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A comprehensive review on classification and application of edible films

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Abstract
A developing trend in the preservation of food ingredients is edible films and coatings. The definition, background, composition, and uses of edible foil for food preservation are all covered in this review. Although the origins of edible films can be traced to the 12th and 13th centuries, their advancements in application continue to this day. Currently, there are over a dozen different kinds of edible films and coatings sold under commercial names that are used to preserve food. Single, thin layers of material are the general definition of edible films or coatings. They are typically composed of polymers that can give the thin, self-contained structure mechanical strength. Films can be formed through various manufacturing processes into capsules, wrappers, pouches, or wrappers. Food-grade materials can have coatings, a unique type of film, applied directly to their surface. Food-grade additives and edible biopolymers are used to create edible films and coatings. Proteins, lipids, and polysaccharides (such as gums and carbohydrates) can all form films of biopolymers. Food products are enhanced by edible films and coatings, which also shield them from deterioration caused by chemicals, microbes, and physical forces.

Keywords: Edible film, coatings, history, classification, application

1. Introduction

Food packaging plays a crucial role in maintaining its sensory, nutritional, and hygienic qualities while it is being stored and marketed. Goods are packaged when they are wrapped in protective materials or placed in containers to improve their performance, maintain their informational value, and prolong their shelf life. During the time between production and consumption, food can be packaged using a variety of materials, including glass, paper, cardboard, aluminum, and plastic. Depending on their individual characteristics, each of these packaging materials causes varying rates of chemical migration into food (Pascall *et al.*, 2014) [13]. Hazardous materials from packaging materials migrate into food, necessitating the use of an alternative that is just as safe as the food.

Packaging materials are separated into two categories: natural and synthetic. Typically made of petrochemicals, synthetic packaging is favored in the industry and effective at preserving the product, but because of pollution and migration concerns, it is advised to use it less (Zuhal *et al.*, 2018) [20]. As an alternative to these wraps, edible wraps made from natural resources have been proposed. These wraps can be used in a variety of foods, including cereals, dairy, fruits and vegetables, dried nuts, meat, and meat products (Otoni *et al.*, 2017) [12]. Due to their high-water content, which causes respiration and perspiration, fruits and vegetables can deteriorate quickly. For this reason, the way these are packaged matters.

2. History of Biodegradable film

Although the use of edible films and coatings seems to have been around for the last fifty years, the use of edible films as a coating goes all the way back to the 12th and 13th centuries. In the 12th century, Chinese farmers used waxes on oranges and lemons to prevent water loss during storage and transportation. Japan created the first edible film formations, known as yuba films, in the early 15th century by pan-cooking and then air-drying soy milk proteins (Erkmen *et al.*, 2018) [5]. In 16th-century England, spiking fruit, vegetables, meat, and fish was a common practice to prevent moisture loss, similar to waxing. The first US patent was issued in the 19th century for gelatin films used to shield various meat products (Choi *et al.*, 2001) [3]. Nuts have been coated with sucrose and sugar derivatives to prevent oxidative rancidity by limiting gas transport through edible coatings.

In order to preserve natural respiration and prevent dehydration during transportation, fruits and vegetables were coated in lipids and commercial wax in the 1930s. During World Wars I and II at the start of the 20th century, there was a great demand for textile products made from agricultural materials based on protein to make military apparel, blankets, and other materials. increased the rate of commercialized protein production. Casein, peanut protein, soy, and corn zein have all been used as wool substitutes to make commercial textiles, boxes, umbrella handles, and buttons. When demand rises, manufacturers of food packaging look for less expensive materials, like petroleum-based products (Chakravartula *et al.,* 2019) [2].

Because of the sharp rise in the price of petroleum in 2005 and 2006, packaging materials became more costly. Since 1990, over 90 patents and 220 scholarly research articles have been published, all of which address the same issues with food packaging: preventing the transmission of water vapour and encapsulating functional ingredients like vitamins, flavorings, antioxidants, and antimicrobials in the films. The production of commercial edible films ready for different food packaging systems is a result of today's growing consumer quality demands for safe, fresh food ingredients and healthy packaging substitutes.

3. Biodegradable film

Utilizing biopolymer materials such as polysaccharides, starches, alginates, pectin, chitosan, carrageenan, gums, and fibers; proteins, such as whey, casein, keratin, soybean protein, wheat gluten, corn zein, gelatin, sunflower protein, and waxes; and lipids, such as triglycerides, acetylated monoglycerides, free fatty acids, sucrose esters, and shellac resin are some examples of biodegradable packaging methods. Because of their production source, bioplastics, as they are commonly called, are thought to be non-toxic to all life forms and environmentally friendly (Mellinas *et al.,* 2016) [11]. The carbon footprint is also produced by it. These compounds can be recycled with far less energy because they are biodegradable.

3.1 Edible films

Food-grade film is a thin layer of material that is safe for consumption and acts as a barrier against moisture, oxygen, and solute movement (Bourtoom *et al.,* 2008) [1]. Both a continuous layer and a full food coating are possible applications for the substance. There is a possibility to use edible films as a gas aroma barrier in conjunction with food. These films can be shaped as food coatings or free-standing films. Since they are superior to synthetic films, edible films and coatings have drawn a lot of attention in recent years. Because they can be consumed along with packaged goods, edible films have one major advantage over conventional plastics. Films can still lessen their impact on the environment even if they are not consumed because there is no packaging to discard. Since only edible, renewable materials were used to make the films, it is anticipated that they will break down more quickly than polymeric materials.

When combined with other ingredients, like bioactive compounds, the films can enhance the organoleptic qualities of packaged foods (Quiros *et al.,* 2014) [14]. The films can be used for single serving packaging of food, especially items like pears, beans, nuts, and strawberries that aren't currently single-serve packaged for practical reasons. They can also be applied to the outside of food to regulate the rate at which preservatives seep into the food's interior in a related application. One potential use for edible films could be in combination with non-edible films to create multi-layered food packaging materials. The inner layers in direct contact with food materials in this scenario would be considered edible films. Though their permeability and mechanical qualities are typically worse than those of synthetic films, the production of edible films produces less waste and pollution.

The primary goals of edible films are to increase product quality and shelf life by applying thin layers of natural biopolymer to the food product's surface. The benefits of edible films over synthetic polymers include their natural appearance, edibility, biodegradability, and biocompatibility. The edible films may offer a selective barrier against oxygen, carbon dioxide, and moisture in addition to preserving flavor and enhancing mechanical and structural qualities. It is possible to inhibit, reduce, or delay the growth of the microorganisms by incorporating different antimicrobial agents into the film formulation.

3.2.1 Classification of edible films

The film-formable material can be used to create edible films. Film ingredients need to be spread out and dissolved in a solvent during production, such as water, alcohol, a combination of water and alcohol, or a combination of different solvents. It is possible to add flavorings, colorants, plasticizers, and antimicrobials. For a given polymer, dispersion can be facilitated by heating the solutions or adjusting the pH (Ramos *et al.,* 2012) [15]. To create free-standing films, the film forming solution is subsequently cast and dried at the appropriate temperature and relative humidity. Film solutions can be applied to food using a variety of techniques, including dipping, spraying, brushing, and waving, and then drying. Three types of materials are used to create edible films: hydrocolloids (which include proteins, polysaccharides, and alginates), lipids (which include fatty acids, acylglycerol, and waxes), and composites. (Suput *et al.,* 2015) [19].

Table 1: Classification of edible films

CLASSIFICATION OF EDIBLE FILM FORMING MATERIALS		
POLYSACHARIDES	PROTEINS	LIPIDS
▪ Cellulose ▪ Starch ▪ Pectin ▪ Seaweeds: alginates, carrageenan & agar ▪ Gums: acacia, tragacanth & guar ▪ Pullulan ▪ Chitosan	▪ Animal source: casein & whey protein concentrate, gelatine, egg albumin ▪ Plant source: corn, soybean, wheat gluten, cottonseed, peanut & rice	▪ Animal and vegetable oils and fats ▪ Waxes ▪ Natural resins ▪ Essential oils ▪ Emulsifiers & surface-active agents

3.3 Polysaccharides

A variety of polysaccharides, such as cellulose, starch derivatives, pectin derivatives, exudate gums (acacia, guar), microbial fermentation gums, pullulan, chitosan, and seaweed extracts (carrageenan, agar, alginate), are utilized in edible films and coatings. Gas and water vapor barriers are poorly maintained by polysaccharides because they are typically highly hydrophilic. Polysaccharide polymer coatings can provide as sacrificial agents, preventing food products from losing moisture even though they might not be an effective water vapor barrier (Gonzalez *et al.,* 2011) [6].

3.3.1 Polysaccharide Films

Films containing starch, alginate, cellulose ethers, chitosan, carrageenan, or pectin are called polysaccharide films, and they give a range of films characteristics like adhesion, hardness, crispness, compactness, and thickening quality. According to Kairunnisa *et al.*, these films' outstanding gas permeability qualities are caused by the polymer chains' composition, which produces desired modified atmospheres that lengthen product shelf life without establishing anaerobic conditions (Kairunnisa *et al.*, 2018) [9]. In addition, by halting oxidative rancidity, surface browning, and dehydration, polysaccharide films and coatings can prolong the shelf life of muscle foods; however, due to their hydrophilic nature, they are not very effective as water vapor barriers (Dhanapal *et al.*, 2012) [4].

4. Bioactive compounds

Non-nutritional ingredients known as "bioactive compounds" are generally present in food in trace amounts (Soni *et al.*, 2018) [18]. These substances are generally present in millions of different species of plants, animals, marine life, and microorganisms. They can be extracted and synthesized through biotechnology methods. Incorporating extracted bioactive compounds into new edible films can enhance the products' nutritional value, shelf life, and consumer acceptability.

Antioxidants, antimicrobials, probiotics, and flavorings are the most often utilized bioactive compounds; nutraceuticals are also utilized (Salgado *et al.*, 2015) [17].

4.1 Essential oils

Aromatic and volatile oil extracts are known as essential oils. The majority of them are made from plant components like bark, buds, roots, leaves, and flowers. They can be added to food as flavorings. However, because of their potent flavor, direct ingestion of essential oils as a food preservative is frequently restricted. Essential oils can be added to the edible films to help prevent this issue. Essential oils like cinnamon, clove, ginger, lemongrass, marjoram, oregano, sage, thyme, Eucalyptus globulus, and Ziziphora clinopodioides are frequently used in bio-based sheet materials. They have demonstrated their effectiveness against a variety of microbes. The primary phenolic compounds in essential oils, such as thymol, eugenol, carvacrol, or terpenoid compounds (-pinene, -pinene, 1,8-cineole, menthol, and linalool), which can be found in concentrations of up to 85%, are responsible for their antimicrobial activity. The primary constituents of various essential oil kinds differed in their capacities to attach to microbial cell membrane proteins and modify membrane permeability (Kris *et al.*, 2002) [10].

5. Product Development

Examining the process from product conception to formulation, testing in the lab, and ultimately operating a pilot plant to full production is helpful when developing edible films. Producing films of excellent quality requires a methodical approach to each of these stages of development. A well-defined idea or concept is the first step in the creation of a product. The difficulty lies in deciding on the components, method of preparing the solution, and drying procedure that will result in a film with the required performance qualities at a reasonable price. This development usually proceeds according to a specified flow of steps.

6. Applications

Edible films are finding commercial uses at a rate that makes it impossible to compile a list that is both up to date and exhaustive. Enhancements in the composition and production procedures of these films add to their increased usefulness. Most applications fall into a few broad categories as shown in Table 2.

Table 2: Edible film applications

Categories	Application examples
Packaging	Vitamins, enzymes, food colors, food additives, beverage mixes, soup
Freestanding films	Breath freshener, toothpaste inclusions, confections, labels, nutraceuticals, over the counter drugs (OTC), contraceptives
Wrapping	Vitamins, meat curing, sushi, enrobing, meat glazes, spice blends

6.1 Method of application of edible film: Fruit that has been harvested and consumed can lose a significant amount of both quality and amount. The term "hidden harvest" refers to financial benefits obtained by lowering post-harvest fruit losses. A number of effective methods for extending shelf life have been developed as a result of improved understanding of the respiration process in fresh fruit. Fruits can be preserved by minimizing changes in quality and quantity lost during storage through the use of controlled atmosphere and modified atmosphere storage techniques. When the internal atmosphere of each fruit is modified and controlled, edible film packaging of fresh fruit can offer an alternative to modified atmosphere storage by minimizing quality change and volume loss.

6.2 Solvent casting: The most widely used method for creating edible hydrocolloid films is solvent casting. On an appropriate substrate, water, water-ethanol solutions, or edible material dispersions are applied, and the surface is then dried. The solubility of the polymer decreases as the solvent evaporates during the film-drying process, causing the polymer chains to align and form films. Selecting the right substrate is crucial to getting films that, once the solvent evaporates, can be removed without causing damage. The films are usually air dried for a few hours in a ventilated oven. In the dried film, 510 percent w/v is the ideal moisture content. The composition of the casting solution, the wet cast thickness, and the drying conditions (temperature and relative humidity) all affect the structure of the film (Kaya *et al.*, 2018) [8].

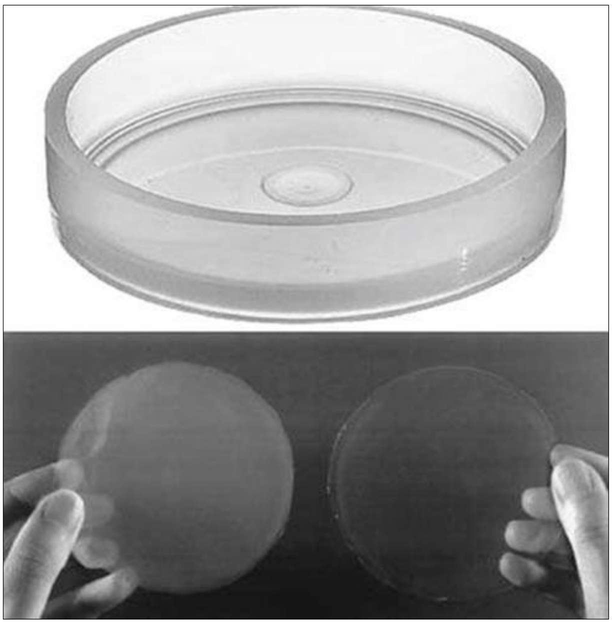

Fig 1: Casting petriplate and films

6.3 Biodegradability

A method involving the breakdown of materials by microorganisms or other biological agents is known as biodegradability. Anaerobic (without oxygen) and aerobic (with oxygen) breakdowns are two possible processes for organic compounds. Microbes produce bio-surfactants to hasten the process of degradation. Various materials need varying amounts of time to deteriorate (Saleha *et al.*, 2013) [16].

6.4 Shelf life

The amount of time that a product or set of goods keeps their freshness and is not rendered useless is determined by their shelf life. Factors like exposure to light, heat, humidity, gas transmission, mechanical stress, and microbial contamination frequently have an impact on it. After the expiration date, food quality declines but may still be safe to eat. Shelf life extension is significantly aided by barrier packaging (Gupta *et al.* 2010) [7]. Packaging that has low moisture vapor transmission rates frequently prevents spoiling by transferring less moisture to the product.

7. Current state and recent advances

Edible films and coatings find extensive uses in the food industry. Among these are: (1) foods that require oxygen, such as nuts, to increase shelf life and minimize packaging; (2) nuts to stop oil from leaking into nearby food ingredients (e.g. g. (3) fragile foods (breakfast cereals, freeze-dried foods, etc.) to increase integrity and decrease breakage loss; (4) whole and pre-cut fresh fruits and vegetables to increase product shelf life by minimizing respiration, moisture loss, and color changes; (5) moisture-sensitive foods or inclusions (e.g. g., cookies, candy, and/or almonds in ice cream) to create a barrier against moisture and maintain the crispness of the products and inclusions; (6) low-fat and fat-free snack foods (e.g. g. chips), which aid in the adhesion of condiments to goods; (7) frozen foods, which shield against oxidation and minimize the migration of moisture, flavor, or color; Film separation layers for mixed foods; and film pouches for dry food components. Among these uses, one that seems particularly promising for active food packaging is the use of edible films and coatings to contain active ingredients.

7.1 Future Trends

Future research should focus on developing new technologies to enhance the carrier properties of edible films and coatings. Such edible films and coatings have limited applications at the moment. Cost is one of the primary barriers, limiting its use to high-end goods. The absence of materials with the required functionalities, the capital costs of putting in new film production or coating equipment, the difficulty of the production process, and the stringency of regulations are additional barriers to the commercial use of edible films and coatings in addition to cost. Notwithstanding these drawbacks, the food industry is searching for edible coatings and films that work well with a variety of foods, enhance their products, prolong their shelf lives, and/or require less packaging. However, further research is required to comprehend the interactions between the materials used in the production of new edible films and coatings that contain active ingredients. The mechanical properties of edible films and coatings can be significantly weakened by the addition of flavorings and active ingredients (such as antioxidants, nutraceuticals, and antimicrobials. To fully comprehend this behavior, more information is required as there are currently very few studies on this subject.

8. Conclusion

Edible films should, in general, offer food materials safe storage protection. Because of the altered gas and moisture exchange between the inner and outer layers of food surfaces, it is especially important to take perishable food shelf life into account when coating food materials with edible films. The type of edible film components and generally recognized quality standards work together to prolong the shelf life of coated food items. It is necessary to conduct preliminary research and develop each food material's distinct edible film material properties in order to choose the best coating material and application. In order to manufacture food materials that, when coated with edible films, have an extended shelf life, it is necessary to thoroughly study edible films and their general property profiles.

9. Data Availability

The data used to support the findings of this study are included within the article.

10. Conflict of interest

The authors declare no conflict of interest.

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