GIDA BİLİMLERİ VE MÜHENDİSLİĞİ

Editör: Dr.Öğr.Üyesi Hicran UZUN KARKA

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İÇİNDEKİLER

GIDA ENDÜSTRİSİNDE YAPAY ZEKÂ UYGULAMALARI

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1. GİRİŞ

Yapay zekâ, (Artificial Intelligence: AI), tipik olarak insan zekası gerektiren görevleri yerine getirebilen bilgisayar sistemlerinin geliştirilmesini bir başka deyişle bilgisayarların ve makinelerin insanlar gibi düşünmesini, öğrenmesini, karar vermesini ve sorunları çözmesini sağlayan bir bilim dalıdır (Chowdhary, 2020). Teknolojinin hızla geliştiği günümüzde yapay zeka, makinelerin, bilgisayar programlarının ve sistemlerin problem çözme, karar verme ve sonuç çıkarma gibi yaratıcı işlevlerini bağımsız olarak yerine getirmesini sağlamaktadır (Rozhkova vd., 2022).

Alan Turing'in 1950 yılında Mind dergisinde yayımlanan "Computing Machinery and Intelligence" başlıklı makalesi yapay zeka tarihinde dönüm noktası olarak kabul edilmektedir (Turing, 2009). Turing testi olarak adlandırılan bu fikirle Alan Turing, bilgisayar bilimlerinin temel taşlarını oluşturmuş ve makinelerin de insanlar gibi düşünüp düşünemeyeceğinin sorgulanmasına yol açmıştır. Turing'e göre, makineye (bilgisayara) sorulan herhangi

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bir soruya makine insanınkinden ayırt edilemeyecek derecede cevap verebiliyorsa makine gerçekten düşünmektedir. Turing'in bu sorusunun cevabını ise, 1956 yılında J. McCarthy, M. L. Minsky, N. Rochester ve C. H Shannon adlı bilim adamları Dartmouth Konferansında cevaplandırmaya çalışmışlardır (McCarthy, 2007; Çoşkun vd., 2021).

Baker ve Smith'e, (2019) göre yapay zeka; öğrenme ve problem çözme sürecine dayalı olarak, genellikle insan zihniyle ilişkilendirilmiş bilişsel işlevleri olan bilgisayarlar olarak tanımlanmakta iken Zeide'e (2019) göre ise AI insan aklının ürünü olarak çalışan makineler ve bu makinelere verilen komutların bir bütünü olarak ifade edilmektedir. Yapay zekanın alt dalları da kendi içerisinde oldukça önemli olup, her bir alanda çalışmalar süratle artmaktadır. Bu alt dallara örnek olarak makine öğrenmesi (Machine Learning), yapay sinir ağları, derin öğrenme, bulanık mantık, bilgisayarlı gömü, görüntü işleme yöntemleri verilebilir. Yapay zeka teknolojileri, gıda kalite kontrolünde, gıdaların sınıflandırılmasında, üretim aşamalarının kontrolü ve otomasyonun sağlanması gibi süreçlerde etkili olmuş ve gıda endüstrisinde talebin artmasına yol açmıştır (Mavani vd., 2021).

Bu çalışmada, teknolojinin hızlı ilerleyişine paralel olarak, yenilikçi ve akıllı teknolojileri kullanarak hızlı bir dönüşüm yaşayan gıda endüstrisinde yapay zekâ teknolojisinin kullanımı incelenmiştir. Özellikle artan nüfusla beraber gittikçe artan gıda talebini karşılamak, toplum ve gelecek için gıda güvenliğini sağlamak, sürdürülebilir gıda sistemleri uygulamaları için yapay zekânın bu sisteme nasıl entegre olacağı konuları ele alınmıştır. Gıda endüstrisinde yapay zeka teknolojilerinin devreye girmesiyle beraber, geleneksel üretim yöntemlerinin yanında yapay zekanın sistemdeki sorunlara nasıl çözüm bulduğuna dair çeşitli araştırma ve uygulamalarla konuya açıklık getirilmeye çalışılmıştır.

2. GIDA ENDÜSTRİSİNDE YAPAY ZEKÂ UYGULAMALARI

2.1. Gıda Endüstrisindeki Temel Sorunlar

Nüfusun hızlı artışı, kaynakların azalması, iklim krizi ile beraber tarımda yaşanan sorunlar, değişen beslenme alışkanlıkları, sağlıklı beslenmeye olan talebin artması, gıda üretiminin daha verimli ve sürdürülebilir hale getirilmesini zorunlu kılmaktadır. Kovid-19 pandemisi sonrasında yaşanan toparlanma sürecinin dünyanın her yerinde eşit bir seyir izlemediği belirtilmektedir. Ayrıca yaşanan savaşlar, güvenli ve besleyici gıdalara erişimi de olumsuz yönde etkileyerek dünya genelinde gıda üretim miktarlarını da olumsuz etkilemiştir (Saxena & Suman 2021).

Birleşmiş Milletler Gıda ve Tarım Örgütü (FAO), mevcut eğilimlerin devam etmesi halinde, Sürdürülebilir Kalkınma Amaçları arasında yer alan '2030 yılına kadar açlığın sona erdirilmesi' hedefine ulaşmanın mümkün olamayacağı yönünde çeşitli uyarılarda bulunmaktadır. Son araştırmalar, açlıkla karşı karşıya kalan insan sayısında artış meydana geldiğini, 2019 yılında 613 milyon olan bu sayının 2023 yılında yaklaşık 735 milyona ulaştığını göstermektedir. Buna bir de 2050 yılına kadar, yaklaşık on kişiden yedisinin kentsel nüfusa dâhil olacağı öngörüsü eklendiğinde, yaşanan açlık, gıda güvensizliği ve dengesiz beslenmeyle mücadele alanında kentleşme eğilimlerinin de dikkate alınarak bu alanda da tedbirlerin alınması gerektiğine vurgu yapılmaktadır.

Gıda alanındaki en büyük sorunlardan birisi küresel nüfus artışı olup, Birleşmiş Milletler dünya nüfusunun 2050'ye kadar 9,7 milyar olacağını öngörmektedir. 2023 yılı verileri incelendiğinde yaklaşık 800 milyon insanın kronik açlık yaşadığı, 2 milyara yakın insanın da çeşitli vitamin ve mineral eksikliğinden kaynaklı beslenme yetersizliği ile mücadele ettiği belirtilmektedir. Buna gittikçe artan yaklaşık 2 milyara yakın obez ve aşırı kilolu insan nüfusunun başta sağlık olmak üzere yaşadığı sorunlar eklenmektedir. Gıda ile ilgili temel sorunlardan birisi de bir yandan açlık çeken insanlar varken diğer taraftan obezite ile mücadele eden nüfusun oldukça hızlı bir şekilde artış göstermesidir. Dolayısıyla gıdanın eşit olarak paylaştırılamaması sonucu bazı insanlar gıdaya erişim sağlayamazken diğer taraftan ihtiyacından fazlasını tükettiği için obezite ve buna bağlı hastalıklarla mücadele eden insanlar bulunmaktadır.

Gıda alanındaki diğer önemli problemlerden birisi de, gıda atıkları ve israfı konusudur. Gıda israfı, gıdanın tüketilmeden çöpe gitmesi veya tüketicinin ihtiyacından fazlasını satın alarak tüketememesi sonucu oluşan kayıplar olarak tanımlanabilir. Gıda atıkları ise genel olarak, üretimin ara basamaklarındaki kayıplar, gıdanın taşınması veya tüketiciye ulaşıncaya kadar olan kayıplar şeklinde tanımlanabilir (Soni & Saxena, 2020) . Bir de bunlara evlerde, restoranlarda gıdaların depolanması, pişirilmesi ve hazırlanması sırasındaki kayıpları eklersek, üretilen gıdanın yaklaşık üçte biri bu aşamalarda maalesef israf olmaktadır. Gıdada bu amaçla başlatılan önemli çalışmalardan birisi de sıfır atık uygulaması olup, bu uygulama insanların tüketeceği kadar almasını, gıdayı iyi saklamasını, hazırlanan ve pişirilen porsiyonlara dikkat ederek gıdanın tüm kısımlarından faydalanmasını öngörmektedir.

Bu yüzden çözülmesi gereken çok sayıda problemle karşı karşıya kalan tarım ve gıda sektörünün, verim açısından daha kazançlı, faaliyet açısından etkili, çevresel değişime karşı dayanıklı ve gelecekte insanlar için sürdürülebilir olabilmesi için çözüm yolları bulması gerekmektedir. Bilgisayar bilimlerinde yeni bir çığır açan yapay zeka (AI), bu yeni dünya görüşünün zorluklarını ele alma yeteneğine sahiptir. Gıda endüstrisinde yapay zeka ihtiyacının ortaya çıkmasının ana nedenleri de bunlardır.

2.2. Yapay Zeka Uygulamaları

Yapay zeka (AI), insan zekasının ve yeteneklerinin makineler, özellikle bilgisayar sistemleri, dijital ve robotik sistemler gibi makineler tarafından taklit edilmesiyle ortaya çıkan bir bilim dalıdır (Ben Ayed & Hanana, 2021). Yapay zekâ uygulamaları incelendiğinde, makine öğrenmesi, derin öğrenme, veri mühendisliği, doğal dil işleme, yapay sinir ağları gibi uygulama alanları ve metotlara bağlı olarak farklı uygulamalarla gerçekleştiğini söylemek mümkündür. Bu kategoriler, yapay zeka teknolojilerinin geniş uygulama alanlarını ve farklı teknik yaklaşımlarını kapsar. Her bir alt kategori, farklı problemlerin çözümüne yönelik özel teknikler ve araçlar sunar.

2.2.1. Makine Öğrenmesi

Makine öğrenimi, açıkça programlanmadan deneyimlerden otomatik olarak öğrenen ve uyum sağlayan bilgisayar sistemlerinin geliştirilmesini ifade etmektedir. Bir başka deyişle makinelerin (bilgisayarların) değişik veri türlerine uygun olarak yaptığı işlemlerden öğrenmesini olanaklı kılan algoritmaların tasarım ve geliştirme süreçlerini kapsamaktadır.

Bu sistemin amaçlarından birisi analiz edilemeyecek kadar çok büyük miktarlardaki verinin analizinin yapılmasını mümkün kılmak ve geçmişteki veya eldeki verileri kullanarak gelecek için tahminlerde bulunmaktır. Bununla ilgili olarak bir başka teknik de veri madenciliği adı verilen, verilerin incelenerek, içerisinden işe yarayan bilginin çıkarılarak ayıklanmasıdır. Makine öğrenmesinde, makine ne kadar çok veri ile analiz ederse, başarısı da o kadar çok artmaktadır.

Gıda mühendisliğinde makine öğreniminin uygulamalarına örnek verilecek olunursa; Zhang ve arkadaşları (2022), yaptıkları çalışmada makine öğreniminin gıda tedarik zincirinin hiperspektral görüntüleme (HSI) teknolojileriyle entegrasyonunu incelemiş ve kalite ve güvenlik denetimindeki rolünü araştırmışlardır. Hiperspektral görüntüleme, gıda ürünlerinin bütünlüğünün korunmasında kritik öneme sahip olan tahribata yol açmadan gıdaların kalite değerlendirmesine izin verdiği için bu ayrıca önem taşıyan bir görüntüleme yöntemi olarak bilinmektedir. Bu çalışma, makine öğrenimi algoritmalarının ayıklama, paketleme ve depolama süreçlerinde nasıl kullanılabileceğini ve nihayetinde gıda güvenliği ve kalite değerlendirmesini nasıl iyileştirebileceğini ana hatlarıyla ortaya koymaktadır (Zhang vd.,2022). Mohd Ali vd., (2021) yaptıkları çalışmada, gıda ve tarım ürünlerinin kalite denetimi için makine öğreniminin kullanımını araştırarak, sınıflandırma ve tahmine dayalı modelleme için kullanılan destek vektör makineleri, yapay sinir ağları gibi çeşitli algoritmaları incelemişlerdir (Mohd Ali vd., 2021).

Saha ve Manickavasagan (2021) ise yaptıkları çalışmada, gıda kalitesini belirlemek için hiperspektral görüntülere uygulanan makine öğrenimi tekniklerinin kapsamlı bir incelemesini sunarlarken, bulanık mantık ve karar ağaçları da dahil olmak üzere çeşitli algoritmaların gıda ürünlerinin analizindeki etkinliğini araştırmışlardır (Saha & Manickavasagan, 2021).

Yapılan çalışmalarda, gıda güvenliği ve kalite kontrol süreçlerini iyileştirmek için makine öğreniminin çeşitli uygulamaları da mevcuttur. Örneğin Pandey ve arkadaşlarının yaptıkları araştırmada (2023), makine öğrenimi algoritmalarının gıda üretim süreçlerini nasıl optimize edebileceğini, israfı nasıl azaltabileceğini ve gıda trendlerini nasıl tahmin edebileceğini ve böylece gıda endüstrisinde daha verimli operasyonlara nasıl katkıda bulunabileceğini ele almışlardır (Pandey vd., 2023). Yavuzer'in (2023) makine öğrenimi kullanarak balık kalitesinin hızlı tespiti üzerine yaptığı araştırma ise, bu tekniklerin gıdaların tazeliğini nasıl değerlendirebileceğini ve gıda ile doğrudan temas etmeden israfı nasıl önleyebileceğini göstermesi açısından önem taşımaktadır (Yavuzer, 2023).

2.2.2. Derin Öğrenme

En basit tanımıyla derin öğrenme, çok katmanlı sinir ağlarına verilen ad olarak tanımlanabilir. Derin öğrenmeyi bilgisayarların daha karmaşık sorunları çözmesini sağlayan bir makine öğrenimi altkümesi olarak da sınıflandırmak mümkündür. Derin öğrenme modelleri kendi kendilerine yeni özellikler de oluşturabilir. Derin öğrenme, bilgisayarlı görü ve ses tanıma, doğal dil işleme, tıbbi görüntü analizi ve oyun stratejileri gibi çeşitli alanlarda başarıyla kullanılmaktadır (Zhou vd., 2019). Ayrıca, otomotiv, eğlence, finans ve sağlık gibi sektörlerde de önemli rol oynar. Yapay sinir ağlarının yapısında birden çok katman bulunduğundan dolayı öğrenme süreci derindir. Her bir katman bir önceki katmandaki çıktıyı girdi olarak almaktadır. Burada öğrenme özellikler çıkarılarak gerçekleşir. Özellikler daha sonraki adımlarda model eğitimi için kullanılmaktadır.

Derin öğrenmenin en dikkat çekici özelliklerinden birisi, çeşitli alanlarda giderek daha fazla kullanılabilir hale gelen büyük miktarda veriyi işleme kapasitesidir. Örneğin, bilgisayarla görmede derin öğrenme, Evrişimsel Sinir Ağlarının (CNN) kullanımıyla görüntü sınıflandırma, nesne algılama ve yüz tanıma gibi görevlerde devrim yaratmıştır (Voulodimos vd., 2018). CNN yapısı temel olarak evrişimli katman, havuzlama katmanı ve tam bağlantılı katman olmak üzere üç katmandan oluşur. Bu katmanlardan geçen görsel, farklı işlemlerden geçirilerek derin öğrenme modeline girecek hale gelir. Bu ağlar özellikle etkilidir çünkü görüntülerdeki uzamsal hiyerarşileri yakalayabilir ve basit kenarlardan karmaşık nesnelere kadar farklı soyutlama düzeylerindeki özellikleri öğrenmelerine olanak tanır.

Son yıllarda derin öğrenme; görüntü sınıflandırma, nesne algılama ve doğal dil işleme gibi alanlarda kayda değer bir başarı göstererek gıda ile ilgili verileri analiz etmek için güçlü bir araç haline gelmiştir. CNN'lerin, görüntülere dayalı olarak gıda maddelerini tanımlamak ve kategorize etmek için kullanıldığı gıda görüntülerin sınıflandırılması dikkate değer bir uygulama alanı olarak öne çıkmaktadır. Örneğin Begum ve Hazarika (2021), gıda teknolojisindeki derin öğrenme uygulamalarına ilişkin kapsamlı bir inceleme yapmış ve CNN mimarilerinin, özellikle diyet takibi ve gıda kalitesi değerlendirmesi için yararlı olan görüntülerden yemeklerin içeriğini nasıl otomatik olarak tanıyabildiğini ortaya koymuştur (Begum & Hazarika, 2021). Araştırmaları, derin öğrenmenin gıda sınıflandırma sistemlerini iyileştirme, daha verimli ve doğru hale getirme potansiyelini ortaya koyması açısından son derece önemlidir.

Bir diğer örnek ise, tedarik zincirini boyunca gıda kalitesinin korunmasının kritik önemini ortaya koyan Hamza vd. (2022) tarafından gerçekleştirilen çalışmadır. Bu çalışmada, tarımsal ürünlerdeki, özellikle de patatesteki hastalıkları tespit etmek ve sınıflandırmak için derin öğrenme tekniklerinin kullanımı araştırılmıştır. Çalışmaları, derin öğrenme algoritmalarının hastalıkları ve zararlıları tanımlamak için görüntüleri nasıl analiz edebileceğini ve böylece ürün yönetimini ve gıda güvenliğini nasıl iyileştirebileceğini göstermiştir (Hamza vd., 2022).

Pan ve arkadaşları (2017), yaptıkları çalışmada, görüntü iyileştirme tekniklerini derin öğrenme ile birleştirerek yeni bir "gıda tanıma yaklaşımı" ortaya koymuşlardır. Çalışmaları, derin öğrenme modellerinin sağlamlığını artırmak için, gerekli olan görüntü dönüştürme yoluyla veri kümesinin boyutunu artırarak gıda sınıflandırma sistemlerinin doğruluğunu artırmaya odaklanmıştır (Pan vd., 2017). Çalışmaları, gıda tanımaya yardımcı olmalarının yanı sıra, gıda endüstrisinde daha iyi envanter yönetimi, daha güçlü sınıflandırma ve atıkların azaltılmasına katkıda bulunması açısından önemlidir.

2.2.3. Veri Madenciliği

Veri madenciliği kavramı, büyük veri kümelerini derinlemesine inceleyip, belirli bir amaca yönelik değerlendirmeye uygun veriyi bulma işlemi olarak ifade edilir. Veri madenciliği, işletmelerin verimliliğini artıran önemli bir teknolojidir. Kurumlar veri madenciliğini kullanarak, iş süreçlerine değer katacak kıymetli verilere ulaşmaya çalışırlar. Öte yandan çok büyük veri setlerinin işlenmesi, depolanması, ayıklanması ve analiz edilmesi için gerekli olan teknik ve yöntemleri araştırır.

Gıda endüstrisinde veri mühendisliği uygulamaları, özellikle gıda işleme ve depolama aşamalarında önemli avantajlar sunmaktadır. Bunun yanında, gıda atıklarının yönetimi gibi sürdürülebilir uygulamalar da veri mühendisliği teknikleri ile desteklenmektedir. Gıda endüstrisinde veri mühendisliği, hem ekonomik kayıpları azaltmak hem de çevresel sürdürülebilirliği artırmak için kritik bir araçtır (Bačiulienė vd., 2023; Bajac vd., 2023).

2.2.4. Görüntü İşleme

Her ne kadar görüntü işleme çalışmalarıyla yapay zeka çalışmalarının birbirinden bağımsız olarak başladığı düşünülse de günümüzde birbirleriyle iç içe geçmiş olarak uygulandığını söylemek daha gerçekçi bir yaklaşım olacaktır. Görüntü işleme, bir görüntüyü dijital bir forma dönüştürme ve ondan bazı yararlı bilgiler elde etmek için belirli işlemleri gerçekleştirme sürecidir.

Gıda endüstrisinde görüntü işleme, gıda kalitesini, güvenliğini ve üretim verimliliğini artırmayı amaçlayan bir dizi uygulamayı kapsar. Bu teknoloji, gıda görüntülerini analiz etmek için çeşitli teknikler kullanarak gıda maddelerinin otomatik olarak tanımlanmasını ve sınıflandırılmasını, kalitenin değerlendirilmesini ve üretim süreçlerinin izlenmesini sağlar (Cárdenas-Pérez vd., 2017). Görüntü işlemenin yapay zeka ve makine öğrenimi ile entegrasyonu bu uygulamaları önemli ölçüde geliştirerek daha doğru ve verimli sistemlerin ortaya çıkmasını sağlamıştır.

Görüntü işleme tekniği kullanılarak, meyve ve sebzeler ağırlıklarına, boyutlarına ve renk özelliklerine göre sınıflandırılır. Geliştirilen sistem, hat başına saniyede 15 meyve işleme yeteneğine sahiptir (Pla vd., 2001). Görüntü analizi, gıda endüstrisinde ayrıca biyofilm oluşumunun izlenmesi ve kontrolü için de kullanılmaktadır. Biyofilm, gıda üretiminde hijyen sorunlarına yol açabilen bir durumdur ve görüntü işleme teknikleri ile bu oluşumların tespiti ve analizi sağlanabilmektedir (Tutar & Dinçer, 2017). Ayrıca, gıda endüstrisinde görüntü analizi, ürünlerin otomatik sınıflandırılması ve kalite kontrol süreçlerinde de önemli bir rol oynamaktadır. Örneğin, mısır yapraklarındaki hastalıkların tespiti için görüntü işleme teknikleri ve yapay zeka algoritmaları kullanılmakta, bu sayede hastalıkların hızlı bir şekilde tespit edilmesi sağlanmaktadır (Bütüner, 2023).

Görüntü işleme teknikleri, gıda ürünlerinin olgunluk derecesi ve hasat zamanını belirlemek için de yaygın olarak kullanılmaktadır. Örneğin, Ji ve arkadaşları (2012) muz olgunluğunu ölçmek için dijital bir görüntüleme yöntemi geliştirmiş ve görüntü işleme yazılımlarının muzun olgunluk derecelerini geleneksel spektrofotometrik yöntemlerden daha doğru bir şekilde tahmin edebildiğini göstermiştir (Ji vd., 2012).

2.3. Yapay Zeka Uygulamalarının Gıda Endüstrisinde Kullanım Alanları ve Avantajları

Gıda endüstrisi, gıdaların üretimi, işlenmesi, taşınması ve depolanması gibi pek çok işlemi bünyesinde barındıran, tarım, hayvancılık ve balıkçılık gibi ilgili endüstriler de dâhil olmak üzere çok çeşitli alanları kapsayan, üretimden tüketime kadar tüm gıda değer zincirini içeren büyük bir küresel endüstridir. Bu endüstri kolu, tüketicilerin taleplerine giderek daha zengin seçenekleri, gıda güvenliğini dikkate alarak sunmaktadır.

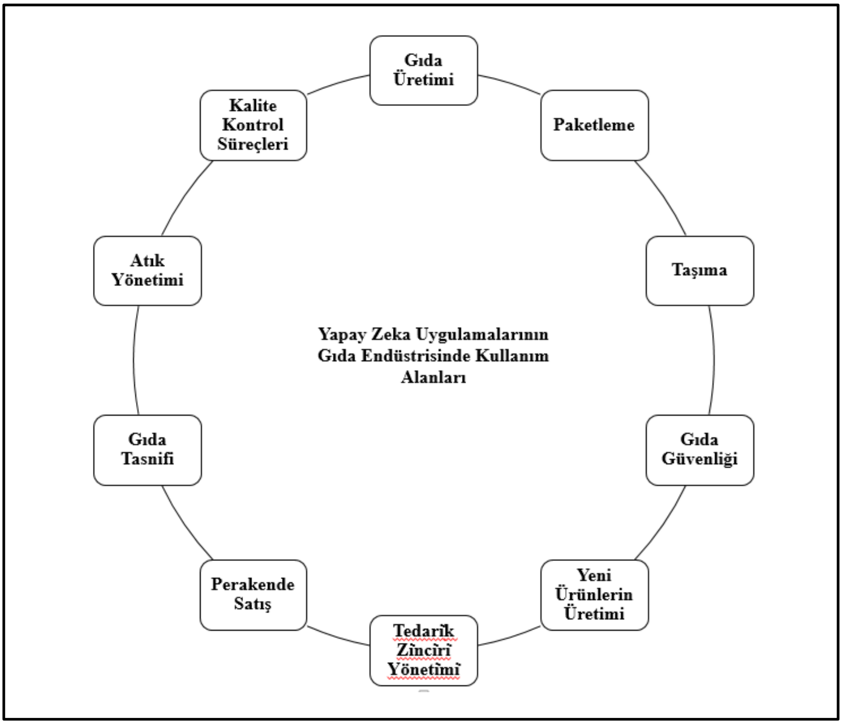
Endüstri 6.0, yapay zeka ve teknolojinin insan becerileriyle daha derin bir uyumunu ifade eden bir başka deyişle makinelerin yetenekleriyle insanların yaratıcılığını birleştiren bir dönem olarak ele alınmaktadır. (Kuosmanen, vd., 2021). Yapay zeka, büyük veri, 3D baskı teknolojisi ve blok zinciri teknolojisi gibi bazı yeni teknolojiler gıda sektöründe yaygın olarak kullanılmakla beraber Endüstri 6.0 sanayi evresi ile daha da yaygınlaşacaktır.

Yapay zeka uygulamalarının gıda endüstrisinde tarladan sofraya gelinceye kadar pek çok uygulama alanı mevcut olup teknolojinin gelişmesine bağlı olarak bu uygulama alanları gittikçe artmakta ve çeşitlenmektedir (Şekil 1).

Yapay zeka teknolojileri, gıda ürünlerinin üretim ve işleme süreçlerinde özellikle kalite kontrol ve denetim prosedürlerini büyük ölçüde geliştirmiştir. Yapay zeka destekli sistemler, gıdalardaki kusurlar ve hataları bulmak için gıda ürünlerinin resimlerini ve videolarını inceleyebilir, ürünlerin görsel özelliklerini belirlenen standartlarla karşılaştırarak hızlı ve kesin bir şekilde anormallikleri tespit edebilir. Bozuk veya hasarlı ürünlerin tüketicilere ulaşmasının önlenmesi, tutarlı ürün kalitesi ve güvenliğinin garanti edilmesine yardımcı olur. Yapay zeka destekli kalite kontrol sistemleri, insan kaynaklı oluşabilecek hataları ortadan kaldırarak işlemleri hızlandırır, işgücü, enerji ve ekonomik tasarruf sağlarlar.

Yapay zeka, tarım ürünlerinde verimliliği artırmak, maliyetleri düşürmek, çevresel etkileri azaltmak ve ürünlerin tüketiciye ulaşmasında en önemli kriterlerden birisi olan güvenli gıda sağlamak için yenilikçi çözümler sunar. Yapılan çalışmalar, yapay zeka uygulamalarının yaygınlaşmasıyla birlikte, sürdürülebilirlik ve verimliliğin daha da artacağını öngörmektedir.

Şekil 1. Yapay Zekâ Uygulamalarının Gıda Endüstrisinde Kullanıldığı Alanlar



Gıda güvenliğinin sağlanması için uygulanan teknolojilerden birisi de blok zinciri teknolojisidir. Blok zinciri teknolojisi, öncelikle üretici ve tüketici arasında izlenebilirliği ve şeffaflığı sağlamak, genel tedarik zincirinde verimliliği artırmak amacıyla gıda endüstrisinde dönüştürücü bir güç olarak ortaya çıkmıştır. Özellikle gıdanın menşeinin bilinmesi, tarladan sofraya kadar olan süreçte yolculuğunun takip edilmesi açısından önemli bir uygulamadır. Blok zinciri uygulamaları sürdürülebilir gıda sistemlerinin sağlanması, şirketler arası rekabeti teşvik ederek daha kaliteli ve ekonomik ürünler sunması, verimlilik açısından fayda sağlaması gibi avantajlara sahiptir (Gerdan vd., 2020).

Gıda üreticileri açısından yapay zekâ uygulamalarının avantajları ele alınacak olunursa şu faydaları sağladığı söylenebilir. Yapay zeka uygulamaları ile toprak analizleri yapılarak, en uygun ürünün yetişmesi için gerekli koşullar belirlenebilir, toprak sıcaklığı ve nemi kontrol edilebilir. Ürünün yeterli ve uygun zamanda sulanması sağlanabilir, su israfının önüne geçilebilir. Bitkide gelişen hastalıkların erken evrede tespiti mümkün olabilir, zirai mücadele başarıyla gerçekleştirilebilir. Ürün için en uygun hasat zamanı tespit edildiği gibi, hasat sonrası sevkiyat işlemleri planlanabilir. Yapay zeka ayrıca meteorolojik koşulların tespit edilmesinde kullanılarak üreticileri bilgilendirmede kullanılabilir.

Bu yeni teknolojilerin uygulanması üretimde verimliliği artırabilir, gıda atıklarını ve israfını azaltabilir, güvenli gıdaya ulaşmanın önünü açarak gıdanın kalitesini iyileştirebilir ve tüketicilerin beklentilerine daha büyük ölçüde hızlı çözümler üretebilir. Yapay zeka algoritmaları ile tüketici isteklerini analiz ederek kişiye özel beslenme planları oluşturmak, beslenme gereksinimlerine göre sağlıklı menüler oluşturmak da mümkün olabilir. Bu çerçevede yapay zeka uygulamaları yüksek ürün standartlarını sağlayarak, tüketici memnuniyetini sağlayan, güvenli gıda üretimini de sağlayabilecektir.

3. SONUÇ

Gıda endüstrisinde Yapay Zekanın (AI) kullanılmaya başlanması ile gıda ürünlerinin kalite değerlendirmesini kolaylaştırdığı görülmektedir. AI uygulamaları ile, gıda üretimini daha yetkin, güvenli ve kazançlı hale getirmek için birçok gelişmiş uygulama bulunmaktadır. Yapay zekâ, geleneksel yöntemlere göre birçok avantaj sunduğu için gıda sektöründe de yaygın olarak kullanılmaktadır. Tüm algoritmaların doğru ve güvenilir olduğu bilinmektedir, ancak algoritmaların avantajları ve sınırlamaları göz önünde bulundurularak gıda endüstrisindeki belirli bir uygulama için dikkatli bir seçim yapılmalıdır. Bir başka deyişle farklı algoritmaların kendilerine göre güçlü ve zayıf yönleri vardır, belirli bir uygulama için algoritma seçimi duruma göre değerlendirilmelidir.

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OXIDATION MECHANISM OF OZONE WITH FOOD PROTEINS

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1. INTRODUCTION

Ozone is generated in the Earth's atmosphere through the interaction of oxygen molecules (O2) with ultraviolet (UV) radiation. This interaction induces the dissociation of oxygen molecules into individual oxygen atoms, which subsequently react with additional oxygen molecules to form ozone. Ozone's potent oxidizing properties render it a valuable agent in water treatment, air purification, and industrial processes, due to its capability to react with and neutralize contaminants (Turhan, 2018). The high reactivity of ozone makes it an essential tool in numerous chemical processes. It is utilized for the oxidation of organic compounds, water disinfection, and the removal of odors and colorants in industrial applications.

Ozone, a powerful oxidizing agent, interacts with cellular constituents, including proteins, in food matrices, leading to diverse outcomes. Ozone treatment alter the secondary and tertiary structures of proteins, leading to a reduction in protein levels and potential changes in the functional properties of proteins in foods.

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2. CHEMICAL AND PHYSICAL PROPERTIES OF OZONE

Ozone, a triatomic oxygen molecule composed of three oxygen atoms, is a powerful oxidizing agent with a redox potential of 2.08 eV (Gupta, 2024; Kumar & Chandni, 2021). It is slightly soluble in water but more so in inert solvents like carbon tetrachloride and fluorocarbons. Physically, ozone is a pale blue gas at room temperature, condensing to a dark blue liquid and a violet-black solid at lower temperatures, and it has a sharp odor reminiscent of post-lightning storm air. Its boiling and melting points are -112 °C and -193 °C, respectively, with a gas density of 2.14 g/L at 0 °C and 1 atm, and a liquid density of 1.572 g/cm^3 at -182 °C. It exhibits broad-spectrum antimicrobial properties, making it a strong oxidizing biocide effective against bacteria and viruses (Appelgrein et al., 2016). Ozone is known for its role in atmospheric chemistry, where its formation from the photodissociation of oxygen molecules is crucial (Niwa et al., 1997). The molecule has a peak UV absorption wavelength at 254 nm (Le &Tao, 2011) and can be utilized in various applications such as bleaching, disinfection, and pollutant removal (Turhan, 2018; Venne et al., 2020; Afsah-Hejri et al., 2020).

3. CHEMICAL REACTIONS OF OZONE WITH BIOMOLECULES

Ozone (O3) possesses several chemical properties that make it highly reactive with biomolecules, including its strong oxidizing potential, ability to generate reactive oxygen species (ROS), and molecular structure. As one of the most powerful oxidizing agents known, ozone has a high oxidation potential (2.07 V), enabling it to react with a wide range of biomolecules, such as proteins, lipids, and nucleic acids by accepting electrons from other molecules, leading to their oxidation. In aqueous environments, ozone decomposes to produce various ROS, such as hydroxyl radicals (•OH), superoxide (O2•−), and hydrogen peroxide (H_2O_2), which are highly reactive and cause significant oxidative damage to biomolecules. Ozone's bent molecular structure, with a bond angle of about 117°, contributes to its high reactivity by making the molecule susceptible to reactions with nucleophiles. As an electrophile, ozone attracts and reacts with electron-rich sites in biomolecules, making it particularly reactive with double bonds and sulfhydryl groups in amino acids and other biomolecules. It readily reacts with double bonds found in unsaturated fatty acids and other organic compounds, leading to the formation of ozonides, disrupting cell membranes and other lipid-containing structures. The process of ozonolysis breaks double bonds and forms aldehydes, ketones, and peroxides, which can further react with other biomolecules (Rakovsky, et al., 2013).

Ozone can also react with specific amino acids, such as cysteine, methionine, and tryptophan, leading to the oxidation of these residues and resulting in alterations to protein structure and function, including the formation of carbonyl groups, which are markers of oxidative damage. Additionally, ozone can cause oxidative damage to DNA and RNA, leading to strand breaks, base modifications, and cross-linking, which interfere with replication and transcription processes. Ozone exposure can also deplete cellular antioxidant defenses, such as glutathione (GSH) and superoxide dismutase (SOD), making cells more susceptible to oxidative damage (Birben et al., 2012).

4. BASICS OF PROTEIN STRUCTURE: PRIMARY, SECONDARY, TERTIARY, AND QUATERNARY

Proteins, essential macromolecules in living organisms, exhibit a hierarchical structure comprising four levels: primary, secondary, tertiary, and quaternary structures. The primary structure refers to the linear sequence of amino acids linked by peptide bonds. This sequence determines the protein's unique identity and influences its folding pattern (Clark & Pazdernik, 2013). Secondary structure involves the local folding patterns of the polypeptide chain, primarily forming alpha helices and beta sheets stabilized by hydrogen bonds between amino acids. These structures contribute to the protein's stability and functionality (Greenfield, 2006). Tertiary structure represents the three-dimensional arrangement of secondary structural elements, forming the overall shape of the protein. It is crucial for the protein's function as it determines the active sites and binding regions. Tertiary structure is stabilized by various interactions like hydrophobic interactions, disulfide bonds, and electrostatic forces (Jumper et al., 2021). Quaternary structure refers to the arrangement of multiple protein subunits in a complex. Proteins with quaternary structure consist of two or more polypeptide chains known as subunits. The interactions between these subunits, such as hydrogen bonding and hydrophobic interactions, contribute to the stability and functionality of the protein complex (Brinda et al., 2005).

5. TYPES OF PROTEIN OXIDATION BY OZONE: CARBONYLATION, SULFHYDRYL OXIDATION, ETC.

Ozone-induced protein oxidation encompasses several specific types of modifications, each with distinct mechanisms and implications. Carbonylation involves the introduction of carbonyl groups (aldehydes or ketones) into protein side chains, typically affecting amino acids like lysine, arginine, proline, and threonine. This modification is often mediated indirectly by ozone through the generation of reactive oxygen species (ROS), leading to altered protein structure and function and serving as markers of oxidative stress. Sulfhydryl oxidation refers to the modification of thiol groups (-SH) in cysteine residues, which are highly reactive to ozone. Ozone oxidizes these thiol groups to form disulfides, sulfenic acid, sulfinic acid, and sulfonic acid, impacting protein folding and function, and potentially causing enzymatic activity loss and protein aggregation. Methionine residues are particularly sensitive to ozone and are oxidized to methionine sulfoxide and further to methionine sulfone, altering protein structure and function and affecting enzyme activity and protein-protein interactions. Aromatic amino acids like tryptophan, tyrosine, and phenylalanine can be oxidized by ozone, leading to the formation of various oxidative products, such as kynurenine and N-formylkynurenine from tryptophan, dityrosine from tyrosine, and hydroxylated derivatives from phenylalanine, which can disrupt protein structure and function, and cause protein cross-linking.

Ozone can also cause cleavage of the peptide backbone, leading to protein fragmentation, typically seen in regions with high oxidative stress, resulting in loss of protein function and generation of smaller peptides that might aggregate or be degraded by cellular mechanisms (Cataldo, 2003). Additionally, nitration and nitrosylation involve the addition of a nitro group (-NO2) to tyrosine residues and a nitroso group (-NO) to cysteine or other residues, respectively, often resulting from ozone's interaction with nitrogen oxides in the environment and forming reactive nitrogen species. These modifications can alter enzyme function and affect signal transduction pathways and protein-protein interactions. Detection and analysis of these oxidative modifications are facilitated by mass spectrometry, which identifies specific oxidative changes on amino acids, spectroscopy techniques like UV-visible and fluorescence spectroscopy, western blotting for detecting carbonylated proteins using specific antibodies, and chromatography for separating oxidized protein fragments (Corpas et al., 2021).

6. EFFECTS OF OZONE TREATMENT ON PROTEINS

Ozone, a powerful oxidizing agent, interacts with cellular constituents, including proteins, in food matrices, leading to diverse outcomes. Ozone affects microbial cells by oxidising the sulfhydryl and amino acid groups of enzymes, which alter the proteins within the cells (Kinsella, 1979). Additionally, ozone treatment has been shown to alter the properties of starch and flour, affecting their pasting properties, which may be attributed to the interaction with proteins present in these food components. Furthermore, ozone exposure negatively affects the S-nitrosylation status of leaf proteins, indicating a direct impact on the post-translational modification of proteins in plant tissues (Khana et al., 2021).

Ozone treatment has also been stated to alter the secondary and tertiary structures of proteins, leading to a reduction in protein levels and potential changes in the functional properties of proteins in foods (Kostić et al., 2015). Moreover, ozone treatment has been demonstrated to inhibit cellular respiration intensity, reduce the production of ethylene, and enhance the activity of some antioxidant enzymes, which may affect the oxidative state and functional properties of proteins in food systems (Zayas, 1997). Additionally, ozone exposure has been associated with increased abundance of proteases and proteasome subunits, which are responsible for the degradation of proteins damaged by reactive oxygen species (ROS) during oxidative stress (Huffman & Harper, 1999). Furthermore, ozone has been used as a food disinfectant, affecting the microbial and physicochemical quality of various food products, which may indirectly impact the proteins present in these foods (Taha et al., 2022). Overall, the effects of ozone on proteins in foods are diverse and can influence protein structure, functionality, and microbial interactions, thereby impacting food quality, safety, and shelf life.

6.1. Effects of Ozone Application on Structural Properties of Proteins

The effect of ozone application on the structural properties of proteins in foods is diverse and can significantly affect various aspects of food quality and safety. Ozone treatment has been reported to alter the secondary and tertiary structures of proteins, leading to changes in protein levels and potential modifications in protein functionality (Sagai & Bocci, 2011). Additionally, ozone treatment has been associated with changes in the physicochemical properties of myofibrillar proteins, potentially altering protein functionality (Cahyana et al., 2018). Furthermore, ozone treatment has been shown to affect the physicochemical properties of wheat proteins, suggesting potential modifications in protein functionality. Moreover, ozone treatment has been reported to affect the physicochemical properties of whole grain flour, indicating its potential impact on the functional characteristics of proteins in food systems (Zhang et al., 2014).

Additionally, ozone treatment has been shown to influence the pasting properties of waxy rice flour and waxy rice starch, indicating its impact on the functional properties of these proteins (Chan et al., 2009). Overall, the effects of ozone treatment on the structural properties of proteins in foods are diverse and can have implications for food quality, texture, and shelf life.

6.2. Effects of Ozone Application on Functional Properties of Proteins

The effects of ozone treatment on the functional properties of proteins in foods are diverse and can significantly impact various aspects of food quality and safety. Ozone treatment has been reported to alter the functional properties of proteins in wheat flour, affecting the quality characteristics of fresh noodles, including chewiness and starch properties (Dinget et al., 2012). Additionally, ozone treatment has been shown to enhance the functional properties of various starches, such as shear and temperature stability, low syneresis, pH stability, gelling, and pasting properties (Thakur et al., 2023). Furthermore, ozone treatment has been demonstrated to affect the physicochemical and functional properties of whole grain flour, indicating its potential impact on the functional characteristics of proteins in food systems (Obadi et al., 2018). Ozone treatment has also been associated with changes in the physicochemical properties of myofibrillar proteins from silver carp during frozen storage, potentially altering protein functionality (Zhang et al., 2017).

Moreover, ozone treatment has been reported to affect the physicochemical properties of wheat proteins, suggesting potential modifications in protein functionality In addition, the modified proteins have different functional properties from those of their unmodified molecules; their emulsifying, foaming, gelling, and water binding properties may be affected as well as the texture of food changed (Obadi et al., 2016). Additionally, ozone treatment has been shown to influence the pasting properties of waxy rice flour and waxy rice starch, indicating its impact on the functional properties of these proteins (Ding et al., 2014). Overall, the effects of ozone treatment on the functional properties of proteins in foods are diverse and can have implications for food quality, texture, and shelf life.

7. THE ADVANTAGES OF OZONE APPLICATION IN THE FOOD INDUSTRY

The use of ozone in the food industry offers numerous advantages, making it a valuable tool for various applications. Some of the main benefits of ozone application in the food industry include:

Disinfection and Decontamination: Ozone is effective disinfection agent for decontaminating produce, equipment, food-contact surfaces, and the processing environment (Khadre et al., 2001).

Extended Shelf Life: Ozone is an important oxidant and disinfecting agent, used as an innovative food processing technology, which enhances shelf life and guarantees food safety (Ummat et al., 2018).

Environmental Friendliness: Ozone has been accepted as an ecologically friendly technology since it does not leave toxic residues in food products or on contact surfaces, making it a sustainable alternative disnfection agent for food processing (Panebianco et al., 2022).

Water Treatment: Ozone treatment is particularly useful for decreasing the biological and chemical oxygen demand of water used in processing and washing, thereby contributing to enhanced water quality in the food sector. (Dubey et al., 2022).

Microbial Control: Ozone gas spraying reduces bacterial growth, slowing down quality degradation due to decay and extending the shelf life of food products.

Versatile Applications: Ozone has broad applications in fruit processing, providing an effective means of preserving the quality of fruits and vegetables (Sroy et al., 2022).

Oxidative Stability: Ozone treatment promotes the physicochemical properties and antioxidant capacity of food products, contributing to improved oxidative stability and quality attributes (Zhang et al., 2005).

Eco-Friendly Technology: Ozone is an environmentally suitable method against microbial biofilm in food processing plants. It has been offered an effective and sustainable approach to maintaining hygiene and quality standards (Panebianco et al., 2022).

Effective Disinfection: Ozone is effective against a wider range of microorganisms and is free of chemical residues, making it a preferred choice for disinfection in the food industry (Zhang et al., 2005).

Food Safety: Ozone application is an alternative disinfection method for maintaining the quality and safety of food products, providing an effective method for microbial control and preservation.

These advantages highlight the diverse and beneficial applications of ozone in the food industry, ranging from disinfection and preservation to environmental sustainability and food safety. Ozone's effectiveness in extending shelf life, controlling microbial growth, and maintaining food quality makes it a valuable agent in food processing and preservation.

8. DAMAGES OF THE OZONE APPLICATION ON FOOD CONSTITUENTS

The application of ozone on food constituents can have various effects on food quality, safety, and nutritional attributes. Some potential damages of ozone application on food constituents are:

Lipid Oxidation: Ozone can affect lipid oxidation, leading to the production of undesirable aromas and potential degradation of lipid components in food constituents (Perna et al., 2022).

Reduction in Nutritional Parameters: Ozone treatment may lead to reductions in nutritional value of food components, such as their antioxidant capacity, polyphenol content, flavonoid content, and ascorbic acid concentration (Panigrahi et al., 2020).

Degradation of Bioactive Compounds: Ozone treatment can result in the degradation of bioactive compounds such as phenols, flavonoids, and ascorbic acid in food constituents, potentially impacting their health-promoting properties (Panigrahi et al., 2020).

Oxidative Damage: Persistent ozone exposure can cause irreversible oxidative damage to plants and reduce crop yield, potentially affecting the nutritional quality of food constituents (Kim et al., 2020).

Impact on Color and Texture: Ozone treatment may affect the color characteristics and texture of food constituents, potentially leading to changes in their sensory attributes and overall quality (Perna et al., 2022).

Reduction in Antioxidant Capacity: Ozone treatment may lead to a reduction in the antioxidant capacity of food constituents, potentially impacting their ability to against oxidative stress and maintain stability (Perna et al., 2022).

Microbial Reduction: While ozone treatment can effectively reduce microbial load, it may also affect the natural microbial flora in food constituents, potentially impacting their functional and sensory attributes (Varga & Szigeti, 2016).

Degradation of Biofilm-Forming Bacteria: Ozone treatment may cause the degradation of biofilm-forming bacteria, potentially impacting the microbial ecology and stability of food constituents (Panebianco et al., 2022).

Reduction in Shelf Life: Ozone treatment may lead to a reduction in the shelf life of food constituents, potentially impacting their storage and preservation characteristics (Sukarminah et al., 2017).

Impact on Physicochemical Characteristics: Ozone treatment may affect the physicochemical characteristics of food constituents, potentially leading to changes in texture, and total soluble solids content (Ummat et al., 2018).

These potential damages highlight the importance of carefully considering the application of ozone in the food industry and conducting thorough assessments of its impact on food constituents to ensure food safety, quality, and nutritional integrity.

9. CONCLUSION

The oxidation mechanism of ozone with food proteins plays a important role in food preservation and quality deterioration. The reaction between ozone and protein containing compounds primarily involves the generation of reactive oxygen species (ROS), which can lead to structural modifications of proteins, including denaturation and fragmentation. These oxidative changes can adversely affect the functional properties of proteins, such as solubility, emulsification, and gelation, ultimately influencing the sensory attributes of food products.

Understanding the specific pathways and kinetics of ozone-induced oxidation is crucial for optimizing its application in food processing. Furthermore, this knowledge can guide the development of techniques to reduce the adverse effects of ozone on protein quality, enhancing the effectiveness of ozone as a preservative while preserving the nutritional and sensory characteristics of food.

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NANOTECHNOLOGICAL APPLICATIONS IN FOOD SCIENCE AND TECHNOLOGY

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1. INTRODUCTION

The multidisciplinary field of nanotechnology focuses on the engineering and manipulation of materials at the nanoscale, which is commonly defined as dimensions ranging from 1 to 100 nanometers. This scale is significant because materials exhibit distinct physicochemical attributes that differ from their bulk equivalents, resulting to new uses across different fields, including medicine, electronics, and materials research (Salas et al., 2023). According to Bayda et al. (2019), the word "nanotechnology" denotes to a variety of methods and uses, showing its development from a specialized field of science to a key component of contemporary technological advancement.

These qualities have wide-ranging ramifications that allow for improvements in many different sectors. Within the food sector, nanotechnology has emerged as a disruptive force, providing cutting-edge solutions in several areas, like processing food, preservation, safety, and packaging. Nanotechnology application in food science is distinguished by its capacity to modify substances at the nanoscale, resulting in improved characteristics and functions that are unattainable using conventional techniques.

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Food packaging is a primary areas where nanotechnology is used in the food industry. The addition of nanomaterials, such as nanoparticles and nanocomposites, improves the mechanical strength, antibacterial activity, and barrier properties of packaging materials. For instance, it’s been proven that the application of silver nanoparticles has strong antibacterial qualities, increasing food product shelf life and decreasing spoiling (Duncan, 2011; Sousa, 2023). Furthermore, food integrity must be maintained during storage and transit. Nanotechnology makes this possible by enabling the development of smart packaging solutions that can monitor food quality and safety by detecting contamination or spoiling (Rossi et al., 2014; Sousa, 2023).

Through the use of nanoencapsulation techniques, nanotechnology makes it easier to incorporate natural preservatives and bioactive chemicals into food preservation. By improving these chemicals' stability and bioavailability, this technique makes food product preservation more successful. As stated by Brandelli et al. (2023) and Shafiq et al. (2020), the capacity to release antibacterial agents under controlled conditions can greatly minimize the requirement for synthetic preservatives, in line with customer desires for natural ingredients. Additionally, the application of nanosensors in food processing allows for real-time monitoring of viruses, toxins, and pesticide residues, improving food safety (He & Hwang, 2016; He et al., 2019).

Furthermore, food items' nutritional worth can only be improved with the use of nanotechnology. By employing nanoemulsions and nanoencapsulation, vital nutrients and bioactive chemicals can be given more effectively, enhancing their absorption and efficacy in the human body (Nile et al., 2020; Sahoo et al., 2020). This is especially important when creating functional meals to treat certain health issues like obesity or dietary inadequacies (Pathakoti et al., 2017; Bajpai et al., 2018).

One application of nanotechnology is in agricultural areas as well as the food industry, with the potential to improve crop yield and sustainability. In order to increase crop yields and lessen their negative effects on the environment, researchers are working to produce nanopesticides and nanofertilizers. (Sampathkumar et al., 2020; He et al., 2019). The potential of nanotechnology to address global concerns connected to food security and safety is highlighted by this holistic approach, which takes into account the entire food supply chain from production to consumption (Rossi et al., 2014; Sousa, 2023).

1.1.Nanotechnologic Application in Food Preservation and Packaging

With its sophisticated techniques for extending food items' shelf lives and ensuring their safety, nanotechnology has become a key invention in food preservation. The use of nanotechnology in this domain primarily revolves around the use of nanomaterials that have special qualities including higher surface area, better reactivity, and stronger antibacterial activity, which collectively contribute to more effective preservation techniques.

Food packaging has come a long way thanks to nanotechnology, which offers cutting-edge solutions that boost food safety, prolong the shelf life and enhance the general quality of the goods. The creation of smart and active packaging that can react quickly to changes in the food and ambient conditions is the result of incorporating nanoparticles into systems for packaging.

Nanotechnology is used in active packaging to include materials that engage in active interaction with the food item or its surroundings. To prolong food products' shelf life, for example, nanoparticles can be incorporated into packaging materials to release antimicrobial compounds that prevent microbial development (Duncan, 2011; Albanie, 2019). This method satisfies consumer preferences for natural ingredients by maintaining food quality while lowering the requirement for artificial preservatives (Sharma et al., 2017). Additionally, nanoparticle integration enhances the mechanical and barrier qualities of packaging, increasing its efficacy in thwarting the intrusion of oxygen and moisture, two major contributors to food spoiling (Sousa, 2023). For example, the incorporation of zinc oxide (ZnO) nanoparticles into packaging materials has been shown to significantly improve the microbial purity and texture of perishable items like cod fillets, effectively extending their shelf life (Mizielińska et al., 2018; Biswas et al., 2022). Similarly, the incorporation of silver nanoparticles into food packaging materials can inhibit the growth of bacteria and fungi, thereby preserving food quality and safety (Duncan, 2011). Likewise, chitosan-based bionanocomposite films have been developed, which not only provide excellent barrier properties but also possess inherent antimicrobial properties that help preserve food quality (Stoleru et al., 2019; Sousa, 2023).

On the other hand, intelligent packaging systems use nanosensors that track the state of the food and deliver up-to-date data on its safety and freshness. By monitoring pH, temperature, and the presence of spoiling signs, these sensors can warn consumers of possible problems before they are consumed (Shafiq et al., 2020; Nile et al., 2020). These kinds of technologies improve food safety while also giving consumers more information to help them make better judgments about what to buy (Young et al., 2020).

Not to mention, food packaging with nanotechnology has significant environmental benefits. It is possible to create lighter, more effective nanostructured materials, which will minimize waste and lower overall resource consumption (Sousa, 2023; Hamad et al., 2018). Moreover, the development of biodegradable nanocomposites is gaining popularity, which may result in more environmentally friendly packaging options that don't pollute the environment (Salgado et al., 2021). Although nanotechnology has shown great promise in food packaging, debates over customer attitudes and safety issues continue. Research suggests that although nanotechnology is becoming more widely accepted for non-ingested uses, including packaging, there is still doubt about its implementation in food products themselves (Stampfli et al., 2010; Young et al., 2020).

The application of nanotechnology also extends to the development of nanosensors that monitor food quality and safety in actual time. These sensors are able to identify spoilage indicators, such as pH variations or the existence of particular microorganisms, thus giving critical information that can prevent food waste and ensure consumer safety (Omerović et al., 2021; Nile et al., 2020). The integration of such intelligent packaging systems represents a significant leap forward in food preservation, enabling proactive measures to be taken before spoilage occurs.

Furthermore, it is impossible to ignore how food preservation using nanotechnology improves the environment. Nanotechnology plays an important role in creating more sustainable food systems by increasing the effectiveness of packaging materials and decreasing food waste. According to Hamad et al. (2018), the lightweight characteristic of nanostructured materials also results in decreased transportation costs and carbon footprints.

Notwithstanding the intriguing uses of nanotechnology in food preservation, it is critical to address any possible safety issues pertaining to the usage of nanomaterials. To fully understand the long-term effects of these elements on the ecosystem and human well-being, further investigation is needed (Sahoo et al., 2020; Bajpai et al., 2018). To guarantee that the advantages of nanotechnology are achieved without sacrificing safety, regulatory structures must also change.

As a result, using nanotechnology in food production has significant environmental benefits. By improving food processing effectiveness techniques and reducing waste, nanotechnology contributes to more sustainable food systems. For instance, the use of nanomaterials can enhance the efficiency of extraction processes for natural flavors and nutrients, reducing the harm that conventional approaches do to the environment (Rossi et al., 2014; Peters et al., 2016).

1.2. Nanotechnology Contribution to Enhancing the Nutritional Qualities of Food Products

A significant role is played by nanotechnology in enhancing the nutritional profile of food products through various innovative applications. Researchers and food technologists can treat nutritional deficiencies and enhance overall food quality by enhancing the bioavailability, stability, and transport of critical nutrients by materials manipulation at the nanoscale.

Nanotechnology facilitates the encapsulation of bioactive compounds, vitamins, and flavors, enhancing their stability and bioavailability. Nanoencapsulation techniques allow for the protection of sensitive nutrients from degradation during processing and storage, ensuring that they remain effective when consumed (Prakash & Sonkar, 2021; Bajpai et al., 2018). This is particularly relevant for functional foods that aim to deliver health benefits beyond basic nutrition. For example, encapsulated probiotics can be effectively delivered to the gut, where they exert their beneficial effects (Bajpai et al., 2018). By encasing essential nutrients inside nanocarriers, this approach both protects and improves their absorption by the human body. Using polymeric and lipid-based systems, for example, carotenoids which are crucial for human health can be stabilized and rendered more accessible by nanoencapsulation (Flieger, 2024). According to Huang et al. (2010), this technique guarantees that the chemicals are efficiently transported to the intended locations inside the body in addition to enhancing their stability during processing and storage.

Additionally, controlled nutrition release made possible by nanotechnology makes delivery systems more effective and capable of meeting the physiological demands of the end user. This is especially advantageous for functional foods, which are meant to offer unique health advantages like strengthened immunity or better intestinal health. To ensure that active ingredients are released at the appropriate times and in the appropriate amounts, nanoparticles have been studied for application in the delivery of nutraceuticals (Salvia-Trujillo et al., 2018). These developments may result in the creation of customized food items that address the unique nutritional requirements of certain demographics, such as children, the elderly, and people with certain medical conditions (Biswas et al., 2022; Pandey, 2024).

Nanotechnology also plays a role in enhancing the sensory attributes of food products. By manipulating the texture and flavor profiles at the nanoscale, food technologists can create products that are not only healthier but also more appealing to consumers (Prakash & Sonkar, 2021; Sekhon, 2010). This is crucial in the development of functional foods, where maintaining desirable sensory qualities while fortifying with additional nutrients can be challenging. Food scientists can produce goods that are more consumer-friendly and healthier by altering food structures at the nanoscale (Shafiq et al., 2020). This is especially crucial when it comes to functional foods, where it might be difficult to preserve sensory aspects while boosting nutrition content (Dhawan, 2017).

One noteworthy use of nanotechnology in food processing is the use of nanoparticles to improve the antimicrobial properties of food products. Nanoparticles such as silver, zinc oxide, and titanium dioxide have been shown to exhibit strong antimicrobial effects, which can help in reducing spoilage and extending the shelf life of food items (Duncan, 2011). Moreover, the creation of novel food products with enhanced nutritional profiles may result from the application of nanotechnology in food processing. For instance, the use of zinc oxide nanoparticles has been examined for dietary fortification in yogurt, suggesting potential benefits in boosting the nutritional value of dairy products (Karmakar et al., 2022). These uses demonstrate how versatile nanotechnology is in treating a range of nutritional issues in diverse food matrices.

Notwithstanding the intriguing advantages of nanotechnology for food enrichment, safety and legal considerations must be made. To make sure that these developments do not pose health concerns to consumers, extensive research and evaluation are necessary due to the potential risks linked with the intake of nanomaterials (Peters et al., 2016). In order to allay these worries and optimize the advantages of nanotechnology in food science, it will be imperative that scientists, policymakers, and members of the public have continuing conversations as the subject develops.

Furthermore, the integration of nanosensors in food processing allows for real-time monitoring of food quality and safety. These sensors can detect spoilage indicators, such as changes in pH or the presence of specific pathogens, enabling proactive measures to be taken before food becomes unsafe for consumption (Yu et al., 2018; Nile et al., 2020). This capability is essential for making sure food is safe at every stage of the supply chain, from production to retail.

1.3. Nanotechnologic Agricultural Applications

In agriculture, nanotechnology has become a disruptive force, bringing creative solutions to improve food security, sustainability, and production. This industry uses nanotechnology for many objectives, including the production of nanopesticides, nanofertilizers, and nanosensors, all of which improve agricultural methods through increased efficiency.

The creation of nano-fertilizers is among the most significant applications of nanotechnology in farming. These fertilizers use nanoparticles to enhance plant uptake and delivery of nutrients. Conventional fertilizers frequently have inefficient use of nutrients, which pollutes the environment and lowers crop yields. On the other hand, Mukhopadhyay (2014) and Solanki et al. (2015) discuss how nano-fertilizers might improve nutrient solubility and availability, enabling more precise application and decreased waste. To promote healthier growth and larger yields, for example, the regulated release of nutrients by nano-encapsulation techniques guarantees that plants receive the essential nutrients over a prolonged length of time (Mohanty, 2024).

In a similar way, nano-pesticides are a major development in pest control. In comparison to traditional pesticides, these formulations use nanoparticles to increase the efficacy of the active components, enabling lower application rates and a smaller environmental impact (Tang, 2023; Periakaruppan, 2023). A significant issue in contemporary agriculture can be addressed by the targeted delivery of nano-pesticides, which can decrease the exposure of non-target organisms and lower the possibility of pesticide resistance in pests (Worrall et al., 2018). Moreover, including nanotechnology into the composition of pesticides can increase their efficacy and stability, extending their duration of action (Mohanty, 2024).

Additionally, nanosensors are essential to contemporary agricultural methods. These tools can track crop health, soil conditions, and environmental variables in real-time, giving farmers useful information to help them make decisions (Worrall et al., 2018; Halake & Haro, 2022). For instance, pathogens, nutrient content, and soil moisture levels can all be detected by nanosensors, enabling precision agriculture techniques that improve crop management and maximize resource utilization (Mohanty, 2024; Worrall et al., 2018). By minimizing input use and environmental impact, this data-driven strategy not only increases crop yields but also supports sustainable agricultural practices.

Furthermore, the creation of biocompatible materials for agricultural purposes can be facilitated by nanotechnology. For example, adding nanomaterials to soil amendments can strengthen the soil's structure and increase its ability to hold water, both of which are advantageous in arid areas (Solanki et al., 2015; Periakaruppan, 2023). Furthermore, in line with the ideas of sustainable agriculture, nanotechnology can help develop biodegradable materials for packaging and crop protection (Pavankumar, 2023; Zamri, 2023).

Even though nanotechnology has many prospective uses in agriculture, there are still issues and worries that need to be resolved. To guarantee the safe and efficient application of these technologies, concerns about the possible toxicity of nanomaterials, their influence on the environment, and regulatory frameworks must be carefully taken into account (Iavicoli et al., 2017; Mwaanga, 2018). To assess the long-term impacts of nanotechnology on ecosystems and human health and to create guidelines for its appropriate application in agriculture, more study is necessary (Iavicoli et al., 2017; Halake & Haro, 2022).

Some nanotechnological studies applied in the food industry and the purpose of these studies are summarized in Table 1.

Table 1. Some nanotechnological studies applied in the food industry and their objectives.

	Scope	Purpose	Reference
1	Encapsulation of nutraceuticals	Better absorption and controlled release of nutrients in the human body	Huang et al., 2010; Nile et al., 2020
2	The incorporation of nanoparticles into packaging materials	Reducing microbial contamination of silver nanoparticles on food surfaces	Prakash & Sonkar, 2021
3	Using nanoparticles in agriculture quality improvement	Improving the yield of a wheat crop of iron and cupper nanoparticles	Yasmeen et al., 2017
4	Using nanoencapsulation technique	Use of nanoemulsions and nanocapsules to improve the delivery of flavors and nutrients	Biswas et al., 2022; Mohammad et al., 2022
5	Using nanosensors	Preventing foodborne illnesses and ensuring consumer safety	Shafiq et al., 2020
6	The use of active packaging systems	Increasing the shelf life of food items by assisting in the suppression of microbiological development	Sharma et al., 2017
7	Adding microencapsulated fish oil to breads	Reducing the taste and smell of fish oil	Serfert et al., 2010
8	Utilization of zein nanomaterial, a major protein found in maize	Determination of its use as a flavoring agent and in dietary supplements	Torres et al., 2007
9	Developing products for lactose intolerant patients by encapsulation	Encapsulation of β-galactosidase enzyme in liposomes to prevent high-sugar taste resulting from the breakdown of lactose into glucose and galactose	Rao et al., 1994
10	Determination of consumer perception of nanotechnology in food applications	Addressing public concerns and making sure that information about the advantages and dangers of nanotechnology in food applications is communicated clearly	Kogovšek et al., 2017; Dimitrijević et al., 2015

2. CONCLUSION

Nanotechnology has several useful applications in the food sector, from enhanced food safety and nutrient delivery systems to cutting-edge packaging solutions. An important development in the food sector is the use of nanotechnology in food packaging, which offers creative solutions that support sustainability by enhancing safety, extending shelf life, and promoting environmental sustainability. Furthermore, through improved bioavailability, regulated nutrient distribution, and the creation of novel food formulations, nanotechnology provides revolutionary possibilities for enhancing the nutritional profile of food products. The issues associated with global nutrition may be significantly mitigated by the incorporation of these technologies into food systems. Conversely, nanotechnology presents a great deal of potential for enhancing nutrient delivery, controlling pests, and enabling real-time monitoring in agricultural techniques. In summary, food processing might greatly benefit from the application of nanotechnology, which could improve food safety, quality, and nutritional value.

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GIDA KATKI MADDELERİ

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1. GİRİŞ

Gıda katkı maddeleri, lezzet, görünüm, doku ve raf ömrü gibi belirli özellikleri geliştirmek için üretim, işleme veya paketleme sırasında gıda ürünlerine eklenen maddelerdir. Bu katkı maddeleri, işlevlerine göre koruyucular, lezzet arttırıcılar, renklendiriciler, emülgatörler ve tekstürize ediciler gibi çeşitli kategorilerde sınıflandırılabilir (Gokçe vd., 2018; Abedi-Firoozjah, 2024). Gıda katkı maddelerinin kullanımı, bu maddelerin tüketim için güvenli olmasını ve gıda üretiminde teknolojik bir amaca hizmet etmesini sağlayan Codex Alimentarius ve ulusal düzenleyici kurumlar da dahil olmak üzere çeşitli kurumlar tarafından düzenlenmektedir (Abedi-Firoozjah, 2024).

Gıda katkı maddelerinin başlıca işlevleri arasında gıdaların korunmasını iyileştirmek, besin değerini arttırmak ve gıda ürünlerinin duyusal özelliklerini güçlendirmek yer almaktadır. Örneğin, koruyucular bozulmayı önlemek ve gıdanın raf ömrünü uzatmak için kullanılırken, lezzet arttırıcılar ve renklendiriciler gıdaları tüketiciler için daha çekici hale getirmek için kullanılmaktadır (Abedi-Firoozjah, 2024; Nyirenda &

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Kumwenda, 2023). Ayrıca, bazı gıda katkı maddeleri doğal kaynaklardan elde edilirken, diğerleri sentetiktir ve her iki türün de gıda kalitesi ve güvenliği üzerinde önemli etkileri olabilir (Zhou vd., 2023; Kane, 2023).

Faydalarına rağmen, gıda katkı maddelerinin kullanımı, özellikle uzun süreli maruziyetten kaynaklanan potansiyel olumsuz etkilerle ilgili olarak tüketiciler arasında sağlık endişelerine yol açmıştır. Bazı çalışmalar, belirli katkı maddelerinin alerji ve intolerans gibi sağlık sorunlarına katkıda bulunabileceğini göstermiştir (Zhou vd., 2023; Hayder vd., 2011). Örneğin, yapay renklendiriciler ve koruyucular hassas bireylerde alerjik reaksiyonlarla ilişkilendirilmiştir (Hayder vd., 2011). Bu nedenlerle, halk sağlığı ve güvenliğini sağlamak için gıda katkı maddelerinin sürekli araştırılması ve izlenmesi gereklidir.

1.1. Gıda Katkı Maddelerinin Sınıflandırılması

Gıda katkı maddeleri, gıda ürünlerindeki işlevsel rollerine göre sınıflandırılabilir. Bu sınıflandırma, amaçlarının ve gıda işleme ve muhafazasında sağladıkları faydaların anlaşılmasına yardımcı olur. Gıda katkı maddelerinin başlıca kategorileri şunlardır:

- ***Koruyucular*: **Bu katkı maddeleri bozulmayı önlemek, gıda ürünlerinin raf ömrünü uzatmak ve gıda kalitesini korumak için kullanılır. Mikroorganizmaların büyümesini engelleyerek gıdanın bozulmasına yol açan kimyasal değişiklikleri yavaşlatırlar. Yaygın örnekler arasında sodyum benzoat ve potasyum sorbat bulunur (Kane, 2023; Abedi-Firoozjah, 2024).

- ***Lezzet Arttırıcılar***: Bu maddeler gıdanın tadını arttırmak için eklenir. Mutlaka kendileri lezzet katmazlar, ancak gıda ürünlerindeki mevcut lezzetleri güçlendirirler. Monosodyum glutamat (MSG) çeşitli mutfaklarda kullanılan iyi bilinen bir lezzet arttırıcıdır (Abedi-Firoozjah, 2024).

- ***Renklendiriciler***: Gıda renklendiricileri, gıda ürünlerinin rengini iyileştirmek veya eski haline getirmek için kullanılır ve bu da onları tüketiciler için daha çekici hale getirir. Doğal kaynaklardan (pancar suyu gibi) elde edilebilir veya sentezlenebilirler (yapay boyalar gibi). Yaygın renklendiriciler arasında karmin ve tartrazin bulunur (Abedi-Firoozjah, 2024; Chazelas vd., 2020).
- ***Emülgatörler ve Stabilizatörler***: Bu katkı maddeleri, bileşenlerin ayrılmasını önleyerek gıda ürünlerinin dokusunu ve kıvamını korumaya yardımcı olur. Emülgatörler yağ ve suyun karışmasını sağlarken, stabilizatörler istenen dokunun korunmasına yardımcı olur. Emülgatörlere örnek olarak lesitin ve pektin verilebilir (Abedi-Firoozjah, 2024; Mortensen vd., 2017).
- ***Tekstürleştiriciler***: Bu katkı maddeleri gıda ürünlerinin dokusunu değiştirerek ağız hissine ve kıvamına katkıda bulunur. Süt ürünlerinin kremasını veya atıştırmalıkların çıtırlığını artırabilirler. Yaygın tekstürleştiriciler arasında modifiye nişastalar ve jelatin bulunur (Abedi-Firoozjah, 2024).
- ***Besin Katkı Maddeleri***: Bunlar, besin değerini artırmak için gıdaya eklenen vitamin ve mineralleri içerir. Popülasyondaki eksiklikleri önlemek için örneğin, D vitamini genellikle süte, demir ise tahıllara eklenir (Abedi-Firoozjah, 2024; Etwaroo et al., 2019).
- ***Antioksidanlar***: Bu maddeler, ekşime ve besin kalitesi kaybına yol açabilecek oksidasyonu önlemek için eklenir. Gıda ürünlerinin lezzetini ve rengini korumaya yardımcı olurlar. Yaygın antioksidanlar arasında askorbik asit (C

vitamini) ve tokoferoller (E vitamini) bulunur (Abedi-Firoozjah, 2024; Etwaroo vd., 2019).

Gıdalarda yaygın olarak kullanılan katkı maddeleri ve kullanıldığı gıdalar Tablo 1 ve Tablo 2'de verilmiştir.

Tablo 1. Gıdalarda Yaygın Kullanılan Doğal Katkı Maddeleri

Doğal koruyucular		
Koruyucu	**Kullanıldığı gıdalar**	**İşlevi**
Tuz (Sodyum klorür)	Et, balık ve salamura ürünleri	Küf, maya ve bakteri oluşumunu engellemek
Şeker	Reçel, jöle, şurup ve şekerleme	Küf, maya ve bakteri oluşumunu engellemek
Sirke (Asetik asit)	Turşu	Antibakteriyel
Limon suyu (Sitrik asit)	Meyve ve sebze	Küf, maya ve bakteri oluşumunu engellemek
Alkol	Bazı fermente yiyecek ve içecekler	Küf, maya ve bakteri oluşumunu engellemek
Yağ	Pesto veya sos gibi ürünler	Oksidasyonu önlemek
Biberiye özü	Etler ve yağlar	Oksidasyonu önlemek
Askorbik asit (C Vitamini)	Meyve ve meyve ürünleri	Oksidasyonu önlemek
Bal	Bazı ürünler	Antimikrobiyal

Tablo 2. Gıdalarda Yaygın Kullanılan Sentetik Katkı Maddeleri

Sentetik koruyucular		
Koruyucu	**Kullanıldığı gıdalar**	**İşlevi**
Sodyum Benzoat	Salata sosları, gazlı içecekler ve meyve suları	Bakteri ve mantar çoğalmasını engellemek
Potasyum Sorbat	Süt ürünleri, unlu mamuller ve şarap	Küf, maya ve bakteri oluşumunu engellemek
Sodyum Nitrit ve Sodyum Nitrat	Pastırma ve jambon gibi işlenmiş etler	Bakteri üremesini önlemek ve rengi korumak
Sülfür Dioksit ve Sülfitler	Kurutulmuş meyveler, şarap, meyve suları	Oksidasyonu ve mikrobiyal büyümeyi önlemek
Butillenmiş Hidroksianisol (BHA) ve Butillenmiş Hidroksitoluen (BHT)	Tahıllar, atıştırmalık gıdalar ve yağlar	Ekşimeyi ve oksidasyonu önlemek
Sorbik Asit	Peynir, şarap ve unlu mamuller	Küf oluşumunu engellemek
Kalsiyum Propiyonat	Unlu mamuller	Küf ve bakteri oluşumunu önlemek
Propiyonik Asit	Ekmek ve diğer unlu mamuller	Küflenmeyi engellemek
Tert-Butylhydroquinone (TBHQ)	Sıvı ve katı yağlar	Oksidasyonu önlemek

1.2. Gıda Katkı Maddelerinin Sağlık Üzerine Etkileri

1.2.1. Olumlu Etkiler

Gıda katkı maddeleri, uygun şekilde kullanıldıklarında sağlık açısından çeşitli olumlu faydalar da sağlayabilmektedir. Gıda katkı maddelerinin faydalı yönlerini vurgulayan bazı çalışmalar yapılmıştır. Birçok gıda katkı maddesi, gıdaları temel vitamin ve minerallerle güçlendirmek ve böylece beslenme profillerini iyileştirmek için kullanılmıştır. Bu zenginleştirilmiş gıdalar, özellikle çocuklar ve yaşlılar gibi hassas popülasyonlardaki beslenme eksikliklerini gidererek halk sağlığında önemli bir rol oynamaktadır (Alkhatib vd., 2017). Yapılan bir çalışmada, süt ürünlerine ve tahıllara A, D ve B_{12} gibi vitaminler eklenerek, popülasyondaki eksikliklerin giderilebileceği incelenmiştir (Özen vd., 2012).

Bazı gıda katkı maddeleri, temel beslenmenin ötesinde sağlık yararları sağlayan biyoaktif bileşikler içeren fonksiyonel gıdalar olarak sınıflandırılır. Örneğin, probiyotikler ve prebiyotikler bağırsak sağlığını desteklemek ve bağışıklık sistemini güçlendirmek için çeşitli gıda ürünlerine eklenmiştir (Sharma vd., 2017). Fonksiyonel gıdaların tüketimi, antioksidan ve anti-inflamatuar özellikleri nedeniyle tip 2 diyabet ve kardiyovasküler hastalıklar da dahil olmak üzere kronik hastalık risklerinin azalmasıyla ilişkilendirilmiştir (Alkhatib vd., 2017). Tüketiciler arasında sağlık bilinciyle beslenmeye yönelik artan eğilim, faydalı katkı maddeleri içeren fonksiyonel gıdaların daha fazla kabul görmesine yol açmıştır (Baker vd., 2022; Seo vd., 2014). Örneğin, çeşitli gıda ürünlerine sıklıkla eklenen omega-3 yağ asitleri, kardiyovasküler faydaları nedeniyle iyi bilinmekte ve sağlık bilincine sahip tüketiciler tarafından aktif olarak aranmaktadır (Annunziata & Mariani, 2019).

Bitki ve baharatlardan elde edilen doğal koruyucular gibi gıda katkı maddeleri, gıda ürünlerinin besin kalitesini korurken raf ömrünü de uzatabilmektedir. Örneğin, tokoferoller (E vitamini) ve askorbik asit (C vitamini) gibi doğal antioksidanlar sadece bozulmayı önlemekle kalmayıp, aynı zamanda gıdanın genel sağlık yararlarına da katkıda bulunmaktadır (Kumar, 2023).

Diğer taraftan, bazı katkı maddelerinin kullanımı, zararlı bakterilerin ve patojenlerin büyümesini engelleyerek gıda güvenliğini artırabilir. Örneğin, sodyum nitrit gibi koruyucular, işlenmiş etlerde Clostridium botulinum'un büyümesini önlemede etkilidir ve böylece gıda kaynaklı hastalık riskini azaltır (Christidis vd., 2011).

1.2.2. Olumsuz Etkiler

Gıda katkı maddeleri, çeşitli faydalı amaçlara hizmet etseler de, dikkat edilmesi gereken önemli sağlık endişeleri de vardır. Gıda katkı maddeleri ile ilgili temel endişelerden biri, olumsuz sağlık etkilerine neden olma potansiyelleridir. Örneğin, monosodyum glutamat (MSG) gibi bazı sentetik katkı maddeleri, hassas bireylerde baş ağrısı ve alerjik reaksiyonlar da dahil olmak üzere çeşitli sağlık sorunlarıyla ilişkilendirilmiştir (Joshi, 2023). Lezzet arttırıcı olarak yaygın bir şekilde kullanılan MSG'nin, özellikle büyük miktarlarda tüketildiğinde hepatotoksisite ve nefrotoksisite riskleri oluşturduğu gösterilmiştir (Joshi, 2023). Benzer şekilde, yapılan bir çalışmada inorganik fosfat katkı maddelerinin kullanımı, artan sağlık komplikasyonları riskiyle ilişkilendirilmiş ve kamu güvenliğini sağlamak için daha fazla araştırma yapılması gerektiği vurgulanmıştır (Anukam & Agu, 2017.

Uzun süreli ve yüksek dozda gıda katkı maddelerine maruz kalmanın toksik, genotoksik ve mutajenik etkilere yol açabileceği gösterilmiştir (Atalay, 2024; Karatepe & Ekerbiçer, 2018). Ayrıca, bazı katkı maddeleri alerjik reaksiyonlara neden olabilmekte ve bu durum özellikle çocuklarda daha belirgin hale gelmektedir (Ertokuş, 2018). Bu nedenle, gıda katkı maddelerinin kullanımı sıkı yasal düzenlemelere tabidir ve tüketicilerin bu maddeler hakkında bilinçli olmaları önemlidir (Şahin, 2024).

Ayrıca, genellikle yüksek konsantrasyonda gıda katkı maddesi içeren ultra işlenmiş gıdaların tüketimi, obezite, diyabet ve kardiyovasküler hastalıklar dahil olmak üzere artan hastalık riski ile ilişkilendirilmiştir (Clark vd., 2019; Liang, 2023).

Doğrudan sağlık etkilerine ek olarak, gıda katkı maddeleri genel sağlıkta çok önemli bir rol oynayan bağırsak mikrobiyomunu da etkileyebilir. Çalışmalar, bazı katkı maddelerinin bağırsak mikrobiyotasının bileşimini ve işlevini değiştirebileceğini, potansiyel olarak gastrointestinal sorunlara ve daha geniş sağlık etkilerine yol açabileceğini göstermiştir (Sun vd., 2022; Yu & Zuo, 2021).

Potansiyel risklere rağmen, tüm gıda katkı maddelerinin zararlı olmadığını kabul etmek gerekir. Birçok katkı maddesi, belirlenen yasal sınırlar dahilinde kullanıldığında güvenli kabul edilmektedir. Gıda katkı maddelerinin güvenliğini değerlendirmek ve tüketicileri potansiyel sağlık etkileri konusunda eğitmek için sürekli izleme ve araştırma gereklidir (Polak, 2024; Mwale, 2023). Düzenleyici kurumlar, gıda katkı maddelerinin güvenli ve etkili bir şekilde kullanılmasını sağlamada kritik bir rol oynamakta, gıda koruma ve geliştirmenin faydaları ile halk sağlığını koruma ihtiyacını dengelemektedir.

1.3. Gıda Katkı Maddelerinde E Kodlarının Önemi

E kodları, ambalaj üzerinde yer alan katkı maddelerinin kimyasal adının uzun olması ve yüzlerce çeşit katkı maddesi bulunması nedeniyle, hangi amaçla kullanıldığı konusunda tüketiciye kolaylık sağlamak amacıyla Avrupa Birliği tarafından her bir gıda katkı maddesi için belirlenen kod numaralarıdır. Gıda katkı maddelerine ilişkin kodların önemi çok yönlüdür; güvenlik, düzenleme, tüketicinin korunması ve halk sağlığını kapsar. Bu kodlar, gıda katkı maddelerinin kullanımı, değerlendirilmesi ve etiketlenmesine rehberlik eden, gıda güvenliğinin sağlanması, tüketicilerin korunması, halk sağlığının desteklenmesi ve uluslararası ticaretin kolaylaştırılması için temel araçlar olarak hizmet ederler.

Güvenlik ve düzenleme kapsamında Codex Alimentarius ve FAO/WHO tarafından oluşturulanlar gibi gıda katkı maddeleri kodları, gıda katkı maddelerinin güvenlik değerlendirmesi ve yönetimi için kapsamlı bilgiler sunar. Bu kodlar, toksikolojik çalışmalar ve kabul edilebilir günlük alım seviyeleri dahil olmak üzere katkı maddelerinin güvenliğini değerlendirmek için gerekli veri gereksinimlerini ana hatlarıyla belirtir (Xu, 2013; Magnuson vd., 2013). Düzenleyici kurumlar bu kodlara bağlı kalarak gıda ürünlerinde yalnızca güvenli katkı maddelerine izin verilmesini sağlayabilir ve böylece tüketicileri zararlı maddelerle ilişkili potansiyel sağlık risklerinden koruyabilir.

Tüketicinin korunması amacıyla oluşturulan kodlar, gıda katkı maddeleri ile ilgili açık etiketleme ve bilgi ifşasını zorunlu kılarak tüketicinin korunmasında kritik bir rol oynamaktadır. Bu şeffaflık, tüketicilerin satın aldıkları ve tükettikleri ürünler hakkında bilinçli seçimler yapmalarını sağlar. Örneğin, düzenlemeler genellikle gıda katkı maddelerinin ürün etiketlerinde listelenmesini gerektirerek tüketicilerin alerjik olabilecekleri veya diyetlerinde sınırlamak isteyebilecekleri katkı maddelerini belirlemelerini ve bunlardan kaçınmalarını sağlar (Xu, 2013; Magnuson vd., 2013). Bu tür önlemler, tüketici güvenini artırmak ve bireylerin sağlık ihtiyaçlarına uygun beslenme tercihleri yapabilmelerini sağlamak için gereklidir.

Yetki alanları arasında standartlaştırma kapsamında uluslararası kodların varlığı, farklı ülkelerde gıda katkı maddelerinin değerlendirme ve onay süreçlerinin standartlaştırılmasına yardımcı olmaktadır. Bu standardizasyon, ürünlerin genellikle uluslararası ticaretinin yapıldığı küreselleşmiş bir gıda pazarında çok önemlidir. Ülkeler yerleşik kodları takip ederek gıda güvenliği düzenlemelerini uyumlu hale getirebilir, gıda ürünlerinin tutarlı güvenlik standartlarını karşılamasını sağlarken ticareti kolaylaştırabilirler (Magnuson vd., 2013). Bu özellikle gıda kaynaklı hastalıkların önlenmesi ve dünya çapındaki tüketicilerin güvenli gıdaya erişiminin sağlanması açısından önemlidir.

Diğer taraftan, gıda katkı maddeleri ile ilgili kodlar, beslenme kalitesini artıran faydalı katkı maddelerinin kullanımını teşvik ederek halk sağlığı girişimlerine de katkıda bulunur. Örneğin, temel gıdaların vitamin ve minerallerle zenginleştirilmesi genellikle bu uygulamaların güvenli ve etkili olmasını sağlayan düzenleyici kodlar tarafından yönlendirilir (Xu, 2013). Bu kodlar, sağlığı geliştiren katkı maddelerinin kullanımını teşvik ederek, besin eksiklikleri ve diyetle ilgili kronik hastalıklar gibi halk sağlığı sorunlarının ele alınmasına yardımcı olabilir.

İzleme ve uyum çerçevesinde, gıda güvenliği standartlarına uyumun izlenmesi için konulmuş kodlar genel bir çerçeve sağlar. Düzenleyici kurumlar bu kodları kullanarak gıda üreticilerini denetleyebilir ve katkı maddelerinin kullanımına ilişkin belirlenmiş kodlara uymalarını sağlayabilir (Xu, 2013; Magnuson et al., 2013). Bu gözetim, düzenleyici standartlardan sapmaların tespit edilip düzeltilmesine yardımcı olduğu için gıda güvenliği ve kalitesinin korunması açısından hayati önem taşımaktadır.

2. SONUÇ

Sonuç olarak, gıda katkı maddeleri gıda güvenliğini ve kalitesini artırabilirken, potansiyel sağlık etkileri dikkatle değerlendirilmelidir. Katkı maddelerinin rollerini ve işlevlerini anlamak, tüketicilerin tükettikleri gıdalar ve bunların potansiyel sağlık etkileri hakkında bilinçli seçimler yapmalarına yardımcı olabilir. Gıda katkı maddelerinin olumlu etkileri, özellikle toplu gıda üretimi ve dağıtımı bağlamında halk sağlığı açısından çok önemlidir. Yapılacak yeni araştırmalar ve düzenleyici gözetim, zararlı katkı maddeleri ile ilişkili riskleri azaltmak ve bilinçli tüketici seçimlerini teşvik etmek için çok önemlidir.

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PROBİYOTİK BAKTERİLERİN MİKROENKAPSÜLASYONU

Eda Elgin KILIÇ[1]

1. GİRİŞ

Probiyotikler, sağlığa faydaları bilinen canlı mikrobiyal takviyelerdir (Rajam vd., 2015). *Lactobacillus* ve *Bifido* cinsi bakteriler yıllar boyunca probiyotik olarak kullanılmıştır ve esas olarak insan gastrointestinal sistemi ile ilişkilidir (Anal ve Singh, 2007). Son yıllarda, *Lactobacillus plantarum*'un probiyotik suşları, sağlık yararları için birçok fermente gıdada sıklıkla kullanılmaktadır: solunum ve ürogenital sistemler, bağırsakta kolonizasyon yolu, laktoz metabolizması, karsinogenezin inhibisyonu, kalsiyum emilimi ve vitamin sentezi vb. (Zommiti vd., 2020). Probiyotik etkinliği, gıda matrisindeki metabolik stabilite ve asidik mide ortamında hayatta kalma yeteneği de dahil olmak üzere, canlılığa ve uygulama dozuna bağlıdır, çünkü alınan probiyotik hücrelerin önemli bir kısmı, gastrointestinal (GI) sistemden geçişi ve depolanması sırasında sindirim sırasında canlılıklarını kaybeder. Bu nedenle, probiyotik suşların kapsüllenmesi, onları zorlu işleme koşullarından korumak ve fonksiyonel gıdaya dahil edildiğinde nihai duyusal özelliği iyileştirmek için gereklidir (Burgain vd., 2011). Probiyotik kavramına ilişkin bilimsel kanıtlar, yirminci yüzyılın başlarında Rus bilim insanı Elie Metchnikoff'un teorileriyle ortaya çıkmıştır. Bilim adamı Metchnikoff, Bulgar çiftçilerin çok fazla fermente süt

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tüketmeleri nedeniyle daha uzun ve sağlıklı yaşadıklarını gözlemlemiştir. İnsan vücudunun gastrointestinal sistemdeki patojenler tarafından üretilen toksik maddeler tarafından yavaş yavaş zehirlendiğini ve böylece vücudun patojenlerin yaşamasına karşı direncinin zayıfladığını öne sürmüştür.

Bu hipotezden kısa bir süre sonra *Lactobacillus* ve *Bifidobacterium* suşları gıda ürünlerinde kullanılmaya başlanmıştır. Örneğin, 1905 yılında Prof. Grigoroff L*actobacillus bulgaricus'u* ticari “kiselomleko” (ekşi süt) üretimi için starter kültür olarak kullanmıştır. Daha sonra, *Lactobacillus acidophilus'*un birkaç suşunun insan bağırsak sisteminde kolonize olduğu tespit edilmiştir. Bu bulgular, *Lactobacillus acidophilus* suşu tarafından fermente edilen gıda ürünlerine ticari ilgiyi tetiklemiştir (Vasiljevic ve Shah, 2008). Daha sonra, 1930 yılında Japonya'da bilim adamı Minoru Shirota, gastrointestinal sistemin zararlı çevresel koşullarında hayatta kalma potansiyeline sahip bir *Lactobacillus* suşu kültürü izole etmiş ve geliştirmiştir. Günümüzde, probiyotik mikroorganizmaların günlük alımının yararlı bağırsak mikroflorasını iyileştirmeye ve korumaya yardımcı olduğu ve böylece çeşitli gastrointestinal enfeksiyonları önlediği kabul edilmektedir. Probiyotiklerle ilgili çalışmalar ilk zamanlarda başlamış olsa da, probiyotiklerin sağlığa faydalarını belirlemeye yönelik yoğun çabalar büyük ölçüde 1980’de başlamıştır. Araştırma hacmi 2000'li yılların başında hız kazanmış ve bugüne kadar 30.000'den fazla araştırma ve inceleme makalesi ve 2000'den fazla probiyotik ürün ortaya çıkmıştır Rajam ve Subramanian, 2022).

1.1.Probiyotiklerin Tanımı

Probiyotik bakteriler, yeterli miktarda uygulandıklarında konakçıya sağlık açısından fayda sağlayan canlı mikroorganizmalar olarak tanımlanmaktadır. Dünya Sağlık

Örgütü (WHO) ve Gıda ve Tarım Örgütü (FAO) tarafından onaylanan bu tanım, bu mikroorganizmaların faydalı etkilerini gösterebilmeleri için canlı olmaları gerekliliğini vurgulamaktadır (Alagawany vd., 2020). Probiyotikler esas olarak *Lactobacillus* ve *Bifidobacterium* cinslerinden belirli bakteri suşlarından oluşur, ancak *Lactococcus, Streptococcus* gibi diğer cinsler ve *Escherichia coli* ve *Bacillus*'un bazı patojenik olmayan suşları da probiyotik olarak sınıflandırılabilir (Đorović vd., 2018).

1.2.Probiyotiklerin Sağlık Üzerine Etkileri

Probiyotiklerin etkilerini gösterdikleri mekanizmalar çok yönlüdür. Yapışma bölgeleri ve besinler için patojen bakterilerle rekabet ederek bağırsak mikrobiyal dengesini geliştirebilir ve böylece zararlı mikroorganizmaların büyümesini engelleyebilirler (Matsuzaki ve Chin, 2000). Probiyotikler ayrıca kısa zincirli yağ asitleri ve bakteriyosinler gibi metabolitler üreterek patojenik bakterileri daha da inhibe edebilir ve bağırsak sağlığını geliştirebilir (Ahmadnejad ve Dolatabadi, 2021). Ek olarak, probiyotiklerin bağışıklık tepkilerini modüle ettiği, potansiyel olarak iltihabı azalttığı ve vücudun enfeksiyonlara karşı savunma mekanizmalarını geliştirdiği gösterilmiştir (Wedajo, 2015). Probiyotik bakteriler, yeterli miktarda uygulandıklarında konakçıya sağlık yararları sağlayan canlı mikroorganizmalardır. En yaygın kullanılan probiyotik bakteriler arasında, sağlığı geliştirici özellikleri açısından kapsamlı olarak incelenmiş olan çeşitli *Lactobacillus* ve *Bifidobacterium* suşları bulunmaktadır. *Lactobacillus acidophilus, Lactobacillus rhamnosus* ve *Lactobacillus plantarum* gibi *Lactobacillus* türleri, özellikle bağırsak sağlığı ve bağışıklık fonksiyonu üzerinde faydalı etkiler gösterebilecekleri gastrointestinal sistemde hayatta kalma yetenekleriyle dikkat çekmektedir (Elgendy vd., 2018; Pundir vd., 2013; Ding ve Shah, 2007).

Lactobacillus acidophilus, yoğurt gibi süt ürünlerinde sıklıkla kullanılan en iyi bilinen probiyotik suşlardan biridir. Bağırsak mikrobiyotasını dengelemeye yardımcı olduğu, laktoz sindirimini artırdığı ve patojenlere karşı antimikrobiyal etkiler sağladığı gösterilmiştir (Ahn vd., 2002; Pundir vd., 2013). Benzer şekilde, *Lactobacillus rhamnosus* gastrointestinal enfeksiyonların önlenmesi ve irritabl bağırsak sendromu ile ilgili semptomların hafifletilmesi ile ilişkilendirilmiştir (Elgendy vd., 2018; Babu, 2023). Bir diğer önemli tür olan *Lactobacillus plantarum*, antimikrobiyal maddeler üretme ve bağırsak bariyer fonksiyonunu iyileştirme kabiliyetiyle tanınır, böylece genel bağırsak sağlığına katkıda bulunur (Lavasani vd., 2010; Pundir vd., 2013). *Bifidobacterium bifidum* ve *Bifidobacterium longum* gibi *Bifidobacterium* türleri de probiyotik formülasyonlarda yaygındır. Bu bakteriler, diyet liflerinin fermantasyonunda ve kolon sağlığı için faydalı olan ve kolorektal kanserin önlenmesine yardımcı olabilecek kısa zincirli yağ asitlerinin üretiminde önemli bir rol oynamaktadır (Ali vd., 2018; Pundir vd., 2013). Bifidobakteriler, anne sütüyle beslenen bebeklerin bağırsak mikrobiyotasında baskın oldukları ve sağlıklı bir bağışıklık sisteminin gelişimine katkıda bulundukları için yaşamın erken dönemlerinde özellikle önemlidir (Elgendy vd., 2018; Pundir vd., 2013). *Lactobacillus* ve *Bifidobacterium*'un yanı sıra *Saccharomyces* (maya) ve *Enterococcus* gibi diğer cinsler de probiyotik uygulamalarında kullanılmaktadır. *Saccharomyces boulardii*, antibiyotikle ilişkili ishalin önlenmesinde ve gastrointestinal bozuklukların yönetiminde etkili olduğu gösterilen bir maya probiyotiktir (Elgendy vd., 2018; Pundir vd., 2013). *Enterococcus f*aecium, antibiyotik direnci ile ilgili endişeler nedeniyle kullanımı bazen tartışmalı olsa da, bağırsak sağlığındaki potansiyel faydaları için çalışılan bir başka türdür (Wong vd., 2015; Rowles, 2017).

Ticari kullanım için probiyotik suşların seçimi, gastrointestinal geçişte hayatta kalma, bağırsak mukozasına yapışma ve konakçı üzerinde faydalı etkiler gösterme yeteneklerine dayanmaktadır (Collado vd., 2007; Ding ve Shah, 2007). Probiyotiklerin etkinliği, suş spesifikliği, dozaj ve faydalı bakteriler için gıda görevi gören prebiyotiklerin varlığı gibi faktörlerden etkilenebilir (Elgendy vd., 2018; Ding ve Shah, 2007; Pundir vd., 2013). Genel olarak, bu probiyotik bakterilerin kullanımı hem klinik hem de tüketici bağlamında büyük ilgi görmüş ve diyet müdahaleleri yoluyla sağlık sonuçlarını iyileştirme potansiyellerini vurgulamıştır. Tüketicilerin bilinçlenmesi nedeniyle probiyotik bazlı fonksiyonel gıdalara olan talep hızla artmıştır (Tripathi ve Giri, 2014) ve çoğu süt ürünleri sektörü fonksiyonel gıdaların formüle edilmesinde probiyotik kültürlere güvenmektedir. Son zamanlarda probiyotikler için yoğurt (Lim vd., 2020), çeşitli peynir türleri (Langa vd., 2021), fermente süt, dondurma, süt tozu, sütlü çikolata (Aspri vd., 2020) olmak üzere geniş bir gıda malzemesi listesi incelenmiştir.

2. PROBİYOTİKLERİN MİKROENKAPSÜLASYONU

Mikroenkapsülasyon, katı partiküller, sıvı damlacıkları veya gaz kabarcıkları gibi aktif maddelerin koruyucu bir kaplama veya matris içine alınmasını içeren gelişmiş bir tekniktir. Bu süreç, kapsüllenmiş malzemelerin immobilizasyonu, korunması, kontrollü salınımı ve işlevselleştirilmesi de dahil olmak üzere birçok amaca hizmet eder. Genellikle çekirdek veya aktif bileşen olarak adlandırılan çekirdek malzeme, polimerik bir madde veya diğer inert malzemeler olabilen bir duvar malzemesi ile çevrelenir ve mikrokapsül olarak bilinen yapı oluşturulur (Xiao vd., 2013;

Ordóñez-García, 2024; Ang vd., 2019). Mikroenkapsülasyonun temel amaçları arasında hassas bileşiklerin oksidasyon, nem, ışık ve ısı gibi bozulmaya yol açabilecek çevresel faktörlerden korunması yer almaktadır (Djekić ve Ćirić, 2022; Desai ve Park, 2005). Farmasötik uygulamalarda mikroenkapsülasyon, ilaçları gastrointestinal sistemin zorlu koşullarından koruyarak ve kontrollü salımı kolaylaştırarak ilaçların stabilitesini ve biyoyararlanımını artırır (Djekić ve Ćirić, 2022; Yan, 2024).

Mikroenkapsülasyon teknikleri çok çeşitlidir ve ilaç, gıda, tarım ve kozmetik dahil olmak üzere çeşitli endüstrilerdeki belirli uygulamalara göre uyarlanabilmektedir. Yaygın yöntemler arasında püskürtmeli kurutma, koaservasyon, dondurarak kurutma ve ekstrüzyon yer almaktadır (Yan, 2024; Bakry vd., 2015).

Probiyotik bakterilerin mikroenkapsülasyonu, bu faydalı mikroorganizmaların stabilitesini, canlılığını ve zorlu ortamlarda, özellikle de gastrointestinal (GI) sistemde iletimini arttırmayı amaçlayan kritik bir teknolojidir. Bu süreç, probiyotiklerin depolama ve işleme sırasında ve ayrıca midenin asidik koşullarından ve bağırsakların enzimatik ortamından geçiş sırasında hayatta kalma kabiliyetlerini önemli ölçüde artırabilen koruyucu bir kaplama içine alınmasını içerir (Mahmoud vd., 2020; Pupa vd., 2021; Tabaar vd., 2021). Mikroenkapsülasyonun birincil amacı probiyotik hücreleri ısı, nem ve oksijen gibi hücre ölümüne ve işlevsellik kaybına yol açabilecek olumsuz koşullardan korumaktır (Gül ve Dervişoğlu, 2016; Tabaar vd., 2021). Mikroenkapsülasyon için çeşitli malzemeler kullanılmakta olup, aljinat ve kitosan biyouyumlulukları ve stabil jel oluşturma yetenekleri nedeniyle en yaygın kullanılanlar arasındadır (Pupa vd., 2021;). Çalışmalar aljinat kullanılarak yapılan mikroenkapsülasyonun, probiyotiklerin simüle edilmiş bağırsak sularında serbest hücrelere kıyasla hayatta kalma kaybını önemli ölçüde azalttığını ve böylece canlılıklarını artırdığını göstermiştir (Gül ve Dervişoğlu, 2016; Qi vd., 2019; Tabaar vd., 2021).

Probiyotiklerin dağıtımını optimize etmek için sprey kurutma, ekstrüzyon ve emülsiyon gibi farklı mikroenkapsülasyon teknikleri araştırılmıştır (Murúa-Pagola vd., 2020; Ramadhani vd., 2022). Özellikle sprey kurutma, canlılıklarını korurken mikro kapsüllenmiş probiyotiklerin büyük ölçekli üretimine izin veren verimliliği ve maliyet etkinliği ile dikkat çekmektedir (Maciel vd., 2014; How vd., 2022). Kapsülleme işlemi sadece probiyotikleri korumakla kalmaz, aynı zamanda mikroorganizmaların bağırsaklara aktif bir durumda iletilmesini sağlayarak kontrollü salıma da izin verir (Iqbal vd., 2018; Pech-Canul vd., 2020). Mikroenkapsülasyon işlemi sırasında prebiyotiklerin dahil edilmesinin probiyotiklerin stabilitesini ve işlevselliğini daha da artırdığı ve bağırsak sağlığını destekleyen sinbiyotik bir etki yarattığı gösterilmiştir (Murúa-Pagola vd., 2020; Kavas vd., 2022). Probiyotikler ve prebiyotikler arasındaki sinerjik etkileşim, sağlık sonuçlarının iyileştirilmesine yol açarak mikroenkapsülasyonu fonksiyonel gıdaların ve diyet takviyelerinin geliştirilmesinde değerli bir strateji haline getirebilir (Pupa vd., 2021; Mhatre ve Gurav, 2020).

Probiyotiklerin mikroenkapsülasyonu için enkapsülasyon yöntemleri ekstrüzyon, emülsiyon ve kurutma gibi üç ana kategoriye ayrılır. Enkapsüle probiyotiklerin endüstriyel üretimi için sprey kurutma, liyofilizasyon, emülsiyon, lipid bazlı dağıtım sistemi, koaservasyon ve ekstrüzyon gibi teknikler yaygın olarak kullanılmıştır. Her teknik, nem içeriği, mikrokapsül boyutu, kapsülleme etkinliği ve sindirim sırasında salınım açısından farklı özelliklere sahip mikrokapsüller üretmektedir.

2.1.Sprey Yöntemi

Probiyotik bakteriler için mikroenkapsülasyon yöntemleri, bu faydalı mikroorganizmaların stabilitesini, canlılığını ve dağıtımını artırma potansiyelleri nedeniyle büyük ilgi görmüştür. Her birinin kendine özgü avantajları ve uygulamaları olan çeşitli teknikler geliştirilmiştir.

Probiyotik bakterilerin sprey mikroenkapsülasyonu, işleme ve depolama sırasında probiyotiklerin canlılığını ve stabilitesini arttırmayı amaçlayan, gıda bilimi ve biyoteknolojide yaygın olarak kullanılan bir tekniktir. Bu yöntem, probiyotik hücrelerin tipik olarak bir polimer veya karbonhidrattan oluşan koruyucu bir matris içinde kapsüllenmesini içerir ve bu da bir sprey kurutma işlemi ile elde edilir. Kapsülleme, probiyotikleri çevresel stres faktörlerinden korumakla kalmaz, aynı zamanda faydalı etkilerini gösterebilecekleri gastrointestinal sisteme iletilmelerini de kolaylaştırır (Fritzen-Freire vd., 2012; Gül ve Atalar, 2018). Püskürtmeli kurutmanın en önemli avantajlarından biri, endüstriyel uygulamalar için uygun hale getiren verimliliği ve ölçeklenebilirliğidir. Proses, sıvı probiyotik kültürlerin çeşitli gıda ürünlerine kolayca dahil edilebilen kuru tozlara hızlı bir şekilde dönüştürülmesini sağlar (Zhou vd., 2023) Mikroenkapsüle probiyotiklerin zorlu depolama koşullarında bile uzun süre yüksek canlılık seviyelerini (6 log CFU/g'ın üzerinde) koruyabildiğini göstermiştir (Fritzen-Freire vd., 2012; Kiekens vd., 2019). Kapsülleyici maddelerin seçimi, sprey kurutma işlemi sırasında probiyotiklerin hayatta kalmasını önemli ölçüde etkiler. Yaygın olarak kullanılan malzemeler arasında, sadece koruyucu bir bariyer sağlamakla kalmayıp aynı zamanda nihai ürünün fonksiyonel özelliklerini de geliştirebilen maltodekstrin, peynir altı suyu proteini ve inülin yer almaktadır (Gül ve Atalar, 2018; Slavutsky vd., 2016). Maltodekstrinin probiyotikleri püskürtmeli kurutma sırasında karşılaşılan yüksek sıcaklıklardan ve kesme kuvvetlerinden etkili bir şekilde koruduğu ve böylece hayatta kalma oranlarını artırdığı gösterilmiştir (Anekella ve Orsat, 2013).

2.2.Dondurarak Kurutma

Dondurarak kurutma veya liyofilizasyon, probiyotik bakterileri korumak için yaygın olarak kullanılan bir tekniktir ve bu mikroorganizmaların canlılıklarını ve işlevselliklerini korurken uzun süreli depolanmasına izin verir. Bu yöntem, süblimasyon yoluyla bakteri hücrelerinden suyun uzaklaştırılmasını içerir, bu da hücresel yapılara verilen zararı en aza indirir ve depolama ve taşıma sırasında probiyotiklerin stabilitesini artırır (Nguyen vd., 2022; Kang vd., 2012).

Dondurarak kurutmanın en önemli avantajlarından biri, sprey kurutma gibi diğer kurutma yöntemlerine kıyasla probiyotik hücrelerin bütünlüğünü koruma kabiliyetidir. Çalışmalar, dondurarak kurutmanın tipik olarak probiyotiklerde daha düşük canlılık kaybına yol açtığını ve canlı hücre sayısındaki azalmaların püskürtmeli kurutmada gözlemlenenlerden önemli ölçüde daha az olduğunu göstermiştir (Gül ve Atalar, 2018; Çelik ve O'Sullivan, 2013). Araştırmalar, dondurularak kurutulmuş *Lactobacillus casei* mikrokapsüllerinin canlılıklarında daha az azalma sergilediğini, spreyle kurutulmuş muadillerinin ise daha önemli kayıplarla karşılaştığını göstermektedir (Gül ve Atalar, 2018). Bu, probiyotiklerle ilişkili sağlık faydalarının sürdürülmesi için özellikle önemlidir, çünkü sağlık etkileri sağlamak için canlı sayılarının belirli eşiklerin üzerinde kalması gerekir (Buahom, 2023).

Probiyotik bakterilerin hayatta kalmasını artırmak için dondurarak kurutma işleminde kriyoprotektanların dahil edilmesi çok önemlidir. Yaygın kriyoprotektanlar arasında, dondurarak kurutma işlemi sırasında hücre zarlarını stabilize etmeye ve buz kristali oluşumunun neden olduğu hasarı azaltmaya yardımcı olan trehaloz, maltodekstrin ve peynir altı suyu protein izolatı (WPI) bulunur (Nguyen vd., 2022; Mahmud vd., 2022). Trehaloz kullanımının, dehidrasyon ve oksidatif strese karşı koruma sağladığı için dondurarak kurutma sırasında laktik asit bakterilerinin hayatta kalma oranlarını önemli ölçüde artırdığı gösterilmiştir (Nguyen vd, 2022; Mahmud vd., 2022). Ayrıca, nişasta gibi polisakkaritlerin dondurarak kurutma sırasında koruyucu etkiler sağlayarak kapsüllenmiş probiyotiklerin canlılığını daha da artırdığı bildirilmiştir (Niro, 2023). Araştırmalar, probiyotiklerin canlılığını en üst düzeye çıkarmak için sıcaklık ve basınç gibi dondurarak kurutma koşullarını optimize etmenin önemini de vurgulamıştır. Dondurarak kurutmada kullanılan düşük sıcaklıklar, diğer kurutma yöntemlerinde kullanılan yüksek sıcaklıklara kıyasla hassas bakteri suşları için genellikle daha az zararlıdır (Kang vd., 2012). Ayrıca, dondurarak kurutma işlemi sırasında mannitol ve sorbitol gibi uyumlu çözücülerin eklenmesinin, proteinleri ve hücresel yapıları stabilize ederek probiyotik kültürlerin hayatta kalmasını arttırdığı gösterilmiştir (Chen vd., 2017; Kim vd., 2018).

2.3.Koaservasyon

Kompleks koaservasyon probiyotiklerin kapsüllenmesi için kullanılan bir diğer yaygın yöntemdir. Bu teknik, probiyotik hücrelerin etrafında koruyucu bir kabuk oluşturmak için tipik olarak bir protein ve bir polisakkarit olmak üzere iki veya daha fazla polimerin faz ayrımını içerir. Koaservasyon, yüksek kapsülleme verimliliği ve kapsüllenmiş probiyotiklerin kontrollü salımını sağlama kabiliyeti ile dikkat çekmektedir (Paula vd., 2021; Zhang vd., 2023). Peynir altı suyu proteini ve arap zamkı gibi malzemelerin koaservasyonda kullanılmasının, probiyotiklerin çeşitli çevresel koşullar altında stabilitesini artırdığı gösterilmiştir (Bosnea vd., 2017; Ho vd., 2018).

2.4.Ekstrüzyon

Probiyotiklerin ve uygun bir matrisin bir karışımının boncuklar veya peletler oluşturmak için bir kalıptan geçirilmesini içerir. Elde edilen mikrokapsüller daha sonra stabilitelerini artırmak için kurutulabilir. Ekstrüzyon, çeşitli gıda ürünlerine dahil edilebilecek daha büyük mikrokapsüller oluşturmak için özellikle yararlıdır (Corona-Hernandez vd., 2013). Ekstrüzyon süreci, probiyotiklerin kapsülleme sırasında ve sonrasında canlı kalmasını sağlamak için optimize edilebilir.

2.5.Elektrospinning

Bir polimer çözeltisini probiyotikleri kapsülleyebilen ince liflere çekmek için bir elektrik alanı kullanır. Elektroeğirmenin probiyotiklerin termal stabilitesini ve canlılığını artırdığı ve mikroenkapsülasyona benzersiz bir yaklaşım sağladığı bildirilmiştir (Ragavan ve Das, 2020; Feng vd., 2018). Üretilen nanolifler probiyotikleri zorlu çevre koşullarından koruyabilir ve bu yöntemi gelişmiş stabilite gerektiren uygulamalar için uygun hale getirir.

2.6.Emülsifikasyon

Probiyotik kültürün hidrofobik bir taşıyıcı malzeme ile emülsiyonunun oluşturulmasını ve ardından mikrokapsüller oluşturmak için katılaştırılmasını içerir. Emülsifikasyon, probiyotiklerin kapsülleme verimliliğini ve canlılığını artırmak için sprey kurutma gibi diğer tekniklerle birleştirilebilir (Corona-Hernandez vd., 2013; Gao vd., 2022).

3. SONUÇ

Mikroenkapsülasyon, fonksiyonel gıdalarda probiyotiklerin stabilitesini ve etkinliğini sağlamak için hayati bir stratejidir. Mikroenkapsülasyon, bu mikroorganizmaları zorlu çevre koşullarından koruyarak ve canlılıklarını artırarak probiyotiklerin tüketicilere sağlık açısından fayda sağlayabilecek bir formda sunulmasını kolaylaştırır. Mikroenkaspülasyon işlemi, koruyucu bir ortam sağlayarak, kontrollü salınımı kolaylaştırarak ve duyusal özellikleri geliştirerek probiyotiklerin tüketiciler için sağlık faydalarını en üst düzeye çıkarmada çok önemli bir rol oynamaktadır.

KAYNAKÇA

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THE NUTRITIONAL CONTENT OF HEMP (*CANNABIS SATIVA L.*) AND ITS USE AS A FUNCTIONAL FOOD

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1. INTRODUCTION

Cannabis is a significant plant that is employed in numerous industries. This species is dioecious, annual, and possesses both male and female structures. Indian hemp (Cannabis indica) and industrial hemp (Cannabis sativa L.) are the two primary types. The resin extracted from the female flowers of the indica plant is what gives it its characteristic potency. Sativa is the most common species, yields relatively little resin, and is grown for its hardy fibers. Hemp appears to be a potential substitute crop in the event of the anticipated future reduction in food supplies (Rusu et al., 2021).

The characteristics of hemp (Cannabis sativa L.) have drawn more attention in recent years. The food sector makes extensive use of hemp seeds, which are acknowledged as a nutrient-dense food source (Zahari et al., 2020). According to Gambuō et al. (2020), hemp seeds are high in calcium, iron, phosphorus, zinc, magnesium, protein, fiber, and oil (25–35%). With more than 80% unsaturated fatty acid content, hemp oil is

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especially rich in linoleic (50–70%), α-linolenic (15–25%), and γ-linolenic (3-5%) acids. It has a good nutritional value because it also has a 3:1 ratio of omega-3 to omega-6 fatty acids (Andre et al., 2016). Cannabis contains anti-inflammatory, antibacterial, and antioxidant qualities. It is rich in substances including phytosterols, tocopherols, polyphenols, carotenoids, phospholipids, and cannabidiol (CBD) (Markowska et al., 2021; Teleszko et al., 2022). Its high concentration of antioxidant-rich phenolic components, including as ferulic acid, caffeic acid, chlorophyll, and carotenoids, makes it a useful diet (Gambuō et al., 2020).

2. POTENTIAL USES OF INDUSTRIAL HEMP SEED

The high-quality, fiber-rich stalks of industrial hemp were once the main source of its economic value. Recently, however, new hemp industrial sectors have emerged with the recognition of the medicinal properties of cannabinoids found in hemp flower buds and the use of hemp seeds as food. Cannabinoids are cannabis-derived compounds with diverse biological effects produced in the trichromes of medicinal and industrial cannabis genotypes, especially flower buds. More than 100 different phytocannabinoids have been shown to be present in the trichromes in cannabis flowers, buds and leaves. The two most important cannabinoids are cannabidiol (CBD) and delta-9-tetrahydrocannabinol (THC). However, cannabinoids are found in trace amounts in hemp seeds (Adesina;2020).

The main cannabinoid of industrial hemp genotypes is CBD, while the main phytocannabinoid of medical hemp genotypes is THC. THC (the main cannabinoid in cannabis) is a psychoactive substance (Cherney and Small; 2016). However, THC has the ability to alleviate the side effects of chemotherapy and radiation, especially in the management of HIV and cancer. In addition to killing cancer cells, it is also used in the treatment of many diseases such as heart disease, epilepsy, rheumatism, asthma, MS, insomnia, stomach and spinal disorders. As a non-psychoactive cannabinoid, CBD has been shown to have therapeutic potential in the treatment of a wide range of conditions, including inflammation, anxiety, arthritis, infantile epilepsy, and neurodegenerative illnesses. Today, specific genotypes have been developed to produce maximum levels of CBD, which can be used in a variety of products and is gaining increasing popularity in the industry (Cherney and Small; 2016, Leonard et al., 2020).

The oil obtained from crushed hemp seeds can be used in many areas such as nutritional supplements, biofuels, personal care products as well as food. Hemp seed oil contains considerable levels of dietary antioxidant components, including sterols, tocopherols, and polyphenols, in addition to its high quantity of polyunsaturated fatty acids (Cherney and Small, 2016). Since hemp flour is a high-protein byproduct that is left over after the oil is recovered, it can be used as a starting point to extract hemp proteins. Hemp protein concentrate (HPC), hemp protein isolate (HPI), and hemp protein hydrolysate (HPH) are the three main categories of hemp protein products. Hemp protein has gained significant traction in the food industry as a functional food component due to its remarkable nutritional quality, biological activity, functionality, and aromatic qualities (Shen et al., 2020).

3. HEMP AS A HUMAN FOOD

In recent years, hemp has become a significant food source in many nations due to its great nutritional content. In Asia and Eastern Europe, hemp seeds and products are gaining increasing attention as a nutritious source for humans and animals (Andre, 2016). Plant-based protein can be obtained from hemp seeds. A few tablespoons of hemp seeds provide about 11 grams of protein containing amino acids such as cysteine, lysine, and methionine (Rehman, 2021). Hemp seeds contain 20-25% protein, 25-35% fat, 20-30% carbohydrates, 10-15% insoluble fiber and important minerals such as phosphorus, potassium, sodium, magnesium, sulfur, calcium, iron and zinc. Its biological value is high, just like chicken egg whites.

Non-medical quantities of psychoactive substances are found in cannabis seeds, with less than 0.3% of the psychoactive substance Δ-9-tetrahydrocannabinol (Δ-9-THC or THC) among them. The high concentrations of polyunsaturated fatty acids (PUFAs) in hemp seed are linked to its health advantages (Kolodziejczyk et al., 2012). Although hemp seed oil lacks psychotropic properties, its ideal ratio of ω-6 linoleic acid to ω-3 alpha-linolenic acid (3:1), which is recommended in a healthy diet, makes it demonstrate health-promoting activity. Other significant elements in hemp oil are the fat-soluble vitamins D and E. Many food items high in protein can be made from the waste left over after hemp seed oil extraction. Water-soluble albumin makes over 75% of the storage proteins found in hemp seeds. Hemp has more nutritional value because of its high arginine and sulfur-rich protein fractions in the seed protein. Thus, hydrolysates and proteins from hemp seeds can be utilized to create functional meals (Siudem et al., 2019; Aluko et al., 2017).

Several approved foods with high nutritional value contain hemp flour and oil because of its high mineral, vitamin (particularly complexes A, C, and E), carbohydrate, protein, and fat content. Bread made with hemp flour has higher protein and antioxidant levels. Additionally, it's utilized in the making of bread without gluten. Hemp flour, however, can make wheat bread thinner.

Studies on hemp seeds or sprouts as a functional diet should be conducted because they exhibit favorable impacts on cells of humans and yeast. According to a current research by Kladar et al., children should not eat foods containing hemp since hemp seed oil may pose serious health hazards due to its high Δ9-THC content. Moreover, strains with high Δ9-THC content can be used to make hemp tea (Frassinetti et al., 2018; Kladar et al., 2021).

This assessment’s objective is to outline what is known about hemp's nutritional qualities, with an emphasis on how it fits into vegetarian diets. The characteristics of hemp that might be useful for a vegetarian diet are outlined in Table 1.

Table 1. Certain Characteristics and Associated Advantages of Hemp

HEMP PROPERTIES	**BENEFITS**
Protein	A vegetarian diet lacking animal sources can nonetheless obtain an acceptable amount of protein thanks to the excellent nutritional value of hemp protein.
Essential Fatty Acids	Vegetarian diets have limited sources of omega-3 fatty acids (EFAs). Hemp oil's advantageous n6/n3 ratio can contribute to a balanced consumption of polyunsaturated fatty acids.
Calsium	The calcium-containing foods in a vegetarian diet devoid of milk and dairy products are restricted. Utilizing a range of plant-based foods, such as cannabis, can assist in meeting the RDA for calcium.
Iron	Since there are few high-bioavailable sources of iron in a vegetarian diet, it is advisable to consume a variety of foods high in this mineral, including cannabis.
Fiber	Although plant-based meals generally have high levels of dietary fiber, the beneficial qualities of hemp's insoluble fiber may promote hemp usage.
Fitochemicals	In a plant-based setting, hemp eating might be encouraged by its high concentration of bioactive compounds with potential health benefits.
Environmental Impact	The minimal environmental effect of hemp farming may promote the use of hemp as an environmentally benign plant-based resource, especially considering the widespread desire to switch to a vegetarian diet.
Multifunctionality	Hemp seeds can be utilized to create a range of industrial products , some of which are interesting for vegetarian diets, like plant-based dairy and meat substitutes. Hemp can also have promising qualities. Additionally, hemp derivatives can be added to supplements and baked foods as fortifiers.

4. CHEMICAL COMPOSITION OF INDUSTRIAL HEMP SEED

Hemp oil, flour, protein powder and milk from hemp seed have high protein and amino acid profiles, a rich combination of vitamins and minerals and good sensory properties. They also have a healthy fatty acid composition. On average, hemp seed contains 35.5% fat, 24.8% protein and 27.6% dietary fiber, of which 22.2% is indigestible and 5.4% digestible fiber. It also contains 5.6% ash and 6.5% moisture. The properties of hemp seed include a high concentration of minerals (calcium, iron, sodium, phosphorus, magnesium, potassium and vitamins B1, B2) and high amounts of β-carotene (Callaway., 2004).

5. HEMP SEED OILS

The oil derived from hemp seeds, namely Cannabis sativa L. seeds, is renowned for its nutritive and health-promoting qualities as well as its bioactive constituents. It has a higher concentration of both n-3 and n-6 essential fatty acids than other vegetable oils. According to Mikulcová et al. (2017), it has a high concentration of the omega-3 fatty acid alpha-linolenic acid (18:3 n-3, 20 wt%) and the omega-6 fatty acid linoleic acid (18:2 n-6, 55 wt%).

While the quantity of stearidonic acid (18:4 n-3) varies from 0.5-2% by weight, that of gamma-linolenic acid (18:3 n-6) ranges from roughly 1-4% by weight.Hemp seed oil has moderate to high concentrations of minerals, phytosterols, phospholipids, carotenes, and tocopherols and tocotrienols (100–150 mg per 100 grams of oil). Because of these advantageous qualities, hemp seed oil can be used as a component in functional meals and has a wide range of potential uses in the management of different health issues. Reducing hypertension and elevated cholesterol are two significant instances of applications (Raikos et al., 2014). The key factor contributing to hemp seed oil's health advantages is its 3:1 ratio of n-3 to n-6 fatty acids, which is optimal for human nutrition. Research has indicated a connection between an imbalanced intake of omega-3 and omega-6 fatty acids and a number of diseases, such as diabetes, heart disease, and cancer. Compared to other common seed oils, hemp seed oil has a distinctive composition that presents prospects for the creation of specialized nutritional formulations (Raikos and Ranawana, 2017). Nevertheless, there is still debate regarding hemp seed oil's antimicrobial, particularly antibacterial, properties despite its well-established nutritional and health benefits. According to a very recent study, hemp seed oil contains antibacterial properties that can be employed against Gram-positive bacteria. To clarify the poorly understood limiting variables affecting the bioactivity of crop oils obtained from hemp, more investigation is necessary. The fabrication of oil-in-water (O/W) emulsions made of mineral or synthetic oils has been the subject of several studies published in the literature; however, the development of these emulsions when vegetable oils are present has received less attention (Mikulcová et al., 2017). The majority of uses for vegetable oil-based emulsions include cottonseed, peanut, coconut, palm, sunflower, rapeseed, rapeseed, palm kernel, and olive oil. The bioavailability of accessible unsaturated fatty acids can be enhanced by putting oil into nanoemulsions because of their high surface-to-volume ratio and smaller droplet sizes.

Hemp seed oil is an organic supplier of antioxidants that can be used in diets to help protect against oxidation and reactions with other chemicals. This can help prevent disease and promote health (Raikos et al., 2017). Limited research has been done on hemp seed oil emulsions (water-in-oil). In one study, hemp seed oil and emulsion composition, characterization, and anticipated antibacterial capabilities were examined. With a 3:1 ratio of necessary fatty acids to non-essential fatty acids, hemp seed oil is very rich in vital fatty acids. It is thought to be ideal for human nutrition. Consequently, it has been demonstrated that these kinds of prepared emulsions can strengthen food items (Mikulcová et al., 2017). Furthermore, because of their non-toxic, biodegradable, and ecologically friendly qualities, oils derived from plants are often used in non-food businesses like both cosmetic and medicinal ones (Reichert et al., 2019).

Because hemp oil has a high concentration of α-linolenic acid (ALA), linoleic acid (LA), and γ-linolenic acid (GLA), it is a highly valued component in cosmetic and cosmeceutical goods. In actuality, skin conditions including psoriasis, acne, and atopic dermatitis can be brought on by a lack of these fatty acids, particularly GLA (Kowasalska et al., 2015).

6. APPLICABILITY OF HEMP AND ITS BY-PRODUCTS IN FOODS

Improved products like hemp powder, concentrate, cake, and isolate made using various technologies are used in bakery goods, snacks, beverages, dairy products, processed meat products, and many other products because of hemp protein's abundant nutritional value and the positive sensory notes it adds to food. Products created with hemp protein have been discovered to have a higher nutritional content and to offer certain technological advantages, in contrast to the widely used casein, whey powder, and soy protein in the food sector (Dabija et al., 2018).

Gluten-free crackers with up to 40% hemp cake were found to have higher protein, dietary fiber, minerals and essential fatty acids (Ω-3, Ω-6) and lower carbohydrate levels compared to brown rice flour. It was also found that the ratio of Ω-6 and Ω-3 fatty acids in all crackers was between 1.7 and 1.83, with an excellent balance. As the proportion of hemp cake in the cracker formulation increased, the amounts of monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) also increased. Similarly, a steady increase in Ca, Fe, Mn, Mg and Zn was observed, with K being the highest mineral content (Radočaj et al., 2014).

It was discovered that adding hemp cake to wheat flour bread at various ratios (0%, 5%, 10%, and 20%) affected the bread's volume, color, and structural characteristics as well as how quickly the dough developed. Proteins and macro- and microelements, especially iron, were increased, while gluten content was decreased in bread enriched with hemp cake. However, the use of more than 20% hemp cake negatively affected the rheological properties of the dough. According to the results of the study, consumption of 300 grams of bread enriched with 20% hemp flour could theoretically meet the daily recommended iron intake (Pojić et al., 2015).

7. USE OF HEMP SEEDS IN FUNCTIONAL FOODS

The food industry uses hemp seeds (43.60%) from Cannabis sativa L. as the most common cannabis plant ingredient because of their high protein content and lipid profile, which makes them a great source of nutrition (Rizzo et al., 2023). Furthermore, because of their better nutritional profile, hemp seeds and goods derived from them have become increasingly popular with customers. Hemp seeds can be eaten raw, shelled, or combined with other food ingredients to create a vast array of hemp seed-derived products (Raihan and Bijoy, 2023).

Produced from Cannabis sativa L., hemp seed oil has become well-known in the marketplace as a natural product with increasing awareness of its potential benefits as a dietary supplement and in medicine (Pannico et al., 2022). Atopic dermatitis, chronic inflammation, oxidative stress, and red blood cell composition are examples of degenerative diseases that have been the subject of numerous research investigating the potential of hemp seed components to treat them. These properties are attributed to their antioxidant and anti-inflammatory qualities. Overall, the research that were examined show that hemp seeds and derivatives have promise as health-promoting dietary supplements (Schwab et al., 2006, Yıldırım and Akçay, 2023).

Energy bars are a popular dietary supplement that people take in order to meet their caloric needs or to make up for not getting enough protein in underdeveloped or nutritionally deficient countries. This is especially true for athletes and people who engage in intense physical activity (Akçay et al., 2023, Göbel et al.,2022).

The findings indicate that hemp seeds can be combined with other ingredients to create rice/hemp extrudates or used independently as powders and additives. According to Dewettinck et al. (2008), both variations successfully add more protein to food and enhance its qualities.

According to recent studies, hemp seed flour has the potential to boost the nutritional value of food products and is a more nutritious alternative to wheat flour. In trials on bread manufacture, the addition of hemp flour had a notable impact on the end product's quality, leading to a decrease in volume and an increase in protein and fat content, particularly when the hemp flour concentration was 20%. Texture and scent were affected, particularly at 30% and 50% hemp flour additions, according to sensory evaluation, which also revealed a decline in the quality of sensory experience (Mikulec et al., 2019). In samples of bread made with hemp flour, there was a noticeable drop in the amount of yeast and mold, which improved the product's energy value. Its proprietary hemp seed oil and method for using hemp seeds to make bread and pastries demonstrate how versatile hemp seeds can be when used to make creative products. Additionally, hemp flour has been used to make baked goods devoid of gluten or to lower the gluten level in bread. The nutritional value of the bread was greatly enhanced by the inclusion of hemp seeds, flour, and proteins, resulting in notable increases in the amount of protein and fiber. The findings imply that hemp flour and proteins can greatly enhance the formulations of baked goods, improving their nutritional value, acceptability to the senses, and flexibility in handling different dough types (Teleszko et al., 2022).

Hemp seeds are a great way to increase the lower nutritional content of gluten-free products because they don't contain natural gluten. This is primarily because total dietary fiber—which comprises both soluble and insoluble fractions—as well as total protein, fat, and minerals, have increased significantly. A specific focus has been placed on the insoluble component. According to Farinon et al. (2020), these results demonstrate how hemp seeds may enhance the nutritional profile of gluten-free goods.

Farinon et al. (2020) looked at the impact of using hemp seed flour in place of regular flour in cookie dough. The mixture's overall hydration qualities were significantly improved, according to the results. In terms of the cookies, substituting hemp flour for regular flour resulted in a rise in hardness and a fall in volume, with cookies enhanced with 60% hemp flour achieving the maximum value. As the amount of hemp seed substituted in the cookies and biscuits increased, the color of the cake and crumb deepened, which improved the product's sensory appeal (Farinon et al., 2020). Wolf et al. (2017) created a method for baking cakes using cannabis seed oil obtained from Cannabis sativa L., which resulted in the development of a productive method for the evaluation and assurance of the quality of edible products containing cannabis. In addition, he wanted to create gluten-free cuisine. He concentrated on making biscuits with decaffeinated green tea leaves and wholesome hemp flour. The product was significantly enhanced by its superior nutritional qualities, which included proteins, crude fiber, minerals, and essential fatty acid properties. These attributes also demonstrated hemp flour's potential as a functional ingredient for the production of wholesome, easily accessible, and possibly functional food products—particularly for those who suffer from celiac disease (Farinon et al., 2020).

Hemp seed milk, derived from the Cannabis sativa L. plant, is a well-liked substitute for cow's milk, ideal for people who have allergies, are lactose intolerant, or are vegetarians or vegans. In order to prepare hemp seed milk at home, a solution of hemp seeds and water is created that contains an essential omega-3 fatty acid called alpha-linoleic acid and 0.83 g of protein per 100 mL This hemp milk has an earthy flavor and creamy texture, with less fat and less calories, protein, and carbs than cow's milk. It is adaptable and provides a delightful and nutritious substitute for other ingredients in a range of recipes, including cereals, coffee, and smoothies (Dewettink et al., 2008).

By using high-pressure homogenization (HPH) and pH change treatment, it is possible to produce heatly untreated hemp "milk" that is stable, has a decreased microbial population, and is physically resistant to oxidative deterioration. These results suggest that hemp "milk" has the potential to replace milk. Additionally, Ferdouse et al. (2024) created a method to produce hemp "milk" that doesn't get bitter or change color when it's pasteurized. In order to create cutting-edge goods, the food sector is concentrating on utilizing the nutritional potential of hemp seeds from Cannabis sativa L. Businesses that emphasize the nutritional and health advantages of cannabis seeds have developed a diverse range of food products under brands including Allive®, Nutiva®, Manitoba Harvest®, and Canah®.

Meanwhile, companies like Turn®, Cannabia®, Mandrin®, Coors Light®, and Appenzeller HanfblüteTM provide a range of hemp-based goods, such as protein shakes, infused beers and wines, hemp cocktails (like Hempfy gin and tonic), spirits (flavoring with hemp seeds), lemonades (like Hempfy Martini) and teas (like HempTea).

The products are especially based on plant-based nutrition claims and do not contain gluten, added sugars, or genetically engineered components (Dewettink et al., 2008). Additionally, the CANNUSE database, which can be accessed at http://cannusedb.csic.es, offers an extensive and well-structured source of data regarding the usage of hemp seeds from Cannabis sativa L., with possible dietary and medicinal benefits (Zajac et al., 2019).

8. NUTRITIONAL ASPECTS

In terms of nutritional value, hemp seeds and subsequently the fruits of C. sativa are the most commonly used parts of the plant for human use. Botanical theory states that hemp seed is an achene, just like quinoa, amaranth, buckwheat, and strawberry achenes, which are dried fruits with an internal seed that is not adhered to by the hardened pericarp (Naraine et al., 2020). Unless otherwise indicated, when we discuss using cannabis as a plant material for nutritional purposes in this book, we are referring typically to cannabis seeds. Although the plant's other anatomical parts, like its flowers and leaves, may be edible, cannabis has very little nutritional value other than as seeds. As a result, the food products that are produced don't contain any cannabinoids and aren't legally forbidden (Kwas Łnica et al., 2020).

Hemp was mostly used for textiles in earlier ages, and the seeds were thought to be waste. It wasn't until lately that there was a significant interest in hemp for nutritional purposes.Roughly fifty distinct types of hemp with varying macronutrient contents are cultivated for nutritional purposes. The percentage of protein is not more than 30%, the percentage of dietary fiber is between 30% and 40%, and the percentage of fat is between 25% and 30%.

The majority of the dietary fibers in seeds are eliminated during the hulling process, which is concentrated in the exterior integuments of the seed (House et al., 2010). Shelled seeds have over 46% oil content and over 35% protein content, respectively. Conversely, the polysaccharide component is virtually exclusively composed of dietary fiber, hence the amount of carbs is typically quite small and insignificant (see special section below). But hemp also contains additional phytochemicals including sterols and polyphenols, as well as bioactive peptides that have antioxidant properties (Malomo et al., 2014). These are intriguing nutritional characteristics of hemp. Hemp seed has versatility and promise, and the nutritional composition of hemp-derived products can satisfy consumer demands. They can be eaten whole, shelled, or as flour, oil, or separate proteins. The process of seed germination enhances the nutritional profile by making accessible phytochemicals more bioavailable. This can boost the health benefits of seeds because of their stronger antioxidant and anti-inflammatory properties. According to Karus et al. (2004), the USDA database is presently the largest repository on food composition.

9. SUSTAINABILITY

The media and scientific publications have raised awareness of the environmental impact of food, which has led to an increase in debate on the subject. It is commonly known that human activities affect the environment by releasing molecules that contribute to the greenhouse effect and contaminate soil and water, as well as by exploiting resources that are not sufficiently replenished to ensure an adequate turnover. Recent research has shown that, among other things, the production of food contributes to environmental effect, and that, when examined throughout all supply chains, the exploitation of food resources has a significant impact on the environment (Dixon et al., 2023). The decision to become vegetarian is influenced by a variety of issues, including ethics and health, but sustainability in the environment and ecology is only one facet of a larger idea that also takes social and human health sustainability into account. Because hemp can be a valuable plant-based food source to support health and nutritional needs, as well as because its cultivation may have positive benefits on agriculture's environmental impact, using hemp for food can be consistent with a vegetarian diet. With its quick growth and effective carbon sequestration, hemp looks to have a smaller environmental impact than other crops. The requirement for herbicides, fungicides, and other pesticides used to manage weeds and pests is reduced by rapid growth (Rupasinghe et al., 2020).

Hemp is also a great crop for crop rotations to prevent over-exploitation of the soil because of its quick exfoliation, which enables effective restoration of farmed soils. Furthermore, hemp requires less irrigation (Ranalli et al., 2004).

There have been reports of using hemp as a phytoremediation method especially to get rid of heavy metals. However, using hemp for both simultaneous food use and soil decontamination poses questions due to the transmission of heavy metals like cadmium to seed. The usage of fertilizer exacerbates this occurrence (Mihoc et al., 2012).

10. CONCLUSION

As a result, it is observed that industrial hemp production and usage areas are increasing day by day in the world. Especially the medical hemp sector is rapidly developing and attracting great interest. In addition, as the demand for hemp products increases in many areas from organic-based food products to clothing and shelter, the preference rate of these products is also increasing. In our country, significant developments have been recorded in recent years regarding hemp utilization areas. The deepening global food crisis, which has led to the search for alternative products, allows us to examine the potential and current applications of hemp more closely. Research has shown that hemp seed, oil and flour have great potential for both social and economic gain in the food sector. Scientific studies have also determined that products such as bread, cookies, cakes, chips, cakes, biscuits and pasta can be made with hemp additives.

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PHYSICOCHEMICAL AND ORGANOLEPTIC PROPERTIES OF *PEKMEZ* (TRADITIONAL TURKISH FRUIT MOLASSES)

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1. INTRODUCTION

Traditional foods are defined as foods that are prepared with local foods and ingredients, accepted by public, and have potential health effects which are tested over time (Ötleş et al. 2016). For a food to be counted as 'traditional', it should not only contain traditional ingredients but also be prepared/processed according to the traditional recipes and/or with traditional methods (Guiné et al. 2021). Traditional foods, which vary based on the cultural prosperity of a country, play important role on local identity, consumer behavior, preserving and transferring the cultural heritage to the next generation (Salık et al. 2021). Furthermore, the interest of both consumers and food manufacturer in to the traditional food increases with apprehension of specific organoleptic properties and health-improving properties of these foods (Tamer et al. 2019).

In Türkiye, *pekmez* (Turkish fruit molasses) is a traditional food and it is produced by fruits such as grapes, mulberries, carob, dates, figs and plums (Korkmaz 2023b).

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Pekmez is an intense sweet syrup with a 70-80% total soluble content and it is produced by pressing sweet fruits, and afterward clarifying and boiling them (Heshmati et al. 2020; Satıl & Selvi 2022). In Turkish Food Codex Grape Pekmez Communiqué, grape pekmez is defined as a viscous food product from unfermented fresh grapes or raisin extracts produced by proper techniques of concentrating under vacuum condition or open (atmospheric) systems after reducing the acidity and clarifying with proper techniques (2017).

Export surplus fruits and legumes are utilized by producing pekmez out of them in Türkiye. On the one hand, with its high sugar content (monosaccharides such as glucose and fructose), it readily provides energy for especially people who needs high energy intake (i.e. athletes, pregnant women, etc.). On the other hand, with its high mineral and organic acid content it has a long shelf life and high nutrition value; at the same time, it has high antioxidants and phenolic contents which are considered as beneficial to human health (Aykas et al. 2023; Şen et al. 2020).

The quality of pekmez varieties generally related to their physicochemical properties (such as °Brix, acidity, pH, etc.), content of sugars, organic acids and volatile compounds as well as their degrees of non-enzymatic browning (Korkmaz 2023a). In pekmez, non-enzymatic reactions occur via caramelization and Maillard reactions. Even though these reactions responsible with desirable color and flavor formation in heat-treated foods, further treatment usually results in degradation of components and lowering the nutritional value of the foods. Thermal treatments cause reactions of amino acids, peptides, and proteins with reducing sugars and other carbonyl groups. Increased concentration of compounds such as 5-hydroxymethyl furfural (HMF) may indicate the degree of high thermal treatment levels (Kuşçu & Bulantekin 2016). HMF level in heat-treated foods is the most important quality indicator in foods with high sugar content because of its risk on human health with its potential carcinogenic and toxic effects (Korkmaz 2023b).

The usual flavor of pekmez originated from the harmonious effect of high sugar content and volatile compounds that are formed from various pathways during pekmez processing (Samborska et al. 2021). Flavor compounds from non-enzymatic browning reactions are responsible for the formation of typical desirable pekmez aroma (Coklar & Akbulut 2020).

Other quality indicators in foods are sensory properties and/or organoleptic properties which are affected by the type of foods, environmental conditions and individual consumers. Consumer acceptance is a situation based on desires of consumers and it is affected by sensory properties of foods and several other factors (Al-Bachir & Othman, 2023). In this chapter, recent studies on physicochemical and organoleptic properties of traditional Turkish pekmez varieties were reviewed.

2. TYPES OF PEKMEZ

Traditional Turkish pekmez varieties are mainly produced from several fruits such as grapes (*Vitis vinifera L.*), mulberries (*Morus alba L.* and *Morus nigra L.*), dates (*Phoenix dactylifera L.*), figs (*Ficus carica L.*) and plums (*Prunus domestica L.*), and fruits of carob (*Ceratonia siliqua L.*) (Korkmaz 2023b).

3. TRADITIONAL PEKMEZ PRODUCTION

In traditional pekmez production, first, fresh fruits are washed thoroughly and then transferred to concrete or wooden vats in which the fruits are trampled by workers with clean boots and the juice (grape must) is extracted. Afterwards, pekmez earth or calcium carbonate ($CaCO_3$) is added and filtered. Pekmez earth is a white soil which naturally contains calcium carbonate and it is used to precipitate tartaric and malic acids as calcium salts (calcium tartrate and calcium malate) to reduce the acidity of the grape must. To make pekmez earth to start working efficiently and quickly, to prevent yeast to acts and to speed up the clarification, the grape must is heated to 70 ˚C. It is cooked in open air vats until it becomes a viscous liquid. The foams that are formed during boiling are collected and a clear pekmez is obtained at the end of the process (Akan 2018; Karababa & Işikli 2005; Özkan et al. 2023).

4. PHYSICOCHEMICAL PROPERTIES OF PEKMEZ VARIETIES

Quality parameters of pekmez varied with the type of the fruit, harvest time, climate changes and the amount and type of acidity regulator that is used during pekmez production (Erbil 2020). Studies on several pekmez types has been investigated and physicochemical properties such as total soluble solids, pH, total acidity, HMF, ratio of glucose to fructose and total sugar content parameters are shown in Table 1.

A total of 24 grape pekmez samples that are produced by traditional and commercial methods (12 samples each) were investigated by Erbil (2020) and °Brix values were found in the range of 60.1-77.95 and 62.7-82.1, respectively. In addition; carob, mulberry, juniper berry, apple and pear pekmez samples were also investigated in the same study and the °Brix values were ranged 72.3-81.6, 72.9-81.5, 69.1-78.2, 54.1-67.4 and 65.6-76.0, respectively. The reasons for these wide ranges were concluded as results of insufficient clarification, filtration, and boiling, and/or uncontrolled concentration by boiling at high temperatures for a long time. In another study, carob pekmez samples that were produced by traditional methods and ultrasonic method were compared and there was no significant difference in °Brix values (Eroğlu 2020). Grape pekmez samples were also produced by traditional concentration and vacuum concentration and their Brix values were measured as 75.6 and 75.8, respectively (Korkmaz 2023a). According to Turkish Food Codex Grape Pekmez Communiqué (2017), total soluble solid in grape pekmez must be at least 68%. These values were acceptable based on Turkish Food Codex. Apart from fruit pekmez types, traditionally produced pine cone (*Pinus nigra* and *Pinus brutia*) pekmez samples were also investigated and °Brix values ranged from 64.6 to 78.7 (Gamli 2022; İncemehmetoğlu 2021). Since those samples were home-made; researchers concluded that the reason for this wide range caused by different boiling durations, usage of different sugars and decision of the final product thickness and cooking levels by sight only.

Table 1. Physicochemical properties of various Turkish pekmez

Pekmez	TSS[a] (°Brix)	pH	TA[b] (g/100)	HMF[c] (mg/kg)	Glucose (g/100)	Fructose (g/100)	F/G[d] (g/100)	Total sugar (g/100)	References.[e]
Grape	60.1-77	3.5-8.4	0.2-1.9	5.9-380.1	17.1-36.4	0.6-35.4	0.6-1.2	49.3-71.1	[1,2,3,4,5]
Mulberry	70.9-84	4.8-5.8	0.5-0.9	38.2-773.5	1.9-32.7	13.8-36.2	0.4-1.5	49-71.8	[2,3]
Carob	64-81.6	4.5-5.8	0.4-0.5	0.3-482.9	6.1-29.5	8.0-32.7	0.6-1.9	46-63.1	[3,6]
Pine cone	64.6-78.7	3.4-4.8	1.2-3.2	36-74.5	17.2-36.5	5.9-30.3	0.4-0.9	49.3-75.8	[7,8]
Juniper berry	69-79.5	4.8-5.7	0.1-0.9	0.08-153.2	10.0-25.9	4.9-26.6	0.7-1.2	35.4-56.0	[2,3]
Apple	54-74.8	3.5-5.7	0.3-0.4	235.3-2244	14.5-24.5	17.4-25.3	0.7-1.7	38.3-49.9	[3,9]
Pear	65.5-76.0	4.2-4.5	0.9-1.2	141-627	16.7-19.8	30.7-36.8	1.6-2.9	53.6-58.8	[3]

a: Total Soluble Solids, b: Total acidity, c: 5-Hydroxymethyl furfural d: Ratio of glucose to fructose, e: References (1: Korkmaz, 2023a; 2: Aykas et.al. 2023, 3: Erbil, 2020, 4: Türkben et.al. 2016; 5: Özcan et.al. 2015 6: Eroğlu, 2020, 7: Gamli, 2022, 8: İncemehmetoğlu, 2021, 9: Kuşçu & Bulantekin, 2016).

The pH value and total acidity ranges of pekmez samples were wide in most samples, especially in grape pekmez samples (Table 1). Even though these ranges might be influenced by used fruit type from different varieties and regions of Türkiye; producing the pekmez with traditional method without any pH measuring device, the amount of acidity regulator or usage of other additives (as in food adulteration) might also be reasons (Türkben et al. 2016; Erbil 2020; Özcan et al. 2015; Korkmaz 2023a). In Turkish Food Codex Grape Pekmez Communiqué (2017), pekmez that have pH values between 5.0 and 6.0 are counted as sweet, while pekmez that has pH values between 3.5 and 4.9 are counted as sour. If this rule was applied to all pekmez samples; carob pekmez would be considered as sweet and fig, pine and pear pekmez would be considered as sour; while grape, mulberry, juniper berry and apple pekmez would be considered as both sweet and sour.

As a Maillard reaction product, 5-hydroxymethyl furfural (HMF) is formed during pekmez production and since at high levels it shows negative effects on human health (Baş and Gürkan 2021), the levels in pekmez is limited to 75 mg/kg (Turkish Food Codex, 2017). It is used as a quality indicator for an appropriate heat treatment in pekmez samples (Batu et al. 2014). Traditional production of pekmez results in formation of almost 10-20 times higher levels of HMF (as compared to commercial production because it uses open vats and boils at high temperature (Erbil 2020; Gamli 2022). There are few methods to reduce HMF formation such as adding zeolite and using vacuum evaporation (Şen et al. 2020; Altiok et al. 2021). The loss of mineral and phenolic compounds during pressing and clarification might also reduce HMF level (Kuşçu & Bulantekin, 2016). Usually, industrial production results in formation of lower levels of HMF, however; usage of ultrasonication was found to increase the levels of HMF in carob pekmez presumably because of the effect of ultrasound on amino acids and sugars (Eroğlu 2020).

According to Turkish Food Codex Grape Pekmez Communiqué (2017), grape pekmez cannot be produced under the names of fruity sweet syrup, grape dessert and grape pekmez syrup by diluting and increasing the volume with added glucose, fructose or other sugars. The legal level of fructose/glucose ratio is in between 0.9-1.1. There are several studies on F/G values of pekmez samples (Table 1). For example, pekmez samples were collected from both traditional and industrial samples by Erbil (2020) and the F/G ranges were found 0.6-1.2 and 0.8-1.1, respectively. It was concluded that samples that did not comply with legal limits of F/G values, might be because of food adulteration.

Table 2. Mineral content of various traditional Turkish pekmez (mg/100g)

Minerals	Grape	Mulberry	Fig	Pine cone	Juniper berry	Apple
Phosphorus (P)	306.6-492.4	54	42-52	69.8-80.4	144.5	-
Iron (Fe)	53.4-132.1	0,9	1.6-1.9	7.6-10.8	0.6	20.1-21.6
Copper (Cu)	1.6-16.5	0,4	0.3-0.5	-	0.3	3.1-3.3
Zinc (Zn)	1.2-6.4	0,4	0.4-0.7	6.1-9.9	1.2	-
Potassium (K)	1811.7-9581.3	438	535-596	586.4-645.4	1884	7754-7914
Sodium (Na)	153.1-248.8	52	72-88	44.3-59.2	3.5	-
Magnesium (Mg)	187.3-332.3	67	87	94.2-101.3	84.3	482-510
Calcium (Ca)	940.1-1491.6	96	496-562	522.7-608.2	149.9	3511-3684
References	[1]	[2]	[3]	[4]	[2]	[5]

References: 1: Özcan et.al. 2015; 2: Karababa & Işikli 2005; 3: Beykaya & Artık 2020; 4: Gamli 2022, 5: Kuşçu & Bulantekin 2016.

In Table 2, minerals contents of grape, mulberry, fig, pine cone, juniper berry and apple pekmez were shown from publications. There is no info on Turkish carob and pear pekmez mineral contents. According to Turkish Food Codex Grape Pekmez Communiqué (2017), maximum levels of certain minerals are as follows: 25 mg/kg for iron, 5 mg/kg for copper, 0.2 mg/kg for arsenic, 0.3 mg/kg for lead and 5 mg/kg for zinc.

Mineral content of traditionally produced pekmez might be related to the high temperature treatment; while some mineral content may increase and some others may decrease during production (İncemehmetoğlu, 2021). Furthermore, high levels of calcium might be caused by addition of pekmez earth or $CaCO_3$ (Kuşçu & Bulantekin 2016). The variety in concentration of these minerals might be affected by factors such as different climate conditions, production methods, boiling time and temperatures, fruit types and varieties and peel properties of fruits, etc. (Gamli 2022).

Table 3. Organic acid contents of traditional Turkish Pekmez

	Malic acid (g/100g)	Tartaric acid (mg/100g)	Citric acid (mg/100g)	Fumaric acid (mg/100g)	References
Grape	0.3-3.5	7.4-308.6	7.3-90.9	-	[1]
Mulberry	0.4-1.2	-	30.2-238.4	29.2-518.7	[1]
Apple	0.4-2.9	31.6-54.5	46.5-81.6	-	[1,2]
Pear	0.3-1.3	-	6.1-76.1	-	[1]

References: 1: Türkmen, 2022; 2: Kuşçu & Bulantekin, 2016.

Organic acids are effective on taste (sourness and tartness) of fruit juices and the unique taste of the fruits (Kuşçu & Bulantekin 2016). There are two studies on organic acid levels on Turkish pekmez from grape, mulberry, apple and pear (Table 3). There is no information of organic acid contents of Turkish carob, fig, plum, pine cone or juniper berries. According to Turkish Food Codex Grape Pekmez Communiqué (2017), the ratio of tartaric to malic acid levels must be $\geq$1. Türkmen (2022) found that some of the pekmez samples did not comply with this value due to low levels or absence of tartaric acid; caused by adulteration on those samples. In addition, Kuşçu ve Bulantekin (2016), found that organic acid values decreased with increased storage time due to precipitation of tartaric and malic acids as tartrate and malate by reacting with $CaCO_3$ that is added during pekmez production.

Table 4. Color values of traditional Turkish Pekmez

	L*	a*	b*	References
Grape	23.1-55.3	2.1-18.7	-0.1-47.5	[1,2]
Mulberry	19.1-32.6	8.2-17.6	2.4-9.1	[3]
Carob	13.2-16.1	9.4-10	-1.1-1.2	[4]
Pine cone	0.4-29.1	6.5-44.1	3.1-36.5	[5,6]
Juniper berry	14.3	8.4	2.3	[7]
Apple	24.2-28.2	0.6-4.6	0.2-4.8	[8]
Pear	24.2-25.2	0.8-1.2	-0.1-1.2	[8]

References: 1: Şimşek et. al. 2022; 2: Özcan et. al. 2015; 3: Salık et. al. 2021; 4: Eroğlu 2020; 5: Gamli 2022; 6: İncemehmetoğlu 2021; 7: Safkan et. al. 2021; 8: Türkmen 2022.

Color is another psychochemical property of food products and the value of L* means lightness; value of a* means green in negative and red in positive numbers; value of b* means blue in negative and yellow in positive numbers. When the L* is at its maximum value (i.e. 100), it means a complete permeability of the light (Eroğlu 2020). Color values of traditional Turkish pekmez from various studies are shown in Table 4. The color of pekmez formed by browning reactions caused by heat treatment during production. Type of production method and duration of production also affects the color. The sugar in pekmez partially burns and results in an increase in a* value and a decrease in L* value with darkening of the color. Non-enzymatic browning reactions are also affecting the color of pekmez during storage (İncemehmetoğlu 2021). Furthermore, the type of fruit affects the color. For example, in a study, L* values from red, black and white grapes were measures as 43.2, 55.3, and 37.5, respectively (Özcan et al. 2015). High quality pekmez samples were reported to have lower a* and b* values, Higher values were also indicated the increased HMF content in pekmez (Ereli 2021).

5. ORGANOLEPTIC PROPERTIES OF PEKMEZ

5.1. Volatile Compounds and Aroma-Active Components in Pekmez Varieties

Food aromas are mixture of various substances that are volatile compounds and have a complex relationship with their odor properties (Johnson et al. 2019). The general aroma profile of pekmez originated from the effect of amino acid content, high sugar content, and the high temperatures during production which results in Maillard reaction and caramelization (Samborska et al. 2021). The main volatiles of pekmez consist of aldehydes, alcohols, acids, esters, lactones, terpenes, and compounds from miscallenous groups (Table 5). Since alcohols and acids have high odor thresholds, they usually do not directly affect the aroma of pekmez. Alcohols are precursors of aldehydes and esters. While aldehydes are generally responsible for fruity and roasted flavor; esters give characteristic fruity and floral aroma. Short-chained aliphatic esters usually have fruity odors, however, longer chained-esters have fatty, soapy and even metallic odors. Esters are usually formed by esterification of carboxylic acids and alcohols Lactones usually gives creamy, fatty, and fruity flavor and they are either formed by cyclization of corresponding hydroxy carboxylic acids or by oxidation of unsaturated aldehydes. Terpene compounds are usually found in essential oils and consist of monoterpene and sesquiterpene hydrocarbons and alcohols and diterpenes. They are also used as antimicrobial agents in food industry. Sulfur and nitrogen-containing heterocyclic compounds are generally formed via Maillard reaction and because of their low odor thresholds, small amounts affect the quality of aroma characteristics of foods (Safkan et al. 2021; Surburg & Panten 2006).

Table 5. Volatile compounds of Turkish molasses and odor properties

Compounds	Odor properties[a]	Grape (TCM)[b] (µg/kg)	Grape (VCM)[c] (µg/kg)	Juniper berry[d] (µg/L)	Apple (VE)[e] (%)	Apple (OPE)[f] (%)
Aldehydes						
2-Methylbutanal	Chocolate-like	1.35	-[g]	-	17.0	2.9
3-Methylbutanal	Chocolate-like	3.39	-	-	-	-
2-Methyl propanal	Aldehydic	-	-	-	-	3.6
1-penten-3-ol	Green				4.1	-
Nonanal	Aldehydic	4.05	2.19	-	-	-
Benzaldehyde	Cherry, bitter almond	12.14	4.09	88.4	-	-
Furfural	Caramel-like	97.29	33.19	1050	8.2	18.5
5-Hydroxymethyl furfural	Caramellike, fatty	-	-	1817	-	-
5-Methylfurfural	Caramel-like	4.42	-	-	-	-
Alcohols						
Ethanol	Fruity	3.97	8.49	-	-	-
3-Methylbutanol	Etheric	-	8	-	-	-
2-Ethylhexanol	Citrus	0.75	6.92	-	-	-
3-Penten-2-ol	Green vinyl	-	-	355	-	-
4-Methyl-2-pentanol	Pungent	-	-	244	-	-
2,3-Butanediol	Buttery	-	-	1869	-	-
Furfuryl alcohol	Caramel-like	-	-	427	-	2.6
Benzyl alcohol	Floral	-	-	72.2	-	-
2-Furanmethanol	Caramel-like	4.28		-	-	-
Acids						
Acetic acid	Acidic	-	25.24	299	41.0	27.2
Butanoic acid	Cheesy	-	8.38	69.8	-	-
Hexanoic acid	Fatty	-	-	928	-	-
Nonanoic acid	Waxy	19.65	40.82	118	-	-
Decanoic acid	Fatty	-	8.82	-	-	-
Ketones						
3-Octanone	Herbal	1.73	2.08	-	-	-
3-Hydroxy-2-butanone	Buttery	-	-	495	-	-
2-Hydroxy-2-propanone	Caramel-like	-	-	492	-	-
2-Propanone	Etheric	-	-	-	15.3	5.6
2-Pentanone	Fruity	-	-	-	-	34.3
Hydroxyacetone	Caramel-like	4.6	-	-	-	-
Ester						
Ethyl acetate	Etheric	3.72	6.6	-	-	-
Metil-2-furoate	Fruity	5.95	-	352	-	-
Lactones						
ϒ-Butyrolactone	Creamy	-	-	599	-	-
Pantolactone	-	-	-	138	-	-
Terpenes						
D-Limonene	Citrus	11.69	-	279	-	-
(*Z*)-Limonene oxide	Citrus	-	-	855	-	-
α-pinene	Pine	-	-	-	6.4	0.5
Carvone	Minty	6.72	9.52	-	-	-
Eucalyptol	Herbal	-	-	-	7.6	1.4
Miscellaneous						
2-Acetylpyrrole	Musty	1.12	-	180	-	-
2-Formylpyrolle	Musty	-	-	102	-	-
2-Acetylfuran	Balsamic	5.15	-		-	1.1
3-Methoxypyridine	-	-	-	154	-	-
Vanillin	Vaanilla	-	-	40.4	-	-

a:Odor properties of compounds were obtained from www.thegoodscentscompany.com; b:Traditional concentration method, Korkmaz 2023b; c:Vacuum concentration method, Korkmaz 2023b; d:Safkan et.al. 2021; e: Vacuum evaporation, Kuşçu & Bulantekin, 2016; f: Open pan evaporation, Kuşçu & Bulantekin, 2016, g:not detected.

There are few methods to determine volatile and aroma-active compound profile of food products. Gas chromatography-mass spectrometry (GC-MS) and headspace solid phase microextraction with gas chromatography mass spectrometry (HS-SPME-GCMS) are used to detect volatile compounds; meanwhile, gas-chromatography olfactometry (GCO) is an equipment that is used to differentiate odorous volatile compounds from non-odorous volatile compounds by utilizing human nose as a detector. In addition, aroma extraction dilution analysis (AEDA) is an effective and comprehensive method to determine and characterize aroma-active compounds (Yao et.al. 2021). Along with these methods, solvent-assisted flavor analysis (SAFE) together with liquid-liquid extraction is an advantageous method for analysis of aroma compounds in pekmez because of using low temperatures and compatibility with different food groups (Safkan et al. 2021).

Korkmaz (2023b) analyzed volatile compounds by SPME-GCMS in grape pekmez produced with two different methods (traditional concentration method (TCM) and vacuum concentration method (VCM) as it seen in Table 5. Relatively high concentrations were found from aldehydes, acids, and terpenes. Compound with the highest concentration was furfural which forms by heat treatment of sugar and has a caramel-like odor. It was the highest in TCM because of longer time and higher temperature during production. This was applied to the other compounds as well. In addition, several compounds might be lost during heat treatment. Six aldehydes, 4 alcohols, 4 acids, 2 ketones, 2 terpenoids, 2 esters and 2 other compounds were detected, however, not all compounds were seen in both type of pekmez. For example, from aldehyde groups, 2 and 3-methyl butanals were only found in TCM; however, nonanal and benzaldehyde were detected in both samples. While nonanal levels were close to each other, TCM contained more benzaldehyde. Similarly, from terpenoids, while carvone was detected in both samples, *D*-limonene was only detected in

TCM. Ethanol was higher in VCM, while ethyl acetate was higher in TCM.

Volatiles of apple pekmez were also analyzed by comparing two methods: open pan evaporation (OPE) which is the traditional production method and vacuum evaporation (VE) (Kuşçu ve Bulantekin 2016) (Table 5). The analysis was perfomed using SPME-GCMS and the samples were taken twice, upon production and after 4 month-storage. At the first sampling, VE contains 2-propanone, 2-methyl propanal, 2-methyl butanal, furfural, acetic acid, 1-penten-3-ol, and eucalyptol. As a result of storage, 2-methyl propanal was found to be lost; while *alpha*-pinene and furfural was formed. In OPE, at the beginning, compounds mainly found were such as 2-propanone, furfural, 2-methyl propanal, 2-methyl butanal, acetic acid, and 2- acetyl furan. As a result of storage, main compounds found in OPE were acetic acid, 2-methyl propanal, 2-methyl butanal, furfural and 2-acetyl furan. In both methods (VE and OPE) compounds from fresh apples were not found in pekmez samples. OPE had more volatiles than VE because of the highness and duration of treatment. In general, predominant compounds were found to be ketones after furfural and acetic acid.

Juniper berry pekmez was analyzed for its aroma-active compounds using combination of methods which are liquid-liquid extraction, SAFE and GCO and GC-MS by Safkan et.al. (2021). Predominant compounds were found to be 2,3-butanediol, 5-hydroxymethyl furfural, hexanoic acid, and (*Z*)-limonene, respectively (Table 5). Another compound with high concentration is furfuryl alcohol which might ve formed both via enzymatic degradation of furfural and via sugar degradation.

Table 6. The composition of essential oil constituents of Turkish pinecone pekmez

Compounds	Odor properties[a]	Concentration (ppm)
α-Terpineol	Citrus, pine	1863.4-1944.2
Terpinen-4-ol	Musty	909.9-924.3
β-Terpinol	Woody	287.4-298.4
endo-Borneol	Balsamic	183.4-194.3
Levo-verbenone	Spicy	132.7-142.7
fenchol	Camphoraceous	90.5-91.7
2-Bornanone	Fruity	73.8-76.2
δ-Cadinene	Herbal	75.8-77.2
α-Curcurmene	Herbal	55.4-57.2
Sorbic acid	Acidic	45.2-49.8
p-Cymen-8-ol	-	13.4-14.1
α-Dihydroterpineol	Herbal	43.9-46.2

[a] Odor properties of compounds were obtained from www.thegoodscentscompany.com.

Source: (Gamli, 2022).

In a study, essential oil content of Turkish pine cone pekmez was analyzed (Gamli 2022) and *alpha*-terpineol, terpinen-4-ol, β-terpineol, endo-borneol, levo-verbenone, fenchol, 2-bornanone, δ-cadinene, α-curcurmene, sorbic acid, *p*-cymen-8-ol, and α-dihydroterpineol were detected (Table 6). These compounds in the essential oil were reported to have antimicrobial, antifungal and antioxidant properties.

Overall, caramel-like, waxy, fruity and citrus flavors in grape pekmez; buttery, caramel-like, fatty and citrus flavors in juniper berry pekmez, caramel-like and fruity flavors in apple pekmez; and citrus and pine flavors in pine cone pekmez were predominant. Also, flavor concentrations were higher in juniper berry pekmez compared to other varieties.

5.2.Sensory Properties and Sensory Evaluation of Turkish pekmez

Sensory properties of foods are affected from the type of food, environmental conditions, and individual consumers. Consumer acceptability is situation directly related to desire to consume and other sensory properties of food, along with other several factors. Color, flavor, taste, and texture properties are important quality parameters in pekmez. While these properties are mainly affected by flavors formed from non-enzymatic browning reactions, flavonoid and phenolic content of pekmez are important contributors of the flavor, as well (Al-Bachir & Othman 2023; Altiok et al. 2021; Coklar & Akbulut 2020).

There are few studies on sensory evaluation on Turkish pekmez. Organoleptic properties and overall liking were examined on different scales. For example, two grape pekmez, which is produced by vacuum concentration method (VCM) and traditional concentration method (TCM), were evaluated by 9 trained panelists (Korkmaz 2023b). The evaluation criteria were color, odor, taste, flavor, tartness, aftertaste, viscosity, and overall acceptability on a 10-point scale (0: too weak to10: too strong). No significant difference was found between samples on flavor and overall liking; however, color, odor and flavor values were relatively lower in VCM and higher in TCM. It was concluded that because of longer heat treatment, flavors from Maillard reaction and caramelization caused higher scores in TCM.

Another example on sensory evaluation on Turkish pekmez was conducted on apple pekmez (Bulantekin 2014). As in previous example; apple pekmez produced by two methods, open pan evaporation (OPE) and vacuum evaporation (VE), were compared and evaluated by panelists. Ten trained panelists used a 5-point scale (the lowest property: 0 to the highest property: 5) to evaluate samples on appearance, odor, viscosity, flavor, and overall properties of pekmez. Especially in appearance, viscosity and overall properties, OPE sample had the highest scores. Even though VE samples were liked by panelists; as in previous example, pekmez that produced by traditional method was preferred more because of familiarity of product, long heat treatment and caramelization.

Finally, the last example on sensory evaluation on pekmez was conducted on juniper berry pekmez (Ereli 2021). Pekmez produced by traditional open pan evaporation, commercial open pan evaporation, and vacuum evaporation methods were evaluated by 9 panelists in a descriptive analysis on a 10-cm line scale. The beginning of line indicated the lowest score and the end of the line indicated the highest score. Pekmez samples were evaluated based on their color, odor, taste, appearance, viscosity, foreign matter, flavor, cooked flavor, acidity, clarity, tartness, and overall properties. In acidity, vacuum evaporated samples had the highest score, while odor and flavor scored higher in both vacuum evaporated and traditional open pan evaporated pekmez. In clarity scores, both commercial open evaporated and vacuum evaporated samples received similar scored. The pekmez produced with traditional open pan method received highest scores on appearance, viscosity, cooked flavor, and tartness by panelists. As indicated from previous examples, panelists gave higher score to the more familiar and longer cooked samples. In addition, tartness might be caused by abundance of phenolic compounds.

6. CONCLUSION

Pekmez is an important traditional food product in Türkiye with its rich nutritional content and produced from different fruits from all over Türkiye and with different methods. For these reasons, it is crucial to control and monitor chemical composition and quality parameters to ensure its authenticity and typical organoleptic properties. As it seen previously, physicochemical and organoleptic properties of pekmez, mainly affected by production methods. When traditional methods used, phenolic compounds, furan-derivatives and especially HMF were found higher. The cooked taste and flavor were more familiar in sensory analysis which provided higher liking scores and the high phenolic content increased the tartness.

In conclusion, flavor of pekmez is mainly influenced by the plant used and the production method; therefore, it directly affects the acceptability of the product. In this chapter, physicochemical and organoleptic properties of Turkish pekmez were investigated and the absence of information on many other types of pekmez was noticed. For the future research, it is recommended to evaluate other pekmez types to expand the knowledge of physicochemical and organoleptic properties on traditional Turkish pekmez which is a nutritional food product with commercial importance.

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