*International Journal of Plant & Soil Science*

***Volume 35, Issue 14, Page 125-135, 2023; Article no.IJPSS.100161***
***ISSN: 2320-7035***

# Edible Coatings: Innovation to Improve the Shelf Life of Guava

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

***Article Information***

DOI: 10.9734/IJPSS/2023/v35i143028

**Open Peer Review History:**
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here:
https://www.sdiarticle5.com/review-history/100161

***Review Article***

***Received: 17/03/2023***
***Accepted: 20/05/2023***
***Published: 31/05/2023***

## ABSTRACT

Fruit and vegetables are rich source of vitamins and minerals and due to their perishable nature, they have a very short shelf life thus making it difficult to store them for longer period. Approximately 30-40% of horticultural products are in lost due to the improper handling during transits, insect, pest attack and miss handling during the preservation of fruits and vegetables. Edible coating is the one of the most appropriate ways to solve this issue and improve the shelf life of the horticulture produce. The protective layer coated over the fruit and vegetables act as barrier for $O_2$ and $CO_2$ and water vapor which may result in the aging of produce. Hence,the different types of edible coating also help to improve the luster thereby making it more attractive to consumers and getting higher price in the market by reducing the post-harvest loss to a great extent. This review paper is an attempt to signify the use and importance of different edible types of edible coating to improve the shelf life of guava.

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*Keywords: Guava; edible coating; post-harvest losses; shelf life.*

## 1. INTRODUCTION

Fruits and vegetables are animportant storehouse of nutrients, including vitamins, minerals, antioxidants, bioflavonoids, dietary fibers, and taste compounds. However, the vulnerability of these products to various biotic and abiotic stresses results in a very short shelf life and perishability of produce [1]. External causes of food loss may include elements such as oxygen, carbon dioxide, ethylene ratios, temperature, and stress [2]. Whereas, internal factors may include the species, cultivar, and development stage. Beside this the microorganisms present over the skin of fruits and vegetables can also results in huge biochemical changes such as browning, off-flavors, and texture change, which will negatively affect the fruits. Fresh fruits are more likely to be sold if they have the right color, shape, texture, flavor, and amount of nutrients and are safe from pathogens [3].

Several types of organic and inorganic edible coatings can help to overcome the issues related to the shelf life and quality deterioration of fruits and vegetables [4,5]. Fruits and vegetables coatedwith edible coatings have a longer shelf life in comparison to the uncoated material. Therefore, new organic and inorganic edible films and coatings have beendeveloped in recent years that are able to preserve freshness of vegetables and fruits with the inclusion of a variety of edible herbs and antibacterial agents [6]. In addition, edible coatings also aid in maintaining the food's firmness and moisture contentthereby, increasing the marketability of produce [7].

For fruits and vegetables, edible coatings primarily act as a natural barrier, between the product and environment hence, help to enhance the storage life (Kumar *et al.,* 2022).Coatings functions as a passive and inactive barrier between the fruits and their surroundings hence, they provide protection against degradation that may be caused by chemical and mechanical stresses. Further, coatings may also help to limit moisture, oxygen, $CO_2$, and ethylene exchanges,thereby further preserving thetaste, aroma and improving mechanical handling and structural integrity of fruits and vegetables [8,9].

Earlier, chemical fungicides and synthetic waxes were used as traditional coatings, which used to harm consumers health as well as the environment which led to the development of innovative coatings which would satisfy the demand for fresh-like foods that would be healthier and safer to consumers [10]. The edible coatings include various beneficial substances such as antibacterial herbs, antioxidants and anti-browning chemicals [11]. As a result, this technology may replace non-edible coatings, which are more effective and less dangerous to consumers and the environment than traditional non-edible coatings [9,12,13]. Therefore, it is now essential to include biopolymers such as in the composition of edible coatings. Carrageenan and other polysaccharides like chitosan have also exhibited to improve the shelf life and pre trapping the nutritional benefits [14,15]. Therefore, keeping in view the importance of edible coating for improving the fruit shelf life, nutritional security and doubling the farmers income. An attempt has been made through this review to study and determine the significance of edible coatings.

## 2. GUAVA (*Psidium guajava* L.)

A member of the Myrtaceae family, Guava (*Psidium guajava L.*) is a tropical fruit. *Psidium guajava* is the most significant fruit in the genus Psidium, which comprises roughly 150 species [16]. The Guava is native to southern Mexico and Central America [17]. The guava tree's capacity to thrive in various soils and temperatures may have contributed to its spread across the world's tropical and subtropical areas. Fruits range in size from medium to big, weighing 100–250 g on average and measuring 5–10 cm in diameter. The apex of the fruit has four fiber-protruding flower remains.Depending on the variety, the fruit may be spherical, ovoid, or pyriform. There is no visible pubescence on the fruit's surface. The immature and unripe fruit has dark green skins that, depending on the cultivar, turn light yellow, yellowish-green, or yellow with a red tint on the shoulders when they are ripe. Ripe fruit has smooth, juicy pulp that might be white, pink, or salmon-red. The fruit's seed cavity may range from tiny to enormous, and the seeds can be hard or semi-hard. Gnarly stone cells (78%) in the mesocarp of guava fruit give it a sandy or gritty appearance, whereas parenchyma cells predominate in the endocarp, which has a high concentration of lignified cell walls. Fruits that are good for eating have thick pulp, few seeds and stone cells, a lot of sugar, and a unique smell.

**Table 1. Classification of guava**

| Kingdom | Plantae |
|---|---|
| Subkingdom | Tracheobionta |
| Superdivision | Spermatophyta |
| Division | Magnoliophyta |
| Class | Magnoliopsida |
| Subclass | Rosidae |
| Order | Myrtales |
| Family | Myraceae |
| Genus | *Psidium* |

*(Source: https://www.botanical-online.com/english/guava_characteristics.h)*

## 3. WORLDWIDE DISTRIBUTION AND ECONOMIC IMPORTANCE

Many nations in the tropics and subtropics commercially produce guavas for their use and consumption. Guavas are primarily grown in India, Pakistan, Mexico, and Brazil, the following four top cultivators. Other nations that produceGuava include Vietnam, Egypt,Venezuela, Thailand, Colombia, Puerto Rico, Indonesia, Sudan, Bangladesh, Cuba, Malaysia, and Australia. There has been a growth in the production of Guava in the present decade, as new plantations of better kinds and hybrids have emerged. In addition, breeding initiatives in several nations may be responsible for guava production and distribution growth. There is currently little commerce in fresh guavas outside Europe and North America. But processed guavas like juice or nectar are growing more popular.

## 4. USES, NUTRITIONAL VALUE, AND HEALTH BENEFITS

There is a long history of using Guava for dietary and medical purposes. The sweet-sour flavor of guava fruit is complemented with a pleasing scent. Fresh salads, juices, nectars, pastes, purees, concentrates, jams, jellies, candy bars, etc., are the most common forms of consumption. Regarding desserts, white-fleshed cultivars are often favored, whereas red-fleshed varieties are used for cooking. It has been extensively utilized for traditional therapeutic applications in Central Africa and America to treat diarrhea, gastroenteritis, and antibacterial colic pathogens in the bowel [18]. Guava leaf extracts have been extensively studied for their antibacterial characteristics and may be used to treat a broad range of ailments, including cancer. Guavas, especially the fresh ones, are low in calories and high in nutrients, including vitamin C and manganese. According to the USDA's national nutrient database, guava fruit contains 8.92 grams of sugar, 228.3 mg of vitamin C, vitamin E, 0.73 mg of vitamin K, 5.2 mg of lycopene, potassium, phosphorus, magnesium, and calcium per 100 grams of fresh guava fruit [19,20]. Vitamin C, ascorbic acid, carotenoids, and phenols are abundant in this food and are known to have an essential role in preventing degenerative disorders such as cancer. The antioxidant power of guavas is primarily due to polyphenols, which, like many other fruits, are found in high concentrations in this tropical fruit. To qualify as an antioxidant dietary fiber, Guava fruit must have at least 48% to 49% dietary fiber in the pulp and peel, making it a natural food product. Different cultivars and fruits have different levels of health-promoting phytochemicals. The flesh has less ascorbic acid and phenols, but fruit skin contains much more. Sugars like sucrose, fructose, and glucose, found in white-fleshed fruits, tend to be higher in white-fleshed cultivars than in red-fleshed ones [21,22].

## 5. GUAVA AND EDIBLE COATING

The sweet and sour guava fruit hails from the Americas and is a popular tropical treat. It is a climacteric fruit with intense respiratory activity and a high ethylene production rate. A variety of edible coatings, including gum (xanthan, chitosan, cashew, and Arabic gums), wax (candelilla and carnauba), cellulose and CMC, starch, and other formulations made from gelatin, triacetin, and lauric acid, have been used to improve the quality of fresh guavas and extend the shelf life of the fruit [23,24,25]. Natural gums coatings demonstrated a significant potential for incorporation into food packaging. Non-toxic exudate polysaccharides derived from the *Anacardium occidentale* tree are called cashew gums [26]. This gum is water-soluble and may be made into films that are both transparent and resistant to damage. Forato *et al.,* 2015investigated the effects of edible coatings based on cashew gum (1%) and CMC (1-2%) on guavas' shelf life. This resulted in less mass loss, protection of stiffness, and a delay in the colour change of the surfaces. According to MRI scans, tissue deterioration in guavas stored at room temperature for eight to twelve days occurred mainly around the peel or the peduncle. They produced edible coatings using sodium caseinate (0–2%),Arabic gum (0–15%), and tulsi extract (0–5%) for Guava. Their optimal coating included 5% Arabic gum, 1% sodium caseinate, and 2.5

mL/100 mL tulsi extract. It maintained a proper internal gas composition to prevent ripening while showing great acceptance and post-harvest shelf-life. Coated Guava's oxygen consumption rates were significantly affected by tulsi extract's interaction with Arabic gum, but sodium caseinate had no impact on water vapour transmission or $CO_2$ evolution rates.

## 6. HISTORY AND APPLICATION OF EDIBLE COATING

Oxygen and germs from external sources are all prevented from entering food by edible coating. Moisture and solutes are also prevented from leaving food with an edible covering. As a semi-permeable barrier that reduces moisture and solute migration, gas exchange, oxidative reaction rates, and respiration while also reducing physiological sickness on freshly cut fruits, the edible coating's primary goal is to increase shelf life [27]. When fruits and vegetables are coated or wrapped to extend their shelf life, as Pavlath and Orts [28] pointed out, the materials used to coat or wrap them are recognized as edible coatings, whether removed or not [28]. Applying edible coatings or films to fruits and vegetables may give them a shiny finish. A coating that is less than 0.3mm thick is edible. The primary purpose of the edible coating is to keep fresh or processed fruits and vegetables from rotting after harvest or being damaged by the environment; this also makes the products last longer. Unripe produce has an edible layer covering the outer membrane to keep it safe for consumption [29]. The edible coatings are a nutraceutical, texture enhancer, and antioxidant carrier. Edible coatings must remain stable and secure in high relative humidity. Mechanical properties of tasteless, colorless, and odorless food coatings and films are critical. Food coatings' gas and moisture barriers are exceptional [30].

## 7. HISTORY OF EDIBLE COATINGS

The food industry has been using edible coatings and films to preserve food for ages; this is not a novel method of food preservation. For example, waxes and cellulose coatings can be found on fruits, vegetables, and meat casings [31]. As far back as the 12th century, the Chinese have applied edible coatings to their food. As far back as 1922, it wasn't until that year that waxing fruits and vegetables was professionally used for the first time [32,33]. Maintaining and controlling freshness and preventing spoiling and disease development are the most prevalent and challenging issues in the fresh-cut fruit sector. Edible films and coatings protect chemical, physical, and biological changes. Consumers evaluate the freshness and quality of fruits and vegetables depending on their appearance at the time of purchase [34]. According to Nawab et al*.* [35], the edible coatings create a barrier to gas exchange and water vapour that is only partially permeable. This changes the rate of breathing, slows weight loss, and stops the ageing process. As a result, microbial growth is inhibited, the texture, colour, and moisture of the food are all preserved, and the product's shelf life is successfully extended. Fruits and vegetables such as Guava have recently been coated with edible coatings. Controlling the interior gas composition is critical to the success or failure of fruit and vegetable edible coating.

**Table 2. Different types of edible coating**

| Sl. No | Vegetables and fruits | Used edible coating |
|---|---|---|
| **1.** | Guava | Salicylic acid, Benzyl adenine, Chitosan/carrageenan, glycerol and Aloe vera gel |
| **2.** | Orange | Alternative coatings include sellac, gelatin, and Persian gum. |
| **3.** | Blueberry | CMC, Chitosan, Monoglycerides, Sodium alginate, Calcium caseinate. Sodium alginate, Pectin, Sodium alginate plus pectin |
| **4.** | Mango | Cassava starch and chitosan coatings |
| **5.** | Papaya | Carboxymethylcellulose coating with essential oil |

*(Source: Susmitha Reddyet al., [36])*

## 8. EDIBLE COATING FORMULATION AND APPLICATION PROCEDURES

The dissolution or dispersion of the coating components is the first stage in the edible coating-formulation technique. The primary coating ingredients (such as gum and glycerol) must be well combined to achieve uniform edible coatings. Gentle stirring and heating at 60-70°C have resulted in optimal combinations of the components [37-40]. The solution must be cooled to room temperature before adding functional additives. Dip, spray, and spread are the most common ways to apply edible coatings. The product is dipped into an edible coating solution for 1–3 minutes, after which it is allowed to dry naturally. For fruits and vegetables, only the dipping technique can create thick coatings on the surfaces [41]. Edible coatings with low viscosity that spray well at high pressure are suitable for spraying methods. Despite the uniformity and aesthetics provided by this method, the gum coatings applied by spraying may be affected by various elements, including the drying temperature, the drying process, and the drying period. When a product is coated using a brushing approach, the solution is brushed directly onto the product's surface. Expertise may be required, for example, in applying the brushing technique to ensure that the film spreads evenly and the layer uniformity is maintained.

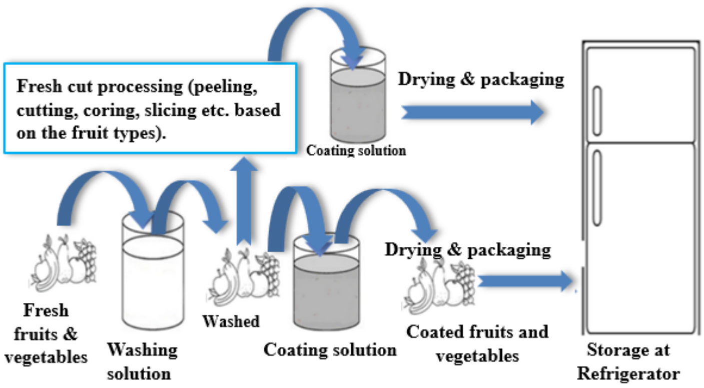


**Fig. 1. Shows a general flow diagram of fruits and vegetable coating treatment.**
*(Source: Tahir et al. [42])*

## 9. CLASSIFICATION OF EDIBLE COATINGS

Edible coatings may include hydrophobic or hydrophilic groups, such as lipids or waxes, hydrocolloids, polysaccharides, or proteins. No chemicals are used to produce edible coatings;it isentirely natural. Preserving the freshness of fruits and vegetables is a common purpose for food coatings [43].

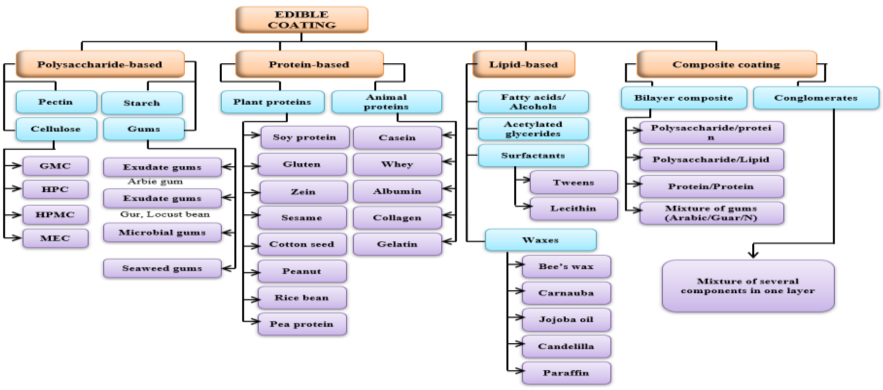


**Fig. 2. Classification of edible coatings**
*(Source: Panahirad et al. [44])*

## 10. PROPERTIES OF EDIBLE COATING

The molecular structure, size, and chemical makeup of edible coatings determine their properties [45]. These properties are following-

- It enhances the appearance and mechanical handling of fruits and vegetables to keep their structure and color intact.
- Fruits and vegetables with these coatings have a longer shelf life because of the protection they give.
- Water, moisture, oxygen, carbon dioxide, and ethylene are all well-protected by edible coatings.
- Antioxidants, vitamins, and other active ingredients are included in edible coatings, which improve the nutritional value of produce without degrading the taste or texture.

**Table 3. Advantages and disadvantages of edible coating**

| Sl. No | Advantages | Disadvantages |
|---|---|---|
| **1.** | Adding edible coatings to fruits and vegetables is a healthy way to eat more fruits and veggies. | Food-grade hygroscopic coatings may aid in the development of microorganisms. |
| **2.** | Preserve the quality of fruits and vegetables in storage. | Anaerobic respiration occurs in fruits and vegetables owing to the high gas barrier qualities of edible coatings. |
| **3.** | Acids, color, taste, and sugar retention are all improved by edible coatings. | Thicker coatings can stop oxygen from getting in and out, stopping flavour development. |

*(Source: Corbo et al., [46]; Ghaouth et al., [47])*

## 11. EFFECT OF EDIBLE COATINGS ON FRUIT CROPS

### 11.1 Impact on Weight Loss of Fruits

The weight of their horticultural products determines farmers' profits. Water vapour pressure changes between the fruit and the atmosphere impact the amount of weight loss due to transpiration. To keep the fruit from evaporating, edible coatings provide an additional barrier between the fruit and the environment. Weight loss, colour change, and TSS all improved dramatically when aloe vera L gel was applied to peaches, according to Hazrati et al. [48].

## 12. EFFECT ON EXTERNAL APPEARANCE AND GLOSSINESS

The horticultural commodity's appearance is critical. In the packaging and transportation process, the natural wax covering is destroyed, and bruising injuries occur due to the rough physical handling of fruits during the post-harvest phase. To protect the fruit's quality after harvest, the edible covering serves as a physical barrier. Gellan gum coatings were shown to have a lower glossiness, taste, colour, and weight loss than whey protein concentrate coatings, according to Javanmard et al. 2011.

## 13. EFFECT ON FRUIT FIRMNESS AND SOFTENING

Excessive evaporation and respiration, which are directly linked to a reduction in storage capacity, may be avoided by applying an edible coating on the product. The edible coating reduces the activity of cell wall destroying enzymes and delays ripening, both of which directly affect fruit firmness. It's well-known that calcium directly impacts fruit firmness; thus, adding calcium to the edible coating worked like a charm. Zhang et al. [49] found that a combination of soybean isolate protein and chitosan effectively decreased the weight loss of the apricot, avoiding a decline in firmness and enhancing exterior characteristics.

## 14. SHELF-LIFE ENHANCEMENT OF GUAVA (PSIDIUM GUAJAVA L.) FRUIT USING A NOVEL COATING MATERIAL

In the post-harvest period at room temperature, guavas are tropical climacteric fruits. At 10%, 20%, and 40%, hydroxypropyl methylcellulose (HPMC) and beeswax (BW) edible coatings were applied to the red guavas'Pedro Sato' to enhance their shelf life (dry basis). Guavas were kept for 8 days at 21°C and examined every two days. The addition of HPMC and BW slowed down the fruit's ripening phase. Protected green color, increased hardness, and reduced mass loss in the coated fruit compared to the uncoated fruit. There was a six-day shelf life for the fruit that had not been covered. Treatment with HPMC + 20% BW preserved fruit quality the best. These coated guavas had the same physical and chemical attributes on the second day of storage as uncoated control guavas, indicating a six-day improvement in shelf life [50].

The application of edible coatings is one way to increase the shelf life of post-harvest products. For fresh fruit, these coatings are formed of edible ingredients that are employed to provide a semi-permeable barrier to gases and water vapour. One of the following polymers used to coat the guavas grown in Aguascalientes, Mexico: Potato starch, sodium alginate, carrageenan, and pectin. A solution of 50°C was used to immerse the fruit for 30 minutes, after which it was dried at 50°C for 30 minutes. The maturity process of coated fruit was compared to that of untreated fruit. The barrier qualities of edible films to water vapour and fragrance components were measured (gravimetrically) to evaluate the functional features of edible coatings (dynamic method). At 25°C and between 50 and 70 percent of R.H., the coated fruit had a shelf life of at least three days longer than the untreated fruit. Potato starch and pectin-based coatings were shown to be the most effective in preserving the fruit's sensory features (size, yellow colour, and scent) for 15 days [51].

CG and CMC-based formulations have been tested as edible coatings on red guavas, both entire and chopped, for their ability to preserve the fruit. For CMC additions of 1 and 2 percent weight, samples were coated by dipping them in aqueous mixes containing 1 percent CG and 1 percent plasticizer (glycerol). To determine the weight loss, pulp and peel colour, and texture of the fruit, it was held at room temperature (25–28°C, 76.0 ±12.4% RH). Images were taken using Magnetic Resonance Imaging (MRI) to examine the degradation of the fruit's interior structure. Skin colour changes were delayed, and mass loss was reduced with both coverings. For the cut coated samples (CG + 2% CMC), mass loss after 12 days of storage was 38.5 percent lower than that of uncoated references. In addition, water loss and colour changes on cut surfaces were decreased by both coating compositions. Between 8-12 days of storage at room temperature, MRI imaging revealed that tissue deterioration occurred mainly around the peel or the peduncle [23].

Chitosan is also one of the most popular edible coating materials in the market. Chitosan is a cationic polysaccharide with a high molecular weight. Using a de-acetylation procedure, chitin may be converted into chitosan. Chitin is readily accessible commercially because it can be removed from the shells of prawns, crabs, and other shellfish by-products. Because it is biodegradable, biocompatible, and extremely resistant to microbial assault. Additionally, it is safe, non-toxic, and promotes the synthesis of immunoglobulin in human hybridoma cells [5]. Krishna et al. [52] stated that chitosan at 1% and 2% improved the shelf life of Guava cv. Allahabad Safeda by 7 days hence delayed ripening. Similarly, Shamshad et al. [53] delivered that chitosan at a concentration of 1.5% and 2% improved the storage life by maintain nutritional attributes. Also, proved to be a great edible coating in many fruits.

**Table 4. Summarization of edible coating**

| Author' Name | Study |
|---|---|
| **Momin et al. 2012** | Fruits and vegetables are popular because of their high nutritional content. There are insects, diseases, harvesting circumstances, transport, and storage that harm 30% of fruit or vegetables. Fruit and vegetable preservation is difficult all over the world. Edible coatings include hydrocolloids, lipids, and plasticizers. Excellent barrier qualities for $O_2$, $CO_2$, moisture, and water vapor. |
| **Druchta and Johnston et al. [54]** | According to the FDA's recommendations, all the parts and functional additives in film-forming materials should be GRAS and used within the limits set by the FDA to ensure the safety and quality of the product. There are also antioxidants, antimicrobials, pigments, and other functional/nutritious ingredients in edible coatings and films. Either the name of the ingredient or an E-number must be on the packaging to show the functional category for which it is meant to be used. |

| Author' Name | Study |
|---|---|
| **Galus et al. [55]** | In the last few decades, the number of edible films and coatings has grown quickly, and this is expected to have a big effect on food in the future. Bio-based polymers have been used a lot in coatings that can be eaten. Unique edible materials and new ways of making them are getting a lot of attention because they have the potential to change the way food is packaged in a big way. The researcher gathers a lot of information, to show how protective new film-forming materials like plant residues, flours, and gums are and how they can be used |
| **Jafarzadeh et al. [56]** | Food packaging materials are becoming more popular. The low thermal, mechanical, chemical, and physical properties of biopolymers, vapour permeability, have piqued people's interest. Bio-nano composites films and edible coatings for fruits and vegetables are discussed in terms of how they may reduce color change, respiration rate, weight loss, shelf life, delay the ripening process, and be environmentally friendly. Research demonstrates that metal nanoparticles in biopolymers impair the shelf life and quality of fruits and vegetables. |
| **Lin et al. [57]** | Chitosan/carrageenan and glycerol as edible covering materials were tested for their ability to preserve fresh longan fruits at room temperature. Coating component concentration was critical to ensuring that quality and quantity were maintained. The fruit's weight loss, respiration rate, and color were employed as indicators of the coating's efficacy in this experiment. A significant (p=0.05) reduction in water loss in fruit coated with chitosan or carrageenan has been found in the results of this study. High concentrations (> 1.19 %s in carrageenan-coated fruits. Because they showed low-quality changes and quantity losses in the multiple response optimization studies, a mixture of 1.29% (w/v) chitosan with 0.42 %glycerol and 1.49 % (w/v) carrageenan with 0.03 %glycerol was projected to yield the required coating. |

## 15. FUTURE PERSPECTIVE

Adding functional and bioactive molecules to the polymeric matrix allows edible coatings to be turned into active systems. This makes coated foods safer, healthier, and tastier and helps the customer's health. A new generation of edible coatings that include antibacterial, antioxidant, anti-browning, texture-changing, and nutritional ingredients, for example, is the most promising way to control the quality of fresh horticultural products. Researchers have come up with the idea of covering fruits and vegetables with edible wraps made of renewable and biodegradable materials to make them last longer on store shelves. These coatings should protect as well as help. This could help prevent microbial decay, enzyme or metabolic damage, and physical or textural change after the harvest. In recent years, pectin, and CMC, both made from polysaccharides, have become popular coverings for fruits and vegetables. These polymers are great for many uses in the biomedical field because they are biodegradable, non-toxic, and mechanically sound, protect against moisture and gases, and carry bioactive agents cheaply. In addition, active coatings made of CMC and pectin may keep chemicals in and slowly release them to the surface of fruits and vegetables, making them more effective. In the future, pectin and CMC-based coatings will be used more often as preservatives [58-60].

## 16. CONCLUSION

The most advanced way to package food is with an edible coating. The packaging industry has found a way to reduce waste by using edible coatings. These coatings are made of either natural or man-made parts that are also edible. Starch, protein, fat, wax, and oils are the main building blocks, and they all have good gelling properties. Plasticizers are added to improve their gelation and other properties, like their ability to block oxygen and water. Glycerol, mannitol, sorbitol, and sucrose are all good plasticizers that are safe for food. Edible coatings are used to make fruits and vegetables last longer on the shelf and keep their nutritional value and freshness. Also, people who care about their health are drawn to products that are high in antioxidants, and Guava could be one of the best ways to get antioxidantsand fiber. The guava fruit has a lot of vitamins, minerals, fiber, and antioxidants that body needs. Inorder to improve these qualities and maximize the shelf-life edible coating is the best option. In this review keeping in view that edible coating can be a great option inorder to improve the overall quality of guava fruit. Hence, proving to be safer for human consumption as well as safer for environment.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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