Effect of novel edible coating formulations on post-harvest quality of Chilli (Capsicum annuum var. Pusa Jwala): A review

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Abstract. Chilli (Capsicum annuum L.) holds a prominent position as a key spice crop, being widely utilized globally. Despite its agricultural significance, chilli is characterized by high moisture content (60–85%) at harvest, necessitating reduction to 8–12% for prolonged storage in a dehydrated form. However, it remains highly perishable, with a short shelf life and susceptibility to postharvest challenges such as fungal diseases, quality degradation, chilling injury, and rapid weight loss. Edible coatings have emerged as a solution to extend the postharvest shelf life of fruits and vegetables, enhancing mechanical handling properties and acting as a barrier to respiratory gases and water vapor. The possibility of hydrocolloid gums, such as gum arabic, as edible coatings has drawn interest. The purpose of this study is to determine whether an edible coating based on gum arabic (GA) can effectively preserve the quality of chilies when stored at room temperature. The goal of the research is to extend the storage life of chilies while improving their physiological and microbiological quality. A composite chitosan – gelatin (CH-GL) edible covering will be used to accomplish this. The effects of pure chitosan, cassava starch, gum arabica, and gelatin coatings on chilies will also be investigated in this study. In order to improve the marketability and resilience of chilli and possibly other horticultural commodities, the research aims to offer insights into the development of efficient and sustainable postharvest strategies by methodically evaluating the effects of these coatings on weight loss, firmness, color retention, and nutritional content.

Keywords: Chitosan, Edible coating, Gum Arabica, Post-harvest quality, and Shelf life.

1. Introduction

Chilli (Capsicum annuum L.) is one of the most economically important vegetable crops in the world. It is a dicotyledonous flowering plant that is a member of the Solanaceae family. It goes by several names, including bell pepper, chilli pepper, and hot pepper, and it has unnecessary nutritional and therapeutic value [1]. The five domesticated species of chilli peppers are Capsicum annuum, Capsicum frutescens, Capsicum chinense, Capsicum pubescens, and Capsicum baccatum. The [2] South-central South America is considered to be the core of chilli variety. Since the dawn of civilization, people have used canned or raw canned tomatoes as a vegetable, spice, or condiment [3]. Chilli pepper green fruits are utilized as vegetables. However, due to their strong tastes and pungency, ripe dried fruits make excellent spices. It is an essential component of practically every kitchen in Bangladesh, and because of its flavor, color, and pungency, demand for it is rising daily [4]. In Bangladesh, numerous cultivars are cultivated, each with unique characteristics such as habit, fruit pungency, size, form, color, yield, and customer preference.

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Vitamin C, a potent antioxidant that boosts immunity against illness, and vitamin A, a fat-soluble vitamin and significant antioxidant that helps lessen the risks to health posed by free radicals, are both abundant in green chillies. Vitamin A is a necessary building block of rhodopsin, the protein that enables light absorption by retinal receptors in the eye, and it aids in the formation of red blood cells. Additionally high in vitamin E, which is necessary for the production of some natural skin oils and helps to delay the aging process of the skin, are green chilli peppers. There is a correlation between eating green chillies and a decreased risk of prostate, stomach, and lung cancer. It is made up of a variety of substances, including fatty acids, proteins, fibers, minerals like potassium and folic acid, and compounds including steam volatile oil, vitamins A, C, and E. The characteristic red color and spicy flavor of chillies are attributed to two unique compounds: capsanthin and capsaicin. Dihydrocapsaicin and capsaicin comprise the majority of total capsaicinoids. The highly valuable pharmaceutical compound capsaicin (C18H27NO3) is responsible for the pungency of chillies. Capsaicinoids are used in pharmaceuticals because of their analgesic, antiarthritic, antioxidant, and anticancer effects. Chilli
magnesium, folate, potassium, thiamin, iron, copper, and vitamin C (ascorbic acid), which is utilized in the food and beverage sectors [5]. It has also gained significant importance due to the presence of "oleoresin," which improves the dispersion of flavor and color in food.

India has a significant comparative advantage in the production and export of chillies; as such, government actions to support farmers and traders by creating transportation infrastructure and other marketing inputs might help realize this potential. Around 20.20 million hectares of land are used to grow chilli worldwide, with a total yield of 37.62 million tonnes. With an annual production of over 13.76 million tonnes, India is the world's greatest producer of chillies, followed by China with 3 million tonnes. About 36.57% of global production is contributed by India. In the world, India comes in first place for both area and chilli production, and second place for productivity. Despite the fact that chilli output contributes significantly to the country's production and export value, around 30–35% of it deteriorates after harvest due to improper handling, and infections like anthracnose are a major cause of post-harvest loss. In most parts of the world, post-harvest losses are a major issue that render the chilli crop unprofitable. In the dry and rainy seasons, respectively, the total post-harvest losses in chilli range between 28.6% and 38.7% of the original weight of the product. Marketing accounts for 6.7%–17.1% of all events. Chilli has different vitamin Constituents as shown in Table 1.

### Table 1. Composition of different vitamin constituents in Chilli
(Source: Modified from USDA National nutrient database)

<table>
<thead>
<tr>
<th>Composition of different vitamins Constituents</th>
<th>Green chilli, raw</th>
<th>Red chilli, raw</th>
<th>Spices, red or cayenne</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin A</td>
<td>530 IU</td>
<td>428 IU</td>
<td>2185 IU</td>
</tr>
<tr>
<td>Retinol</td>
<td>0.0 mcg</td>
<td>0.0 mcg</td>
<td>0.0</td>
</tr>
<tr>
<td>Retinol activity equiv.</td>
<td>26.5 mcg</td>
<td>21.6 mcg</td>
<td>109</td>
</tr>
<tr>
<td>α-Carotene</td>
<td>10.4 mcg</td>
<td>16.2 mcg</td>
<td>0.0</td>
</tr>
<tr>
<td>β-Carotene</td>
<td>302 mcg</td>
<td>240 mcg</td>
<td>1146</td>
</tr>
<tr>
<td>β-Cryptoxanthin</td>
<td>22.5 mcg</td>
<td>18.0 mcg</td>
<td>328</td>
</tr>
<tr>
<td>Lycopene</td>
<td>0.0 mcg</td>
<td>0.0 mcg</td>
<td>0.0</td>
</tr>
<tr>
<td>Lutein + Zeaxanthin</td>
<td>326 mcg</td>
<td>319 mcg</td>
<td>691</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>109 mg</td>
<td>64.7 mg</td>
<td>4.0</td>
</tr>
<tr>
<td>Vitamin K</td>
<td>6.4 mcg</td>
<td>6.3 mcg</td>
<td>4.2</td>
</tr>
<tr>
<td>Thiamin</td>
<td>0.0 mg</td>
<td>0.0 mg</td>
<td>0.0</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>0.0 mg</td>
<td>0.0 mg</td>
<td>0.0</td>
</tr>
<tr>
<td>Niacin</td>
<td>0.4 mg</td>
<td>0.6 mg</td>
<td>0.5</td>
</tr>
<tr>
<td>Vitamin B6</td>
<td>0.1 mg</td>
<td>0.2 mg</td>
<td>0.1</td>
</tr>
<tr>
<td>Folate</td>
<td>10.4 mcg</td>
<td>10.4 mcg</td>
<td>5.6</td>
</tr>
<tr>
<td>Food folate</td>
<td>10.4 mcg</td>
<td>10.4 mcg</td>
<td>5.6</td>
</tr>
<tr>
<td>Folic Acid</td>
<td>0.0 mcg</td>
<td>0.0 mcg</td>
<td>0.0</td>
</tr>
<tr>
<td>Dietary folate equiv.</td>
<td>10.4 mcg</td>
<td>10.4 mcg</td>
<td>5.6</td>
</tr>
<tr>
<td>Vitamin B12</td>
<td>0.0 mcg</td>
<td>0.0 mcg</td>
<td>0.0</td>
</tr>
<tr>
<td>Pantothenic acid</td>
<td>0.0 mg</td>
<td>0.1 mg</td>
<td>-</td>
</tr>
<tr>
<td>Choline</td>
<td>5.0 mg</td>
<td>4.9 mg</td>
<td>2.7</td>
</tr>
</tbody>
</table>

One of the most important factors to consider in order to preserve the quality of agricultural commodities is postharvest loss. The quality of fruits can be significantly reduced by handling them incorrectly. One tactic to preserve the quality of fruit or fresh cut fruit after harvesting is to apply an edible coating. Because it is now easier to consume fresh cut fruit without having to peel it, the amount consumed has increased. But the fruit is readily damaged because it is not covered by a protective layer [7]. If chilli is kept at room temperature, its quality will deteriorate after two to three days. If stored in a room with a low temperature (5-7 °C) and a high humidity level (90-95%), chilli can last for 10-20 days. Equipment that is not inexpensive will undoubtedly be needed for the storage of chilli fruits in cold climates, particularly if the fruits must be sold in locations distant from the harvesting site. According to earlier studies [8], applying an edible coating to sliced fruit can help prevent weight loss,
preserve vitamin C levels, postpone deterioration, and preserve sensory qualities, particularly firmness and color. According to a number of earlier research, applying an edible coating to fresh fruit and vegetables can help preserve their freshness.

The characteristics of the harvested goods are significantly influenced by the cultivation process [9]. Due to its year-round high demand, red chillies are one of Indonesia's most significant agricultural commodities. This product is very perishable and deteriorates quickly. The moisture content of red chillies is high roughly 90%. Red chillies are quickly harmed by transpiration because of the high moisture content, which persists even after harvest. The respiration process, which continues after harvesting, is what causes the decrease in weight loss, color change, and vitamin C levels. In order to prevent damage to fruit, fruit packing and coating are therefore required. These materials have the ability to lower and suppress the rate of respiration and transpiration. Using an edible coating is one possible method to lessen the harm done to red chillies. The formation of a semi-permeable barrier by edible coating allows it to alter the interior atmosphere of the fruit, postponing maturity and reducing the rate of fruit transpiration. Coating restricts the release of gas, moisture and contact with oxygen, therefore the transpiration and respiration process can be slowed down. As per [10] *Pseudomonas solanacearum*-caused anthracnose disease, which originates from Colletotrichum species, is a major hindrance to the cultivation of chillies. In addition, viral illnesses like cucumber mosaic virus (CMV) and chilli veinal mottle virus (CVMV) might reduce the yield of chillies. According to reports, anthracnose disease is a major issue that causes losses in the production of chillies in tropical and subtropical regions. Green chillies are vulnerable to insect and pathogen attacks either before or after harvest, which can have an impact on the nutrients that determine how they look on the outside and reduce their vitamin C content while they are being stored. Due to its non-climacteric nature, green chillies deteriorate quickly after harvest, causing significant losses. The green chillies are vulnerable to fungal infection because of their high moisture content (60–85%) during harvest [11].

Common problems with postharvest handling and storage include quality degradation, shrivelling with weight loss, skin color changes, and chilling injury when stored at temperatures below 7 °C. Due to these issues, green chillies finally become an extremely perishable food [12]. However, compared to bell peppers, very few attempts have been made to extend the shelf life of green chillies. The medicinal qualities and extensive usage of chilli fruit require that its production be sustained globally. A number of biotic and abiotic diseases have attacked in recent years, causing in a decline in fruit production. Fungi, such as anthracnose, Fusarium wilt, damping-off, dry root, stem rot, and collar rot, are believed to be the primary causes of these losses. Colletotrichum truncatum alone caused anthracnose in chillies, which reduced yield by 50% worldwide.

2. Edible Coating

A thin layer of an edible substance known as an edible coating can act as a barrier against oxygen, moisture vapor, and the transfer of dissolved components to meals. Foods can be directly coated with edible materials using a variety of techniques, including dipping, spraying, and bruising [13]. Because edible coating is biodegradable, composed of materials that are safe for ingestion, and helps to preserve the quality of food products, it is advantageous for the environment [14]. Edible coatings can be applied on processed food in addition to the surface of fresh commodities to enhance the product's quality. Products can be coated with edible material by spraying or dipping. Recently, the use of tubers as a raw material for making edible coatings has been studied when harnessing natural resources. the utilization of tubers due to their high starch content. Prior studies have documented the potential benefits of using tuber starch as an edible coating raw material, including increased product quality. The use of plasticizer in the edible coating manufacturing process is a crucial factor in determining the suitability of the coating [13].

2.1 Properties of edible coating

Molecule size and composition have less of an impact on edible coating properties than molecular structure. Not every material can be used to coat something. According to [14], edible films and coatings must meet particular requirements. It must be water-resistant to stay in place after application and properly cover the product; it should not degrade the quality or flavor of fruits or vegetables or introduce any irritating or unwanted aroma.

It shouldn't create an excessive amount of carbon dioxide or lower oxygen levels. A minimum of 1-3% oxygen must be present in the area surrounding a commodity in order to prevent the transition from aerobic to anaerobic respiration. It should be visually appealing, preserve structural integrity, enhance mechanical handling qualities, and convey volatile taste components. Vitamins and antioxidants are examples of active ingredients that Water vapor permeability should be reduced. It should be easily emulsifiable and non-sticky. It should also be capable of performing well after drying and not tacky. The coating should dissolve in a variety of solvents, including alcohol, water, and mixtures of several solvents. It should have a low viscosity and be reasonably priced. The coating
material should be able to sustain light pressure and be translucent to opaque not like glass. It should melt without breaking down over 40 °C.

2.2. Composition of edible coatings

Edible coatings are recognized to enhance food quality because they act as selective barriers to moisture transfer, oxygen uptake, and the loss of volatile tastes and odors. Researchers have learned a great deal about edible coatings' moisture barrier qualities by examining their water vapour properties, as water plays a crucial role in the processes that lead to food deterioration. But the primary source material from which edible coatings are made has a significant impact on their barrier properties. The majority of edible coatings are composed of naturally occurring polymers such as proteins, lipids, and polysaccharides that have the ability to form films. Edible coatings are made with chemicals that form films. It consists of proteins like whey protein, casein, collagen, keratin, gelatin, soy protein, cornzein, wheat gluten, peanut protein, cottonseed protein, etc., and polysaccharides like starch, cellulose, chitin, chitosan (Cs), pectins, alginates, etc. and lipids like wax and oil-based coatings, fatty acid resins and emulsions, monoglycerides [14].

During the production of edible coatings, the film materials are dissolved and distributed in solvents such as water, alcohol, or a combination of the two, or in a mixture of several solvents. This technique can be used to add plasticizers, antimicrobials, vitamins, minerals, colors, and flavors. To promote dispersion for a given polymer, the pH may be adjusted and/or the solutions heated. Freestanding films are created by casting and drying the film solution at an appropriate temperature and humidity level. The film solutions can be applied to food in a variety of ways, such as dipping, brushing, spraying, and panning, and then allowed to dry [15], [16]. But proteins, lipids, and polysaccharides can't provide the necessary protection on their own; therefore, they work better when combined [17].

3. Methods of edible coating application

The method of application, which is based on the nature of the commodity to be coated, surface characteristics, rheological features of the solution, and the coating's primary objective, is a major determinant of the efficiency and success rate of edible coatings in preserving fruits and vegetables [18]. Coatings must stick to the product surface in order to fulfill their intended function [19]. The interface interaction that takes place between the product surface and the coating is measured using wetability. This factor should be taken into account while assessing the coating solution's efficacy on the product's surface [20].

3.1. Dipping

One of the most widely used techniques for coating fruits in laboratories is immersion because of its simplicity, lack of equipment requirements, and uniformity of film application. With this method, the entire surface of the produce is submerged in the film-forming solution steadily, making sure that every square inch of it is moist [21]. Extra solution is drained from the fruit surface after application in order to eliminate any excess [22]. The surplus liquid and solvent evaporated when the produce was dried, leaving the film in contact with the food's surface. After the solution has been drained, drying can take place either naturally or with the help of a heated air tunnel.

Coating solutions with a broad range of viscosities can be used with this technique [23]. A disadvantage of this procedure is the possibility of cross-contamination between fruits during the immersion process due to residue and microbiological organism build-up [24]. To avoid this problem, the produce that will be coated must be well cleaned and sanitized, and the coating solution must be changed on a regular basis [25]. According to Raghav et al., 2016 [26], fruits and vegetables are usually immersed in the coating solution for a duration of 5 to 30 seconds.

3.2. Spraying

The spraying method provides a consistent and visually appealing covering and is most frequently used in packing houses. It also stops contamination of the coating solution [27]. This process raises the fluid's surface area and distributes it throughout the product by forming drops [24]. The fruit or vegetable is sprayed under manually or mechanically operated dispersion nozzles, either on a tray or on rotating rollers at a synchronized pace. This technique is repeated until the appropriate coating thickness is achieved. The drawback of this technique is that viscous liquids block the apparatus, making it impossible to spray them [28].

3.3. Hand coating

Wearing gloves is an additional method of applying the filmogenic solution to the fruit's surface. Wearing rubber gloves, one can apply a uniform layer of coating solution to fruits with their hands. On a laboratory scale, it is appropriate to minimize solution waste and prevent contamination during
screens. The uneven coating thickness that forms on the fruit surface is a disadvantage, though [29].

4. Potential active components that edible coatings could contain

One of the unique qualities of edible coatings is their capacity to introduce active ingredients into the matrix and enhance its efficacy and usefulness. Antioxidants, antimicrobials, and other functional chemicals can therefore be added to produce to significantly improve its quality, stability, safety, and shelf life.

4.1. Nutraceuticals

Researchers have attempted to add vitamins, minerals, and fatty acids to the composition of edible coatings in an effort to increase the nutritional value of particular fruits and vegetables that are lacking in certain micronutrients. The amount of nutrients added to the coatings needs to be carefully studied because it is critical to comprehend the effects on the basic functionality of coatings, particularly on their mechanical and protective properties [30]. Investigated the feasibility of delivering high concentrations of calcium (5 or 10% w/v) and vitamin E (0.1 or 0.2% w/v) via edible films based on milk proteins.

4.2. Texture enhancer

Pectic enzymes cause the firmness of fruit tissues to extensively deteriorate while they are being stored. The most common way to keep fresh fruit from softening is to treat it with calcium salts. Pectic polymers found in fruits and vegetables react with calcium ions to form a network that increases mechanical strength, delays senescence, and controls physiological disorders [31]. Texture enhancers can be incorporated into the coating composition to lessen the production of softening phenomenon.

4.3. Antimicrobial agents

Another potential method to improve produce safety is to use edible coatings as carriers of antimicrobial chemicals. During post-harvest processing, the epidermis's physical and chemical barrier that keeps germs from growing on crop surfaces is broken. Soaking product in antimicrobial-rich aqueous solutions is the most feasible way to increase its microbiological lifespan. However, because the active ingredients quickly neutralize or diffuse into the product, applying antimicrobial compounds/agents directly to the surface may have limited effects and reduce the efficiency of antimicrobial compounds. Thus, by maintaining effective concentrations of the active ingredients on the product surface, antimicrobial edible coatings may provide enhanced inhibitory qualities against spoiling and hazardous microorganisms [32].

The edible coatings can have a variety of antibacterial chemical additions. These consist of fatty acid esters, polypeptides (peroxidase, lysozyme), organic acids (acetic, lactic, and benzoic acid), essential oils derived from plants (cinnamon, lemon grass, etc.), and nitrates and sulphates [33].

5. Characterization of edible coating

Evaluating edible coatings is an essential stage in confirming their suitability and efficacy in maintaining the safety and quality of food products. Evaluations of the coatings' mechanical strength, adherence to the food surface, thickness, evenness, microstructure, and suitability as barriers are all part of this process. To evaluate a coating's ability to prevent moisture loss and oxygen exposure, it is crucial to evaluate its barrier qualities, such as its ability to withstand water vapor and oxygen transmission. The impact of a 2% montmorillonite nano-clay and a carnauba wax coating on the freshness and shelf life of blood oranges was examined in a study.

Following coating application, the fruit had increased firmness, color, antioxidant activity, and overall acidity after being stored for 100 days at 7 °C. The mechanical characteristics, which include resistance to punctures, tensile strength, and flexibility, aid in determining how well the coatings can withstand handling and protect the food product [34]. Understanding the inner structure of the coating can be gained by analyzing the microstructure using methods like atomic force microscopy (AFM) and scanning electron microscopy (SEM). Additionally, adhesion testing evaluates how well the coating adheres to the food surface, and coating thickness and uniformity measurements guarantee constant performance [35]. Manufacturers can adjust their formulas and application methods to meet the unique needs of various food products by characterizing edible coatings, which will ultimately increase the shelf life and quality of such products [36].

6. Different types of coating materials

6.1. Chitosan

Fruit deterioration can be managed by utilizing the potent antibacterial and antifungal capabilities of chitosan (2-amino-2-deoxy-β-d-glucan). It is a naturally occurring substance that is extracted from
the shell of shellfish. Chitosan is naturally non-toxic and biodegradable. Chitosan is an edible covering made of polysaccharides. Chitosan has the ability to create a transparent coating on the outside of vegetables, which modifies the permeability of oxygen and carbon dioxide and lowers the rate of respiration. Vegetable ripening can also be delayed by using chitosan coating. Additionally useful in preventing fungal infections, weight loss, and tomato, cucumber, and bell pepper wilting is chitosan coating.

[37] carried out an experiment to investigate how chitosan and gum Arabic affect the rate of respiration and amount of vitamin C in green chillies. Different concentrations of chitosan (0%, 1%, 1.5%, and 2%) and gum arabic (0%, 5%, 10%, and 15%) were utilized, with three replications (R1, R2, and R3) for each treatment. For fifteen days, the coated fruits were kept at room temperature (28 °C). Gum Arabic at 10% and chitosan at 1.5% concentration produced the greatest outcomes. After 15 days, the chilli fruit's respiration rate dropped to 42–62%. However, chitosan exhibits the least amount of respiration rate reduction (51.78%) at a concentration of 1.5%. After storing for 15 days, the vitamin C content of chilli fruits dropped by 72–98%. In comparison to chilli fruits that are not coated, chitosan at a 1.5% concentration slows down the loss of vitamin C.

In an experiment, iodate-coated chitosan was employed as an edible coating for chilli fruits by [38]. This coating contributes to the improvement of public health by preventing thyroid cancer. Chitosan-iodate was applied to chilli fruits at a concentration of 1.5 m. Chitosan-iodate solution was immersed into chilli fruits for five to seven minutes. The anti-oxidant effects of chilli were unaffected by the covering made of chitosan. The concentration of iodamate was measured at 620 nm using a spectrophotometer. Chitosan-based coating extended the chilli fruits' shelf life by 15 to 20 days. In [39] and colleagues investigated the impact of chitosan as an edible covering on a variety of vegetables, including tomato, brinjal, and chilli. They investigated the effects of chitosan against a variety of plant pathogens, including Pythophthora infestans, Colletotrichum acutatum, Rhizoctonia solani, and Fusarium oxysporum, because it possesses antifungal and antioxidant qualities. Chitosan was applied to vegetables at concentrations of 1%, 2%, 3%, 4%, and 5%. When compared to control veggies, vegetables with a 3% concentration of chitosan exhibited the best effects in terms of reducing weight loss and extending their shelf life. The efficacy of chitosan as an edible covering against the anthracnose illness in the chilli variety jinda was studied [41].

Colletotrichum gloeosporioides is the causative organism of anthracnose disease in chilli. Fruit with chilli peppers was covered with 1.2% and 1.6% chitosan. By postponing the onset of illness and weight loss, chitosan at 1.6% outperformed chitosan at 1.2%; however, it also ferments fruit. Chitosan, at 1.2%, increases the shelf life of chilli fruits by lowering respiration and ethylene generation rates; firmness loss and color changes are unaffected. More attention has been paid to combining multiple edible coating sources to increase the stability and efficacy of edible coatings [42] found that red bell peppers coated with a chitosan-gelatin mixture had a much lower incidence of microbial deterioration than a gelatin-based coating treatment, improved fruit firmness, and extended shelf life.

According to [43], blueberries with an edible covering made of chitosan-A. vera liquid fraction could have their microbial growth inhibited by up to 50% and their shelf life extended by about five days. According to these earlier research, combining two or more coating sources may be a better option than using just one to enhance the physicochemical characteristics of fruits. An alternate postharvest method, chitosan and A. vera gel-based coatings could be employed to enhance the quality of red chillies while they are being stored. The optimal mixture, consisting of 10% A. vera and 2% chitosan, showed the lowest percentage of red chilli degradation (43%) across all formulations. Additionally, this coating formulation exhibits strong antifungal action, potentially inhibiting Colletotrichum capsici mycelium development by up to 52%. In general, an edible covering composed of chitosan and A. vera is harmless. When compared to coatings made entirely of chitosan or 100% pure A. vera gel, it can offer a less expensive option. To effectively improve coating performance, it is worthwhile to investigate certain technical coating application and formulation improvements.

6.2.Gum Arabica

Grown in sub-Saharan Africa, the acacia tree (Acacia senegal L.) yields gum Arabica, a soluble fiber. Gum Arabic is a film-forming chemical that finds applications as an emulsifier, thickening agent, and coating material. It has been discovered that gum Arabic coating works well to extend the shelf life of tomatoes and cucumbers. 2018 saw research on the impact of a composite edible coating on green chillies. For this study, a composite edible coating made of tween 80 (0.05%), thyme oil (0.5%), glycerol (1%), and gum Arabic (5%), is prepared in order to extend the shelf life of fresh green chilli. The fresh chilli is then immersed in the edible coating solution for one to three minutes at room
temperature. The study's findings indicate that coated chillies retain more of their ascorbic acid, total chlorophyll content, color, firmness, and good organoleptic qualities than uncoated ones. They also show less weight loss and better production of phenolic acid and capsicain. In addition, the shelf life of coated chilli is improved to 12 days, compared to 6 days for uncoated chilli. The impact of gum arabic as an edible coating on enhancing the postharvest quality of potato tubers was studied [44]. This study sought to determine how 10% gum arabic, combined with 1% glycerol and 1% CaCl2, affected potato tubers stored for 35 days at 8 °C and 30±5 °C as an edible covering. The total counts of molds, yeast, and bacteria as well as the pH, weight loss percentage, and total soluble solids (TSS) observations had all been analyzed. Potato tubers with a gum arabic composite covering can last up to 32 days on the shelf, however fruit that isn't coated deteriorates after 25 days at 8 °C. Potato tuber samples that were coated with gum arabic composite coating and stored at 30±5 °C showed no signs of deterioration for up to 30 days. The impact of gum arabic and fruwash coatings on the postharvest quality of summer squash (Cucurbita pepo) was examined [45]. In order to minimize moisture loss on the summer squash, they investigated the effects of gum arabic concentrations of 5, 10, and 15% as well as fruwash, an edible coating that was stored at 10 °C. When compared to fruwash-coated fruit and control, gum arabic at a 10% concentration produced the greatest results in terms of limiting water loss and color retention (Lvalue). At 10% concentration, the proline content in gum arabic coated samples (235.052 g/g fruit weight) was 68% greater than that of the control group (140.06¢ g/g fruit weight). Strong antibacterial and antifungal properties of chitosan make it a promising tool for controlling fruit deterioration. It was simple to coat fruits and vegetables, and by modifying the permeability of carbon dioxide and oxygen, it was possible to lower the pace at which the fruits and vegetables respired. Owing to chitosan's outstanding qualities, it has been effectively used to a variety of postharvest fruits and vegetables, including guava, fresh-cut lotus root, strawberries, grapes, and jujube. Gum Arabic, also known as Acacia seyal Delile or Acacia senegal (L.) Willd., is a soluble fiber derived from acacia trees cultivated in sub-Saharan Africa. Gum Arabic is a common emulsifier, thickening agent, and film-forming substance. According to reports, tomatoes and cucumbers can have their shelf lives extended by coating them with gum Arabic. Gum Arabic and chitosan coating can preserve the banana's permeability to CO2 and O2, creating the ideal modified environment and extending its shelf life. Chillies have not yet been coated with edible coatings made of chitosan and gum Arabic. Consequently, the primary goal of the current study was to determine how treatment modifications in the concentrations of gum Arabic and chitosan could extend the shelf life of chilli fruits, particularly in terms of regulating respiration rate and vitamin C content. An approach for preserving fruits and vegetables would be to apply chitosan and gum Arabic together as an edible coating. For a period of fifteen days, the chitosan and gum Arabic combination was able to keep the respiration rate of the chilli fruits constant while gradually reducing their vitamin C content.

6.3. Cassava starch

Starch is a naturally occurring carbohydrate polymer made up of anhydro glucose residues. Amylose, a polymer of glucose with a branched chain structure, and amylase, a linear chain polymer, are the two primary components of starches. Starches are naturally limited in many industrial processes and technological applications.

The functional qualities of starch, as well as edible starch-based films, coatings, and foams, can be enhanced through modification. Chemical modifications such as crosslinking, esterification, and etherification can enhance the functional characteristics of starch. Because of its high amylose content (17% w/w), cassava (Manihot esculenta crantz) is one of the plants with the ability to make cassava starch form films and improved qualities [46]. However, without any prior chemical processing or plasticizer, cassava starch can make flexible films and translucent coatings [47]. Coatings made of cassava starch have no taste, smell, or look and don't alter the product's flavor or appearance. Despite being a cheap and plentiful substance that can build a continuous polymer matrix, starch has a strong hydrophilic nature, making it a poor barrier to water vapor. Edible films and coatings can improve the quality and extend the shelf life of nearly any food system. Edible films and coatings have the ability to regulate the transmission of flavor, fragrance, fat, oxygen, and carbon dioxide between food ingredients as well as to and from the environment around the food.

According to [48], an edible coating is often defined as a thin layer of edible material created on a food, whereas an edible film is a thin layer of edible material that has already been prepared and placed on or between food components. Cross-linking, acetylation, oxidation, blending with other polymers, creating composite films, and combining blending with composite film production are methods that can improve the mechanical properties
of starch-based films [49]. The acetylation of cassava starch resulted in the enhanced mechanical and physical characteristics of the starch-based films. The results of another experiment involving the combination of chemical and physical modification of cassava starch with acetic anhydride show that a high concentration of acetic anhydride will enhance the modified starch's ability to swell. Examining how modified cassava starch differs from natural starch in terms of physicochemical qualities and creating an edible coating from both natural and modified starch under ideal conditions are the main goals of this project.

6.4. Gelatin

Gelatin possesses favorable mechanical, optical, and gas flow-barrier qualities [50]. Gelatin from the waste of the fish business is an additional source of gelatin that can be used. Utilizing by-products or agro-industrial and aquatic waste, such as fish skin by-products from tilapia, will increase economic value and benefit society and the environment [51]. The hydrophilic character of gelatin results in a rather high water vapor permeability (WVP) value, which limits the use of gelatin and necessitates improving this feature [52]. Adding polysaccharides like pectin to gelatin is one method of enhancing its qualities and addressing these shortcomings. Pectin is an excellent mechanical property and an effective oil and oxygen barrier [53]. Although edible coatings, such as chitosan coating, have been used extensively on chilli peppers themselves, gelatin has been used extensively in food preparation. This has been shown to preserve quality and lessen damage to green peppers [54]. By using antimicrobial substances like essential oils to delay spoiling, we can enhance the mechanical and functional qualities of edible coatings in addition to composites. Widely used essential oils, such as rosemary in fish gelatin, have been demonstrated to lower WVP by as much as 54% because they are hydrophobic, which enhances the hydrophilic qualities of gelatin. Furthermore, mycotoxins in corn and edible films are composed of protein, and garlic essential oil has antifungal properties [55].

Numerous research have been conducted on the application of edible coatings made of composite materials on fruits and vegetables, particularly those that are high in chilli content. In comparison to single coatings (noncomposite coating) and untreated fruit, Outstanding firmness preservation was demonstrated by applying a chitosan-gelatin composite material as an edible coating to post-harvest red bell peppers. As far as we are aware, there aren't any publications on how this composite works together to increase the shelf life and maintain the quality characteristics of red chillies or how to use an edible coating made of gelatin and pectin that incorporates garlic essential oil into the chilli to extend its useful life. Therefore, the goal of this experiment was to determine how applying an edible coating made of gelatin and pectin composite with added garlic essential oil affected the red chillies shelf-life, weight loss, and physicochemical characteristics (color, firmness, vitamin C, and titrable acidity), as well as the incidence of disease during postharvest storage at room temperature.

6.5. Aloe-vera gel

Aloe-vera gel is made from the leaves of the aloe-vera plant, and it contains antibacterial and antioxidant qualities. Aloe-vera gel is now widely utilized in a variety of beverages, face washes, shampoos, soaps, and other products. In addition, aloe-vera gel is employed as an edible vegetable coating due to its antibacterial qualities, which inhibit the growth of germs, mold, and yeast. Aloe vera gel coatings also aid in lowering ethylene generation rates, respiration rates, and peroxidase and polyphenol oxidase activities. Aloe vera gel functions as a barrier between the internal and exterior atmosphere, which lowers the rate of respiration in fruits and vegetables when coated. The application of aloe-vera gel to grapefruits demonstrates how the coating helps to retain moisture, maintain firmness, regulate fruit respiration and maturity, postpone oxidative browning, and inhibit the growth of microorganisms. Alginates chemical is extracted from brown seaweeds. In addition to serving as effective oxygen barriers, alginate coatings stop lipid oxidation. Alginate can lessen microorganism counts and weight loss in carrots that have undergone minimal processing.

An experiment was carried out to assess the impact of chitosan coating and aloe-vera gel on the quality features of red chilli. For fifteen days, red chilli was kept at room temperature after being treated with varying concentrations of chitosan (1, 1.5, and 2%) and aloe-vera gel (5 and 10%). Aloe-vera gel at 10% and chitosan at 2% concentration were shown to be helpful in demonstrating the least amount of red chilli degradation (43%). Strong antifungal characteristics of chitosan and aloe vera gel-based coating aid to limit Colletotrichum capsici mycelial growth by up to 52% [56].

7. Future trends

A new class of edible coatings is being developed with the aim of adding active ingredients and/or regulating their release by the application of nanotechnological methods such nanoencapsulation
and multi-layered systems. Nanotechnologies are now being used to enhance the nutritional value of food through the use of nanoscale additions, vitamins, and minerals, as well as nanosized delivery mechanisms for bioactive substances [57]. By being micro-and nano-encapsulated in edible coatings, active compounds can be shielded from heat, moisture, and other hostile environments. This can help regulate their release in specific situations [58]. As a result, they will be more stable and viable and will be shielded from these surroundings [59]. Alginate is the substance that is most commonly used for encapsulating, while materials from other sources may also be used. The most beneficial substances to be enclosed are marine oils (omega-3 fatty acids), prebiotics, probiotics, and enzymes. Conversely, there is intriguing potential in the use of layer-bilayer (LbL) multi-layered nanolaminate systems, in which interfacial films consisting of multiple nanolayers cover the charged surfaces [60]. Immersing the substrate repeatedly in coating solutions containing species with opposing charges is the method that creates structures with numerous layers. Foods are sprayed with materials to form a nano laminated coating, or they are dipped in a series of fluids containing compounds that will eventually be adsorbed by their outermost layer [61]. The only ingredients in these nanolaminate coatings that are safe for ingestion are proteins, lipids, and polysaccharides. A range of functional additives, including flavorings, colors, enzymes, antimicrobials, and anti-browning agents, may also be included [62].

8. Conclusion
Coatings can stop perishable fresh food from going bad by slowing down dehydration, stopping respiration, improving texture quality, helping to retain volatile flavor compounds, and reducing microbial contamination. Future trends will surely see a rise in the importance of edible coatings with specific purposes, as consumer desire for minimally processed, fresh produce grows. Protein- and polysaccharide-based coatings are becoming more and more popular as substitutes for traditional lipid coatings, especially those that have inherent antifungal or antibacterial qualities. These coatings usually perform effectively as moisture barriers but poorly as oxygen barriers at low to moderate humidity levels. The main goal of reducing the moisture loss from commodities with edible coatings must be accomplished by continuing efforts to develop stable emulsion coatings with the appropriate moisture-barrier properties. Meanwhile, investigations to increase the coating's adhesion and permanence on the outer layer of fruits and vegetables, as well as studies on the sensory quality and customer acceptability of coated foods, are needed.

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Conflict of interest
The authors declare that they have no conflict of interest.

9. References
11. S. Charmongkolpradit, K. Triratantasirichai, N. Srihajong. Drying characteristics of chilli using


36. X. Fang, Y. Li, Y.L. Kua, Z.L. Chew, S. Gan, K.W. Tan, H.L.N. Lau. Insights on the potential of natural deep eutectic solvents (NADES) to fine-tune durian seed gum for use as edible food coating, Food Hydrocolloids 132 107861 (2022).


