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Novel Edible Coatings to Reduce Fruit and Vegetable Post-Harvest Losses

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Introduction:

Fruit and vegetable post-harvest losses are a major worldwide problem, but they are made worse in developing nations by poor infrastructure and subpar handling techniques. Food security, environmental sustainability, and agricultural productivity are all impacted by the loss or waste of about 45% of annual production before it is consumed. Post-harvest deterioration is caused by the microbial and physiological deterioration of produce during marketing, storage, and transportation. By extending shelf life, maintaining quality, and reducing post-harvest losses, innovative edible coatings have emerged as a practical and environmentally friendly way to deal with this problem. In addition to acting as semi-permeable barriers against moisture, gases, and microbial contamination, thin, edible coatings can be directly applied to fruits and vegetables to preserve their texture, flavour, and nutritional value. Novel composite coatings that combine bioactive compounds, essential oils, antioxidants, and nanomaterials to enhance the functional properties of coatings have been created by recent advances in materials science and food technology. These coatings enhance preservation and provide antimicrobial and antioxidant properties while focussing on common post-harvest pathogens and oxidative spoiling. In keeping with green and sustainable technologies, the use of edible coatings reduces reliance on artificial packaging and preservatives. Current studies concentrate on improving application techniques, maximising formulation parameters, and evaluating how coating ingredients interact with different kinds of produce.

Edible Coating Types

1. **Polysaccharide-based coatings:** Polysaccharide-based edible coatings are extensively employed owing to their great film-forming ability and good oxygen barrier qualities, although having only moderate water resistance. Chitosan, alginate, starch (from maize, potato or cassava), pectin, and cellulose derivatives are examples of often used components.

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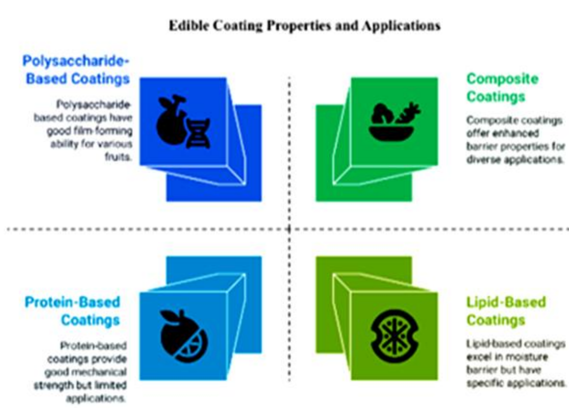
These coatings work especially well on fruits like apples and strawberries, as well as vegetables like tomatoes and bell peppers. For example, chitosan coatings have been demonstrated to increase the shelf life of strawberries from 3-4 days to 10-12 days by decreasing microbial deterioration and delaying moisture loss.

2. **Protein-Based Coatings:** Protein-based coatings, which are manufactured from whey protein, soy protein, gelatin, casein, and egg white protein, are noted for their high mechanical strength, heat sealing ability, and exceptional water vapour barrier qualities. They are widely used to keep fresh-cut fruits, green vegetables, and even cheese surfaces from oxidising. A famous example is the application of whey protein coatings to fresh-cut apples, which may successfully prevent enzymatic browning while retaining look and texture for up to two weeks.
3. **Lipid-Based Coatings:** Lipid-based coatings employ hydrophobic components such as natural waxes (e.g., carnauba, candelilla), fatty acids, and essential oils to provide good moisture barrier performance, antibacterial properties, and an appealing glossy finish. These coatings are particularly effective on moisture-sensitive produce including citrus fruits, apples, and tropical fruits. Carnauba wax coats, for example, may minimise weight loss in citrus fruits by up to 60%, therefore preserving firmness and market value throughout long-term storage and transportation.
4. **Composite Coatings:** Composite coatings combine two or more components, generally polysaccharides, proteins, and lipids, to improve overall functioning and adjust barrier qualities to suit post-harvest requirements. Depending on the product, these formulations may be tailored to increase moisture resistance, mechanical strength, or antibacterial activity. One example is the application of chitosan-alginate composite coatings loaded with essential oils, which have increased antibacterial properties and are applied to a variety of fruits and vegetables to prevent rotting and extend shelf life.



Application Methods

- **Dipping**: Immersing produce in coating solution (most common for small-scale)

- **Spraying**: Using spray guns or atomizers for large-scale operations
- **Brushing**: Manual application for delicate or irregularly shaped produce
- **Foam application**: For fresh-cut products requiring gentle handling

Advantages and Limitations

Advantages

- **Cost-effective:** Cheap raw materials and an easy way to use
- **Good for the environment:** Breaks down naturally, compostable, and cuts down on plastic packaging
- **Safe for food**: Made from things that are safe to eat, don't leave behind harmful chemicals, and are GRAS (Generally Recognised as Safe)
- **Adaptable:** Works for a wide range of crops and can be made to fit your needs
- **Easy to use:** Needs little equipment and is good for small businesses
- **Nutritional boost:** Can add vitamins, antioxidants, and probiotics
- **Longer shelf life:** 50–200% longer, depending on the type of coating and the produce
- **Maintained quality**: Keeps texture, colour, flavour, and nutritional value
- **Less use of chemicals:** A natural alternative to synthetic preservatives
- **Good for the environment:** Biodegradable, compostable, and less plastic packaging

Limitations:

Novel edible coatings have several limitations despite their benefits. In humid environments, they often lack water resistance and need to be applied expertly for consistent coverage. Protein-based coatings may cause allergies, and some may subtly change appearance, texture, or flavour. Coating solutions have a short shelf life, coated product still needs appropriate storage, and their efficacy is contingent upon precise timing and stringent quality control.

How Edible Coatings Reduce Post-Harvest Losses

1. **Moisture Regulation:** Edible layers form a semi-permeable shield that controls water vapor transfer, stopping excessive moisture loss while avoiding anaerobic conditions. This keeps product turgor pressure, stopping shrinking and weight loss that make fruits and veggies unmarketable.
2. **Gas Exchange Control:** Coatings change the internal climate around produce by controlling oxygen and carbon dioxide levels. This controlled environment lowers respiration rates,
delays ripening in climacteric fruits, and

extends shelf life greatly. For example, covered bananas ripen 7-10 days slower than bare ones.

3. **Antimicrobial Protection:** Natural antibacterial chemicals added into coats (essential oils, organic acids, plant extracts) provide protection against bacterial and fungal pathogens that cause decay. Chitosan-based coats show particular success against common post-harvest pathogens like Botrytis and Alternaria.
4. **Physical Barrier:** Coatings provide mechanical defence against small physical damage during handling and transportation. This stops the creation of entry spots for germs and lowers bleeding that leads to fast decline.
5. **Enzymatic Browning Prevention:** For fresh-cut fruit, coats containing antioxidants (ascorbic acid, citric acid) prevent chemical browning processes that make cut surfaces unappealing to consumers, lowering waste at store and consumer levels.
6. **Ethylene Management:** Some coats can contain ethylene scavengers or inhibitors that slow down the natural maturing process in ethylene-sensitive produce, allowing for longer storage and transportation times.

Success Factors

- Proper timing (apply immediately after harvest)
- Clean, dry produce surfaces
- Appropriate coating concentration (1-3% typically)
- Controlled drying conditions
- Quality storage environment
- Regular monitoring and quality control

Future Trends

In order to decrease post-harvest losses, edible coatings are developing to improve sustainability, functionality, and technological integration. Real-time preservation is made possible by smart coatings that react to environmental cues using nanotechnology. In line with the ideas of the circular economy, waste-to-coating innovations are turning food waste and agricultural byproducts into biodegradable coating materials. Bioactive compounds enhance the nutritional value of functional coatings. The accuracy and efficacy of applications are increased through digital integration using sensor-based systems. These developments are supported by sustainability programs and governmental policies.

Conclusion

Edible coatings are a new technique that can reduce fruit and vegetable losses. These food-safe, biodegradable polymers can increase shelf life by 50–200%, giving farmers and industries of all scale solution. They aid in regulating gas exchange, controlling moisture, forming a physical barrier, and providing defence against pathogens. Edible coatings can be used globally. The benefits exceed the drawbacks, even with obstacles like storage constraints and application skill needs. The technique can be swiftly implemented with little infrastructure requirements, is inexpensive, and is environmentally beneficial. With each coated fruit or vegetable, edible coatings save food, cost, and resources, giving hope for a more sustainable food future. Now that the technology, expertise, and advantages have been documented, the time for execution has come. For the benefit of farmers, consumers, and the environment, there must be a shared commitment to revolutionising food systems through sustainable preservation technology. Purchasing edible coatings can promote a more sustainable agriculture sector, improve food security, and reduce food waste. The collective commitment to transform food systems through sustainable preservation technologies is crucial for farmers, consumers, and the environment.