convection: calculation steps

Surface type	Layer element	Element thickness d (m)	Thermal cond. λ (W/mK)	Conduction resistance R, (m^2K/W)	Overall coefficient U (W/m^2K)	Surface area A (m^2)	Heat loss A x U (W/K)
Wall surfaces	Ri			0,13			
	Plaster	0,02	1	0,02			
	lime sandstone	0,172	0,35	0,491			
	Plaster	0,008	0,35	0,023			
	Re			0,04			
			Total	0,704	1,419	202,5	287,5
Wall surfaces (reinforced concrete)	Ri			0,13			
	Plaster	0,02	1	0,02			
	Reinforced Concrete	0,172	2,5	0,069			
	Plaster	0,008	0,35	0,023			
	Re			0,04			
			Total	0,282	3,551	53,4	189,6
Ceiling	Ri			0,13			
	Plaster	0,02	1	0,02			
	Reinforced Concrete	0,18	2,5	0,072			
	Re			0,08			
			Total	0,302	2,65	484,2	1478,3
Floor	Ri			0,17			
	PVC flooring	0,005	0,23	0,022			
	Screed	0,03	1,4	0,021			
	Leveling Screed	0,02	1,4	0,014			
	lightweight concrete	0,1	1,1	0,091			
	Re			0			
			Total	0,317	1,573	484,2	761,9
External Door					4	7,92	31,68
Window					2,4	65,48	157,15
Sum of the heat loss from the building elements by conduction and convection $\mathbf{H_T}$,							2710,428

The value for the total heat loss through conduction and convection of the daycare was found as H_T = 2710,428 W/K. Next, the heat loss through ventilation, (only natural ventilation in our building) was calculated using Eq. (7) and the following value was found as H_V = 378.3 W/K. Finally, the total heat loss of the building was obtained by summing up H_T and H_V according to equation (1). The total heat loss coefficient of the building is **H = 3088.78 W/K.**

Once the heat losses due to the building structure and ventilation system were determined, we calculated the heat gains (Φ) of the building as the sum of internal gains (Φ_i) and solar gains (Φ_s). The internal heat gain was calculated as an average value using Eq

(9), which is about Φ_i = 2866.3 W. On the other hand, the average solar gain was calculated monthly, in each cardinal direction, as described in Eq. (10). The calculation steps and results are reported in Table 3. Note that $r_{i,month}$ and $g_{i,month}$ values are taken from the TS 825 standard as 0,8 and 0,68, respectively.

Table 3. Average monthly solar gains: calculation steps

	$\mathbf{I_{i,ay}}$			$\mathbf{A_i\ (m^2)}$				$\boldsymbol{\phi_s}$
	I_{South}	I_{North}	$I_{East/West}$	A_{South}	A_{North}	A_{East}	A_{West}	(W)
Jan.	72	26	43	15,6	20,58	16,3	13	1587,5
Feb.	84	37	57					2035,6
Mar.	87	52	77					2547,8
Apr.	90	66	90					2937,2
May	92	79	114					3482,3
Jun.	95	83	122					3680
Jul.	93	81	118					3576,9
Aug.	93	73	106					3296,1
Sept.	89	57	81					2684,5
Oct.	82	40	59					2084,1
Nov.	67	27	41					1524,4
Dec.	64	22	37					1379,2

Gain utilization factor was calculated for each month via Eq. 12, and the values are reported in Table 4. At last, the annual heating energy requirement of the building (Q_{year}), was determined as the sum of the monthly heating energy requirement values (Q_{month}) by using Eqs. (14) and (15), respectively.

Table 4. Main calculation steps and results on the annual heating energy requirement of the building

	Heat losses			Heat gains				
	Specific Heat loss	Temp. diff.	Heat loss	Internal heat gain	Solar energy gain	KKO	Gain utilization factor	Heating energy require-ment
Months	$H=H_T+H_V$ (W/K)	$\theta_i-\theta_e$ (K,°C)	$H(\theta_i-\theta_e)$ (W)	ϕ_i (W)	ϕ_s (W)	γ (-)	η_{month} (-)	Q_{month} (kJ)
Jan.	3088.78	11,6	35829,8	2866,3	1587,5	0,12	0,99	$8,13\times10^7$
Feb.		11	33976,6		2035,6	0,14	0,99	$7,53\times10^7$
Mar.		8,4	25945,8		2547,8	0,20	0,99	$5,33\times10^7$
Apr.		4,2	12972,9		2937,2	0,42	0,90	$2,02\times10^7$
May		θ_e high	0		3482,3	0	0	0
Jun.		θ_e high	0		3680	0	0	0
Jul.		θ_e high	0		3576,9	0	0	0
Aug.		θ_e high	0		3296,1	0	0	0
Sept.		θ_e high	0		2684,5	0	0	0
Oct.		1,5	4633,2		2084,1	1,004	0,63	$4,21\times10^6$
Nov.		7	21621,5		1524,4	0,190	0,99	$4,47\times10^7$
Dec.		10,7	33049,9		1379,2	0,12	0,99	$7,47\times10^7$

The total heating energy requirement of the building was calculated as the sum of the monthly heating energy needs, and found as: $Q_{year} = 3,54\times10^8$ kJ. This value corresponds to $9,83\times10^4$ kWh. This theoretical value obtained using the TS 825 standard assumes a permanent daily and monthly use of electricity in the building. In reality, the building is functional 12 hours a day, 23 days a week, or 276 hours monthly. It represents only 38% of 720 hours calculated. This means that in reality, only 38% of the energy calculated is needed. The real heating energy requirement becomes $3,74\times10^4$ kWh.

Table 5. Annual energy consumption of devices in the daycare

Device	Pcs.	Power (W)	Daily working hour (h)	Daily Energy consumption (KWh)	Monthly energy consumption (KWh)	Annual energy Consumption (KWh)
Computer	1	15,2	8	0,12	3,6	108
Washing Machine (A++)	1	800	1	0,8	24	720
Camera System	1	10	24	0,24	7,2	216
Fridge (a++)	1	60	24	1,44	43,2	1296
Deep Freeze (A+, 102 litres)	1	50	24	1,2	36	1080
Microwave (A++)	1	300	1	0,3	9	270
Oven	1	2500	1	2,5	75	2250
Fume Hood	1	12	1	0,012	0,36	10,8
Kettle	1	1200	0,5	0,6	18	540
	1	28	8	0,224	6,72	201,6
Total				7,436	223,1	6692,4

We have calculated that the annual energy consumption of electrical devices used in the daycare is about 6692,4 kWh; therefore, the total energy requirement of the building per year rises to $4{,}40\times10^4$ kWh.

The remaining energy requirement for the daycare was assessed by identifying all devices consuming electricity in the building and calculating their monthly and annual consumption, reported in Table 5.

Five different types of PV-panels were investigated to provide the amount of energy needed for the investigated daycare, t. The criteria considered for this selection are the amount of solar irradiation at the building location, the total area to be covered with PV-panels considering individual panel size, and the calculated energy requirement of the building. The average daily irradiation time for each month at the building location are presented in Table 6.

Table 6. Çiğli district annual sunbathing time [11]

Month	Duration (h)
January	4,98
February	5,99
March	7,17
April	8,19
May	9,88
June	12,07
July	12,38
August	11,6
September	9,8
October	7,78
November	5,69
December	4,39

The types of PV-panels investigated in our work and their properties are reported in Table 7.

Table 7. Monocrystalline PV-panels and main properties [12]

Panel	Power (W)	Dimensions (mm)	Weight (kg)	Efficiency (%)	Price (TRY)
Jinko Solar JKM370M-72-J	370	1956×992×50	27	19.1	3689
Jinko Solar JKM535M-72H	535	2278×1134×35	28	20.8	5632
Lexron LXR-410M	410	1987×1001×35	22	19.1	5044
AlfaSolar 3S72M400	400	1994×1008×42	24	20.0	4016
ELINPlus ELNSM6612M	395	1979×1002×40	22.5	19.9	3965

For each PV-panel type investigated, the corresponding number of panels and the total area needed to provide the amount of energy requirement of the daycare, were calculated according to the amount of solar irradiation. The calculation was made for the month of January as it is the month during which the energy need reaches its peak value: 9142,58 kWh. Table 8 presents the values obtained.

Table 8. Number of PV-panels required

PV-Panel	Sunbathing time (h)	Panel Power (kW)	Energy generation (Jan) (kWh)	Energy requirement (Jan.) (kWh)	Number of PV	Total surface needed (m^2)
Jinko Solar JKM370M-72-J	149,4	0,37	55,278	9142,58	166	320,93
Jinko Solar JKM535M-72H		0,535	79,929		115	295,5
Lexron LXR-410M		0,41	61,254		150	296,87
AlfaSolar 3S72M400		0,4	59,76		153	307,5
ELINPlus ELNSM6612M		0,395	59,013		155	307,21

We observed that with the PV-panels investigated, the number of panels needed to cover the daycare energy needs, is in the range of 115 to 166, meaning an average of 140 panels depending on the panel power. It corresponds to an area between 307 and 321 m^2, or an average of 315 m^2. Among our PV-panels, the best performer is the Jinko Solar JKM535M-72H: with its efficiency of 20.8% it can generate enough energy for the daycare with 115 panels, which represents a surface of just 296 m^2.

The optimal tilt angle (β) for the panels was calculated for the investigated building located in the Cilgi district in Izmir, at a latitude of 38,5º. The results are reported in Table 9.

Table 9. Optimal tilt angle for Çiğli district

Season	β
Summer	11,15º
Spring	41º
Autumn	36º
Winter	63,65º

Alternatively, a constant value for (β) can also be calculated using eq. (17) in case the solar panel will stay in the same direction all through the year. In our case, the annually constant tilt angle was found as $\beta = 36{,}6º$.

As mentioned in the previous sections, our building does not have insulation although it is recommended in the TS825 standard. In this view, we have conducted theoretical calculations assuming cases in which a layer of insulation material is applied to the walls and the ceiling components of the daycare. Three cases have been considered. For each case, a different insulation material was selected for the walls, while one single material was maintained for the ceiling in all three cases. The materials used for the wall insulation are Extruded Polystyrene (XPS) Styrofoam, Glass foam, and Wood fiber, while the ceiling insulation was evaluated using Expanded Polystyrene (EPS) Styrofoam. These materials were selected based on their thermal conductivity values in accordance with the suggestions from TS828, and their availability on the market. The thickness of the materials is an important factor when considering insulation. Thicker layers allow better insulation, but they should remain in compliance with local building codes and regulations. In our work, we have calculated the thickness of the investigated materials in order to obtain a reduction of 50% in heat loss through conduction and convection (H_T) value, for each case considered.

The insulation materials investigated with their properties and the calculated thickness values required for the desired insulation performance are shown in Table 10.

Table 10. Properties of insulation materials used in experimental cases

Material	Wall insulation			Ceiling insulation
	Case 1	Case 2	Case 3	EPS Styrofoam
	XPS Styrofoam	Glass foam	Wood fibered	
Thermal conductivity (W/mK)	0,035	0,055	0,065	0,04
Thickness required (m)	0,01536	0,0158	0,016	0,02

The impact of these insulation materials on the heat loss and the total energy demand of the building were calculated and compared with the real case where there is no insulation. The results are presented in Table 11.

Table 11. Impact of insulation on heat loss and total energy demand

	Insulation Material	Thermal conductivity (W/mK)	Thickness required (m)	Heat loss (W/K)	Energy need (kWh)
Case 1	XPS Styrofoam	0,035	0,01536	2180	63730,39
Case 2	Glass foam	0,055	0,0158	2206	64748,32
Case 3	Wood fibered	0,065	0,016	2215	65087,57
Real Case	No insulation			3088,79	98292,18

As we can see from these results, the use of insulation material to reduce (H_T) value by 50%, results in 29.4%, 28.5% and 28.2% drops in heat loss for insulation cases 1, 2 and 3 respectively.

Consequently, the annual total energy need of the building in each of the three insulation cases drops by 35.2%, 34.1%, and 33.8% respectively. With these new values, the corresponding number of PV panels required was determined for the three insulated cases, with each of the five PV-panels selected previously, and comparison was made with the real situation where there is no insulation. These results are detailed in Table 12.

Table 12. Number of PV-panels needed for insulation cases

	Case 1	Case 2	Case 3	Real Case
Jinko Solar JKM370M-72-J	113	115	115	165
Jinko Solar JKM535M-72H	78	79	80	114
Lexron LXR-410M	102	104	104	149
AlfaSolar 3S72M400	105	106	107	153
ELINPlus ELNSM6612M	106	108	108	155

As shown from these results, when insulation is applied, the number of PV-panels needed to cover the entire energy need of the daycare decreases by approximately 30% depending on the PV-panel used. From these panels, the Jinko Solar JKM535M-72H has the best performance and would allow to cover the energy demand with just 78, 79, or 80 panels in each of the three insulated cases respectively, while the initial case without insulation requires 114 panels. We observe here the use of insulation plays a very important role in limiting the heat loss of the building, allowing the energy need to decrease significantly. While our theoretical study assumed insulation layers only on the wall surface and ceiling components of the building, it is important to remember that insulation layers can also be applied to other components like the reinforced concrete part of the walls or the floor. Furthermore, the thickness of the insulation layers used in our study was minimized in order to provide the most realistic case possible, but the average thickness of insulation layers is well above our values, as it can be seen in the examples from the TS825 standard, where the thickness of the layers is about 3 times our value. All these remarks imply that the use of insulation have potential to reduce exponentially the energy need.

In order to evaluate the real cost of utilizing the investigated PV-panels to meet the total energy demand of the daycare building, a cost analysis was conducted. This analysis takes into account the price of the PV-panels, estimation of Turkish market prices for installation and maintenance costs.

The prices of the investigated PV-panels are provided in Table 13.

Table 13. Total price of the PV-Panels

Panel	Price for single panel (TRY)	Number of panels	Total Price (TRY)
Jinko Solar JKM370M-72-J	3689	166	612374
Jinko Solar JKM535M-72H	5632	115	647680
Lexron LXR-410M	5044	150	756600
AlfaSolar 3S72M400	4016	153	614448
ELINPlus ELNSM6612M	3965	155	614575

The price varies from approximately 613000TRY to 757000TRY, depending on the type of PV-panel used, with an average of 700000TRY.

The most recent information we have gathered concerning the installation price for PV-panels from suppliers and reviewers indicates that installation of solar panels costs between 21TRY and 25TRY per Watt installed [13], [14]. This value is fairly in the range of prices given by Forbes [15] for PV-panels installation in the US. This represents on average of 1.4 million TRY to be paid for labor.

The total cost of the project is found to be in the range of 2.023 to 2.18 million TRY. The maintenance of PV-panels is estimated to be between 1% and 2% of the installation cost. In our case, this represents approximately 21000TRY per year. On the other hand, when we consider the insulated cases, the cost of PV-panels changes according to the new number of PV-panels needed to cover the energy demand. For each case, the total prices of the PV-panels are given in detail in Table 13.

Table 13. Total price of the PV-Panels for insulated cases

Panel	Price for single panel (TRY)	Number of panels			Total Price		
		Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
Jinko Solar JKM370M-72-J	3689	113	115	115	417671	423398	425306
Jinko Solar JKM535M-72H	5632	78	79	80	440998	447045	449059
Lexron LXR-410M	5044	102	104	104	515370	522436	524790
AlfaSolar 3S72M400	4016	105	106	107	420592	426359	428280
ELINPlus ELNSM6612M	3965	106	108	108	420508	426273	428194

The results show that the total prices of the PV panels decrease by around 30% for the insulation cases. The price of the insulation materials was calculated according to their unit price and the surface to be covered: 202.5m of wall surface, and 484.1m for the ceiling. Table 14 shows an estimation of these prices for each case.

Table 14. Price of insulation materials

	Material	Price (TRY)
Case 1	XPS Styrofoam	21796,93
Case 2	Glass foam	65390,78
Case 3	Wood fibered	54492,32
Ceiling	EPS Styrofoam	3647,57

In order to get the total cost of the project, the labor cost was also calculated with the same method used previously for the real case and found to be in the range of 966000TRY and 985000TRY.

According to these data, the total cost of the project for insulation cases ranges between 1.38 and 1.56 million TRY.

Conclusion

In this work, we have explored the feasibility of meeting the energy needs of a daycare building through the use of photovoltaic (PV) solar cells. The global increase in energy demand and the need for sustainable and environmentally friendly solutions, has led to a growing interest in renewable energy sources such as solar power and emphasized the importance of solutions like PV-aided net zero-energy buildings. Our study focused on the heating, ventilation, and air conditioning (HVAC) energy requirements, as they represent the biggest share in both residential and commercial buildings. By utilizing the TS825 standard, which provides guidelines for calculating the energy performance of buildings, the heating energy requirement of the daycare building was determined. The analysis took into account factors such as building dimensions, thermal insulation properties, heat losses, and heat gains. The monthly and annual energy demand of the building was accurately estimated based on these calculations. We then considered other energy needs, including lighting and electrical devices, to determine the overall energy requirement of the building.

Based on our analysis, we proposed the use of monocrystalline PV panels to meet the energy demand of the daycare building. After scaling the selected PV-panels to our project, the orientation and power potential of the PV panels were determined based on the maximum energy requirement experienced in January. The required number of PV-panels needed to cover the energy demand of the building was found to be in the range of 115 to 166 panels. Since our building lacks insulation which is an important parameter when dealing with heat loss and energy demand in buildings, as shown in the TS825 standard, theoretical calculations were conducted, assuming the presence of insulation layers in the walls and the ceiling components of our building. Three cases have been considered. For each case, a different material with different thermal conductivity was selected for the wall insulation, while one standard material was kept constant for the ceiling insulation. Comparison between the results of real case without insulation and theoretical cases with insulation, showed that the total energy demand of the building can be reduced by 33.8%, 34.1%, and 35.2%, which are very significant. Likewise, the number of PV-panels required to cover the energy demand of the daycare dropped by approximately 30%, with an optimal value of just 78 PV-panels, using the Jinko Solar JKM535M-72H under the insulation conditions described in case 1.

We conducted a cost analysis to evaluate the economic aspects of implementing the solutions suggested. The total cost of the project includes the price of the panels and the labour for installation and was found in the range of 2.023 to 2.18 million TRY depending on the PV -panel selected. The initial investment associated with implementing a PV panel system capable of meeting the entire energy demand of the building may represent a challenge, especially for buildings with limited budgets. On the other hand, the use of insulation material allows this initial investment to be reduced by a very significant amount as shown by our theoretical calculations with insulation, where the total cost of the project dropped to values between 1.38 and 1.56 million TRY. Furthermore, insulation has potential to reduce the initial cost even more, as layers could be applied to other components of the building. A good number of insulation materials can be chosen from, according to the cost and the thermal conductivity, among other factors. The optimal thickness can be determined according to the building regulation and the desired insulation performance. For these reasons, the use of insulation is our main recommendation in view of the implementation of the project. Besides insulation, some other options remain available to make the project more realistic and deserve further evaluations. A more specific PV-panel system could be considered, with usage exclusively limited to the ideal irradiation conditions, allowing a reduced dependence on the grid electricity. Also, the use of energy storage could have a great positive impact since solar energy is intermittent. Additional energy generated in peak irradiation period would serve during days with less daylight.

Overall, our findings suggest that it is indeed possible to cover the entire energy needs of the daycare building through PV-panels, making it a net zero-energy building. The use of renewable energy sources like solar power not only reduces greenhouse gas emissions but also contributes to a sustainable and environmentally friendly future. The results of this study provide valuable insights and recommendations for improving energy efficiency in commercial and residential buildings.

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References

[1] A. B. Kaviraj and P. S. Robi, "Global energy demand and population growth: A review article," Renewable and Sustainable Energy Reviews, vol. 89, pp. 128-140, 2018.

[2] 2. M. E. Ardehali, M. A. Rosen, and J. R. B. Miller, "Renewable energy sources for electricity generation: A review of their state-of-the-art, and emerging trends," Renewable and Sustainable Energy Reviews, vol. 76, pp. 1359-1378, 2017.

[3] Fumo, N., Ranzi, G., Vitali, M., & Ferraro, V. (2021). Renewable energy sources for a sustainable future: A review. Journal of Cleaner Production, 278, 123955.

[4] J. Zhang, Y. Liu, and Y. Cao, "A review on zero energy buildings: Concepts, technologies, and challenges," Renewable and Sustainable Energy Reviews, vol. 87, pp. 381-392, 2018.

[5] J. K. Tonui, "The use of photovoltaic energy in zero energy buildings: A review," Renewable and Sustainable Energy Reviews, vol. 55, pp. 399-412, 2016.

[6] Firth, S. K., Mellisho, C. D., Lee, Y., & Kang, J. (2016). A review of energy consumption in buildings across developed countries: Spatial patterns and influencing factors. Renewable and Sustainable Energy Reviews, 65, 976-991.

[7] National Academies of Sciences, Engineering, and Medicine. 2010. Real Prospects for Energy Efficiency in the United States. Washington, DC: The National Academies Press. https://doi.org/10.17226/12621.

[8] Turkish Standards Institution (TSE). Energy Performance of Buildings - Calculation of Energy Use for Heating and Cooling, TS 825. Ankara: TSE; 2018.

[9] Standard 62.1-2022 -- Ventilation and Acceptable Indoor Air Quality (ANSI Approved) STANDARD by ASHRAE, 2022

[10] Standard 55-2017 -- Thermal Environmental Conditions for Human Occupancy (ANSI/ASHRAE Approved) STANDARD by ASHRAE, 2017

[11] Güneş Enerji Potansiyel Atlası (GEPA), https://gepa.enerji.gov.tr/MyCalculator/pages/35.aspx.

[12] Website for PV panel properties, https://solaravm.com/solar-gunes-paneli, Last accessed: May 5th,2023.

[13] https://www.globalenerjimarketim.com/

[14] https://www.keremcilli.com/gunes-enerjisi-santrali-kurulum-maliyeti-2022/

[15] https://www.forbes.com/home-improvement/solar/cost-of-solar-panels/

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Impact of Cable Pre-Tension over the End Point Vibrations for Beam Systems

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Abstract

Beam systems are used in many areas today. They are preferred because of their light weight, high efficiency, high operating speed and low cost, but their excessive vibration causes problems. In order to prevent these vibrations, the rigidity of the system must be high. At this point, the use of cables is of great importance. Cable tensions affect the rigidity of the system. Cabled structures are preferred because lightweight stiffening, easy deployability, and shape control capability. In addition, they are also used in large-sized structures, as they can transmit their effects over long distances.

In this study, a linear velocity applied to a flexible beam is given, trapezoidal velocity inputs are given and various acceleration conditions are considered. In the model, natural frequencies are investigated for cableless and cabled situations with different pre-tension values applied. The changes in the endpoint vibrations were investigated by using the transient analysis method via ANSYS workbench. Thus, the effectiveness of using cable pre-tension in beam systems has been demonstrated.

Keywords: Flexible beams, cable pre-tension, transient analysis

Introduction

Flexible beams are widely used today due to their light weight, high operation speed and high efficiency. They are frequently preferred especially in robot manipulators. However, excessive vibrations are the biggest disadvantage of flexible beams. Therefore, the control of flexible beams has become the focus of researchers. In these researches, various active and passive control methods were studied. Nudehi et al. controlled end point vibrations of flexible beam using buckling type end force. They gathered vibration measurements of the beam, used an observer to estimate a set of modal vibration amplitudes and applied an end load only when it will remove energy from the beam [1]. Jnifene worked on the control of a single-link flexible manipulator using delayed position feedback and showed that if the control gain and time delay are chosen properly, control will occur quickly [2]. Jnifene et al. used fuzzy logic control to reduce the endpoint vibrations of flexible beams. They used the relation between angular displacement and end point deflections predicted by neural networks and obtained a significant reduction [3]. Sohn et al. also used shape memory alloy wire actuators for vibration control in flexible beams [4]. Achkire demonstrated the effectiveness of cables in passive and active control in cable-stayed bridges [5]. The use of cables to increase the rigidity of the structures has been a solution in terms of preventing these excessive vibrations.

In this study, the passive control effect of cable pre-tension on the endpoint vibrations of the flexible beam during and after the movement was investigated.

System Definition and Method

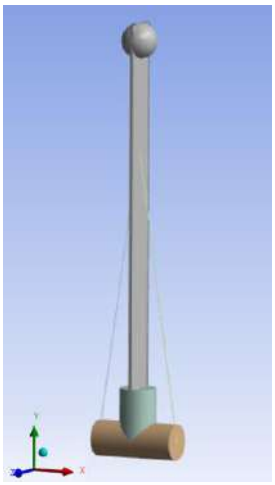


Figure 1. Beam system

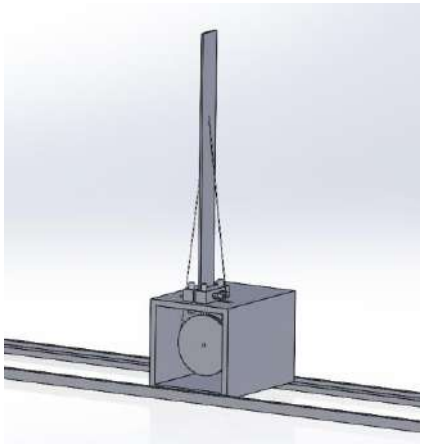


Figure 2. Solidworks model of system

In this study, we have 420mm long flexible beam, 1.25kg point mass at 400mm, junction point of flexible beam and cables at 280mm (Figure 1). Cables and flexible beam made by steel and also has cross section R=1 mm and 4x40 mm respectively. Both cables work for only tensile. The system moves linearly in the X-axis on the rails (Figure 2). By using transient analysis method we apply various trapezoidal velocity inputs and cable pre-tension values and observe endpoint vibrations via ANSYS.

Rigidity Effect of Cable

In order to see the effect of the cable on the system rigidity, modal analysis was performed for no cable, no pre-tension and three different pre-tension situations. When the natural frequencies are examined, the increase in the rigidity of the cabled systems is clearly seen and it is observed that the rigidity effect increases as the pre-tension values increase (Table 1).

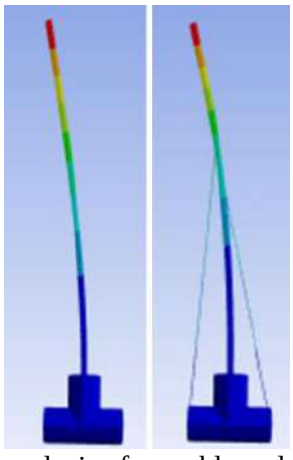


Figure 3. Modal analysis of no cable and cabled situations

Table 1. Modal analysis results

Natural frequencies (Hz)	
No cable	6.0243 Hz
Cabled without pre-tension	11.3079 Hz
10N pre-tension	11.3177 Hz
75N pre-tension	11.3808 Hz
100N pre-tension	11.4049 Hz

In order to show the effect of this rigidity increase on the end point vibrations, no cable and no pre-tension situations were handled. The transient analysis was performed by applying the velocity input in Figure 4, and the effectiveness of the cable on the end point vibrations was observed (Figure 5).

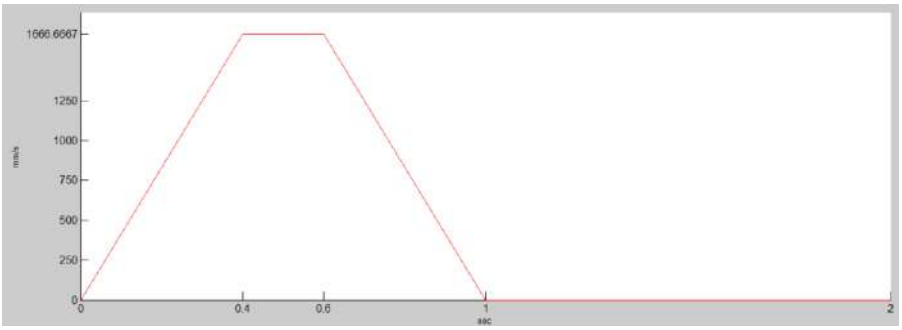


Figure 4. Trapezoidal velocity profile (40% acc-dec time)

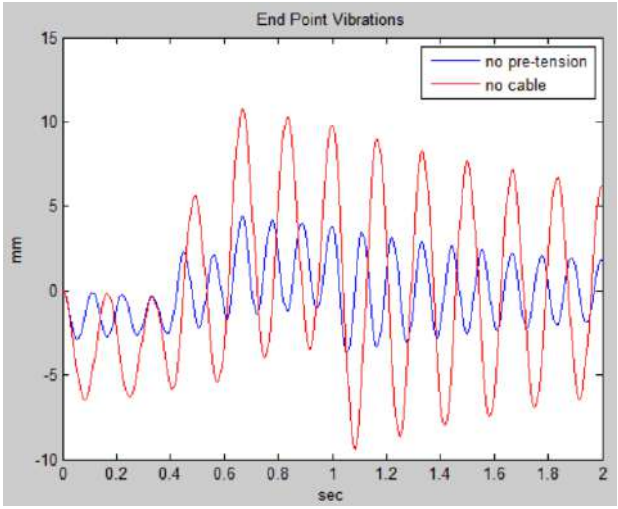


Figure 5. End point vibrations for no pre-tension and no cable situations

Determination of the Appropriate Pre-Tension Value

Time parameters of trapezoidal velocity profile is crutial for reducing the end point vibrations of flexible beams. When the time parameters defined as integer multiple of natural period of flexible beams, the residual vibrations reduces effectively [6].However if we control the beam with the cable pre-tension, this information alone is not enough for evaluation. We need to check cable stability to have optimal and reliable results. We can find minimum pre-tension value required by investigate the axial forces of cables. If we do not have enough axial forces on the cables to beat the acceleration values at the junction of the flexible beam, the system allows random vibrations to occur. We should also pay attention to the buckling to choose the maximum value of the pre-tension.

Results and Discussion

In this section, four different trapezoidal velocity profile inputs are applied to the system by reducing the acceleration and deceleration times, respectively. The changes in the endpoint vibrations of the

system were investigated for the cases where no pre-tension is applied to the cables and three selected pre-tension values are applied. At the same time, comments were made about whether these pre-tensions provide sufficient axial force on the cables.

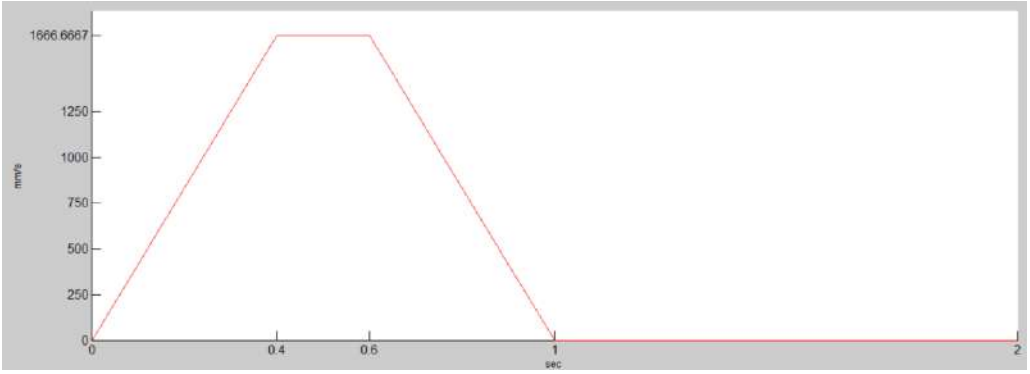
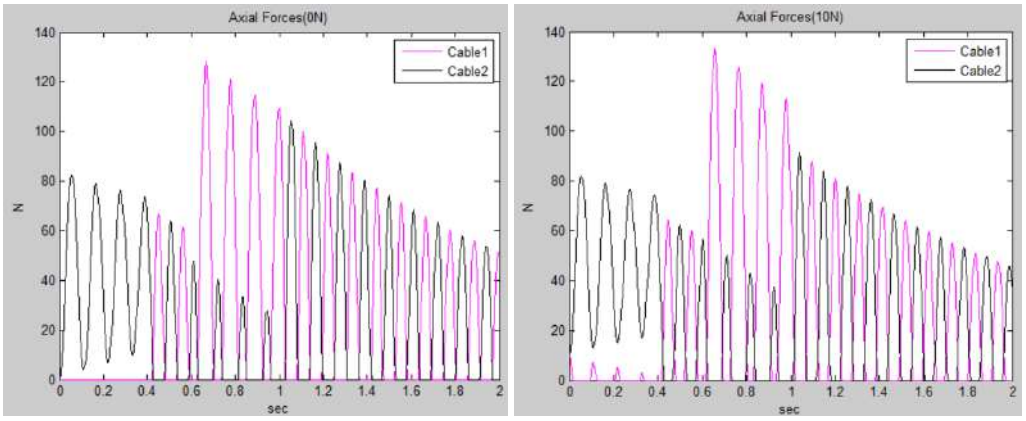
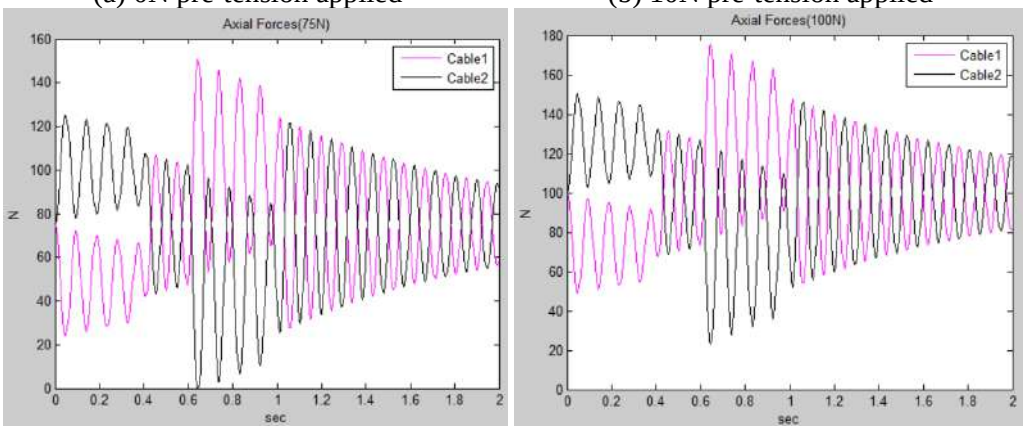


Figure 6. Trapezoidal velocity profile (40% acc-dec time)



(a) 0N pre-tension applied (b) 10N pre-tension applied



(c) 75N pre-tension applied (d) 100N pre-tension applied

Figure 7. Axial forces on cables for different pre-tension values (40% acc-dec time)

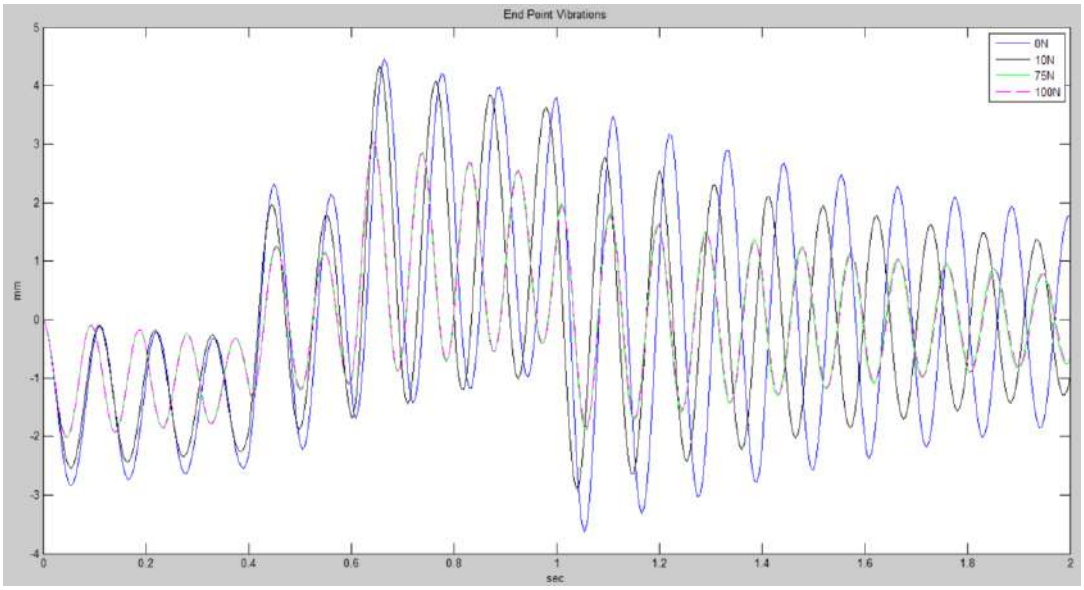


Figure 8. End point vibrations for 0N, 10N, 75N, 100N pre-tension values (40% acc-dec time)

The trapezoidal velocity profile input seen in Figure 6 was applied to the system. The pre-tension values applied in 0N and 10N cases are not sufficient to ensure cable stability. The axial forces on the cables have dropped to 0N (Figure 7). In this case the cables are free and random vibrations may occur. The pre-tension values applied in 75N and 100N cases are sufficient to ensure the stability of the cable (Figure 7). A reliable reduction in the endpoint vibrations was achieved.

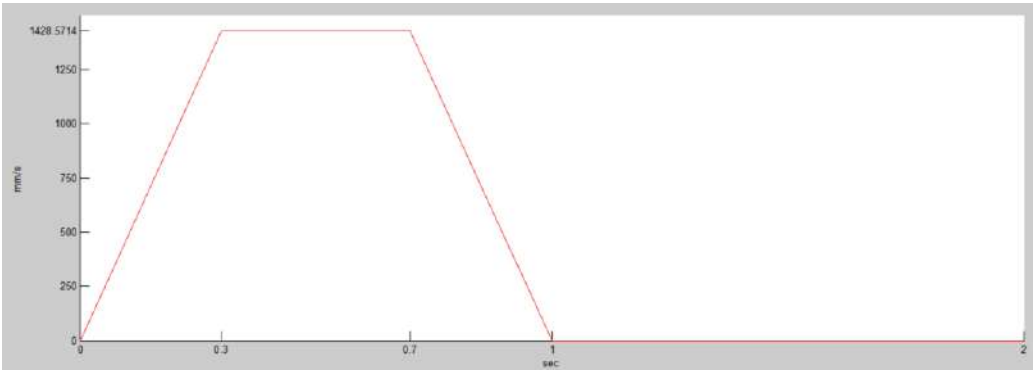
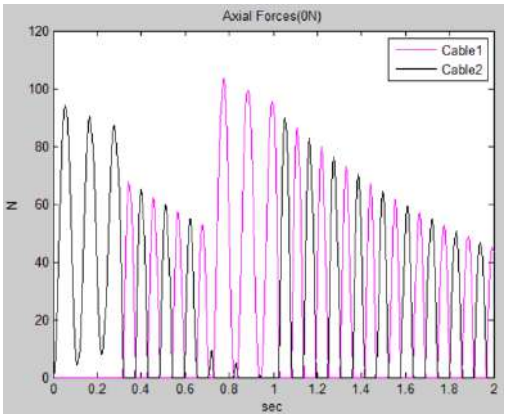
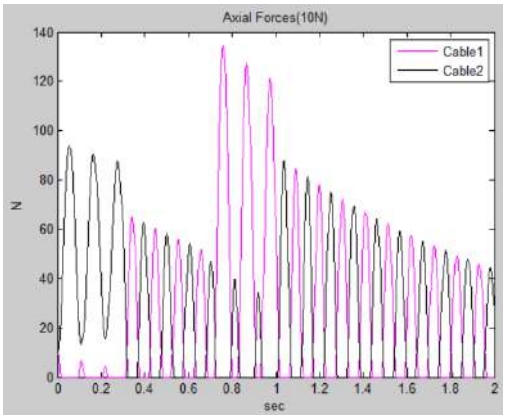


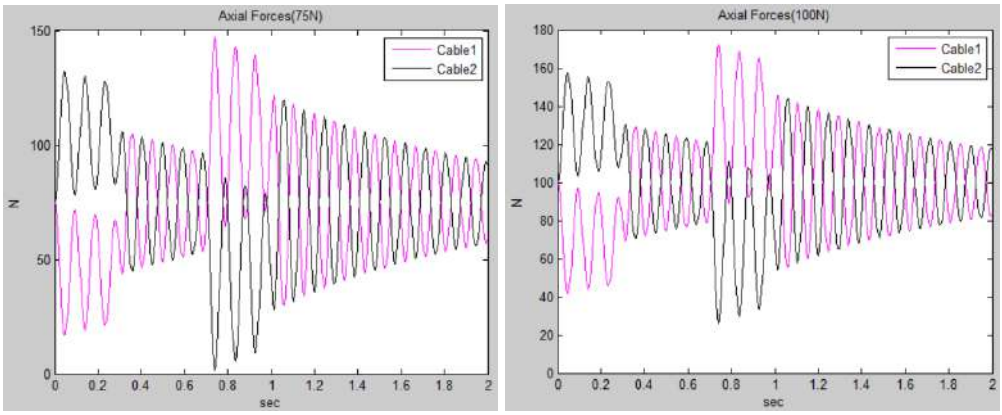
Figure 9. Trapezoidal velocity profile (30% acc-dec time)



(a) 0N pre-tension applied



(b) 10N pre-tension applied



(c) 75N pre-tension applied (d) 100N pre-tension applied

Figure 10. Axial forces on cables for different pre-tension values (30% acc-dec time)

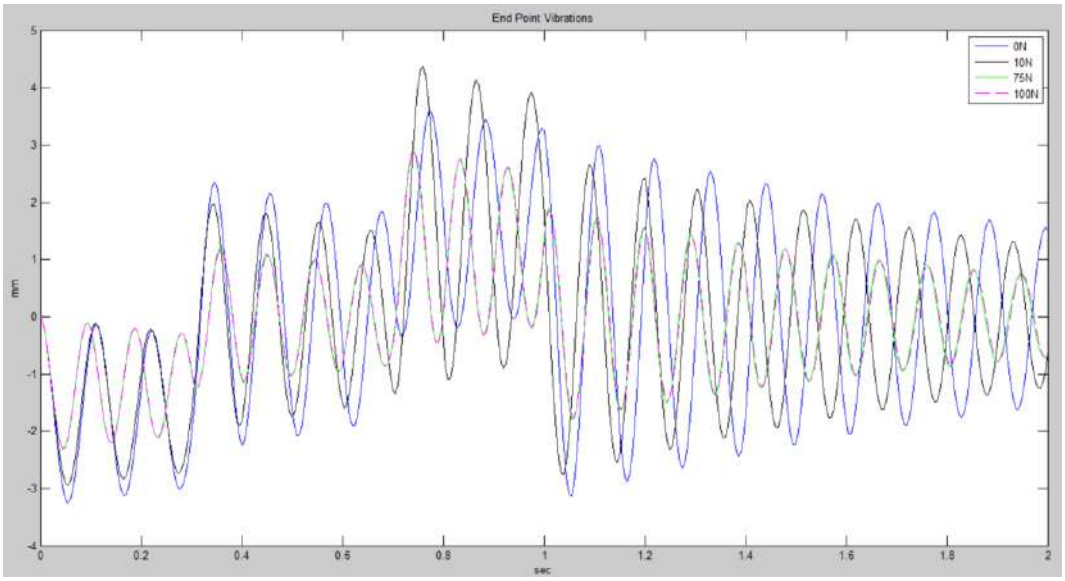


Figure 11. End point vibrations for 0N, 10N, 75N, 100N pre-tension values (30% acc-dec time)

The trapezoidal velocity profile input seen in Figure 9 was applied to the system. The pre-tension values applied in 0N and 10N cases are not sufficient to ensure cable stability. The axial forces on the cables have dropped to 0N (Figure 10). In this case the cables are free and random vibrations may occur. As you can see, there is an irregularity in the deceleration part where 0N and 10N pre-tension is applied (Figure 11). This is because in the absence of sufficient pre-tension, vibrations are affected by the distance of time parameters to multiples of the natural period [6]. The pre-tension values applied in 75N and 100N cases are sufficient to ensure the stability of the cable (Figure 10). A reliable reduction in the endpoint vibrations was achieved.

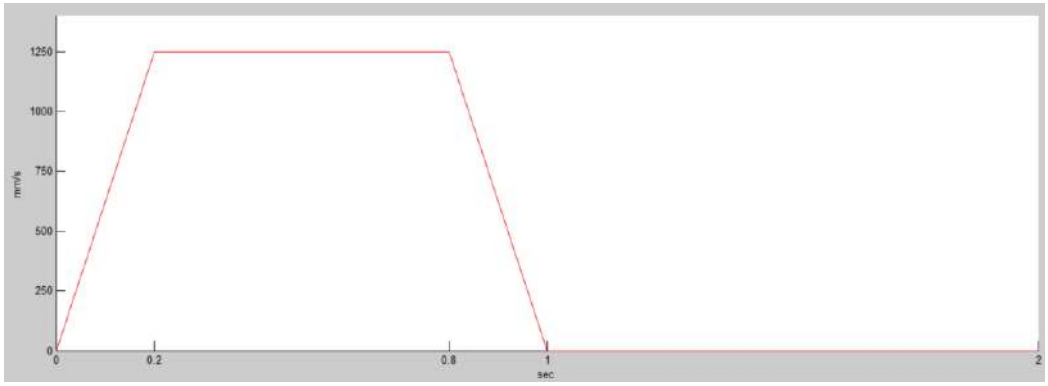
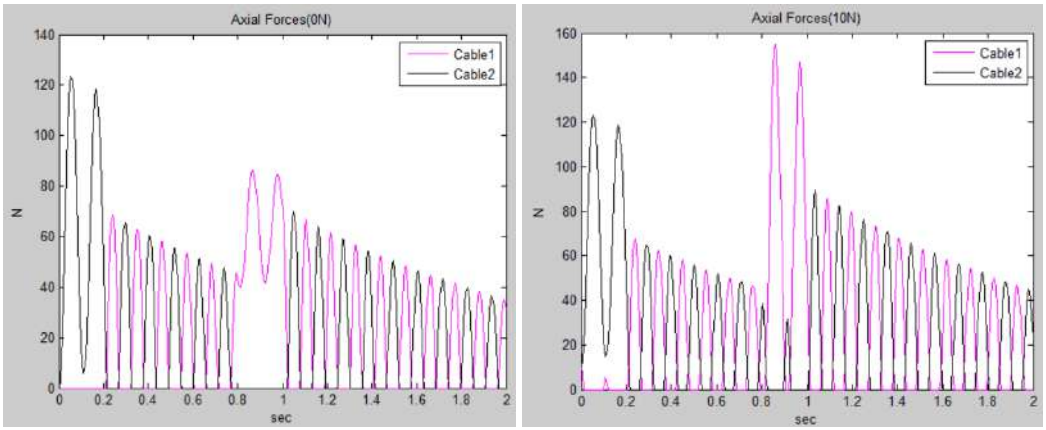
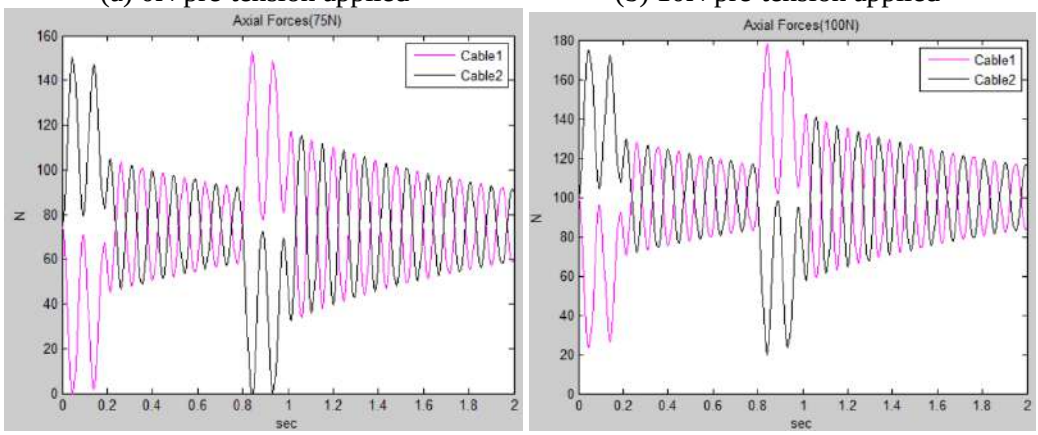


Figure 12. Trapezoidal velocity profile (20% acc-dec time)



(a) 0N pre-tension applied (b) 10N pre-tension applied



(c) 75N pre-tension applied (d) 100N pre-tension applied

Figure 13. Axial forces on cables for different pre-tension values (20% acc-dec time)

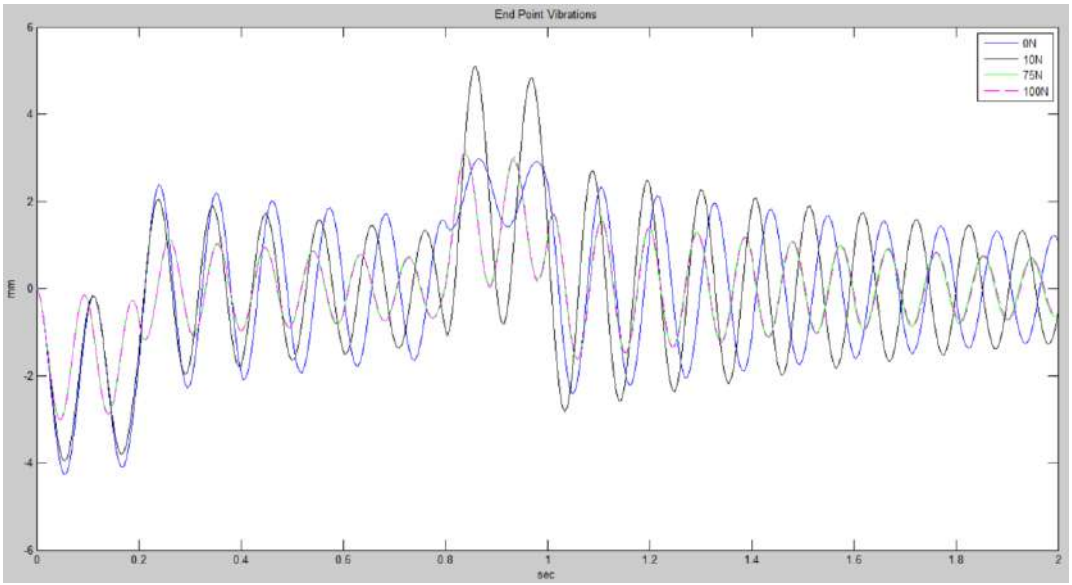


Figure 14. End point vibrations for 0N, 10N, 75N, 100N pre-tension values (20% acc-dec time)

The trapezoidal velocity profile input seen in Figure 12 was applied to the system. The pre-tension values applied in 0N and 10N cases are not sufficient to ensure cable stability. The axial forces on the cables have dropped to 0N (Figure 13). In this case the cables are free and random vibrations may occur. As can be seen, the system with 0N pre-tension causes excessive amplitude reductions in the deceleration and residual part (Figure 14). This reductions is not reliable. This is because in the absence of sufficient pre-tension. Vibrations are affected by the distance of time parameters to multiples of the natural period [6]. The pre-tension values applied in 75N and 100N cases are sufficient to ensure the stability of the cable (Figure 13). A reliable reduction in the endpoint vibrations was achieved.

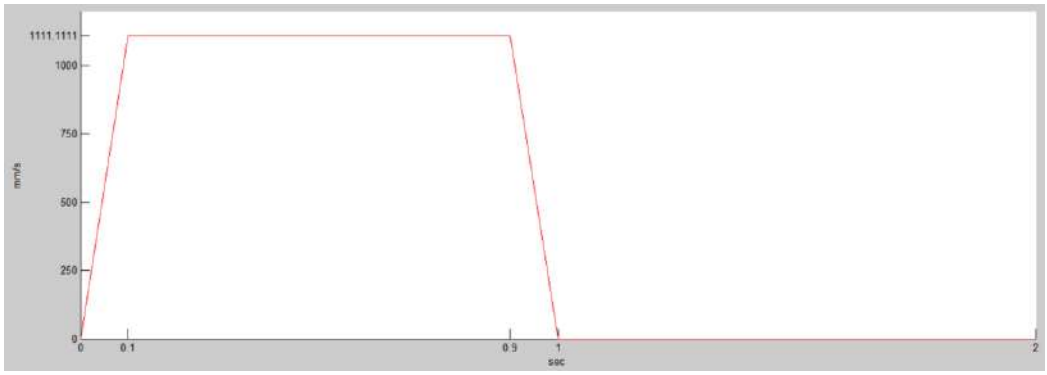
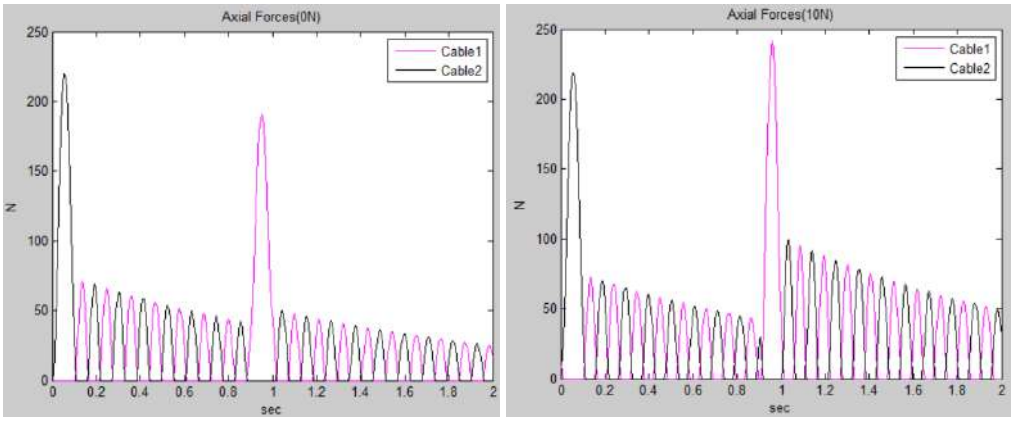
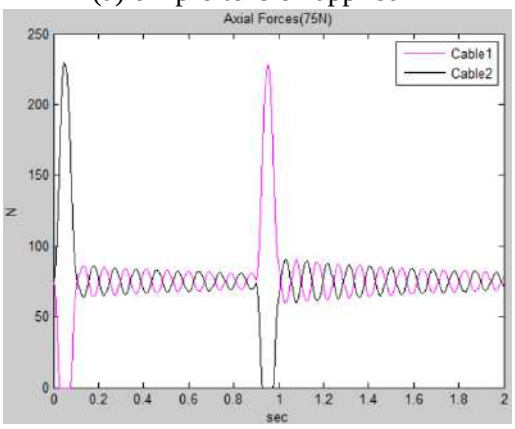


Figure 15. Trapezoidal velocity profile (10% acc-dec time)

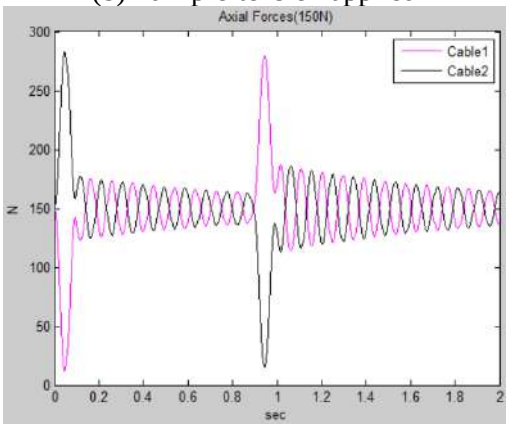


(a) 0N pre-tension applied

(b) 10N pre-tension applied



(c) 75N pre-tension applied



(d) 150N pre-tension applied

Figure 16. Axial forces on cables for different pre-tension values (10% acc-dec time)

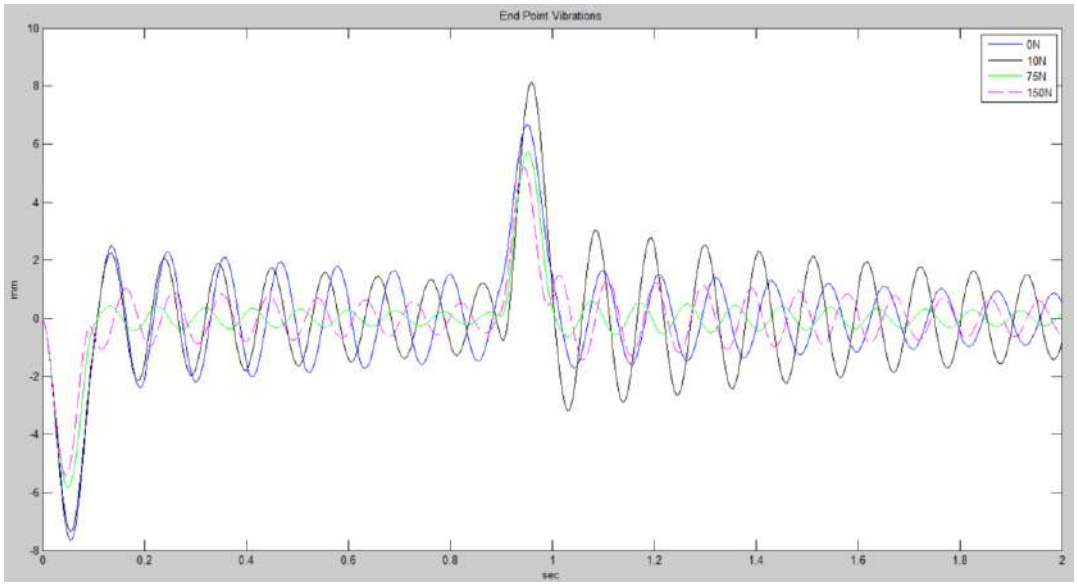


Figure 17. End point vibrations for 0N, 10N, 75N, 150N pre-tension values (10% acc-dec time)

The trapezoidal velocity profile input seen in Figure 15 was applied to the system. The pre-tension values applied in 0N, 10N, 75N cases are not sufficient to ensure cable stability. The axial forces on the cables have dropped to 0N (Figure 16). In this case the cables are free and random vibrations may occur. The pre-tension value applied in 150N case is sufficient to ensure the stability of the cable (Figure 16). A reliable reduction in the endpoint vibrations was achieved.

Table 2. Max amplitude reduction in the translational part

Translational												
40% acc-dec time			30% acc-dec time			20% acc-dec time			10% acc-dec time			
	max vib(+)	max vib(-)		max vib(+)	max vib(-)		max vib(+)	max vib(-)		max vib(+)	max vib(-)	
0N	4.464mm	2.841mm	0N	3.582mm	3.250mm	0N	2.970mm	4.278mm	0N	6.671mm	7.668mm	
10N	4.325mm	2.541mm	10N	4.368mm	2.947mm	10N	5.101mm	3.967mm	10N	8.154mm	7.352mm	
75N	3.043mm	2.015mm	75N	2.917mm	2.303mm	75N	3.145mm	3.021mm	75N	5.738mm	5.816mm	
100N	3.043mm	2.015mm	100N	2.917mm	2.303mm	100N	3.145mm	3.021mm	150N	5.328mm	5.527mm	
	Max amplitude reduction (%)			Max amplitude reduction (%)			Max amplitude reduction (%)			Max amplitude reduction (%)		
	31.80%	29.07%		33.21%	29.13%		38.34%	29.38%		34.65%	27.92%	

Table 3. Max amplitude reduction in the residual part

Residual												
40% acc-dec time			30% acc-dec time			20% acc-dec time			10% acc-dec time			
	max vib(+)	max vib(-)		max vib(+)	max vib(-)		max vib(+)	max vib(-)		max vib(+)	max vib(-)	
0N	3.476mm	3.632mm	0N	3.004mm	3.128mm	0N	2.324mm	2.425mm	0N	1.657mm	1.724mm	
10N	2.772mm	2.894mm	10N	2.651mm	2.758mm	10N	2.707mm	2.837mm	10N	3.042mm	3.163mm	
75N	1.815mm	1.879mm	75N	1.730mm	1.796mm	75N	1.560mm	1.631mm	75N	0.598mm	0.625mm	
100N	1.776mm	1.847mm	100N	1.694mm	1.768mm	100N	1.560mm	1.631mm	150N	0.631mm	0.665mm	
	Max amplitude reduction (%)			Max amplitude reduction (%)			Max amplitude reduction (%)			Max amplitude reduction (%)		
	48.90%	49.14%		43.60%	43.47%		42.37%	42.50%		79.25%	78.97%	

In Table 2 and Table 3, the maximum amplitude values in the transient and residual parts and the maximum reduction amounts in the amplitudes are given. The amplitudes increased due to the inertial forces caused by the increase in acceleration in the transient part. The results show that there is a significant reduction in endpoint vibrations if sufficient pre-tension is applied.

Conclusion

In this study, the effect of cable usage and pre-tensions on the rigidity of flexible beam systems is demonstrated. It was explained how to select the appropriate pre-tension value in a moving system and how to interpret it by evaluating the axial forces on the cable. By using the transient analysis method with various cable pre-tension values and trapezoidal velocity inputs, endpoint vibrations were observed via ANSYS. As can be seen from the results, the cable pre-tension provides a significant reduction in the amplitudes. It was observed that if the acceleration and deceleration time parameters are defined close to the integer multiplier of the natural period, the endpoint vibrations decrease, if not, they increase. Also you can review the article to see the effect of time parameters on endpoint vibrations in trapezoidal velocity inputs [6]. Cable pre-tension, which will provide the required axial force, prevents these increases and ensures a reliable reduction in the endpoint vibrations. This effect of cable pre-tensions on beam systems is valuable and shows that it can also be used effectively as a passive control method.

References

[1] Nudehi S, Mukherjee R, Shaw S. Active Vibration Control of a Flexible Beam Using a Buckling-Type End Force. Journal of Dynamic Systems Measurement and Control-Transactions of the ASME. 2006;128:278-286.

[2] Jnifene A. (2007). Active vibration control of flexible structures using delayed position feedback. Systems & control letters. 2007;56(3):215-222.

[3] Jnifene A, Andrews W. Experimental study on active vibration control of a single-link flexible manipulator using tools of fuzzy logic and neural networks. IEEE transactions on instrumentation and measurement. 2005;54(3):1200-1208.

[4] Sohn JW, Han YM, Choi SB, Lee YS, Han MS. Vibration and Position Tracking Control of a Flexible Beam Using SMA Wire Actuators. Journal of Vibration and Control. 2009;15(2):263-281.

[5] Achkire Y. Active tendon control of cable-stayed bridges (doctoral dissertation). Bruxelles: Université libre de Bruxelles, Faculté des sciences appliquées; 1997

[6] Akdağ M, Şen H. S-curve Motion Profile Design for Vibration Control of Single Link Flexible Manipulator. Dokuz Eylül Üniversitesi Mühendislik Fakültesi Fen ve Mühendislik Dergisi. 2021; 23(68):661-676.

Optimization of Oxidation Time During Graphene Oxide Production

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Abstract

Graphene oxide (GO) consists of one or several stacked graphene structures equipped with various functional groups. It has applications in many areas such as biomaterials, energy storage. sensors and photocatalytic degradation thanks to its high surface area, adjustable band gap and dispersibility in various solvents. Although there are various production techniques for GO synthesis, Improved Hummer's Method stands out with its high efficiency and controllable production parameters. In this method, graphite is oxidized after intercalation with various acids and GO is obtained by exfoliation in the next stages. The effects of production parameters such as oxidation time, oxidant type, oxidant amount, drying processes are generally investigated in Hummer's method. In this study, the effect of oxidation time on GO structure was investigated. In this context, GO was synthesized with various oxidation times by using Modified Hummer's Method. Then, the structural and optical properties of GO were investigated by X-Ray diffraction (XRD), Fourier-Transform infrared spectroscopy (FTIR) and UV-Visible Light spectrophotometer (UV-Vis). The results showed that there is an optimum oxidation time for the oxidation degree of GO structure.

Keywords: Graphene oxide, oxidation time, modified Hummer's method

1. Introduction

Graphene consists of a single layer of sp^2 hybridized carbon atoms, and it has many applications such as energy storage (1), supercapacitors (2), catalyst, drug transport (3) and sensor (4) due to its superior properties. However, the high-scale availability of graphene applications is only possible with high-volume production. The easiest way of mass production of graphene is based on the reduction of GO. GO consists of sp^2 and sp^3 hybridized hexagonal carbon atoms with various oxygen-containing functional groups such as carboxyl, carbonyl and hydroxyl on its two-dimensional surface (5). GO materials are used in applications such as energy storage, photocatalyst, polymer composites and various filters and membranes, as well as being a precursor of graphene (6). The Hummers method is the most widely used method for GO production by researchers all over the world due to advantages such as high efficiency, ease and safety reaction (7,8). In the Hummer's Method, oxidation of graphite layers begins after acid intercalation followed by the addition of $KMnO_4$. However, the Hummer's Method has long production times and, unoxidized graphite structures remain in the structure. The presence of unoxidized graphite hinders the reduction to graphene structure. Therefore, various studies have been carried out for the modification of the Hummer's Method. In this context, GO production was modified by Marcano et al. (9) with high efficiency and reducing the formation of toxic gas and, it's called Improved Hummer's method. Production parameters of Improved Hummer's method effects the properties of the GO (10). In terms of its use in various applications, it is important to increase oxidation degree of the GO with functional groups. For this purpose, the effect of the amount of oxidant (11), acid type and reaction temperatures (12) were investigated for the GO structures (13). Literature review regarding the different oxidation reaction times of GO production by Hummer method is given in Table 1.

Table 1. Studies with different oxidation reaction time.

Intercalating Agent/Oxidizing Agent	Reaction Time	Ref.
HNO_3, H_2SO_4, H_3PO_4 /$KMnO_4$	3 h	(6)
H_2SO_4/$KMnO_4$	1 h	(14)
H_2SO_4/$KMnO_4$	2 h	(15)
H_2SO_4, H_3PO_4 /$KMnO_4$	24 h	(16)
H_2SO_4, H_3PO_4 /$KMnO_4$	12 h	(13)
$NaNO_3$, H_2SO_4/$KMnO_4$	0.5 h	(1)
H_2SO_4/$KMnO_4$	0.5 h	(17)

In addition to these parameters, it was observed that the first oxidation reaction time was different in many studies for Hummer's Method and, some of these studies were shown in Table 1. When the studies were examined, the reaction times in the first oxidation process can vary from 0.5 to 24 hours.

In a study by Suhaimin N. S. et al.(10), effect of oxidation times (1, 5 and 7 days) were investigated in the produced GO with Hummer's Method. According to the results, it was determined that the types of functional groups did not change with the oxidation time. In addition, it was stated that the increasing oxidation time did not affect the interplanar distance of the graphite after reaching the optimal size. In the study of Aixart J. et al.(8), the oxidation process of graphite continued for a period ranging from 30 minutes to 540 minutes with the Eigler's Modified Hummer's Method. According to the result, the degree of exfoliation increased strongly with the reaction time, while there was no significant difference between GO materials in terms of their chemical structure. However, there was not enough study on oxidation time in the produced GO by Modified Hummer's Method.

In this study, the effect of oxidation time on GO structures produced by the Modified Hummer's Method was investigated. Then, structural characterization was carried out with XRD and FTIR analysis. In this context, phase structure and oxidation degree were determined by XRD analysis. Functional groups were defined by FTIR analysis. Also, optical characterization with UV-Vis was applied to determine optical properties for GO samples.

2. Materials and Methods

2.1. Materials

GO was produced from graphite (<20 μm, 99%, Sigma-Aldrich) by using Modified Hummer's Method. $KMnO_4$ as oxidant is 99% pure and was purchased from Merck Millipore. H_2SO_4 (95-98%), H_3PO_4 (85%, extra pure), HCl (37%, acs reagent), and H_2O_2 (35%, extra pure) were purchased from Isolab Chemicals.

2.2. Method

The production of GO was carried out with the Modified Hummer's Method (6). For this purpose, firstly, H_2SO_4 and H_3PO_4 were mixed with graphite powder. Then, the mixture was stirred for 1 hour to pre-exfoliate step. Afterwards, $KMnO_4$ was added slowly, and the first oxidation step was started. At this stage, the oxidation process was continued at a temperature of 45±5°C for 3 different periods of 1, 2 and 6 hours to investigate effect of oxidation time on the formation of GO structure. Then H_2O_2 and purified water were added to stop the oxidation reaction. Afterwards, the washing stage was performed until the pH reached neutral level. The produced GO materials were abbreviated as O1, O2 and O6 according to their oxidation time.

2.3. Characterization

XRD analysis is generally used to determine the phase of structure. Therefore, XRD analysis (Rigaku DMax-2100/PC) was performed using Cu K_α radiation (λ=0.154 nm) at a scanning rate of 1°C/min to investigate the phase structure, oxidation degree and interplanar distances of GO samples. FTIR analysis is generally used to detect functional groups in the material using infrared light (1,6,9). In this study, FTIR analysis was performed with Thermo Scientific FTIR Spectroscopy with the attenuated total reflectance (ATR) module to determine the presence of functional groups in the GO structure. FTIR analysis was carried out at a scanning range of 4000-525 cm^{-1} and at a resolution of 1 cm^{-1}. Uv-Vis analysis provides information about the bonds of the material by scanning the material with UV-visible light in the 200-600 nm range. In this study, UV-Vis analysis spectra were obtained on

Thermo Scientific Evolution 260 BIO UV Spectrophotometer in order to determine the sp^2 conjugation in the GO structure. UV-Vis analysis was performed with a scanning range of 800-200 nm and a resolution of 1 nm.

3. Results and Discussion

XRD analysis of graphite and GO samples with different oxidation times are given in Figure 1. According to the results, the characteristic peak of the graphite was obtained at 26.53° and shows the (002) plane of the graphite. Other peaks for graphite also show high crystalline graphite structure (15,18,19). In GO samples, the diffractions are centered at approximately 11°, demonstrate characteristic peak of the (001) plane of the GO (20). The characteristic peak of GO was found in all GO samples. In addition, no graphite phase was found in the XRD results of the produced GO samples which means that all graphite powders were oxidized at all oxidation times. In terms of the degree of oxidation, O1 sample has a peak at the lowest angle of 2θ and at 12.02°. XRD peaks of O2 and O6 samples was found at similar 2θ values of 11.44° and 11.5°, respectively. In addition, the interplanar distance of GO and graphite was calculated according to the 2θ angles according to Bragg's Law and was shown in Table 2. (21). Accordingly, while the interplanar distance of graphite is 3.37 A°, the interplanar distance increases for GO samples. During the oxidation process, more functional groups are added to the graphene basal plane, and this causes an increase in the distance between the layers. Therefore, characteristic peak of GO shifts to the lower 2θ values with increasing oxidation (1). When the oxidation reaction time was evaluated, it was determined that the O1 sample was less oxidized. In the study of Suhaimin N.S. et al. (10), it was stated that as the reaction time increases in the oxidation stage, it will cause more functional groups and more exfoliation. However, in another study (8), it was stated that the interplanar distance of GO would not increase further when it reached the optimum oxidation level. Therefore, O2 and O6 samples have similar interplanar spacing and exfoliation.

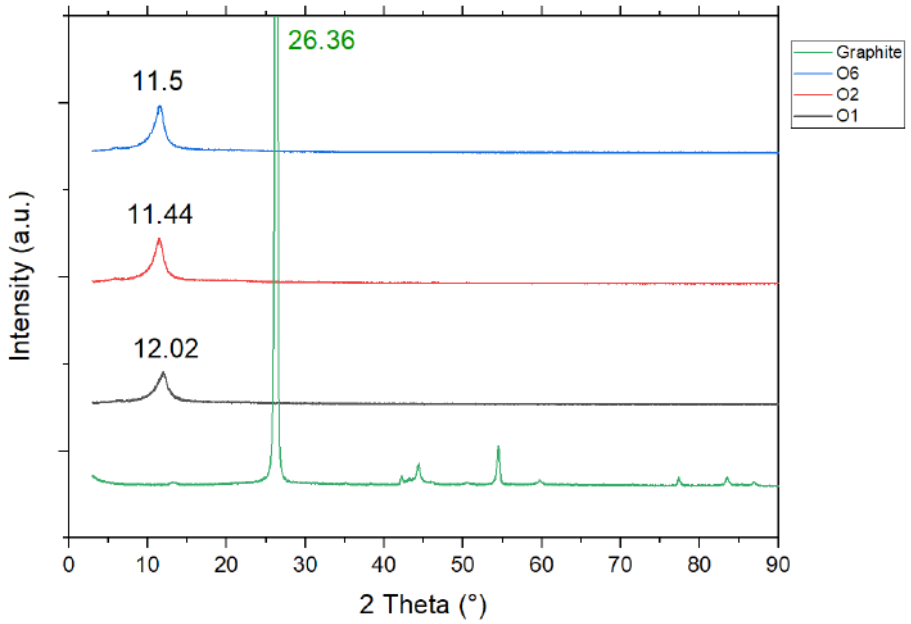

Figure 1. XRD analysis of graphite and GO produced with different oxidation times

Table 2. Interplanar distance of graphite and GO samples produced with different oxidation time

Samples	2Θ (°)	Interplanar Spacing (d) (A°)
Graphite	26.36	3.37
O6	11.5	7.68
O2	11.44	7.72
O1	12.02	7.35

FTIR analysis results of GO samples are shown in Figure 2. According to the results, it belongs to the wide band O-H vibration in the region of 3500-3200 cm^{-1}. The absorbance peak around 1721 cm^{-1} belongs to the C=O carbonyl stretch. The absorbance peak around 1623 cm^{-1} correlates to the deformation vibrations of the water molecules trapped between the hydrophilic GO layers (9). In

addition, the peaks around 1223, 1045 and 975 cm^{-1} correspond to epoxy, carboxyl and C-O bending, respectively (22,23). When the FTIR results were compared, similar peaks were observed in all samples and all functional groups that should be in GO were found. However, the intensity of the functional groups changed. Accordingly, it was seen that the absorbance of the functional groups of the O1 sample was below the other samples. The intensity of functional groups in the FTIR analysis, indicate the degree of oxidation of the GO samples. The degree of oxidation increases with increasing functional group (24). Accordingly, the low degree of oxidation of the O1 sample was confirmed by the FTIR results due to low absorbance of the functional groups. As stated in the study of Suhaimin N. S. et al.(10), it was determined that the oxidation time had no effect on the type of functional groups. Similar functional groups were obtained in this study as well.

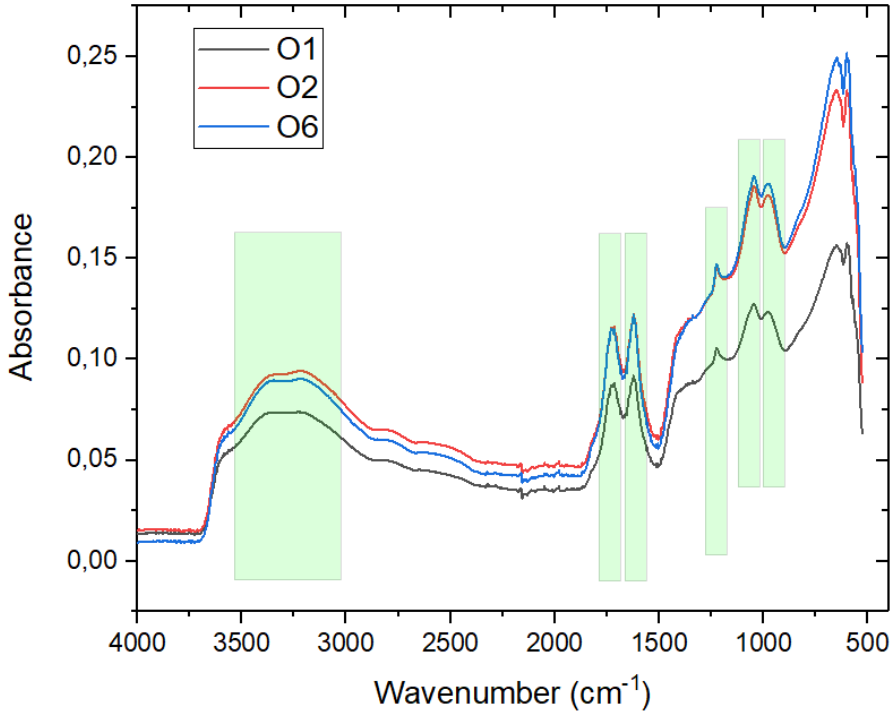

Figure 2. FTIR analysis of GO produced with different oxidation times.

The UV-Vis analysis of GO samples at different oxidation times is shown in Figure 3. In the UV-Vis analysis of GO, it shows absorbance at two wavelengths. These absorbances are occurring around 300 nm and 230 nm wavelengths and show the oxidation of GO and its sp^2 conjugate structure of basal plane, respectively. The absorbance band at 300 nm shows the $n \rightarrow \pi$ electron transition in the C=O bond. The absorbance band around 230 nm shows the $\pi \rightarrow \pi$ electron transition between C-C bonds (6). According to the results, all samples gave a shoulder around 300 nm, indicating that all samples were oxidized. In addition, it was observed that there was a change around 230 nm wavelength according to the oxidation time. Accordingly, the absorbance of the O1, O2 and O6 samples are 230, 229 and 229 nm, respectively. The absorbances of O2 and O6 samples shifted to a lower wavelength compared to the O1 sample. This indicates that the degree of oxidation was increased and supports the results of FTIR and XRD (13).

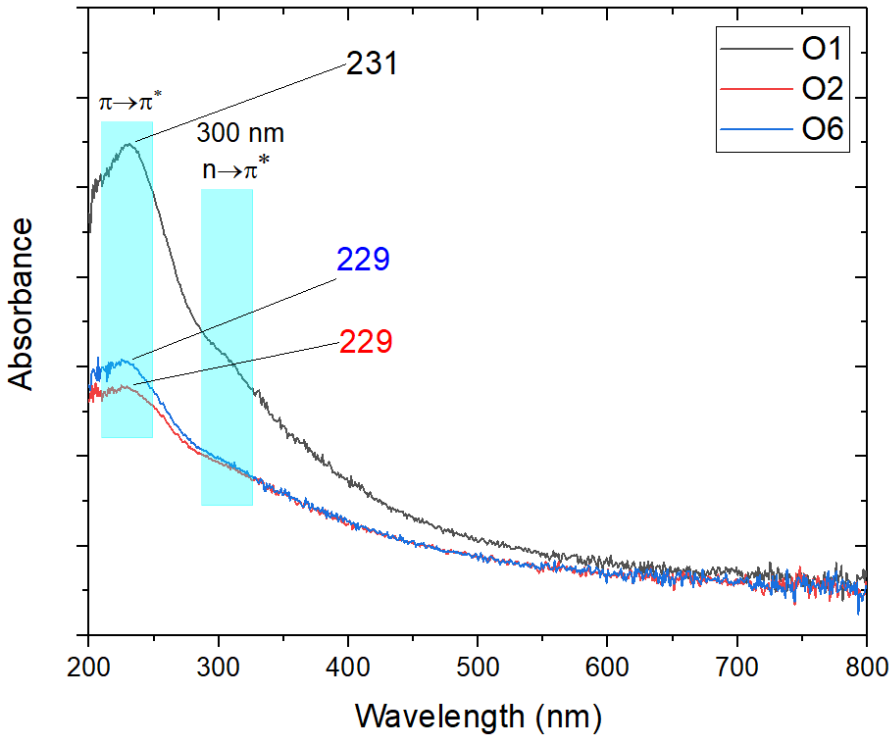

Figure 3. UV-Vis analysis of GO produced with different oxidation times.

4. Conclusions

According to the overall results, GO samples were successfully produced without residual graphite phase for all oxidation times. It was determined that the amount of functional groups increased with increasing oxidation time. The XRD results were supported by the FTIR, and UV-Vis results and it was investigated that the oxidation degree of GO was increased with the increasing oxidation time. On the other hand, it was observed that the reaction time was sufficient for 2 hours for the first oxidation process of GO.

Acknowledgment

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References

[1] Yadav N, Lochab B. A comparative study of graphene oxide: Hummers, intermediate and improved method. FlatChem. 2019;13(February):40–9.

[2] Soam A, Kumar R, C M, Singh M, Thatoi D, Dusane RO. Development of paper-based flexible supercapacitor: Bismuth ferrite/graphene nanocomposite as an active electrode material. Journal of Alloys and Compounds. 2020 Jan 15;813:152145.

[3] Bai RG, Husseini GA. Graphene-based drug delivery systems. Biomimetic Nanoengineered Materials for Advanced Drug Delivery. 2019 Jan 1;149–68.

[4] Abid, Sehrawat P, Islam SS, Mishra P, Ahmad S. Reduced graphene oxide (rGO) based wideband optical sensor and the role of Temperature, Defect States and Quantum Efficiency. Scientific Reports. 2018;8(1):1–13.

[5] Ikram R, Jan BM, Ahmad W. An overview of industrial scalable production of graphene oxide and analytical approaches for synthesis and characterization. Journal of Materials Research and Technology [Internet]. 2020;9(5):11587–610. Available from: https://doi.org/10.1016/j.jmrt.2020.08.050

[6] Panwar V, Chattree A, Pal K. A new facile route for synthesizing of graphene oxide using mixture of sulfuric-nitric-phosphoric acids as intercalating agent. Physica E: Low-Dimensional Systems and Nanostructures [Internet]. 2015;73:235–41. Available from:

http://dx.doi.org/10.1016/j.physe.2015.06.006

[7] Sun L, Fugetsu B. Mass production of graphene oxide from expanded graphite. Materials Letters [Internet]. 2013;109:207–10. Available from: http://dx.doi.org/10.1016/j.matlet.2013.07.072

[8] Aixart J, Díaz F, Llorca J, Rosell-Llompart J. Increasing reaction time in Hummers' method towards well exfoliated graphene oxide of low oxidation degree. Ceramics International [Internet]. 2021;47(15):22130–7. Available from: https://doi.org/10.1016/j.ceramint.2021.04.235

[9] Marcano DC, Kosynkin D V., Berlin JM, Sinitskii A, Sun Z, Slesarev A, et al. Improved synthesis of graphene oxide. ACS Nano. 2010;4(8):4806–14.

[10] Suhaimin NS, Hanifah MFR, Jusin J wani, Jaafar J, Aziz M, Ismail AF, et al. Tuning the oxygen functional groups in graphene oxide nanosheets by optimizing the oxidation time. Physica E: Low-dimensional Systems and Nanostructures [Internet]. 2021 Jul;131:114727. Available from: https://doi.org/10.1016/j.physe.2021.114727

[11] Krishnamoorthy K, Veerapandian M, Yun K, Kim S-J. The chemical and structural analysis of graphene oxide with different degrees of oxidation. Carbon [Internet]. 2013 Mar;53:38–49. Available from: http://dx.doi.org/10.1016/j.carbon.2012.10.013

[12] Kang D, Shin H-S. Control of size and physical properties of graphene oxide by changing the oxidation temperature. Carbon letters [Internet]. 2012 Jan 31;13(1):39–43. Available from: http://koreascience.or.kr/journal/view.jsp?kj=HGTSB6&py=2012&vnc=v13n1&sp=39

[13] Habte AT, Ayele DW, Hu M. Synthesis and Characterization of Reduced Graphene Oxide (rGO) Started from Graphene Oxide (GO) Using the Tour Method with Different Parameters. Advances in Materials Science and Engineering. 2019;2019(Vc).

[14] Sohail M, Saleem M, Ullah S, Saeed N, Afridi A, Khan M, et al. Modified and improved Hummer's synthesis of graphene oxide for capacitors applications. Modern Electronic Materials [Internet]. 2017;3(3):110–6. Available from: https://doi.org/10.1016/j.moem.2017.07.002

[15] Hanifah MFR, Jaafar J, Othman MHD, Ismail AF, Rahman MA, Yusof N, et al. Facile synthesis of highly favorable graphene oxide: Effect of oxidation degree on the structural, morphological, thermal and electrochemical properties. Materialia [Internet]. 2019;6(May):100344. Available from: https://doi.org/10.1016/j.mtla.2019.100344

[16] Ranjan P, Agrawal S, Sinha A, Rao TR, Balakrishnan J, Thakur AD. A Low-Cost Non-explosive Synthesis of Graphene Oxide for Scalable Applications. Scientific Reports. 2018;8(1):1–13.

[17] Chen J, Yao B, Li C, Shi G. An improved Hummers method for eco-friendly synthesis of graphene oxide. Carbon [Internet]. 2013;64(1):225–9. Available from: http://dx.doi.org/10.1016/j.carbon.2013.07.055

[18] Muzyka R, Kwoka M, Smędowski Ł, Díez N, Gryglewicz G. Oxidation of graphite by different modified Hummers methods. Xinxing Tan Cailiao/New Carbon Materials. 2017;32(1):15–20.

[19] Yu H, Zha B, Chaoke B, Li R, Xing R. High-efficient Synthesis of Graphene Oxide Based on Improved Hummers Method. Nature Publishing Group. 2016; (November):1–7.

[20] Trikkaliotis DG, Mitropoulos AC, Kyzas GZ. Low-cost route for top-down synthesis of over- and low-oxidized graphene oxide. Colloids and Surfaces A: Physicochemical and Engineering Aspects [Internet]. 2020; 600 (March): 124928. Available from: https://doi.org/10.1016/j.colsurfa.2020.124928

[21] Junaid M, Khir MHM, Witjaksono G, Tansu N, Saheed MSM, Kumar P, et al. Boron-doped reduced graphene oxide with tunable bandgap and enhanced surface plasmon resonance. Molecules. 2020;25(16).

[22] Frogley MD, Wang C, Cinque G, Barber AH. Polarised infrared microspectroscopy of edge-oriented graphene oxide papers. Vibrational Spectroscopy. 2014 Nov;75:178–83.

[23] Ţucureanu V, Matei A, Avram AM. FTIR Spectroscopy for Carbon Family Study. Critical Reviews in Analytical Chemistry [Internet]. 2016;46(6):502–20. Available from: http://dx.doi.org/10.1080/10408347.2016.1157013

[24] Guerrero-Contreras J, Caballero-Briones F. Graphene oxide powders with different oxidation degree, prepared by synthesis variations of the Hummers method. Materials Chemistry and Physics [Internet]. 2015;153:209–20. Available from: http://dx.doi.org/10.1016/j.matchemphys.2015.01.005

Photocatalytic Performance of 3D Printed Polymer Composites: Effect of Matrix Material

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Abstract

Additive manufacturing has started to be used in many sectors today (e.g. aerospace, dentistry, biomaterials, drug industry) and is still a developing material production method. Three-dimensional (3D) printers are the main devices used in this method, which enables production without the need for molds. These 3D printers are divided into mechanical, electrical and photochemical types. Photosensitive resins are used for production in photochemical three-dimensional printers. These resins contain monomer, oligomer, photoinitiator and optionally filler material. The change of monomer, oligomer, and filler materials in the structure also affects various characteristics of the obtained polymer including mechanical, electrical, magnetic, and photochemical properties.

To the extent of our literature review, it has been determined that there are not enough studies on the effect of the change in the matrix material of the polymer matrix composite materials produced with 3D printers on the photocatalytic performance. With this motivation, in this study, the photocatalytic performance of composite samples obtained by the incorporation of nano-sized TiO_2 particles (1.5 wt.%) into two different acrylate-based resin mixtures was compared. Bisphenol-A glycidyl dimethacrylate (bis-GMA) and urethane dimethacrylate (UDMA) based monomers were used as matrix material, and triethylene glycol dimethacrylate (TEGDMA) was used as the diluent. TiO_2 nanoparticles and photoinitiator were added into the prepared mixtures and mixed in a magnetic stirrer until a homogeneous mixture was obtained. Then, polymer samples were obtained by printing the resins with a 3D printer in 20x35x3 mm dimensions. The photocatalytic activity of the obtained polymers under visible light irradiation was tested. Experimental results revealed that even a small amount of TiO_2 is effective in imparting photocatalytic activity to the structure, and besides, the effect of bis-GMA-based matrix material on photocatalytic performance is more pronounced than that of UDMA-based matrix material.

Keywords: 3D printing, acrylate-based polymer, photocatalysis, TiO_2

Introduction

Additive manufacturing has started to be used in many sectors today (e.g. aerospace, dentistry, biomaterials, drug industry) and is still a developing material production method [1,2]. Three-dimensional (3D) printers are the main devices used in this method, which enables production without the need for molds. These 3D printers are divided into mechanical, electrical and photochemical types. To give examples of these: fused deposition method (FDM) [3], selective laser sintering (SLS) [4], direct metal laser sintering (DMLS) [5], laser metal deposition (LMD) [6], binder jetting [7], material jetting [8], stereolithography (SLA) [9], and digital light processing (DLP) [10] are the most widely used methods.

Photosensitive resins are used for production in photochemical three-dimensional printers. These resins contain monomer, oligomer, photoinitiator and optionally filler material [2]. The change of monomer, oligomer, and filler materials in the structure also affects various characteristics of the obtained polymer including mechanical, electrical, magnetic, and photochemical properties [11,12]. In this regard, TiO_2 nanoparticles come to the fore with their high UV absorbance, antibacterial properties, biocompatibility, self-cleaning properties, and photocatalytic performance [13–15].

When the literature is reviewed, it has been seen that TiO_2 nanoparticles are able to show photocatalytic performance in the composite structure and the matrix material has an effect on this performance [16,17]. However, considering the recent use of acrylate-based photosensitive resins that

can be shaped with 3D printers, it has been determined that there are not enough studies on the effect of the change in matrix material of acrylate-based polymer matrix composite materials on photocatalytic performance. With this motivation, in this study, the photocatalytic performance of composite samples obtained by the incorporation of nano-sized TiO_2 particles (1.5 wt.%) into two different acrylate-based resin mixtures was compared.

Materials and Methods

TiO_2 nanoparticles were produced by sol-gel method, firstly, sol was prepared using TTIP (Titanium (IV) isopropoxide), IPA (isopropyl alcohol) and TEA (Triethanolamine). All chemicals were purchased from Sigma-Aldrich and used as supplied. 7.5 ml of TEA was added to a 0.5 M solution which is prepared by adding 15 ml of TTIP wisely into 100 ml of IPA and mixed for 30 minutes on a magnetic stirrer. After obtaining a clear solution with a turbidity value of 1.44 NTU, distilled water was added until the pH value was 9.5 and aged at 70 °C for 6 hours. After the solution became gel, it was dried at 250 °C for 2 hours and calcined at 550 °C for 2 hours. After these processes, nanoparticles were successfully produced.

UDMA (Urethane dimethacrylate), bis-GMA (Bisphenol-A glycidyl dimethacrylate), TEGDMA (Triethylene glycol dimethacrylate) and TPO (Diphenyl (2,4,6-trimethylbenzoyl) phosphine oxide) were purchased from Sigma-Aldrich and used without further purification. Two different photosensitive resin mixtures were used as a matrix material of nanocomposite resin. The contents of the resins are specified in Table 1. UDMA/TEGDMA and bis-GMA/TEGDMA mixtures were stirred in magnetic stirrer until the mixture become homogeneous. TiO_2 nanoparticles and photoinitiator were added to both prepared resins and mixed in a magnetic stirrer for another 2 hours. After obtaining a homogeneous mixture, the printing process of the composite resins was carried out.

Table 1. Contents of the composite resins (wt. %)

Name	UDMA	Bis-GMA	TEGDMA	TPO	TiO_2
UDMA-TiO_2	57.9	-	38.6	2	1.5
Bis-GMA-TiO_2	-	43.425	53.075	2	1.5

Prepared resins were printed by a DLP type printer (Creality Halot-Sky CL 89) 20x35x3 mm dimensions. During the printing process, the layer thickness was set as 50 μm and the exposure time applied for each layer was set as 5 s. Each sample obtained was washed in IPA (Isopropyl Alcohol) for 10 minutes and then exposed to the post-curing process for 60 minutes using the Creality UW-02 Washing/Curing Machine to remove the residual resin remaining on specimens and to bind the unbound monomers in the structure.

Structural, morphological and photocatalytic properties of the obtained NPs and composites were performed. The phase and crystal structures of TiO_2 NPs were determined by an X-ray diffractometer (XRD, BRUKER D2 Phaser) using Cu-Kα radiation (1.54178 Å). XRD data was recorded at a scan rate of 5 °/min in the range of $5° \leq 2\theta \leq 90°$. Morphological properties of NPs and composites were obtained using scanning electron microscopy (SEM, Zeiss 300 VP). Photocatalytic activities of the composite samples were carried out in a methylene blue solution diluted with distilled water, under a daylight light source (Osram, UltraVitalux E27, 300 W). The average irradiation intensity of the employed light source was 18 W/m^2 for the visible bandwidth, 3.2 W/m^2 for UV-A, 0.004 W/m^2 for UV-B and 0.004 W/m^2 for UV-C [18]. Methylene blue (MB), an organic compound belonging to the heterocyclic aromatic class, serves as an artificial impurity. Its aqueous solution (MB+) is a positively charged dye that exhibits a peak absorption of light at approximately 664 nm [19]. In this experiment, the catalysts were placed in beakers, and 30 ml of the aqueous MB solution was added dropwise to each beaker. The catalysts were then positioned at a fixed distance (30 cm) from a light source. To evaluate the photocatalytic activity of the samples, the changes in absorbance of the aqueous MB solutions were measured using a UV spectrometer (1240 UV–vis/Thermo Scientific) over different time intervals. However, the determination of photocatalytic activities mainly relied on tracking the concentration changes of the aqueous MB solutions over time. A linear Lambert-Beer correlation was used to convert absorbance values into concentrations using the same MB solutions and equipment [18]. Ultimately, the collected data were employed to calculate the kinetics of the degradation reaction.

Results and Discussion

Figure 1 illustrates the XRD findings of the produced TiO_2 nanoparticles. Upon analysis of the Figure 1, it can be observed that the nanoparticles synthesized exhibit a tetragonal crystal structure

comprising both anatase and rutile phases. By comparing the X-ray diffraction (XRD) pattern of the produced nanoparticles with JCPDS cards, it can be deduced that peaks marked with an asterisk correspond to the anatase phase (JCPDS: 21-1272) while peaks marked with a square equal the rutile phase (JCPDS: 21-1276).

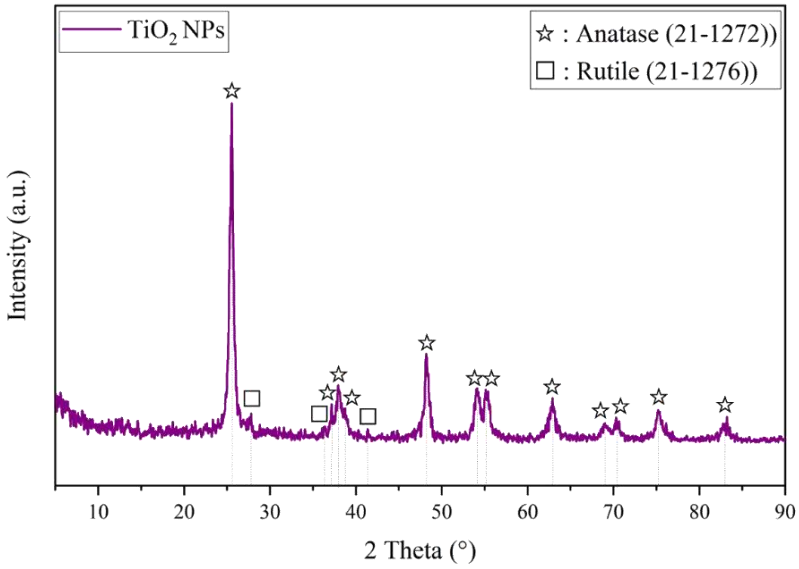

Figure 1. XRD chart of TiO_2 nanoparticles

The experimental outcomes obtained in this investigation exhibit concurrence with the outcomes documented in prior studies conducted by Al-Âmin et al. and N. Bahremandi Tolou et al. [11,20]. The average size of the crystalline particles is determined by employing the Debye-Scherrer formula, as presented in Equation 1 [21]. In this calculation, the highest peak (101) of the anatase phase is utilized as a reference point.

$$D = \frac{K*\lambda}{\beta*cos\,\theta} \quad (1)$$

The average size of the crystalline particles is determined using the Debye-Scherrer formula (Equation 1) with the given parameters: the Scherrer constant (K) is 0.9, the diffraction angle (θ) is measured in radians, the full-width at half-maximum (FWHM) of the peak (β) is also measured in radians, and the wavelength of the X-Ray (λ) used is 0.15178 nm for Cu Kα. The calculated crystallite size of the obtained particles is 13.87 nm, while details are presented as Table 2.

Table 2. Crystallite size calculation of TiO_2 nanoparticles

2θ of (101) peak (°)	FWHM (rad)	Crystallite Size (nm)
25.53	0.0107120	13.87

Morphological properties of nanoparticles, pure polymers and composite materials were analyzed using scanning electron microscopy (SEM). As can be seen in Figure 2, nanoparticles were studied in secondary electron mode (SE), and polymers and composites were studied in back-scattered electron mode (BSE). SEM image of the nanoparticles (Figure 2a) reveals the presence of TiO_2 particles ranging from 100 to 200 nm. When SEM images of pure polymers (Figure 2b and 2c) and composites (Figure 2d and 2e) are examined, it is seen that the particles in the structure are homogeneously dispersed. Since the images were taken in the backscattered electron mode, the bright white colored dots show the filler material in the structure. When the images are compared with the studies in the literature, it can be interpreted that the behavior of nanoparticles in acrylate group-terminated resins is similar [22].

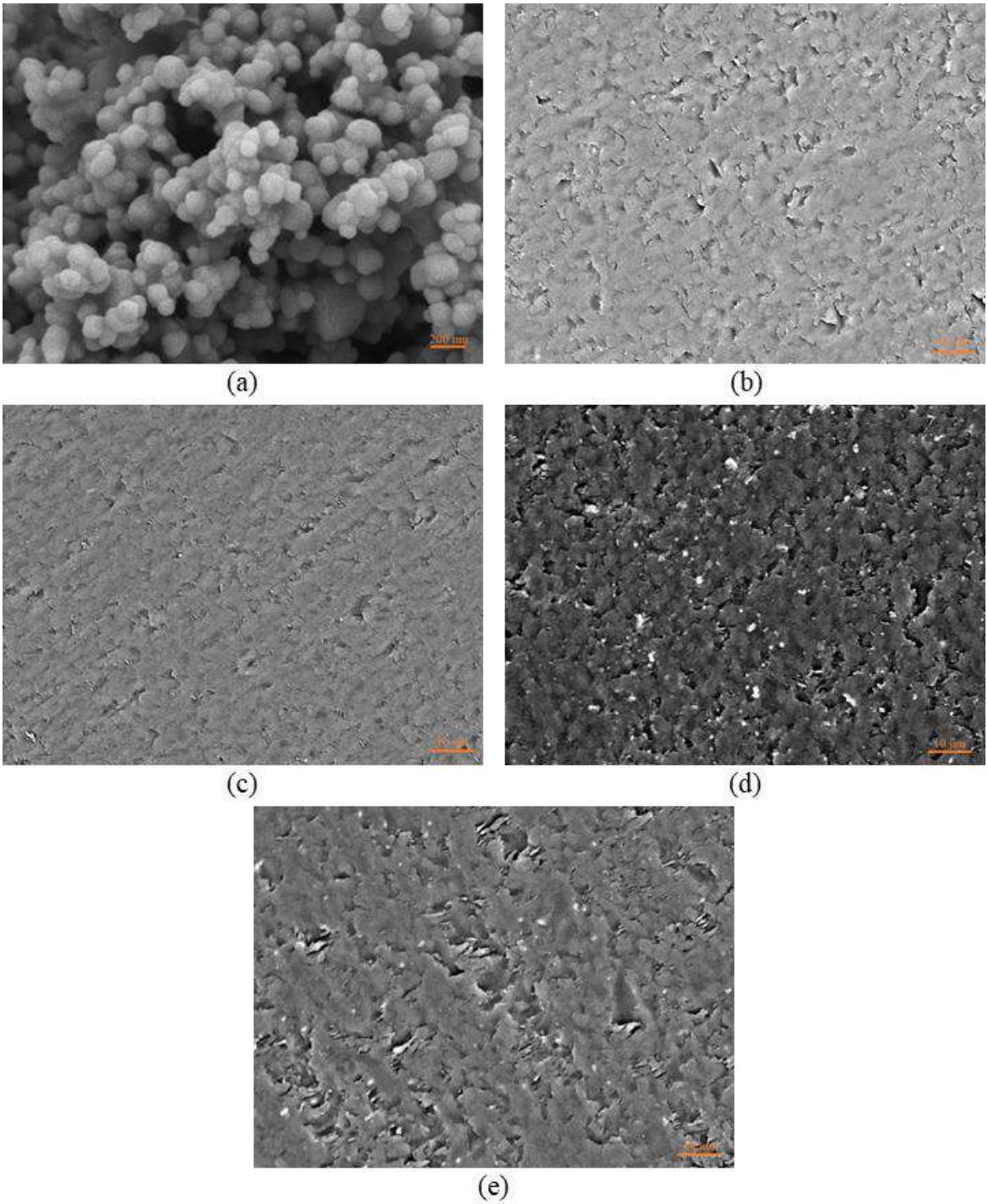

Figure 2. SEM images of (a) TiO_2 nanoparticles, (b) UDMA/TEGDMA polymer, (c) bis-GMA/TEGDMA polymer, (d) UDMA-TiO_2 composite, and (e) bis-GMA-TiO_2 composite

The photocatalytic performance of polymer matrix nanocomposites including Bis-GMA/TiO_2 and UDMA/TiO_2 was assessed by examining the degradation of methylene blue (MB) dye under visible daylight irradiation. The kinetics of photocatalytic degradation was analyzed for the first four hours of the decomposition process using the Langmuir-Hinshelwood (L-H) kinetics model. According to the L-H model, the relationship between the natural logarithm of the initial concentration to the instant concentration (ln(C0/C)) and the irradiation time (t) is directly proportional. This relationship allows us to determine the apparent kinetic rate constant (kapp), where C0, C, and t represent the initial concentration, instant concentration, and irradiation time, respectively [23]. In light of this, the experimental data of ln(C0/C) versus time were graphed for each sample.

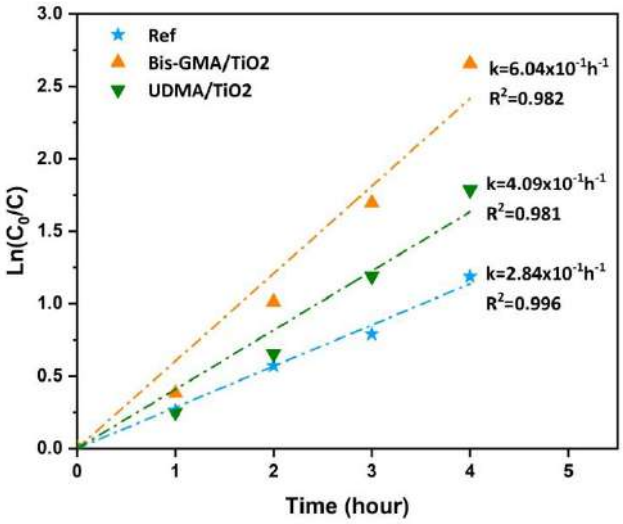

Figure 3. Photocatalytic degradation kinetics

It is evident from Figure 3 that all the data points align closely with the L-H model, indicating a fitting with pseudo-first-order kinetics. As anticipated, the correlation coefficients (R2 values) for all samples exceeded 0.98, demonstrating a strong agreement with the model [24]. According to the figure, it is also clear that MB solution (ref) without any catalyst exhibited the lowest apparent kinetic rate constant (kapp) value of $2.84 \times 10^{-1}h^{-1}$, such that this can be attributed to the sole effect of photolysis. On the other hand, the reaction rates of the composite samples are quite high compared to the reference solution, $6.44 \times 10^{-1}h^{-1}$ and $4.09 \times 10^{-1}h^{-1}$ for Bis-GMA/TiO_2 and UDMA/TiO_2, respectively, thanks to their TiO_2 content. Furthermore, the photocatalytic activity of Bis-GMA/TiO_2 was found to be approximately 1.5 times greater than that of UDMA/TiO_2.

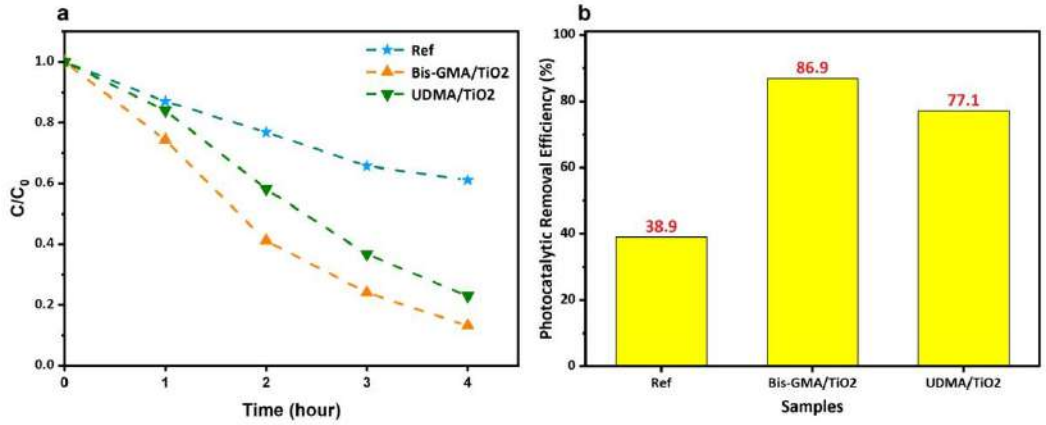

Figure 4. (a) Photodegradation curves and (b) photocatalytic removal efficiency

In order to provide a more quantitative assessment of the photocatalytic activity, photodegradation curves (Figure 4a) were generated and given along with the corresponding percentages of degradation efficiency (Figure 4b). After 4 h irradiation, when considering the composite samples, the Bis-GMA/TiO_2 catalyst sample degraded 86.9% of the initial concentration of MB while this ratio was lower in UDMA/TiO_2 with 77.1%. In addition, the decomposition rate of MB in the catalyst-free reference solution, where only photolysis occurs, was measured to be 38.9%.

Conclusion

The production of TiO_2 nanoparticles, the addition of these particles into acrylate-based photosensitive resin and the shaping of the obtained nanocomposite resin with a 3D printer were successfully carried out. It was determined by XRD analysis that the TiO_2 nanoparticles were in the anatase phase and had a crystallite size of 13.87 nm. The morphologies of the samples showed that the TiO_2 nanoparticles were in the range of 100 to 200 nm and their distribution in the composite resin was also homogeneous. The photocatalytic reaction kinetics were found to be in a good agreement with the Langmuir-Hinshelwood kinetic model. Nonetheless, it was determined that altering the matrix material had an impact on the kinetics of the photocatalytic reaction.

As a result of this study, it has become possible to carry out more comprehensive studies on the usability of different matrix materials and additives with different photocatalytic activities in the future.

References

[1] Silva AL, Salvador GM da S, Castro SVF, Carvalho NMF, Munoz RAA. A 3D Printer Guide for the Development and Application of Electrochemical Cells and Devices. Front Chem 2021;9. https://doi.org/10.3389/fchem.2021.684256.

[2] Zhang J, Xiao P. 3D printing of photopolymers. Polym Chem 2018;9:1530–40. https://doi.org/10.1039/C8PY00157J.

[3] Kim S, Seong H, Her Y, Chun J. A study of the development and improvement of fashion products using a FDM type 3D printer. Fashion and Textiles 2019;6. https://doi.org/10.1186/s40691-018-0162-0.

[4] Geng LC, Ruan XL, Wu WW, Xia R, Fang DN. Mechanical Properties of Selective Laser Sintering (SLS) Additive Manufactured Chiral Auxetic Cylindrical Stent. Exp Mech 2019;59:913–25. https://doi.org/10.1007/s11340-019-00489-0.

[5] Sedlak J, Rican D, Piska M, Rozkosny L. Study of materials produced by powder metallurgy using classical and modern additive laser technology. Procedia Eng, vol. 100, Elsevier Ltd; 2015, p. 1232–41. https://doi.org/10.1016/j.proeng.2015.01.488.

[6] Lei Z, Bi J, Chen Y, Chen X, Tian Z, Qin X. Effect of TiB2 content on microstructural features and hardness of TiB2/AA7075 composites manufactured by LMD. J Manuf Process 2020;53:283–92. https://doi.org/10.1016/j.jmapro.2020.02.036.

[7] Ziaee M, Crane NB. Binder jetting: A review of process, materials, and methods. Addit Manuf 2019;28:781–801. https://doi.org/10.1016/j.addma.2019.05.031.

[8] Yap YL, Wang C, Sing SL, Dikshit V, Yeong WY, Wei J. Material jetting additive manufacturing: An experimental study using designed metrological benchmarks. Precis Eng 2017;50:275–85. https://doi.org/10.1016/j.precisioneng.2017.05.015.

[9] Weng Z, Zhou Y, Lin W, Senthil T, Wu L. Structure-property relationship of nano enhanced stereolithography resin for desktop SLA 3D printer. Compos Part A Appl Sci Manuf 2016;88:234–42. https://doi.org/10.1016/j.compositesa.2016.05.035.

[10] Alsandi Q, Ikeda M, Arisaka Y, Nikaido T, Tsuchida Y, Sadr A, et al. Evaluation of mechanical and physical properties of light and heat polymerized udma for dlp 3d printer. Sensors 2021;21. https://doi.org/10.3390/s21103331.

[11] N. Bahremandi Tolou, M. H. Fathi, A. Monshi, V. S. Mortazavi FS, M. Mohammadi. The Effect of Adding TiO2 Nanoparticles on Dental Amalgam Properties. IUST 2013;10:46–56.

[12] Rezvani MB, Atai M, Hamze F, Hajrezai R. The effect of silica nanoparticles on the mechanical properties of fiber-reinforced composite resins. J Dent Res Dent Clin Dent Prospects 2016;10:112–7. https://doi.org/10.15171/joddd.2016.018.

[13] Poosti M, Ramazanzadeh B, Zebarjad M, Javadzadeh P, Naderinasab M, Shakeri MT. Shear bond strength and antibacterial effects of orthodontic composite containing TiO2 nanoparticles. Eur J Orthod 2013;35:676–9. https://doi.org/10.1093/ejo/cjs073.

[14] Pathak G, Pandey S, Katiyar R, Srivastava A, Dabrowski R, Garbat K, et al. Analysis of photoluminescence, UV absorbance, optical band gap and threshold voltage of TiO2 nanoparticles dispersed in high birefringence nematic liquid crystal towards its application in display and photovoltaic devices. J Lumin 2017;192:33–9. https://doi.org/10.1016/j.jlumin.2017.06.021.

[15] Yurddaskal M, Dikici T, Yildirim S, Yurddaskal M, Toparli M, Celik E. Fabrication and characterization of nanostructured anatase TiO2 films prepared by electrochemical anodization and their photocatalytic properties. J Alloys Compd 2015;651:59–71. https://doi.org/10.1016/j.jallcom.2015.08.064.

[16] Tekin D, Birhan D, Kiziltas H. Thermal, photocatalytic, and antibacterial properties of calcinated nano-TiO2/polymer composites. Mater Chem Phys 2020;251:123067. https://doi.org/https://doi.org/10.1016/j.matchemphys.2020.123067.

[17] Romero-Sáez M, Jaramillo LY, Saravanan R, Benito N, Pabón E, Mosquera E, et al. Notable photocatalytic activity of TiO2-polyethylene nanocomposites for visible light degradation of organic pollutants. Express Polym Lett 2017;11:899–909. https://doi.org/10.3144/expresspolymlett.2017.86.

[18] Erol M, Bilgin K. Boron doped titaniumdioxide nanotube arrays: production, characterization and photocatalytic properties. Journal of Porous Materials 2017;24:1295–302. https://doi.org/10.1007/s10934-017-0370-9.

[19] Erol M, Ertugrul O. HIPed TiO2 dense pellets with improved photocatalytic performance. Ceram Int 2018;44:2991–9. https://doi.org/https://doi.org/10.1016/j.ceramint.2017.11.053.
[20] Al-Amin M, Chandra Dey S, Rashid TU, Ashaduzzaman M, Shamsuddin SM. Solar Assisted Photocatalytic Degradation of Reactive Azo Dyes in Presence of Anatase Titanium Dioxide. International Journal of Latest Research in Engineering and Technology (IJLRET 2016;2:14–21.
[21] Kasapoğlu N, Baykal A, Toprak MS, Köseoğlu Y, Bayrakdar H. Synthesis and characterization of NiFe2O4 nano-octahedrons by EDTA-assisted hydrothermal method. Turk J Chem 2007;31:659–66.
[22] Mussatto CMB, Oliveira EMN, Subramani K, Papaléo RM, Mota EG. Effect of silica nanoparticles on mechanical properties of self-cured acrylic resin. Journal of Nanoparticle Research 2020;22. https://doi.org/10.1007/s11051-020-05050-y.
[23] Yavaş A, Atan E, Sütçü M. Self-cleaning and photocatalytic properties of eco-friendly clay-based facing bricks from industrial and natural wastes. Environ Sci Pollut Res Int 2023. https://doi.org/10.1007/s11356-023-27798-1.
[24] Yavaş A, Güneş F, Erol M, Sütçü M, Güler S, Torman Kayalar M, et al. Development of visible light active self-cleaning clay roofing tiles as novel building materials: An investigation on the effects of α-Fe2O3 coating and firing temperature. J Clean Prod 2022; 362:132302. https://doi.org/https://doi.org/10.1016/j.jclepro.2022.132302.

Vibration Control of Flexible Manipulators by Active Cable Tension

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Abstract

The end point vibrations of the serial manipulator should be controlled during motion or working process. In this study the residual vibrations of the flexible manipulator were controlled with cable tensions. The finite element model was established in ANSYS Mechanical APDL. The open loop and closed loop control simulations were performed under the trapezoidal velocity motion profiles. Zero and three different initial strain values were assigned to the cables. As a result, the end point vibration amplitudes, axial forces of the cables and the bending strain values of the one element near the fixed end were observed in order to define the limitations of the sensors and actuators which will be selected for experimental setup.

Keywords: Vibration control, flexible manipulator, finite element analysis

Introduction

The serial manipulators are commonly used in industry for many applications as path following motions, pick and place operations etc. The end effector vibrations must be controlled during the operations. There are two ways to suppress the end point vibrations as passive and active control. The passive vibration control can be achieved by using appropriate velocity motion profiles to actuate the manipulator.

Trapezoidal velocity motion profile is the basic velocity motion profile in order to actuate a serial manipulator. Trapezoidal velocity profiles consist of three-time parameters as acceleration time, deceleration time and constant velocity time. Selection of these time parameters are crucial for elimination of end point vibrations of a flexible manipulator or to keep them at a certain level. Some studies [1, 2] proved that selection of the trapezoidal motion profile time parameters which are related with the natural period of the one degree of freedom flexible manipulator, reduces the residual vibrations. The same approach was also applied on two degrees of freedom flexible manipulator and the reduced residual vibrations were obtained in the study [3]. In these studies, [1-3] when the deceleration time of trapezoidal motion profile was selected as integer multiples of first natural period of the manipulator, the residual vibrations were suppressed.

In the literature, different velocity profiles that have smoother acceleration changes than trapezoidal velocity motion profiles were suggested and used to drive a motor or dynamic system. The firstly proposed the 3rd order S-curve motion profile which has seven-time segment by Castain and Paul [4] was used also in practice [5-7].

The effect of the time parameters of 3rd order polynomial S-curve and trapezoidal motion profiles on transient and residual vibrations of a flexible manipulator were investigated [8]. Finite element model of manipulator was established, and numerical calculations were done by using Newmark method.

Active vibration control of the flexible manipulators can be performed by using another actuator such as piezoelectric actuators or input shaping methods [9, 10].

Vibration control was achieved by using active cable tension for many different cases such as vibration control of large trusses [11, 12], cable stayed bridges [13] or even membrane antenna structure vibrations [14].

In this study, the finite element model of the flexible beam with cables was established Ansys Mechanical APDL instead of Ansys Workbench in order to perform the closed loop control simulations. The open loop and closed loop control simulations were performed under the trapezoidal motion profiles. Zero initial strain and three different initial strain values were assigned to the cables for performed simulations. As a result, the end point vibration amplitudes, axial forces of the cables and the bending strain values of the one element near the fixed end were observed in order to define the limitations of the sensors and actuators which will be selected.

Methodology

The finite element model of the flexible beam with cables was established in ANSYS APDL in order to perform the closed loop control simulations by writing scripts. Flexible beam was modeled by using BEAM188 element and the cables were modeled by using LINK180 element. LINK180 elements were modeled as members that carry only axial tension forces to model the cables. Detailed schematic view of the model is shown in Figure 1. The model parameters were given in Table 1 and established model in Ansys APDL was shown in Figure 2.

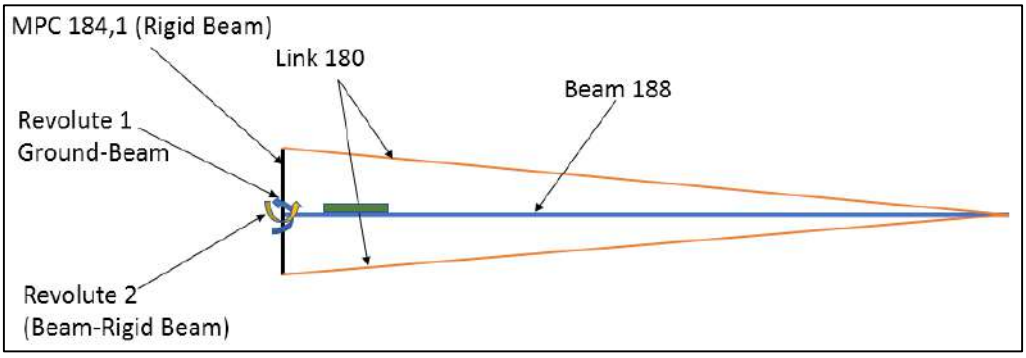


Figure 1. Schematic FE model of the tendon controlled flexible beam

Table 1. Model parameters

Elastic modulus	$2x10^{11}$ Pa
Poisson ratio	0.3
Density	7850 kg/m^3
Payload mass	1.25 kg
Inertia of payload	$633.445x10^{-6}$ kgm^2
Cable Diameter	Ø1 mm
Cross section	3.8x40 mm^2
Beam length (L_2)	400 mm
Rayleigh damping coefficients	η=0 and β=$3.75x10^{-5}$
Motor rotational spring constant	K_{m2}=16000 Nm/rad
Number of finite elements	ne2=80
Time step	Δt=0.005 s

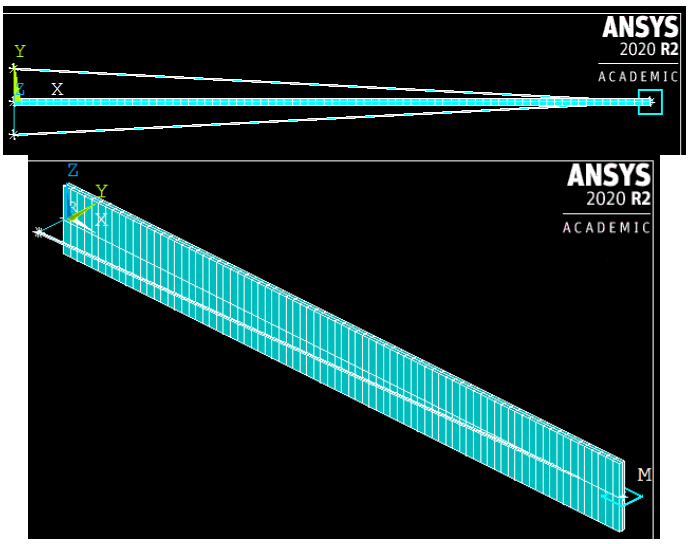


Figure 2. Established model in ANSYS APDL

Symmetric trapezoidal velocity motion profiles were used to actuate the manipulator. The manipulator was rotated 90˚ in 1 sec. The motion vector of trapezoidal motion profiles was defined as qm=[T_{acc}-T_{dec}-T_m]. Used symmetric trapezoidal motion profile parameters were defined acceleration and deceleration times as percentage of the motion time. T_{acc} and T_{dec} values were defined in Tables and Figures as %T_m. The used velocity motion profile is shown Figure 3.

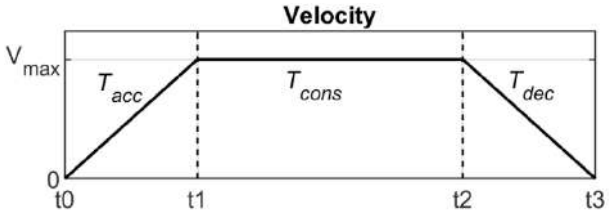


Figure 3. Trapezoidal velocity motion profile

The effect of the pretension amount of the cables on the natural frequency of flexible manipulator was also observed. The closed loop control algorithm which includes proportional control (K_p) was established in ANSYS APDL. Bending strain values on an element which is away 15 mm from fix end was used as a feedback for closed loop control.

Results and Discussions

Obtained natural frequencies from both modal analyses and fast Fourier transform by using free vibration responses of residual vibrations were shown in Table 2. The reason the differences between the modal analyses and fast Fourier transform frequency result, both cables are not effective at the same time on the stiffness matrix. The axial load on one of the cables becomes zero during motion and that cable cannot make any contribution to the stiffness. The duration of this noncontributing region changes according to the actuation velocity profile. This situation was understood from the observation of the axial forces on the cables during the motion as shown in Figure 4.

Table 2. Obtained first natural frequencies

		Trapezoidal Motion Cases				
Pretension	Modal Analyses	**[0.1-0.1-1]**	**[0.2-0.2-1]**	**[0.3-0.3-1]**	**[0.4-0.4-1]**	**[0.5-0.5-1]**
No cable	5.5786 Hz	5.5786	5.5786	5.5786	5.5786	5.5786
0	7.9992 Hz	6.9316	6.8777	6.9794	6.9628	6.9134
5N	8.0279 Hz	6.9128	6.9466	7.7108	7.1592	6.9994
10N	8.0564 Hz	6.9319	7.0433	7.4993	7.3843	7.0978
15N	8.0848Hz	6.9504	7.1987	7.4894	7.9754	7.2699

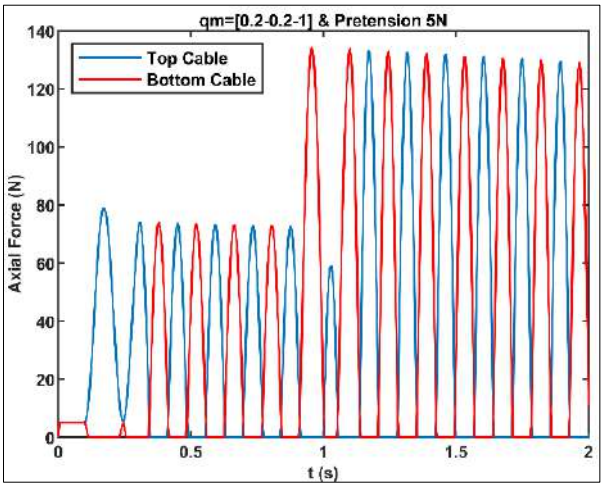
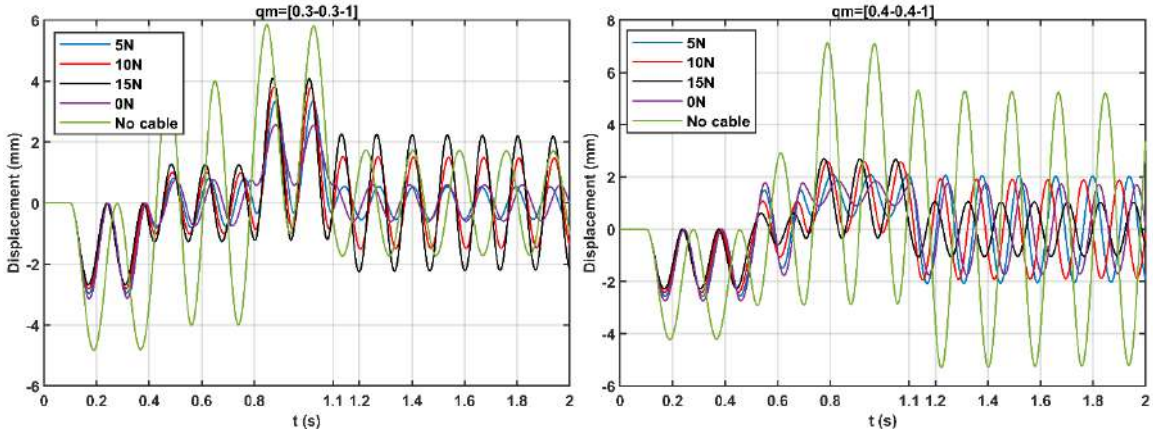


Figure 4. Axial Forces on the cables during the qm=[0.2-0.2-1] with 5N pretension

The observation of the pretension amount effect on the vibration results for both qm=[0.3-0.3-1] and qm=[0.4-0.4-1] for all pretension values and without cable model were shown in Figure 5 (a) and (b). It was obtained that the vibration amplitudes are not directly affected by the pretension amount on cables. It is related with the natural period and given motion profile parameters. It was known that the coinciding or close values of the first natural period of the manipulator and the acceleration time of the motion profile reduce the vibration amplitudes. These effects were explained in detail in [8, 15].



(a) (b)

Figure 5. The effect of the pretension values on the vibration amplitudes

There should be a limitation for initial pretension amount. Two parameters should be taken into consideration. During the motion axial force on the cables should not reach up to yield force. And the axial force of the cable should not cause the buckling failure of the beam. For this reason, axial yield force (Fax_{yield}) and maximum axial load (P_{crt}) that the beam can carry can be calculated from Eq1 and Eq2, respectively. During the motion, these values should be observed. The obtained max Fax_{yield} on cables will also be used for calculation of the needed torque amount of control motor. According to the obtained result from Table 2 and Table 3 reached max Fax load 208.9676 N for 15N pretension and for qm=[0.1-0.1-1]. However, this value is higher than Fax_{yield}. Therefore, if the 15N pretension are going to be used motion case qm=[0.1-0.1-1] should not be chosen. If the diameter of cable increased, then it can be safe for use. The reached maximum holding torque value was obtained as 4.179352Nm. This can be taken as a reference for selection of the control motor. However, the real torque value of the motor should be selected after performing the closed loop control simulations.

$$Fax_{yield} = \sigma_{yield} A_{cable} \rightarrow \sigma_{yield} = 250Mpa, A_{cable} = \pi(0.5x10^{-3})^2 \quad (1)$$

$$Fax_{yield} = 196.35\ N$$

$$P_{crt} = \frac{\pi^2 EI}{L_e^2} \rightarrow L_e = 2L \rightarrow P_{crt} = 564N \quad (2)$$

Table 3. Axial forces on Cable 1 for Open Loop Control

	Trapezoidal Motion Cases/CableTension1 (N)				
Pretension	**[0.1-0.1-1]**	**[0.2-0.2-1]**	**[0.3-0.3-1]**	**[0.4-0.4-1]**	**[0.5-0.5-1]**
5N	161.5214	133.1011	60.7261	53.3922	97.4236
10N	186.3857	119.3072	62.7435	55.4848	94.5357
15N	205.5897	98.3538	65.0928	57.945	83.83
	Needed Holding Torque (Nm)				
5N	3.230428	2.662022	1.214522	1.067844	1.948472
10N	3.727714	2.386144	1.25487	1.109696	1.890714
15N	4.111794	1.967076	1.301856	1.1589	1.6766

Table 4. Axial forces on Cable 1 for Open Loop Control

	Trapezoidal Motion Cases/CableTension2 (N)				
Pretension	**[0.1-0.1-1]**	**[0.2-0.2-1]**	**[0.3-0.3-1]**	**[0.4-0.4-1]**	**[0.5-0.5-1]**
5N	162.0161	134.2044	67.7446	44.6053	98.7319
10N	187.1463	122.4846	81.1568	58.7313	98.3083
15N	208.9676	109.608	91.2579	65.5933	94.4689
	Needed holding torque (Nm)				
5N	3.240322	2.684088	1.354892	0.892106	1.974638
10N	3.742926	2.449692	1.623136	1.174626	1.966166
15N	4.179352	2.19216	1.825158	1.311866	1.889378

In Ansys APDL closed loop control algorithm includes proportional control (Kp) was established by written a script. Bending strain value on the element which is away 15 mm from the fix-end was read from the simulation and used as a feedback for closed loop control. Obtained closed loop results for different Kp values and different motion profiles were shown in Figure 6.

The closed loop simulations were also studied for different motion profiles. The end point vibrations were suppressed significantly only using proportional controller and vibration control has been successfully performed.

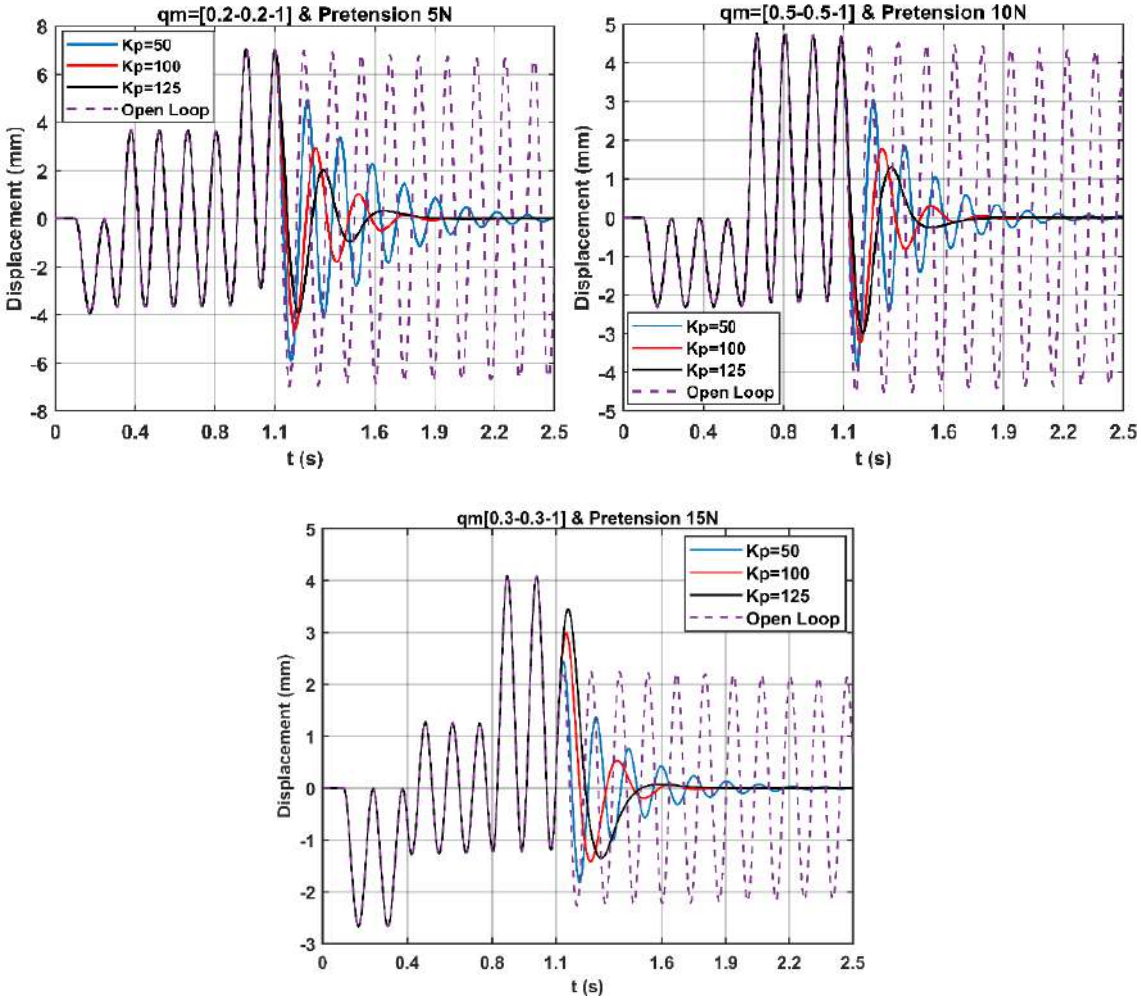


Figure 6. Closed loop control for different Kp values for same pretension axial load

Conclusions

The finite element model of the flexible beam with cables was established using Ansys Mechanical APDL instead of Ansys Workbench in order to perform the closed loop control simulations. The open loop and closed loop control simulations were performed under the trapezoidal motion profiles. Zero initial strain and three different initial strain values were assigned to the cables for performed simulations. As a result, the end point vibration amplitudes, axial forces of the cables and the bending strain values of the one element near the fixed end were observed in order to define the limitations of the sensors and actuators which will be selected. According to the obtained results the outcome will be as follows.

- For this system for control motor torque should be at least 4.2 Nm and strain gauge max limit value at least $3x10^{-4}$ m/m. These values should multiply minimum 1.5 as a safety factor.
- And for the setting of the initial pretension values a force measuring sensor is needed. That can carry up to 200N because the max Fax on the cables reaches approximately this value.
- According to obtained results the closed loop vibration control of flexible manipulator can be achieved by active cable tension.

References

[1] Malgaca L, Yavuz Ş, Akdağ M, Karagülle H. Residual vibration control of a single-link flexible curved manipulator. Simulation Modelling Practice and Theory. 2016;67:155-70.
[2] Yavuz Ş, Malgaca L, Karagülle H. Vibration control of a single-link flexible composite manipulator. Composite Structures. 2016;140:684-91.
[3] Karagülle H, Malgaca L, Dirilmiş M, Akdağ M, Yavuz Ş. Vibration control of a two-link flexible manipulator. Journal of Vibration and Control. 2017;23(12):2023-34.
[4] Castain RH, Paul RP. An on-line dynamic trajectory generator. The International Journal of Robotics Research. 1984;3(1):68-72.
[5] Liu C, Chen Y. Combined S-curve feedrate profiling and input shaping for glass substrate transfer robot vibration suppression. Industrial Robot: the international journal of robotics research and application. 2018;45(4):549-60.
[6] Lu T-C, Chen S-L. Genetic algorithm-based S-curve acceleration and deceleration for five-axis machine tools. The International Journal of Advanced Manufacturing Technology. 2016;87(1-4):219-32.
[7] Liu S, editor An on-line reference-trajectory generator for smooth motion of impulse-controlled industrial manipulators. 7th International Workshop on Advanced Motion Control Proceedings (Cat No 02TH8623); 2002 3-5 July; Maribor, Slovenia: IEEE.
[8] Akdağ M, Hayrettin Ş. S-curve Motion Profile Design for Vibration Control of Single Link Flexible Manipulator. Dokuz Eylül Üniversitesi Mühendislik Fakültesi Fen ve Mühendislik Dergisi. 2021;23(68):661-76.
[9] Malgaca L, Uyar M, Yavuz Ş. Active vibration suppression of a single-link smart flexible manipulator. International Journal of Natural and Engineering Sciences. 2017;11(1):13-9.
[10] Tzes A, Yurkovich S. An adaptive input shaping control scheme for vibration suppression in slewing flexible structures. IEEE Transactions on Control Systems Technology. 1993;1(2):114-21.
[11] Preumont A, Achkire Y. Active damping of structures with guy cables. Journal of guidance, control, and dynamics. 1997;20(2):320-6.
[12] Preumont A, Achkire Y, Bossens F. Active tendon control of large trusses. AIAA journal. 2000;38(3):493-8.
[13] Warnitchai P, Fujino Y, Pacheco BM, Agret R. An experimental study on active tendon control of cable-stayed bridges. Earthquake engineering & structural dynamics. 1993;22(2):93-111.
[14] Liu X, Zhang H, Lv L, Peng F, Cai G. Vibration control of a membrane antenna structure using cable actuators. Journal of the Franklin Institute. 2018;355(5):2424-35.
[15] Akdağ M, Şen H. Investigation of Performance and Sensitivity of S-Curve Motion Profiles on Reduction in Flexible Manipulator Vibrations. Arabian Journal for Science and Engineering. 2023:1-14.

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Mechanical and Thermal Characterization of Congolese *Agave Sisalana* Natural Fibers

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Abstract

In this study, *Agave Sisalana* plant fibers supplied from the Democratic Republic of the Congo (DRC) are characterized. Tensile test to determine their mechanical properties and Thermogravimetric Analysis (TGA) to determine their thermal properties are performed. Fiber diameter is measured using an Industrial Optical Microscope (Nikon Eclipse LV150, Japan) considering the average value from 3 sections of 3 fiber samples with 50X, 100X and 200X magnification. Furthermore, the ASTM D3379 standard is used in the evaluation of the tensile properties by using a Universal Tensile Testing Machine (Shimadzu Autograph AGS-X, Japan) with a 5kN load cell capacity. The experiment is performed with a 30 mm gauge length and 1 mm/min crosshead speed. To ensure sufficient fiber fastening to the tensile machine, fiber is glued earlier to a rectangular structure of 40 mm in width and 50 mm in length. Both sides of the frame are cut to free the fiber sample before the tensile test. Thermogravimetric analysis is performed to determine the thermal stability of the fibers. The results obtained from these test and analysis are compared with similar studies in the literature and interpreted comparatively.

Keywords: Congolese *agave sisalana*, natural fiber

Introduction

The proliferating plastic waste represents one of the major problems of the centuries. Nations are mobilizing and investing to provide sustainable solutions aimed at better managing this waste. The use of natural fibers as reinforcement materials for composites allows both the reduction of the use of plastic and waste recovery. Numerous recent review articles have amply attested to the success of using natural fibers (such as hemp, sisal, flax, jute, coconut, banana, ramie, etc.) in the production of innovative, lightweight, and inexpensive biocomposites that exhibit good mechanical performance. The *agave sisalana* fiber (sisal), one of the many natural fibers used to manufacture biocomposites, is particularly intriguing.

There are multiple studies in the literature on natural fibers characterization. To cite some, Upendra S. et al. [1] studied the Mechanical and Surface Characterization of Sisal Fiber (*Agave Sisalana*) After Cold Glow Discharge Oxygen Plasma Treatment. Sridhar K. et al. [2] performed the analytical and experimental investigation on Sisal fibers reinforced polymer composites in aviation. Binoj J.S. & Bibin J.S. [3] performed a Failure analysis of discarded *Agave tequilana* fiber polymer. Tamanna T.A. et al. [4] studied the Characterization of a new natural fiber extracted from *Corypha taliera* fruit. Diyana Z.N. et al. [5] performed a study on the Extraction and Characterization of Natural Cellulosic Fiber from *Pandanus amaryllifolius* Leaves. Kılınç A.Ç. et al. [6] performed the Extraction and investigation of lightweight and porous natural fiber from *Conium maculatum* as a potential reinforcement for composite materials in transportation. Moshi A. et al. [7] published a comprehensive review on the Characterization of New Natural Cellulosic Fibers. Baékou A. et al. [8] studied the Physico-chemical and microstructural characterization of "*Rhectophyllum camerunense*" plant fiber. Saravanakumar S.S. et al. [9] conducted a study on the Characterization of a novel natural cellulosic fiber from *Prosopis juliflora* bark. Binoj J.S. et al. [10] investigated the Morphological, Physical, Mechanical, Chemical and Thermal Characterization of Sustainable Indian Areca Fruit Husk Fibers (*Areca Catechu L.*) as Potential Alternate for Hazardous Synthetic Fibers.

In this study, the mechanical and thermal characterization of fibers extracted from *Agave Sisalana* leaves supplied from the DRC is performed through tensile test to determine mechanical properties and TGA to determine thermal properties. Results are compared with those in the literature.

Material and Methods

Material Origin

Agave Sisalana fibers were collected from the Kisantu Botanic Garden in Kongo Central province in the DRC. Fibers were extracted from fresh leaves.

Fiber Extraction

The fiber extraction method involved in this study is partial retting followed by soft pounding. Leaves were washed then placed in a water bath to undergo partial water retting process for 3 days. This process softened the leaves. Afterwards they were softly pounded and fibers were removed by manual peeling and were cleaned and given a day to dry in full sunlight. Fibers were further dried in the oven for one day under 80°C. (see Figure 1)

(a) (b)

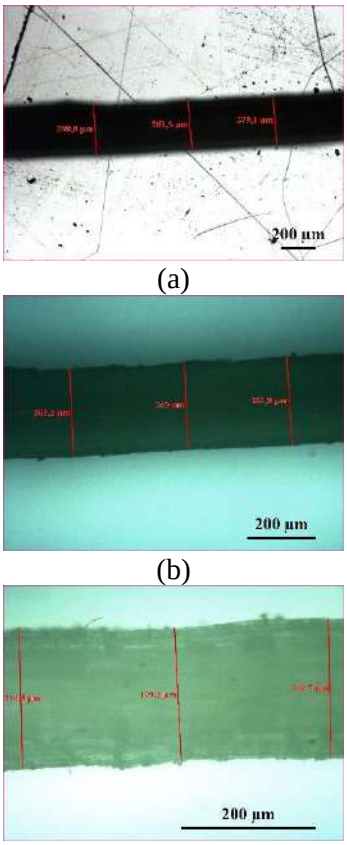
Figure 1. Fiber Extraction: (a) Leaves pounding (b) Dried fibers

Characterization

Fiber Length and Diameter

Fiber diameters were measured under an Industrial Optical Microscope (Nikon Eclipse LV150, Japan) shown in Figure 2, considering the average value from 3 sections of fiber samples with 50X, 100X and 200X magnification as seen in Figure 3. A total of 10 samples were measured. The fiber length was long enough for tensile testing.

Figure 2. Industrial optical microscope tester



(a)

(b)

(c)

Figure 3. Fiber diameter with (a) 50X (b) 100X and (c) 200X magnification

Mechanical Testing

As illustrated in Figure 4, fiber is previously glued to a rectangular cardboard frame with dimensions of 40 mm in width and 50 mm in length to provide adequate fiber fastening to the tensile tester. Before performing the test, both sides of the frame are sliced to release the fiber sample.

The evaluation of the tensile test was conducted utilizing the ASTM D3379 standard and a universal tensile testing machine (Shimadzu Autograph AGS-X, Kyoto, Japan) with a load cell capacity of 5 kN, see Figure 5. The experiment was run with a gauge length of 30 mm and a crosshead speed of 1 mm/min.

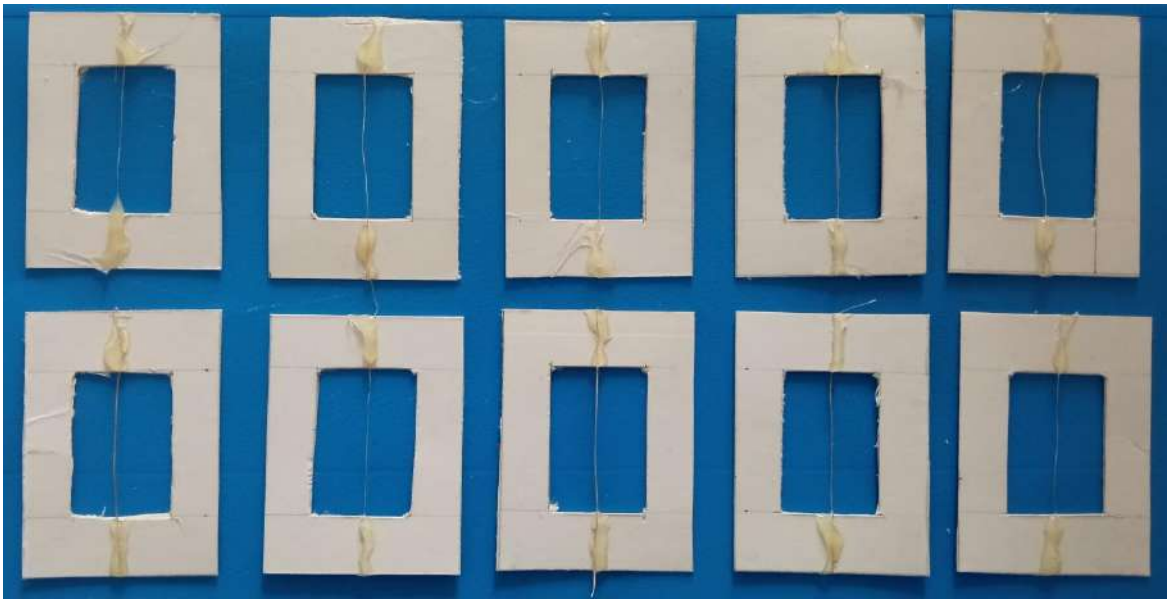


Figure 4. Glued fibers on cardboard frames

Figure 5. Tensile testing machine with fiber samples

Thermogravimetric Analysis (TGA)

The thermal stability of the fibers was evaluated by a TGA. For this purpose, about 5g of the fiber was heated in an alumina crucible pan between 30 and 600°C at a heating rate of 20°C/min and a flow rate of 20 mL/min in an inert (nitrogen) atmosphere. Thermogravimetric tester and the sample are seen in Figure 6.

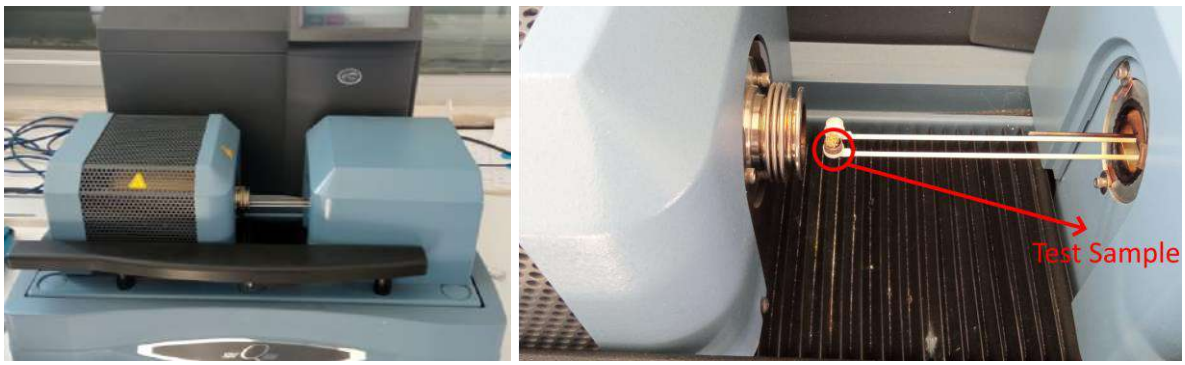


Figure 6. Thermogravimetric tester

Results and Discussion

Fiber Length and Diameter

The maximum fiber length measured was 385 mm. The result of fiber diameters for 3 samples are presented in Table 1.

Table 1. Fiber diameters

Magnification	Fiber Diameter (µm)			Average		
	285.9	261.7	241.8	263.1		263.1
50X	148.5	145.9	156.1	150.2		-
	298.8	281.5	279.1	286.5		286.5
	261.3	260	262.8	261.4		261.4
100X	296.2	311.4	316.4	308.0		-
	244.9	202.2	203.7	216.9		216.9
	265.2	265.5	262.7	264.5		264.5
200X	210.5	199.3	203.7	204.5		204.5
	185.3	185.8	193.4	188.2		188.2
			Average	*238.1*	*Upper Limit 289.2*	
			Standard Deviation	*51.1*	*Lower Limit 187.0*	
					Last Average	**240.7**

After evaluation considering values within the limits, we get 240.7 µm as average fiber diameter, distributed as 237.35±49.15 µm**.**

Mechanical Testing

10 samples were tested, diameter values of every single were entered as test parameter with crosshead speed of 1 mm/min.

Figure 7 illustrates a typical stress-strain curve with a quasi-linear behavior in initial elastic region. There was no notable plastic deformation observed.

Tensile test results including the tensile strength which corresponds to the maximum stress at break, the elastic modulus, the maximum strain (at break) are presented afterwards.

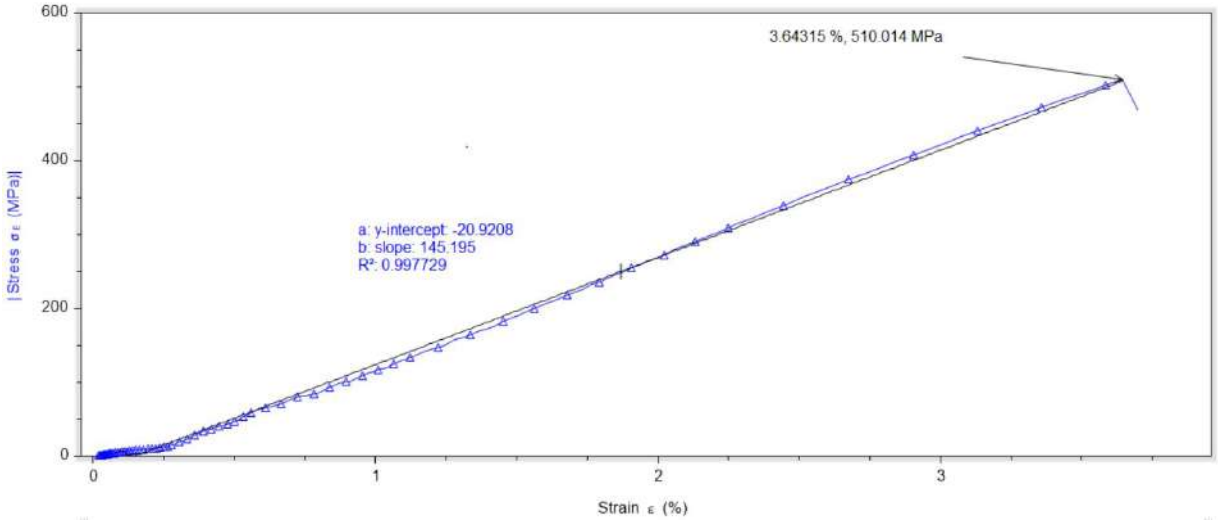


Figure 7. Stress-strain curve

Overlaid stress-strain curves for all samples are displayed in Figure 8 below.

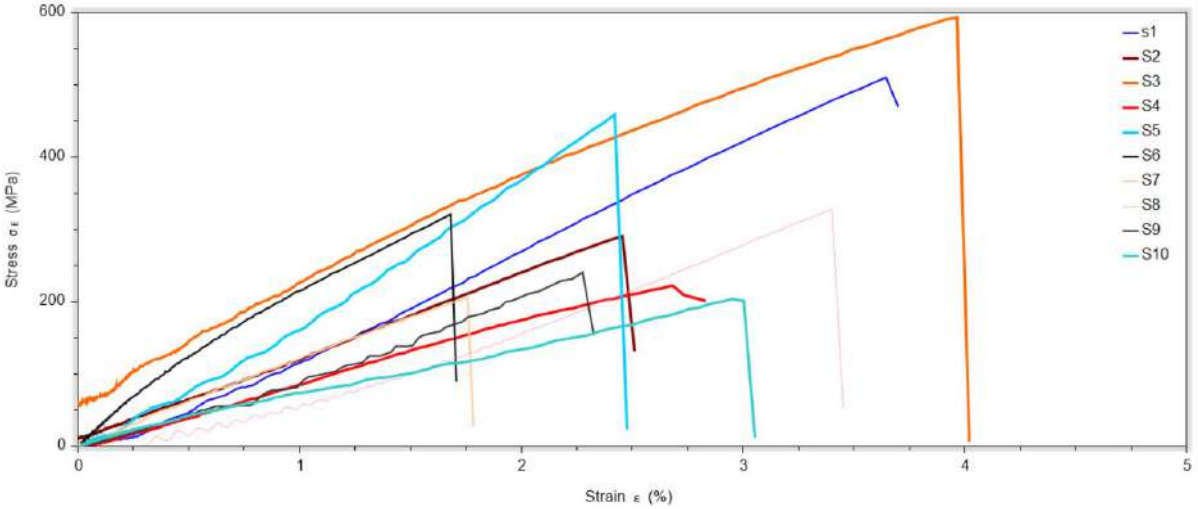


Figure 8. Stress-strain curves

Table 2. Tensile test results

Sample No	Tensile Strength (MPa)	Tensile Modulus (GPa)	Elongation at Break (Ɛ, %)	Actual Tensile Strength (MPa)
S1	510	14.01	3.64	-
S2	290	11.84	2.45	290
S3	638	16.11	3.96	-
S4	234	8.73	2.68	234
S5	436	18.02	2.42	436
S6	335	19.94	1.68	335
S7	212	12.11	1.75	212
S8	305	9.00	3.39	305
S9	225	9.91	2.27	225
S10	204	6.80	3.00	204
Average	***339***	***12.65***	***2.72***	**280.1**
Std. Deviation	145.30			
Upper Limit	484			
Lower Limit	194			

According to the values given in Table 2 as test results, the elongation at break is between 1.68% - 3.39%, the tensile strength is between 204 - 436 MPa and the tensile modulus is between 6.8 – 19.9 GPa. A comparison of these values with those of similar studies in the literature is given in Table 3.

Table 3: Comparison of values with similar studies in the literature

Fiber	Tensile Strength (MPa)	Tensile Modulus (GPa)	Elongation at Break (Ɛ, %)	Reference
Agave sisalana (Sisal)	204 - 436	6.8 – 19.9	1.68 - 3.39	Present
Sisal	511-635	2.2-9.4	1.5	[5]
Sisal	511-635	9.4-22	2-2.5	[3,10]
Sisal	274-526	-	-	[7]
Conium maculatum	260.48-395.3	8.73	2.14-3.2	[6]
Prosopis juliflora	544.6-571.4	-	1.33-1.81	[9]

Thermogravimetric Analysis

TGA results are shown in Figure 9 below.

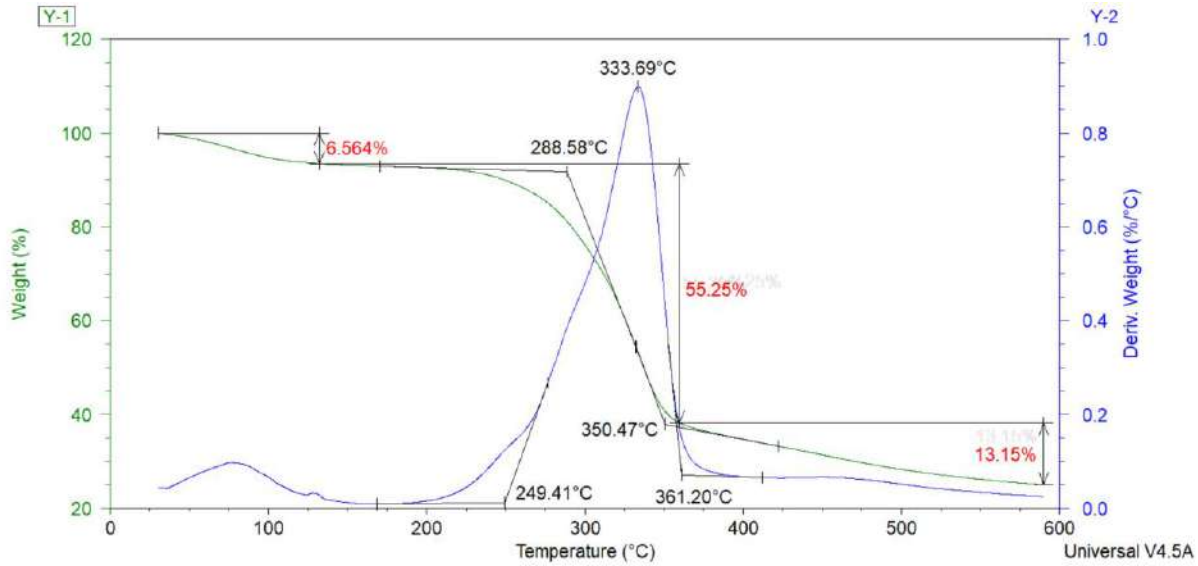


Figure 9. Thermogravimetric analysis (TGA) curve

TGA curve reveals that there was about 6.5 % moisture in the fiber which is lost at the temperature range between 25-125°C, major weight loss of about 55.25 % happened in the temperature ranging from 210-360° which is attributed to the loss of cellulose and hemicellulose components with a peak happening at 333.69°C. The next weight degradation of about 13.15 % is attributed to the lignin components (wax) and in the last phase we have residues. From this curve, we can infer that our fiber can be used for plastic matrices whose polymerization temperature doesn't exceed 210°C.

This result is consistent with other similar studies in the literature.

Conclusion

The *Agave Sisalana* fibers were extracted from the plant leaves with partial retting followed by soft pounding.

- Moisture content analysis indicated that there was about 6.5 % moisture in the fibers.
- The tensile strength of the fiber was found 320 ±116 MPa.
- An average fiber diameter of 237.35±49.15 µm was measured.
- The thermogravimetric analysis showed the thermal stability of *Agave Sisalana* fiber up to 210°C which is within polymerization process temperature of most of thermoplastics.
- The study's findings demonstrate that Congolese *Agave Sisalana* fiber can be used as reinforcement material to the manufacturing of bio-based composites.

References

[1] Gupta U.S, Tiwari S, Shama U. Mechanical and Surface Characterization of Sisal Fiber (Agave Sisalana) After Cold Glow Discharge Oxygen Plasma Treatment. Research Square 2022. CrossRef]

[2] Sridhar K, Suthan R, Suresh P, Sivakumar P. Analytical and Experimental Investigation on Sisal Fibers Reinforced Polymer Composites in Aviation. International Journal of Engineering Applied Sciences and Technology, 2019; 94-97. [IJEAST]

[3] Binoj J.S, Bibin J.S. Failure analysis of discarded Agave tequilana fiber polymer composites. Engineering Failure Analysis, 2019 ; 95 : 379–391. [CrossRef]

[4] Tamanna T. A, Belal S.A, Shibly M, Khan A.N. Characterization of a new natural fiber extracted from *Corypha taliera* fruit. Scientific Reports, 2021; 11:7622. [CrossRef]

[5] Diyana Z. N, Jumaidin R, Selamat M. Z, Alamjuri R. H, Yusof F. A. Extraction and Characterization of Natural Cellulosic Fiber from *Pandanus amaryllifolius* Leaves. Polymers 2021, 13, 4171. [CrossRef]

[6] Kılınç A.Ç. et al. Extraction and investigation of lightweight and porous natural fiber from *Conium maculatum* as a potential reinforcement for composite materials in transportation. Composites Part B 2018; 140: 1–8. [CrossRef]

[7] Moshi A, Ravindran D, Bharathi.S.R, Suganthan.V, Singh G. Characterization of New Natural Cellulosic Fibers–A Comprehensive Review. International Conference on Materials Engineering and Characterization, 2019; 574: 012013. [CrossRef]

[8] A. Béakou A, Ntenga R, Lepetit J, Atéba J.A, Ayina L.O. Physico-chemical and microstructural characterization of ‘‘*Rhectophyllum camerunense*’’ plant fiber. Composites: Part A, 2008; 39: 67–74. [CrossRef]

[9] Saravanakumar S.S, Kumaravel A,Nagarajan T, Sudhakar P, Baskaran R. Characterization of a novel natural cellulosic fiber from *Prosopis juliflora* bark. Carbohydrate Polymers, 2013; 92:1928-1933. [CrossRef]

[10] Binoj J. S, Edwin Raj R, Sreenivasan V. S, Rexin Thusnavis G. Morphological, Physical, Mechanical, Chemical and Thermal Characterization of Sustainable Indian Areca Fruit Husk Fibers (*Areca Catechu L.*) as Potential Alternate for Hazardous Synthetic Fibers. Journal of Bionic Engineering, 2016;13:156–165. [CrossRef]

[11] Militello C, Bongiorno F, Epasto G, Zuccarello B. Low-velocity impact behaviour of green epoxy biocomposite laminates reinforced by sisal fibers. Composite Structures, 2020; 253:112744. [CrossRef]

Chorogenic Acid, Dehydrocarpaine I and D1 Alpha Tocopherol from Papaya Leaves (*Papaya Carica*) as an Anti-Inflammatory Candidate That Inhibits TNF Alpha Receptors

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Abstract

Introduction. TNF alpha is a significant mediator that plays a role in acute and chronic inflammatory processes or chronic that induces cell apoptosis. Papaya leaves have anti-inflammatory effects, but the mechanism is not yet known with certainty. The study aimed to predict the mechanism of action of active compounds of papaya leaves as anti-inflammatory through the mechanism of death receptor (1DOG) / TNF receptors family inhibiting in insilico method. In addition, the study aims to determine the solubility, pharmacokinetics, and toxicity of active compounds insilico.

Methods. Computational research using docking server.com application to predict the binding affinity of active compounds with 1DOG, PKCSM application to assess the rules of 5 of Lipinski, pharmacokinetics and toxicity of active compounds.

Results. The results showed that papaya leaf active compounds such as chlorogenic acid, dehydrocarpaine I and D1 alpha-tocopherol have an affinity to 1DOG, but the potency is lower than hydrochloroquine. The three compounds have good solubility when given orally and good pharmacokinetics and are not hepatotoxic or carcinogenic when given in the long term.

Conclusion. Chlorogenic acid, dehydrocarpaine I, and D1 alpha-tocopherol contained in papaya leaves are predicted have the effect of antiinflammation through inhibition 1DOG, have drug ability when given orally, safe and not toxic.

Keywords: *Papaya carica*, TNF alpha, death receptor, ADMET

Introduction

TNF alpha is a primary inflammatory mediator that plays a role in acute and chronic inflammatory processes. TNF alpha has functions for cell proliferation, tissue regeneration, cell defense, inflammation, and cell death. Increased levels of TNF alpha in the blood are produced by macrophage cells in response to bacterial lipopolysaccharide (LPS), T lymphocytes, and NK cells. TNF alfa has two kinds of transmembrane receptors, namely TNFR-1 and TNFR-2. The binding between TNF alpha and TNFR-1 will cause the activation of Mitogen Activating Factor kinase, which in turn activates the transcription factor NfKB. Activation of NFKB will activate genes that function to produce other inflammatory mediators. The binding between TNF alpha and TNFR-1 also activates cell death receptors, thus triggering the activation of the cell death cascade through apoptosis, necroptosis, or pyroptosis. The binding between TNF alfa and TNFR-2 does not induce cell death but plays a role in cell proliferation, cell defense against inflammation, and tissue regeneration. Thus, inhibition of the binding between TNF alpha and TNFR-1 is a breakthrough to prevent cell death and the formation of inflammatory mediators in chronic inflammation due to bacterial infections, viral infections, autoimmunity, and malignancies (Jang, Lee , Shin, Song, & et.al, 2021)

The papaya plant, or *Carica papaya*, belongs to the *Caricaceae* family, widely found in Indonesia. This plant originated in Mexico and Central America and has spread to various tropical countries on the African and Asian continents, including Indonesia (Jati, Prasetya, & Mursiti, 2019). Each 100g papaya leaf contains 38.6% vitamin C, 5.6% protein, 0.225% phosphorus, 8.3% carbohydrate, 0.0064% Fe and 0.035% magnesium (Shrivastava, Alagarasu, Cherian, & Parashar, 2022). Papaya leaves contain active compounds of flavonoids, saponins, phenols, tannins, steroids, and alkaloids proven to have pharmacological effects. The main active compounds in papaya leaves are pseudocarpaine, dehydrocarpain, vitamin C and Vitamin E. Papaya leaves have functioned as anticancer, helminthiasis, antitussive, prevent pregnancy, antihyperglycemic, anti-inflammatory, and antipyretic (Singh, et al., 2020)

Figure 1. Papaya plant (*Papaya carica*)

The research was conducted computationally /insilico to predict the potential of active compounds as anti-inflammatory. The choice of in-silico or computational methods is based on the advantages of using in-silico methods, which are easier and faster to predict the affinity of an active compound to receptors or proteins to cause pharmacological effects and save research costs for new drug discovery (Meng, Zhang, Mezei, & Cui, 2011) (Brogi, Ramalho, Kuca, Medina- Franco, & Valco, 2020).

Methods

The research was conducted computationally using an Asus laptop supported with an Intel CORES i5 CORE i5 8th Gen processor with 4 GB RAM and the Discovery Studio Visualizer (DSV) program. The active compounds of papaya leaves were taken from the literature, namely chlorogenic acid, dehidrocarpaine I, D1 alpha-tocopherol, beta-cryptoxanthin, benzyl isothiocyanate, 5,7 dimethoxy-coumarin, caffeic acid, beta carotene, p-coumaric acid, protocatechuic acid (Singh, et al., 2020) (Shrivastava, Alagarasu, Cherian, & Parashar, 2022).

To predict the potential of papaya leaf active compounds as anti-inflammatory, the STITCH application http://stitch.embl.de/cgi/network.pl?taskId=S8iGaoTB7xKU (Kuhn, Szklarczyk, Pletscher-Frankild, Blicher, & et.al, 2014). To predict the affinity of the active compound to the target protein TNF alpha using the molecular docking method with the dockingserver.com application. The docking process begins with ligand preparation. The 3D structure of the active compound was taken from PubChem (https://pubchem.ncbi.nlm.nih.gov/) and saved as a SDF file. For protein preparation, the 3D structure of death receptor (1DOG) was taken from Protein Data Bank (www.rcsb.org) and saved in a PDB file. The control drug used was hydrochloroquine.

The stored protein was removed from the water molecule, native ligand, and hydrogen. Next, redocking between 1DOG and hydrochloroquine was done again for validation. Grid box size x 20 axis, y axis 20, z axis 20 with 5 torque.The docking process was repeated 1 times. The docking process used a flexible docking approach. The bonding between ligand and receptor will be done flexibly to determine the best bonding location between ligand and receptor to cause pharmacological effects (Meng, Zhang, Mezei, & Cui, 2011). The results obtained are the best selected computationally with RMSD less than 2Å. A drug is valid for use as a control if it has an RMSD of less than 2 Å (Brogi, Ramalho, Kuca, Medina- Franco, & Valco, 2020) (Pratama, Poerwono, & Siswodihardjo, 2021). The docking process used uses blind docking, because hydrochloroquin is not an antive ligand of the 1DOG. Based on the validation results, it is predicted that hydrochloroquin binds to the active side of the 1DOG.

After validation, the docking process determine the bond between the active compound of papaya leaves and 1DOG. Indicators of bond affinity between papaya leaf active compounds and 1DOG use the value of free bond energy, Ki, interfacial interactions, and bonds with 1DOG active site amino acid residues (Meng, Zhang, Mezei, & Cui, 2011).

Data analysis used descriptive comparative by comparing the affinity indicator values between the control and the active compound of papaya leaves against 1DOG. The process of visualizing the bond between the active compound of papaya leaves to 1DOG using Biovia Studio Drug Discovery.

To determine the drugability and solubility of active compounds using PKCSM application. Physicochemical indicators namely the number of hydrogen bond acceptors (HBA) , hydrogen bond donors (HBD), MW and Log P predict oral drug bioavailability based on the rules of 5 of Lipinski An active compound is said to have good absorbance if it meets the rules of 5 of Lipinski, namely having a molecular weight of less than 500, having a hydrogen donor of less than 5, having a hydrogen acceptor of less than 10, and having a log P value of less than 5 (Leslie Z. Benet, Hosey, Ursu, & Oprea, 2016).

To predict pharmacokinetics (Absorption, Distribution, Metabolism, and Excretion) and toxicity, we used the online PKCSM application (http://biosig.unimelb.edu.au/pkcsm/prediction) using the SMILES format. The absorption indicator uses the percentage of drugs absorbed in the intestine. The higher the percentage of drug absorbed in the intestine, the higher the bioavailability of the drug. The distribution indicator is the amount of free drug in the blood. The greater the amount of drug distributed in free form and does not penetrate the blood-brain barrier, the stronger the pharmacological effect. The metabolism indicator uses drugs as substrates or inhibitors of CYP enzymes. Drugs that do not inhibit CYP enzymes will be quickly metabolized into an inactive form to reduce the toxic effect. The excretion indicator is the clearance value of the drug in the kidney. The higher the clearance value of the drug, the more it is excreted from the body so that the toxic effect will be reduced. Prediction of hepatotoxic and carcinogenic effects is used to predict the safety of drugs when consumed in the long term (Grogan & Preuss, 2023).

Results

Anti-Inflammatory Prediction of Papaya Leaf Active Compounds Using Stitch Application

The results of predicting the potential of papaya leaf active compounds as anti-inflammatory using the STITCH application can be seen in the figure below.

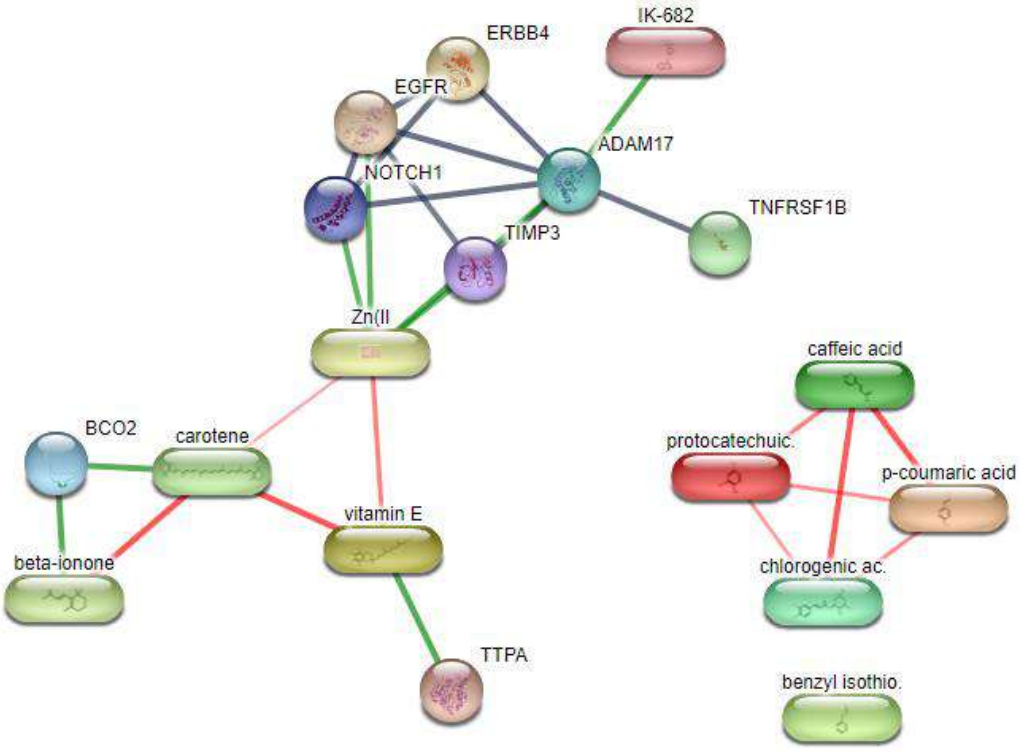

Figure 2: Prediction of the interaction of active compounds of papaya leaves as anti-inflammatory using the STITCH application. The red line shows the interaction between active compounds, while the green line shows the relationship between active compounds and specific proteins.

The prediction results using the STITCH application predicted that the active compounds of papaya leaves, namely Vitamin E and beta carotene interact with each other and are related to the protein TNFRS1B.

Prediction of Affinity of Papaya Leaf Active Compounds To 1DOG Using Molecular Docking

The inhibition results of papaya leaf active compounds against 1DOG can be seen in Table 1 below.

Table 1. Inhibition results of papaya leaf active compounds against 1DOG

No	Active Compound Name	CAD Code	Free Bond Energy (Kcal/mol)	Inhibition Constant (μM)	Surface Interaction (Å)	Intermolecular Interaction	Percentage of binding to active side amino acid residues Target protein
1	**Hydroxychloroquine (control)**	3652	-10.10	39.62	734.218	Hydrogen bonding: Pro437, Gln406 Cation-pi: - Hydrophobic: - Polar: - Other: His415, Ala439, Thr347, Val403, Val434, His405, Leu401	100
2	**Chlorogenic acid**	1794427	-7.85	1.78	689.627	Hydrogen bonding: **Ala439** Cation -pi: - Hydrophobic: - Polar **: His405, Thr347** Other : Ile438, **Leu401**, Val440, **Val434**	55
3	**Dehydrocarpaine I**	6991982	-7.85	1.78	689.627	Hydrogen bonding: P**ro437** Cation -pi: - Hydrophobic: Ile438, Leu350, His409, Pro356, **His415** Polar: **Thr347** Other:**His405**, Glu406	44
4	**D1 alpha-tocopherol**	14986	-7.55	2.90	999.365	Hydrogen bonding: **Thr347** Cation -pi: - Hydrophobic: **His405**, Ala439, Leu348, **Val434**, Ile394, Val402, **Leu401** Polar: - Other: Glu398, Asn389, Met345	44
5	**Beta cryptoxanthin**	5281235	-6.57	15.23	1278.238	Hydrogen bonding: - Cation -pi: - Hydrophobic: **Leu348, His415**, Leu350, His409, **Ala439,** Pro356 Polar: - Other: Asn389, **His405**, Lys392, Ser355, Glu406, Glu398	44
6	**Beta carotene**	131752119	-6.15	30.87	1165.772	Hydrogen bonding: - Cation -pi: - Hydrophobic: Tyr390, **His415**, **Pro437**, Pro356, Leu348, **Ala439**, Ile394 Polar: - Other: Asn389, Lys392	33
7	**Benzyl isothiocyanate**	2346	-6.04	37.32	433.618	Hydrogen bonding: Val440 Cation -pi: - Hydrophobic: **His450, Leu401** Polar: - Other: Val402	22
8	**5,7 dimethoxy-coumarin**	2775	-5.99	40.54	518.765	Hydrogen bonding: - Cation -pi: - Hydrophobic: Val402, **Ala439**, **Leu401**, Leu348, Val440 Polar: **His405**, Glu406 Other: Glu398	33

9	**Caffeic acid**	689043	-5.59	79.79	479.409	Hydrogen bonding: - Cation -pi: - Hydrophobic: - Polar: **His405** Other: **Leu401**, Val440, **Thr347, Val434**	44
10	**Ferulic acid**	445858	-5.26	138.41	535.061	Hydrogen bonding: Leu348, Gly349 Cation -pi: - Hydrophobic: Val440 Polar: **His405,** Glu406 Other: **Thr347**, **Val434, Leu401**	44
11	**P-coumaric acid**	637542	-4.79	310.56	469.691	Hydrogen bonding: - Cation -pi: - Hydrophobic: **His405**, Leu348, Val440 Polar: Glu406 Other: **Thr347**	22
12	**Protocatechuic acid**	72	-2.48	96.40	402.879	Hydrogen bonding: Val440 Cation -pi: - Hydrophobic: - Polar: **His405**, Glu406 Other: Val402	11

From Table 1, based on the affinity indicators of papaya leaf active compounds against 1DOG, it is found that the best three compounds, namely chlorogenic acid, dehydrocarpaine I, and D1 alpha-tocopherol, are predicted to have good affinity for 1DOG. However, their potential is lower than hydrochloroquine.

Drugability Prediction of Papaya Leaf Active Compounds Based on the 5 Rules of Lipinski

The physicochemical prediction results of papaya leaf active compounds using the 5 rules of Lipinski can be seen in Table 2.

Table 2: Prediction of drugability of papaya leaf active compounds based on the 5 rules of Lipinski

No	Name of Active Compound	CID	Chemical Formula	BM	Log P	HBA	HBD	5 rules of Lipinski
1	Chlorogenic acid	1794427	$C_{16}H_{18}O_9$	354.311	-0.6459	8	6	yes
2	Dehydrocarpaine I	6991982	$C_7H_{13}NO_3$	159.185	-1.5983	3	0	yes
3	beta-alpha-tocopherol	14986	$C_{28}H_{48}O_2$	416.69	8.53184	2	1	yes
4	Beta cryptoxanthin	5281235	$C_{40}H_{56}O$	552.887	11.5766	1	1	No
5	Beta carotene	131752119	$C_{40}H_{56}O_2$	568.886	10.7878	2	1	No
6	Benzyl isothiocyanate	2346	C_8H_7NS	149.218	2.2894	2	0	yes
7	5,7 dimethoxy-coumarin	2775	$C_{11}H_{10}O_4$	206.197	1.8102	4	0	yes
8	Caffeic acid	689043	$C_9H_8O_4$	180.159	1.1956	3	3	yes
9	Protocatechuic acid	72	$C_7H_6O_4$	154.121	0.796	3	3	yes
10	Ferulic acid	445858	$C_{10}H_{10}O_4$	194.186	1.4986	3	2	yes
11	P-coumaric acid	637542	$C_9H_8O_3$	164.16	1.49	2	2	yes

Table 2 shows that of the 11 active compounds available, the active compounds obtained, beta-cryptoxanthin and beta-carotene, do not meet the 5 rules of Lipinski criteria. Of the three best compounds from the docking results against 1DOG, chlorogenic acid, dehydrocarpaine I, and beta tocopherol all meet the 5 rules of Lipinski criteria.

ADMET Prediction of Papaya Leaf Active Compounds Using PKCSM

The results of pharmacokinetic prediction (ADMET) of papaya leaf active compounds using PKCSM application can be seen in Table 3.

Table 3. ADMET Prediction of Papaya Leaf Active Compounds Using PKCSM

Compound Name	Absorbtion		Distribution		Metabolism							Excretion	Toxicity	
	Intestinal absorption (%)	Water permeability (log mol/L)	Fraction unbound (Fu)	BBB (log BB)	CYP 2D6 substrat	CYP 3A4 substrat	CYP 1A2 inhibitor	CYP 2C19 inhibitor	CYP 2C9 inhibitor	CYP 2D6 inhibitor	CYP 3A4 inhibitor	Total Clearance (log ml/min/kg)	Hepatotoxic	AMES
Chlorogenic acid	36.377	-2.449	0.658	-1.407	no	no	no	no	no	no	no	0.307	no	no
Dehydrocarpaine I	100	0.258	0.884	-0.223	no	no	no	no	no	no	no	0.449	no	no
D1 alpha-tocopherol	90.043	-7.602	0	0.739	no	yes	no	no	no	no	no	0.821	no	no
Beta cryptoxanthin	90.524	-7.21	0	0.777	no	yes	no	no	no	no	no	0.923	no	no
Beta carotene	91.363	-7.136	0	-0.103	no	yes	no	no	no	no	no	0.498	no	no
Benzyl isothiocyanate	-2.629	-2.629	0.379	0.45	no	no	no	no	no	no	no	0.305	no	no
5,7 dimethoxy-coumarin	98.027	-2.12	0.318	0.154	no	no	yes	no	no	no	no	0.832	no	no
Caffeic acid	69.407	-2.33	0.529	-0.647	no	no	no	no	no	no	no	0.508	no	no
Protocatechuic acid	71.174	-2.069	0.648	-0.683	no	no	no	no	no	no	no	0.551	no	no
Ferulic acid	93.685	-2.817	0.343	-0.239	no	no	no	no	no	no	no	0.623	no	no
P-coumaric acid	93.494	-2.378	0.428	-0.225	no	no	no	no	no	no	no	0.662	no	no

From Table 3, it can be seen that of the three best compounds docking results against protein 1DOG, it was found that D1-alpha tocopherol and dehydrocarpaine I were absorbed in the intestine better than chlorogenic acid. Dehydrocarpaine and chlorogenic acid distribution are primarily free, while D1-alpha tocopherol is protein-bound, and all active compounds do not cross the blood-brain barrier. The three compounds do not act as substrates or inhibit the action of CYP enzymes. Clearance of D1-alpha tocopherol through the kidney is better than dehydrocarpaine and chlorogenic acid. All three compounds are not potentially hepatotoxic and carcinogenic.

Discussion

Anti-Inflammatory Prediction of Active Compounds from Papaya Leaves Using Stitch Application

Insilico research is starting to be developed in order to find new drugs from an active compound. This computational prediction can shorten the process and save research costs to find new drugs from an active compound. Insilico research is used to predict the mechanism and affinity of a compound to proteins or receptors to cause pharmacological effects (Brogi, Ramalho, Kuca, Medina- Franco, & Valco, 2020).

STITCH is a database that can provide information about the interaction of a molecule with a protein, the strength of its affinity, and the pattern of simultaneous interaction between molecules and proteins in living cells to cause biological effects (Kuhn, Szklarczyk, Pletscher-Frankild, Blicher, & et.al, 2014). 1DOG belongs to the TNF receptors family that is activated by TNF alpha to cause cell apoptosis (Green, 2023) . The prediction results using STITCH found that beta caroten and D1 alpha tocopherol are related

to TNFRS1B activity. TNFRS1B is a family of TNF receptors that function for the induction of cell apoptosis (www.rcsb.org). The alpha TNF mechanism induces apoptosis after activating the death receptor through mitochondrial membrane permeability damage mechanism. Mitochondrial membrane damage increases intracellular ROS production which induces cell death (Kokolakis, Sabata, Krüger-Krasagakis, & Eberle, 2021). Vitamin E and beta caroten are known as antioxidants. Inhibition of the apoptosis process is thought to inhibit the process of cell death through the process of free radiacular scavenger and inhibit fat peroxidation (Tucker & Townsend, 2005).

Prediction of Affinity of Papaya Leaf Active Compounds to Protein 1DOG Using Molecular Docking

Molecular docking is a computational approach to look at the interaction between an active compound and a target protein at the atomic level, which allows us to estimate the characteristics of the active compound binding to the active side of the target protein to cause cell biological effects. The docking process consists of two steps, namely the prediction of the conformation of the position and orientation of the active compound's interaction with the active side of the target protein and the measurement of its affinity. Then an assessment is made based on several indicators to determine the affinity strength using the value of free bond energy, inhibition constant, interfacial interaction, and interaction with amino acid residues on the active side of the target protein. The smaller the free bond energy value, the smaller the inhibition constant value, the smaller the interfacial interaction value, and the more active side amino acid residues bound compared to the control, the affinity of the active compound to the target protein is considered good. This study uses a flexible docking approach, where the active compound/ligand and target protein will flexibly search for the best interaction position to cause an effect (Meng, Zhang, Mezei, & Cui, 2011).

Based on the affinity indicators of papaya leaf active compounds against 1DOG. The three best compounds such as chlorogenic acid, dehydroarpaine I, and D1 alpha-tocopherol are predicted to have good affinity for 1DOG. However, their potential is lower than hydro chloroquine. Chlorogenic acid is a polar phenol compound produced by plants during aerobic respiration. Chlorogenic acid is known to have effects as an antioxidant, hepatoprotective, nephroprotective, antibacterial, antitumor antihyperglycemic, antihyperlipidemic, anti-inflammatory, neuroprotector, and vasoprotective (Wang, et al., 2022). Carpaine (pseudocarpaine, dehydrocarpaine I, and dehydrocarpaine II) is papaya leaves' primary alkaloid group compound (60% of total alkaloids). Carpaine is known to have dengue antiviral, antiplasmodium, antitumor, antihelmintic, and anti-inflammatory effects. The Carpaine also contributes to the bitter taste of papaya leaves (Shrivastava, Alagarasu, Cherian, & Parashar, 2022). D1 alpha tocopherol is a fat-soluble antioxidant. The antioxidant mechanism is through the mechanism of free radicals scavenger and stopping lipid peroxidation. Nevertheless, in certain doses D1 alpha tocopherol can also change as a prooxidant (Tucker & Townsend, 2005)

The use of hydrochloroquine as a control. Hydrochloroquine is clinically proven to have the ability as an anti-inflammatory. It can reduce inflammatory mediators such as TNF alpha, IL-1, IL-6, IL-8, and VEGF in patients with Systemic Lupus Erythematosus (SLE) (RisaWakiya, et al., 2022). Hidrochloroquin is not native ligan for 1DOG. The re-docking results of hydrochloroquine against 1DOG showed a free bond energy of -10.10kcal/mol with RMSD less than 2Å, so hydrochloroquine is validly considered as a control (Pratama, Poerwono, & Siswodihardjo, 2021). The docking process uses a blind docking approach. The interaction location of hydrochloroquine with 1DOG amino acid residues can be considered hydrochloroquine bonding with the active side of 1DOG (RisaWakiya, et al., 2022).

Prediction of Drugability of Pepaya Leaf Active Solutions Based on 5 Rules of Lipinski

The 5 rules of Lipinski are rules for determining whether or not an active compound has drug-like properties when administered orally. An active compound is said to have a poor absorption/permeation value if the H donor is more than 5, the H-bond acceptor is more than 10, the molecular weight is more than 500, and log P is more than 5 (Benet, Hosey, Ursu, & Oprea, 2016). The results showed that the active compounds of papaya leaves, namely chlorogenic acid, dehydrocarpaine I, and D1-tocopherol, fulfill the rules of 5 of Lipinski criteria, so they are predicted to have drug-like properties, have high solubility and are well absorbed in the intestines if given orally.

ADMET Prediction of Papaya Leaf Active Compounds Using PKSCM

PKCSM is a computational method to predict the pharmacokinetics and toxicity of an active compound. In discovering new drugs, knowing a drug's pharmacokinetics, safety, and potential is necessary. Therefore, knowing the pharmacokinetics of a drug candidate is needed. Pharmacokinetics includes absorption, distribution, metabolism, excretion, and toxicity. The absorption indicator is the

percentage of intestinal absorption. Distribution indicators consist of the number of free compounds and the ability of active compounds to penetrate the blood-brain barrier. Metabolism indicators consist of cytochrome P450 (CYP) enzyme substrates and inhibitors. Excretion indicators consist of renal clearance. The toxicity indicators are hepatotoxic and carcinogenic potential (Pires, Blundell, & Ascher, 2015).

The results of pharmacokinetic prediction using PKCSM application obtained that the active compounds D1-alpha tocopherol and dehydrocarpaine I have good intestinal absorption, while the intestines slightly absorb chlorogenic acid. Absorption describes how quickly and much of a drug reaches the circulation system from the administration site. The absorption process is related to the bioavailability of the drug. Bioavailability is the amount of drug that reaches the circulation system. This bioavailability depends on the route of drug administration. The bioavailability of drugs administered intravenously can reach 100%. Oral drug administration will cause blood levels to be more negligible due to the process of drug metabolism by digestive enzymes and stomach acid (Pires, Blundell, & Ascher, 2015)(Grogan & Preuss, 2023).

From distribution indicators, dehydrocarpaine and chlorogenic are primarily free, while D1-alpha tocopherol is protein-bound, and all active compounds do not cross the blood-brain barrier. Most drugs are bound by albumin or glycoprotein proteins. Only free drugs can bind to receptors in target organs to cause pharmacological effects (Pires, Blundell, & Ascher, 2015)(Grogan & Preuss, 2023). D1 alpha-tocopherol is a fat-soluble vitamin E bound to albumin dissolving in the blood. The inability to cross the blood-brain barrier indicates that the three compounds do not have neurotoxic potential (Grogan & Preuss, 2023).

Drug metabolism causes the drug to become inactive and hydrophilic (Pires, Blundell, & Ascher, 2015). Drug metabolism mainly occurs in the liver, although other organs also metabolize, such as the kidney, lung, skin, and gastrointestinal. The metabolic process occurs in 2 stages, namely, the oxidation stage and the conjugation stage. Both processes cause the drug to be inactive and polar, making it easy to be excreted through the kidneys (Grogan & Preuss, 2023). The results showed that chlorogenic acid, dehydrocapine I, and D1 alpha-tocopherol did not act as substrates or inhibit the work of CYP enzymes. This data suggest that the three compounds can be inactivated in the liver and excreted through the kidneys.

The excretion process uses the indicator of renal clearance. Clearance of a drug shows the ratio of the amount of drug excreted from the body to the amount in the blood. The more drugs that are excreted from the body, the smaller the risk of toxic effects due to the accumulation of drugs in the blood (Grogan & Preuss, 2023). The results showed that the excretion of D1-alpha tocopherol through the kidneys was better than dehydrocarpaine and chlorogenic acid. This data indicates that the blood accumulation risk and the toxic effects of dehydrocarpain and chlorogenic acid are higher than D1 alpha-tocopherol.

Indicators of drug toxicity using the presence of hepatotoxic potential and carcinogenic tendencies (Grogan & Preuss, 2023). The results showed that chlorogenic acid, dehydrocarpaine I, and D1 alpha-tocopherol had no hepatotoxic or carcinogenic potential. Thus the three compounds are safe for long-term consumption.

Conclusion

From this study, the active compounds of papaya leaves, especially Chlorogenic acid, dehydrocarpain I, and D1 alpha-tocopherol, are predicted to have the potential as anti-inflammatory through the mechanism of protein 1DOG receptor inhibition. The three active compounds have high solubility and bioavailability when given orally, have good pharmacokinetics, and are not toxic or carcinogenic. This research is the initial research of the drug discovery process, so it needs to be followed up with preclinical and clinical research to obtain a drug that is safe for consumption by the public.

Conflict of Interest

The authors declare that there is no conflict of interest in this research.

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References

Brogi, S., Ramalho, T. C., Kuca, K., Medina- Franco, J. L., & Valco, M. (2020). Editorial: In silico Methods for Drug Design and Discovery. *Frontier in Chemestry*, 1-5.

Green, D. R. (2023). *The Death Receptor Pathway of Apoptosis*. Cold Spring Harbor Laboratory Press.

Grogan, S., & Preuss, C. V. (2023). *Pharmacokinetics*. Bethesda: StatPearls Publishing.

Jang, D.-i., Lee , A.-H., Shin, H.-Y., Song, H.-R., & et.al. (2021). The Role of Tumor Necrosis Factor Alpha (TNF-α) in Autoimmune Disease and Current TNF-α Inhibitors in Therapeutics. *International Journal of Molecular Science*, 1-16.

Jati, N. K., Prasetya, A. T., & Mursiti, S. (2019). Isolasi, Identifikasi, dan Uji Aktivitas Antibakteri Senyawa Alkaloid pada Daun. *Jurnal MIPA*, 1-6.

Kokolakis, G., Sabata, R., Krüger-Krasagakis, S., & Eberle, J. (2021). Ambivalent Effects of Tumor Necrosis. *Skin Pharmacology and Physiology*, 94-102.

Kuhn, M., Szklarczyk, D., Pletscher-Frankild, S., Blicher, T. H., & et.al. (2014). STITCH 4: integration of protein–chemical interactions with user data. *Nucleic Acids Research*, D401-407.

Leslie Z. Benet, Hosey, C. M., Ursu, O., & Oprea, T. I. (2016). BDDCS, the Rule of 5 and Drugability. *Advance Drug Delivery Reviews*, 89-98.

Meng, X.-Y., Zhang, H.-X., Mezei, M., & Cui, M. (2011). Molecular Docking: A powerful approach for structure-based. *Current Copmputer Aided Drug*, 146–157.

Pires, D. E., Blundell, T. L., & Ascher, D. B. (2015). pkCSM: Predicting Small-Molecule Pharmacokinetic and Toxicity. *Medicinal Chemestry*, 4066-4072.

Pratama, M. R., Poerwono, H., & Siswodihardjo, S. (2021). Introducing a two-dimensional graph of docking score difference vs. *Indonesian Journal of Biotechnology*, 54-60.

RisaWakiya, Ueeda, K., Nakashima, S., Shimada, H., Kameda, T., & et.al. (2022). Efect of add-on. *Scientifc Reports*, 14571-6.

Shrivastava, N., Alagarasu, K., Cherian, S., & Parashar, D. (2022). Antiviral & platelet-protective properties of Carica papaya in dengue. *Indian Journal of Medical Research*, 459-463.

Singh, S. P., Kumar, S., Mathan, S. V., Tomar,, M. S., Singh, R. K., & et.al. (2020). Therapeutic application of Carica papaya leaf extract in the management of human diseases. *Daru*, 735-744.

Tucker, J., & Townsend, D. M. (2005). Alpha-tocopherol: roles in prevention and therapy of human disease. *Biomedicine and Pharmacotherapy*, 380-387.

Wang, L., Pan, X., Jiang, L., Chu, Y., Gao, S., & et al. (2022). The Biological Activity Mechanism of Chlorogenic Acid and Its Applications in Food Industry: A Review. *Frontiers in Nutrition*, 1-22.

A Comprehensive Analysis of Urban Heat Island Determination Methods

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Abstract

Population density in urban centers causes an increase in the amount of construction and energy consumption. In addition to being the areas where human activities that cause climate change are most intense, cities are also the areas where the negative effects of climate change are observed most intensely. One of the most obvious effects of climate change observed in urban areas is the formation of urban heat island, which occurs due to reasons such as the increase in the number of structural areas and impermeable surfaces, the amount of energy consumption, the number of vehicles and people, the decrease in open green areas, and the lack of planning to increase the ecosystem service quality in the planning of these areas. While the formation of urban heat island negatively affects the thermal comfort of the citizens in the summer months, it also increases the amount of energy used for cooling indoors, and this situation causes a vicious circle when the directly proportional relationship between energy consumption and heat island formation is considered. Urban heat islands have been the subject of many different occupational disciplines, and various methods have been tried for the determination of heat island formation. In this study, different methods used in urban heat island determination studies were examined, the accuracy of the applied methods in the context of the study area scale, and the advantages and disadvantages of each method were discussed comparatively, considering today's technological possibilities.

Keywords: Urban heat island, climate change, urban heat island measurement

Introduction

Cities consume a lot of energy and are often responsible for the majority of greenhouse gas emissions that cause climate change because of their dense populations and intense human activities (Wright et al, 2011). Carbon dioxide levels in the atmosphere have risen from around 280 parts per million (ppm) prior to the Industrial Revolution to 413 ppm in early 2020. This level of CO2 has never been observed in recorded history. Cities are gradually warming as CO2 levels rise. Urban heat islands are defined as local temperature increases caused by urban growth (Ningrum, W., 2018). Because of the heat emitted by urban structures and the reflection of solar radiation, urban areas are warmer than surrounding rural areas. The primary causes are:

- Anthropogenic activities
- Population expansion
- Impermeable surfaces
- Excessive emissions
- Thermal power plants
- Air Pollution
- Energy consumption…etc.

The urban heat island (UHI) phenomenon was first discovered by Luke Howard in London in 1818, and it has since been recognized to exist in many countries and regions around the world. It's also one of the most serious urban climate and environmental issues (Zhou & Chen, 2018).

Mapping the formation of urban heat islands aids in the development of solution-oriented planning approaches. The term "urban heat island," coined in the 1940s, refers to the atmospheric warmth of a city in comparison to its surroundings (Balchin & Pye, 1947). The traditional definition of a heat island is one that is measured at standard screen height (1-2 m above ground), below the city's mean roof height, in a thin section of the boundary layer atmosphere known as the urban canopy layer, which is present in almost all urban areas, large or small, in warm or cold climates. (I. D. Stewart and Oke, 2012)

In comparison to rural areas, the urban underlying surface has a higher heat capacity and thermal conductivity, as well as being mostly waterproof. Furthermore, building surfaces increase the area of the urban under-lying surface, resulting in multiple reflections and absorption. As a result, these characteristics increase the amount of heat flux absorbed and stored in urban areas. Worse, the city has many high buildings, which increases the roughness of the urban area and thus reduces urban ventilation. Heat absorption, storage, and convection increase in urban areas due to their unique characteristics and morphology, causing a large amount of heat to remain and accumulate. Furthermore, anthropogenic heat from human activities contributes to this accumulated heat. As a result, urban areas are more likely than rural areas to experience higher outdoor air temperature levels (Gaur et al., 2018).

There are two types of urban heat islands:

- AUHI (atmospheric urban heat island)
- SUHI (surface urban heat island)

While AUHIs are revealed by air temperature analyses, SUHIs are revealed by evaluating land surface temperature measurements (LST).

Urban warming studies range in scale from large-scale studies revealing differences between urban and rural areas to examining the cooling effect of trees in a city park. The purpose of this study is to examine the various methods used in urban heat island determination studies, to discuss the accuracy of the methods used in the context of the study area's scale, and the benefits and drawbacks of each method, taking into account today's technological possibilities.

Different Scales in Urban Heat Studies

Based on data obtained from the literature, this study aims to reveal the methods by which urban warming is dealt with at various scales, using various data sets. The literature review predicted that urban heat island studies could be classified into three major scales.

- Heat Island Studies at the City-Wide Scale
- Heat Island Studies Carried Out at Urban Part Scale
- Heat Island Studies at Urban Design Scale

1. Heat island studies at the city-wide scale

When the studies conducted on this scale are examined, the sub-study titles have been generalized as follows.

- How urban warming has evolved over time,
- The relationship between urbanization and rising temperatures,
- The effect of land use decisions on urban temperature,
- The difference in temperature between rural and urban areas.

In these studies, a land use map of the city is created using remote sensing over satellite images. Land use decisions are grouped under broad headings, and detailed functional differences within the city are ignored. Typically classified as:

- Built- up areas,
- Woodlands,
- Farming areas,
- Water surfaces
- Bare surfaces.

Land Surface Temperature maps are created over satellite images using remote sensing as shown at Figure 1.

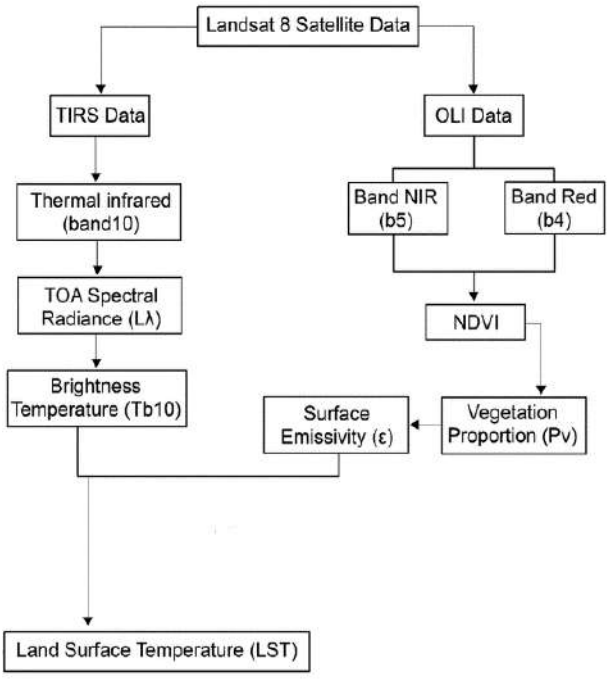

Figure 1. Calculation of land surface temperature maps from satellite imagery

Figure 2 depicts the LST map we created for the Çiğli district of İzmir Province as part of Gökçe Gönüllü Sütçüoğlu's PhD thesis study using the above method.

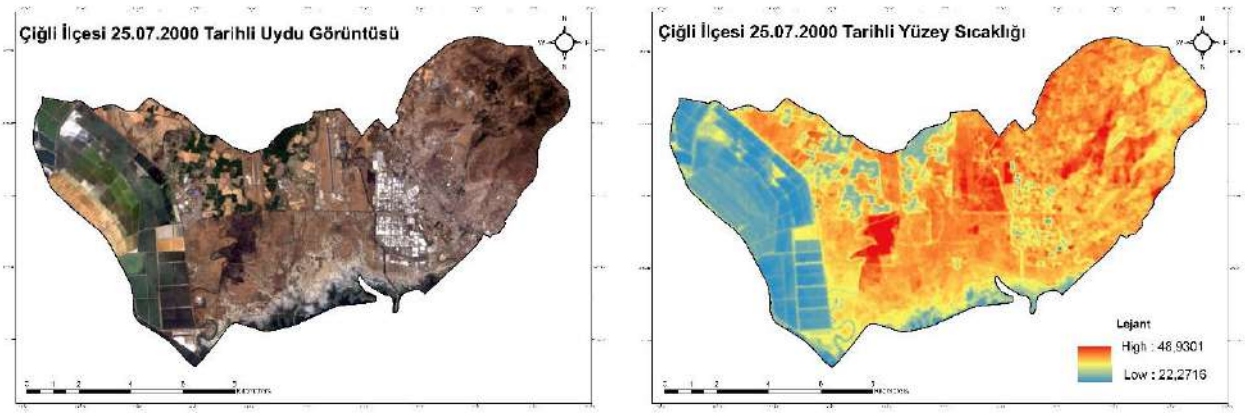

Figure 2. Çiğli district satellite image and LST map from July 25, 2000

In their study, Keeratikasikorn and Bonafoni (2018) identify SUHI patterns in different land use categories of Bangkok city plan using reflective and thermal data from Landsat 8 imagery from 2014 to 2016 (Keeratikasikorn & Bonafoni, 2018).

Li et al. (2012) discovered spatially significant LST gradients from the city center to surrounding rural areas in their study. Their findings highlight the urgent demands for planers and decision-makers to deliberately take urban expansion, UHI effects, and their impact on local climate change into account in future planning.

2. Heat island studies carried out at urban part scale

At this scale, the city is classified using Local Climate Zones. Building track, building height, road width, amount of permeable surface, surface albedo, and other data are used to create Local Climate Zones (Stewart and Oke, 2012). The relationship between temperature and the city's various built areas can be investigated by this method.

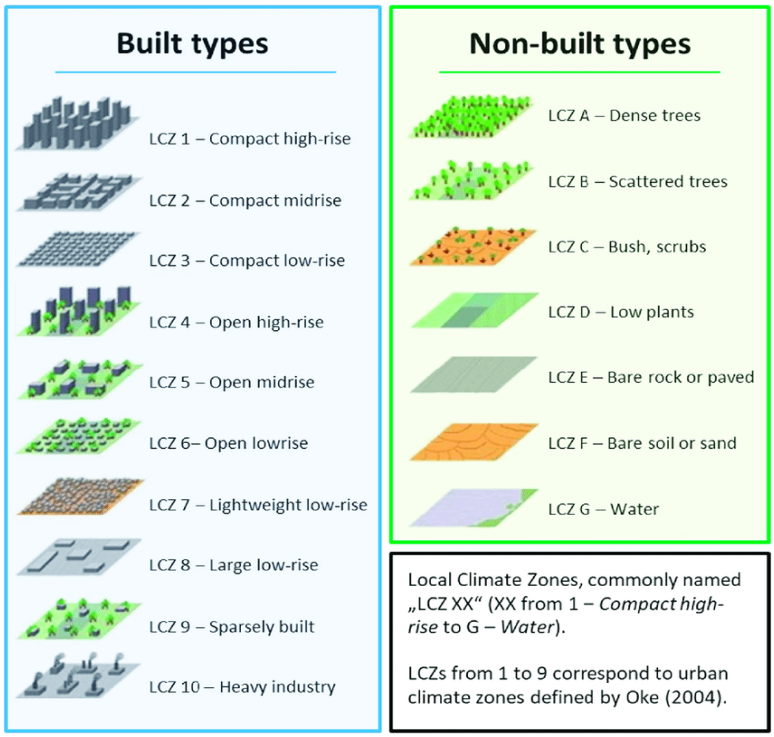

Figure 3. LST zones (Stewart and Oke, 2012)

There are a total of 17 classes, of which 10 are settled areas and 7 are land cover. The LCZ classification is a standard and quantitative method for describing the physical characteristics of urban morphology as well as the corresponding urban climate characteristics. The system was initially intended to serve as a framework for urban heat island research and as a common language in studies. Today, city planners, landscape architects, surveyors, and global climate change researchers use it.

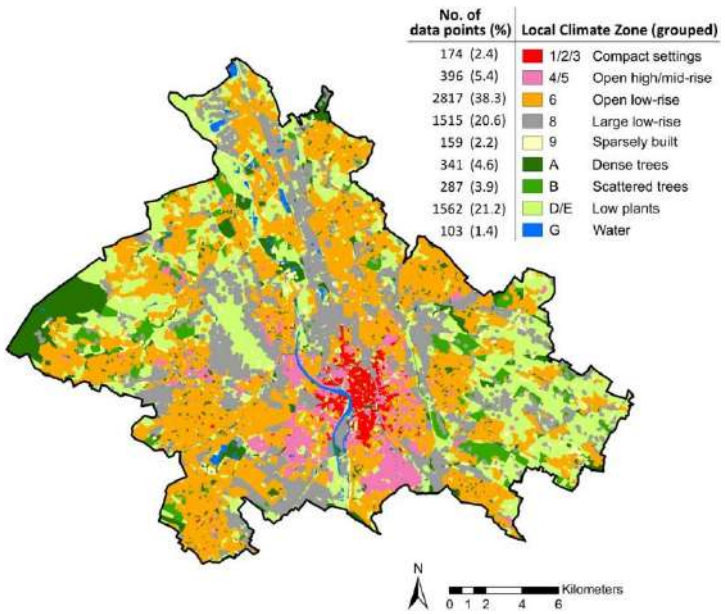

Figure 4. An example for spatial distribution of local climate zones

Rather than data from satellite images, LST maps are created using data from thermal cameras installed on vehicles such as unmanned aerial vehicles, automobiles, pickup trucks, or weather measurement stations installed at regular intervals throughout the study area (Figure 5,6).

(a)

(b)

Figure 5. (a) :Image of unmanned air vehicle and thermal camera (b): Image of car-based mobile measurement system

Figure 6. Image of mini meteorological measurement station

Kim et al.'s (2019) work demonstrated that heat maps based on satellite images are insufficient when scaled down. They discovered that producing LST maps from satellite images is not appropriate in small-scale studies (Figure 7) (Kim et al., 2021).

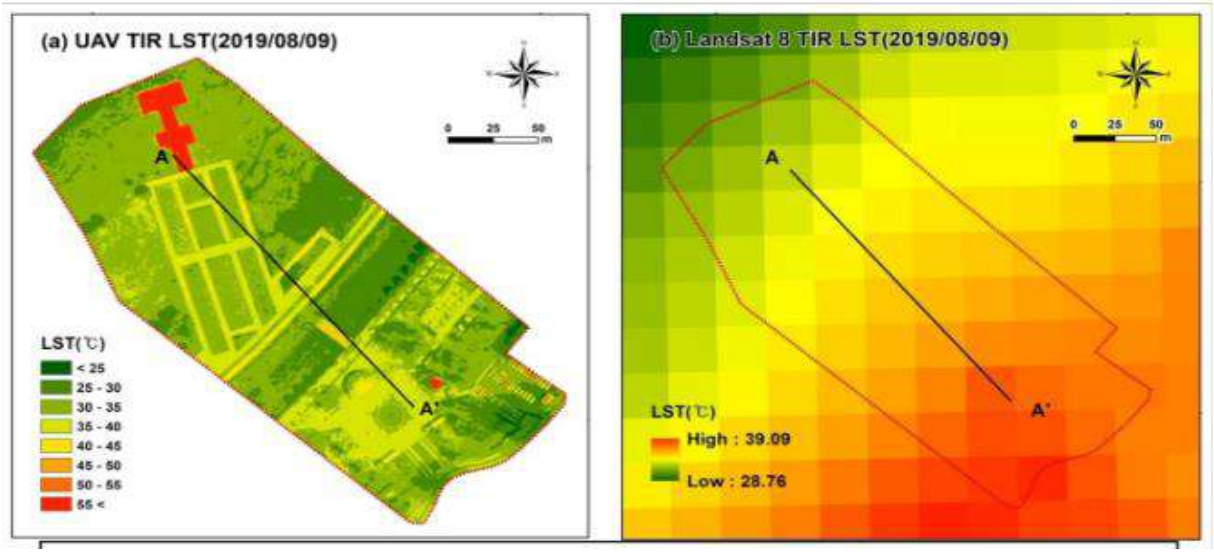

Figure 7. Unmanned aerial vehicle LST and Landsat Satellite image LST comparison of 09.08.2019 (Kim et al., 2021).

3. Heat island studies at urban design scale

These are the studies carried out to measure the effect of materials used in areas such as parks and squares or planting on heat. The plants in the area and the materials used are mapped with the field study. Heat maps are created by measuring the temperature with thermal devices mounted on bicycles

in the area or by measuring the surface temperature on different surfaces in the study area (Figure 8). By superimposing these maps, the relationship between material/plant and heat is revealed. These studies are mostly carried out to measure the thermal comfort level of individuals in the space.

(a) (b)

Figure 8. (a): Image of the bicycle-based mobile measurement system: 1. GPS; 2. relative humidity and air temperature; 3. air temperature; 4. sky view factor camera location (not shown); 5. Datalogger and barometric pressure; 6. Ground surface temperature; 7. Four component net radiometer. (b): Image of surface temperature meter

Rajkovich and Larsen (2016) in their study advocates; fixed weather stations cannot be deployed quickly to capture data from a heat wave. While remote sensing can provide data on land cover and ground surface temperatures, resolution and cost remain significant limitations. But bicycle permits movement from space to space within a city to assess the physical and thermal properties of microclimates (Rajkovich & Larsen, 2016).

Conclusion

The study of urban heat is a complex project that includes an extensive variety of devices and data sets capable of providing valuable insights. The key to conducting an effective study is accurately determining the working scale, a critical factor that has a significant impact on the results. During the study's construction phase, careful consideration should be given to determining the appropriate scale, selecting the most appropriate methodology, identifying the tools that best align with the research objectives, and selecting the relevant data sets for analysis.

The study of urban heat is an interdisciplinary endeavor that draws on the expertise of professionals from various fields. Meteorologists are critical in determining the atmospheric conditions and weather patterns that contribute to urban heat. Their knowledge of temperature differentials, air flow patterns, and the impact of microclimates is invaluable in understanding the complex dynamics at work.

City planners approach the study of urban heat from a unique perspective, focusing on the spatial arrangement of infrastructure, buildings, and green spaces within urban environments. City planners work to reduce the urban heat island effect and promote sustainable urban design by taking into account factors such as urban morphology, land use patterns, and building materials. Their input contributes to the development of strategies for improving heat dissipation, optimizing shading, and creating urban green spaces that provide relief from high temperatures.

Landscape architects also make significant contributions to urban heat studies through their expertise in designing and implementing green infrastructure. Landscape architects can reduce heat by incorporating vegetation such as trees, green roofs, and vertical gardens, which provide shading, reduce heat absorption, and promote evaporative cooling. They work with city planners to create comprehensive urban cooling strategies that improve livability and create resilient, climate-responsive cities.

Other experts, such as environmental scientists, urban ecologists, and geographers, contribute to the study of urban heat, each bringing their own perspectives and methodologies. This interdisciplinary

approach promotes a comprehensive understanding of urban heat by recognizing its complex interplay with various environmental, social, and economic factors.

Urban heat studies can gain valuable insights into the complex nature of heat dynamics within cities by using the collective expertise of these diverse disciplines. Meteorologists, city planners, landscape architects, and other experts working together to develop innovative strategies, policies, and interventions for mitigating the negative effects of urban heat and fostering sustainable urban environments that prioritize human well-being and environmental harmony.

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References

[1] Chen, Y., Zheng, B., & Hu, Y. (2020). Mapping local climate zones using arcGIS-based method and exploring land surface temperature characteristics in Chenzhou, China. Sustainability (Switzerland), 12(7). https://doi.org/10.3390/su12072974

[2] Demuzere, M., Kittner, J., & Bechtel, B. (2021). LCZ Generator: A Web Application to Create Local Climate Zone Maps. Frontiers in Environmental Science, 9, 112. https://doi.org/10.3389/FENVS.2021.637455/BIBTEX

[3] Gaur, A., Eichenbaum, M.K., Simonovic, S.P., 2018.Analysis and modelling of surface urbanHeat Island in 20 Canadian cities under climate and land-cover change. J. Environ.Manag. 206, 145–157.

[4] Hujebri, B., Ebrahimikia, M., & Enayati, H. (2019). Automatic building extraction from lidar point cloud data in the fusion of orthoimage. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives, 42(4/W18), 541–546. https://doi.org/10.5194/isprs-archives-XLII-4-W18-541-2019

[5] Keeratikasikorn, C., & Bonafoni, S. (2018). *remote sensing Urban Heat Island Analysis over the Land Use Zoning Plan of Bangkok by Means of Landsat 8 Imagery*. https://doi.org/10.3390/rs10030440

[6] Kim, D., Yu, J., Yoon, J., Jeon, S., & Son, S. (2021). Comparison of accuracy of surface temperature images from unmanned aerial vehicle and satellite for precise thermal environment monitoring of urban parks using in situ data. *Remote Sensing*, *13*(10). https://doi.org/10.3390/rs13101977

[7] Ningrum, W. (2018, February). Urban heat island towards urban climate. In *IOP Conference Series: Earth and Environmental Science* (Vol. 118, No. 1, p. 012048). IOP Publishing.

[8] Rajkovich, N. B., & Larsen, L. (2016). A bicycle-based field measurement system for the study of thermal exposure in Cuyahoga county, Ohio, USA. International Journal of Environmental Research and Public Health, 13(2). https://doi.org/10.3390/ijerph13020159

[9] Wang, R., Ren, C., Xu, Y., Lau, K. K. L., & Shi, Y. (2018). Mapping the local climate zones of urban areas by GIS-based and WUDAPT methods: A case study of Hong Kong. Urban Climate, 24, 567–576. https://doi.org/10.1016/J.UCLIM.2017.10.001

[10] Zheng, Y., Ren, C., Xu, Y., Wang, R., Ho, J., Lau, K., & Ng, E. (2018). GIS-based mapping of Local Climate Zone in the high-density city of Hong Kong. Urban Climate, 24, 419–448. https://doi.org/10.1016/j.uclim.2017.05.008

[11] Zhou, X., & Chen, H. (2018). Impact of urbanization-related land use land cover changes and urban morphology changes on the urban heat island phenomenon. *Science of the Total Environment*, *635*, 1467–1476. https://doi.org/10.1016/j.scitotenv.2018.04.091

Effects of Sound Perception in Square Design

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Abstract

Public spaces contribute to their psychological and mental well-being by enabling people to interact socially with others. Public squares have a social communication purpose by enabling people from different social, cultural and economic levels to come together in a common area. Squares are spaces open to everyone with different belongings and different social perspectives. This social interaction allows people to perceive others, themselves and the environment. Surrounded by other structures, these spaces have a balancing function in today's crowded and congested urban fabric. These urban voids function as an intersection connecting roads and areas. In addition, squares should provide the functions of people to see, be seen, relax and communicate with others. Therefore, it is important to consider the user-attracting effects and environmental conditions of the squares. Although auditory perception has weaker information than visual perception, it is richer in emotion. In addition to natural and cultural data, soundscape perception data should also be considered in the design of the square. In this study, the effects of sound on square users are investigated. Sound types with positive and negative effects were examined. Design recommendations have been developed to eliminate the negative effects of sound.

Keywords: Acoustic environment, acoustic perception, urban squares

Introduction

From history to the present, urban open spaces are the most widely used areas of urban life. City squares are the most effectively used public spaces of urban open spaces. The city square is an important public space used by the citizens for cultural, political, social and commercial purposes on special occasions, in short, where urban life takes place. City squares are important urban living spaces that reveal the identity and personality of our cities throughout history [1].

In addition to being a common use area for individuals living in the city, squares also have social, economic and political functions. Squares have been very important places in terms of both urban politics and national politics throughout history. Squares, which are the communication areas where the political power conveys its message to the society and the society to the political power, have a political structure [2].

The square, which is among the urban spaces, has been defined by Ruşen Keleş as a wide flat area around or near important buildings, which is not generally kept open to vehicle circulation, has been made suitable for everyone to sit and rest, and those who wish can hold political meetings when necessary [3]. As a dictionary meaning, a square is an open and wide place where people gather, mostly surrounded by buildings. In its broadest sense, square means emptiness [2].

Squares are divided into 5 by Zucker in terms of their various forms. The first of these are closed squares, which have a distinctive geometric form, around which architectural structures are repeated. Secondly, there are dominant squares oriented towards a single building or a group of buildings. Another is the core squares formed around a single center and the grouped squares formed by the aesthetically related squares. Finally, Zucker's distinction includes formless squares without borders, form and shape [2].

As a result, squares are public spaces open to the use of everyone, where all kinds of social, economic and cultural activities are carried out, where one can be in without any time limit. In addition to trade and socialization, city squares play an active role in reaching urban consciousness and protecting the right to the city. Squares, which form an important place in the urban structure, contribute to the democratization of the society as they provide the opportunity to socialize and be together [2].

Squares, which can be of different shapes and sizes in line with their usage purposes, are often located next to a power center within the settlement such as mosque courtyard, church front, government

square or business center [4]. In the whole of urban space, architectural structures, no matter how beautiful works of art, have no meaning on their own. What needs to be resolved is to provide an organic unity with them, which will fit the needs and functions in the areas around them, and the settlement in general terms. In the urban design process, urban spaces gain details with the facades of buildings, squares, streets, roads, parks, historical buildings as individual or group. Squares, which are one of the indispensable subjects of urban life, have the functionality of a historical bridge and a cultural environment from past to present [5].

According to Lynch, there are some structural and natural elements that are effective in defining cities. These; borders, roads, urban areas with distinctive features, squares, and finally buildings and signs with historical and social meaning. Urban image elements often interact with each other. Emphasizing the image of the city. The clarity of the visual structure is possible by arranging all these elements individually and together within the framework of certain principles [6].

The squares that make up the outer space should be unifying rather than separating the surrounding structuring and should be considered in a unity. Each element has a unique degree of influence. These items are; land use patterns, the nature of the environment, the size and proportion of environmental components, time, color, material, plastic, light and green element, as well as the social and cultural characteristics of the users who use that space [5].

We can define time as a fourth dimension that reflects the changing rhythm of the natural environment, the past reflection of the architectural environment, the mobility and variability in living conditions to the city users through perception. When the time is considered as the duration of the users in the space, it contributes to the formation of the square, the livability of the square and the perception period. As long as a person perceives that place, that place is a living, livable place. This is a phenomenon that changes over time. The time during which the physically measurable space is observed varies from person to person due to the different understanding of time evaluation [5].

In order for the users to feel comfortable and at peace in urban spaces, the scale and proportion of these spaces should be associated with the human scale. The human scale is the measurement of real dimensions. The space is created by comparing the proportions of the human figure. In square arrangements, the relationship between human and building dimensions is very important. If the building dimensions are designed in accordance with the human scale, it positively affects the character of the square. The square should make people feel surrounded and a sense of space [5].

Another important issue to be addressed in the design of the square is the soundscape. A soundscape is the combination of all natural and artificial acoustic sources in a given area as modified by the environment. Soundscape quality has a major impact on other environmental attributes such as the role of the site, its readability, identity, sense of belonging, and location. Contrary to the seen and perceived visual perspective, the sound landscape is heard regardless of the will of the individual [7].

Today, sirens, car sounds, noise and disturbing sounds heard in urban areas cause noise pollution. Exposure to this unpleasant sound environment causes noise-induced irritations and diseases. In recent years, research on noise has revealed the importance of soundscape. In this study, the effects of sound on square users are investigated. Sound types with positive and negative effects were examined. Design recommendations have been developed to eliminate the negative effects of sound.

Effects of Sound on Human Health

Noise is briefly defined as unwanted and objectionable sound because it is a risk for human health, as well as preventing human movements and creating serious stress and discomfort [8]. Noise causes hearing impairment, its effect on voice communication, sleep disturbance, cardiovascular and physiological effects, psychological effects, effects on performance, and general behavior and disturbances in residential areas [9].

Worldwide, hearing impairment due to environmental noise is the most common irreversible hazard. In developing countries, environmental noise is also an increasing risk factor for hearing impairment. Most countries generally accept 85 dB(A) per day as the standard, which specifies measures that must be taken to protect people from adverse impact [8].

Noise can have an impact on speech understanding as well as result in multiple behavioral changes. Problems related to concentration disorder, fatigue, indecision, self-confidence, anger, misunderstandings, decreased work performance, problems in human relations and some stress reactions can be listed [8].

The primary sleep disorder effects are: difficulty falling asleep, frequent awakenings, and changes in sleep stages or depth, particularly a reduced rate of REM2 sleep. Other physiological effects are noise-induced high heart rate during sleep, including increased blood pressure, increased finger pulse tension, vasoconstriction, respiratory changes, heart palpitations, and increased body movements. Noise

exposure in the evening also causes secondary effects called delayed effects. These effects are those that can be measured while the person is awake the day following nighttime noise exposure. Secondary effects include decreased sleep quality, increased fatigue, depression or happiness, and decreased performance [8].

Acute noise exposure activates the autonomic and hormonal systems leading to temporary changes such as increased blood pressure, increased heart rate and constriction of blood vessels. After prolonged exposure, susceptible individuals in the general population may develop persistent effects such as hypertension and ischemic heart disease associated with exposure to high sound pressure levels [8].

Environmental noise is not believed to be a direct cause of mental illness, but is assumed to accelerate and intensify the development of latent mental disorder. Studies on the negative effects of environmental noise on mental health cover a variety of symptoms, including anxiety. They are general psychiatric disorders such as emotional stress, nausea, headache, indecisiveness, aggression, sexual impotence, mood swings, increase in social conflicts, neurosis, psychosis, and hysteria [8].

It is observed that noise affects cognitive task performance negatively in people exposed to noise. In children, too, environmental noise disrupts a number of cognitive and motivational parameters. Concerning the effects of noise on performance and safety, it has been shown that noise can create a task disorder and increase the number of errors in the job, but the effects depend on the type of noise and the task being performed [8].

Noise, which has physiological, psychological and performance effects, is classified in five different degrees [10, 11, 12]. 1st degree noises between 30-65 dB(A) sound values cause discomfort, loss of comfort, concentration and sleep disturbance. 2nd degree physiological noises between 65-90 dB(A) sound values; It causes an increase in heart rhythm and respiratory rate, a decrease in pressure in the brain, 3rd degree noise between 90-120 dB(A), 4th degree noise between 120-140 dB(A) and 5th degree noise above 140 dB(A). It causes headache, inner ear disorders and rupture of the eardrum.

Soundscape Approach

Just as painting is the sum of visual interactions, soundscape is the sum of audible events. The soundscape consists of events that are heard, not seen [13]. It is defined as the detection of the auditory environment, which is formed as a result of more than one sound source and environmental interaction, independently of positive or negative judgments [14].

According to Schafer, although the sounds in the sonic environment are similar, each sound is different from each other and no sound can be heard the same again. In short, no sound can be imitated again, and this gives the sound the value of uniqueness and non-repeatability [13].

For sound to exist, it is the existence of two real objects experienced. No object can make a sound on its own. All sounds occur when two or more objects move and touch each other. What is interesting here is that when two objects touch each other, a single sound emerges [13].

No sound lives forever. Every sound fades or is covered by another sound. Sound is a tool for perceiving time, each time zone has a unique sound. Summer sounds different from winter, day from night. A certain sound is tied to a certain place. Sound is a tool in perception of space [13].

Another feature of sound is that it provides continuity. Hearing evokes the continuity of life. There is always sound in the whole of changing and ending sounds. Sound is a code felt by the sense organs. It can be interpreted differently between individuals or societies. This gives sound its relativity value. Therefore, it is difficult to define or generalize any sound event [13].

Listening requires a sociological and psychological interpretation. Hearing is a gift, but listening is learned. From this point of view, hearing is an ordinary human ability. The ear has its limits and cannot be kept strong with physical exercises like other body organs, but the ability to distinguish with listening can develop [13].

Hearing is a way of connecting to the place as well as a psychosociological phenomenon. Our body and our movements are in constant interaction with the environment. The world and the self constantly inform and define each other. The perception of the body and the image of the world become one continuous experience; there is no body separate from its place in space, no space that is not connected with the unconscious image of the perceiving self [15].

In summary, people are deluded by hearing, trying to perceive the truth, questioning their relationship with the object, and interpreting their question-misconceptions with their own superconscious and subconscious knowledge [16].

A soundscape is the combination of all natural and artificial acoustic sources in a given area as modified by the environment. The term "soundscape" is also defined with a sound recording or performance of sounds that create the feeling of experiencing a particular acoustic environment, or compositions created using sounds found in an acoustic environment, or musical performances [7].

Biphony, geophony, and anthroponym are terms used to characterize sounds that occur in the landscape (Figure 1). Biphony refers to sounds produced by living organisms, often used by animals as a means of communication. This can include birds, amphibians, insects, mammals, fish and amphipods in both terrestrial and aquatic systems. Geophony is the sum of the sounds caused by physical processes such as wind, water flow, thunder, precipitation, and ground motion. The sounds that people make using mechanical devices are called anthroponym (or technophony). This includes sounds from stationary machinery such as fans and air conditioners, aircraft, cars, trucks, boats, construction cranes, bulldozers, and mobile machinery used for transportation and construction [17].

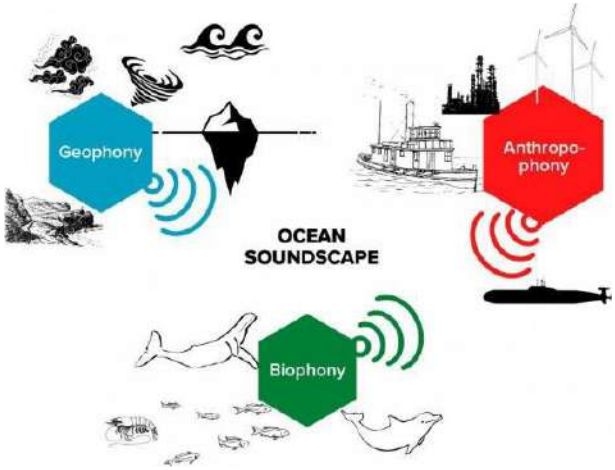

Figure 1. Three different sound sources in an ocean soundscape; anthroponym, biphony and geophony [18].

Soundscape quality has a major impact on other environmental attributes such as the role of the site, its readability, identity, sense of belonging, and location. Contrary to the seen and perceived visual perspective, the sound landscape is heard regardless of the will of the individual. Today, sirens, car sounds, noise and disturbing sounds heard in urban areas cause noise pollution. Exposure to this unpleasant sound environment causes noise-induced irritations and diseases.

Soundscape design

Soundscape design is explained by examining through examples.

Sheaf Square can be defined as the open space in front of the train station in Sheffield, England, which was used as a parking lot and taxi rank. Since the square is located on the ring road, which is especially heavily used, it has been exposed to high noise levels, especially from the highway. The redesign process of the square was based on creating a warmer space for pedestrians and transforming it into a resting area for station users. The designers aimed to improve the audio landscape environment and reduce the loud noise from traffic while designing a space where people would like to relax. In this context, in the square; A barrier has been constructed along the road, which will serve to reduce traffic noise, through a sloping upper level and steps descending to the lower side. This barrier is also a wall of water flowing down from the top and ending in the water pool formed at the point near the station entrance. A large water fountain, which is intended to mask most of the traffic noises, has also been added to the lower part of the building (Figure 2). With the water elements added in the design, the traffic noises in the background are masked and thus the auditory landscape quality of the area is increased [19, 20, 21].

Figure 2. Images from the area of Sheaf Square [22]

It has been determined that the noise pollution caused by traffic and human density in the Nauener square in Berlin is quite high. For this reason, expert in square acoustics Prof. Dr. It was designed to be revised again by Brigitte Schulte-Fortkamp and related experts at the Technical University of Berlin. Before the revision, sound measurements were taken and the lines with the noise were determined. In this context, sound walks were carried out by the square users in order to produce noise maps. Areas where the noise is concentrated have been identified and acoustic comfort has been created by bringing various acoustic suggestions to these areas. According to the results obtained, sound islands providing acoustic comfort were created from the acoustic seating elements in the park. Thanks to these benches, users can hear many peaceful natural sound elements such as the sound of waves and bird sounds during the day (Figure 3). At the same time, noise walls were created in the area. Thanks to these walls, a decrease of 3 dB (A) was observed in the sound measurements. The sound and traffic noise emanating from the seating elements created an unexpected harmony and created a strange harmony [23].

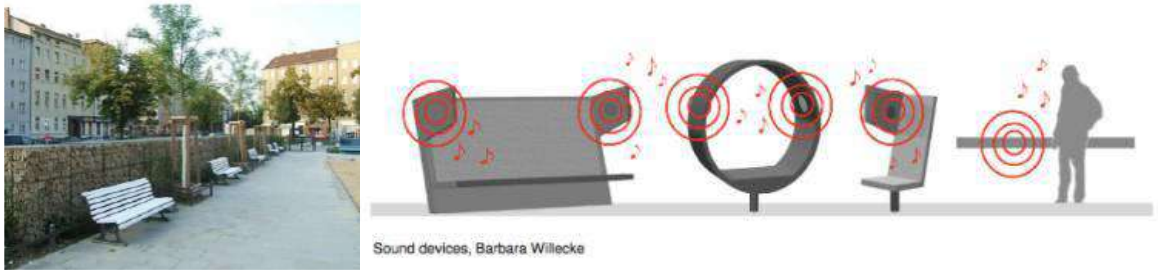

Figure 3. Images from the area belonging to Nauener Platz [24]

Located in Manhattan, one of the busiest centers of New York, Paley Park is surrounded by tall buildings. This park, which is under intense city noise due to intense urbanization, is visited by the users of the business and trade centers around it, especially in the afternoon and evening hours. Therefore, there is heavy vehicle traffic on the road passing next to this park. For this reason, a waterfall flowing from the wall was designed in the opposite direction of the flow of traffic and circulation in the park in order to prevent human and traffic-induced noise pollution (Figure 4). Thus, in this park, which is under the pressure of intense construction and has the effect of a tiny oasis, noise pollution is masked by the sound of water created by the effect of waterfall [25, 26].

Figure 4. Images from the area of Paley Park [27]

Within the scope of this study carried out for Meydan Park, Fatih Park and Atapark, which are adjacent to the road in the center of Trabzon, the sound reduction effect of the vegetation used for noise filtering was investigated in two different periods between 2007 and 2014. According to the sound measurements taken in this context, the noise level in Meydan Park is 14.24 dB(A) and in Fatih Park 6.16 dB(A) due to the different plant species used, the difference in the growth rates of the plants and the different usage styles of the parks (children's playground, tea garden, sitting units).) and 9 dB(A) in Atapark. As a result, in these studies, where the noise level and conditions were similar, it was determined that the noise pollution decreased compared to the previous period with the growth of the plants used for curtaining the road and the increase in closure [28].

In order to repair the destruction suffered by the Croatian city of Zadar during the Second World War and to distract the citizens from the effects of the war, a park called the Sea Organ was designed on the coast of the city to emphasize the sound of water. In this park, the effect of water was used as the main auditory landscape element that provides acoustic comfort, and for this purpose, the therapeutic sea waves were used in an integrated manner into the design process of the park. With the steps

descending to the sea, the relationship between the sea and the human has been increased. The 35 pipes used under the steps act as musical instruments (Figure 5). Thanks to the sea tides, the park constantly serves the auditory landscape concept [29, 30, 31].

Figure 5. Nautical organ design [32]

Located in Shenzhen, China, this barrier is designed as a semi-enclosed structure that can pass the sun's rays in the form of a tunnel to the area where the noise is most intense on the highway with traffic density. Constructed from recycled materials plastic bottle, PV, glass skylights, solid panels and vegetative cover and mild steel to minimize construction cost, this tunnel reduces the disturbing effect of noise (Figure 6). The PV fill in the structure generates and stores electricity for the barrier and surrounding highway lighting, the vegetation fill in the barrier reduces the heat radiation from the highway. It has been determined that the noise coming from the highway is reduced by collecting and isolating the sound thanks to its hollow structure. Thus, this noise barrier, which is designed in an environmentally friendly way, isolates highway noise for both highway users and users in the surrounding areas [33, 34].

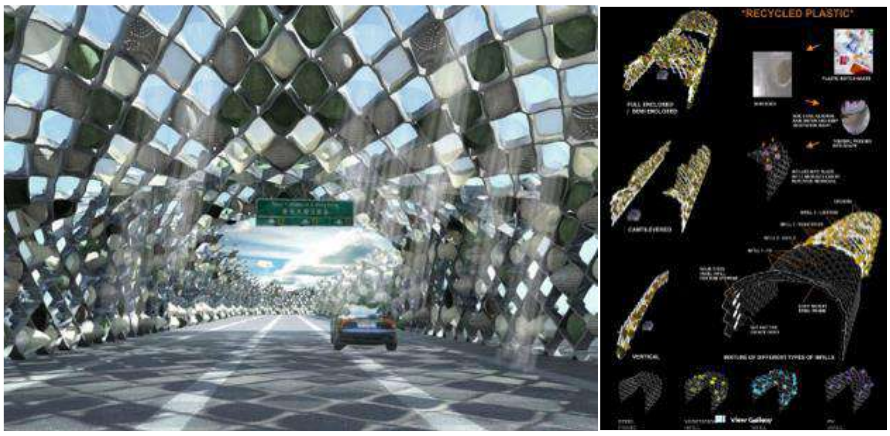

Figure 6. Noise barrier design [35]

Conclusion

If the sound level in the squares exceeds the 55 dBA sound level determined by the world health organization, there are harms for human health. While designing the square, it is necessary to measure the sound levels in the area and keep the sound level below 55 dBA. It can have dramatic effects if landscape elements, urban furniture and noise barriers can be designed by paying attention to the limit of the sound level while designing the square. While designing the soundscape, two types of soundmarks, passive and active, can be used. The first consists of functional items with pleasant sounds such as sonic sculptures and fountains, while the second is soundmarks created through events.

As passive soundmarks, waterfalls, springs, and fountains are often used as landscape elements. Water and vegetation can be defined as primary landscape qualities with visual aesthetics. In the samples examined, it is seen that the sound of water is primarily used as a sound barrier. When using water as a landscape element, it is necessary to pay attention to the flow rate. Keeping the sounds at a constant level can cause a psychological loss of interest in the users.

As active soundmarks, it is important to design spaces for people to produce events. Green areas and hard areas need to be well organized in squares. By designing green areas, it allows to increase activities such as bird sounds. By designing hard areas, activities such as cycling and skateboarding can be provided. Such activities are important for creating exciting sounds. It is necessary to prevent possible disturbances of other users by designing sound barriers for these activity areas. Also, live music is always very interesting. Artistic activities that come with live music attract people's attention.

While designing the square, it is necessary to separate the users according to their age levels. Special sound barriers should be designed especially for children's playgrounds.

Today, traffic noise is a problem for many squares and parks. It is of great importance to design sound barriers that will prevent traffic noise. While designing the square, it is necessary to make sound controls and take measures to create a sound barrier during the design phase.

While disturbing sound levels are suppressed by sound barriers, areas should be created to increase pleasant sound levels. In particular, areas should be designed for the sounds that can be considered as the identity sounds of the area, which are pleasing to the users in the area, and these sounds should be increased in the area.

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References

[1] Özer MN, Ayten MA, Kuntay O. Kamusal odak olarak kent meydanları. Planlama 2005; 3: 96-103.

[2] Akman K. Kent meydanlarının önemi ve değişen işlevi. Akademik Düşünce Dergisi 2020; 1: 17-33.

[3] Keleş R. Kent Bilim Terimleri Sözlüğü. İstanbul: İmge Yayınevi; 1989.

[4] Şavklı F, Yılmaz T. Kent meydanı kullanım nedenlerinin Antalya Cumhuriyet Meydanı örneğinde irdelenmesi. Süleyman Demirel Üniversitesi Orman Fakültesi Dergisi 2013; 14: 138-142.

[5] Altınçekiç S, Nilüfer K. Kentsel tasarım sürecinde meydanlar. Journal of the Faculty of Forestry Istanbul University 2000; 50(2): 111-120.

[6] Lynch K. The image of the city. Cambridge: MIT Press; 1960.

[7] Pouya S. İdeal ses peyzajının planlanması ve tasarımı. Journal of Architectural Sciences and Applications 2022; 7(2): 919-934.

[8] Doğan H, Çataltepe ÖA. Gürültünün insan sağlığı üzerine etkileri. Journal of Health and Sport Sciences 2018; 1(1): 29-38.

[9] Toprak R, Aktürk N. Gürültünün insan sağlığı üzerindeki olumsuz etkileri. Türk Hijyen Deneysel Biyoloji Dergisi 2004; 49-58.

[10] Demirkale SY, Aşcıgil M. Sağlıklı kentlerle ve yapılarla ilgili Türkiye'nin gürültü politikası. VIII. Ulusal Tesisat Mühendisliği Kongresi 2007; 267-285.

[11] Özdemir B, Bayramoğlu E, Demirel O. Noise pollution and human health in Trabzon parks. Studies on Etno-Medicine 2014; 8(2): 127-134.

[12] Pouya S. The role of landscape architecture on soundscape experience. Turkish Journal of Forest Science 2017; 1(2): 183-193.

[13] Schafer MR. Our sonic environment and the soundscape: The tuning of the world. Destiny Books; 1997.

[14] Özçevik A, Can ZY. İşitsel peyzaj kavramı ve kapalı mekanların akustik konfor değerlendirilmeside kullanılabilirliği. In: Presented at the Building Physics and Sustainable Design Congress; 2010 March. 5.

[15] Voegelin S. Listening to noise and silience: towardds the philosophy of soundart. Continuum Publishing; 2010.

[16] Akkaya B. Kentsel ses peyzajları: Kadıköy tarihi çarşı ve çevresinde işitsel katmanların değerlendirilmesi (doctoral thesis). Fen Bilimleri Enstitüsü; 2014.

[17] Fuller S, Axel AC, Tucker D, Gage SH. Connecting soundscape to landscape: Which acoustic index best describes landscape configuration?. Ecological indicators 2015; 58: 207-215.

[18] Rey Baquero MP, Parcerisas C, Seger KD, Perazio C, Botero Acosta N, Mesa F, et al. Comparison of two soundscapes: an opportunity to assess the dominance of biophony versus anthropophony. Oceanography 2021; 34(4): 62-66.

[19] Xiao J, Tait M, Kang J. The design of urban smellscapes with fragrant plants and water features. Designing with Smell 2017; 83-95.

[20] Cerwen G. On the intersection between speaker installations and urban environments: a soundscape design perspective. In: Handbook of research on perception-driven approaches to urban assessment and design. IGI Global, 2018. 23-45.

[21] Oberman T, Jambrosic K, Aletta F, Kang, J. Towards a soundscape surround index. In: Proceedings of the International Congress on Acoustics. International Congress on Acoustics, 2019. 829-835.

[22] Atlas Obscura [Internet]. [Erişim tarihi 01.05.2023]. https://www.atlasobscura.com/places/water-sculptures-of-sheaf-square

[23] Schulte-Fortkamp B, Brooks B. Urban planning integrating the soundscape approach. In: INTER-NOISE and NOISE-CON Congress and Conference Proceedings. Institute of Noise Control Engineering; 2018. 3551-3556.

[24] Nauener Platz [Internet]. [Erişim tarihi 01.05.2023]. https://sonicagents.wordpress.com/2013/01/04/a-soundscape-re-modeled/

[25] Armato F. Pocket park: Product urban design. The Design Journal; 2017, 20.sup1: 1869-1878.

[26] Labuz R. Pocket park–a new type of green public space in Kraków (Poland). In: IOP Conference Series: Materials Science and Engineering. IOP Publishing; 2019. (11): 112018.

[27] Paley Park [Internet]. [Erişim tarihi 01.05.2023]. https://www.tclf.org/landscapes/paley-park

[28] Özdemir B, Bayramoğlu E, Demirel O. Noise pollution and human health in Trabzon parks. Studies on Ethno-Medicine; 2014, 8.2: 127-134.

[29] Claus C, Pak B. Towards Urban Sound Design for Transitional Public Railway Park/Places: Sonic Strategies for Engagement, Critical and Spatial Design. In: CA2RE: Conference For Artistic and Architectural (Doctoral) Research Proceedings. Aarhus School of Architecture; Aarhus, 2018. 108-119.

[30] Denic-Jukic V. Hydrology and physical limnology in Croatia. Geofizika; 2019, 36(2): 185–194.

[31] Oberman T, Jambrosic, K, Horvat M, Bojanic Obad Scitaroci B. Using virtual soundwalk approach for assessing sound art soundscape interventions in public spaces. Applied Sciences; 2020, 10(6): 2102.

[32] Oddmusic Project Park [Internet]. [Erişim tarihi 01.05.2023]. http://www.oddmusic.com/gallery/om24550.html

[33] Han X, Huang X, Liang H, Ma S, Gong J. Analysis of the relationships between environmental noise and urban morphology. Environmental pollution; 2018, 233: 755-763.

[34] Bao Z, Lu W. A decision-support framework for planning construction waste recycling: A case study of Shenzhen, China. Journal of cleaner production; 2021, 309: 127449.

[35] Archello Highway Noise Barrier. [Internet]. [Erişim tarihi 01.05.2023]. https://archello.com/project/highway-noise-barrier

Evaluation of User Experience of Indoor Display in Virtual Reality (VR)

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Abstract

Housing is one of the most essential needs of humanity since the beginning of existence. The discipline of architecture has emerged and developed based on this need and has continued to evolve with the advancement of civilization and technology. When looking at the history of architecture, it can be seen that the visualization of architectural design has a long history. Nowadays, with the parallel development of computer technologies, architectural visualization techniques have also greatly advanced.

Virtual reality (VR) technology is used in many sectors such as education, health, and entertainment today. The discipline of architecture enables designers to visualize their designs in a realistic way. Especially in the architecture field, where visualization is very important, the use of this technology is crucial in increasing the realism of the user's experience in the design phase.

VR is a developing and wide-spreading technology in the field of architecture these days. Although there are studies on this subject in literature, studies which are examining the effect of VR technology in architectural visuals on people's sense of reality and feelings about the VR experience are limited. The aim of this study is to help fill the gap in this subject of literature. The main purpose of this study is to investigate the experience and reality sense of architectural design visuals' materials, light and shadow, outdoor view, indoor plants, furniture, objects, and participants' feelings of provide through the use of virtual reality (VR). In this context, the use of VR technology in architecture was examined first. Later, a three-dimensional interior space environment designed was visualized using computer techniques and experienced by users through a VR headset. In the study, the participant's feelings about the VR experience and their thoughts on the realism of the experience were revealed through the prepared survey questions.

Keywords: Architectural visualization, architecture, virtual reality

Introduction

One of humans' remarkable passions is to show and transmit their designs, views and, intentions. This has helped improve humanity throughout history. This adventure has begun with cave paintings. One of the most recent steps in this progression is the use of virtual reality (VR) [1].Virtual reality technology (VR) is the electronic stimulation of environments experienced via headset to enable the user to interact with realistic 3-dimensional environments produced by a computer [2]. Virtual reality contains the creation and experience of environments. Its main goal is to put the person in a situation that is unusual or difficult for them to experience by creating a connection between the person and the artificial world [3].

The Stereoskip Television Device for Individual Use (STAIU), developed by Morton Heilig in 1957, came the closest to the functionality of modern VR systems in the past. The second phase is the computer-based head-mounted display (HMD), developed by Ivan Sutherland at MIT in 1966. Then, in 1982, Thomas Furness developed the Super Cockpit, a helmet for pilots. Later, NASA developed a visualization-assisted virtual reality (VR) helmet that enables the outside robot to function in real time for use by scientists exploring inaccessible fields while working on the space station [4].The term "virtual reality" was first used in 1986 [5]. With the development of technology, VR has become accessible to individuals. Nowadays, modern VR head-mounted displays have become popular and easy to use in many fields [6].

Visualized representations of structures have long been important instruments for describing and understanding architectural space. Their origins have been traced to the time between the development of prehistoric civilisation and the invention of contemporary digital technology [7].

VR technology allows architectural designers to showcase their work in a real-life setting. This technology can be used to change designs before they are built, due to the continuous and realistic experience [8]. The benefits of using VR technology in architecture are; the opportunity to work with artificial intelligence algorithms, an immersive experience that appeals to the visual and auditory senses, the ability to make the most accurate design possible, the ability to optimize the design, and the ability to see the realistic outcome of the structure even at the design stage. These technology have handicaps beside It's benefits. These are integration into the design is challenging, expensive, and time-consuming (Table 1) [9].

Table 1. Advantages and disadvantages of using VR technology in the field of architecture

Advantages	Disadvantages
Providing an immersive experience	Difficult to integrate into design
Appealing to the visual and auditory senses	Time consuming
Allowing the designer to make the most accurate design	Costly
Allows the design to be optimized	
Providing the opportunity to see the realistic result of the building even when it is in the design phase	
Providing the opportunity to work with artificial intelligence algorithm	

VR technology used successfully in architecture may inspire new ideas, evaluate the general viability of suggested planning and architectural concepts, and conceptualize the design, learning, and teaching processes [10].

The main purpose of this study is to investigate the effect of architectural designs presented with VR on people. In the study, how materials, light and shadow, outdoor images, indoor plants, furniture, objects, architectural design experience and perception of reality and emotions of participants in a visualized interior design through VR were examined through a survey study.

Materials and Methods

Methods

This study consists of five main stages. In the first stage, the research questions of the study were determined by scanning the literature. In the second stage, a survey study was prepared by making use of the literature study conducted in the first stage. 30 participants were selected for the VR experience, and the volunteers and participants' privacy rights were reserved. Finally, the interiors were designed in three dimensions with the 3DMAX program and panoramically visualized by the Vray rendering engine. In the VR experience, the participants examined the places transferred to VR for 5 minutes. After the VR experience, they answered the questionnaire prepared for the study. In the analysis phase of the study, statistical analysis of the data was made. The study was completed by interpreting the data obtained from the findings (Figure 1).

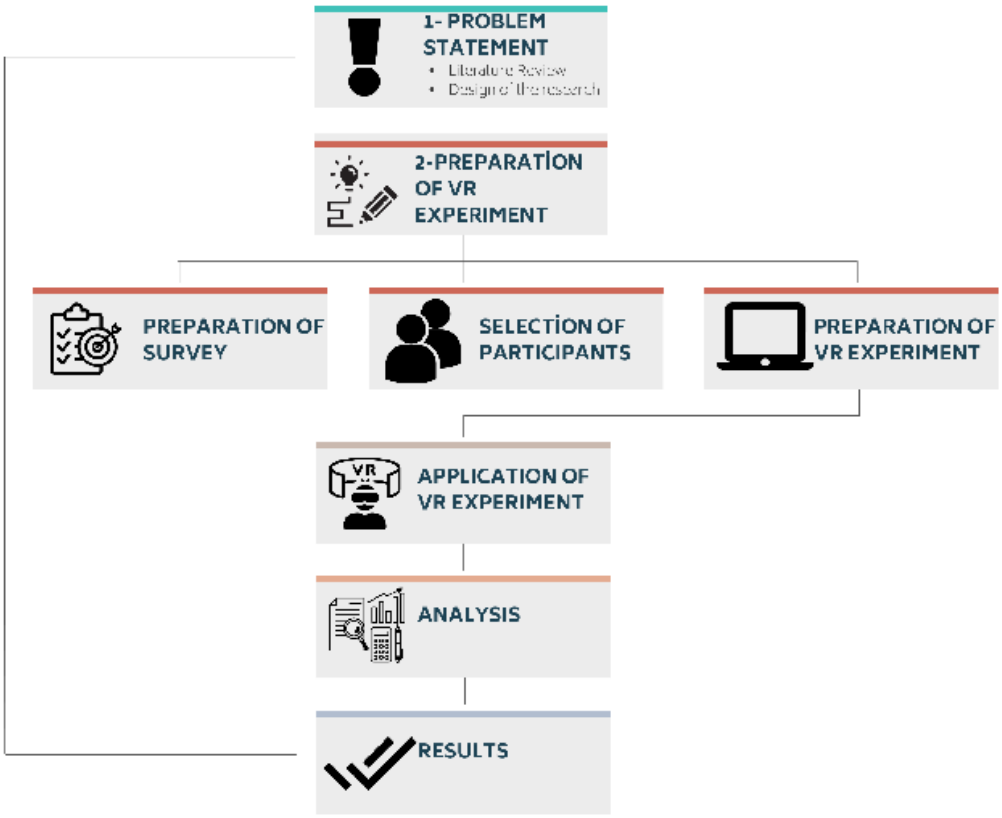

Figure 1. Flow Chart

Materials

In the study, the visualization of interior designs was done via the V-Ray rendering engine and 3DSMAX modeling software. The Oculus Quest 2 VR headset was used for the VR experience. Another key component is the survey form that was developed for the study. The survey data were analyzed using the IBM SPSS (Statistical Package for the Social Sciences) 26.0 program. First, frequency analysis was used in the study to assess the demographic details of the participants and their responses to the questions. Secondly, ANOVA comparison tests were conducted for two or more variables.

Findings

Participants are 50% women and 50% men. Age-related groupings of the participants show that 33.3% are between the ages of 23 and 30, 43,3% are between the ages of 31 and 40, 13,3% are between the ages of 41 and 50, and 3.3% are beyond the age of 51. According to their education level, 30% is undergraduate, 40% is post graduate and 30% is PhD (Table 2.).

Table 2. Demographic Information

Variable	Category	Percentage (%)
Gender	Female	50
	Male	50
Age	23-30 1	43,3
	31-40 2	40,0
	41-50 3	13,3
	51+ 4	3,3
Education	Undergraduate D.	30
	Post Graduate	40
	Ph.D. Graduate	30

In an investigation of whether the participants have VR experience and whether they have worked on 3D visualization professionally, 53.3% of the participants said they have done dimensional modeling and visualization professionally, while 46.7% said they have not. In addition, in contrast to 63% of the participants who had previously used VR, 36.7% had not (Table 3.).

Table 3. Information about 3D visualization and VR experience

Question	Yes (%)	No (%)
Do you do 3D modeling and visualization in your professional life?	53,3	46,7
Have you had any previous VR experience?	63,3	36,7

Participants evaluated the realism of the design elements of the 3D model in the virtual reality experience. They evaluated the surfaces used in the model: 3.3% were not realistic at all, 16.7% were unrealistic, 56.7% are realistic, and 23.3% are very realistic. According to participants' evaluation of the materials used to model, 3.3% of them were unrealistic, 20% were undecided, 63.3% were realistic, and 23.3% are very realistic. 3.3% of the participants don not find the light and shadow in the design realistic; 20% found it undecided; 43.3% found it realistic; and 33.3% found it very realistic. Evaluation of the exterior of the design by the participants: 6.7% stated that it was unrealistic, 16.7% were undecided, 46.7% were realistic, and 36.7% were very realistic. When the realism of the indoor plants used in the design was evaluated by the participants, 6.7% were not realistic, 10% were undecided, 33.3% were realistic, and 50% were very realistic. When the 3D furniture in the design is evaluated by the participants, 20% were undecided, 33.3% were realistic, and 46.72% were very realistic. The participants expressed the realism of the objects used in the model: 13.3% evaluated it as undecided, 50% as realistic, and 36.7% as very realistic (Table 4.).

Table 4. Evaluation of the realism of the design elements in the VR model

Design elements 1 (not at all realistic) to 5 (very realistic)	Not at all realistic (%)	Not realistic (%)	Un Decided (%)	Realistic (%)	So realistic (%)
Surfaces (walls, floors, etc.)	3,3	16,7	0	56,7	23,3
Materials in the VR model (wood, marble, etc.)	0	3,3	10	63,3	23,3
Shading & lighting in the VR model	0	3,3	20	43,3	33,3
Outdoor view in VR model	0	0	16,7	46,7	36,7
Indoor plants in VR model	0	6,7	10	33,3	50
Furniture in VR model	0	0	20	33,3	46,7
Objects in the VR model	0	0	13,3	50	36,7

The thoughts and feelings of the participants about the VR experience were evaluated in Table 5 according to the level of participation in the given statements. While 33% of the participants stated that they were undecided on the statement "I could clearly perceive the size of the space in the VR model"; 46.7% agreed, and 20% of them stated that they strongly agreed. The level of participation of the participants in the statement 'The VR model gave me a very realistic experience'; 3.3% disagree, 20% undecided; 60% agree, and 16.7% strongly agree. While 13.3% of the participants did not agree with the statement 'The VR experience disconnected me from the real (external) world," 23.3% were undecided, 23.3% of them stated that they agreed, and 40% of them strongly agreed. In the statement "I experienced a sense of continuity in design', 3.3% of the participants did not agree; 30% were undecided; 30% agreed; and 36.7% of them marked strongly agree options. Participants' level of participation in the expression 'Experiencing places using VR is very practical": 3.3% strongly disagree; 10% undecided; 43.3% agree. It was determined that 43.3% strongly agreed. On the other hand, 63.3% of the participants strongly disagreed with the statement 'I found it unnecessary and complicated to experience places using VR'; 26.7% do not agree; 3.3% are undecided; 3.3% agree; and 3.3% strongly agree. 50% of the participants strongly disagreed with their level of participation in the statement 'I got bored while experiencing the VR model'; 23.3% disagreed; 16.7% were undecided; 6.7% agreed; 3.3% stated that they strongly agreed. Responses of the participants to the statement 'I had fun experiencing the VR model', 23.3% are undecided; it was determined that 30% agree and 46.7% strongly agree. 3.3% disagreed with the participants' level of agreement with the statement 'I felt comfortable in the VR experience'; 20% were undecided; 50% agreed, and 26.7% strongly agreed. While 73.3% of the participants strongly disagreed and 23.3% disagreed with the statement "I felt frustrated in the VR experience"; 3.3% of them stated that they were undecided. 53.3% of the participants strongly disagreed with the statement 'I felt tired in the VR experience'; 26.7% did not agree; 16.7% stated that they were

undecided, and 3.3% agreed. 3.3% of the participants did not agree with the statement 'I found the VR experience impressive'; 20% were undecided; 40% agreed, and 36.7% of them strongly agreed. The statement 'It is enough to experience an area that has not yet been built with VR' was stated by the participants, 3.3% disagree; 36.7% undecided; 43.3% agree; 16.7% were evaluated as strongly agreeing.

Table 5. Evaluation of participants' opinions and feelings about VR experience

Opinion/feeling about VR	Strongly disagree (%)	Disagree (%)	Un Decided (%)	Agree (%)	Strongly Agree (%)
I could clearly perceive the size of the space in the VR model	0	0	33,3	46,7	20
The VR model gave me a very realistic experience	0	3,3	20	60	16,7
The VR experience disconnected me from the real (external) world	0	13,3	23,3	23,3	40
I experienced a sense of continuity in design	0	3,3	30	30	36,7
Experiencing places using VR is very practical	3,3	0	10	43,3	43,3
I found it unnecessary and complicated to experience places using VR	63,3	26,7	3,3	3,3	3,3
I got bored while experiencing the VR model	50	23,3	16,7	6,7	3,3
I had fun experiencing the VR model	0	0	23,3	30	46,7
I felt comfortable in the VR experience	0	3,3	20	50	26,7
I felt frustrated in the VR experience	73,3	23,3	3,3	0	0
I felt tired in the VR experience	53,3	26,7	16,7	3,3	0
I found the VR experience impressive	0	3,3	20	40	36,7
It is enough to experience an area that has not yet been built with VR	0	3,3	36,7	43,3	16,7

There was no statistical difference between the genders when the information about 3D visualization and VR experience was examined according to the participant's gender (Table 6.).

Table 6. Evaluation of information about 3D visualization and VR experience by gender

Question	Gender	Mean	Std. D.	Sig.
Do you do 3D modeling and visualization in your professional life?	Female	1,571	0,514	0,586
	Male	1,375	0,500	
Have you had any previous VR experience?	Female	1,357	0,497	0,846
	Male	1,375	0,500	

* Statistically significant at $p < 0.05$

No statistically significant gender difference had occurred when By participants gender, the realism of the VR model's design elements is evaluated (Table 7.).

Table 7. Evaluation of the realism of the design elements in the VR model by gender

Design elements 1 (not at all realistic) to 5 (very realistic)	Gender	Mean	Std. D.	Sig.
Surfaces (walls, floors, etc.)	Female	4,286	0,611	0,371
	Male	3,688	0,946	
Materials in the VR model (wood, marble, etc.)	Female	4,214	0,579	0,88
	Male	3,938	0,772	
Shading and lighting in the VR model	Female	4,429	0,646	0,425
	Male	3,750	0,856	

Outdoor view in VR model	Female	4,429	0,646	0,643
	Male	4,000	0,730	
Indoor plants in VR model	Female	4,429	0,852	0,565
	Male	4,125	0,957	
Furniture in VR model	Female	4,286	0,726	0,303
	Male	4,250	0,856	
Objects in the VR model	Female	4,357	0,633	0,976
	Male	4,125	0,719	

* Statistically significant at $p < 0.05$

As shown in Table 8. female participants stated that they were disconnected from the real world during the VR experience with an average of 4, while male participants stated that they were 3.75.

Table 8. Evaluation of participants' opinions and feelings about VR experience by gender.

Opinion/feeling about VR 1 (strongly disagree) 5 (strongly agree)	Gender	Mean	Std. D.	Sig.
I could clearly perceive the size of the space in the VR model	Female	3,786	0,699	0,879
	Male	3,938	0,772	
The VR model gave me a very realistic experience	Female	4,071	0,616	0,26
	Male	3,750	0,775	
The VR experience disconnected me from the real (external) world	Female	4,000	0,877	0,048*
	Male	3,813	1,276	
I experienced a sense of continuity in design	Female	4,071	0,997	0,618
	Male	3,938	0,854	
Experiencing places using VR is very practical	Female	4,357	0,745	0,952
	Male	4,125	1,025	
I found it unnecessary and complicated to experience places using VR	Female	1,643	1,151	0,395
	Male	1,500	0,817	
I got bored while experiencing the VR model	Female	2,000	1,301	0,438
	Male	1,813	0,981	
I had fun experiencing the VR model	Female	4,500	0,650	0,203
	Male	4,000	0,894	
I felt comfortable in the VR experience	Female	3,929	0,829	0,822
	Male	4,063	0,772	
I felt frustrated in the VR experience	Female	1,357	0,633	0,21
	Male	1,250	0,447	
I felt tired in the VR experience	Female	1,571	0,852	0,891
	Male	1,813	0,911	
I found the VR experience impressive	Female	4,286	0,914	0,494
	Male	3,938	0,772	
It is enough to experience an area that has not yet been built with VR	Female	3,929	0,829	0,759
	Male	3,563	0,727	

* Statistically significant at $p < 0.05$

There was no statistical difference between the age when the information about 3D visualization and VR experience was examined according to the participant's age (Table 9.).

Table 9. Evaluation of information about 3D visualization and VR experience by age

Question	Age	Mean	Std. D.	Sig.
Do you do 3D modeling and visualization in your professional life?	23-30	1,300	0,483	0,232
	31-40	1,417	0,515	
	41-50	1,667	0,516	
	51+	2,000	0,000	
Have you had any previous VR experience?	23-30	1,200	0,422	0,201
	31-40	1,583	0,515	
	41-50	1,167	0,408	
	51+	1,500	0,707	

* Statistically significant at $p < 0.05$

No statistically significant age difference had occurred when By participants age, the realism of the VR model's design elements is evaluated (Table 10).

Table 10. Evaluation of the realism of the design elements in the VR model by age

Design elements 1 (not at all realistic) to 5 (very realistic)	Age	Mean	Std. D.	Sig.
Surfaces (walls, floors, etc.)	23-30	3,900	1,197	0,633
	31-40	3,917	0,669	
	41-50	4,333	0,516	
	51+	3,500	0,707	
Materials in the VR model (wood, marble, etc.)	23-30	3,900	0,876	0,824
	31-40	4,167	0,577	
	41-50	4,167	0,753	
	51+	4,000	0,000	
Shading and lighting in the VR model	23-30	3,700	0,949	0,094
	31-40	4,167	0,718	
	41-50	4,667	0,516	
	51+	3,500	0,707	
Outdoor view in VR model	23-30	4,300	0,823	0,845
	31-40	4,083	0,669	
	41-50	4,167	0,753	
	51+	4,500	0,707	
Indoor plants in VR model	23-30	4,300	1,059	0,238
	31-40	4,417	0,669	
	41-50	4,333	0,817	
	51+	3,000	1,414	
Furniture in VR model	23-30	4,500	0,707	0,725
	31-40	4,167	0,718	
	41-50	4,167	0,983	
	51+	4,000	1,414	
Objects in the VR model	23-30	4,300	0,675	0,911
	31-40	4,167	0,577	
	41-50	4,167	0,983	
	51+	4,500	0,707	

* Statistically significant at $p < 0.05$

As stated in Table 11, when participant opinions and feelings about VR were compared according to their ages, there was no statistically significant difference between the participants ages.

Table 11. Evaluation of participants' opinions and feelings about VR experience by age.

Opinion/feeling about VR 1 (strongly disagree) 5 (strongly agree)	Age	Mean	Std. D.	Sig.
I could clearly perceive the size of the space in the VR model	23-30	3,600	0,699	0,062
	31-40	4,000	0,739	
	41-50	4,333	0,516	
	51+	3,000	0,000	
The VR model gave me a very realistic experience	23-30	4,000	0,667	0,948
	31-40	3,833	0,718	
	41-50	3,833	0,983	
	51+	4,000	0,000	
The VR experience disconnected me from the real (external) world	23-30	4,300	1,059	0,324
	31-40	3,500	1,087	
	41-50	3,833	1,169	
	51+	4,500	0,707	
I experienced a sense of continuity in design	23-30	4,000	0,943	0,531
	31-40	4,250	0,866	
	41-50	3,667	1,033	
	51+	3,500	0,707	
Experiencing places using VR is very practical	23-30	4,300	1,252	0,959
	31-40	4,167	0,718	
	41-50	4,167	0,753	
	51+	4,500	0,707	
I found it unnecessary and complicated to experience places using VR	23-30	1,600	0,699	0,853
	31-40	1,667	1,155	
	41-50	1,500	1,225	
	51+	1,000	0,000	
I got bored while experiencing the VR model	23-30	1,900	0,994	0,551
	31-40	1,833	1,267	
	41-50	2,333	1,211	
	51+	1,000	0,000	
I had fun experiencing the VR model	23-30	4,200	0,789	0,54
	31-40	4,250	0,866	
	41-50	4,000	0,894	
	51+	5,000	0,000	
I felt comfortable in the VR experience	23-30	4,200	0,632	0,085
	31-40	3,917	0,669	
	41-50	3,500	1,049	
	51+	5,000	0,000	
I felt frustrated in the VR experience	23-30	1,200	0,422	0,624
	31-40	1,333	0,492	
	41-50	1,500	0,837	
	51+	1,000	0,000	
I felt tired in the VR experience	23-30	1,600	0,966	0,565
	31-40	1,750	0,866	
	41-50	2,000	0,894	
	51+	1,000	0,000	

I found the VR experience impressive	23-30	4,300	0,675	0,669
	31-40	3,917	0,996	
	41-50	4,000	0,894	
	51+	4,500	0,707	
It is enough to experience an area that has not yet been built with VR	23-30	3,400	0,843	0,269
	31-40	3,833	0,577	
	41-50	4,167	0,983	
	51+	3,500	0,707	

* Statistically significant at $p < 0.05$

There was no statistical difference between the education when the information about 3D visualization and VR experience was examined according to the participant's education (Table 12.).

Table 12. Evaluation of information about 3D visualization and VR experience by education

Questions	Education	Mean	Std. D.	Sig.
Do you do 3D modelling and visualization in your professional life?	Undergraduate	1,444	0,527	0,976
	Post Graduate	1,500	0,535	
	Ph.D.	1,462	0,519	
Have you had any previous VR experience?	Undergraduate	1,111	0,333	0,132
	Post Graduate	1,375	0,518	
	Ph.D.	1,539	0,519	

* Statistically significant at $p < 0.05$

As shown in Table 13, there was no statistically significant difference between the participant groups' educational levels when the realism of the design elements of VR were compared.

Table 13. Evaluation of the realism of the design elements in the VR model by age of education

Design elements 1 (not at all realistic) to 5 (very realistic)	Education	Mean	Std. D.	Sig.
Surfaces (walls, floors, etc.)	Undergraduate	3,667	1,225	0,376
	Post Graduate	4,250	0,463	
	Ph.D.	4,000	0,707	
Materials in the VR model (wood, marble, etc.)	Undergraduate	3,889	0,928	0,255
	Post Graduate	3,875	0,641	
	Ph.D.	4,308	0,480	
Shading and lighting in the VR model	Undergraduate	3,889	0,782	0,463
	Post Graduate	4,375	0,744	
	Ph.D.	4,000	0,913	
Outdoor view in VR model	Undergraduate	4,000	0,866	0,451
	Post Graduate	4,125	0,641	
	Ph.D.	4,385	0,650	
Indoor plants in VR model	Undergraduate	4,444	0,882	0,768
	Post Graduate	4,125	1,126	
	Ph.D.	4,231	0,832	
Furniture in VR model	Undergraduate	4,444	0,726	0,702
	Post Graduate	4,125	0,835	
	Ph.D.	4,231	0,832	
Objects in the VR model	Undergraduate	4,111	0,601	0,582
	Post Graduate	4,125	0,835	
	Ph.D.	4,385	0,650	

* Statistically significant at $p < 0.05$

Participants with doctoral education (1.47) and undergraduate education (1.56) stated they did not find the VR experience boring, in comparison to participants with graduate education who stated they were undecided about whether they found the VR experience boring (3). While participants with a master's degree did not agree that the VR experience was unnecessary and complex, with an average of 2.25, participants with a bachelor's degree were 1.4, and Ph.D. graduates did not participate at all, with an average of 1.23. (Table 14.).

Table 14. Evaluation of participants' opinions and feelings about VR experience by education

Opinion/feeling about VR 1 (strongly disagree) 5 (strongly agree)	Education	Mean	Std. D.	Sig.
I could clearly perceive the size of the space in the VR model	Undergraduate	4,222	0,833	0,124
	Post Graduate	3,500	0,535	
	Ph.D.	3,846	0,689	
The VR model gave me a very realistic experience	Undergraduate	4,000	0,707	0,774
	Post Graduate	3,750	0,886	
	Ph.D.	3,923	0,641	
The VR experience disconnected me from the real (external) world	Undergraduate	3,889	1,269	0,995
	Post Graduate	3,875	1,126	
	Ph.D.	3,923	1,038	
I experienced a sense of continuity in design	Undergraduate	4,222	0,833	0,383
	Post Graduate	3,625	1,061	
	Ph.D.	4,077	0,862	
Experiencing places using VR is very practical	Undergraduate	4,556	0,527	0,306
	Post Graduate	3,875	1,458	
	Ph.D.	4,231	0,599	
I found it unnecessary and complicated to experience places using VR	Undergraduate	1,444	0,726	0,053*
	Post Graduate	2,250	1,488	
	Ph.D.	1,231	0,439	
I got bored while experiencing the VR model	Undergraduate	1,556	0,726	0,002 *
	Post Graduate	3,000	1,309	
	Ph.D.	1,462	0,776	
I had fun experiencing the VR model	Undergraduate	4,222	0,833	0,288
	Post Graduate	3,875	0,835	
	Ph.D.	4,462	0,776	
I felt comfortable in the VR experience	Undergraduate	4,222	0,667	0,106
	Post Graduate	3,500	0,926	
	Ph.D.	4,154	0,689	
I felt frustrated in the VR experience	Undergraduate	1,222	0,441	0,127
	Post Graduate	1,625	0,744	
	Ph.D.	1,154	0,376	
I felt tired in the VR experience	Undergraduate	1,333	0,500	0,181
	Post Graduate	2,125	0,835	
	Ph.D.	1,692	1,032	
I found the VR experience impressive	Undergraduate	4,222	0,833	0,181
	Post Graduate	4,000	0,756	
	Ph.D.	4,077	0,954	
It is enough to experience an area that has not yet been built with VR	Undergraduate	3,889	0,601	0,736
	Post Graduate	3,750	1,165	
	Ph.D.	3,615	0,650	

* Statistically significant at $p < 0.05$

Results

In the context of this study, VR technology was used to experience 3D interior design that had been modeled and represented using computer techniques. The realism of the experience as well as the participants' thoughts and feelings about the experience were evaluated.

The study's key conclusions are listed below:

- Participants thought the experience's surface, materials, shadow-light, views, interior plants, and objects were mostly realistic. Only 3.3% of respondents said they thought the surface was not realistic at all.
- The general opinion of the participants is that the VR experience is realistic.
- Most participants thought the VR experience was realistic and useful when their opinions on it were reviewed.
- The VR experience was described as fun, comfortable, and interesting by participants.
- Participants thought that just being in a space that has not yet been developed in VR is enough.
- During the VR experience, female participants felt more disconnected from reality than male participants.

Acknowledgement and Limitations

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This study was limited to 30 participants due to the fact that the sampling size for the experimental part of the thesis was determined to be 30. It is thought that researching this subject with more participants in future studies will contribute more to the literature.

References

[1] Sherman WR, Craig AB. Understanding virtual reality. San Francisco, CA: Morgan Kauffman. 2003;

[2] Steuer J, Biocca F, Levy MR. Defining virtual reality: Dimensions determining telepresence. Communication in the age of virtual reality. 1995;33:37–9.

[3] Latta JN, Oberg DJ. A conceptual virtual reality model. IEEE Comput Graph Appl. 1994;14(1):23–9.

[4] Chan C-S. Virtual reality in architectural design. In: CAADRIA. 1997. p. 1–10.

[5] Yoh M-S. The reality of virtual reality. In: Proceedings seventh international conference on virtual systems and multimedia. IEEE; 2001. p. 666–74.

[6] Angelov V, Petkov E, Shipkovenski G, Kalushkov T. Modern Virtual Reality Headsets. In: 2020 International Congress on Human-Computer Interaction, Optimization and Robotic Applications (HORA). 2020. p. 1–5.

[7] Wu Z, Guo W. Analysis on Historical Periods of Architectural Visualization Under the Perspectival Consciousness. In: HCI International 2016–Posters' Extended Abstracts: 18th International Conference, HCI International 2016, Toronto, Canada, July 17-22, 2016, Proceedings, Part I 18. Springer; 2016. p. 296–301.

[8] Xu J. The Future Application of Virtual Reality Technology in Architectural Design. 2021;

[9] Özkuyumcu Aykutalp, Karcı Ahenk, Kalaycı Önaç Ayşe. Mimarlık Disiplininde Sanal Gerçeklik Kullanımı. In: Alaybeyoğlu Ayşegül, Onan Aytuğ, editors. (ICADA'21) 1st International Conference on Artificial Intelligence and Data Science. İzmir: İzmir Katip Çelebi Ünivesitesi Yayınları; 2021. p. 32–5.

[10] Portman ME, Natapov A, Fisher-Gewirtzman D. To go where no man has gone before: Virtual reality in architecture, landscape architecture and environmental planning. Comput Environ Urban Syst. 2015;54:376–84.

Sponge City Based on Blue – Green Urbanism

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Abstract

Blue-Green Infrastructure systems are essential and valuable solutions for urban and rural areas which are facing climate change problem. As climate change negatively affects vegetation systems, water systems, and life cycles, blue-green infrastructure solutions enhance the urban and rural landscape. The system combines the green and water networks and also manages stormwater. BGI develops a variety of urban ecological, economic, social functions, and also urban sustainability and liveability. In addition to these, the systems decrease the need of grey infrastructure and the negative impacts on urban ecology. BGI plays a specific role on development of stream and coastal systems, and also urban green areas. The system emphasizes the protection of hydrologic system and hydrodynamic processes, accordingly, water management systems which consist of rain gardens, green roofs, vertical greening systems, and permeable pavements are used. In the scope of the study, creation of Sponge City with Blue-Green Infrastructure systems and the construction processes are scrutinized. In connection with the idea, sponge city design tools are described.

Keywords: Blue-green urbanism, green infrastructure, sponge city, sustainable cities

The Definition of Blue – Green Infrastructure

A green-blue city implements the natural system in urban areas and provides stormwater management, as well as utilizing the ecological and amenity value with urban greening. Green values consist of trees, parks, and gardens, while blue assets consist of water-sensitive urban design (WSUD), drainage areas, and flood storage (Victoria State Government 2017). The results of climate change are longer-lasting and intensive droughts and the intensity of heavy rainfall events. Especially, drought and heavy rainfall impact natural and anthropogenic systems, involving infrastructure which are road washouts, and damage to houses, and also impact agriculture consisting of soil erosion and loss of crops and livestock. Blue and Green Infrastructure means an interconnected network of designed landscape components and nature. The system involves water bodies and green-open spaces, which include multiple functions such as water storage for irrigation and industry use, flood control, wetland areas for wildlife habitat, or water purification (Ghofrani, Sposito and Faggian 2017). Blue and green infrastructure enhances water management and landscape values for climate-resilient and livable cities. The most popular Blue and Green Infrastructure elements are rain gardens, green roofs, vertical greening systems, and also permeable pavements (Pochodyła, Glińska-Lewczuk and Jaszczak 2021). Balany et al. (2022) describe blue and green infrastructure as a planned network of natural and semi-natural areas with other environmental features. The systems serve a wide range of ecosystem services such as microclimate regulation and developed human thermal comfort.

Urbanization causes to increase in the share of impermeable surfaces and also changes in the natural water cycle when traditional urban drainage is used. Besides, the system connects to spatial planning and water management. The aim of the BGI is reducing surface runoff, reducing peak flows, or improving water quality, and also the system processes are retention, infiltration, and evapotranspiration (Radinja, Atanasova and Lamovsek 2021) (Figure 1). Groundwater recharge starts to decrease, while the runoff increases. Thus, several negative impacts are begun to observe such as higher runoff peak rates, larger runoff volumes, higher potential of flooding events, urban heat islands, etc. One of the new strategies is best management practices (BMPs), low impact development (LID), sustainable urban drainage systems (SUDS), and water-sensitive urban design (WSUD) for runoff control (Xu, et al. 2019). For a Blue and Green Infrastructure system, Low Impact Development (LID) strategies are essential and widely known methods in stormwater management (Leimgruber, et al. 2019). Ecological and technological factors are essential for blue and green infrastructure, for instance, the use of water storage is determined by climate and soil characteristics. Blue-Green Infrastructure is mentioned in

Southeast Asian countries and river basins as green infrastructure, natural infrastructure, nature-based solutions, river restoration, or river rehabilitation (Hamel and Tan 2022).

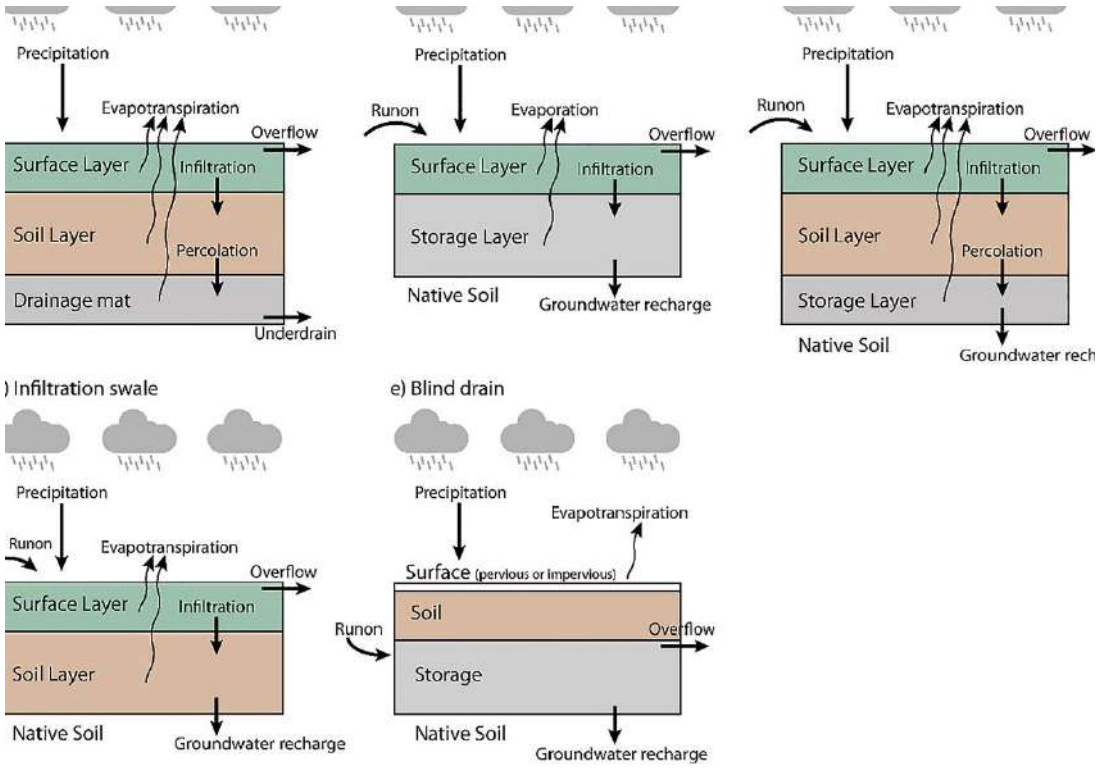

Figure 1: Blue and Green Infrastructure Process
(Source: Leimgruber, et al. 2019)

Benefits of Blue and Green Infrastructure

Blue and Green Infrastructure (BGI) helps climate change adaptation, mitigation, health and wellbeing, and biodiversity (Brown and Mijic 2019) Blue-green infrastructure involves developing water quality, improving resilience to climate change, decreasing infrastructure costs, increase space for communities and wildlife. Besides, BGI includes multiple mental and physical health benefits to communities and also is a house for urban wildlife and pollinators (Michigan Association of Planning 2020). BGI provides hydrological and biological water treatment trains. The combination of blue and green infrastructure support to urban ecosystem. The system improves the retention of stormwater, which protects valuable wetland areas, and also reduces the risk and impact of flooding, and urban heat island effects, balancing diurnal temperature fluctuation and also developing natural air ventilation. In addition to these, the systems support social benefits which consist of space for recreation, exercise, and social activities (Wouters, et al. n.d.). BGI provides to reduce carbon dioxide by walking and cycling, managing flood risk, storage of surface water in time of peak flow, and reducing pollution (APS Group Scotland 2011). The system develops land connectivity and secures marine ecological biodiversity and enhances groundwater storage, stability of water systems, quality, and purification. BGI is a popular system by impacting energy consumption, reducing polluted stormwater runoff, enhancing air quality, carbon reduction, and sequestration, property prices, recreation and other elements of community health and vitality. The purpose of a blue and green city is to recreate a naturally oriented water cycle for water management, protecting the hydrological and ecological values of the urban landscape with resilient and adaptive measures to deal with flood events (Afata, Debrid and Nemo 2022).

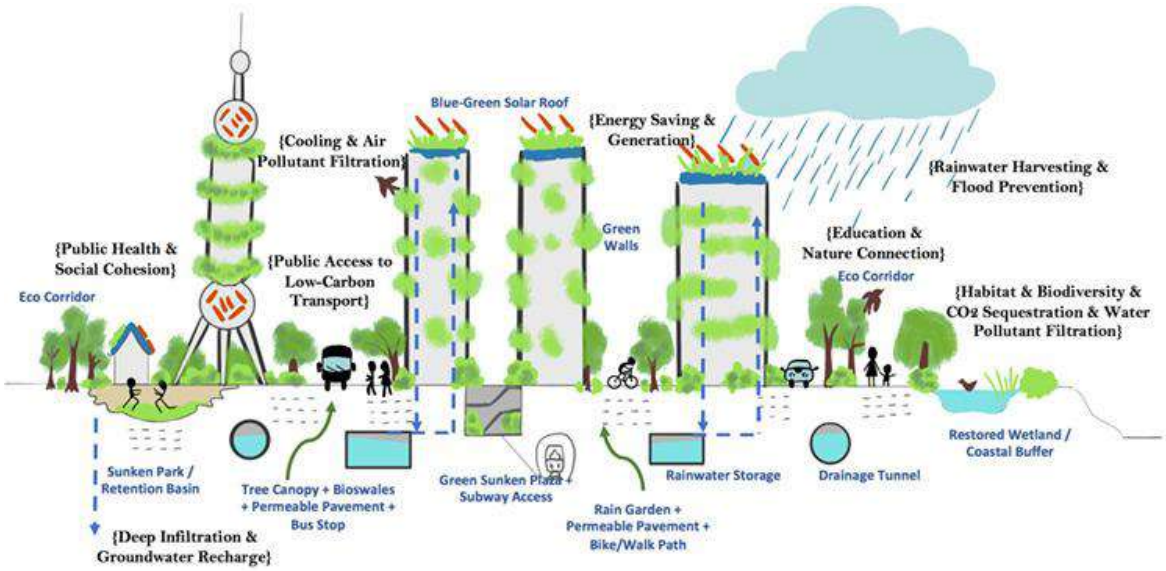

Figure 2: The Integration of Blue – Green Infrastructure in urban area
(Source: Siehr, Sun and Nucamendi 2022)

The Elements of Blue and Green Infrastructure

Blue and green elements are significant for integrating blue-green infrastructure systems. Blue elements are rivers, canals, ponds, wetlands, floodplains, and water treatment facilities, and also, green elements consist of trees, forests, fields, and parks, in urban and land use planning (Afata, Debrid and Nemo 2022). The systems can be integrated into macro and micro-scale, such as regional, neighborhoods, and streets. BGI includes natural and affordable solutions in the infrastructures such as green roofs, green walls, rain gardens, pocket parks, permeable pavements, runoff water seepage drains throughout the road, hedgerows, and planting trees indoors and outdoors residences. The regional scale includes the development authority and municipality interventions. The intervention designs are green highways, rainwater harvesting, stormwater management, bioswales, bioretention basins, street trees, etc. (Das and Kumar 2022) (Table 1).

Table 1: Blue and Green Infrastructure Tools

Rain Garden	Green Roof	Green Wall	Permeable Pavement	Rainwater Harvesting
				

Bioswale	Bioretention	Green Street	Downspout Disconnection	Planter Boxes
				

Blue-Green Infrastructure and Sponge City

Sponge city urbanization construction is the essential idea for eliminating the end drainage characteristics of the traditional urban drainage system. The concept of a sponge city is permeability,

hysteresis, storage, net, and row (Zhou 2022)At the beginning of city construction, the relationship between water ecology and the water environment is a complex issue. Water resources problems are related to bodies of water, and the river itself. In time, ecological systems with rain gardens or plant grass ditches as the main method have been chosen to replace past city rain management aspects and traditional drainage lines (Yu-shu 2017). For the construction of the sponge city, the collected rainwater can be used, for instance, road cleaning, greening irrigation, and residents' daily water use. The concept of a sponge city provides social effects, such as expanding the green space and ecological environment of the city and increasing new employment opportunities. With the construction of a sponge city, urban green areas are developed, and also the ecological environment of cities is enriched. The sponge city helps to the transformation of nature to improve a suitable living environment for people (Ma, Liu and Wang 2023). Sponge cities get support from natural base solution systems which consist of wetlands, greenways, parks, rain gardens, green roofs, and bioswales. Both gray and green measures are integrated into urban areas. The purpose of a sponge city is to enhance the management of local water cycles; besides, the devastation of stormwater is removed by storing it and slowing it down (Rau 2022). The concept uses generally and systematically blue and green spaces in the urban environment for stormwater management and control. The construction of Sponge City is a parallel concept for the Low Impact Development (LID) in the United States, Sustainable Urban Drainage System (SUDS), and the Blue-Green Cities (BGCs) approach in the United States, Water Sensitive Urban Design (WSUD) in Australia, or Low Impact developments Urban Design (LIDUD) in New Zealand (Chan, et al. 2018).

Case Studies of Sponge Cities

Jiangxi Pingxiang Integrated Rural and Urban Infrastructure Development Project

Flooding is a big problem in Pingxiang Jianxi, so An Asia Development Bank provides Pingxiang's pilot sponge city design project to reduce river flooding. Ecological river rehabilitation for stormwater management is integrated with improving climate resilience and biodiversity, increasing urban green spaces as well as improving the livability and competitiveness of the city (Rau 2022) (Figure 3).

Figure 3. Jiangxi Pingxiang Integrated Rural and Urban Infrastructure Development Project

Sponge City Planning Project of Qinhuai District, Nanjing City

The project includes sponge measures to mitigate pluvial flooding and enhance surface water quality, in addition to this, the project provides to mitigate the urban heat island effect, strengthening water culture. Also, the sponge city planning approach involves spatial analysis, sponge size calculation, hydraulic modeling, and suggested sponge measures (Figure 4). In the scope of the project, the water system is redesigned, and new public green spaces, residential green spaces, and green roofs are

provided. Retention and detention systems are integrated into the project. The plan provides information, objectives, and implementation approaches such as urban spatial planning, water system planning, flood control planning, green system planning, and ecological protection planning (Chen, et al. 2021).

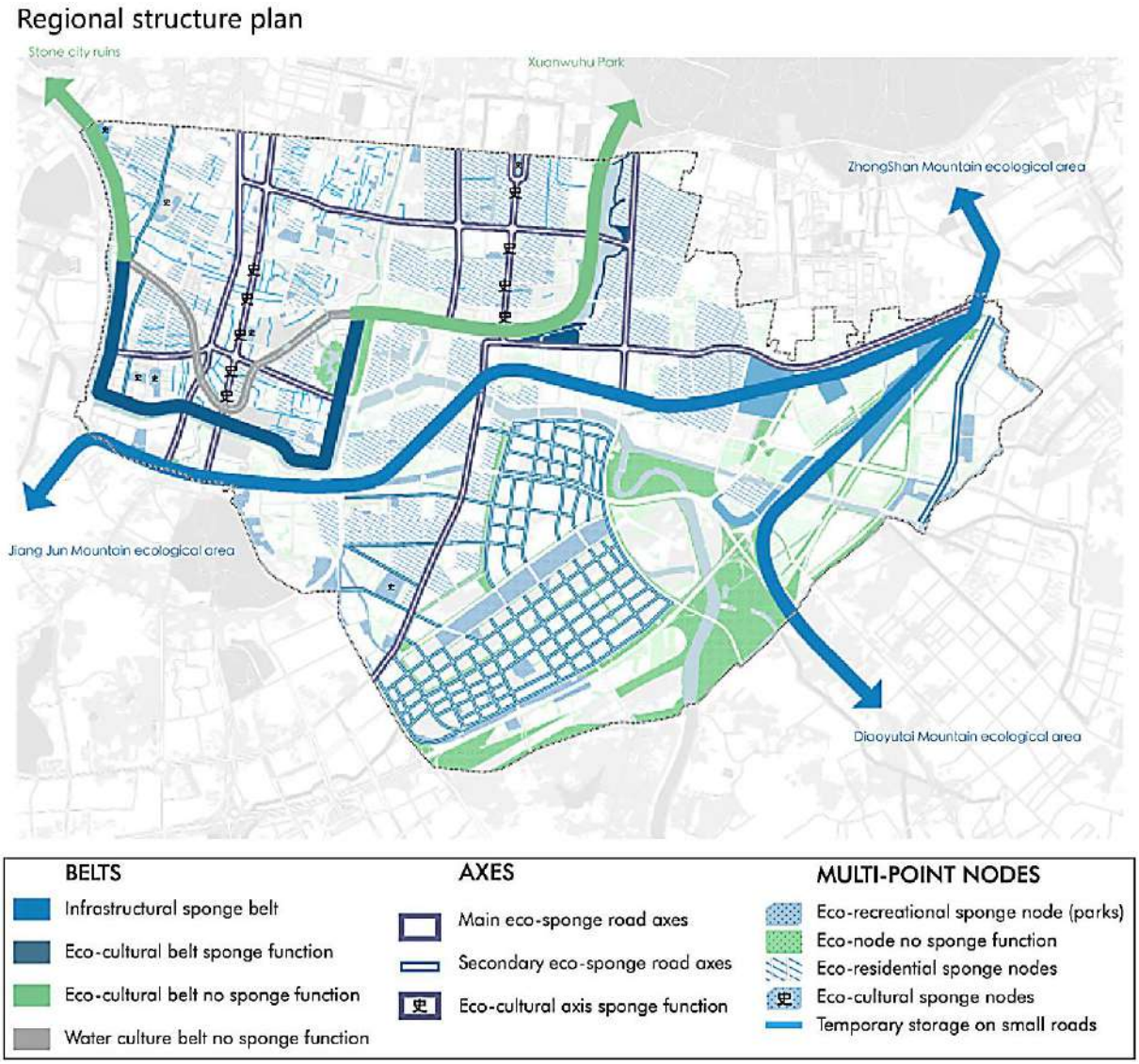

Figure 4. Sponge City Planning Project of Qinhuai District, Nanjing City

Peiyang Campus in China

The project was constructed in 2015 with a sponge city concept. The site is approximately 2.5 km2 and it includes a complex of waterways, wetlands, and uplands. In the scope of the project, green infrastructure systems which consist of landscape elements such as green spaces, pervious pavers, bioswales, green roofs, rain gardens, detention basins, and a treatment wetland are used. The purpose of the study is to protect the site's original ecosystem, using ecological restoration and mitigation. Besides, the water body and natural environment are restored and repaired with the sponge city project (Yin, et al. 2022) (Figure 5).

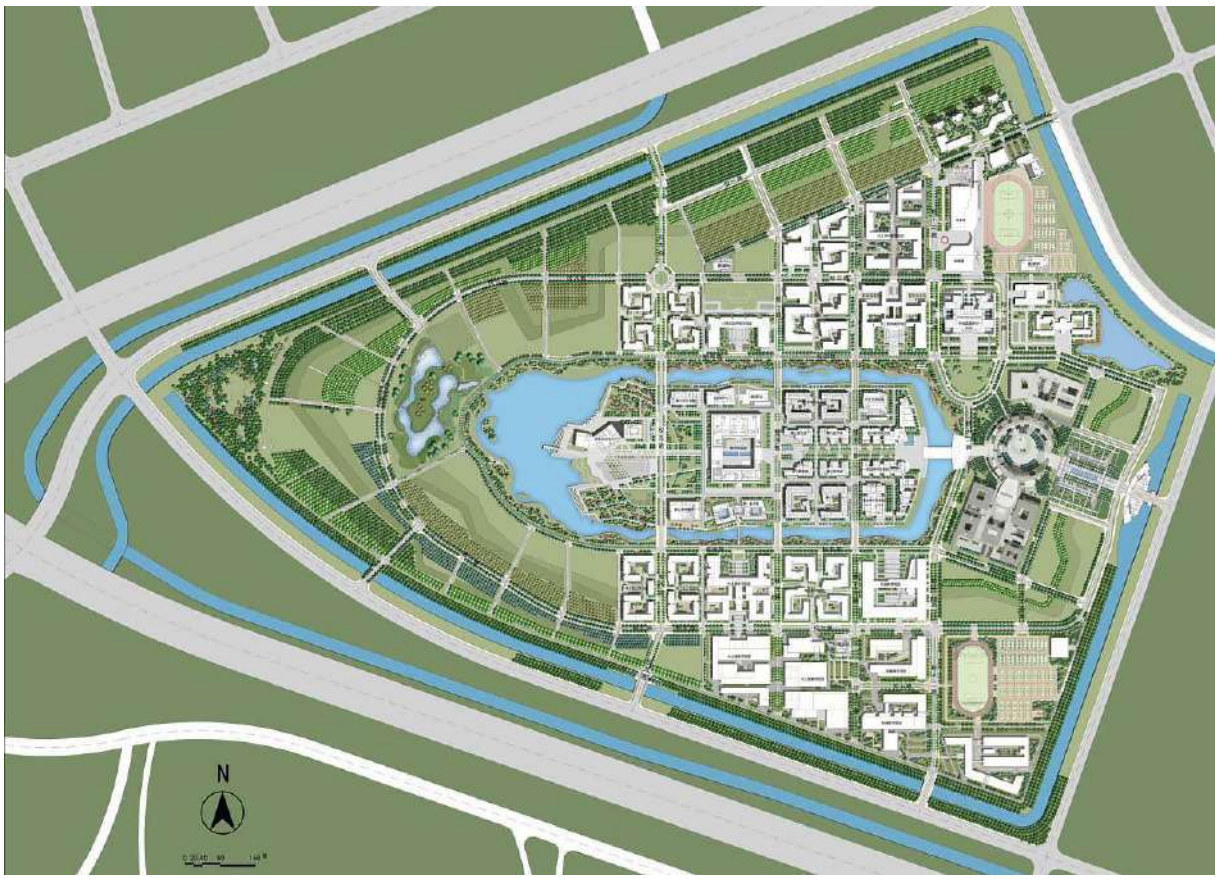

Figure 5. Peiyang Campus in China

Conclusion

Sponge city studies on the basis of blue and green infrastructures are significant tools in urban and rural areas, within the scope of adaptation to climate change. The fact that the structural areas are dense throughout the city causes the surface flow to be high and as a result, important disasters such as flood risk are experienced. In addition, urban heat island effect and extreme weather events are the most adverse events of climate change and sponge city studies are the most important planning and design tools to prevent this situation. Planning and design studies from macro scale to micro scale should be supported by appropriate policies. Blue and green infrastructure projects have ecological effects as well as social and economic effects. It offers new green areas, urban parks, sports areas, and recreation areas for the people of the city. Within the scope of urban design and urban regeneration projects, it should be mandatory to create climate change adaptation designs. The application of the sponge city concept throughout the city aims to breathe new life into the city. The establishment of an ecologically based urban system is a very important development for urban habitat. Urban areas are not only places where people live, but also plants and animals that form the cornerstone of urban habitat. With the sponge city study, the fauna and flora of the city begin to be renewed. In this context, ecological-based studies are very valuable.

References

[1] Afata, T N, S Debrid, and R Nemo. "Review of Blue-Green Infrastructure in Some Selected Countries." American Journal of Environmental Sciences, 2022: 81-88. DOI: 10.3844/ajessp.2022.81.88.

[2] APS Group Scotland. Green Infrastructure Design and Placemaking. Guide, Edinburgh: The Scottish Government, 2011.

[3] Balany, F, N Muttil, S Muthukumaran, M S Wong, and A W.M Ng. "Studying the Effect of Blue-Green Infrastructure on Microclimate and Human Thermal Comfort in Melbourne's Central Business District." Sustainability, 2022: 14, 9057. https://doi.org/10.3390/su14159057.

[4] Brown, K, and A Mijic. "Integrating green and blue spaces into our cities: Making it happen." Grantham Institute Briefing paper No 30, 2019: 1-12.

[5] Chan, F K, et al. "“Sponge City” in China—A breakthrough of planning and flood risk management in the urban context." Elsevier, 2018: 772-778. https://doi.org/10.1016/j.landusepol.2018.03.005.

[6] Chen, S, et al. "Revisiting China’s Sponge City Planning Approach: Lessons From a Case Study on Qinhuai District, Nanjing." Frontiers in Environmental Sceince, 2021: 1-18. doi: 10.3389/fenvs.2021.748231.

[7] Das, M, and S Kumar. "Assessment of Blue-Green Infrastructure Index: A Case of Odisha." International Research Journal of Modernization in Engineering Technology and Science , 2022: 77-90. e-ISSN: 2582-5208 .

[8] Ghofrani, Z, V Sposito, and R Faggian. "A Comprehensive Review of Blue-Green Infrastructure Concepts." International Journal of Environment and Sustainability [IJES], 2017: Sustainability [IJES]. Vol. 6 No. 1, pp. 15-36.

[9] Hamel, P, and L Tan. "Blue–Green Infrastructure for Flood and Water Quality Management in Southeast Asia: Evidence and Knowledge Gaps." Environmental Management, 2022: 69:699–718. https://doi.org/10.1007/s00267-021-01467-w.

[10] Leimgruber, J, G Krebs, D Camhy, and D Muschalla. "Model-Based Selection of Cost-Effective Low Impact Development Strategies to Control Water Balance ." Sustainability, 2019: 1-20. doi:10.3390/su11082440.

[11] Ma, J, D Liu, and Z Wang. "Sponge City Construction and Urban Economic Sustainable Development: An Ecological Philosophical Perspective." International Journal of Environmental Research and Public Health, 2023: 1-17. . https://doi.org/10.3390/ijerph20031694.

[12] Michigan Association of Planning. Blue Green Infrastructure. Report, Michigan: Michigan Association of Planning, 2020.

[13] Pochodyła, E, K Glińska-Lewczuk, and A Jaszczak. "Blue-green infrastructure as a new trend and an effective tool for water management in urban areas." Landscape Online, 2021: Volume 92. 1-20. DOI 10.3097/LO.202192.

[14] Protection, Massachusetts Department of Environmental. Megamanual Geosyntec. 2023. https://megamanual.geosyntec.com/npsmanual/bioretentionareasandraingardens.aspx (accessed June 7, 2023).

[15] Radinja, M, N Atanasova, and A Z Lamovsek. "The water-management aspect of blue-green infrastructure in cities." Urbani izziv, 2021: volume 32, no. 1, 98-110. DOI: 10.5379/urbani-izziv-en-2021-32-01-003.

[16] Rau, S. "Sponge Cities: Integrating Green and Gray Infrastructure to Build Climate Change Resilience in the People’s Republic of China." ADB Briefs, 2022: 1-11. DOI: http://dx.doi.org/10.22617/BRF220416-2.

[17] Siehr, S A, M Sun, and J L Nucamendi. "Blue-green infrastructure for climate resilience and urban multifunctionality in Chinese cities." Wires Energy and Environment, 2022: https://doi.org/10.1002/wene.447.

[18] United States Environmental Protection Agency. EPA. 2023. https://www.epa.gov/green-infrastructure/what-green-infrastructure (accessed June 7, 2023).

[19] Victoria State Government. Planning a Green-Blue City . Guide, Australia: E2Designlab, 2017.

[20] Wouters, P, et al. "Blue-Green Infrastructures as tools for the management of urban development and the effects of climate change." Del 28 De Noviembre Al 1 De Diciembre , n.d.: 1-20.

[21] Xu, C, et al. "Benefits of coupled green and grey infrastructure systems: Evidence based on analytic hierarchy process and life cycle costing." Elsevier, 2019: 1-10. doi.org/10.1016/j.resconrec.2019.104478.

[22] Yin, D, et al. "Sponge City Practices in China: From Pilot Exploration to Systemic Demonstration." Water, 2022: 7-29. https://doi.org/10.3390/w14101531.

[23] Yu-shu, Z. "Sponge City Theory and its Application in Landscape." Universe Scientific Publishing, 2017: 29-33. doi: 10.18686/wc.v6i1.84.

[24] Zhou, L. "Sponge City Design Based on Intelligent Displacement Optimization." Wiley, 2022: 1-6. Volume 2022, Article ID 2956191. https://doi.org/10.1155/2022/2956191.

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Green Biosynthesis of Silver Nanoparticles from Wild Mushroom (*Ganoderma lucidum*) First Time in Iraq

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Abstract

Nowadays there is an increasing interests about nanoparticle due to its application in medical and industrial products, green rout and safely producing of nanoparticles consider important for recent life technology, silver nanoparticles (AgNPs) one of the most safe compound to human and environment due to its low effect an low toxicity even with direct contacting and consuming release low particles of silver, for these reasons , the availability and low costing technology we produced silver nanoparticles from eco-friendly mushroom *G. lucidum* first time in Iraq**.**

AgNPs were prepared by using aqueous extract of G. lucidium as a reducing agent for silver nitrate ($AgNO_3$). The characteristics of silver-nanoparticles were determined, including: Determining the highest absorption of silver nanoparticles by UV-VIS spectrophotometer, the shape and size of silver nanoparticles by atomic force microscopy (AFM), as well as determining the type of chemical bonds or functional groups bound to the prepared AgNPs by Fourier-transform infrared spectroscopy-FTIR. Scanning Electron Microscopy used for study of Particle size and shape.

The results showed the emergence of a spectral imaging beam using a spectrophotometer that ranged between 350-900 nm, where the best absorption beam was at a wavelength of 450 nm, while the result of AFM showed the surface topography of silver nanoparticles with an average size of 62.78 nm. FTIR spectrum revealed strong absorption peaks 1091-3434 cm^{-1}, as well as their role in the stability of these molecules. The size of spherical particles ranged between 17.15 - 25.81 nanometers under SEM.

Keywords: Nanoparticles by Ganoderma, AgNPs, FTIR

Introduction

Nanotechnology has been a well-known and important field of research since the last century. Its idea dates back specifically to the American physicist Richard P. Feynman, the Nobel Prize winner, when he presented a research paper before the American Physical Society entitled “There’s Plenty of room at the Bottom” in 1959 (Feyman, 1960) during which an evolutionary revolution occurred in the field of nanotechnology (Khan et al, 2019). It was followed by researcher Norio Taniguchi by coining the term nanotechnology for the first time in 1974 in reference to the ability to manufacture and develop materials into nanoparticles (Bayda S et al.2019).

The biological preparation of nanoparticles from fungi is known as Myconanotechnology, which is usually made from fungal biomass and the metabolites such as enzymes and proteins (Sudher et al. 2022). In addition, one of the most important part of the fungi cell for manufacture of nanoparticles is cell wall (Khandel & Shahi, 2018). The mechanism and nature of the biological manufacture of nanoparticles are largely unknown because fungi can manufacture nanoparticles inside their bodies (inVivo and inVitro) (Sudheer et al, 2022). Generally, silver nanoparticle consider medicinally and environmentally safe even if combined with other active group like D-amino acid (Jasim et al, 2020)

Like other wide distributed macrofungi in Iraq, the genus *Ganoderma* is considered one of the most important medicinal fungi due to the content of some species of active compounds (about 400 active compounds) (Al-Khesraji etal.2019).

The past studies indicate that these species have different biological activities, including anti-cancer, anti-oxidant, anti-bacteria and liver protection effects (Jasim et al.2020). The globally famous species *G. lucidum* (Reishi or Lingzhi) is known in Asia as the king of medicinal herbs for its medicinal value due to its effective content of terpenoids, sterols, steroids, carbohydrates, fatty acids, trace elements, proteins and peptides. On the basis of the foregoing, the current study aimed to prepare and characterize silver nanoparticles for the first time in Iraq from the large Iraqi wild mushroom *G. lucidum* (Wachtel-Galor S et al.2011).

Materials and Methods

Specimens' collection

The mushroom was obtained from the laboratories of the College of Science / Department of Life Sciences / Tikrit University which was previously diagnosed by Assistant Professor Dr. Sara Qahtan Suleiman.

Preparation of silver nanoparticles

1. Preparation of the aqueous extract of G. lucidium

Initially, the fruiting body of the pre-dried mushroom was ground by an electric grinder to obtain a fine powder. 15 grams of mushroom powder was dissolved in 150 milliliter of D.W aided with vibrated water bath under a constant speed and 55 ° C for 48 hours.

Obtained mixture was filtered by *whatman* No.1 type filter paper and then filtered again using 0.22 micron micro filters. The mushroom extract was stored in the freezer until its use (Al Nasiri et al.2020; Nguyen et al.2021; Al-Khesraji et al.2019; Hamzah et al, 2018).

2. Preparation of silver nanoparticles

The aqueous solution of 1 Mmol silver nitrate was prepared as follows:

- 0.169 g of silver nitrate added to 1000 ml of deionized water.
- Heating the silver nitrate solution under 30ºC for half an hour with continuous shaking.
- The bio-nano particles were prepared by distilling 50 ml of mushroom extract prepared in section 1 to 950 ml of 1 mmol silver nitrate solution under ultrasonic conditions, with an ultrasonic power of 100 watts and a frequency of 42 kHz. Then, after sonication for 20 minutes, the solution was stirred at 800 rpm at 25°C for 30 minutes, and placed in a shaking incubator at 25°C for 120 hours. The color changes were observed, which is evidence of the formation of nanoparticles (Mohanta et al. 2018).

Purification of silver nanoparticles

The solution containing silver nanoparticles prepared in paragraph 2 was placed in buffy test tubes, then placed in a cooled centrifuge device at a speed of 10,000 rpm for 10 minutes. The distilled was placed in the centrifugal device at a speed of 10,000 rpm for a period of 10 minutes, and the process was repeated 3 times until the filtrate became free of any color. The sediment is collected after drying and kept until used (Agrawal et al., 2014).

Diagnostics of silver nanoparticles

Spectrophotometer UV-VIS

The optical properties of the silver particles were determined by taking 2 ml of the prepared solutions and diluting them 10 times with deionized water to reduce the false readings. The samples were transferred for examination by a spectrophotometer and UV rays with a wavelength range from 190 to 850 nm and the appropriate wavelength was fixed (Al-Shammari, 2016).

Fourier transform infrared FTIR-

This technique used for identifying active groups that make up the biomass extract of the mixture of silver nitrate solution and the mushroom extract (silver nanoparticles). The samples were prepared by depositing a drop of each sample on a glass slide and dried at a temperature of 60 degrees Celsius inside the electric oven for 30 minutes, then it was made into a paste with a high-viscosity liquid substance such as paraffin oil (Nujol) after which a small amount of this paste was placed Between two discs of potassium bromide to form a very thin layer then examined by Fourier transform infrared (Al-Shammari, 2016).

Atomic Force Microscope - AFM

As we know Atomic force microscopy stabilizes shape and size of nanoparticles. The process included placing a thin film of a sample of nanoparticles on a glass slide by dropping 100 µl of the sample onto the slide and allowing it to dry for 5 minutes. Then the slides are scanned using AFM (Kaman et al. 2019).

Scanning Electron Microscopy-SEM

The SEM used for study of the surface of nanoparticles.

Results and Discussion

Visual Change Detection

The optical and spectral characteristics of silver nanoparticles(Ag-No3) demonstrated by observing the presence of color changes when adding the aqueous extract of the fungus *G.lucidium* to the silver nitrate solution compared with the solution containing the aqueous extract of the fungus without $AgNo_3$. These color changes ranged from Hyaline transparent color (colorless) to settle to light yellow color as shown in Figure 1. It was also noted that the color change process took 120 hours at a temperature of 26±2°C.

Figure 1: Color change of extract containing nanoparticles, A-extract without AgNo3. B- Extract with AgNPs

The occurrence of these changes is evidence of the formation of those particles and color appearance is caused by the excitation of the surface Plasmon resonance (SPR) of particles. This properties, also can be found in gold and copper particles in the visible light region which responsible for changing their colors when these elements reach the nano size and have many properties and applications (Xia et al, 2005).

UV-VIS Spectra Analysis

U.V spectroscopy was applied to study the surface plasmon excitation of the nano-particles in the solution to record the highest absorbance at the wavelength of 450 nm, as shown in Figure (2). This absorption peak was recorded by several studies (AlSalhi et al, 2016; Alfuraydi *etal*, 2017; AL-Ansari et al 2020) this peak confirms the formation of silver nanoparticles and the spherical nature of them. In addition, fungi are characterized by their ability to help form larger quantities of nanoparticles compared to bacteria due to their ability to secrete large amounts of nanoparticles. There are a large number of enzymes that reduce silver to metal particles and form nanoparticles (Mohanpuria et al., 2008).

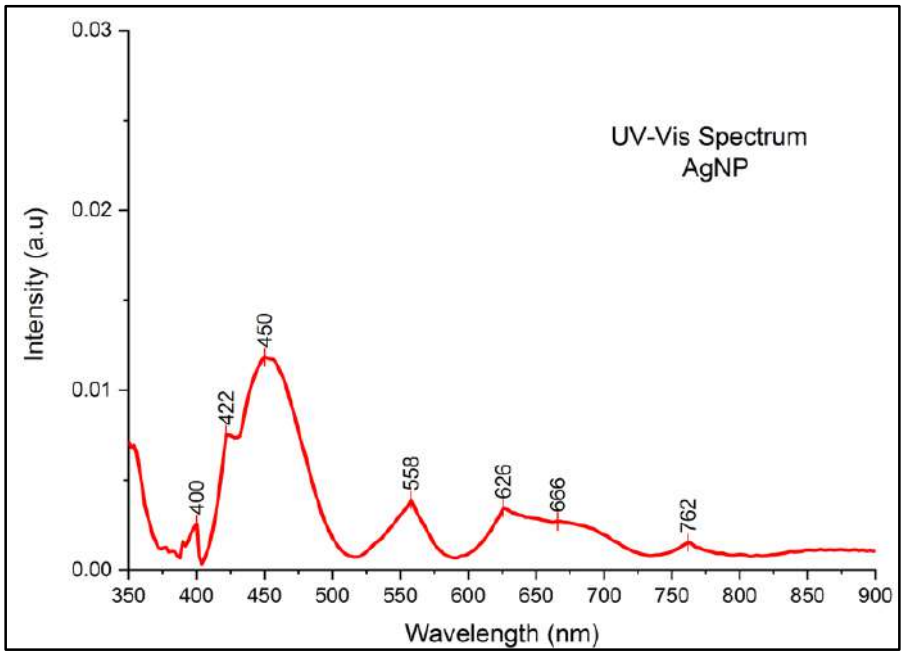

Figure 2: Absorption spectrum of bio-silver nanoparticles prepared using ultraviolet and light spectroscopy

Fourier-transform infrared

Numerous curves appeared which indicate the presence of bonds when analyzing the aqueous extract as well as the prepared nanoparticles, Figure 3.

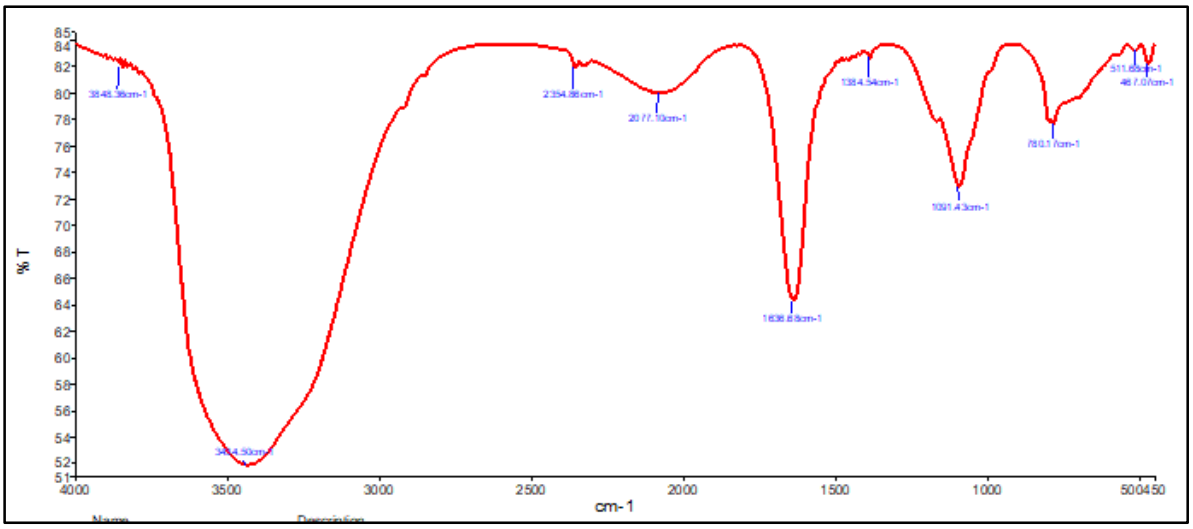

Figure 3: Infrared spectroscopy of silver nanoparticles prepared by aqueous extract of the fungus.

The absorption band that appeared at (3434) cm-1 frequency is caused by the (OH) bond pattern, while the appearance at (2354) cm-1 and (2077) both belong to (CO2) group. Thịs was demonstrated by infrared spectroscopy- cm-1- is a member of the isothịocyanate group (N=C=S), alongside an absorption band appearing at frequency (1636), the group consisting of azomethine (C=N), an absorption band that appear at frequency (1384), an alcoholic group (C-O) and the etheriċ group (C-O), with an absorption band showing at frequency (1091).. These results were similar to (Aftan et al., 2021a; Aftan et al., 2021b) studies.

Atomic force microscope

Atomic force microscopy has been adopted as a useful tool for studying the morphological characteristics of biofunctional particles (Debnath et al., 2019).

The process of revealing the nature of the surface of the synthesized nanoparticles using an atomic absorption microscope showed the nature of the synthesized nanoparticles as in Figure 4.

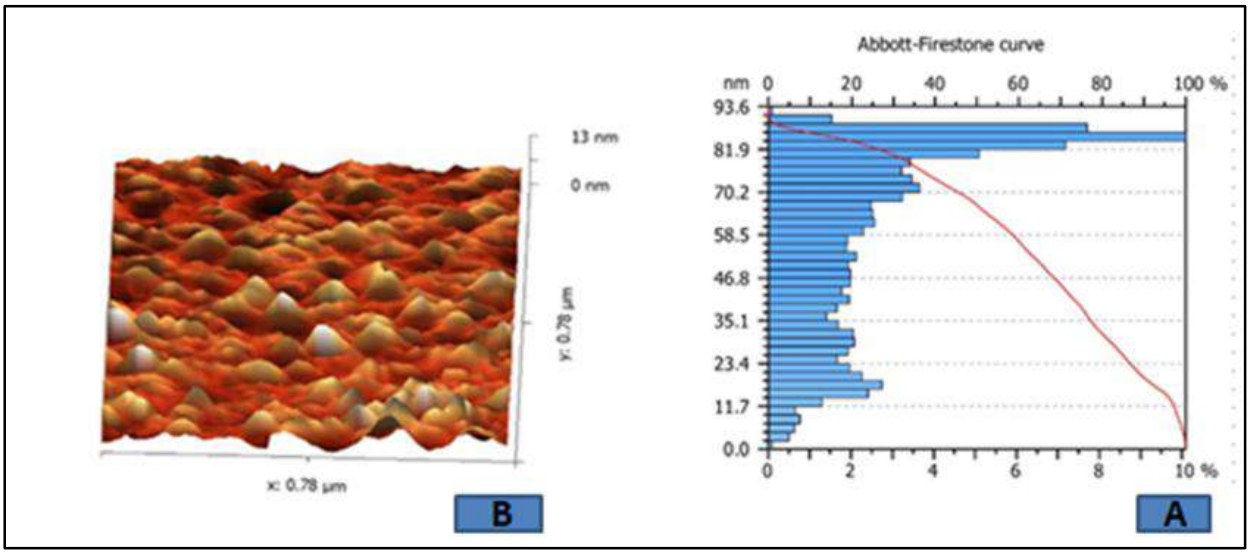

Figure 4. Atomic force microscopy result. (A) Graph of the size of silver nanoparticles, (B) 3D image of silver nanoparticles

The above figures show that the nanoparticles prepared by the aqueous extract of the fungus were characterized by spherical shapes, and Figure 4 shows distribution of silver AgNPs nanoparticles size, average size of the nanoparticles was (62.78 nm).

The shape, size and distribution of nanoparticles depends on physical and chemical properties such as temperature, time, and pH.

Scanning Electron Microscopy

The shape and size of nanoparticles determined by electron microscope. Figure 5 shows that the nanoparticles have spherical shape and size that ranged between 17.15-25.81 nanometers.

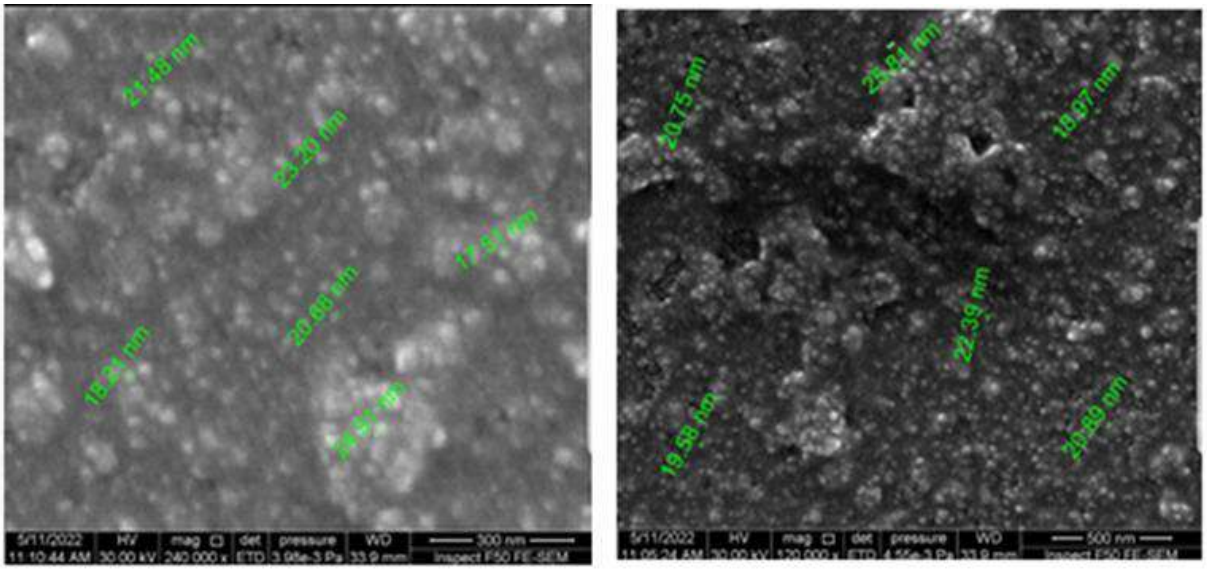

Figure 5: Scanning electron microscope results (240000X)

These results were close to the results of Devi and Joshi (2015), in which the S-electron microscope revealed the spherical shape of the bio-silver nanoparticles, as well as several studies that indicated the same shape for the silver nanoparticles (Salehi, 2017). It also coincided with the study of Nagajyothi et al (2013) in which the use of a scanning electron microscope revealed the formation of spherical nanoparticles ranging from 14.7 - 35.2 nm, which were synthesized from the extract of the fungus *Inonotus obliquus*.

Conclusions

The project demonstrated an ecofriendly and economical way for Ag-NPs biosynthesis of using aqueous extraction of wild macro fungi (G. lucidum).

Obtained particles affected by several parameters like pH condition, concentration of materials, reaction time and temperature, silver nanoparticles Ag-NPs produced in 120 hrs.

The nano-particles were highly stable.

The results proposed a potential of utilizing AgNPs in the medical application, especially as antimicrobial, anticancer treatment and furthermore.

References

Aftan, M. M., Jabbar, M. Q., Dalaf, A. H., & Salih, H. K. (2021a). Application of biological activity of oxazepine and 2-azetidinone compounds and study of their liquid crystalline behavior. *Materials Today: Proceedings*, *43*, 2040-2050.

Abed, S.M., Mahdi, E.M., Dallus, I.S., & Lafta, S.M. (2019). Studying the inhibitory effect of local honey, black seed oil against some bacterial isolates with a comparisons. *Tikrit Journal for Agricultural Sciences*.

Al-Khesraji, Talib O., Suliaman, S. Q., Al Hayawi, A. Y., & Sadiq, S. T. (2019). First report on molecular identification of Iraqi macrofungi. In International Agriculture and Forest Congress (pp. 400–410). Izmir, Turkey: Ege University.

Aftan, M. M., Toma, M. A., Dalaf, A. H., Abdullah, E. Q., & Salih, H. K. (2021b). Synthesis and characterization of new azo dyes based on thiazole and assess the biological and laser efficacy for them and study their dyeing application. *Egyptian Journal of Chemistry*, *64*(6), 2903-2911.

Agrawal, N. K., Singh, M., Vijay, Y. K., & Swami, K. C. (2014). Synthesis and characterization of colloidal TiO2 nanoparticles: through titanium chloride rich solutions. *Advanced Science, Engineering and Medicine*, *6*(5), 595-602.

Al-Ansari, M. M., Dhasarathan, P., Ranjitsingh, A. J. A., & Al-Humaid, L. A. (2020). Ganoderma lucidum inspired silver nanoparticles and its biomedical applications with special reference to drug resistant Escherichia coli isolates from CAUTI. *Saudi Journal of Biological Sciences*, *27*(11), 2993-3002.

Alfuraydi, A. A., Devanesan, S., Al-Ansari, M., AlSalhi, M. S., & Ranjitsingh, A. J. (2019). Eco-friendly green synthesis of silver nanoparticles from the sesame oil cake and its potential anticancer and antimicrobial activities. *Journal of Photochemistry and Photobiology B: Biology*, *192*, 83-89.

Al-Khesraji, T. O., Suliaman, S. Q., Al Hayawi, A. Y., & Sadiq, S. T. (2019). First report and molecular identification of Iraqi macrofungi. In *International Agriculture and Forest Congress* (pp. 400-410).

AlSalhi, M. S., Devanesan, S., Alfuraydi, A. A., Vishnubalaji, R., Munusamy, M. A., Murugan, K. ... & Benelli, G. (2016). Green synthesis of silver nanoparticles using Pimpinella anisum seeds: antimicrobial activity and cytotoxicity on human neonatal skin stromal cells and colon cancer cells. *International journal of nanomedicine*, *11*, 4439.

Al-Shammari, Hazim Idan, Al-Zubaidi, Hamza Kahdum. (2016). Toxicity of silver nanoparticles prepared by extract of Eucalyptus sp in some biological aspects of Citrus mealybug Planococcus citri (Risso), Hemiptera: Pseudococcidae, European Academic Research, Vol. IV, Issue 9.

Bayda S, Adeel M, Tuccinardi T, Cordani M, Rizzolio F. (2019) The History of Nanoscience and Nanotechnology: From Chemical-Physical Applications to Nanomedicine. Molecules.

Debnath, G., Das, P., & Saha, A. K. (2019). Green synthesis of silver nanoparticles using mushroom extract of Pleurotus giganteus: characterization, antimicrobial, and α-amylase inhibitory activity. *Bionanoscience*, *9*(3), 611-619.

Devi, L. S., & Joshi, S. R. (2015). Ultrastructures of silver nanoparticles biosynthesized using endophytic fungi. *Journal of Microscopy and Ultrastructure*, *3*(1), 29-37.

Feynman, R. P. (1960). “There’s Plenty of Room at the Bottom". Engineering and Science (California Institute of Technology).

Jasim, S.T., Noori, A.M., Sadiq, S.T., & Flayyih, M.T. (2020). Antimicrobial and Antibiofilm Activity of D-amino acids Combined with Nanoparticles against Candida albicans. *Systematic Reviews in Pharmacy*.

Hamzah, H., Salah, R.F., & Maroof, M.N. (2018). Fusarium mangiferae as New Cell Factories for Producing Silver Nanoparticles. *Journal of microbiology and biotechnology, 28 10*, 1654-1663.

Kámán, J., Huszánk, R., & Bonyár, A. (2019). Towards more reliable AFM force-curve evaluation: a method for spring constant selection, adaptive lever sensitivity calibration and fitting boundary identification. *Micron*, *125*, 102717.

Khan, I., Saeed, K., & Khan, I. (2019). Nanoparticles: Properties, applications and toxicities. *Arabian journal of chemistry*, *12*(7), 908-931.

Khandel, P., & Shahi, S. K. (2018). Mycogenic nanoparticles and their bio-prospective applications: current status and future challenges. *Journal of Nanostructure in Chemistry*, *8*(4), 369-391.

Mohanpuria, P., Rana, N. K., & Yadav, S. K. (2008). Biosynthesis of nanoparticles: technological concepts and future applications. *Journal of nanoparticle research*, *10*(3), 507-517.

Mohanta, Y.K., Nayak, D., Biswas, K., Singdevsachan, S.K., Abd Allah, E.F., Hashem, A., Alqarawi, A.A., Yadav, D., & Mohanta, T.K. (2018). Silver Nanoparticles Synthesized Using Wild Mushroom Show Potential Antimicrobi al Activities against Food Borne Pathogens. *Molecules: A Journal of Synthetic Chemistry and Natural Product Chemistry*, *23*.

Nagajyothi, P. C., Sreekanth, T. V. M., Lee, J. I., & Lee, K. D. (2014). Mycosynthesis: antibacterial, antioxidant and antiproliferative activities of silver nanoparticles synthesized from Inonotus obliquus (Chaga mushroom) extract. *Journal of Photochemistry and Photobiology B: Biology*, *130*, 299-304.

Nguyen, V. P., Le Trung, H., Nguyen, T. H., Hoang, D., & Tran, T. H. (2021). Synthesis of biogenic silver nanoparticles with eco-friendly processes using Ganoderma lucidum extract and evaluation of their theranostic applications. *Journal of Nanomaterials*, *2021*.

Sudheer, S., Bai, R. G., Muthoosamy, K., Tuvikene, R., Gupta, V. K., & Manickam, S. (2022). Biosustainable production of nanoparticles via mycogenesis for biotechnological applications: A critical review. *Environmental research*, *204*, 111963.

Wachtel-Galor S, Yuen J, Buswell JA, et al. Ganoderma lucidum (Lingzhi or Reishi): A Medicinal Mushroom. In: Benzie IFF, Wachtel-Galor S, editors. Herbal Medicine: Biomolecular and Clinical Aspects. 2nd edition. Boca Raton (FL): CRC Press/Taylor & Francis; 2011. Chapter 9

Xia, Y., & Halas, N. J. (2005). Shape-controlled synthesis and surface plasmonic properties of metallic nanostructures. *MRS bulletin*, *30*(5), 338-348.

Havacılık Sanayiinde Kullanılan Bir Parçanın Alüminyum Alaşım ve Karbon Fiber Takviyeli Kompozit Malzeme Mukavemet Analizi

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Özet

Modern uçak gövdelerinin en az yüzde 30-40'ı artık fiber takviyeli polimer kompozit malzemelerden yapılmaktadır ve bu alandaki teknolojik gelişmeler nedeniyle bu oran hızla artmaktadır. Bu çalışma, polimer kompozitlerin havacılık endüstrisindeki kullanımlarını ve sonlu elemanlar metodu ile yapılan karşılaştırmalı bir mukavemet analizini içermektedir.

Çalışmamızda, F-16 savaş uçaklarında hâlihazırda kullanılmakta olan ana iniş takımı FS 341.80 kodlu alüminyum alaşımlı yapısal parçasının geometrik yapısı, ağırlığı ve maruz kaldığı kuvvetler ile sınır şartları tespit edilmiştir. Mevcut parçanın, zorlu bir iniş senaryosu durumunda maruz kaldığı kuvvetlere göre sonlu elemanlar analizi ANSYS yazılımı ile yapılmıştır. Ardından, aynı parçanın karbon fiber takviyeli kompozit malzemeden sonlu eleman modeli oluşturulmuştur. Önceki senaryoda uygulanan yükleme durumu yeni modele de uygulanmıştır. Her iki malzeme ile oluşturulmuş modellerdeki eşdeğer gerilme, eşdeğer toplam gerinim, maksimum kayma gerilmesi ve toplam deformasyon değerleri sayısal olarak hesaplanmıştır. Her iki malzeme için elde edilen sonuçlar karşılaştırılmıştır. Karşılaştırma sonucunda aynı yükleme ve sınır şartları için kompozit malzemede eşdeğer gerilme değerlerinde, eşdeğer toplam gerinim değerlerinde, maksimum kayma gerilmesi değerlerinde ve toplam deformasyon değerlerinde azalma olduğu görülmüştür. Bunun yanında parçanın toplam ağırlığında da azalma sağlanmıştır. Bu gelişmenin, uçağın ağırlığı azaltmanın yanında yorulma ömrünü ve bakım süresini de uzatması beklenmektedir.

Anahtar Kelimeler: F-16 savaş uçağı, ağırlık azaltma, karbon fiber kompozit malzeme, sonlu elemanlar metodu

Giriş

Modern havacılık endüstrisi oldukça ilericidir ve polimer kompozit malzemelerin bunun üzerinde olumlu ve önemli bir etkisi vardır. Modern uçak gövdelerinin en az yüzde 30-40'ı artık bu kompozitlerden yapılmaktadır ve bu alandaki teknolojik gelişmeler nedeniyle bu oran hızla artmaktadır. Fiber takviyeli polimer kompozit malzemeler, uçak ve uzay araçlarının yapımında tercih edilen malzemeler olarak hızla yer kazanmaktadır. Bu çalışma, polimer kompozitlerin bileşenleri, özellikleri ve havacılık endüstrisindeki kullanımları ile sonlu elemanlar metodu ile yapılan mukavemet analizi hakkındadır.

Kompozit malzemeler biraz daha pahalı olmalarına rağmen, ağırlık olarak hafif ancak ağır yükleri taşıyacak kadar güçlü olması gereken yüksek performanslı ürünler olarak daha fazla popülerlik kazanmışlardır. Uzay aracı yapıları (hem birincil hem de ikincil yapılar), tekne ve gemi gövdeleri, bisiklet ve yarış arabası gövde çerçeveleri, rüzgâr türbini kanatları vb. bunlardan bazılarıdır. Bu malzemeler ayrıca tekrarlanan kalkış/iniş operasyonlarında diğer metallere göre daha fazla yorulma direnci sağlayarak, uçağın ömrü boyunca gerekli olan denetim sıklığında ve bakım maliyetlerinde azalmaya neden olurlar [1].

Kompozit malzemelerin yaygınlığı, güvenilirliği ve üstün özellikleri arttıkça, uçaklarda gövde ve kanat gibi birincil yapıların yapımında kullanımları da artmıştır. Örneğin: öncelikle, F-15E'de uçak yapılarının imalatında kullanılan kompozitlerin ağırlık yüzdesi çok düşüktü, yaklaşık %2 idi. Bununla birlikte, F/A-18E/F'de ve F-22 savaş uçaklarında ağırlık yüzdesi sırasıyla %19'a ve %25'e kadar, önemli ölçüde artmıştır [2,3].

Gerçekleştirdiğimiz çalışmada, F-16 uçaklarında kullanılmakta olan ana iniş takımının alt bölümünde bulunan alüminyum alaşımlı FS 341.80 kodlu yapısal parçanın, karbon fiber malzemeden üretilmesi senaryosu ele alınmış ve kompozit malzeme mukavemet analizi ANSYS Sonlu Elemanlar Yazılımı kullanılarak yapılmıştır.

Çalışmamızda temel olarak, F-16 uçaklarında, alüminyum alaşımdan imal edilmiş bazı parçaların yerine kompozit malzemeden üretilmiş parçalar kullanılması suretiyle ağırlık azaltılabilir mi sorusuna cevap aranmıştır. Bu amaçla önce, envanterde mevcut parça üzerinden sağlanan ölçülendirilmiş teknik çizimlere dayanarak, Unigraphics NX 7.5 CAD yazılımı ile bir 3D model oluşturuldu ve ardından eşdeğer statik analizleri gerçekleştirmek için ANSYS Sonlu Elemanlar yazılımına aktarıldı. Bu analizler, bileşenin plastik alana girip girmediğini ve en kötü durumda kullanım ömrü boyunca kırılma meydana gelip gelmeyeceğini belirlemeyi amaçlamıştır.

Karbon fiber ve alüminyum malzemelere ait ayrı ayrı mukavemet analizleri yapılarak karşılaştırılmıştır. Ayrıca kütlesel olarak avantaj elde edilmiş bunun da harekât kabiliyetine sağladığı katkılar belirtilmiştir. [4,5]

Kritik Bileşen Seçimi

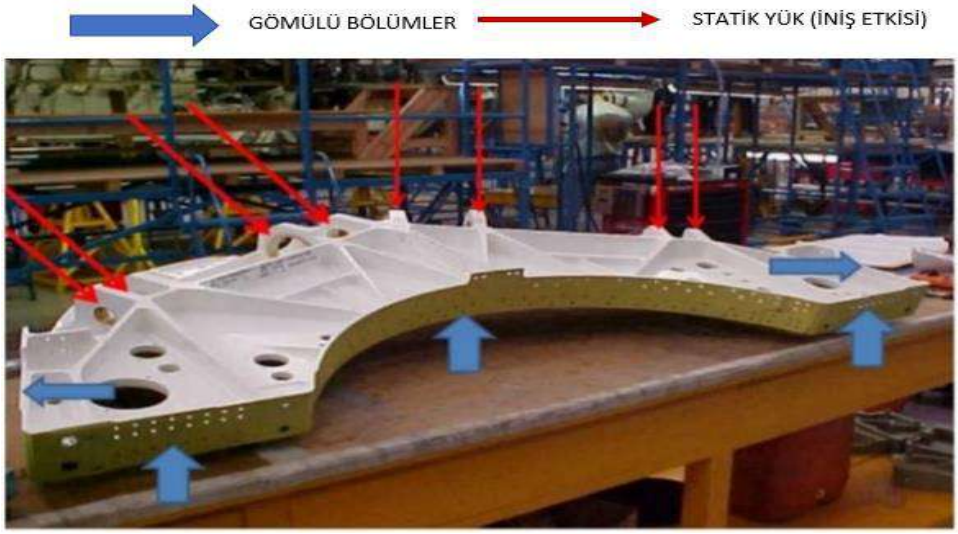
Bu çalışma için, F-16 savaş uçağında gerçekleştirilen yapısal değişikliklere dayanarak, değiştirilen bileşenlerden birinin seçilmesine ve eşdeğer statik analizinin yapılmasına karar verildi. Değiştirilmesi hedeflenen çeşitli bileşenlerden ana iniş takımının alt bölümünde bulunan FS-341.80 kodlu parça çalışma için seçildi.

Ana iniş takımı, özellikle adından da anlaşılacağı gibi, inişte uçaklar için son derece önemlidir. Bu iniş aşamasında, uçak diğer tüm aşamalardan daha fazla çaba harcar. Şekil 1'de görülen bu parça, uçak gövdesi ile iniş takımı arasındaki bağlantıyı sağlayan bileşen olduğundan, iniş sırasında uçağın çoğu bileşeninden çok daha fazla kuvvete maruz kalmaktadır.[6-9]

Şekil 1: FS 341.80 numaralı parça

Mukavemet Analizi

Parçaya uygulanacak sınır koşulları, bu bileşenin montajının uçağın kendisinde yorumlanmasına dayanmaktadır. Şekil 2'de görülebileceği gibi, mavi oklar, bileşenin takıldığı yerlere karşılık gelir ve uçağın diğer bileşenlerine/yapılarına cıvatalı bağlantıları temsil eder. Bu bağlantılar yukarıdan ana iniş takımının üst parçasına, yanlardan gövde kaplamasına ve merkezi kavisli yüzeyden motor bölmesine yapılır.[10]



Şekil 2: FS 341.80 uygulanan kuvvetler

Kuvvet Büyüklüklerinin Hesaplanması

(1) denkleminde mF16 uçağın kütlesini, $aF16$ ivmesini ve viniş yer tepki kuvveti yönündeki hızı temsil eder. m_{F16} değeri için azami kalkış ağırlığı, F-16 Block 50 modeli referans alınarak 19200 kg alınmıştır. Senaryolara göre mühimmat ve yakıt ağırlıkları da hesaplamaya dâhil edilmiştir.

$$F = m_{F16}.a_{F16} = m_{F16}\frac{v_{iniş}}{\Delta t} \quad (1)$$

Çarpma şeklinde ani bir iniş olduğundan Δt değeri 0,1 saniye olarak kabul edilmiştir. Literatürde, F-16'nın maksimum iniş hızının (güvenli sınırlar içinde bir iniş için) 160 knot olduğu ve SI birimlerine dönüştürüldüğünde 82.31 m/sn veya daha belirgin olarak 296.32 km/saat'e ulaştığı bulunmuştur. F-16'yı indirmek için ideal hücum açısı, 11°<AoA<15° aralığında olup Hücum Açısı (AoA)=13° olarak kabul edilmiştir [11].

İniş yapan bir F-16 için, tekerleklerin yere temas ettiği andaki zemin reaksiyonu yönündeki hız bileşeni şu şekilde hesaplanmıştır:

$$v_{iniş} = v\ sin\ AoA \quad (2.2)$$

Burada v, uçağın kendi hareket yönü doğrultusundaki hızıdır. Ayrıca,

$$W_{F16} = W_{MKA} - W_{cmin} - W_{Yakıt} = 19200 - 4500 - 1000 = 13700\ \text{kg} \quad (2.3)$$

(3) numaralı denklemde W_{MKA}, Maksimum Kalkış Ağırlığını, W_{cmin} inişte taşınan minimum mühimmat ağırlığını ve $W_{Yakıt}$ uçuş esnasında tüketilen minimum yakıtın ağırlığını temsil eder. Buna göre uçağın inişteki en düşük ağırlığı 13700 kg olur.

Uçağın havalandığı ve çok kısa bir süre sonra tespit edilen bir arıza nedeniyle acil iniş yapması gerektiği kurgulanmıştır. Bu durumda kütlesi yaklaşık olarak kalkış anının kütlesine eşit, yani, yaklaşık 18750 kg olarak alınmıştır. İniş hızı yine 296,32 km/s (160 knot)'tir. Bu durumlarda, iniş sırasında uçağın kütlesini azaltmak için yakıtın önemli bir yüzdesi kasıtlı olarak püskürtülür, ancak yakıtın püskürtülmediği durum yalnızca simülasyon amacıyla değerlendirilmiştir.

Bahsedilen durum Tablo 1'de özetlenmiş olup, parçanın deliklerine gelen kuvvetler Tablo 2'de verilmiştir. Eksi işareti basma etkisinin gerçekleştiğini gösterir. Tablo 3'te ise parçaların malzeme özellikleri belirtilmiştir [12].

Tablo 1: İniş durum bilgileri

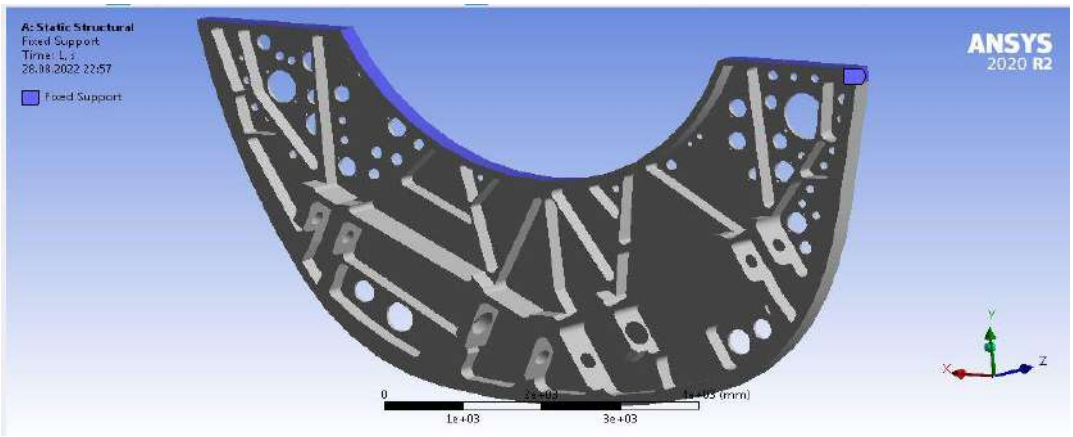
İniş ağırlığı (kg)	İniş hızı (km/sa)	Tek/çift tekerlek teması
18750	296,32	Çift

Tablo 2: Parça delikleri üzerindeki kuvvetler

Delikleri zorlayan şok desteği, basma kuvveti [kN]	Gerilme desteği, deliklere etkiyen çekme kuvveti [kN]
–1748,40	768,85

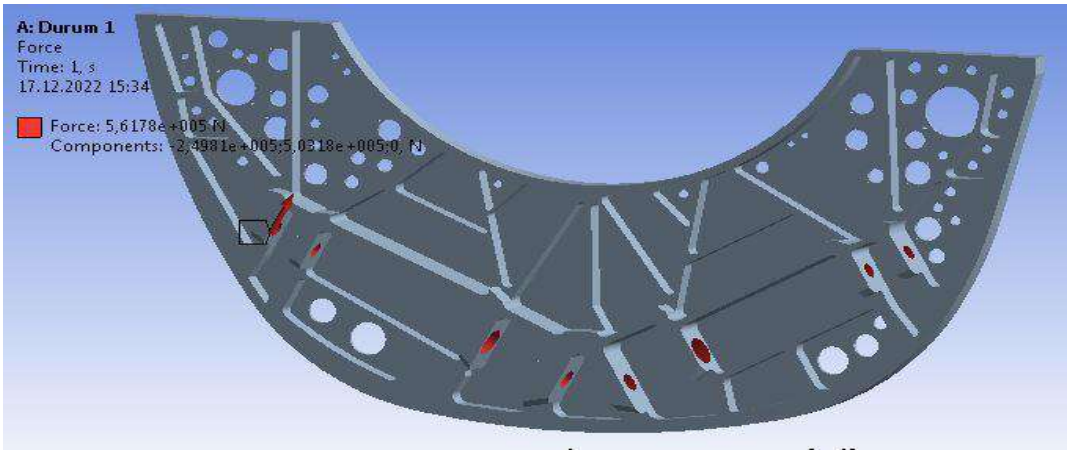
Tablo 3: Parçaların malzeme özellikleri

Malzemenin Mekanik Özellikleri	Mevcut malzeme (2024-T351)	Yeni malzeme (Kompozit)
Akma Gerilmesi, $\boldsymbol{\sigma_y}$ [MPa]	241,32	400
Kopma Gerilmesi, $\boldsymbol{\sigma_{UTS}}$ [MPa]	351,63	450
Elastisite Modülü, $\boldsymbol{E}$ [GPa]	73,77	395
Kayma Modülü, $\boldsymbol{G}$ [GPa]	27,58	141,07
Poisson katsayısı, $\boldsymbol{\nu}$	0,33	0,4
Termal Genleşme Katsayısı, $\boldsymbol{\alpha}$ [$^oC^{-1}$]	$2{,}27\times10^{-5}$	$4{,}45\times10^{-5}$



Şekil 3: FS 341.80 mesnet yüzeyi

Şekil 3'te mesnet yüzeyleri görünmektedir.

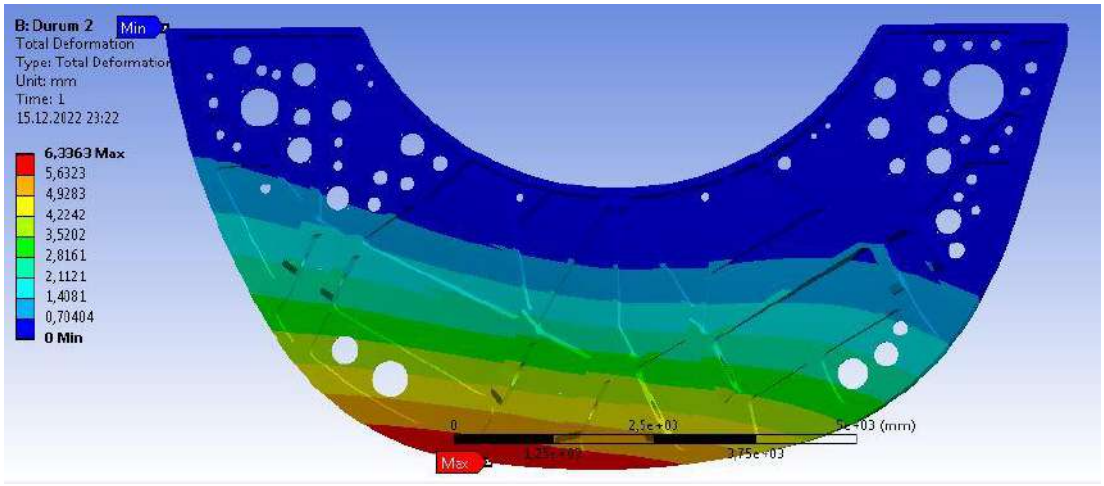


Şekil 4: Parçaya uygulanan kuvvetler

Şekil 4'te parçaya uygulanan kuvvetler ve uygulama noktaları görülmektedir.

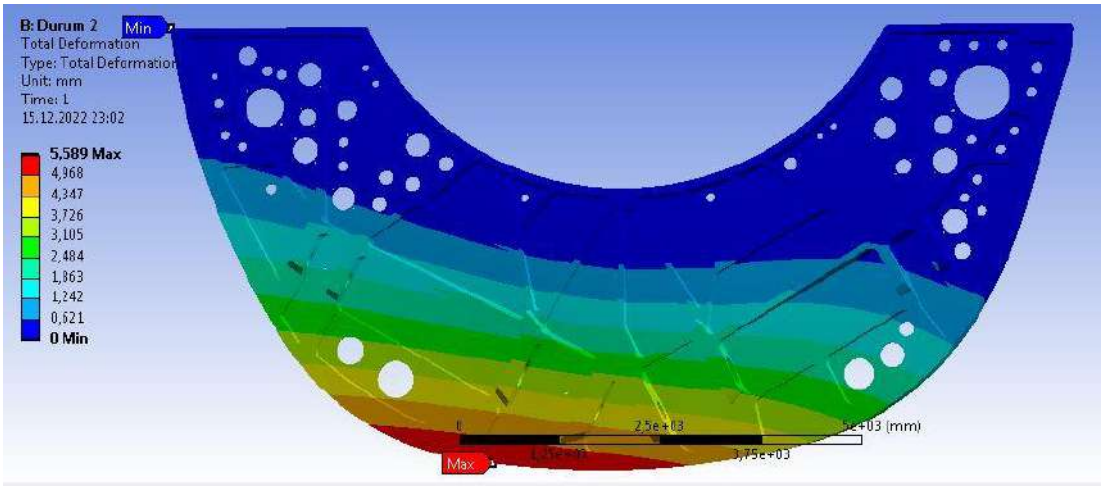
Yukarıda gösterilen mesnet yüzeyleri, kuvvet değerleri ve kuvvetlerin uygulama noktaları esas alınarak ANSYS Workbench ile hem mevcut alüminyum alaşımlı parçanın hem de önerilen karbon fiber takviyeli kompozit malzemeden üretilmiş parçanın mukavemet analizi yapıldı. Yükler, uçağın iniş esnasında karşılaşabileceği durumlar göz önüne alınarak hesaplandı.

Senaryoda, uçağın havalandığını ve bir süre sonra tespit edilen bir arıza nedeniyle acil iniş yapması gerektiği kurgulanmıştır. Senaryoya bağlı yapılan analizler neticesinde; toplam deformasyon değerinde %11,9, eşdeğer (von-Mises) gerilme değerinde %0,8, eşdeğer toplam gerinim (şekil değiştirme) değerinde %12 ve maksimum kayma gerilmesi değerinde %0,7 azalma sağlanmıştır. Her iki malzeme için analiz sonucunda hesaplanan deformasyon değerleri bulunmuştur. Şekil 5'te alüminyum parçaya ait toplam deformasyon sonuçları görülmektedir.



Şekil 5: Alüminyum- Toplam Deformasyon

Şekil 6'de karbon fiber parçaya ait toplam deformasyon sonuçları görülmektedir.



Şekil 6: Karbon Fiber- Toplam Deformasyon

Tablo 4'te parçaya ait toplam deformasyon değerleri karşılaştırmalı olarak verilmiştir.

Tablo 4: Toplam maksimum deformasyon değerleri (mm)

Alüminyum	Karbon Fiber	Değişim Oranı (%)
6,3363	5,5890	0,117939

Sonuç

F-16 savaş uçaklarında kullanılan mevcut alüminyum alaşımlı parçanın mukavemet analizi Sonlu Elemanlar Metodu kullanılarak ANSYS Workbench ile yapıldı. Aynı parçanın teknik ölçüleri değiştirilmeksizin karbon fiber malzeme için de analiz çalışması yapıldı. Yükler, uçağın iniş esnasında karşılaşabileceği durumlar göz önüne alınarak hesaplandı.

Senaryoda, uçağın havalandığını ve bir süre sonra tespit edilen bir arıza nedeniyle acil iniş yapması gerektiği kurgulanmıştır. Senaryoya bağlı yapılan analizler neticesinde; toplam deformasyon değerinde %11,9, eşdeğer (von-Mises) gerilme değerinde %0,8, eşdeğer toplam gerinim değerinde %12 ve maksimum kayma gerilmesi değerinde %0,7 azalma sağlanmıştır.

Alüminyum ile benzer mukavemet özelliklerine sahip ve yaklaşık olarak 20,77 kg ağırlığa sahip olan kompozit malzeme kullanımı ile analizi yapılan F-16 parçasının toplam ağırlığında %33,37 oranında azalma sağlanmıştır.

Söz konusu ağırlık kazanımı tek parça için olup çalışma diğer yapısal parçalar için yapıldığında ağırlık kazanımı çok daha iyi seviyelerde olacaktır. Böylece F-16 savaş uçağının harekât kabiliyeti, mühimmat miktarının arttırılması, yakıt tasarrufu sayesinde arttırılabilecek ve savaş uçaklarımız sahada daha etkin kullanılabilecektir.

Günümüz koşullarında analiz sonuçlarını sağlayacak kompozit malzeme üretimi maliyetli ve zor olacaktır. Ancak gelişmekte olan teknoloji, yeni hammadde arayışları, havacılık alanında yapılan çalışmalar, harekât doktrinlerinin gelişmesi gibi nedenlerle yakın gelecekte kompozit malzemeli yapısal parçalar da üretilecek ve kullanılacaktır.

Kaynaklar

[1] Irving P, Soutis C. Polymer Composites in the Aerospace Industry, 2nd ed. Elsevier; 2014.

[2] Park SJ. Recent Uses of Carbon Fibres, 2nd ed. Springer; 2018.

[3] Mrazova M. Advanced composite materials of the future in aerospace industry. INCAS Bulletin 2013; 5(3): 139-150. doi.org: 10.13111/2066-8201.2013.5.3.14

[4] Anonymous. USAF sheet, International Directory of Military Aircraft,[72] Flight Manual for General Dynamics F-16 Fighting Falcon F-16C/D; 2016.

[5] Turkish Air Force, Structural Repair Technology, 16-351, 2014.

[6] Anonymous. Aerospace & Defense Thermoplastic Composites Market Report, Report code - SRAD156, 288 sayfa, 2021.

[7] Atique Md SA, Probha NN, Nafi AS. Polymer composites: a blessing to modern aerospace engineering, International Conference on Mechanical, Industrial and Energy Engineering; 2014 Dec 26-27 Khulna, Bangladesh.

[8] Deo R, Starnes JH, Holzwarth R. Low-Cost Composite Materials and Structures for Aircraft Applications. 2003.

[9] Nayak VN. Composite Materials in Aerospace Applications. International Journal of Scientific and Research Publications 2014; 4(9): 1-10.

[10] Kesarwani S. Polymer Composites in Aviation Sector: A Brief Review Article. International Journal of Engineering Research & Technology 2017; 6(6) doi:10.17577/IJERTV6IS060291

[11] Anonymous. Learning to Land the F-16 the Viper Pilot way. 2015.

[12] Baş O, Ateş E, Öztürk F. Thermoplastic Composite Materials for the Aerospace Industry. Research & Development in Material Science 2021; 15(5): 1745-1748.

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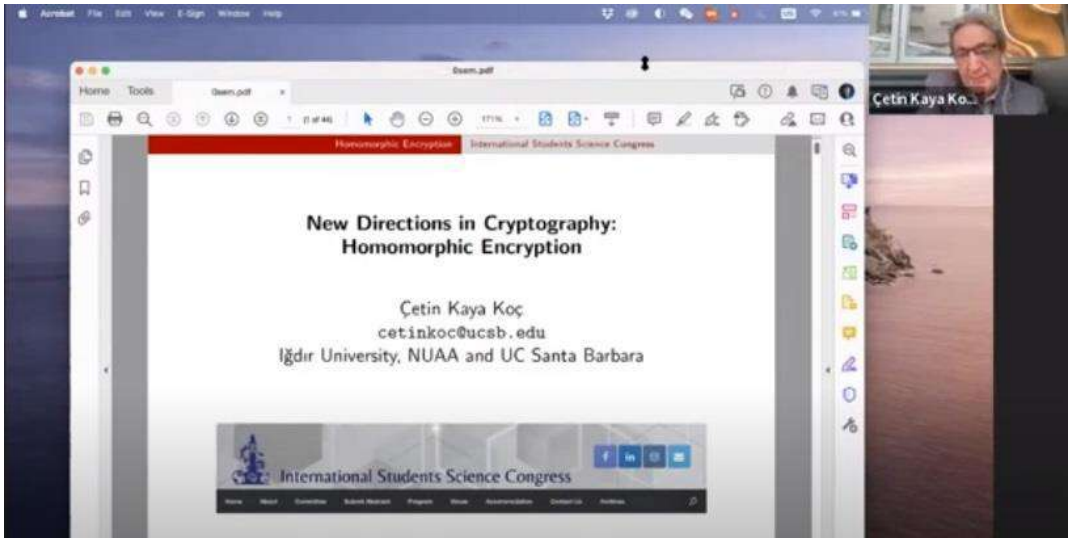
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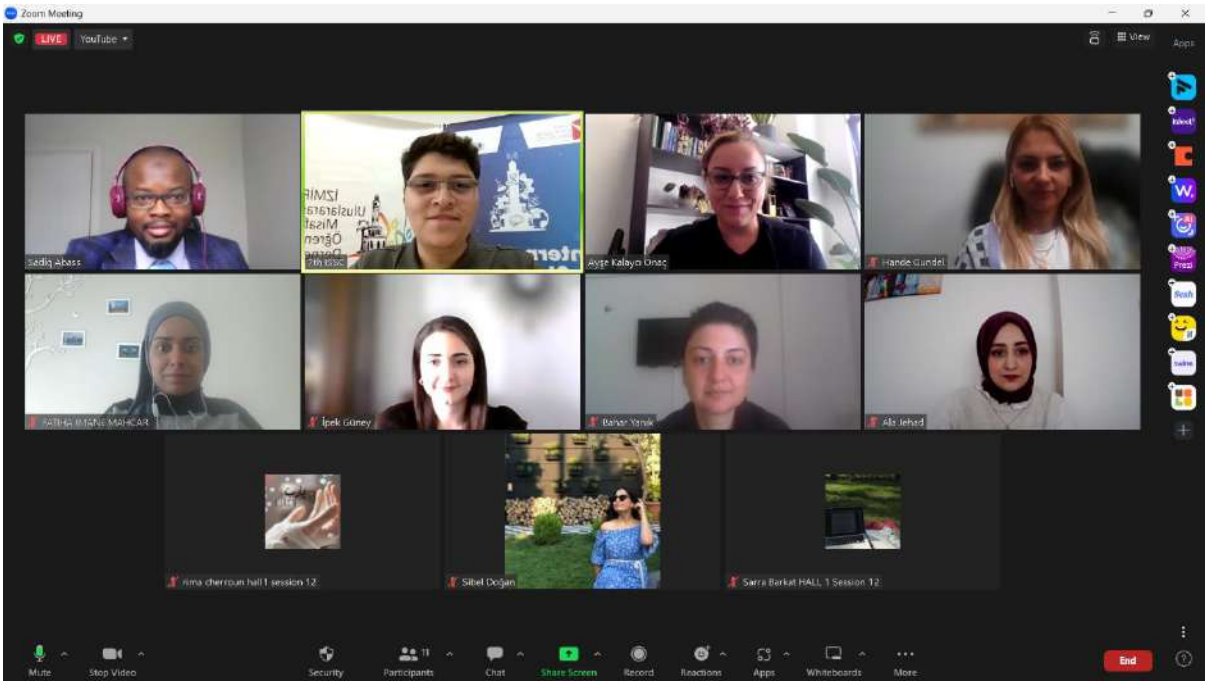
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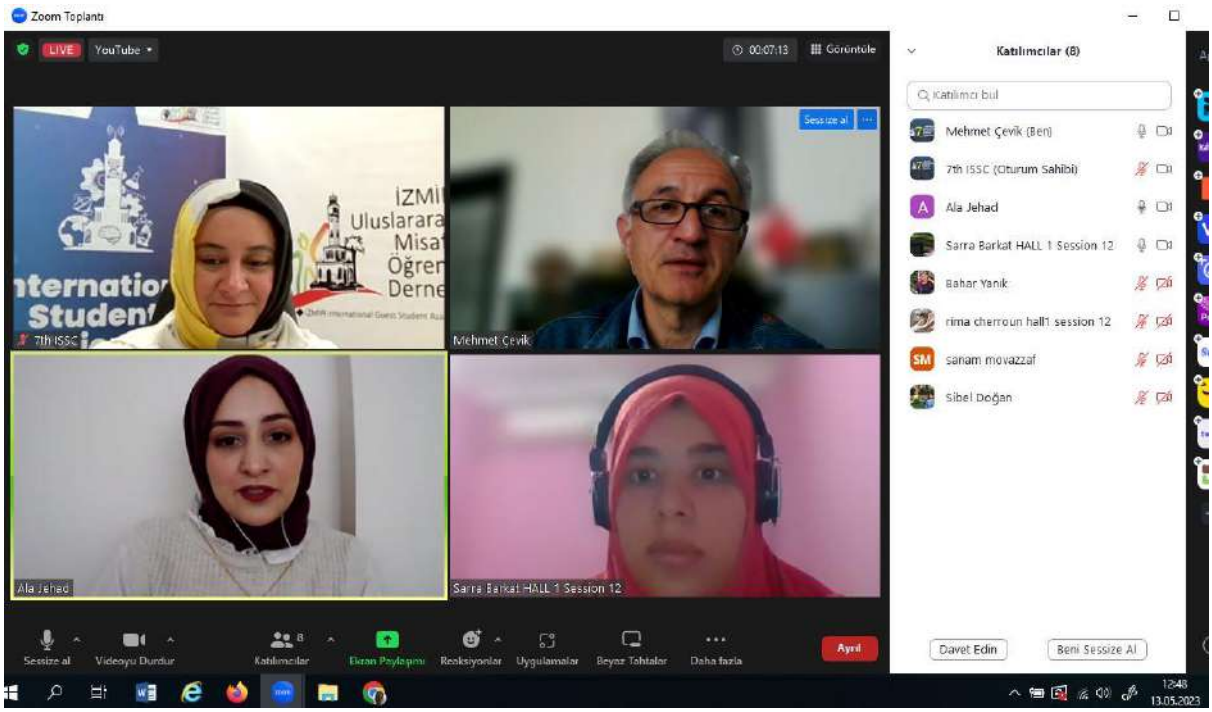
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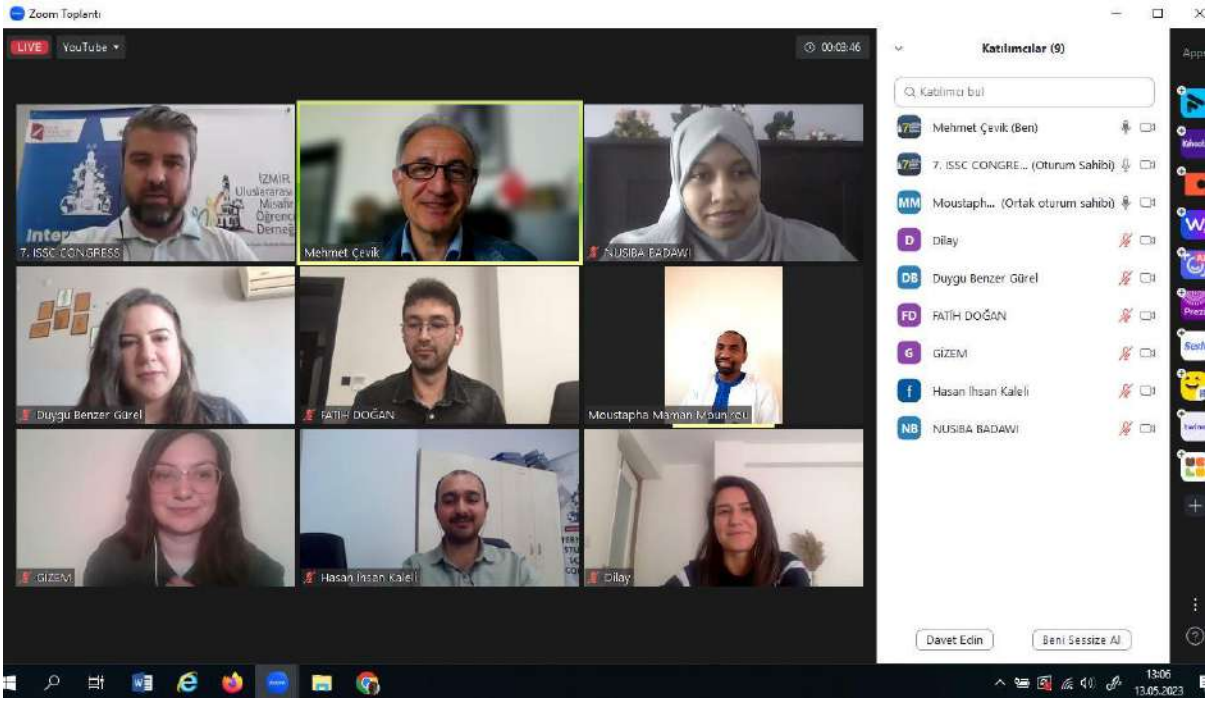
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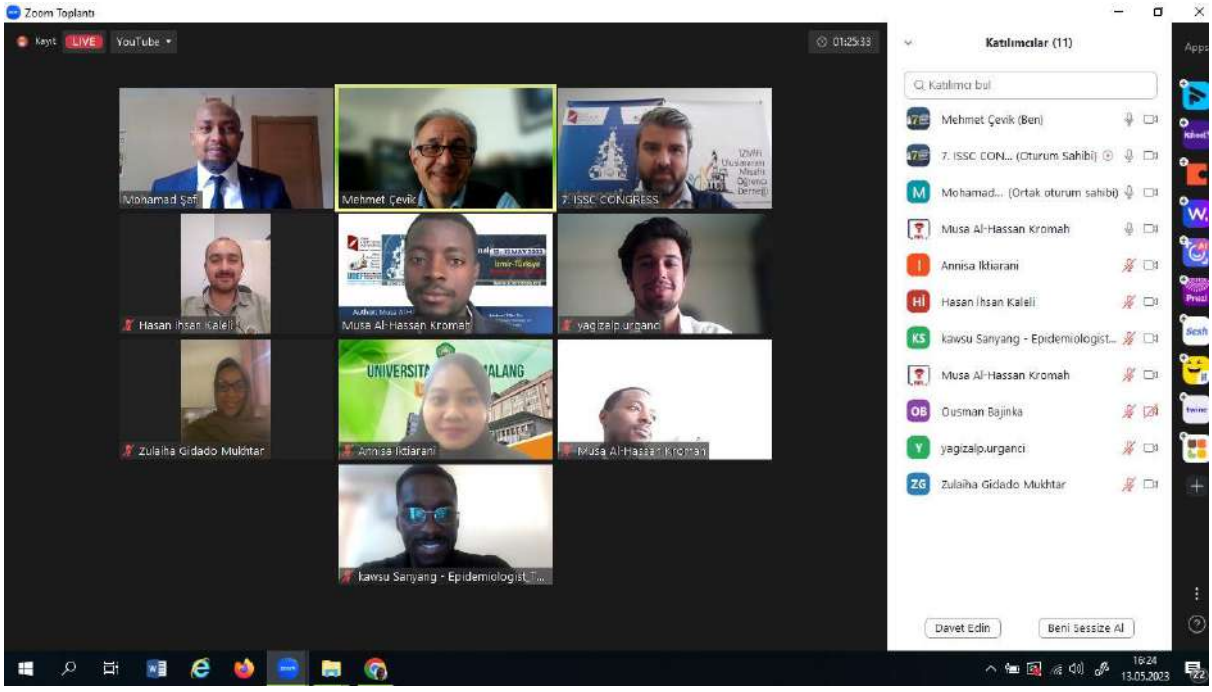
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