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A Brief Overview of the Scientific Foundations and Results of Some Studies on Edible Coatings in Turkish Literature

Gamze Alkaç[1], Enes Kavrut[2]*

[1]Postgraduate Education Institute, Department of Food Engineering, Iğdır University, 76000 Iğdır- Türkiye
[2]Faculty of Tourism, Department of Gastronomy and Culinary Arts, Iğdır University, 76000 Iğdır, Türkiye

*Corresponding: eneskavrut.gm@hotmail.com

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Abstract
This study investigates edible coatings, a smart solution designed to protect our food, maintain its quality, and keep it fresh for much longer. As we all become more conscious about sustainability, the need to find natural, biodegradable, and recyclable alternatives to plastic has never been more urgent. Produced from natural building blocks such as proteins, lipids, and plant-based sugars, these coatings do more than just sit on the surface. They serve as a 'breathable' barrier that controls moisture and gas exchange, effectively protecting food from spoilage and bacteria. Research is yielding some exciting results: when enriched with natural powerhouses like propolis, gelatin, chitosan, and various plant extracts, the benefits of these coatings are undeniable. Whether it's a piece of fruit, a vegetable, or a fresh fish fillet, these coatings keep microbes at bay while preserving the food's weight, vibrant colour, and firm texture. As a result, edible coatings are not just a scientific innovation; it is an environmentally friendly way to combat food waste and create a more sustainable food industry.

Keywords: *Edible Coatings, Active Packaging, Shelf-Life, Food Quality*

INTRODUCTION

Packaging refers to all materials used to protect food from the moment it is produced until it reaches the consumer, to maintain its quality and functionality, and to provide essential information about the product.[1] Food packaging has changed considerably due to the globalisation of the food supply chain, as well as consumers' increasing preference for products that are fresher, more convenient, and easier to use, together with rising expectations for food safety and quality. Alongside these developments, consumer preferences continue to evolve, with a growing demand for packaging derived from natural sources that is biodegradable, recyclable, and not limited to single use.[2] Biodegradable packaging materials, including polymer-based edible films and coatings, have become the focus of scientific research and industrial applications in recent years due to their superior barrier properties against oxidative and physical stresses. The fact that these materials offer environmental sustainability advantages and functional qualities for food preservation has led to considerable interest in this type of packaging.[3] Edible coatings have been commercially used on oranges in some countries since 1930 in the form of paraffin wax coatings. In the early days, the purpose of coatings was to prevent water loss during storage and transport. However, over time, the functionality of edible coatings has been increasingly enhanced. Today, these materials are applied to preserve the quality characteristics (physical, chemical, microbiological, sensory) of foods and extend their shelf life.[3,4,5,6,7,8] The functional effectiveness of edible coatings depends on the structural and molecular properties of the film components. The choice of film-forming agent or additive is determined by the intended function, the structural properties of the food product, and the application method. For example, hydrophobic components such as lipids, resins, and certain insoluble proteins are considered the most effective barrier materials due to their capacity to limit moisture transmission. In contrast, water-soluble hydrocolloids such as polysaccharides and proteins do not form a significant barrier against moisture transfer; however, these components provide edible coatings with superior mechanical properties compared to lipids.[9] Edible coatings are used as active, smart packaging and halochromic materials that not only enhance basic barrier properties but also improve the organoleptic, microbial, and oxidative stability of the foods they are applied to, thanks to the functional additives they contain. These films serve as carriers of antimicrobial and antioxidant agents, prebiotics, and various compounds, enabling their sustained release. In this context, active renewable films/coatings are defined as protective barriers with enhanced functionality through the addition of bioactive components.[10] The use of edible coatings has significantly expanded and diversified in terms of application methods, with the aim of minimising quality losses in fresh, frozen, and processed foods, prolonging shelf-life, and preserving the sensory properties of foods.[11] This study will compreh ensively evaluate some fundamental research conducted in Turkish literature

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on edible coatings. The results of this research will contribute to future studies on edible packaging.

EDİBLE COATİNGS

Edible coatings are materials that form a thin layer on the surface of foodstuffs and can be consumed with the food, with the aim of extending its shelf life. These packaging materials are not synthetic but are derived from natural sources and are edible, providing moisture, gas, and solid mobility.[1,12] Edible coatings are typically prepared as composite, two-layer structures consisting of a mixture of polysaccharides, proteins, and lipids. These approaches aim to enhance film permeability and mechanical properties according to specific application requirements. Polysaccharides and proteins with a polymer structure can provide oxygen, aroma, and lipid barriers at low relative humidity due to their hydrophilic properties, but they are limited in their moisture barrier properties. These coatings are used in various application methods, such as emulsions and multi-layer coatings, due to their high barrier properties, which enable a the combination of lipid and gas barrier properties.[7] Furthermore, additives such as pigments, minerals, vitamins, essential oils, and texture enhancers can be incorporated into edible coatings to improve the nutritional value and shelf life of products. Plant proteins such as zein and gluten enhance coating function, and flexibility is imparted by various plasticisers (such as glycerol, sorbitol, and etc.). These coatings extend the shelf life of products by delaying the ripening of fruits and vegetables, reducing the rate of wilting, and controlling microbial load. Furthermore, polysaccharides such as alginate and carrageenan prevent oxidation and spoilage of fresh fruits and vegetables through their water-permeable and oxygen-barrier properties. These approaches aim to develop film permeability and mechanical properties according to specific application needs.[13] It has been found that coatings containing cheese whey isolate with added thyme extract improve the quality of beef meatballs.[8] Many other foods using edible coatings have been reported in the literatüre (Fig 1).

SOME SCIENTIFIC STUDIES

Mesci and Esim [14] showed that integrating of bee products and natural components into coating materials increases the durability of foods while also improving their sensory properties. Propolis, due to its phenolic content, enhances mechanical and barrier properties while preventing water loss and colour change. Additionally, the use of materials such as microcapsules and lipids ensures the stability and controlled release of bioactive components, thereby preserving the storability and nutritional value of foods. These studies highlight the importance of using natural and bio-based materials, particularly for extending the freshness and shelf life of fruits and vegetables and for edible coatings.[14]

In a study by Yılmaz and Kılınçeker[15] the effects of bovine gelatin solutions at different concentrations on chicken meatballs were investigated. Gelatin solutions at 5% and 7.5% concentrations positively affected meatball quality by improving adhesion and sensory properties. Additionally, these solutions reduced TBA (Thiobarbituric acid) values and did not adversely affect product quality during storage. Gelatin coatings were reported to significantly affect on the appearance, colour, and odour of the meatball samples. Coating applications were reported to extend the storage life of products by preventing deterioration such as oxidation and microbiological spoilage, and to enhance the visual qualities of foods.[15]

Karabulut et al.[16] investigated various edible coating applications to extend the shelf life of strawberries. The coating methods included whey protein, water containing Bacillus subtilis, and coating material containing this microorganism. The applications were stored at 25°C for 5 days and evaluated for mould growth, bacterial preservation, weight loss, pH, colour, and sensory characteristics. The results showed that the coating con-

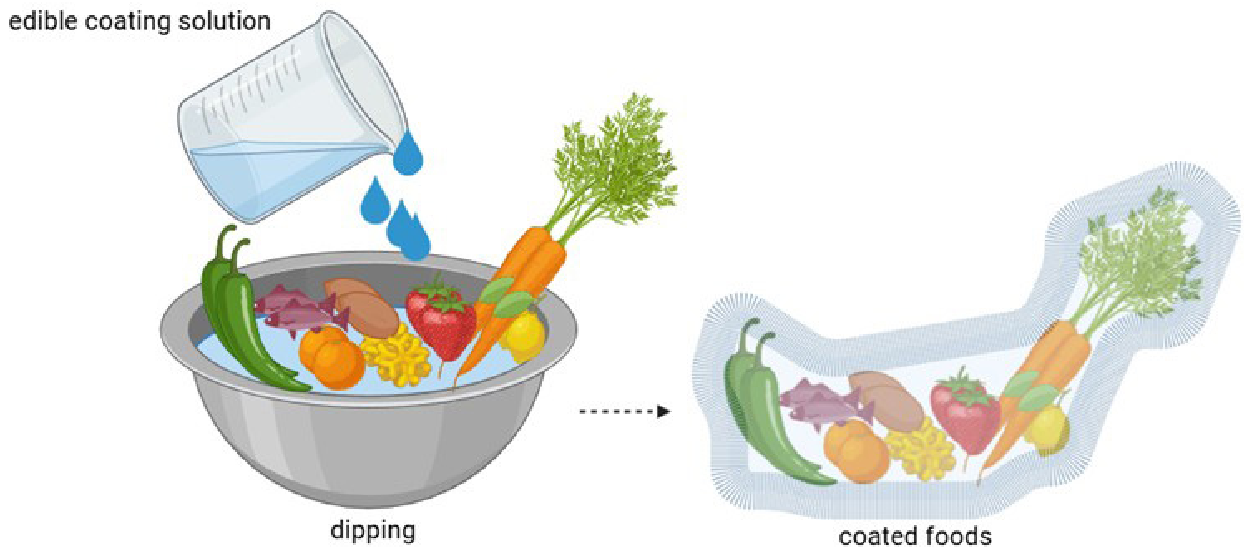

Figure 1. Products dipped in edible coating solution

taining *B. subtilis* significantly reduced mould growth and maintained high bacterial viability. Additionally, the coatings reduced weight loss in strawberries, and the strawberries were highly accepted in terms of sensory properties. Therefore, the edible coating containing *B. subtilis* was evaluated as an innovative and effective method for preserving strawberry quality and extending shelf life.[16]

Çoban et al. [17] investigated the effects of edible coating materials used on rainbow trout fillets on shelf life and quality. In the study, chitosan-based coatings were enriched with blueberry and goji berry extracts. The storage temperature was 8°C, and the samples were analysed chemically and organoleptically at three-day intervals. The findings showed that chitosan and plant extracts positively affected the products chemical and sensory properties throughout storage. Especially, it was determined that chitosan coatings enriched with blueberry and goji berry increased the overall liking scores and preserved the freshness of the product. Additionally, a statistically significant effect of storage time was observed across all experimental groups. As a result, it was reported that these natural and enriched coating methods could be effective in extending food quality and shelf life and could yield even more successful results at lower temperatures.[17]

Kılınçeker et al.[18] examined the quality characteristics of deep-fried chicken nuggets. The effects of coatings made using different types of flour (wheat, corn, rye, soy) were evaluated. The oil content of the cooked samples ranged from 8.50% and 9.93%. Samples coated with corn flour absorbed the least amount of oil. No difference in moisture content was found. Other quality parameters, such as coating thickness and cooking yield, were also analysed. The oil content in the soy flour groups was higher than in the other groups. The physical and chemical properties of the flours used in the coating were reported to be among the important factors affecting oil absorption.[18]

Öztürk and Geçer[19] investigated the effects of edible coatings on the physicochemical properties of roasted carrots. The use of coatings such as hydroxypropyl methylcellulose, chitosan, agar agar, and pectin was aimed at preventing issues such as colour loss and texture softening during the roasting process. The study focused on water activity, colour values, and texture properties. The colour analysis results showed that the chitosan coating exhibited the greatest colour difference. Additionally, it was noted that chitosan and pectin coatings provided low H values, while agar agar reduced the browning reaction.[19]

Akın and Berber [20] investigated the effects of applying edible coating films to oranges and lemons. The coating films were prepared using carnauba wax, shellac, and other components, and the fruits were packaged with these coatings. The findings revealed that the coatings exhibited antimicrobial activity against *E. coli* and *S. aureus* bacteria. Edible coatings were reported to play an important role in extending shelf life and preventing food waste by reducing fruit weight loss.[20]

Kahramanoğlu and Usanmaz [21] conducted a study on the effects of an edible coating enriched with flaxseed oil on strawberry peservation. The study involved three applications (control, edible coating, and coating enriched with flaxseed oil) over 15 days, and quality parameters such as fruit weight loss, chemical deterioration, and disease severity were evaluated. The results show that the flaxseed oil increased coating improved fruit quality and extended storage time. The edible coating applications reduced deterioration by preserving strawberry weight and significantly reduced disease severity compared to the control group. While fruits in the control group experienced a 12.40% weight loss, the coating enriched with linseed oil showed a 6.74% loss. These findings demonstrate that edible coatings are an effective method for preserving fruit and maintaining fruit quality.[21]

In a study examining the effects of sodium alginate coating on Yenipazar peppers, the peppers were divided into a control group and groups treated with 1% and 2% sodium alginate and stored at +10°C and 90-95% humidity for 24 days. The analyses revealed a weight loss of 2.40% in the control group, 1.05% in the group treated with 1% sodium alginate, and 1.20% in the group treated with 2% sodium alginate. Additionally, positive changes in total phenol and antioxidant capacity were observed during storage. It was emphasised that edible coatings have the potential to prevent weight loss by controlling the respiration rate and enzymatic activities of fruits and vegetables during storage. Sodium alginate coating was observed to be an effective method for extending shelf life by preserving the quality of peppers.[22]

It has been observed that protecting blackcurrants with edible coatings significantly improves fruit quality and extends storage life. The results of this study show that the types of coating affect the titration acidity, total sugar, and phenolic compound values of the fruit. In this context, coatings have reported to play an effective role in preserving fruit quality and preventing spoilage.[23]

The effects of edible packaging applications on the shelf life and quality characteristics of gooseberries were investigated. In the study, gooseberries of the 60TM60 genotype were coated with Semperfresh™ and Wax, then stored at 0 °C for 3 months. During storage, quality parameters, including weight loss, pH, firmness, and respiration rate were evaluated. The findings indicate that edible packaging is effective in improving fruit quality. The Wax application resulted in the lowest weight loss, while the Semperfresh™ application most effectively reduced respiration rate.[24]

CONCLUSIONS

This study highlights how edible coatings are transforming the way we preserve food. By applying these natural layers to meat, poultry, fish, and produce, we can significantly reduce spoilage, slow down oxidation, and extend shelf life.

The real magic happens when we use materials like polysaccharides, proteins, or lipids especially when they are enriched with natural bioactive ingredients. These coatings act as a protective shield, locking in moisture to prevent weight loss while keeping the food's color and texture exactly as it should be. Beyond just being functional, these coatings are a win for the planet. They offer a sustainable, eco-friendly alternative to plastic, and research in Turkey shows that both plant and animal-based polymers are already being successfully integrated into everyday food products.

Recommendations

To bring this technology to its full potential, we should focus on the following:

We need to dive deeper into how different biopolymers and natural additives work together to create the most effective protective barrier.

Improving how well these coatings stick to food and how they release freshness-preserving components will make them much more efficient.

A "one size fits all" approach doesn't work here. Developing specific coatings tailored to different food categories will help make industrial-scale use a reality.

It is vital to conduct more studies on consumer acceptance. We need to ensure these coatings maintain—or even improve—the sensory experience (taste and feel) of the food.

To see these coatings in every grocery store, we must develop cost-effective production methods and find ways to plug this technology directly into existing factory lines.

Edible films and coatings are more than just a promising research topic; they are a vital tool for the future of sustainable food management. As we continue to refine these technologies, they will undoubtedly play a major role in making the food industry smarter, greener, and more efficient.

In conclusion, edible films and coatings are a promising technology for both sustainable packaging and food quality management, and it is anticipated that advanced research in this field will make significant contributions to the food industry.

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