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# Polysaccharide, protein, lipid-based coatings and their impact on fruit crops: Review

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**Abstract**
It is believed that the production of edible films and coatings, which have developed dramatically in recent years, will considerably impact on the quality of fruits and vegetables in the next years. People want good-quality, healthy fresh fruits with a long shelf life free of pesticide residues. An innovative approach to a sustainable solution to this issue is the addition of edible films to fruits and vegetables. Various studies show that such coatings are good barriers to oxygen, increase shelf life, maintain fruit quality, and have antimicrobial properties. This paper describes the usefulness, trends, and perspectives of polysaccharide, protein, and lipid coatings, as well as their influence on the value of fruits and vegetables Different coating methods are also discussed i.e. Dipping, Spraying, Brushing, Electro-spraying, Drop casting, Panning, and Fluidized- bed by these methods we can apply coatings on fruits. The Paper gives recent details on the various edible films utilized to prolong the shelf life of fresh and less processed fruits.

**Keywords:** Coatings, uses, methods, polysaccharide, lipid, protein

## Introduction

Fruit crops are a major part of agricultural production. The significance of fruit crops is widely acknowledged in many areas, including innovation, production, quality maintenance, improving the financial situation of farmers and business owners, and ensuring the public's access to a healthy diet. Fruit improvement has seen significant technological advancement in recent years (concepts, approaches and applications), which has completely changed the way fruits are produced (Soni *et al*., 2018). In India total area under cultivation of fruits is 9.6 million hectares and production is 102.48 million metric tonnes (NHBC 2020-21).

The continuous physiological and biological changes taking place in the biological cells up till consumption are the main cause of fresh fruits' short postharvest shelf life. Inappropriate handling and transportation have been linked to significant financial losses due to mechanical damages and pathological changes (Iordăchescu 2019) [27]. Traditional synthetic waxes and chemical fungicides have been utilized as post-harvest applications to decrease losses in fresh fruits. Health and environmental concerns have been raised by these materials (Bayer *et al*., 2020) [9]. The antimicrobial agents that are resistant to food borne pathogenic strains have been connected to chemical-based coatings strengthened with artificial antimicrobial preservatives (Kocira *et al*., 2021) [32].

Fruit postharvest losses can increase by up to 40% due to improper handling, storage, preservation methods, and microbial spoilage. Due to some significant heat or cold resistance, the microbial effect is crucial in fruit deterioration. Processed or canned products may also be harmed by microorganisms (Sharma *et al*., 2013).

Fruits that are lost after harvest are a serious issue because handling, transportation, and storage cause them to quickly deteriorate. Fruits and vegetables are coated with edible material to maximize the quality and shelf life (Kumar *et al*., 2014) [33]. Several studies from the past ten years have described the use of natural and biodegradable edible coatings as sustainable substitutes for synthetic plastic packaging that are frequently used in the market because they have superior barrier properties (Galus *et al*., 2020) [21]. Fruit is so perishable that controlling its ripening is essential for extending its shelf life after harvest. Today, numerous chemicals that are injurious to human health are utilized to maximize the shelf life of fruits. Previous research showed that fruits coated with some edible coating substances had longer shelf lives, less spoiled fruit, and better fruit quality because the coatings delayed senescence during storage. The effect of various edible coating materials that are readily available and safe for humans on the storage life of fruits was therefore planned (Singh *et al*., 2017).

**Edible coating:** Thin layers that can be consumed as a component of the final product and are used to protect and enhance its quality are known as edible films and coatings. Their typical thickness is less than 0.3 mm (Ribeiro *et al*., 2021) [55]. The cuticle, a naturally occurring waxy layer on the surface of most fruits and vegetables, typically exhibits low water vapor permeability (Oliveira *et al*., 2018). Lipids, proteins, and carbohydrate molecules can be utilized alone or in a variety of composite formulations to generate an edible coating that functions as a good moisture barrier due to its hydrophobic qualities (Al-Tayyar *et al*., 2020) [7]. Today's world is moving away from synthetic forms of edible coating in favor of biodegradable, natural, non-toxic coatings (González-Reza *et al*., 2018) [25].

### Importance of edible coatings

Edible coating is utilized to enhance food appearance and maintain food safety because it is eco-friendly. Either their involvement or the addition of an antimicrobial compound reduces food deterioration and increases safety (Sharma *et al*., 2019) [57]. Edible films help to improve the shelf life of fruits and vegetables by reducing physiological disturbances such as water loss, solute mobility, gas exchange, and others. Edible coatings have a strong potential to reduce fruit and vegetable browning, discoloration, off-flavors, microbial activity, and shelf life. Active substances such as anti-browning agents, colorants, tastes, nutrients, spices and antimicrobial chemicals have the ability to extend the shelf life of products and reduce the effect of pathogen growth on food surfaces in edible coatings (R.K. Dhall 2013) [53].

### Methods of Edible Coating Applications

The different application techniques such as dipping, spraying, brushing, fluidized-bed, drop casting, electro-spraying and panning have an impact on the effect of applied coating materials on food products like fruits, vegetables, etc. The process of adhesion, which involves dispersion between the coating mixture and the food product's surface area, occurs with the application of an edible coating solution to food products. The surface coating materials of food products were adjusted using drying, heating, condensation and coagulation processes (Suhag *et al*., 2020) [62].

### 1. Dipping method

In order to prevent water content loss and gas transfer, the most common way of coating food products is dipping, which involves depositing a thin layer that serves as a semi-permeable membrane on the surface (Gupta *et al*., 2022). The excess coating from the food surface is then removed by draining the coating solution. In order to create a well-retained coating with the food surface, the fruit is finally dried. The method of applying an edible coating on food products involves three steps as shown in Fig. (1):

1. Immersion and dwelling.
2. Deposition.
3. Evaporation of solvents (Suhag *et al*., 2020) [62].

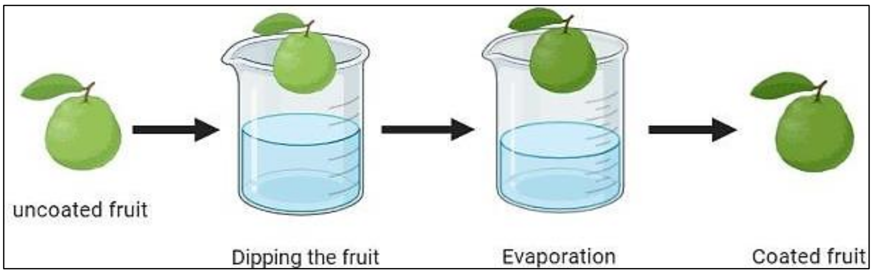


**Fig 1:** Dipping

### 2. Spray Method

The spraying technique is more suitable for coating solutions that are less viscous and sprayed at high pressure. Using this technique, food products are sprayed with a liquid solution the liquid solution breaks down into tiny droplets as shown in Fig. (2). For the same amount of liquid solution, the surface area of such droplets will be higher. Droplets will therefore cover more of the substance as a result (Suhag *et al*., 2020) [62]. This technique has the advantage of boosting the liquid coated surface area by making droplets and spreading them across the fruit's surface (Filho *et al*., 2021) [15].

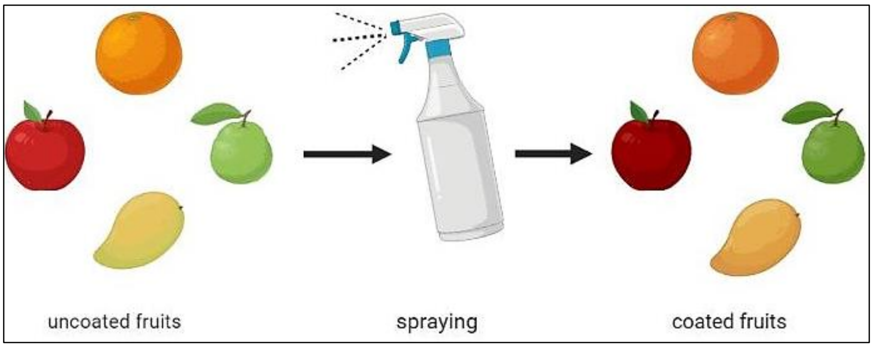


**Fig 2:** Spraying

### 3. Panning method

The panning technique involves placing the food and other items that need to be coated in a large spinning basin known as a pan. The layering solution is then drizzled or dusted into a bowl that is rotating in order to spread the coating solution over the surface of the food product uniformly. It is an established and well-liked technique for coating uniformity and powder deposition quality, as shown in Fig. (3). It is a successful method for applying the coating material to conductive materials (Birla *et al*., 2022) [11]. The panning method is used in batch processes to apply thin or thick coatings on hard, almost round particles. The pharmaceutical, confectionery and food processing industries use this method for coating products (Mahmud *et al*., 2021) [40].

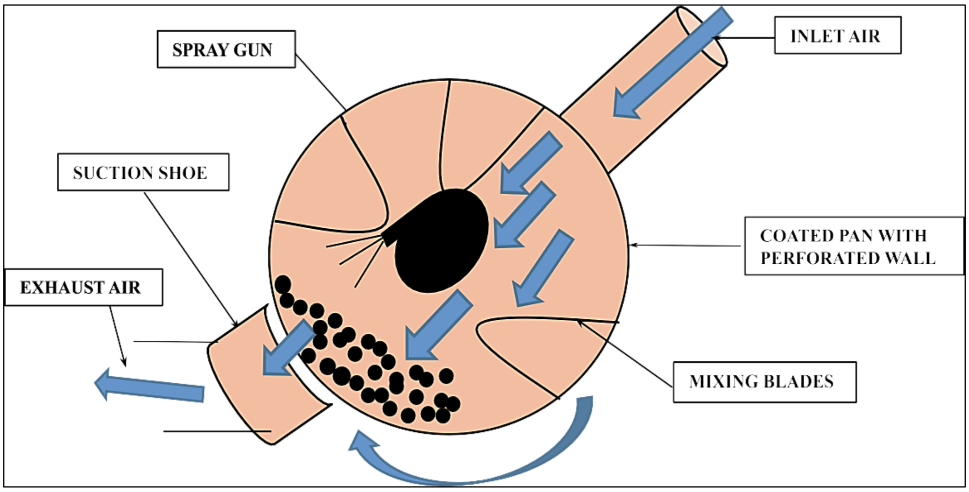


**Fig 3:** Panning

## 4. Fluidized-bed processing method

This Technique of edible coating is often used in food manufacturing and research applications (Aayush *et al*., 2022) [1]. In a fluidized coating process, the coating solution and suspension are sprinkled onto the fluidized powder surface through a number of nozzles to create a shell-like structure. When a liquid flow travels upward through a bed of particles, it fluidizes when it reaches a quick speed to help the particles without displacing them into the liquid stream as shown in Fig. (4). (Suhag *et al*., 2020) [62].

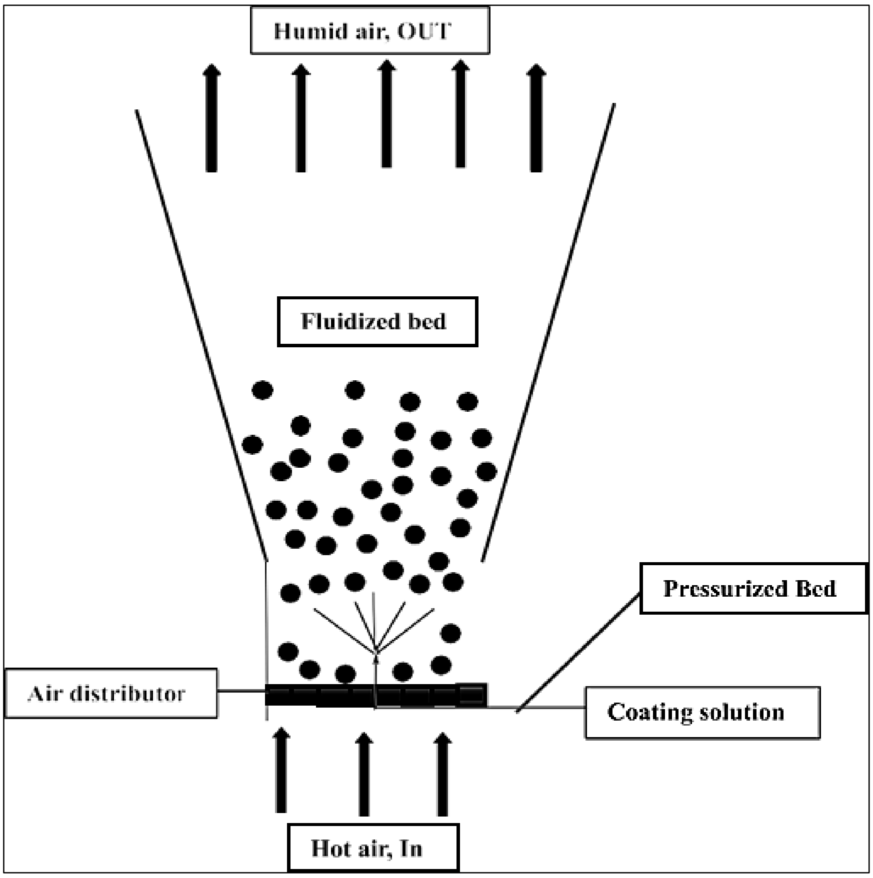


**Fig 4:** Fluidized bed processing

## 5. Brushing Method

The brushing method, which involves applying high viscosity coating to the fruit surface with a sterile brush, is dependent on the parameters governing the degree of wetting and the rate of spreading before drying as shown in Fig. (5) (Sharma *et al*., 2019) [57]. Brushing is often conducted manually by trained operators in order to produce better coating layer uniformity and eliminate human application error. Their efficiency is also affected by structure, thickness, surface tension, density, drying temperature and relative humidity (Shiekh *et al*., 2022) [59].

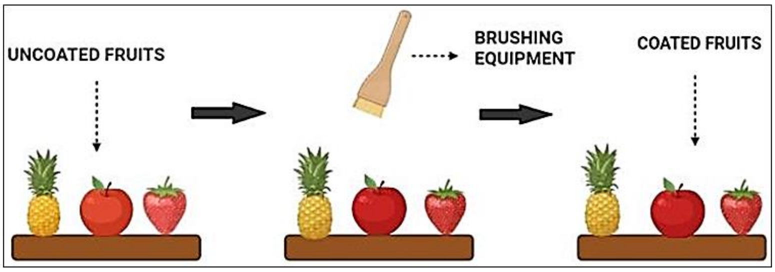


**Fig 5:** Brushing

### 6. Electrospraying

By atomizing a coating substance in the presence of a strong electric field, a novel coating technology known as electrospraying permits the creation of micrometric and sub-micrometric charge droplets with a very small size distribution as shown in Fig. (6). The tip of an emitter disturbs the liquid surface, creating a cluster of charged particles to form a Taylor cone (Lu *et al*., 2020) [37]. Due to electrostatic interactions between tiny charged droplets, electrospraying effectively adheres to the surface of the fruit when compared to traditional spraying (Mahalakshmi *et al*., 2020) [39].

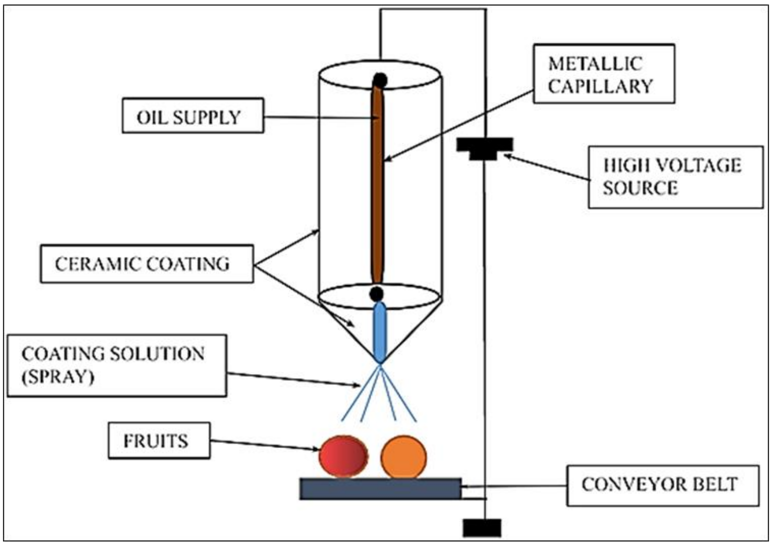


**Fig 6:** Electro spraying

### 7. Drop casting Method

This technique is used to create thin coatings on tiny surfaces. There is hardly an solvent needed. This process generates several droplets, which offers a separate environment for managing the direction of shrinkage and rate of evaporation of the droplets (Liu *et al*., 2014) [36]. Droplets of solution are applied to the media and allowed to dry without spreading (Riera-Galindo *et al*., 2018) [56]. As droplets are projected onto a substrate, the liquid first spreads on the surface from the drop sites due to interfacial forces that tend to push the droplet outward as shown in Fig. (7).

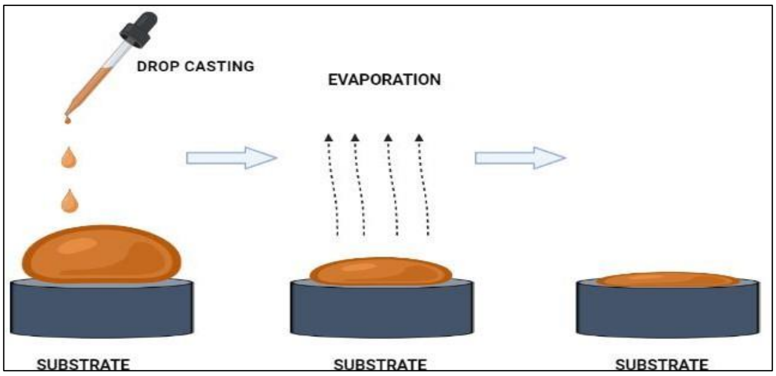


**Fig 7:** Drop casting

## Types of edible coatings

### 1. Polysaccharides based coatings

To replace traditional plastic packaging, biopolymers made of polysaccharides like pectin, carrageenan, alginate, starch, and xanthan gum have been utilized to generate edible films (Kocira *et al.*, 2021) [32]. One recent development in the formulation of coatings and edible films uses polysaccharides as a sustainable material (Mellinas *et al.*, 2016). In nature, polysaccharides are non-toxic, abundant and selectively permeable to oxygen and carbon dioxide (Erginkaya *et al.*, 2014).

Polysaccharides, which are natural polymers, are commonly utilized to produce edible coatings and films. Polysaccharides such as pectin, cellulose, starch, chitosan, alginates and pullulan are employed in the production of these films as shown in Table (1). Polysaccharides are the essential coating that is regarded to be an excellent oxygen inhibitor due to their structure and hydrogen chain. They are commonly used to increase the shelf life of vegetables and fruits (Oduro, K.O. A. 2021) [48].

**Table 1:** Effect of Polysaccharides based coatings on fruits

| Crop | Coating method | Edible coating | Impact | Reference |
|---|---|---|---|---|
| Strawberry | Drop casting | Chitosan/glycerol 30% films | Decrease microbial activity and increase the physical appearance, flavor, aroma, texture. | Pavinatto *et al.*, (2020) [50] |
| Guava | Casting | Chitosan (100%Q)<br>Alginate (100%A)<br>Chitosan (50%Q)+alginate (50%A)<br>Chitosan (90%Q)+aliginate (10%A)<br>Chitosan (10%Q)+alginate (90%A) | Both coatings i.e. 100%Q and (90%Q + 10%A) indicated the best conditions to prevent Rotting appearance. | Arroyo *et al.*, (2020) [8] |
| Grape | Dipping | Tamarind seed starch and 1% apricot oil | Maintained TSS, TA, reduced weight loss and microbial activity. | Ghoshal *et al.*, (2022) [24] |
| Strawberry | Dipping | Gum Arabic (3%), carrageenan (0.5%), and xanthan gum (0.1w/v) with lemongrass oil (1%v/v) | Reduced weight loss, decrease decay percentage, increase antioxidant activity and firmness. | Wani *et al.*, (2021) [67] |
| Banana | Dipping, Brushing and spraying | Pullulan (5%) + $Cacl_2$ (1%) and lemon juice (2%)<br>Pullulan (10%) + $Cacl_2$ (1%) and lemon juice (2%)<br>Pullulan (15%) + $Cacl_2$ (1%) and lemon juice (2%) | Pullulan (10%)+$Cacl_2$(1) and lemon juice (2%) coating gives best results in decrease weight loss, less browning index, decrease pulp to peel ratio increased fruit firmness, reduced vitamin C content. | Ganduri, V. R. (2020) [22] |
| Plum | Dipping | Pectin (0.5%) + glycerol (0.3%)<br>Pectin (1%) + glycerol (0.3%)<br>Pectin (1.5%) + glycerol (0.3%) | Pectin (1.5%) coating shows best result i.e. increased ascorbic acid, anthocyanin, flavonoid contents, enzymes activity, and antioxidative capacity of the fruit. | Panahirad (2020) [49] |
| Guava | Dipping | Acetylate cassava starch (ACS) (25%, 50%, 75% 100%) and hydroxycellulose (HEC) (25%, 50%, 75%, 100%) | HEC (75%) and ACS (25%) coatings results good effect in increasing firmness, maintained green skin color of fruit. | Francisco *et al.*, (2020) [19] |
| Plum | Casting | Starch (3%), Carrageenan (1.5%) and fatty acid esters FAEs (2%) | Fatty acid esters (FAEs 2%) coating shows reduction in both weight loss (WL) and respiration rate and inhibiting ethylene production. | Thakur *et al.*, (2018) [63] |
| Strawberry | Dipping | Hydroxyethyl cellulose (HEC1.5g)<br>Sodium alginate (SA1.5g)<br>Hydroxyethyl cellulose (HEC1g) + sodium alginate (SA0.5g)<br>(Contains asparagus waste extract) | HEC(1g)+ SA(0.5g) coatings showed best results in inhibiting antifungal activity, color change, and weight loss were delayed, while total phenolic and flavonoid contents were maintained. | Liu *et al.*, (2021) [35] |
| Blackberries | Dipping | Pectin (1%) Pectin (1%) + bacteriocin of Bacillus methylotrophicus (BM47) | Pectin(1%)+ BM47 coating shows successful application as a bio preservative, inhibited the fungal growth, decreases decay loss | Tumbarski *et al.*, (2020) [65] |

### 2. Protein based coatings

Globulous or fibrous proteins are the most common forms of proteins. Although fibrous proteins are insoluble in water and typically serve as a fundamental structural component of animal tissues, they are dissolved in aqueous solutions of salt, bases, or acids and carry out a variety of functions in living systems (Al-Tayyar *et al.*, 2020) [7]. Edible films contain a variety of globular proteins, including corn zein, whey protein, wheat gluten, and soy protein (Chhikara *et al.*, 2022). Casein, gluten, and soy protein are used in coatings made from proteins as shown in Table (2) because they are effective oxygen blockers and protect food products from deteriorative reactions. It has been claimed that proteins have excellent mechanical and gas barrier properties (Oduro, K. O. A. 2021) [48].

**Table 2:** Effect of protein-based edible coatings on fruits

| Crop | Coating method | Edible coating | Impact | Reference |
|---|---|---|---|---|
| Guava | Dipping | Casein (5%)<br>Casein (10%)<br>Casein (5%) + ascorbic acid (1%) | Casein (5%) and Casein (10%) both coatings show decreased firmness and titratable acidity, increased pH, TSS and carotenoids. | Beulah *et at.*, (2021) [10] |

| | | | | |
|---|---|---|---|---|
| | | Casein (10%) + ascorbic acid (1%) | | |
| Fig | Dipping | 5% of unmodified whey proteins<br>5% of formaldehyde whey proteins<br>5% of esterified whey proteins<br>5% of deaminated whey proteins<br>5% of unmodified casein protein<br>5% of formaldehyde treated casein<br>5% of esterified casein<br>5% of deaminated casein | Whey proteins (modified and unmodified) coating gives good impact in delaying ripening, reduced titratable acidity (TA), increases polyphenol oxidase (PPO activity). | Marf *et al*., (2022) |
| Pineapple | Dipping | Honey (50ml/L, 100ml/L and 150ml/L)<br>Soy protein isolate (SPI) (50g/L)<br>Honey (50ml/L)+SPI(50 g/L)<br>Honey (100ml/L)+SPI(50 g/L)<br>Honey (150ml/L)+SPI(50 g/L) | Honey (100mL/L) + SPI (50g/L) and Honey (150mL/L) + SPI (50g/L) coatings combinations gave best results in retarding microbial growth and retention of phenolic compounds. | Yousuf *et al*., (2019) [70] |
| Banana | Dipping | Soybean protein isolate (SPI)<br>Soybean protein isolate (SPI)+ cinnamaldehyde (CIN)<br>Soybean protein isolate (SPI)+ Zinc nanoparticle+ cinnamaldehyde (CIN) (1 mg $mL^{-1}$) | SPI+ ZNP + CIN coatings shows best satisfactory effect in maintaining nutrient content, hinder the water loss, carbohydrate hydrolysis, pectin conversion and weight loss. | Li *et al*., (2019) [34] |
| Dates (Barhee) | Dipping | Soy protein (6%) + thyme oil.<br>Soy protein (9%) + thyme oil.<br>Soy protein (12%) + thyme oil.<br>Gelatin (6%) + thyme oil Gelatin (9%) + thyme oil Gelatin (12%) + thyme oil. | Recommended to use soy protein as a carrier for thyme oil was best (6%, 9%) i.e. least fruit weight loss, highest fruit firmness, decrease level of pectinase enzyme activity. | Yousef *et al*., (2020) [69] |
| Cherry | Dipping | Soya protein extract Soya protein extract + maltodextrin with (spray drying and freeze drying) | Maintained Anthocyanin content. | Dumitrașcu *et al*., (2021) [17] |
| Pear | Dipping | Whey protein isolate (8%) whey protein isolate (8%) + essential oils (lemon oil (1%) or lemongrass oil (0.5%)) | Whey protein isolate (8%) coating shows significance results i.e. reduced the browning, maintained firmness and colour. | Galus *et al*., (2021) [20] |
| Nectarine and apple | Dipping | Corn zein + nisin(1 g $L^{-1}$) (CoZWN), Corn zein (CoZW). | CoZWN coating good in monocytogenes reduction. | Mendes-Oliveira *et al*., (2022) [42] |
| Avocado | Dipping | ZNP(zein nanoparticles), ZPL (zein and polylysine nanoparticles), ZS (zein solution) and ZPL (polylysine solution). | ZPL and ZNP coatings was observed retained higher firmness, Lowest fungal severity and lowest respiration rates. | Garcia *et al*., (2022) [23] |
| Grape | Dipping | Corn Zein (2, 4 and 6% w/w) + Wheat Gluten (2, 4 and 6% w/w). | Best result shows with combination of gluten and zein (6%) i.e. least weight loss and better fruit appearance. | Shokouhian *et al*., (2021) [60] |

### 3. Lipid based coatings

Lipid which includes fats, waxes, sterols, fat-soluble vitamins, and other naturally occurring tiny, hydrophobic molecules, are commonly referred as lipids. Lipids are typically used as a barrier against water vapor due to their hydrophobic properties, which include their apolar nature. Lipid molecules' hydrophobic nature and structural characteristics are often what accounts for their mass transfer resistance to gas and vapor transfer (Yousuf *et al*., 2022) [71].

They are organic substances that come from living things like plants, animals and insects. Phospholipids, phosphatides, terpenes, cerebrosides, fatty alcohols, and fatty acids make up a variety of lipid functional groups. In recent years, the food industry has concentrated on the preservation properties of lipids' edible films. Lipids in the edible film offer a variety of benefits, including gloss, a reduction in moisture loss, a reduction in cost and a simplification of packaging as shown in Table (3) (Mohamed *et al*., 2020) [44].

**Table 3:** Effect of lipid-based edible coatings on fruits

| Crops | Coating method | Edible coating | Impact | Reference |
|---|---|---|---|---|
| Strawberry | Dipping | Beeswax solid lipid nanoparticles (BSLN)(0, 10, 20, and 30 g/L) | BSLN (10g/l) gives positive results in decreasing decay rate, less fungal growth, reduces weight loss. | Zambrano-Zaragoza *et al*., (2020) [72] |
| Asian pear | Dipping | Beeswax (0g, 20g, 30 g, 40g $L^{-1}$) | Beeswax (30g $L^{-1}$) coating retarded oxidative browning, maintained fruit firmness and quality parameters, reduces ascorbic acid levels and total phenolic content. | Adhikary *et al*., (2022) [2] |
| Mango | Brushing | Aloe Vera gel (AVG) (50% and 100%) and beeswax (1.5% and 3%) | Beeswax (3.0%) coating results best in reducing weight loss, increase enzymatic activities, retarded the polygalacturonase (PG) and cellulose activities. | Mshora *et al*., (2020) [45] |
| Pomegranate | Dipping | Carnauba (0.5%) + GABA (5 mM)<br>Carnauba (0.5%) + GABA (10mM) | Carnauba (0.5%) + GABA (5mM) treatment inhibits chilling injury symptoms, reduces aroma loss and increases antioxidant activity. | Nazoori *et al*., (2022) [47] |
| Jujube | Dipping | carnauba wax + glycerol monolaurate (CW- | CW-GML coating shows the best results in | Chen *et al*., |

| | | | | |
|---|---|---|---|---|
| | | GML) | Reducing weight loss and respiration rate increase antibacterial properties, inhibits decay incidence | (2019) [12] |
| Papaya | Brushing | Carnauba wax nanoemulsion (CWN) (4.5, 9.0, 13.5 and 18.0%) | CWN 18.0% produces the best outcomes by lowering weight loss, delaying ripening and lowering ethylene production. | Zucchini *et al*., (2019) [73] |
| Guava | Dipping | Aloe Vera (5%, 10%, 15%), beeswax (5%, 10%, 15%), carnauba wax (5%, 10%, 15%) and combined three (10%) | Bee wax (10%) coating show the best results in reducing chemical changes (TSS, Acidity and ascorbic acid). | Sharma *et al*., (2022) [58] |
| Citrus | Dipping | Carnauba wax with rootstocks combinations such as Rangpur lime, Cleopatra mandarin, Sunki mandarin, Swingle citrumelo and C-1 citrange. During 0, 20, 40 and 60 days the fruits were kept at 4 ± 1 °C in a cold room and at 90% RH. | Carnauba wax treatment and cold storage extended the shelf life of 'Salustiana' oranges by 40 days while preventing weight loss and keeping their physicochemical and sensory properties. | De Carvalho *et al*., (2019) |
| Avocado | Dipping | Beeswax and aloe vera gel at ambient temperature and zero energy cool chamber (ZECC). | Bee wax coating stored in ZECC gives best result in Extending marketability and maintaining quality attributes | Kelbessa *et al*., (2020) |

**Conclusion and Future prospectus**

Edible coating is another approach for boosting the shelf life of fruits. The materials used in edible coatings have a considerable impact on their efficacy and acceptance. The key challenges in edible coating techniques that should be investigated further are the capacity of the various materials to enhance the shelf life of fruits without degrading their sensory and nutritional properties.

Additionally, edible coatings have a significant amount of potential to help fruit exporters and customers keep them. Fruit quality is high during storage. A review of scientific papers that have been published in past years indicates that recent developments in edible coatings, such as the use of plant-based essential oils, irradiation treatment, and nanotechnology, have created a coating that has the potential to preserve the physicochemical characteristics of fruits during storage.

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