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Review Paper / Derleme Makale

Recent Advances in Water-Soluble Edible Pouches: Production Methods, Industrial Applications, and Legal Regulations

Aslıhan Begüm Dadaş, Bahar Demircan, Yakup Sedat Velioğlu

Ankara University, Faculty of Engineering, Department of Food Engineering, 06830 Golbasi, Ankara, Türkiye

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Corresponding author (Yazışmalardan Sorumlu Yazar): velioglu@ankara.edu.tr (Y.S. Velioğlu)
+90 312 2033300 / 3619 +90 312 3178711

ABSTRACT

Food packaging, crucial for protecting foods from various environmental impacts, is commonly produced from petroleum and its derivatives. However, the slow decomposition of plastics in nature leads to environmental pollution. One of the alternatives presented as a solution to this problem is biodegradable packaging materials. In this context, edible films stand out as a new packaging material with various non-toxic and environmentally degradable features. Edible films offer an eco-friendly option with properties like oxygen and moisture barriers. Recently, the production of pouches derived from these edible films has gained popularity. Edible pouches are designed as an alternative to the environmental pollution caused by disposable materials arising from practical usage demands. These pouches stand out as packaging with controlled release properties and their ability to dissolve in water, aiding in preserving the enclosed foods. This review examines edible films' purpose, characteristics, and applications, focusing on the use and functions of pouches derived from edible films. Additionally, the review discusses the experimentation of these pouches in various products, production purposes, methods, manufacturers, and the legal regulations associated with them.

Keywords: Biodegradable packaging, Edible film, Edible bag, Food packaging, Industrial applications

Suda Çözünebilen Yenilebilir Keselerdeki Son Gelişmeler: Üretim Yöntemleri, Endüstriyel Uygulamalar ve Yasal Düzenlemeler

ÖZ

Gıdaların farklı çevresel etkilerden korunması için büyük önem taşıyan gıda ambalajları genellikle petrol ve türevlerinden üretilmektedir. Ancak, plastiklerin doğada zor bozunması çevre kirliliğine yol açmaktadır. Bu soruna çözüm olarak, gösterilen alternatiflerden biri biyo-bozunur ambalaj materyalleridir. Bu bağlamda, yenilebilir filmler çeşitli özellikleriyle dikkat çeken, toksik olmayan ve doğada bozunabilen yeni bir ambalaj malzemesi olarak öne çıkmaktadır. Yenilebilir filmler, oksijen ve nem bariyeri gibi özelliklere sahip olmalarının yanı sıra çevre dostu bir seçenek sunmaktadır. Son zamanlarda, bu yenilebilir filmlerden türetilen keselerin üretimi de popülerlik kazanmıştır. Yenilebilir keseler, pratik kullanım talepleri doğrultusunda ortaya çıkan tek kullanımlık materyallerin neden olduğu çevre kirliliğine alternatif olarak tasarlanmıştır. Bu keseler, suda çözünme özelliğine sahip olmalarının yanı sıra içerdikleri gıdaların korunmasına yardımcı olan, kontrollü salınım özelliğine sahip ambalajlar olarak öne çıkmaktadır. Bu derlemede, yenilebilir filmlerin ortaya çıkış amacı, özellikleri, yenilebilir filmlerden elde edilen keselerin kullanım amaçları ve işlevleri irdelenmiştir. Bu konuların yanı sıra, bu keselerin hangi ürünlerde denendiği, üretim amaçları, üretim yöntemleri, üreticileri ve bunlara ilişkin yasal düzenlemeler ele alınmıştır.

Anahtar Kelimeler: Biyobozunur ambalaj, Yenilebilir film, Yenilebilir kese, Gıda ambalajı, Endüstriyel uygulamalar

INTRODUCTION

In contemporary times, consumers are increasingly inclined towards fresh, nutritious, and high-quality food. Food packaging is paramount in delivering healthier and safer food products to consumers. Food packaging contributes to preventing spoilage of food products in the food supply chain, minimizing damage during transportation, ensuring hygiene, and reducing food waste.

The importance of food packaging helps to provide the provision of healthier and safer foods. It has been emphasized that food packaging in the food supply chain contributes to preventing spoilage of food products, minimizing damage during transportation, ensuring hygiene, and reducing food waste [1]. Food packaging performs various functions, such as reducing food interaction with spoilage factors like microorganisms, water vapor, oxygen, and undesirable tastes, preventing the loss of desired compounds like aroma, and extending the shelf life of foods [2]. Packaging protects food from processing to transportation. Packaging materials, such as paper, plastic, glass, metal, or composites, have certain limitations in food packaging. Plastics (e.g., polyethene, polypropylene, polyethene terephthalate) are derived from the processing of petroleum or petroleum-based products. Additionally, non-eco-friendly of these single-use plastic food containers, discarded into oceans or landfills after use, poses serious issues such as CO_2 and greenhouse gas emissions from their incineration, contributing to ozone layer depletion [3].

Common packaging materials are produced from synthetic polymers due to their excellent mechanical properties, transparency, smoothness, and lightness. Synthetic polymers like polyethene and polypropylene are not biodegradable. They also exhibit good barrier properties against gases such as water vapor, O_2, and CO_2. The non-biodegradability of synthetic polymers causes environmental problems. Monomers and additives from synthetic packaging can migrate into the food, leading to serious health issues. To overcome such problems, research is being conducted on using biodegradable and naturally derived packaging materials (e.g., proteins, polysaccharides) instead of non-biodegradable synthetic polymers [4]. Consumers have changed their attitudes towards food packaging, quality, and environmental concerns in our modern era. This shift has prompted researchers to focus on biodegradable, sustainable packaging materials that contribute to reducing carbon footprint. Edible packaging is considered an eco-friendly alternative to food packaging, allowing consumers to consume packaging materials derived from plants, animals, marine life, or natural food group polymers such as polysaccharides, proteins, and lipids [5, 6]. With the advancement of technology, it has been indicated that edible materials can be transformed into edible packaging, which preserves food quality, extends shelf life, and contributes to waste reduction. Edible films are mentioned as packaging materials for separating the top or bottom of frozen products (such as pizza), for use as packaging material in sushi or sandwiches, or as dissolving pouches for food products [7, 8]. Edible pouches, categorized as edible packaging, have gained popularity due to their biodegradability. They serve as packaging materials with good oxygen, moisture, and aroma barrier properties. They minimize gas permeability to prevent oxidative rancidity, allow controlled mass transfer, and facilitate the release of active components such as antimicrobials, antioxidants, and additives [9].

This review aims to provide recent developments, mostly in last 5 years, on the emergence, characteristics, production methods, usage purposes, features, functions, and analyses of edible films. Additionally, it aims to provide insight to the companies in the industry producing edible pouches, the products for which they are manufactured, their purposes, and the legal regulations about edible pouches.

EDIBLE FILMS

In recent years, there has been an increasing global demand from consumers for fresher and healthier foods. This trend has led to an increase in the use of plastic-based packaging materials to preserve product quality and extend shelf life. According to statistical data reported by Mostafavi and Zaeim [10], the production of petroleum-based packaging materials worldwide increases by 8% annually, with less than 5% of the materials being recycled. This contributes to the continuous accumulation of plastics in the environment, disposing millions of tons of plastic-based packaging materials into landfills each year, leading to a significant global issue. The slow decomposition of plastics in nature, taking up to hundreds of years, exacerbates the environmental pollution caused by plastics. In response to these challenges, biodegradable and environmentally friendly edible films have emerged as an alternative to synthetic polymers to reduce plastic-related environmental pollution.

As indicated by Mostafavi and Zaeim [10], edible films offer a sustainable solution to mitigate environmental pollution caused by plastics. According to Martinez et al. [11], Mostafavi and Zaeim [10], and Ebrahimzadeh et al. [12], these films can prevent the transfer of moisture, oxygen, and aroma between the food and the surrounding atmosphere. Consequently, the use of edible films has rapidly increased to preserve the quality of various foods. The statistical data presented by Mostafavi and Zaeim [10] underscores the urgency for sustainable alternatives to petroleum-based packaging materials, supporting the growing adoption of edible films to minimize the environmental impact of plastic pollution.

Properties of Edible Films

Edible films play a crucial role in ensuring the safety and freshness of foods throughout their shelf life, protecting them from adverse conditions. The purposes of using edible films vary based on the needs during food preservation, and the natural properties of film-forming materials can limit their protective features due to moisture and gas transport mechanisms. Edible films must meet specific criteria to be suitable for use with food. The ideal characteristics of an edible film can be outlined as follows [13, 14]:

1. Safe for Human Consumption: The film-forming materials must be considered safe for human consumption (Generally Recognized as Safe, GRAS) and approved by the Food and Drug Administration (FDA).
2. Non-Toxic and Allergen-Free: The film should be non-toxic, allergen-free, fully digestible, and biologically degradable.
3. Mechanical Durability: It should be mechanically durable to withstand potential damages during the transportation and storage of food products.
4. Solubility in Safe Solvents: The film-forming materials should readily disperse and dissolve in solvents such as water, alcohol, or mixtures commonly used in production.
5. Adequate Coverage: The film should cover the entire product.
6. Good Mechanical and Rheological Properties: It should possess good mechanical and rheological properties under production and application conditions.
7. Control of Water Vapor Transmission: The film should be able to control water passage inside and outside the protected food to maintain the desired moisture content.
8. Control of Cohesion and Adhesion: It should control the cohesion between polymer molecules constituting the film and the adhesion between the film and the food.
9. Non-Impact on Sensory Properties: It should not adversely affect taste, smell, appearance, or flavor to be acceptable to consumers, and improvements in these properties can be considered.
10. Carrier for Desired Additives: Edible films can carry desired additives such as colorants, antioxidants, antimicrobial agents, vitamins, and nutrients.
11. Ease of Production and Economic Applicability: It should be readily producible and economically viable.
12. Control of Gas Balance: It should control the balance of gases involved in aerobic and anaerobic respiration of foods.
13. Biochemical and Microbial Stability: It should ensure biochemical and microbial surface stability, protecting against contamination, microbial growth, and other forms of deterioration.

Gas barrier properties, moisture barrier properties, light permeability, sensory and mechanical properties, and organoleptic characteristics in edible films constitute significant quality criteria. These criteria and their effects are illustrated in Table 1. Moreover, these criteria may vary based on internal and external factors, where external factors include temperature, humidity, pressure, relative humidity, and pH, and internal factors include the chemical properties and concentration of components constituting the films [15].

- Mechanical Properties: Good mechanical properties are essential in edible films to prevent early cracking during production, distribution, transportation, storage, and food packaging consumption [16].
- Optical Properties: The optical properties of edible films (opacity, colour, light transmission) are crucial parameters affecting their appearance, acceptability, and suitability for various applications [17].
- Antimicrobial Properties: Antimicrobial properties in edible films are effective in minimizing or preventing spoilage and the development of pathogenic microorganisms in antimicrobial food products. This contributes to the extension of shelf life, food quality, and safety. Antimicrobial materials, such as bacteriocins, essential oils, plant extracts, enzymes, organic acids (e.g., lauric acid), and inorganic/metallic nanoparticles, can be incorporated into the matrix for this purpose [18].
- Sensory Properties: The sensory properties of edible films are crucial for consumer acceptability. Properties such as appearance, texture, taste, and aroma can influence acceptability. Additionally, the interaction of films with the included food or food additives should be evaluated since they are considered edible together [19].
- Water Vapor Permeability: The water vapour barrier property is highly effective for food preservation and shelf life extension. Edible films should have low water vapour permeability to prevent moisture transfer between the food and the environment, impacting food preservation and shelf life [20].
- Oxygen Permeability: Oxygen permeability is one of the most researched and effective carrier properties of edible films. Controlling the passage of oxygen is essential to prevent quality loss due to processes such as lipid oxidation, microbial growth, enzymatic browning, and vitamin loss, as well as to prevent quality losses resulting from respiration in fresh fruits and vegetables [21].
- Chemical Properties: The solubility, hydrophobic-hydrophilic interactions, and chemical characteristics of components in materials with high water content can effectively determine their biodegradability [15].

Edible films should comprise at least two components: a biopolymer-based matrix capable of forming a compatible structure and a solvent (usually water). Biopolymers, such as polysaccharides, proteins, and lipids, are extracted from biomass. Additives are included in the formulation to enhance mechanical, functional, organoleptic, and nutritional properties. Plasticizers increase flexibility, antimicrobials (preservatives) enhance shelf life, antioxidants protect against oxidation. Antimicrobial and antioxidant properties can be achieved by incorporating essential oils, plant extracts, and metallic nanoparticles. Probiotics, prebiotics, vitamins, and minerals can be added for health benefits [5]. The components of edible films are illustrated in Figure 1.

Production of Edible Films

Edible films are commonly used as a solid matrix wrapped around the surface of food products, primarily serving as primary packaging without any sensory or nutritional appeal. Additionally, it has been noted that edible films can be used as pouches or bags for beverages that dissolve when added to cold or hot liquids, releasing their contents. This provides consumers convenience and portion control and can be used as an alternative to traditional meal packaging [22].

Edible films derived from edible materials are obtained through two different methods [30]. The wet or solvent casting method is a commonly used laboratory-scale method for producing thin films. It is widely employed in scientific studies for formulating and evaluating formulations due to its effectiveness and cost efficiency in determining film formation properties [31, 32]. In the production, the film-forming materials should disperse and dissolve in a solvent such as water, alcohol, a water-alcohol mixture, or other solvent mixtures. Plasticizers, color and flavor agents, and antimicrobial and antioxidant substances are added during this process. Subsequently, the film solution is cast and allowed to dry at the desired temperature and relative humidity [33, 34]. While the wet process is advantageous for its simplicity, it is challenging to scale up for industrial production. The high water content of the film-forming solution leads to prolonged drying times and, consequently, high energy consumption, limiting the industrial application of this method [35]. Santosa et al. [36] produced antimicrobial edible films using solvent-casting with various concentrations of starch and lemongrass oils. Jridi et al. [37] manufactured antioxidant and antimicrobial edible films using fish gelatin and blood orange peel pectin in different ratios through solvent casting. Ribeiro et al. [38] produced edible films of different thicknesses using three different biopolymers (chitosan, sodium alginate, gum arabic), and polyphenols extracted from elderberry through the solvent casting method, suggesting their potential as alternatives to plastic packaging materials for preserving food products and facilitating the transportation of active components. In extrusion processes, biopolymers are plasticized. This involves heating and plasticizing the extrusion polymers under low water content conditions at the glass transition temperature. The extrusion process is used to produce flexible films. Biopolymers are plasticized at the end of the extruder with heat, pressure, and shear force to create a homogeneous melt. In addition to film formation, this soft and rubbery melt can be transformed into different shapes after cooling using traditional processing methods such as thermal compression or injection molding [39]. Compared to the solvent casting method, the extrusion method offers advantages such as lower energy consumption, shorter processing times, suitability for commercial use, absence of solvent, ease of processing of highly viscous polymers, and efficiency. However, limitations include the restricted use of specific polymers and the processing of only temperature-sensitive and low-moisture raw material mixtures [22, 40]. Using the extrusion method, Cheng et al. [41] produced edible films using starch/gelatin and beeswax, candelilla wax, and carnauba waxes. Krishna et al. [42] developed edible films using fish gelatin through twin-screw extrusion at 110°C and 120°C, followed by compression molding at 80°C. They compared these films with solvent-cast films, finding that the extrusion method produced more flexible films. Castro et al. [43] produced edible films using modified starch through the extrusion method at an extrusion temperature of 100°C and a screw speed of 120 rpm.

Uses of Edible Films

It has been indicated that edible films operate in various industries, such as food, cosmetics, and pharmaceuticals. In the food industry, edible films are used as edible decorations, such as logo printing on pastries or cakes, or as interleaves between frozen products like hamburger patties to prevent them from sticking together. Additionally, in cosmetics, edible films can be used as facial masks. In the pharmaceutical sector, edible films are produced from different components, such as caffeine, nutrients, or herbal ingredients, to promote oral hygiene and alertness. These films dissolve upon ingestion. Moreover, water-soluble edible films can also produce drug strips or ribbons. They offer a solution for individuals, especially the elderly, children, or those with swallowing difficulties, who can use them without water [44].

Whey protein based edible films are quite common in industry. Castro et al. [46] developed edible films based on whey protein enriched with green tea extract using solvent casting. These films aimed to minimize or delay lipid oxidation in salmon by exhibiting antioxidant effects. The study results showed that edible films with green tea extract effectively delayed lipid oxidation in salmon on the 14th day of storage. In a study [47], whey protein isolate, incorporating thyme oil, garlic oil, nisin, and natamycin were applied to Kashar cheese. The findings revealed that the developed films had antimicrobial efficacy.

Xia et al. [48] designed double-layered edible films with an outer layer of zein (hydrophobic) and an inner layer of gelatin (hydrophilic) enriched with tea polyphenols using the solvent casting method. These films were tested on freshly cut kiwi, avocado, and banana fruits. The study aimed to develop packaging that reduces water vapor permeability and controls moisture, thereby preserving product stability and positively impacting shelf life. The addition of tea polyphenols facilitated the continuous release of antioxidant compounds, preventing browning and maintaining the freshness of the fruits. The results indicated that the developed films controlled mass loss in kiwi, improved color stability in avocados, and inhibited microbial growth in fresh bananas after two days of storage.

Table 1. Analysis of edible pouches

Polymer and components	Production method	Analysis of pouch	Packaged product	Results	Reference
Soybean polysaccharide, gelatin	Thermal bonding	Water solubility	Instant coffee, coconut powder	Pouches dissolved within a few seconds (<30 s).	[23]
Apple and citrus pectin, soy protein isolate	Thermal bonding	Water solubility (95°C)	Instant coffee	Citrus and apple pectin-based pouches dissolved in less than 30 s. Pouches derived from soy protein isolate took a longer time to dissolve.	[24]
Natural whey protein isolate	With solution	Water solubility (90°C), Sensory analysis	Instant coffee, dry Italian salad dressing mix, blueberry cake mix	The coffee pouch dissolved instantly, the salad dressing pouch in less than 10 s, and the cake mix in 2.5-3 min. Consumers needed help distinguishing between the pouches used in the study and the ones packaged.	[25]
Starch, Laver (seaweed), xylose	Not specified	Water solubility (85°C)	Spice mix	It dissolved within a few seconds.	[26]
Cassia gum, ethyl cellulose,	Thermal bonding	Water solubility (in boiling water)	Dried vegetable mix	The bag with the dried vegetable mix was dissolved in 2 min.	[27]
Manioc starch, various mixtures of medium starch phosphate manioc starch, and kaolin	Thermal bonding	Not specified	Biscuit	It is noted that adding kaolin enhances the barrier properties of the pouches, making them more resistant to tearing.	[28]
Fish gelatin, glucose	Thermal bonding	Color, light transmittance, differential scanning calorimetry	Flaxseed oil	The pouches preserved the product's colour and provided adequate protection against UV.	[29]

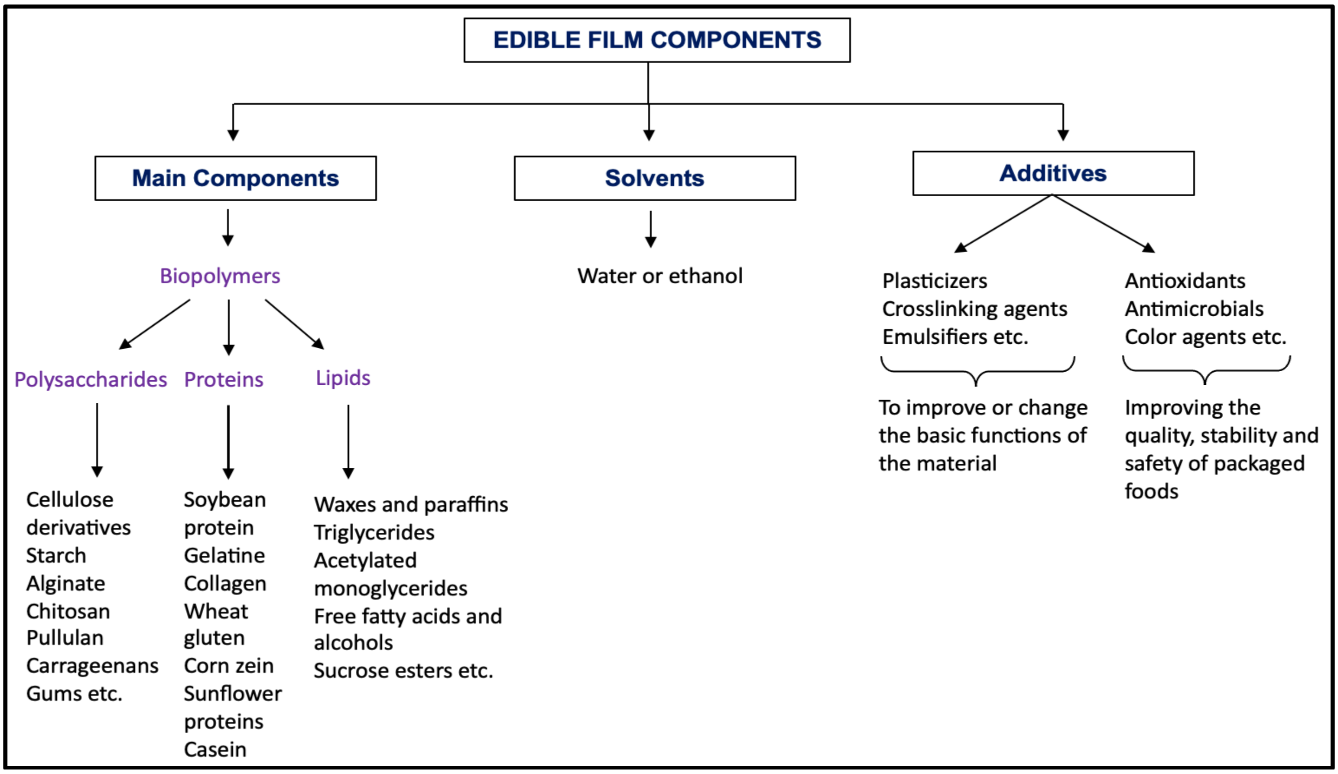

Figure 1. Components of edible films [45]

In conclusion, edible films have diverse applications in the food, cosmetic, and pharmaceutical industries, offering innovative solutions, including decoration, antimicrobial packaging, and controlled release of bioactive compounds.

EDIBLE POUCHES

In the food industry, products such as ready-made soups, dried vegetables, noodles, and instant coffee are typically packaged using aluminum-laminated plastic or other plastic films before being consumed. Before use, these packages are torn open, and the contents are used this way before pouring water onto them. This usage could be more convenient and environmentally friendly, as these materials end up in landfills and not degrade. The concept of making water-soluble bags from edible films is derived from this context. The idea is to produce bags that can dissolve or be cooked in hot water by pouring water onto them, allowing for quick consumption without tearing the packaging. Such applications include spice bags, ready-to-drink beverage bags, sugar bags, and cheese slice bags. In the detergent industry, water-soluble bags are used for packaging detergents. In the agricultural industry, predetermined quantities of fertilizers are transformed into fertilizer bags. These bags gradually dissolve upon contact with moist soil or during irrigation, facilitating convenient application [44].

Properties of Edible Pouches

In some practical food packaging applications, such as those involving powdered substances like ready-made foods, instant coffee, coconut powder, milk powder, noodles, beverage mixes, tea leaves, and seasoning and flavoring additives, the use of edible films has been preferred (Table 1 and Table 2). It has been explained that soluble sachets, bags, packages, or pouches are processed to contain powdered substances. The principle behind using pouches involves mixing them with food products like yoghurt or dissolving them by placing them in water for beverages or soups. It has been noted that such a packaging system's most significant advantages include requiring simple technology, the ability of edible packaging to carry pre-weighed amounts of the product, addressing waste disposal issues (being eco-friendly), being readily convertible to a usable form, and being reliable from a health perspective.

Edible pouches also assist in transporting aroma compounds to contribute to sensory characteristics. Additionally, the heat-sealing property is a crucial criterion for pouches in practical applications and for preserving liquid or dry food products. It is emphasized that heat insulation should be durable to prevent leakage under storage conditions. Adequate sealing force is crucial to prevent the pouches from opening prematurely and to support the packaged materials. The stretching properties of the pouch and the barrier properties (moisture, oxygen, gas, and oil) should be good to minimize the chemical degradation of the product. It is explained that these features depend on the selection of the matrix used in pouch production [23, 53-56].

Table 2. Analysis of packaged products in edible pouches

Polymer and components	Production method	Packaged product	Analysis of product	Results	Reference
Chicken protein isolate, fish skin gelatin, gallic acid, tannic acid	Heat sealing	Chicken skin oil	Peroxide value, Thiobarbituric acid reactive substance (TBARs)	Pouches containing phenolic compounds protected chicken skin oil against oxidative deterioration	[49]
Fish gelatin, glucose	Heat sealing	Flaxseed oil	Peroxide value, TBARs value, free fatty acid content	The peroxide value, TBARs value, and free fatty acid content of flaxseed oil stored in gelatin-based pouches containing glucose were lower than those stored in pouches without glucose.	[29]
Soy protein isolate, Pinhão seed extract	Heat sealing	Flaxseed oil	Peroxide value, free fatty acid content	Low peroxide and free fatty acid content were determined.	[50]
Pumpkin pulp, corn zein	Heat sealing	Flaxseed oil	Peroxide value, content of conjugated dienes and trienes, sensory analysis	Low peroxide value, low content of conjugated dienes and trienes, and inadequate sensory characteristics were found.	[51]
Pectin-sodium alginate, casein, copper nanocomposite	Heat sealing	Coconut oil	Peroxide value, TBARs, free fatty acid content	It was emphasized that it prevents oxidation and can extend shelf life.	[52]

Soluble edible pouches also possess other characteristics, such as controlled mass transfer (migration, adsorption, absorption, and permeability) between food and the environment or among components in food, enhanced product appearance, and structural integrity. The rapid dissolution upon contact with water, enabling the segmentation of various foods like breakfast cereals or ready-to-drink beverages into individual portions and extending shelf life, provides convenience for consumers and enhances the efficiency of industrial-scale food production. Pre-measurement of ingredients, requiring less cleaning, delivering products cleanly and accurately, and reducing dependence on workers or chefs are advantages of edible pouch production on an industrial scale. It is emphasized that more than the edibility feature is required in pouch production. From the consumer's perspective, instant and complete dissolution, allowing controlled release of products, and fulfilling a protective function in packaging are essential requirements [25].

Production of Edible Pouches

Edible films are produced in the form of pouches. One of the methods commonly used to prevent opening or leakage in these pouches is heat sealing [57]. Heat sealing is frequently employed in industrial applications to produce flexible packaging. It involves pressing and squeezing two thin film layers between hot metal bars for a specified period, subsequently allowing the layers to cool. The method relies on the principle that the polymer matrix melts due to heat. Mass diffusion and interfacial interaction take place along the melted layers. After cooling, the polymers of these two layers, which melted at the interface, blended and solidified due to diffusion [58]. The studies related to the production of edible pouches are provided in Table 3.

Table 3. Production methods of edible pouches

Polymer and components	Production method	Pouch measurements	Process details	Reference
Soybean polysaccharide, gelatin	Heat sealing	20 mm x 70 mm	Sealed under 150°C, 300 kPa, for 1.5 min.	[23]
Soy protein isolate, corn zein	Heat sealing	40 mm x 50 mm	Sealed under 3 s, 3 atm, at 120-130°C.	[60]
Chicken protein isolate, fish skin gelatin, phenolic content (gallic acid and tannic acid)	Heat sealing	25 mm x 20 mm	Heated at 150°C for 1.25 s, then closed by cooling for 1.50 s.	[49]
Whey protein isolate (natural and heat-denatured)	Heat sealing	Not specified	Films with heat-denatured whey protein isolate were sealed for 2.5 s. Films with naturally denatured whey protein isolate were sealed for 2 s, with temperatures of 205 and 165°C, pressure of 293 kPa, and cooling time of 4.5 s.	[25]
Hydroxypropyl methylcellulose, soy protein isolate	Heat sealing	25 mm × 79 mm	Sealed for 2 s with heat for denaturation.	[61]

Uses of Edible Pouches

Convenience and pleasant flavors are essential for meeting consumers' fast-paced lifestyles and nutritional needs regarding ready-made foods. In other words, ready-made foods fulfil the demand for quick preparation and nourishment in consumers' lives. It is well-known that the packaging of products such as flavoring powders, oil/sauce blends, and dried vegetables, provided alongside ready-made foods, is typically made from petroleum-based polymers and is widely used. However, these packages can impact both human health and product quality. Therefore, it has been explained that in the packaging of these products, bio-based polymers are used to produce environmentally friendly and user-friendly pouches, which are then introduced into the market [59].

Oil Packaging

Carpine et al.'s [62] study focused on producing edible films based on coconut oil-added soy protein isolate emulsions for packaging. The films were initially produced using soy protein isolate (SPI), untreated virgin coconut oil (VCO), and soy lecithin (SL). Thickness, opacity, moisture content, water vapor permeability, mechanical properties, and thermogravimetric analyses were conducted on the films. Subsequently, the films were cut into 100 mm x 40 mm dimensions and sealed using a heat sealer. The prepared pouches contained 5 g of olive oil. The oxidative stability of the olive oil in the pouches was observed over 28 days through peroxide analyses. The results indicated that the peroxide values (13.197, 11.164 mEq O_2/kg) did not exceed the maximum limit (20 mEq O_2/kg) set by the Codex Alimentarius. It was concluded that these pouches, by protecting olive oil from oxidation and rancidity, provided environmental benefits and enhanced product quality, serving as an alternative to non-biodegradable traditional packaging materials.

In the study conducted by Rosenbloom and Zhao [61], edible, water-soluble, heat-sealable, and antioxidant pouches were developed using hydroxypropyl methylcellulose (HPMC) and SPI for packaging sesame oil. Initially, edible films were produced from hydroxypropyl methylcellulose and soy protein isolate. Additionally, formulations were enriched with 0.1% or 0.2% DL-α-tocopherol acetate (VE) and 0% or 0.25% oleic acid to impart antioxidant and hydrophobic properties. Cellulose nanocrystals (CNC) were also added. The films were tested for color, water vapor permeability, solubility, Scanning Electron Microscopy

(SEM), mechanical properties, and more. For pouch production, two 25 mm × 79 mm films were stacked, heat-sealed on three sides for 2 s, filled with 3 mL of sesame oil per pouch, and the fourth side was sealed. After pouch production, peroxide value analysis was performed on the sesame oil within the pouches. The results demonstrated that the lowest peroxide values (8.1±0.9 mEq/kg) were observed in SPI-based pouches after 60 days of storage at 35°C. Oleic acid was found to influence the heat-sealing of SPI-based pouches. The developed pouches were identified as a promising packaging alternative in the industrial context, contributing to reducing plastic waste, extending the shelf life of lipid-based foods, and enhancing consumer convenience.

In the work by Cho et al. [60], heat-sealable pouches were produced based on soy protein isolate (SPI) coated with corn zein (CZ). Initially, films were produced by coating soy protein isolate with corn zein, and analyses were conducted for water vapor permeability, color, SEM, solubility, and mechanical properties. The heat-sealing properties of soy protein isolate corn zein bilayer films were analyzed at temperatures ranging from 85 to 155°C under 3 atm pressure for 3 s. The heat-sealability of soy protein isolate film was optimized at 120-130°C and enhanced by adding corn zein film. Pouches containing 2 g of olive oil were created by cutting the films into 40 mm x 50 mm pieces and heat-sealing three sides. Peroxide analysis was performed on the olive oil in the pouches. It was concluded that soy protein isolate and corn zein-based pouches extended the shelf life of olive oil and exhibited excellent oxygen barrier properties by preventing oxidative deterioration during storage. Moreover, these pouches demonstrated good mechanical properties and were deemed suitable for packaging and processing.

Nilsuwan et al. [49] produced pouches based on a mixture of chicken protein isolate/fish skin gelatin containing various concentrations (0%, 0.375%, 0.75%, 1.5%, and 3.0%) of phenolic compounds (gallic acid and tannic acid). Before pouch production, films were manufactured, and analyses were performed for thickness, color, solubility, mechanical properties, water vapor permeability, opacity, SEM, total phenolic analysis, and antioxidant activity. The films were then cut into 25 mm x 20 mm pieces, sealed with a heat sealer at 150°C for 1.25 s, and cooled for 1.50 s to determine leakage strength and efficiency. Pouches were further produced by heat-sealing three sides of 50 mm x 50 mm films. These pouches contained 2 g of chicken skin oil. Peroxide value, free fatty acid, and TBARs value analyses were conducted on the oil in the pouches. The pouches with 0.75% gallic acid demonstrated a lower peroxide value, TBARS, and volatile compounds during the 15-day storage period compared to the oil stored in pouches without phenolic compounds. It was suggested that phenolic-containing pouches exhibited antioxidant effects, effectively protected chicken skin oil from oxidative deterioration, and preserved the quality and nutritional value of the product. Additionally, the addition of phenolic compounds positively influenced the durability and shelf life of the pouches.

The research by Kchaou et al. [29] involved the production of fish gelatin-based pouches with or without glucose. Before pouch production, films were prepared from fish gelatin, with and without glucose, and dried in oven at 25°C and 120°C. Subsequently, pouches were produced, and 10 mL of flaxseed oil was added to each pouch. Product analyses included peroxide value, TBARS, and free fatty acid analyses. Also, color, light permeability, and Differential Scanning Calorimetry (DSC) analyses were performed in pouches. The results indicated that the pouches preserved the product's color and provided UV protection. Pouches with glucose demonstrated lower peroxide values, TBARS values, and free fatty acid content in the stored oil than those without glucose, suggesting that glucose-containing gelatin-based pouches reduced oxidative damage and helped preserve the oil's freshness. Furthermore, these pouches were proposed as a potential alternative to synthetic packaging for protecting foods against oxidation.

The study conducted by Souza et al. [50] involved the production of pouches using soy protein isolate and extracts from Pinhão seeds, with only the selected high antioxidant capacity extract at 2%. Control pouches were also produced. Before pouch production, films were produced from Pinhão seed extracts and analyzed for color, water vapor permeability, mechanical properties, Fourier-Transform Infrared Spectroscopy (FTIR), total phenolic, and antioxidant capacity. The peroxide value was also determined in samples. Pouches were produced by cutting films of the highest antioxidant capacity into 3 cm x 7 cm pieces, which were sealed. These pouches contained 5 mL of flaxseed oil. The oxidative stability of flaxseed oil in pouches was confirmed, with lower peroxide and free fatty acid values observed after 60 days of storage at 60°C. The study concluded that pouches containing phenolic compounds contributed to the oxidative stability of flaxseed oil, displaying low peroxide and free fatty acid content. These pouches were considered a potential alternative for active packaging, contributing to the preservation of the quality and nutritional values of the packaged product.

In the research by Gautam and Mishra [52], laminated pouches were produced by laminating pectin-sodium alginate and casein, adding copper nanocomposites to the pectin layer. Films were manufactured, and analyses were conducted for thickness, color, opacity, water vapor permeability, solubility, mechanical properties, antimicrobial analysis, X-ray diffraction (XRD), SEM, and thermogravimetric properties. The films were then cut into 70 mm x 50 mm pieces and heat-sealed on three sides. These pouches contained 5 mL of coconut oil. Analyses were performed for peroxide value, free fatty acid, and TBARs on the oil in the pouches. The pouches were found to preserve the oxidative stability of coconut oil during storage, extending its shelf life. Packaging coconut oil in edible and water-soluble sodium alginate-pectin/casein pouches was identified as an effective and sustainable packaging solution, contributing to both ease of consumption and preservation of coconut oil.

Dry Powder Mixture Packaging

Jakub et al. [24] studied producing pouches using apple and citrus pectin with soy protein isolate. Before pouch production, films were manufactured and analyzed for thickness, color, moisture content, solubility, opacity, water vapor permeability, and mechanical properties. The prepared films were heat-sealed on three sides to produce pouches. Each pouch was filled with 2 g of instant coffee, and the fourth side was sealed. Solubility analysis was performed on the pouches. It was observed that pouches made from citrus and apple pectin entirely and instantly dissolved (in less than 30 s) when in contact with water, while those derived from soy protein isolate required more time (due to thermal denaturation). The study aimed to provide an eco-friendly packaging alternative catering to coffee enthusiasts who seek a quick and easy coffee preparation method without the need for traditional brewing techniques.

Liu et al. [23] focused on producing gelatin-based pouches using soybean polysaccharide (SSPS). In the study, soybean polysaccharide and gelatin solutions were prepared separately, plasticized with glycerol, and mixed, then films were cast using a casting method. The weight ratios of the films were 100/0, 80/20, 60/40, 40/60, 20/80, and 0/100. Analyses were performed on the films for mechanical properties, optical properties, water vapor permeability, thickness, solubility, SEM, Atomic Force Microscopy (AFM), DSC, XRD, Attenuated Total Reflection (ATR)-FTIR, and heat-sealing strength. The films were cut into 20 mm x 70 mm pieces for heat-sealing, and pouches were created by sealing two films together at 150°C, 300 kPa pressure, and 1.5 min. Pouches were filled with 3 g of instant coffee and coconut powder, and the fourth side was sealed. Solubility analysis in water at 95°C was conducted on the pouches. Both types of pouches dissolved rapidly in hot water (95°C) within a few s (<30 s), releasing the encapsulated powders quickly. The research suggested that these pouches are potential alternatives for manufacturing quickly dissolving packaging for powdered food and beverage products.

Janjarasskul et al. [25] produced pouches using whey protein isolate (WPI) in natural and thermally denatured forms. Before pouch preparation, films were created from denatured and natural WPI, and analyses were conducted for solubility, mechanical properties, ATR-FTIR analysis, and oxygen permeability. Pouches were created by heat-sealing films at 205°C for 2.5 s for denatured WPI films and 165°C for 2 s for natural WPI films, with a pressure of 293 kPa. Pouches were left to cool for 4.5 s. The pouches were filled with ready coffee, dry Italian salad dressing, and blueberry cake mix. The study aimed to produce WPI-based pouches for the packaging of pre-weighed dry foods, emphasizing their quick solubility and the principle of being edible and sealable. The solubility (at 90°C) and sensory properties of coffee pouches were highlighted. It was observed that heat-sealed whey protein isolate (HWPI) pouches softened and swelled but did not dissolve in hot water. In contrast, solution-sealed natural whey protein isolate (NWPI) pouches dissolved rapidly, except for the sealed part, due to thermal denaturation during sealing. Sensory evaluation indicated that panelists could not distinguish between coffee prepared from fully dissolved solution-sealed NWPI pouches and traditionally prepared coffee. The study concluded that WPI -based pouches could effectively package pre-weighed dry foods without affecting consumer acceptability.

Chen et al. [26] conducted a study on the production of starch-based edible spice pouches that could be placed inside instant noodles. Starch-based pouches containing laver (seaweed) were produced at different ratios (10%, 20%, and 30%) and xylitol. The research used xylitol as a plasticizer, cellulose crystals as a reinforcing agent, and laver to reduce gas permeability. Film analyses were initially conducted, including thickness, moisture, water vapor permeability, mechanical properties, and SEM. The addition of both laver and cellulose crystals increased tensile strength. Although laver reduced water vapor permeability, the overall flexibility of the starch film was compromised. Xylitol was found to reduce film hardness. After the addition of cellulose and laver, a decrease in moisture sensitivity was observed. Solubility analysis was conducted on the pouches at 85°C. It was observed that the pouches dissolved in hot water within a few s at 85°C. The study aimed to produce quickly dissolving pouches for flavoring instant noodles. The researchers concluded that starch-based edible films were successfully used as spice pouches, enhancing consumer convenience for flavoring instant noodles.

Nawab et al. [63] conducted a study on the production of heat-sealed pouches using mango seed starch and plasticizers such as glycerol, sorbitol, and a combination of glycerol: sorbitol (1:1). Mango seed starch was extracted before producing films, and subsequently, 10 cm x 20 cm pieces were cut from the films and heat-sealed using a sealer to close three sides. Polyethylene bags were used as control pouches. The pouches were filled with 50 g of red pepper powder to extend their shelf life. The heat-sealing capability of the pouches was investigated, with the optimal results observed at 70°C for 3 s for all pouches. Pouches with glycerol as a plasticizer exhibited higher impermeability strength (70%) than others. After six months of storage, mango seed starch pouches were observed to preserve the color and sharpness of packaged red pepper powder for a longer duration than commercially available polyethene pouches. This was attributed to mango seed starch pouches' better barrier properties than polyethene. The study suggested that mango seed starch pouches could effectively preserve red pepper powder without compromising consumer acceptability.

Other Product Packaging

In the study by Kumar et al. [64], chitosan and basil essential oil were used to create pouches to impart antioxidant properties. Films were formed using chitosan and basil essential oil, and these films analyzed for moisture, solubility, FTIR, Thermogravimetric analysis (TGA), water vapor permeability, mechanical properties, antioxidant capacity, color, and opacity. Subsequently, pouches were produced from these films, and fried finger potatoes were placed inside them. Comparative analysis of oxidation was conducted using FTIR spectroscopy during the oxidative damage analysis of the product within the pouch. It was observed that the pouches significantly reduced oxidative damage during storage (7 days). The study concluded that the pouches could preserve the quality and freshness of fried finger potatoes by preventing or reducing the formation of oxidation-related off-odors and undesirable tastes. The research aimed to contribute to producing sustainable food packaging to prevent oxidative deterioration within the pouch, consequently reducing food waste.

Li et al. [27] produced pouches by adding 5% ethyl cellulose to cassia gum and cassia gum-based films. Films were created with cassia gum and cassia gum with 5% ethyl cellulose, and analyses were performed for thickness, mechanical properties, water vapor permeability, light permeability, solubility, SEM, FTIR, and thermogravimetric analysis. Subsequently, pouches were produced by heat-sealing films measuring 6.5 cm x 6.5 cm. Dried vegetable mixtures and carrot cubes were placed in the pouches. It was observed that pouches containing a dried vegetable mixture were wholly dissolved in boiling water within 2 min. The weight of the carrot cubes placed in the pouches with 53% relative humidity was measured after conditioning at 12, 24, 72, and 120 h. Growth rates and inhibition rates were calculated. The study also indicated that the addition of ethyl cellulose in pouches with carrot cubes helped reduce moisture content, had a significant effect on water vapor permeability, and could be more suitable for pouch production to extend the shelf life of dry vegetables and protect them from water vapor. The study aimed to develop and evaluate a sustainable and eco-friendly packaging material that could enhance the quality and shelf life of dried vegetables while reducing waste and pollution.

Rammak et al. [28] aimed to package biscuits using various cassava starch blends and medium phosphate cassava starch, adding kaolin (5%, 10%, 15%). Initially, films were produced, and mechanical properties, thermogravimetric analysis, SEM, water vapor permeability, swelling ratio, FTIR analysis, and soil biodegradability were examined. The films were sealed and closed from the bottom and sides to create pouches. It was noted that adding kaolin increased the pouches' barrier properties, making them more resistant to tearing. Pouches containing 10% kaolin were found to be semi-transparent, preventing light and UV absorption, thereby preserving both the shelf life and quality of the packaged food. The study aimed to produce durable packaging for biscuit products, maintaining a balance between the external environment and food and creating biodegradable pouches that dissolve quickly in nature, evaluating the potential use of such packaging.

Industrial Production of Edible Pouches

It has been noted that commercially produced edible packaging is gaining increasing market value despite concerns such as high production costs and safety issues leading to a decrease in market value. The global market for seaweed-based edible packaging in Europe has been highlighted, followed by North America. Companies such as Notpla, Loliware, Evoware, and Monosol have been reported to be producing edible packaging [65].

Monosol

Monosol, a company, has introduced edible and water-soluble polymer pouches containing odor and tasteless food to the market. These pouches' ability to dissolve in cold and hot water is a significant feature. Another characteristic is their suitability for ready-to-eat foods, allowing predetermined quantities to be added to the pouches. Consequently, the pouches dissolve instantly when placed in water, becoming consumable along with the enclosed food product [66].

Evoware

Evoware, an Indonesian company, utilizes seaweed to produce biologically degradable alternatives to single-use plastics, creating edible packaging. These packages (Figure 2) are made with seaweed-based, thermally adhesive materials that dissolve in warm water, offering an edible and sustainable solution. The biological degradability allows the packaging to be used as fertilizer for plants. The company is known for manufacturing spice pouches for instant noodles, coffee pouches, and packaging for hamburgers and sandwiches [65].

Notpla

Notpla produces packaging and pouches (Figure 3) made from brown seaweed. The most remarkable feature of the pouches produced by the company is their ability to self-disintegrate in nature and their cost-effectiveness compared to plastic. They are used for various products such as water, beverages (alcoholic or non-alcoholic), spices, and some cosmetic items [67].

Stonyfıeld Farm, Inc.

Stonyfield Farm, Inc., is one of the pioneering companies commercially selling a product with edible packaging. In 2014, they launched a frozen yoghurt product called WikiPearlsTM. This product consists of small capsules with a gelatinous shell encapsulating yoghurt. It was designed and developed by David Edwards, a Harvard scientist, in a laboratory in Paris. The edible shell is made of a seaweed-based material containing alginate and calcium, complementing the enclosed food product. Additionally, WikiFoods has collaborated with other companies and initiated efforts to produce edible packaging for chilled foods like cheese or fruit juices, soups, water, and coffee [68].

Figure 2. Seaweed-based water-soluble pouches produced by Evoware

Figure 3. Seaweed-based water-soluble and edible pouches produced by Notpla

Loliware

Loliware, established in 2015, introduced the first non-toxic, plastic-free, gelatin-free, gluten-free, and GMO-free edible cups. These cups, in addition to being edible, are also biodegradable. Made from seaweed (specifically agar), these cups derive their flavors and colors from organic sweeteners and extracts obtained from fruits and vegetables. The cups can be served at room temperature or cold and have an immediate dissolving feature in hot water. However, their slightly higher cost is the only issue associated with these cups [69]. The Loliware brand has also produced edible straws with different flavors, including vanilla [70]. Using LOLIWARE®'s SEA Technology™, the company is producing carbon-neutral, 100% biobased (seaweed-based), plastic-free, home compostable straws, aiming to prevent carbon emissions [71].

Legal Regulations for Edible Pouches

Legal regulations regarding food packaging vary from country to country. According to European Directives and U.S. regulations, edible pouches are produced from edible films. Within edible films, food components fall under substances in contact with food or food packaging materials. Therefore, all components must be GRAS according to FDA regulations. According to EU Regulation 1935/2004, all materials in contact with food must meet four basic requirements. Firstly, they should not jeopardize human health; secondly, they should not alter the composition of the enclosed food; thirdly, they should not alter the taste, smell, or texture of the food; and finally, they should be produced by Good Manufacturing Practices (GMP). According to this regulation, a material will only be permitted for food packaging when proven not to harm human health. Additionally, it is emphasized that the addition of nanomaterials to food packaging and the safety assessment of their toxicological effects should be explicitly addressed [19].

Edible pouches may contain antimicrobials, antioxidants, colorants, and other functional components. However, some consumers may have allergies to ingredients such as milk (whey or casein), soybeans, peanuts, nuts, fish, or wheat (gluten). Therefore, it is stated that if these components are present in the packaging material, even in small amounts, they should be indicated. Another substance causing allergic reactions is essential oils, classified as GRAS by the European Commission and the United States and used for their antimicrobial effects. However, high-dose usage of these oils can cause severe oral toxicity. In summary, it is mentioned that the use of antimicrobials, volatile oils, antioxidants, colorants, or other additives in edible pouches and the related regulations are the same as those used in food formulations [72].

DISCUSSION and CONCLUSION

One of the crucial steps in the delivery of food to consumers is food packaging. Plastics obtained from petroleum or its derivatives are commonly used as packaging materials. However, due to their non-biodegradable nature and widespread environmental pollution, researchers have conducted numerous studies on alternative packaging materials that can replace plastics. Edible packaging materials, including proteins, polysaccharides, and lipids, have been the most prominent focus of these studies. Many research efforts have been dedicated to producing edible films based on proteins, polysaccharides, and lipids and their use as direct packaging materials or in the form of pouches.

Water-soluble edible pouches should not be toxic, be biologically degradable, and have protective functions against biological, physical, chemical, or microbial deterioration. They should also possess good barrier properties (such as moisture, oxygen, and gas) and thermal adhesion characteristics. Numerous studies have explored the potential of edible pouches as alternatives to traditional packaging materials for products such as ready-to-eat foods, instant coffee, tea, cake mix, oil, coconut powder, spices, or sweeteners. The studies have evaluated whether these pouches, produced in different formulations, have the potential to be manufactured and used, suggesting that research should continue for their potential use and further development. Companies known for producing these pouches on an industrial scale include Stonyfield Farm, Loliware, Monosol, Evoware, and Notpla. These companies emphasize the importance of using eco-friendly, bio-degradable packaging that contributes to bio-degradability.

In addition, new technologies and approaches are needed for these pouches to be more effective in terms of functionality and features. Among these new technologies are techniques such as multilayer systems, biocomposites, encapsulation, and nanotechnology. These new techniques could allow the creation of active compounds through micro or nano-capsulation of functional ingredients such as enzymes, prebiotics, and probiotics enriched in edible pouch formulations. As a result, it may help reduce moisture loss and provide protection against heat or light. It is necessary to conduct more research on developing single-layer systems and transitioning to multilayer systems. Using compounds such as additives, antioxidants, and antimicrobials in controlled release mechanisms can make a difference in pouch production.

Finally, sufficient studies need to be conducted on sensory properties and the legal and safety-related approval procedures for successful edible pouch production. Moreover, more detailed toxicological studies on the polymers used are required.

REFERENCES

[1] Petkoska, A.T., Daniloski, D., D'Cunha, N.M., Naumovski, N., Broach, A.T. (2021). Edible packaging: sustainable solutions and novel trends in food packaging. *Food Research International*, 140, 1-15.

[2] Mohammed, S.A.A., Sakhawy, M.E., Sakhawy, M.A.M.E. (2020). Polysaccharides, protein and lipid-based natural edible films in food packaging: a review. *Carbohydrate Polymers*, 238, 116-178.

[3] Kumar, L., Ramakanth, D., Akhila, K., Gaikwad, K.K. (2022a). Edible films and coatings for food packaging applications: a review. *Environmental Chemistry Letters*, 20, 875-900.

[4] Akhtar, MJ, Aider, M. (2018). Study of the barrier and mechanical properties of packaging edible films fabricated with hydroxypropyl methylcellulose (HPMC) combined with electro-activated whey. *Journal of Packaging Technology and Research*, 2, 169-180.

[5] Hamed, I., Jakobsen, A.N., Lerfall, J. (2022). Sustainable edible packaging systems based on active compounds from food processing byproducts: A review. *Comprehensive Reviews In Food Science and Food Safety*, 21,198-226.

[6] Karakus, E. (2022). Development and characterization of biobased food packaging material from pomegranate and orange peel waste. MSc Thesis, Sakarya University, Institute of Sciences, Division of Food Engineering, 83, Sakarya, Turkiye.

[7] Viana, R.M., Sa, N.M.S.M., Barros, M.O., Borges, M.F., Azeredo, H.M.C. (2018). Nanofibrillated bacterial cellulose and pectin edible films added with fruit purees. *Carbohydrate Polymers*, 196, 27–32.

[8] Saklani, P., Nath, S., Das, S.K., Singh, S.M. (2019). A review of edible packaging for foods. *International Journal of Current Microbiology and Applied Sciences*, 8(7), 2885-2895.

[9] Kaur, J., Gunjal, M., Rasane, P., Singh, J., Kaur, S., Poonia, A., Gupta, P. (2022). Edible packaging: An overview. In "*Edible Food Packaging" (Eds: A. Poonia, T. Dhewa.)*, 3-25. Springer Link.

[10] Mostafavi, FS, Zaeim, D. (2020). Agar-based edible films for food packaging applications - A review. International *Journal of Biological Macromolecules*, 159, 1165–1176.

[11] Martinez, C.L.M., Valdez, H.Z., Aguilar, R.P., Arreola, W.T., Felix, F.R., Rios, E.M. (2018). Edible protein films: sources and behavior. *Packaging Technology and Science*, 31, 113-122.

[12] Ebrahimzadeh, S., Biswas, D., Roy, S., McClements, D.J. (2023). Incorporation of essential oils in edible seaweed-based films: A comprehensive review. *Trends in Food Science & Technology*, 135, 43–56.

[13] Erkmen, O, Barazi, A.O. (2018). General characteristics of edible films. *Journal of Food Biotechnology Research*, 2, 1- 4.

[14] Eyiz, V. (2019). Effects of edible films on physical, chemical and sensory properties of fruit and cereal bars. MSc Thesis, Necmettin Erbakan University, Institute of Sciences, Division of Food Engineering, 88, Konya, Türkiye.

[15] Bozkurt, S., Altay, Ö., Koç, M., Ertekin, F.K. (2023). Edible films and coatings in food systems. *Turkish Journal of Agriculture - Food Science and Technology*, 11(1), 1-9.

[16] Pajak, P., Roznowska, I.P., Juszczak, L. (2019). Development and physicochemical, thermal and mechanical properties of edible films based on pumpkin, lentil and quinoa starches. *International Journal of Biological Macromolecules*, 138, 441–449.

[17] Wang, Q., Liu, W., Tian, B., Li, D., Liu, C., Jiang, B., Feng, Z. (2020). Preparation and characterization of coating based on protein nanofibers and polyphenol and application for salted duck egg yolks. *Foods*, 9(4),1-16.

[18] Chawla, R., Sivakumar, S., Kaur, H. (2021). Antimicrobial edible films in food packaging: Current scenario and recent nanotechnological advancements- a review. *Carbohydrate Polymer Technologies and Applications*,2, 1-19.

[19] Jeevahan, J.J., Chandrasekaran, M., Venkatesan, S.P., Sriram, V., Joseph, G.B., Mageshwaran, G., Durairaj, R.B. (2020). Scaling up difficulties and commercial aspects of edible films for food packaging: A review. *Trends in Food Science & Technology*, 100, 210-222.

[20] Meshram, B.D., Lule, V.K., Vyawahare, S., Rani, R. (2023). Application of edible packaging in the dairy and food industry. *Food Preservation and Packaging-Recent Process and Technological Advancements*, Intechopen, 384.

[21] Kandasamy, S., Ham, J.S., Yun, J.J.Y., Kang, H.B., Seol, K.H., Kim, H.W. (2021). Application of whey protein-based edible films and coatings in food industries: an updated overview. *Coatings*, 11(9), 1-26.

[22] Suhag, R., Kumar, N., Petkoska, A.T., Upadhyay, A. (2020). Film formation and deposition methods of edible coating on food products: A review. *Food Research International*, 136, 1-16.

[23] Liu, C., Huang, J., Zheng, X., Liu, S., Lu, K., Tang, K., Liu, J. (2020). Heat sealable soluble soybean polysaccharide/gelatin blend edible films for food packaging applications. *Food Packaging and Shelf Life*, 24, 1-9.

[24] Jakub, W., Kamil, Z., Sabina, G. (2022). An attempt to develop fast-dissolving biopolymer-based pouches for instant coffee. *Technological Progress in Food Processing*, 2, 70-78.

[25] Janjarasskul, T., Tananuwong, K., Phupoksakul, T., Thaiphanit, S. (2020). Fast dissolving, hermetically sealable, edible whey protein isolate-based films for instant food and/or dry ingredient pouches. *LWT - Food Science and Technology*, 134, 1-10.

[26] Chen, H., Alee, M., Chen, Y., Zhou, Y., Yang, M., Ali, A., Liu, H., Chen, L. and Yu, L. (2021). Developing Edible Starch Film Used for Packaging Seasonings in Instant Noodles. *Foods*, 10, 1-9.

[27] Li, T., Meng, F., Chi, W., Xu, S., Wang, L. (2022). An edible and quick-dissolving film from cassia gum and ethyl cellulose with an improved moisture barrier for packaging dried vegetables. *Polymers,* 14(19), 1-11.

[28] Rammak, T., Boonsuk, P., Kaewtatip, K. (2021). Mechanical and barrier properties of starch blend films enhanced with kaolin for application in food packaging. *International Journal of Biological Macromolecules*, 192, 1013-1020.

[29] Kchaou, H., Jridi, M., Nasri, M., Debeaufort, F. (2020). Design of gelatin pouches for the preservation of flaxseed oil during storage. *Coatings*, 10 (150), 1-15.

[30] Lisitsyn, A., Semenova, A., Nasonova, V., Polishchuk, E., Revutskaya, N., Kozyrev, I., Kotenkova, E. (2021). Approaches in animal proteins and natural polysaccharides application for food packaging: edible film production and quality estimation. *Polymers*, 13, 1-57.

[31] Ribeiro, A.M., Estevinho, B.N., Rocha, F. (2021). Preparation and ıncorporation of functional ıngredients in edible films and coatings. *Food and Bioprocess Technology*, 14, 209–231.

[32] Walait, M., Mir, H.R., Anees, K. (2022). Edible biofilms and coatings; its characterization and advanced industrial applications. *Natural Resources for Human Health*, 3, 28–37.

[33] Umaraw, P, Verma, A.K. (2017). Comprehensive review on application of edible film on meat and meat products: An eco-friendly approach. *Critical Reviews In Food Science And Nutrition*, 57(6), 1270–1279.

[34] Kumar, A., Hasan, M., Mangaraj, S., M.P., Verma, D.K., Srivastav, P.P. (2022b). Trends in edible packaging films and its prospective future in food: a review. *Applied Food Research*, 2, 1-17.

[35] Chen, W., Ma, S., Wang, Q., McClements, D.J., Liu, X., Ngai, T., Liu, F. (2022). Fortification of edible films with bioactive agents: a review of their formation, properties, and application in food preservation. *Critical Reviews in Food Science and Nutrition*, 62(18), 5029-5055.

[36] Santosa, H., Djaeni, M., Ratnawati, Rokhati, N., Setiatun, A.P., Afriyanti. (2019). Effect of sago starch concentrations, stirring speeds, and lemongrass oil concentration for edible film production using solvent casting method. *IOP Conference Series: Journal of Physics: Conference Series 1295*, 1-6.

[37] Jridi, M., Abdelhedi, O., Salem, A., Kechaou, H., Nasri, M., Menchari, Y. (2020). Physicochemical, antioxidant and antibacterial properties of fish gelatin-based edible films enriched with orange peel pectin: wrapping application. *Food Hydrocolloids*, 103, 1-10.

[38] Ribiero, A.M., Estevinho, B.N., Rocha, F. (2020). Edible films prepared with different biopolymers, containing polyphenols extracted from elderberry (*Sambucus Nigra* L.), to protect food products and to improve food functionality. *Food Bioprocess Technology*, 13, 1742–1754.

[39] Tufan, E.G., Borazan, A.A., Koçkar, Ö.M. (2021). Edible film and coating applications on fresh and dried fruits and vegetables (in Turkish). *Bilecik Seyh Edebali University Journal of Science*, 8(2), 1073-1085.

[40] Kaushani, K.G., Priyadarshana, G., Katuwavila, P., Jayasinghe, R.A., Nilmini, A.H.L.R. (2022). Recent advances in edible packaging as an alternative in food packaging applications. *Asian Journal of Chemistry*, 34(10), 2523-2537.

[41] Cheng, Y., Zhai, X., Wu, Y., Li, C., Zhang, R., Sun, C., Wang, W., Hou, H. (2023). Effects of natural wax types on the physicochemical properties of starch/ gelatin edible films fabricated by extrusion blowing. *Food Chemistry*, 401, 1-7.

[42] Krishna, M., Nindo, C.I., Min, S.C. (2012). Development of fish gelatin edible films using extrusion and compression molding. *Journal of Food Engineering*, 108, 337–334.

[43] Castro, A.C., Garcia, M.O.V., Morales, J.J.Z., Vargas, P.R.F., Lopez, A.C., Dorado, R.G., Valenzuela, V.L., Palazuelos, E.A. (2018). Effect of

extrusion process on the functional properties of high amylose corn starch edible films and its application in mango (*Mangifera indica* L.) cv. Tommy Atkins. *Journal of Food Science and Technology*, 55(3), 905–914.
[44] Moey, S.W., Abdullah, A., Ahmad, I. (2015). Edible films from seaweed *(Kappaphycus alvarezii). International Food Research Journal*, 22(6), 2230-2236.
[45] Salgado, P.R., Ortiz, C.M., Musso, Y.S., Giorgio, L.D., Mauri, A.N. (2015). Edible films and coatings containing bioactives. *Current Opinion in Food Science*, 5, 86-92.
[46] Castro, F. V. R., Andrade, M.A., Silva, A.S., Vaz, M.F., Vilarinho, F. (2019).The Contribution of a Whey Protein Film Incorporated with Green Tea Extract to Minimize the Lipid Oxidation of Salmon (*Salmo salar* L.). *Foods*, 8(8), 1-16.
[47] Seydim, A.C., Tutal, G.S., Sogut, E. (2020). Effect of whey protein edible films containing plant essential oils on microbial inactivation of sliced Kasar cheese. *Food Packaging and Shelf Life*, 26, 1-7.
[48] Xiao, J., Zhang, M., Wang, W., Teng, A., Liu, A., Ye, R., Liu, Y., Wang, K., Ding, J. (2019). An attempt to use β-sitosterol-corn oil oleogels to improve the water barrier properties of gelatin film. *Journal of Food Science*, 84 (6), 1447-1455.
[49] Nilsuwan, K., Arnold, M., Benjakul, S., Prodpran, T., Caba, K.D.L. (2021). Properties of chicken protein isolate/fish gelatin blend film incorporated with phenolic compounds and its application as pouch for packing chicken skin oil. *Food Packaging and Shelf Life*, 30, 1-10.
[50] Souza, K.C., Correa, L.G., Silva, T.B.V.D., Moreira, T.F.M., Oliveira, A.D., Sakanaka, L.S., Dias, M.I, Barros, L., Ferreira, I.C.F.R, Valderrama, P, Leimann, F.V., Shirai, M.A. (2020). Soy protein isolate films incorporated with Pinhão (*Araucaria angustifolia* (Bertol.) Kuntze) extract for potential use as edible oil active packaging. *Food Bioprocess Technology*, 13, 998–1008.
[51] Hromis, N., Lazic, V., Popovic, S., Suput, D., Bulut, S., Kravic, S., Romanic, R. (2022). The possible application of edible pumpkin oil cake film as pouches for flaxseed oil protection. *Food Chemistry*, 371, 1-8.
[52] Gautam, G, Mishra, P. (2017). Development and characterization of copper nanocomposite containing bilayer film for coconut oil packaging. *Journal of Food Processing and Preservation*, 41, 1-11.
[53] Jalil, H.M. (2017). Effects of whey-based films on various properties of kashar cheese. MSc Thesis. Van Yüzüncü Yıl University, Institute of Sciences, Division of Food Engineering, 74, Van, Turkiye.
[54] Ciannamea, E. M., Castillo, L. A. Barbosa, S. E., Angelis, M.G.D. (2018). Barrier properties and mechanical strength of bio-renewable, heat-sealable films based on gelatin, glycerol and soybean oil for sustainable food packaging. *Reactive and Functional Polymers*, 125, 29–36.
[55] Tsai, MJ, Weng, Y.M. (2019). Novel edible composite films fabricated with whey protein isolate and zein: Preparation and physicochemical property evaluation. *LWT - Food Science and Technology*, 101, 567–574.
[56] Azeredo, H.M.C., Otoni, C.G., Mattoso, L.H.C. (2022). Edible films and coatings – Not just packaging materials. *Current Research in Food Science,* 5, 1590-1595.
[57] Izzi, Y.S., Gerschenson, L.N., Jagus, R.J. and Resa, C.P.O. (2023).Edible films based on tapioca starch and WPC or gelatine plasticized with glycerol: Potential food applications based on their mechanical and heat-sealing properties. *Food and Bioprocess Technology*, 16, 2259-2269.
[58] Das, M, Chowdhury, T. (2016). Heat sealing property of starch based self-supporting edible films. *Food Packaging and Shelf Life*, 9, 64–68.
[59] Zuo, G., Song, X., Chen, F., Shen, Z. (2019). Physical and structural characterization of edible bilayer films made with zein and corn-wheat starch. *Journal of the Saudi Society of Agricultural Sciences*, 18, 324–331.
[60] Cho, S.Y., Lee, S.Y., Rhee, C. (2010). Edible oxygen barrier bilayer film pouches from corn zein and soy protein isolate for olive oil packaging. *LWT - Food Science and Technology*, 43, 1234-1239.
[61] Rosenbloom, RA, Zhao, Y. (2021). Hydroxypropyl methylcellulose or soy protein isolate-based edible, water-soluble, and antioxidant films for safflower oil packaging. *Journal of Food Science*, 86(1), 129-139.
[62] Carpine, D., Dagostin, J.L.A., Bertan, L.C., Mafra, M.R (2015). Development and characterization of soy protein isolate emulsion-based edible films with added coconut oil for olive oil packaging: barrier, mechanical, and thermal properties. *Food Bioprocess Technology*, 8, 1811–1823.
[63] Nawab, A., Alam, F., Haq, M.A., Haider, M.S., Lutfi, Z., Kamaluddin, S., Hasnain, A. (2018). Innovative edible packaging from mango kernel starch for the shelf life extension of red chili powder. *International Journal of Biological Macromolecules*, 114, 626–631.
[64] Kumar, H., Ahuja, A., Kadam, A.A., Rastogi, V.K., Negi, Y.S. (2022c). Antioxidant film based on chitosan and Tulsi essential oil for food packaging. *Food and Bioprocess Technology*, 16, 342–355.
[65] Ghosh, T, Katiyar, V. (2021). Edible Food Packaging: An Introduction. In: Nanotechnology in Edible Food Packaging. Materials Horizons: From Nature to Nanomaterials. *Springer*,452, Singapore.
[66] Narvekar, S. (2022). Review of innovations in the use of edible containers and cutlery, In "Advances in Chemical Engineering & Material Sciences". A. Ghosh, S. Bose (eds), *International Conference on Advances in Chemical and Materials Sciences*, 14-16 April, Kolkata.
[67] Batta, K. (2022). Upgrade your lifestyle with edible packages. *Agriculture & Food: E-Newsletter*, 4(8), 15-18.
[68] Neogi, A.G., Upadhyaya, A., Sumatra, M., Reddy, M. (2022). Edible packaging– food for thought and food for the future. *The Electrochemical Society Transactions*, 107(1), 13757-13771.

[69] Natarajan, N., Vasudevan, M., Velusamy, V.V., Selvaraj, M. (2019). Eco-friendly and edible waste cutlery for sustainable environment. *International Journal of Engineering and Advanced Technology*, 9, 615-624.
[70] Williams, A.T, Buitrago, N.R. (2022). The past, present, and future of plastic pollution. *Marine Pollution Bulletin*, 176, 1-20.
[71] Anonymous. (2023). Web Site: https://www.loliware.com/straw. (Accessed: 25.05.2023)
[72] Galus, S., Kibar, E.A.A., Gniewosz, M., Krasniewska, K. (2020). Novel materials in the preparation of edible films and coatings-a review. *Coatings*, 10(7), 674.