Volume 03, Issue 07, 2025
ISSN: 2584-153X
Article ID: G-25-0704

EDIBLE COATING APPLICATION IN FRUIT CROPS

Mohamed Jassim J[*], Raja V, Thamizhvanan A and Gurudivya P

Department of Fruit Science, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Periyakulam - 625 604, Tamil Nadu, India

**Corresponding Author Mail ID: jassim.phdfsc2022@tnau.ac.in*

Abstract

Edible coatings have emerged as an innovative and sustainable postharvest technology for preserving the quality and extending the shelf life of fresh fruits. Composed of natural biopolymers such as polysaccharides, proteins, and lipids, these coatings form a thin, invisible, and biodegradable layer on the fruit surface that serves as a semi-permeable barrier to moisture, oxygen, and solute movement. The primary function of edible coatings is to reduce physiological weight loss, delay ripening, minimize microbial contamination, and retain nutritional and sensory attributes during storage and transportation. Recent advances have led to the incorporation of bioactive compounds such as antioxidants, antimicrobials, and essential oils into the coatings, further enhancing their functionality and extending their application in minimally processed and fresh-cut fruit products. Fruits like apples, bananas, mangoes, citrus, guava, papaya, and strawberries have shown positive responses to edible coating treatments, with significant improvements in firmness, color retention, and microbial stability. As consumer demand for chemical-free, safe, and eco-friendly preservation methods increases, edible coatings offer a promising alternative to synthetic preservatives. Furthermore, their compatibility with organic and sustainable farming practices positions them as a key tool in the future of postharvest handling and quality management of fresh fruits.

Introduction

The postharvest management of fruit crops poses a significant challenge due to their high perishability, rapid physiological changes, and susceptibility to microbial spoilage. Conventional preservation methods often involve synthetic waxes, refrigeration, or chemical fumigation, which may raise concerns regarding food safety, environmental impact, and consumer health. In this context, edible coatings have gained substantial attention as an eco-friendly, biodegradable, and functional approach to improve the shelf life and quality of fresh fruits (Krochta & De Mulder-Johnston, 1997).

Edible coatings are thin layers of edible material applied directly to the surface of fruits to act as a protective barrier. These coatings are typically composed of natural polymers such as polysaccharides (e.g., starch, chitosan, alginate), proteins (e.g., whey, soy, casein), and lipids (e.g., waxes, fatty acids), either alone or in combination. Their application helps to reduce transpiration, respiration rates, oxidation, enzymatic browning, and microbial activity, thus maintaining the freshness and nutritional value of fruits during storage (Baldwin *et al*., 2011).

Moreover, edible coatings can be enriched with functional additives such as essential oils, plant extracts, antimicrobials, and antioxidants to provide enhanced protection against spoilage organisms and oxidative stress. Research has demonstrated their effectiveness in a wide range of fruit crops, including mango, banana, guava, citrus, apple, pomegranate, papaya, and berries (Rojas-Graü et al., 2009).

The growing consumer preference for minimally processed and chemical-free produce, along with rising awareness about environmental sustainability, makes edible coatings a valuable innovation in postharvest technology. This article explores the types, mechanisms, applications, and benefits of edible coatings in fruit crops, highlighting their potential to revolutionize postharvest quality management and reduce food losses in the supply chain.

Composition and Types of Edible Coatings

Polysaccharide-Based Coatings

Polysaccharides are among the most commonly used materials in edible coatings due to their excellent film-forming properties, biodegradability, and non-toxic nature. These coatings are primarily hydrophilic and form transparent films that act as barriers to oxygen and carbon dioxide, although their moisture barrier properties are relatively weak. Chitosan, a deacetylated derivative of chitin, is widely studied for its antimicrobial and antioxidant activity. It has been successfully applied to fruits like strawberries, bananas, and papayas to extend shelf life and reduce fungal infections (Elsabee & Abdou, 2008; Romanazzi et al., 2017). Alginate, derived from brown seaweed, forms gels in the presence of calcium ions and has been used effectively in fresh-cut apple and pear slices (Rojas-Graü et al., 2007). Starch-based coatings, while inexpensive and abundant, often require modification with lipids or plasticizers to improve flexibility and water resistance (Jongjareonrak et al., 2006). Cellulose derivatives like hydroxypropyl methylcellulose (HPMC) and carboxymethyl cellulose (CMC) are also used, offering good film-forming ability and compatibility with active compounds.

Protein-Based Coatings

Proteins offer superior mechanical strength and gas barrier properties compared to polysaccharides, although they too are poor moisture barriers. Common proteins used in edible coatings include whey protein, casein, gelatin, and soy protein isolate. Whey protein coatings are particularly effective in reducing oxidative browning and improving sensory characteristics in apple and banana slices (Krochta, 2002). Gelatin-based coatings have shown promising results in maintaining firmness and color in strawberries and cherries by reducing respiration rates and microbial decay (Debeaufort & Voilley, 1995). Soy protein coatings are also employed for their antioxidant potential, particularly when enriched with essential oils or green tea extracts. These coatings are well-suited for climacteric fruits like guava and mango, where they help delay ripening and senescence.

Lipid-Based Coatings

Lipids are naturally hydrophobic and form effective barriers against moisture loss. However, due to their brittleness and opacity, they are often combined with other biopolymers. Beeswax, carnauba wax, fatty acids, and mono- and diglycerides are commonly used lipid-based coating agents. They are especially useful in citrus fruits, apples, and pomegranates to reduce weight loss and enhance glossiness (Baldwin *et al*., 1999). However, their limited gas permeability can lead to anaerobic respiration and off-flavors if not carefully regulated. Lipid-based coatings are often incorporated into multilayer or composite coatings to balance moisture and gas barrier properties.

Composite Coatings

Composite coatings are formed by combining two or more types of biopolymers—usually polysaccharides, proteins, and lipids—to overcome the limitations of individual components. This approach provides a balanced barrier to both moisture and gas, while enhancing mechanical strength and coating flexibility. For instance, a starch-lipid composite coating has been shown to reduce water loss and delay ripening in bananas (Zapata *et al*., 2008). Similarly, chitosan-protein or alginate-lipid combinations have been effective in enhancing microbial stability while maintaining fruit firmness and appearance during storage. Composite coatings offer the flexibility to tailor barrier and functional properties to specific fruit types and storage conditions.

Additives and Bioactive Compounds

To enhance the functionality of edible coatings, various additives such as antioxidants, antimicrobials, essential oils, plant extracts, and nanoparticles are incorporated into the coating matrix. These active coatings not only serve as physical barriers but also actively protect against microbial spoilage and oxidative degradation. Essential oils like thymol, carvacrol, and eugenol possess broad-spectrum antimicrobial properties and have been used successfully in coating strawberries, citrus, and grapes (Perdones *et al*., 2012). Plant extracts such as neem, moringa, and green tea provide natural antioxidant and antimicrobial functions. Moreover, the use of nanomaterials (e.g., nano-chitosan or silver nanoparticles) is being explored for controlled release and enhanced stability of the coating components (Campos *et al*., 2011). These innovations align with the increasing demand for clean-label and eco-friendly postharvest treatments in the fresh produce industry.

Mechanism of Action of Edible Coatings

Edible coatings serve as multifunctional barriers applied to fruit surfaces to improve postharvest life and maintain quality by modifying internal and external physiological and biochemical processes. Their effectiveness is primarily attributed to their ability to regulate gas exchange, reduce water loss, limit oxidative reactions, and inhibit microbial growth. The mechanisms below detail how these benefits are achieved:

3.1 Reduction of Respiration and Transpiration

Fruits are biologically active even after harvest, undergoing respiration, which accelerates ripening and senescence, and transpiration, which causes moisture loss and wilting. Edible coatings reduce both processes by forming a semi-permeable film that limits the diffusion of oxygen and water vapor (Zagory & Kader, 1988). For example, chitosan- and alginate-based coatings applied to mango and banana significantly reduced weight loss and delayed ripening by slowing respiration and water evaporation (Maftoonazad & Ramaswamy, 2005).

Barrier to Gas and Moisture Exchange

The polymeric structure of edible coatings acts as a physical barrier to gas (O_2, CO_2, ethylene) and water vapor exchange between the fruit and environment. This modified internal atmosphere delays senescence and preserves texture and juiciness. For instance, whey protein isolate coatings applied to apple slices reduced both oxygen ingress and moisture loss, helping to preserve texture and flavor (Krochta, 2002). Lipid-based coatings, though poor in gas permeability, are especially effective in limiting moisture loss in high-transpiring fruits like citrus and pomegranate (Baldwin *et al*., 1999).

Antimicrobial and Antioxidant Effects

Certain edible coatings possess natural antimicrobial and antioxidant properties, either inherently (e.g., chitosan) or due to incorporated bioactives such as essential oils, plant extracts, or organic acids. These coatings inhibit spoilage microorganisms like *Penicillium*, *Botrytis*, and *Aspergillus* species. Chitosan coatings, for example, disrupt microbial cell membranes and have been shown to significantly reduce decay in strawberries and papayas (Romanazzi *et al*., 2017). Similarly, coatings enriched with cinnamon or clove essential oil improved microbial stability and oxidative resistance in apples and grapes (Perdones *et al*., 2012).

Role in Enzymatic Browning and Color Retention

Enzymatic browning, particularly in cut or bruised fruits like apples, bananas, and guava, is catalyzed by polyphenol oxidase (PPO) in the presence of oxygen. Edible coatings slow this reaction by reducing oxygen availability at the fruit surface, thereby inhibiting PPO activity. For example, alginate and gelatin coatings reduced browning and maintained the color of fresh-cut apple and guava slices during storage (Rojas-Graü *et al*., 2007). Additionally, coatings enriched with ascorbic acid or green tea extract scavenge free radicals, enhancing color retention and delaying oxidation.

Reference:

1. Baldwin, E. A., Nisperos-Carriedo, M. O., & Baker, R. A. (1995). Edible coatings for lightly processed fruits and vegetables. HortScience, 30(1), 35–38. https://doi.org/10.21273/HORTSCI.30.1.35
2. Baldwin, E. A., Nisperos-Carriedo, M. O., & Baker, R. A. (1999). Use of edible coatings to preserve quality of lightly (and slightly) processed products. Critical Reviews in Food Science and Nutrition, 39(1), 55–67.

3. Bautista-Baños, S., Hernández-López, M., Bosquez-Molina, E., & Wilson, C. L. (2003). Effects of chitosan and plant extracts on growth of *Colletotrichum gloeosporioides*, anthracnose levels and quality of papaya fruit. Crop Protection, 22(9), 1087–1092. https://doi.org/10.1016/S0261-2194(03)00113-0
4. Campos, C. A., Gerschenson, L. N., & Flores, S. K. (2011). Development of edible films and coatings with antimicrobial activity. Food and Bioprocess Technology, 4, 849–875.
5. Debeaufort, F., & Voilley, A. (1995). Effect of surfactants and drying rate on barrier properties of emulsified edible films. International Journal of Food Science & Technology, 30, 183–190.
6. Elsabee, M. Z., & Abdou, E. S. (2008). Chitosan-based edible films and coatings: A review. Materials Science and Engineering: C, 28, 199–206.
7. Hasheminejad, N., Khorram, M., & Gholami, M. (2019). Antimicrobial and physical properties of chitosan-based films incorporated with essential oils: A review. Progress in Organic Coatings, 134, 349–365. https://doi.org/10.1016/j.porgcoat.2019.05.037
8. Jin, T., Zhang, H., Bi, J., & Chen, X. (2014). Effects of essential oil film coatings on quality and shelf life of fresh strawberries (Fragaria × ananassa). International Journal of Food Science & Technology, 49(5), 1232–1240. https://doi.org/10.1111/ijfs.12316
9. Jongjareonrak, A., Benjakul, S., Visessanguan, W., & Tanaka, M. (2006). Effect of plasticizers on the properties of edible films from skin gelatin of bigeye snapper and brownstripe red snapper. European Food Research and Technology, 222, 229–235.
10. Jongsri, P., Wangsomboondee, T., Rojsitthisak, P., & Seraypheap, K. (2016). Effect of chitosan coating and storage temperatures on quality and shelf life of mango fruit. International Journal of Food Science, 2016, Article ID 9701531. https://doi.org/10.1155/2016/9701531
11. Krochta, J. M. (2002). Proteins as raw materials for films and coatings: Definitions, current status, and opportunities. In J. H. Han (Ed.), Innovations in Food Packaging (pp. 103–120).
12. Kumar, D., Sethi, S., & Sharma, R. R. (2017). Edible coatings for enhancing shelf life of fruits. In Eco-friendly agro-biological techniques for enhancing crop productivity (pp. 277–298). Springer. https://doi.org/10.1007/978-81-322-2787-9_14
13. Maftoonazad, N., & Ramaswamy, H. S. (2005). Postharvest shelf-life extension of avocados using methyl cellulose-based coating. LWT - Food Science and Technology, 38(6), 617–624. https://doi.org/10.1016/j.lwt.2004.08.006
14. Nair, A. A., & Singh, Z. (2020). Postharvest application of chitosan and essential oils for enhancing shelf life and quality of pomegranate fruit. Scientia Horticulturae, 261, 109013. https://doi.org/10.1016/j.scienta.2019.109013
15. Olivas, G. I., & Barbosa-Cánovas, G. V. (2005). Edible coatings for fresh-cut fruits. Critical Reviews in Food Science and Nutrition, 45(7–8), 657–670. https://doi.org/10.1080/10408690490911837
16. Perdones, Á., Vargas, M., Atarés, L., & Chiralt, A. (2012). Physical, antioxidant and antimicrobial properties of chitosan–cinnamon leaf oil films as affected by oleic acid. Food Hydrocolloids, 29(2), 372–381. https://doi.org/10.1016/j.foodhyd.2012.03.005

17. Rhim, J. W., Park, H. M., & Ha, C. S. (2020). Bio-nanocomposites for food packaging applications. Progress in Polymer Science, 38(10–11), 1629–1652. https://doi.org/10.1016/j.progpolymsci.2013.05.008
18. Romanazzi, G., Feliziani, E., Baños, S. B., & Sivakumar, D. (2017). Shelf life extension of fresh fruit and vegetables by chitosan treatment. Critical Reviews in Food Science and Nutrition, 57(3), 579–601. https://doi.org/10.1080/10408398.2014.900474
19. Sathivel, S., Beuchat, L. R., & Liu, S. Q. (2005). Evaluation of cassava starch–based edible coatings for extending shelf life of fresh-cut banana. Journal of Food Science, 70(7), E400–E406. https://doi.org/10.1111/j.1365-2621.2005.tb11453.x
20. Sharma, R. R., Singh, D., & Singh, R. (2019). Biological control and postharvest technology. In Postharvest Disinfection of Fruits and Vegetables (pp. 191–212). Academic Press. https://doi.org/10.1016/B978-0-12-812698-1.00008-5
21. Siracusa, V., Rocculi, P., Romani, S., & Rosa, M. D. (2015). Biodegradable polymers for food packaging: A review. Trends in Food Science & Technology, 19(12), 634–643. https://doi.org/10.1016/j.tifs.2008.07.003
22. Valencia-Chamorro, S. A., Palou, L., del Río, M. A., & Pérez-Gago, M. B. (2011). Antimicrobial edible films and coatings for fresh and minimally processed fruits and vegetables: A review. Critical Reviews in Food Science and Nutrition, 51(9), 872–900. https://doi.org/10.1080/10408398.2010.485680
23. Zagory, D., & Kader, A. A. (1988). Modified atmosphere packaging of fresh produce. Food Technology, 42(9), 70–77.

Zapata, P. J., Guillén, F., Martínez-Romero, D., Castillo, S., Valero, D., & Serrano, M. (2008). Use of alginate coating and ethanol vapor treatment to maintain fruit quality in mandarins cv. Orri. Postharvest Biology and Technology, 49, 96–102