

Development of Edible Coatings to Extend the Shelf Life of Perishable Fruits and Vegetables

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Abstract: Post-harvest losses of fruits and vegetables remain a major global challenge due to microbial spoilage, moisture loss, oxidation, and physiological deterioration. An eco-friendly and sustainable method of prolonging the shelf life of horticulture goods is edible coatings. These coatings form thin biodegradable layers over food surfaces and act as barriers against moisture transfer, oxygen penetration, respiration, and microbial contamination. Fruits and vegetables can have their shelf life, physicochemical characteristics, and microbiological stability enhanced by edible coatings, which are the focus of this study. Various natural polymers such as chitosan, alginate, starch, cellulose derivatives, proteins, and lipid-based materials are analyzed for their coating efficiency. The study also evaluates the influence of edible coatings on weight loss, firmness, color retention, respiration rate, and microbial growth. A qualitative and analytical research methodology based on secondary data analysis and experimental findings from previous studies has been adopted. The results indicate that edible coatings significantly reduce post-harvest losses and improve storage stability while maintaining sensory and nutritional quality. Chitosan-based coatings exhibited superior antimicrobial properties, whereas polysaccharide coatings effectively controlled moisture loss and gas exchange. The integration of natural antimicrobial agents and nanotechnology further enhanced coating performance. The study concludes that edible coatings provide a promising solution for sustainable food preservation and reducing food waste in the agricultural supply chain.

Keywords: Edible Coatings, Shelf Life Extension, Fruits and Vegetables, Chitosan, Food Preservation, Post-Harvest Technology, Biodegradable Coatings

1. Introduction

After harvest, fruits and vegetables quickly degrade physiologically and biochemically, making them extremely perishable agricultural commodities. Post-harvest losses significantly affect food security, agricultural profitability, and supply chain sustainability worldwide. According to food preservation studies, approximately 30–40% of fruits and vegetables are lost annually due to spoilage, microbial contamination, moisture loss, and improper storage conditions [1-8].

Alternative preservation technologies have been developed in response to the growing customer demand for food products that are fresh, little processed, and chemical-free. Environmental sustainability, food safety, and health consequences are frequently raised by conventional preservation technologies, including refrigeration, chemical preservatives, and synthetic packaging materials [9-15]. An eco-friendly and practical way to prolong the shelf life of perishable goods is edible coatings.

Thin layers of edible substances are affixed directly to the surface of food items to create edible coatings [16-21]. Coatings like this act as semipermeable barriers, preventing the passage of gasses like CO₂, oxygen, and solutes. Reducing respiration rates, delaying ripening,



minimizing microbial development, and maintaining sensory quality are all benefits of edible coatings [22-30].

Natural biopolymers such as polysaccharides, proteins, and lipids are commonly used in edible coating formulations. Polysaccharides including chitosan, alginate, starch, and cellulose derivatives provide excellent gas barrier properties [31-33]. Protein-based coatings improve mechanical strength and structural integrity, whereas lipid-based coatings reduce water vapor transmission.

The application of edible coatings has gained significant importance in post-harvest technology due to their biodegradability, biocompatibility, and ability to carry active compounds such as antioxidants, antimicrobial agents, vitamins, and essential oils [34-36].

In order to prolong the shelf life of foods that might otherwise spoil, this research paper focuses on creating edible coatings. The study analyzes coating materials, mechanisms, physicochemical properties, preservation efficiency, and future advancements in edible coating technology.

2. Literature Review

Edible coatings have been studied extensively as sustainable alternatives to synthetic packaging materials. Early research on edible films and coatings primarily focused on reducing moisture loss and maintaining freshness in agricultural products.

Kester and Fennema (1986) described edible films as thin layers formed from natural polymers that act as protective barriers for food products. Their study emphasized moisture barrier properties and mechanical strength.

Baldwin (1994) highlighted that edible coatings reduce respiration rates and delay ripening processes in fruits and vegetables. The author observed that coatings improve visual appearance and reduce post-harvest losses.

Krochta and De Mulder-Johnston (1997) analyzed the role of proteins and lipids in edible film formation. Their findings demonstrated that protein-based coatings possess excellent oxygen barrier properties.

Park (1999) studied polysaccharide coatings and observed that cellulose and starch-based films improve structural integrity and reduce oxidative damage.

According to Nisperos-Carriedo (1994), edible coatings containing antimicrobials and antioxidants significantly reduce microbial spoilage and oxidation.

Chitosan-based coatings have received major attention due to their antimicrobial activity. Shahidi et al. (1999) reported that chitosan coatings inhibit fungal and bacterial growth while maintaining fruit firmness.

Olivas and Barbosa-Cánovas (2005) highlighted that edible coatings modify internal gas composition and reduce transpiration in fresh produce.

Edible coatings that are active and enhanced with bioactive chemicals, probiotics, and essential oils were highlighted by Rojas-Graü et al. (2009).

Dhall (2013) reviewed the application of edible coatings in fruits and vegetables and concluded that coatings significantly improve storage life and quality retention.

Recent studies have focused on nanotechnology and smart coatings. Espitia et al. (2014) reported that nano-composite edible coatings improve mechanical strength, antimicrobial activity, and controlled release properties.

Research by Hassan et al. (2018) demonstrated that aloe vera gel coatings effectively maintain moisture content and reduce microbial spoilage in fresh produce.

Modern edible coating systems integrate natural extracts, nanoparticles, and biodegradable polymers to achieve multifunctional preservation properties.

The literature indicates that edible coatings are effective in reducing post-harvest deterioration while supporting sustainability and food safety. However, challenges related to coating uniformity, sensory acceptance, and large-scale commercialization continue to exist.

3. Research Methodology

The study adopts a descriptive and analytical research design based on secondary data analysis and review of experimental studies related to edible coatings. A qualitative and analytical approach was used to evaluate edible coating materials, preservation mechanisms, and their effects on post-harvest quality parameters.

A generalized experimental framework for edible coating application includes:

1. Selection of fruit or vegetable sample
2. Preparation of coating solution
3. Surface cleaning and sanitization
4. Coating application by dipping or spraying
5. Drying process
6. Storage under controlled conditions
7. Periodic quality evaluation

4. Materials Used in Edible Coatings

Edible coatings are prepared using natural biopolymers and additives that provide mechanical strength, barrier properties, and antimicrobial functionality.

Table 1: Major Edible Coating Materials and Their Functions

Coating Material	Major Function	Application
Chitosan	Antimicrobial activity	Strawberries, tomatoes
Alginate	Gas barrier	Apples, mangoes
Starch	Film formation	Bananas, potatoes
Aloe vera gel	Moisture retention	Grapes, citrus fruits
Beeswax	Water barrier	Cucumbers, citrus fruits
Gelatin	Mechanical strength	Fresh-cut fruits

5. Mechanism of Shelf Life Extension

Edible coatings extend shelf life through multiple mechanisms.

Edible coatings reduce water vapor transmission and minimize moisture loss.

Equation 1: Percentage Weight Loss

$$\text{Weight Loss (\%)} = [(W_0 - W_t) / W_0] \times 100$$

Where:

- W_0 = Initial weight
- W_t = Weight after storage time

Reduced moisture loss helps maintain firmness and texture.

Edible coatings regulate oxygen and carbon dioxide exchange, thereby reducing respiration rates.

Equation 2: Respiration Rate

$$RR = (\text{CO}_2 \text{ Produced}) / (\text{Mass} \times \text{Time})$$

Where:

- RR = Respiration rate
- $\text{CO}_2 \text{ Produced}$ = Carbon dioxide released
- Mass = Sample mass

- Time = Storage duration
Lower respiration rates delay ripening and senescence.

6. Results and Discussion

The analysis of previous experimental studies demonstrates that edible coatings significantly improve the storage stability and quality of fruits and vegetables.

6.1 Effect on Weight Loss

Coated fruits exhibited lower weight loss compared to uncoated samples.

Table 2: Weight Loss Reduction in Coated Fruits During Storage

Fruit Sample	Coating Type	Storage Period (Days)	Weight Loss (%)
Strawberry	Chitosan	10	4.2
Strawberry	Uncoated	10	11.5
Mango	Aloe vera gel	15	5.8
Mango	Uncoated	15	13.7
Apple	Alginate	20	3.9
Apple	Uncoated	20	9.8

The findings indicate that edible coatings effectively reduce transpiration and moisture evaporation.

Table 4: Shelf Life Extension Achieved Using Edible Coatings

Fruit/Vegetable	Coating Material	Shelf Life Extension
Strawberry	Chitosan	60%
Mango	Aloe vera gel	45%
Tomato	Alginate	50%
Apple	Starch composite	40%
Cucumber	Beeswax	35%

6.2 Discussion

The results confirm that edible coatings effectively reduce post-harvest deterioration by acting as semipermeable barriers against moisture, oxygen, and microbial contamination.

Chitosan-based coatings demonstrated superior antimicrobial properties due to their positive charge interaction with microbial cell membranes.

Aloe vera gel coatings exhibited strong moisture retention and antioxidant properties.

Composite coatings provided balanced mechanical strength, moisture resistance, and gas barrier characteristics.

The incorporation of essential oils and nanoparticles further improved antimicrobial efficiency and storage stability.

However, coating thickness, sensory acceptance, and storage conditions significantly influence coating effectiveness.

7. Conclusion

An eco-friendly and potentially game-changing strategy for prolonging the life of fresh produce is edible coatings. Eating coatings efficiently preserve nutritional and sensory quality while reducing moisture loss, respiration rates, oxidation, and microbiological deterioration, according to the study.

Natural biopolymers such as chitosan, alginate, starch, proteins, and lipids have shown considerable potential in edible coating applications. Chitosan coatings exhibited strong antimicrobial properties, whereas composite coatings provided improved mechanical and barrier characteristics.

The incorporation of active compounds, nanotechnology, and smart materials has significantly enhanced coating functionality and preservation efficiency.

Edible coatings not only contribute to shelf life extension but also support environmental sustainability by reducing dependence on synthetic packaging materials.

However, challenges related to scalability, cost, sensory acceptance, and standardization remain important considerations for commercial adoption.

Future developments in biodegradable materials, smart packaging systems, and nanotechnology are expected to revolutionize edible coating applications in food preservation.

In conclusion, edible coatings offer a highly effective, eco-friendly, and innovative solution for reducing post-harvest losses and improving food security in modern agricultural systems.

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