AGRICULTURE AND ALLIED SCIENCES

RESEARCH, PRACTICE AND POLICY PERSPECTIVES

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Contents

Chapter 14

Edible Coatings for Shelf-Life Extension

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1. Introduction

Presently, people have become more health conscious, so the demand for fresh fruits and vegetables is increasing day by day in the market. Even consumers judge the freshness and quality of fresh fruits and vegetables from their external appearance at the time of purchase (Kadar, 2002).On the other hand, due to the increasing demand for fresh produce, the global production of fresh horticultural produce is also increasing day by day to meet the needs of people. But fresh fruits and vegetables spoil quickly, so their shelf life is short.About 25-30% of fruits and vegetables are spoiled or damaged due to pests, microorganisms, improper handling before and after harvesting, during transportation and preservation. Increasing the shelf-life of fresh horticultural produce is a major challenge for the post-harvest industry.The solution to this problem is edible coatings (Rojas-Grau et al., 2007; Raghav et al., 2016). Nowadays edible coating is the most effective solution to this problem. It helps to enhance the appearance and quality of fresh fruits and vegetables and it is beneficial for the consumer as well as the environment.Keeping this in mind, this chapter highlights the application of edible coatings, their effects and ways to reduce post-harvest losses.

Edible coatings play a vital role in the quality, safety, storage, transportation and performance of a wide range of fresh and processed foods. Edible coatings prevent moisture loss and maintain quality, preventing food spoilage and microbial contamination.Edible coatings are defined as the thin layer of edible material which can be consumed with food and provide a barrier to oxygen, microbes, moisture and solute movement for food. Edible coating provides a semi-permeable barrier and is intended to increase shelf life by reducing moisture and gas exchange, oxidative reactions, respiration and solute movement as well as reducing physical damages of fresh fruits and vegetables (Baldwin et al., 1996).It is non-toxic, biodegradable, biocompatible and microbe-resistant, chitosan is currently attracting considerable attention and its scientific testing at a large scale is in progress to explore its possible applications in different fields (Du *et al*., 2009). Edible coating should be stable, generally recognised as safe (GRAS) under high relative humidity. Edible coatings have good mechanical properties (Pavlath and Orts, 2009).

1.1. Definition

Edible coatings are food materials applied to the surface of fresh fruits and vegetables to reduce gaseous exchange, reduce weight and improve food quality and shelf life. Generally, the thickness of an edible coating is less than 0.3 mm (Tharantharn, 2003). In other words, edible coating is generally taken to mean that the added edible substance forms an outer coating on the coated object (Duan et al., 2007; Raghav et al., 2016).

"Edible coating is defined as a thin layer of edible material that is applied to the surface of food and reduces gaseous exchange, protects against external damage, microbes and reduces moisture loss of food. It can be eaten with or without food and is also environment friendly, non-toxic in nature."

Shelf life

Shelf life is defined as the time duration, where a food product is not only safe to eat, but still has acceptable appearance, taste and texture after being removed from its natural environment.

1.2. History

Edible coatings and films are used from ancient time to preserve and increase the shelf-life fresh foods. According to Hardenburg (1967), the first edible coating is used in 12th Century by China to preserve and extend the shelf life of fresh citrus fruits. The wax was used for coatingpreparation and thenEngland using animal fat (lard), called larding to extendingthe shelf life of various meat products (Contrereas-Medellin and Labuza, 1981). Edible coatings have been used to reducemoisture loss and add a glossy appearance to fruits and vegetables and as some sort of sugar coatings on confectionary products, including chocolates (Baldwin, 1994; Biquet and Labuza, 1988).Recently, various edible coatings were applied successfully for preserving fruits and vegetables such as orange, apples, grapefruit, cherries, papaya, cucumber, strawberry, tomato and capsicum were applied successfully(Salleh, 2013).

1.3. Herbal Edible Coatings

Herbal edible coatings are generally prepared by incorporating the herbal extracts in edible coatings to improve and enhance the nutritional quality of edible coatings. Among these edible coatings shows to increase the shelf life of mangoes, nectarines, strawberries, apples, cherries, papayas, plums, peaches, tomatoes, cucumbers, pears, cantaloupes and table grapes. These coatingsare environment friendly and transparent in nature. Extracts were used in edible coatings include ginger, garlic, tulsi, mint, marigold, neem, aloe vera, lemon grass, turmeric and rosemary have excellent antimicrobial properties ((Raghav *et al*., 2016; Chauhan *et al*., 2014). These herbal extracts contain antioxidants, antimicrobial, essential minerals and vitamins. Plant based natural gums and their derivatives as edible coatings which are nontoxic, easily available, biodegradable and economical (Saha, 2017).

1.4. Types of Edible Coatings Material

Edible coatings are prepared from different type of edible material. Edible coating or edible films provide shiny appearance to fruits and vegetables. Generally, edible coatings can be classified into five main groups; Polysaccharides-based edible coatings, Proteins-based coatings, Lipids-based coatings, Composites coatings and Agro Industrial waste-based coatings. Functionalcompounds such as antioxidants, antimicrobials, nutrients, vitamins, anti-browning agents, enzymes and probiotics are also used in edible coatings to improve the quality of coatings (Pascall and Lin, 2013).

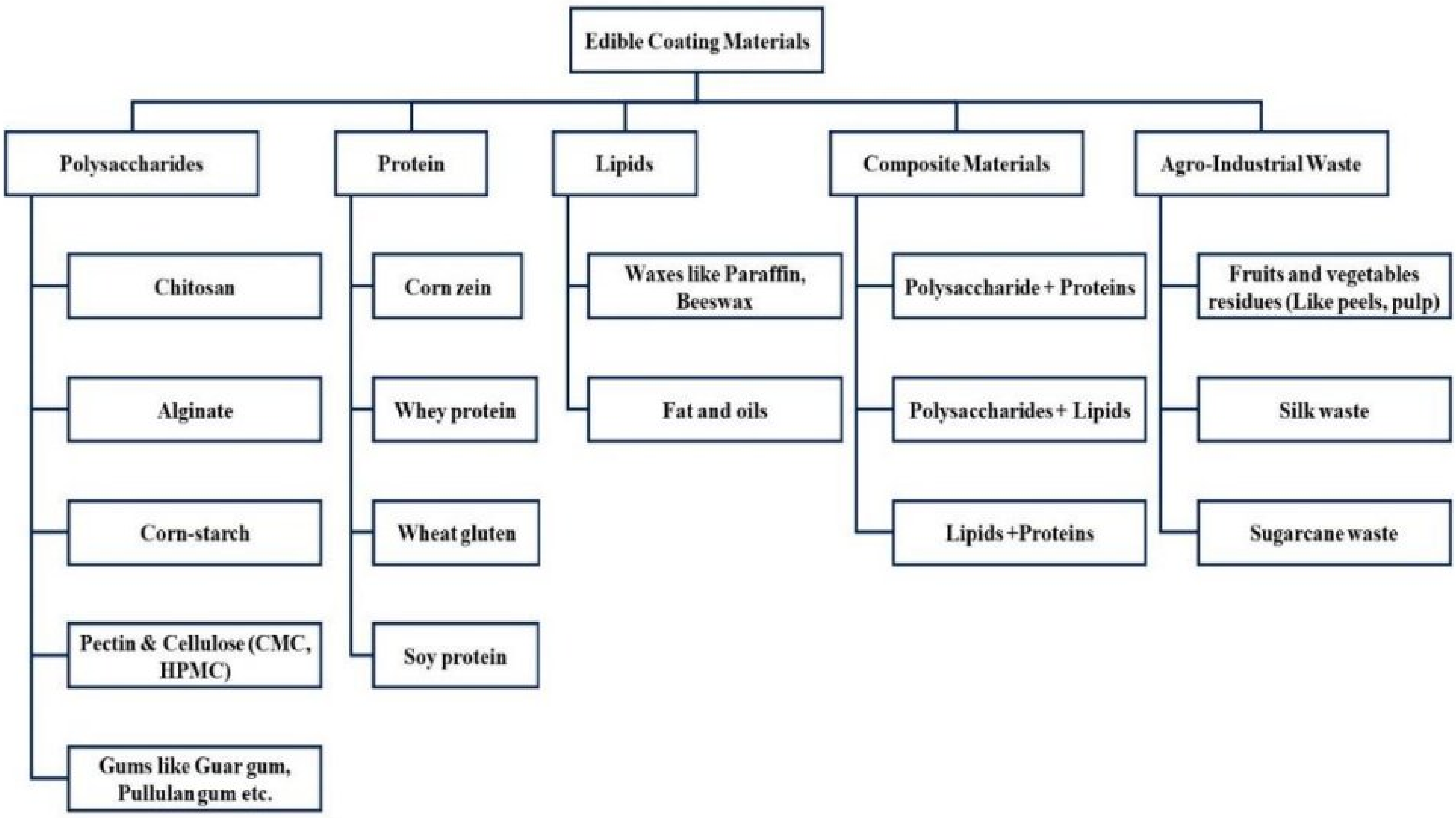

Figure 1: Types of Edible Coatings Material.

1.4.1. Polysaccharides based edible coatings

Polysaccharides are natural polymers widely used to prepare edible coating.Most common polysaccharides material used in preparation of edible coatings are pectin, carboxy-methyl cellulose, cellulose, guar gum, carrageenan, starch, chitosan, alginates and pullulan. Polysaccharides are the main component of edible coatings that are considered to be an effective barrier of gases. Whereas, the polysaccharides have poor barrier against moisture due to its hydrophilic nature. They are usually used to extend the shelf life of fruits and vegetables.Some research studies have been carried out to starch based edible coatings are tasteless, odourless and colourless. They have a rough or oil-free appearance. They can decrease the respiration rate of the fresh fruits and vegetables. Chitosan is formed by deacetylation of natural *chitin that can be used in edible coating (Khatri et al., 2020). The main source of chitin is crustacean animal.*

*Alginate*is commonly used in edible coatings derived from some species of brown algae and it composed of sodium salt of alginic acid. Alginate is an unbranched, indigestible natural polysaccharides and it is used as thickening agent in the food industry (Carvalho *et al.*, 2020).Pullulan is a polysaccharide which is generally used as thickening agent that may form effective coating. The use of pullulan edible coatings in combination with chito-oligosaccharide and glutathione which have excellent antibacterial properties and also a powerful reducing agent.These properties make it effective coating in extending the shelf life of various fruits and vegetables.The cellulose has lower water solubility properties. However, various chemically modified forms of cellulose like CMC (carboxy-methyl cellulose), hydroxypropyl cellulose, hydroxypropyl methyl cellulose (HPMC) and methylcellulose are most suitable for film and edible coating applications. Pectin is main compound of plant cell walls found in middle lamella of plant cells. They are complex heteropolymers consist D-galacturonic acid units that may present different composition, structure and molecular weight (Lara-Espinoza *et al.*, 2018).

1.4.2. Protein based edible coatings

Different types of globular proteins such as whey protein, wheat gluten, corn zein and soy protein are involved in edible coatings. Protein-based coatings which include whey protein, casein, gluten and soy protein serve as good oxygen barriers and thus help extend the shelf life of the food products from any deteriorative reactions. Proteins are reported to impart good mechanical properties and gas barrier properties.Edible coating made from corn zein shows very good film properties. They are good moisture barrier because of its hydrophobic in nature.Gelatin coatings usually show good transparency, mechanical and barrier properties.

1.4.3. Lipid based edible coatings

Lipids are very good materials to be used for making in edible coating to prevent the moisture loss and improve the appearance of food. It is naturally hydrophobic in nature. Mostly, beeswax, paraffin wax, essential oils and oils are used in edible coatings.

1.4.4. Composite Edible Coatings

The composite edible coatings made up of combination of polysaccharides, proteins and lipid material to make improves the quality of edible coating. The composite edible coating helps the improves the quality of edible coating as well as its nutritional properties with excellent moisture barrier, gas barrier and have long shelf life as compared to other polysaccharides, protein and lipids based edible coatings.

1.4.5. Agro-processing waste-based coatings

Agro-processing industry have many beneficial materials which have great nutritional value. The agro waste such as potato, citrus fruit, pomegranate peel and pulp, fibre and bagasse are had good excellent, antioxidant and thickening properties.

1.5. Application Methods of Edible Coating

Edible coatings are applied on fresh fruits and vegetables by various methods, these are following-

1.5.1. Dipping Method

Dipping is a most common method for application of edible coatings on the surface of fresh fruits and vegetables. In this method highly viscous coating solution are used for application. This method has three steps for application i.e. immersion, deposition and evaporation. Fresh fruits and vegetables are immersed in prepared solution for some time than drained the excess coating from food surface at ambient temperature. The applied coating is rest at room temperature for evaporation. Dipping method is easy to use but excess coating material are used and waste during the coating application. However, dipping method have numerous disadvantages. This method generally results in a thick layer with heavy thickness leading to substantially decreased fruit respiration, damaged food surfaces and degraded function. Additionally, Edible coating solution may be contaminated by dirt and microorganisms from the fruit and vegetables surface, therefore challenging the industrial up-scaling. Another drawback of this method is needed large quantity for application of the dipping approach is the large quantity (Mann *et al*., 2021).

1.5.2. Spraying

Spraying method is more appropriate method and it is less viscous coating solution than dipping. Coating solution can be sprayed on the surface of fresh fruits and vegetables at high pressure. Formation of polymeric coating using spraying method is influenced by drying time and temperature. The advantage of applying the spraying technique is, the surface area of the coating solution increased by the formation of droplets and distribution over the fruit and vegetables surface.

1.5.3. Foaming Or Brushing

Foaming and dripping method are used as traditional coating application methods. Nowadays popularity of this coating application method is reduced. In this method coating is applied on the surface of fresh produces by brushes. However, with the foam application, a foaming agent is added to the coating. Then, compressed air is blown into the air of applicator tank. Extensive tumbling action is applied to break the foam for uniform distribution.

1.5.4. Vacuum Impregnation Technique

This technique is advanced technique of the dipping method. A vacuum environment is created in this technique during fruit dipping. That is, instead of dipping the food material in a normal dipping container the fresh food is submerged in an airtight vacuum application. The food material is subjected to atmospheric restoration while it remains immersed in the coating solution under atmospheric pressure.

1.5.5. Layer by layer method

In this method is based on alternate deposition of opposite charged electrolytes. This method makes several layers of the coating on the food surfaces which works more effectively than other application method.

1.6. Effect of Edible coatings on fresh fruits and vegetables

1.6.1. *Effect on appearance*

Appearance is an important attribute of fresh fruits and vegetables. Improper pre and post- harvest practices is one of the major reasons to destroy of natural waxy layerand bruising injury. The edible coating acts as aphysical barrier on fruit surface.Whey protein concentrate showed high rate of glossiness, color, taste and minimum weight loss (Javanmard, 2011).

1.6.2. Effect on Texture

Edible shows a direct effect on the texture of fresh produces by reducing the loss of moisture, decreases the activity of cell wall degrading enzymes and delay the ripening process. Some studies are showed that the incorporation of calcium in the edible coating effectively increase fruit firmness (Zhang *et al*., 2018). Several research studies were also found that the edible coatings effectively reduce the weight loss of fresh fruits and vegetables and helps to maintain the firmness and appearance.

1.6.3. Effect on Ethylene production and respiration rate

The edible coating limits the entry of oxygen inside the fresh produces which prevent the ethylene production and reduce the respiration rate. Hence, the fruits remain firm, fresh and nutritious for a longer period and their shelf life almost doubles (Nasrin, 2020).

1.6.4. Effect on Physiochemical properties

Several research studies found that the edible coatings have a direct and indirect part in altering the biochemical components, which are responsible for enhance their taste and shelf life of the fresh horticulture produces. Physiochemical properties include viz. weight loss, total soluble soilds, titratable acidity, total phenolic content, firmness, pH, and total ascorbic acid. The edible coating helps to reduce the weight loss and showed the positive effect on titratable acidity, pH, phenolic and ascorbic content.The edible coatings have shown the good sensory acceptability which are treated with chitosan, corn starch, alginate, beeswax and other coatings incorporated with essential oils and herbal extracts (Li, 2017; Hosseini, 2018; Saini and Raghav, 2018).

1.7. Edible Coating Applied on Fresh Fruits and Vegetables

Edible Coatings are applied on fresh fruits and vegetables (Arnon *et al*., 2015; Youssef*et al*., 2015). Fresh fruits and vegetables which has been coated are-

Edible coated Fruits: Sapota, Blackberry, Guava, Ber, Orange, Apple, Grapefruit, Cherry, Papaya, Lemon, Strawberry, Mango, Peach etc. and fresh-cut Apple, fresh-cut Peach, fresh-cut Pear etc.

Edible Coated Vegetables: Tomato, Cucumber, Egg plant, Okra, Squash, Capsicum, Cantaloupe and minimally processed Carrot, fresh-cut Potato, fresh-cut Cabbage, fresh-cut Tomato slices, fresh-cut Onion, Lettuce.

Table 1: Edible coatings applied on fresh fruits and vegetables (Raghav *et al*., 2016; Reddy and Singh, 2020; Oduro, 2021).

Food Materials	Type of Edible Coating	Impact
Mango	Carnauba wax with Aloe vera Chitosan and Lemon grass essential oil Chitosan and Calcium chloride Cassava starch and Chitosan Gum Arabic with calcium chloride Chitosan, modified starch and cellulose	Delay ripening; Improves firmness & appearance; Reduce the respiration rate; Anthracnose control during postharvest practices
Blueberry	Sodium Alginate+ Pectin,	Maintain the firmness, reduce microbial growth
Grapes	Chitosan nanoparticles coatings Shrimp chitosan and Mentha essential oil Native and octenyl succinic anhydride modified wheat starch coatings	Improve the postharvest quality; Control the fungal spoilage; Decrease spoilage; Extend shelf life; Improve the fruit quality; Maintain total carotenoids including total phenolic content; Increase the shelf life and quality
Apple	Aloe-vera gel Aloe Vera, Neem oil and marigold flower extracts	Retention of firmness; Decrease moisture loss; Maintain the storage quality

Strawberry	Beeswax+chitosan +acetic acid Three polysaccharide-based coatings (alignate, chitosan and pullulan) Lemon peel essential oil with cassava starch and sodium alginate Banana starch chitosan, Aloe Vera gel	Reduce fungal growth and weight loss; Improve the postharvest quality; Decrease microbial spoilage; Extend shelf life; Improve the fruit quality; Improve physiochemical properties; Increase the shelf life and quality
Banana	Chitosan, modified starch and cellulose Cellulose nanomaterials emulsion as coatings	Increase and improve the shelf life and quality; Reduce fungal growth and weight loss; Improve the postharvest quality;
Orange	Shellac, Gelatin and Persian gum	Influence and slow down the changes of physiochemical properties of coated fruits
Papaya	Chitosan and pectin Aloe Vera gel	Improve the appearance and colour; lower juice leakage; Increase organoleptic acceptability; Maintain color; Improve physical changes in storage; Extend the shelf-life up to 15 days
Guava	Arabic gum Alginate and chitosan Carboxymethylcellulose with essential oil	Protect postharvest quality; Reduce microbial load; Extend shelf life

	Guar gum Chitosan and alginate along with peel extract of pomegranate	Improve physical changes in storage; Increase the quality during storage at low temperature
Plum	Alginate Lac-based, Semeperfresh and Niprofresh coatings	Decreased weight loss; Inhibits ethylene production; Delay ripening Process; Improve quality; Increase antioxidant activity
Sapota	Aloe vera juice	Increase shelf life Improve the quality
Cantaloupe	Chitosan, calcium salt	Extend the shelf life Improve the appearance and quality
Pear	CMC Cornstarch + aqueous Tulsi extract Soy protein isolation, Hydroxypropyl methylcellulose and Olive oil	Decrease weight loss; Lower respiration rate; Increase glossiness; Extend shelf life; Improve pH, TSS and TA values
Fresh-cut Pineapple	Pectin & Alginate	Increase shelf life Improve color and quality Decrease weight loss
Guava (fresh-cut)	Aloe vera juice	Increase shelf life Improve color and quality Decrease weight loss
Ber	Guar gum blended with Aloe Vera Chitosan, Guar gum and Gum tragacanth	Maintain fruit firmness, colour and acidity under ambient storage; Extend the shelf life
Kinnow mandarin	Chitosan based coatings with Cinnamaldehyde	Decrease the fruit decay rate;

	Hydroxyl-propylmethylcellulose coating combination with $CaCl_2$ and $MgSo_4$ Polysaccharides from opuntia	Improve the quality of fruits; Minimize loss in weight and ethylene production; Improve values of acidity and vitamin C contents; Extend shelf life; Retain maximum moisture; Increase the shelf life and quality
Peach	Rhubarb extract+Sodium Alginate Mango peel and extract of seed kernel	Extend the shelf life; Decrease CO_2 and ethylene production; Lower O_2 consumption
Avocado	Carboxyl methylcellulose	Firmness and weight loss retention; Reduce the respiration rate; Act as a antimicrobial; Increase the shelf life
Muskmelon	Gellan + Sodium alginate	Maintain fruit firmness; Prevent desiccation
Kiwifruit	Pullulan	Control the post-harvest decay caused by fungal growth
Vegetables		
Tomatoes	Aloe juice/Cinnamaldehyde Pectin Aloe vera gel Vegetable oil, Cellulose, gum	Reduce weight loss; Delay ripening process; Reduce respiration rate; Increase shelf life
Mushroom	Vegetable oil, Cellulose, gum	Increase shelf life
Potato	Chitosan, WPC, Coconut oil.	Reduce weight loss; Increase shelf life
Pumpkin	Chitosan, calcium salt.	Reduce weight loss; Delay ripening process; Reduce respiration rate; Increase shelf life

Carrot	Alginate Casein, casein-monoglyceride, xanthan gum	Reduce moisture loss; Improve color
Cucumber	Pectin/sorbitol/bee wax Carboxy methyl cellulose + corn starch Chitosan + Aloe vera gel	Reduce weight loss; Reduce mechanical damage & microbial damage; Slow down the changes in physiochemical properties like pH, titrable acidity, ascorbic acid and TSS
Radish,	Chitosan, calcium salt	Reduce weight loss; Reduce respiration rate; Increase shelf life
Capsicum	Cellulose, Chitosan	O_2 and CO_2 barrier; Reduce respiration rate; Improve colour; Prevent wilting, fungal infection; Delay ripening process

2. Conclusion

Edible coatings are the best solution to reduce post-harvest losses. It is an easy to use and low-cost method.On the other hand, no special training is required for the use or application of this method, in short, even an ordinary farmer can easily use this technique to improve and increase the shelf life of freshly harvested crops.According to this chapter, edible coatings increase shelf life, reduce moisture loss, delay ripening process and also prevent the growth of microorganisms in fresh fruits and vegetables. Recently, herbal edible coatings have also been introduced in this context.It gives better results and health benefits than ordinary edible coatings. Fruits and vegetables with herbal edible coatings have good nutritional properties that work as medicines.

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