USE OF EDIBLE FILMS AND COATINGS IN FOOD PRESERVATION: AN OVERVIEW

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https://doi.org/10.11118/978-80-7701-100-6-0308

ABSTRACT

Edible films and coatings have emerged as a sustainable alternative to conventional synthetic packaging, addressing both environmental and health concerns. This review explores their definitions, recent advancements, and functional properties, focusing on their composition and applications in the food industry. Derived from renewable biopolymers such as polysaccharides, proteins, and lipids, these materials are biodegradable and enhance food preservation by incorporating active agents like antioxidants and antimicrobials. Applications span various sectors, including fresh produce, meat, seafood, and bakery products, improving shelf life, quality, and safety while minimizing synthetic waste. Despite challenges like scalability and cost, innovations such as composite films and nanomaterial incorporation offer promising directions for future development. This review emphasizes the potential of edible films and coatings to transform sustainable food packaging and improve food quality, aligning with global priorities for environmental sustainability and consumer health.

Keywords: edible films, food packaging, food preservation, sustainability

INTRODUCTION

Edible films and coatings have been used for centuries to protect food products and enhance their appearance. Historically, wax coatings on fruits were common practices in China as early as the 12th century, and similar methods have been used in various cultures to preserve and improve the aesthetic qualities of food. The modern concept of edible films, however, has only been formally recognized in the past 50 years, with significant commercial use beginning around the 1960s (Paylath and Orts, 2009).

The concept of edible films has evolved significantly, especially in recent decades, as a response to increasing environmental and health concerns associated with traditional synthetic packaging materials (Otoni et al., 2017; Díaz-Montes and Castro-Muñoz, 2021).

The use of edible films dates back centuries, but their modern development has been driven by the need for sustainable and environmentally friendly packaging solutions. Initially, these films were simple and primarily used for basic food preservation. Over time, advancements in food science and technology have led to the incorporation of various functional ingredients, such as antioxidants, antimicrobials, and essential oils, to enhance the protective and preservative qualities of edible films (Ávila-Sosa et al., 2016; Ribeiro et al., 2020).

Edible films and coatings are defined as thin layers made from naturally occurring renewable sources such as polysaccharides, proteins, lipids, and composites. These materials are safe for consumption and can be eaten along with the food product they protect (Tavassoli-Kafrani et al., 2016; Hassan et al., 2017; Nurjanah et al., 2023).

This kind of films and coatings protect food products, extend shelf life, improve organoleptic characteristics, and enhance nutritional value by carrying active ingredients like colorants, flavors, and natural extracts (Ribeiro et al., 2020).

Recent advances in edible films and coatings incorporate natural extracts, improving shelf life, organoleptic characteristics, and nutritional value, while addressing health and environmental concerns (Díaz-Montes and Castro-Muñoz, 2021).

ENVIRONMENTAL BENEFITS OF EDIBLE FILMS AND COATINGS

Edible films and coatings have emerged as a sustainable alternative to traditional synthetic packaging, offering numerous environmental benefits. These biodegradable materials are primarily derived from natural polymers such as polysaccharides, proteins, and lipids, which can be consumed along with the food product, thereby reducing waste and environmental pollution.

Reduction in Synthetic Packaging Use

One of the primary environmental benefits of edible films and coatings is their potential to significantly reduce the reliance on synthetic polymer materials. Traditional plastic packaging contributes to environmental pollution due to its non-biodegradable nature. In contrast, edible films and coatings are made from renewable resources and are biodegradable, thus offering an eco-friendly packaging solution (Umaraw and Verma, 2017; Hammam, 2019; Kocira et al., 2021). The use of natural polymers like polysaccharides not only reduces the consumption of synthetic materials but also utilizes waste products generated during food processing, further enhancing their environmental appeal (Kocira et al., 2021).

Biodegradability and Reduced Waste

Designed to naturally decompose without leaving harmful residues, these biodegradable solutions are the core feature of edible films and coatings. This characteristic is crucial in addressing the global issue of plastic waste. By replacing non-biodegradable packaging with edible alternatives, the burden of waste disposal is significantly alleviated, contributing to a cleaner environment (Umaraw and Verma, 2017; Butu et al., 2023; Matloob et al., 2023).

The incorporation of natural extracts and biopolymers ensures that these films and coatings decompose harmlessly, reducing the overall environmental footprint (Hashemi et al., 2022; Butu et al., 2023).

Utilization of Natural and Renewable Resources

The production of edible films and coatings often involves the use of natural and renewable resources such as polysaccharides, proteins, and lipids. These materials are not only abundant but also renewable, making them a sustainable choice for packaging solutions. For instance, polysaccharides like alginates and carrageenans are derived from seaweed, a renewable resource that can be harvested sustainably (Tavassoli-Kafrani et al., 2016). The use of such materials ensures that the production of edible films and coatings does not deplete natural resources, aligning with the principles of sustainable development (Hassan et al., 2017).

Health Benefits

The shift from petrochemical-based packaging to edible films and coatings addresses both environmental and health concerns. Traditional plastic packaging materials are not biodegradable and pose significant environmental hazards. In contrast, edible films and coatings are eco-friendly alternatives that decompose naturally, reducing the environmental footprint of food packaging (Bizymis and Tzia, 2021; Song et al., 2021).

Additionally, the use of natural antioxidants and antimicrobial agents in these films mitigates the health risks associated with synthetic compounds, aligning with consumer preferences for natural and safe food preservation methods (Ribeiro et al., 2020; Hashemi et al., 2020).

TYPES AND COMPOSITION OF EDIBLE FILMS AND COATINGS

Polysaccharide-Based Films and Coatings

Polysaccharides such as pectin, starch, alginate, carrageenan, and xanthan gum are commonly used to create edible films and coatings. These materials are renewable, biodegradable, and provide excellent barriers to oxygen and carbon dioxide, making them suitable for food packaging applications (Tavassoli-Kafrani, 2016; Mohamed et al., 2020). Polysaccharide-based films are particularly effective in maintaining the quality of fruits and vegetables by preventing moisture loss and reducing spoilage (Kocira et al., 2021). Additionally, the incorporation of essential oils into polysaccharide matrices has been shown to enhance their antimicrobial properties, further extending the shelf life of food products (Anis et al., 2021).

Protein-Based Films and Coatings

Proteins are another category of biopolymers used in the formulation of edible films and coatings. These films are known for their good mechanical properties and ability to form strong, cohesive films. Proteins such as casein, whey, soy, and gelatin are commonly used in these applications. Protein-based films can be tailored to improve their functionality by blending with other biopolymers or incorporating active ingredients like antioxidants and antimicrobials (Hassan et al., 2017; Mohamed et al., 2020).

Lipid-Based Films and Coatings

Lipids are widely used in edible coatings and films to provide hydrophobic properties, which help in reducing moisture loss from food products. Lipid-based films can be made from natural waxes, resins, acetoglycerides, fatty acids, and various oils. These films are particularly useful for protecting foods that are sensitive to moisture, such as fresh and processed fruits, vegetables, and bakery products (Ribeiro et al., 2020; Yousuf et al., 2021). The emulsification of lipids in an aqueous phase is often necessary to create stable, functional coatings (Galus and Kadzinska, 2015).

Composite Films and Coatings

Composite films and coatings combine different types of biopolymers, such as polysaccharides, proteins, and lipids, to leverage the complementary advantages of each component. These composite materials often exhibit improved mechanical and barrier properties compared to films made from a single type of biopolymer. For example, combining polysaccharides with lipids can enhance water barrier properties while maintaining the mechanical strength provided by the polysaccharides (Galus et al., 2015; Hassan et al., 2017). Recent research has focused on developing multilayered and blended composite films to address specific food preservation needs (Liyanapathiranage et al., 2023).

Herbal and Essential Oil-Based Films and Coatings

Herbal extracts and essential oils are increasingly being used in the formulation of edible films and coatings due to their natural antimicrobial and antioxidant properties. Aloe vera gel, for instance, has been extensively studied for its potential as a base material for edible films and coatings. It contains bioactive compounds that can extend the shelf life of perishable food items (Maan et al., 2021). Essential oils like citral and eugenol are also incorporated into polysaccharide matrices to enhance the antimicrobial efficacy of the coatings (Anis et al., 2021).

Functional Additives in Edible Films and Coatings

To improve the performance of edible films and coatings, various functional additives are often incorporated. These include plasticizers like glycerol and sorbitol, which enhance the flexibility and durability of the films.

Other additives such as cross-linkers, surfactants, and nanosilver particles can modify the physical and chemical properties of the coatings to better suit specific applications (Hassan et al., 2017; Kocira et al., 2021). Additionally, natural extracts and active compounds are used to impart antimicrobial and antioxidant properties, further enhancing the shelf life and safety of the food products (Ribeiro et al., 2020).

APPLICATION OF EDIBLE FILMS AND COATINGS IN FOOD SYSTEMS

Fruit and vegetables

The application of edible films and coatings in fruits and vegetables has gained significant attention due to their potential to enhance food quality, extend shelf life, and provide an environmentally friendly alternative to synthetic packaging materials. These films and coatings are primarily composed of natural biopolymers such as polysaccharides, proteins, and lipids, which can be further enhanced with various additives to improve their functional properties.

Edible films and coatings offer several benefits, including acting as barriers to moisture, gases, and volatiles, thereby reducing the respiration rate and delaying ripening of fruits and vegetables (Kocira et al., 2021; Jafarzadeh et al., 2021). They also help in maintaining the nutritional value and sensory attributes of the produce (Nair et al., 2020). For instance, chitosan-based films have been shown to protect strawberries from fungal attacks without significantly altering their flavor, appearance, aroma, and texture (Pavinatto et al., 2020).

The functionality of edible films and coatings can be significantly enhanced by incorporating various additives such as plasticizers, surfactants, antimicrobial agents, and nanoparticles. These additives improve the mechanical and barrier properties of the films, making them more effective in preserving the quality of fruits and vegetables (Xing et al., 2019; Nair et al., 2020; Kocira et al., 2021). For example, the inclusion of metal nanoparticles in biopolymeric films has been shown to decrease color changes, reduce weight loss, and extend the shelf life of tropical fruits and vegetables (Jafarzadeh et al., 2021).

Meat and seafood

By preventing moisture loss, delaying microbial spoilage, and reducing lipid, protein, and pigment oxidation, edible films play a crucial role in extending the shelf life of meat and seafood. These packaging materials are composed of biopolymers derived from food industry wastes or underutilized sources of proteins, lipids, or polysaccharides, making them biodegradable and edible (Umaraw et al., 2020; Ribeiro et al., 2020; Hashemi et al., 2023). The incorporation of natural extracts, essential oils, and other bioactive compounds into these films and coatings further enhances their protective effects, ensuring the sensory and quality characteristics of the packaged products are maintained for longer periods (Umaraw et al., 2020; Ribeiro et al., 2020).

The integration of antimicrobial and antioxidant agents into edible films and coatings is a significant advancement in food packaging. These active components, such as natural extracts and essential oils, inhibit the growth of pathogenic microorganisms and reduce oxidative reactions that compromise the quality and safety of meat and seafood (Song et al., 2021; Abdollahzadeh et al., 2021; Hamann et al., 2021). For instance, polysaccharide-based films incorporated with lipid-based nanosystems loaded with bioactive compounds have shown promising results in enhancing the oxidation stability and microbial safety of meat products (Hashemi et al., 2023; Maciel et al., 2020).

Bakery and confectionery

Various bakery and confectionery products benefit from the application of edible films and coatings, which enhance shelf life and maintain product quality. For instance, a study by Pilli (2020) demonstrated the use of an edible film made from vegetable oil and egg proteins to replace preservatives and primary plastic packaging for sweet baked goods. This film effectively prevented fungal growth and maintained the sensory characteristics of the products over an 85-day storage period. Another research by San et al. (2022) highlighted the use of functional polymeric packaging incorporating antimicrobial agents to preserve the quality of bakery products by preventing microbial spoilage and moisture loss.

Edible coatings are effective in mitigating quality losses in bakery products by restricting moisture migration, preventing texture changes, and inhibiting mold growth. For instance, the use of edible coatings on bread has been shown to retain moisture and maintain textural quality during storage (Chakravartula and Sirisha, 2019).

CHALLENGES AND FUTURE PROSPECTS

Despite the benefits, the large-scale application of edible films and coatings faces challenges such as cost, consumer awareness, and the need for further research to enhance their functional properties.

Edible films often do not match the mechanical strength and barrier properties of conventional plastic packaging. The development of composite films and the incorporation of nanomaterials are promising strategies to improve the mechanical and barrier properties of these packaging materials (Jeevahan and Chandrasekaran, 2019; Bizymis and Tzia, 2021; Hamann et al., 2021).

Future research should focus on optimizing the formulations and production methods to make edible films and coatings more cost-effective and widely acceptable in the food industry (Umaraw et al., 2020; Díaz-Montes and Castro-Muñoz, 2021).

CONCLUSIONS

Edible films and coatings offer an innovative and sustainable solution to the challenges associated with food packaging. Their evolution, from rudimentary applications to complex formulations incorporating antioxidants, antimicrobials, and natural extracts, highlights their potential to extend food shelf life, enhance sensory attributes, and reduce environmental impact. However, technical and economic challenges still hinder their large-scale adoption. Continued research is essential to optimize formulations, improve mechanical and barrier properties, and lower production costs. The future of these technologies relies on the food industry's ability to integrate them into sustainable and accessible packaging systems while fostering greater consumer acceptance.

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