

# NANOCOATING-FRONTIER

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# Nano Coating of Aloe-Gel Incorporation Additives to Maintain the Quality of Freshly Cut Fruits

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The edible coating is an environmentally friendly technology that is applied to fresh-cut fruit products. One of the natural ingredients that are potentially applicable is aloe-gel because it contains several functional components. The main advantage of aloe-coating is that additives can be incorporated into the polymer matrix to enhance its properties. Additives tend to improve the safety, nutritional, and sensory attributes of fresh fruits, but in some cases, aloe-coating does not work. Furthermore, particle size determines the effectiveness of the process on fresh-cut fruits. Aloe-gel nano-coating can be used to overcome the difficulty of adhesion on the surface of fresh-cut fruits. However, quality criteria for fresh cut fruit coated with aloe-gel nano-coating must be strictly defined. The fruit to be processed must be of minimal quality so that discoloration, loss of firmness, spoilage ratio, and fruit weight loss can be minimized. This study aims to discuss the use of nano-coating aloe-gel incorporated with additional ingredients to maintain the quality of fresh-cut fruits. It also examined the recent advances in preparation, extraction, stabilization, and application methods in fresh fruits.

**Keywords:** aloe-gel, fresh-cut, fruit, nano-coating, shelf-life

## INTRODUCTION

Fresh-cut fruits are being grown rapidly and are popular, especially during the pandemic due to the high consumer demand as they are considered fresh, convenient, safe, nutritious, and healthy food. Some of the advantages of fresh-cut fruits are short preparation, reduced household waste, uniform quality, smaller volume, and cheaper transport costs (Suriati et al., 2020b; Chen et al., 2021; Deshi et al., 2021). However, the process of removing the peel causes a rapid reduction in the quality of fresh-cut fruit as well as a shorter shelf life (Awad et al., 2021; Zhao et al., 2021). One of the environmentally friendly ingredients that can be applied is edible coating combined with cold (Maringgal et al., 2020; Basaglia et al., 2021; Bassej et al., 2021; Liu et al., 2021). The advantage of using this method is that some active ingredients can be incorporated into the polymer matrix and consumed with food, to maintain its nutritional and sensory attributes (Rehman et al., 2020; Tabassum and Khan, 2020; Deshi et al., 2021; Ochoa-Velasco et al., 2021). One of the potential natural ingredients applicable as edible coating for fresh-cut fruits is a polysaccharide found in aloe vera gel (Aloe-gel) that contains functional components (Rehman et al., 2020; Shah and Hashmi, 2020; Hasan et al., 2021).

Aloe-gels have the advantages of being biodegradable, permeable to oxygen, antioxidant power, and low toxicity effects (Chauhan and Kumar, 2020; Sánchez et al., 2020; Sonawane et al., 2021). However, in some cases, the edible coating does not maximize its role in maintaining quality and extending the shelf life of the fruit. The stability of aloe-gel also decreases when stored at room

temperature and the size of its particles determines the effectiveness of the coating process (Suriati et al., 2020c; Sonawane et al., 2021). Nano edible coating or nano-coating of aloe-gel incorporated with additives can be used to overcome the difficulty of material adhesion on the fresh-cut surface of the fruit (Sánchez et al., 2020; Basseyy et al., 2021). Food additives that are applicable include citric and ascorbic acids as well as potassium sorbate as an acidulant, antioxidant, and antimicrobial, respectively (Nascimento et al., 2020; Rodríguez et al., 2020; Tkaczewska, 2020; Manzoor et al., 2021; Suriati et al., 2021a). Quality criteria for fresh cut fruit coated with aloe-gel nano-coating must be strictly defined. The fruit to be processed must be of minimal quality so that discoloration, loss of firmness, spoilage ratio, and fruit weight loss can be minimized. This review discusses the use of nano-coating of Aloe-gel incorporated with additional ingredients to maintain the quality of fresh-cut fruits in cold storage.

## FRESH-CUT FRUIT

The minimal processing of fruits is a preparation and handling effort to maintain natural freshness without degrading quality, and nutrition, as well as extending the shelf-life of products (Suriati et al., 2020d; Sadler et al., 2021; Silveti et al., 2021). Fruit minimal processing products are also known as fresh-cut fruits (Chen et al., 2021; Yousuf et al., 2021). They are produced through cleaning, washing, trimming/peeling, coring, slicing, shredding, and packaging (Tabassum and Khan, 2020). According to Etemadipoor et al. (2020), García-Pastor et al. (2020), Nourozi and Sayyari (2020), Suriati et al. (2020b), Ali et al. (2021), fresh-cut fruit storage is usually carried out at low temperatures.

Some of their advantages include presenting consumers with a variety of choices in one package, short time of preparation, reducing household waste, directly showing the internal condition of the product, to guarantee the quality compared to the whole fruit, and easy assessment of the quality of the products purchased, uniform and consistent, lower product volume, and cheaper transport costs (Nicolau-Lapeña et al., 2021). Fresh-cut fruits circulated in the market currently include mango, mangosteen, rambutan, jackfruit, melon, watermelon, papaya, durian, orange, pineapple, and fruit mixture (Alves et al., 2017). They are widely found in supermarkets, fast food restaurants, and catering services. Furthermore, some of the considerations needed in handling post-harvest fresh-cut fruit are physiological, physical, and pathological (Wen et al., 2020; Xu et al., 2020; Awad et al., 2021; Deshi et al., 2021). Whole cells and injured or cut cells are shown in **Figures 1A,B**. The minimal process also has an impact on product deterioration; hence, handling techniques are needed to maintain quality and extend shelf life as shown in **Figure 2**. Measures to overcome problems arising from minimal processing include the use of food additives that can extend shelf life, and edible coating as a primary packer to preserve as well as maintain the freshness and quality of the product (Hasan et al., 2021; Ochoa-Velasco et al., 2021; Paidari et al., 2021).

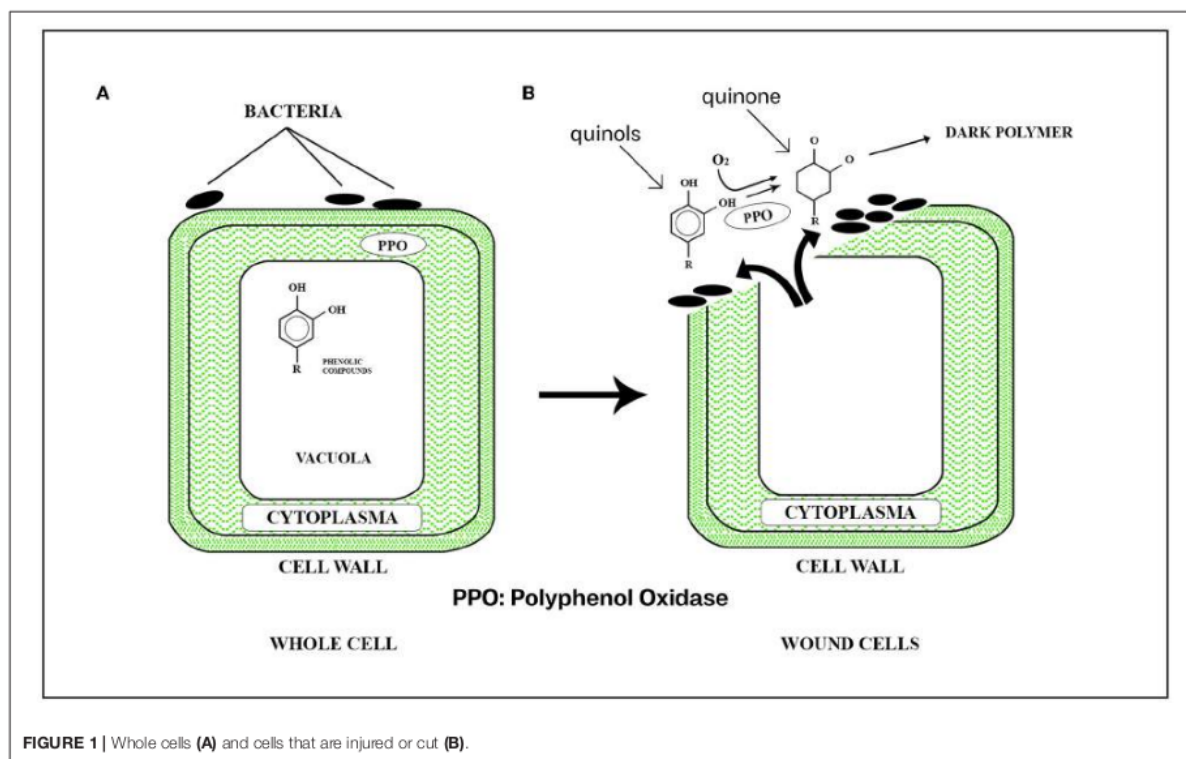
## EDIBLE COATING

Edible coatings are made from eatable materials and are part of all fresh-cut fruit products (Abu-Shama et al., 2020; Al-Tayyar et al., 2020; Anjum et al., 2020; Suriati and Suardani, 2021; Zhang et al., 2021). They are biodegradable, formed to coat a food, or placed between components that serve as a barrier to chemical, physical, and biological changes (Nicolau-Lapeña et al., 2021) such as mass decay by moisture, oxygen, light, lipids, and solutes, additive carriers, water vapor as well as the exchange of O<sub>2</sub> and CO<sub>2</sub> gases (Yu et al., 2021). According to Parven et al. (2020), La et al. (2021), Yu et al. (2021), the application of edible coating also serves to improve appearance in the form of bright and shiny colors, retaining moisture, prevent weight loss, as well as antimicrobials.

The use of edible coatings has been widespread since the mid-1980s and is likely to grow along with public awareness of the healthy and safe food benefits (Chottanom et al., 2020; Daniloski et al., 2021; Kuai et al., 2021; Mousavian et al., 2021). They are majorly used to protect products from the outside environment such as gas effects, water, evaporation, odor, microorganisms, dust, shock, vibration, and pressure (**Figure 3**). Oxygen gas levels must be monitored because it influences certain reactions that affect shelf life including microbial growth, discoloration, oxidation of fats that have an impact on freshness, and fruit maturation (Cheng et al., 2020; Sánchez et al., 2020; Ozturk et al., 2021; Praseptiangga et al., 2021; Rosu et al., 2021). The advantage of using edible coatings is that some active ingredients can be included in the polymer matrix and consumed with food, to maintain its nutrition and sensory attributes (Panahirad et al., 2021).

The constituent components of edible coating are divided into three groups namely hydrocolloids such as polysaccharides, proteins, and alginate; lipids including fatty acids, aryl glycerides, waxes, and composites namely protein-protein, polysaccharide-protein, and fat-polysaccharide formulated with the addition of surfactants and plasticizers as shown in **Figure 4** (Liu et al., 2021; Ochoa-Velasco et al., 2021; Paidari et al., 2021; Suriati et al., 2021b). The constituent components of edible coating can provide maximum protection in a combined form. The application of coatings in fruits and vegetables is carried out in several ways, namely dipping, foaming, spraying, casting, and controlled testing (Chottanom et al., 2020).

The effectiveness depends on the structure, size of the molecule, and chemical constituents. Special requirements are as follows; water, minimal 1–3% oxygen around the commodity, function as a barrier, permeable against gases, water vapor, volatile compounds, and solutes, form an emulsion, non-sticky, quickly dry, does not interfere with the quality of the fruit and can apply pressure. It must also have low viscosity, be transparent, tasteless, and do not give an unwanted influence on the coated product. The formulation of edible coatings does not contain harmful additives, technology, and the raw materials are relatively cheap (Nasrin et al., 2020; Parven et al., 2020; Tabassum and Khan, 2020; Tkaczewska, 2020; Umaraw et al., 2020; Le et al., 2021; Ozturk et al., 2021; Perdana et al., 2021; Piazzolla et al., 2021).



Edible coatings made from polysaccharides have also been developed to inhibit gas transfer and reduce respiration rates. Plant sources and chemical structures are very suitable as edible coatings, due to their great potential and safety when in contact with food (Ali et al., 2020; Le et al., 2021; Panahirad et al., 2021). Recently, the incorporation of antimicrobial compounds in food packaging has become a concern. Coatings with antimicrobial activity can help control the growth of pathogenic microorganisms and decay (Al-Tayyar et al., 2020; Ochoa-Velasco et al., 2021). Nano-additive antimicrobial coatings are in high demand due to their barrier properties and structural integrity (Das et al., 2020).

The function of edible coatings can also be improved by including antioxidant acidulant agents, and functional ingredients such as minerals and vitamins (Rodríguez et al., 2020; Zhang et al., 2020). Antioxidants are added to protect fruits against oxidation processes, degradation, and discoloration (Rodríguez et al., 2020; Zhang et al., 2020; Chen et al., 2021). For example, citric antioxidants and ascorbic acid are incorporated to control oxygen permeability and reduce the loss of vitamin C in fruit during storage (Nourozi and Sayyari, 2020; Gürbüz and Kahramanoglu, 2021). Several studies also applied edible coatings to preserve whole fruits such as cherry (Sánchez et al., 2020), papaya (Mendy et al., 2019), apple (Liu et al., 2021), grapes (Sellitto et al., 2021), mango (Ebrahimi and Rastegar, 2020), and apricot (Nourozi and Sayyari, 2020).

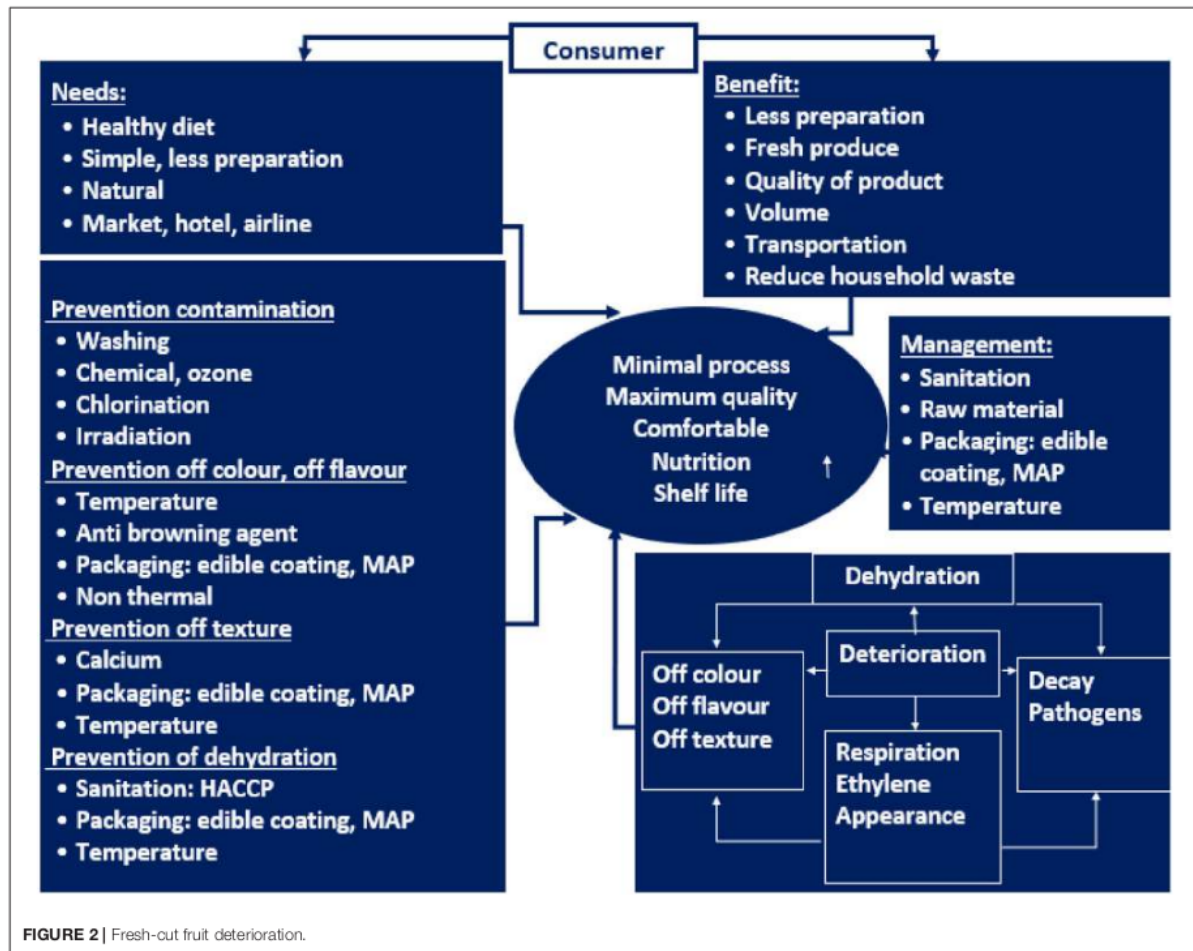
## EDIBLE COATING FOR FRESH-CUT FRUIT

The ability of edible coatings to maintain the quality of fresh-cut fruits differs depending on the product. Some factors to consider are the level of ripeness, surface coverage, storage conditions, as well as the composition and thickness of the layer (Tkaczewska, 2020; Nicolau-Lapeña et al., 2021; Suriati et al., 2021a). The application of edible coatings must report the problem of the adhesion on the surface of hydrophilic fruit slices (Salgado-Cruz et al., 2021; Suriati et al., 2022).

Furthermore, it aims to provide a modified atmosphere, time transfer inhibitors, reduce moisture and aroma loss, delay discoloration, and improve appearance (Chauhan and Kumar, 2020; Ochoa-Velasco et al., 2021). Another advantage of the edible coating is the reduction of synthetic packing waste because this layer consists of biodegradable raw materials (Yousuf and Qadri, 2020; Kumar S. et al., 2021; Le et al., 2021). Therefore, the potential use of fresh-cut fruit is to reduce the modification of the internal atmosphere, decrease decay, postpone maturation in climacteric fruit, prevent water loss, retain color and taste, increase the appearance, decrease the loss of aroma and moisture exchange between fruit and environmental cranks, as well as improve texture, antioxidant carrier, volatile compounds, and nutrients (Ochoa-Velasco et al., 2021).

One potential natural ingredient as an edible coating on fresh-cut fruit is aloe vera (Sánchez et al., 2020; Liu et al., 2021). Several studies reported that edible coatings can be used as agents





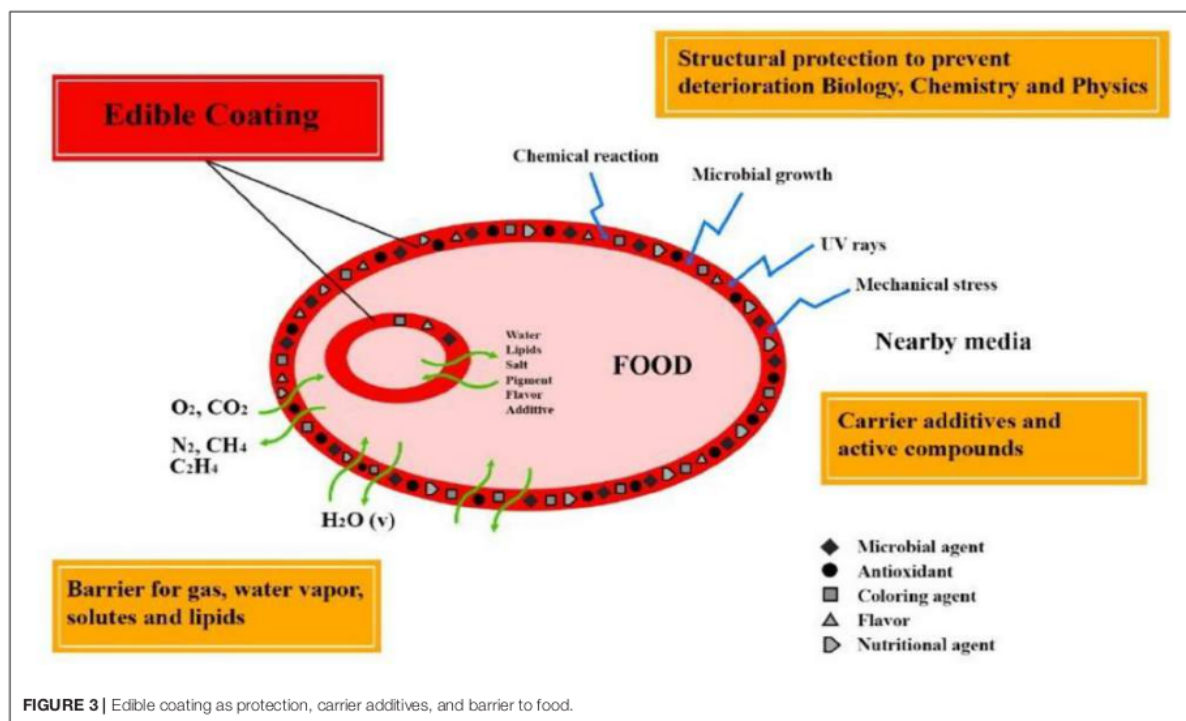
to inhibit microbes and reduce the detrimental effects of fresh-cut kiwi (Manzoor et al., 2021), mango (Suriati et al., 2020d), apples (Liu et al., 2021), cherry (Ozturk et al., 2019), guava (Rehman et al., 2020), and papaya (Parven et al., 2020). Aloe gel tends to reduce the rate of respiration, ethylene production, heavy shrinking, and softening. It can be used to extend the shelf life after harvest and maintain the product's sensory capabilities during the storage period (Chauhan and Kumar, 2020; Ehtesham Nia et al., 2021; Hasan et al., 2021).

## ALOE-GEL

Aloe vera belonging to the family Liliaceae has been used for thousands of years and is often called the wonder plant (Sánchez-Machado et al., 2017; Rehman et al., 2020). The species that is widely grown in Indonesia is *Aloe barbadense* Miller, which has the characteristics of bright green leaves with irregular white spots as well as an average weight of about 0.5–1 kg. The harvest

period ranges from 10 to 12 months after planting (Chauhan and Kumar, 2020; Suriati et al., 2020a) and the leaf layers are shown in **Figure 5**.

Aloe vera leaves consist of three parts: the first layer also called Aloe-gel contains parenchyma cells and produces mucilage that is clear and tasteless (Nourozi and Sayyari, 2020). It consists of polysaccharides, minerals, proteins,  $\beta$ -100 sitosterols, long-chain hydrocarbons, and esters (Liu et al., 2021). The second part is exudate which consists of yellow sap and colorless mucus. Yellow mucus contains various components such as anthraquinone along with its derivatives, aloin, barbaloin, aloe-emodin, and glycosides (Chauhan and Kumar, 2020). Anthraquinone is a phenolic compound that has anti-inflammatory, antioxidant, and antibacterial effects. Furthermore, colorless mucus contains various types of phenolic components, which act as antioxidants to inhibit free radicals, fat peroxidation, and enzymes. The third part is the outer layer or skin consisting of 15–20 cells, has a protective function, and synthesizes carbohydrates as well as proteins.



The chemical composition of aloe-gel is estimated to contain more than 75 chemical compounds (Sánchez et al., 2020). The biological activity of the leaf extract is largely due to the synergy of several compounds. Aloe-gel majorly contains water which ranges from 99 to 99.5% (Suriati et al., 2022), while the other contents are in the form of solids consisting of various compounds that are soluble in air, including fat, vitamin, minerals, enzymes, phenolics, polysaccharides, amino acids, lipids, sterols, and organic acids. Based on the dry weight analysis. Aloe-gel is composed of approximately 55% polysaccharides, 17% sugar, 16% minerals, 7% protein, 4% lipids, and 1% phenolics which have antioxidant and antimicrobial abilities (Farina et al., 2020; Sánchez et al., 2020; Suriati et al., 2022). Furthermore, acemannan (acetylated glucomannan) and glucomannan are the main functional components together with other various organic and inorganic constituents. Ace mannan is a rich polysaccharide unit of mannose located in the protoplasm of the parenchyma cell (Sánchez et al., 2020).

The various contents of aloe-gel depend on process, growth, soil, climate, and other geographical conditions. It can be used as a bio preservative and create a wax-like coating to increase shelf life (Ehtesham Nia et al., 2021). Moreover, aloe-gel is easy to apply, able to maintain moisture, and will produce maximal effects when used in fresh conditions (Suriati and Utama, 2019). According to Suriati et al. (2020a), the constituent enzyme is very active as it affects the bonds of compounds as well as the viscosity of the gel. When it is diluted, the viscosity decreases drastically close to that of water under a storage condition at

room temperature for 24–36 h (Farina et al., 2020) due to the hydrolysis of polysaccharides (Li et al., 2021). Furthermore, aloin which is bound as a glycoside in the presence of enzyme activity can form a free structure. Adlakha et al. (2021) stated that quinone and anthrax in Aloe-gel in the presence of light will cause a change in color. Aside from the discoloration, they also cause unpleasant flavors and loss of amino acids (Chauhan and Kumar, 2020; Yang et al., 2021).

## ALOE-GEL EXTRACTION

Gel extraction from leaves is an important step due to its applications in the food, drug, and cosmetic industries (Chauhan and Kumar, 2020). The fresh gel can be harvested directly from aloe vera leaves and stored for further use. The new aloe-gel extract is colorless, thick, slimy, and clear with connective tissues, while the quality is determined by species and growing state, including climate, amount of water, fertilization, as well as harvest time, and the extraction method (Liu et al., 2021). Furthermore, the extraction often involves several stages of processing such as crushing, grinding, and pressing the entire leaf, or fileting to remove the outer leaves and grinding the gel to produce juice followed by various filtration and stabilization steps. One of the main factors that affect the functional properties of Aloe-gel is the handling of leaves after harvest.

The freshness of the leaves is relatively fixed when stored at a cold temperature of 8°C for 6 h after harvest before going to the processing unit. The leaves are washed with a disinfectant

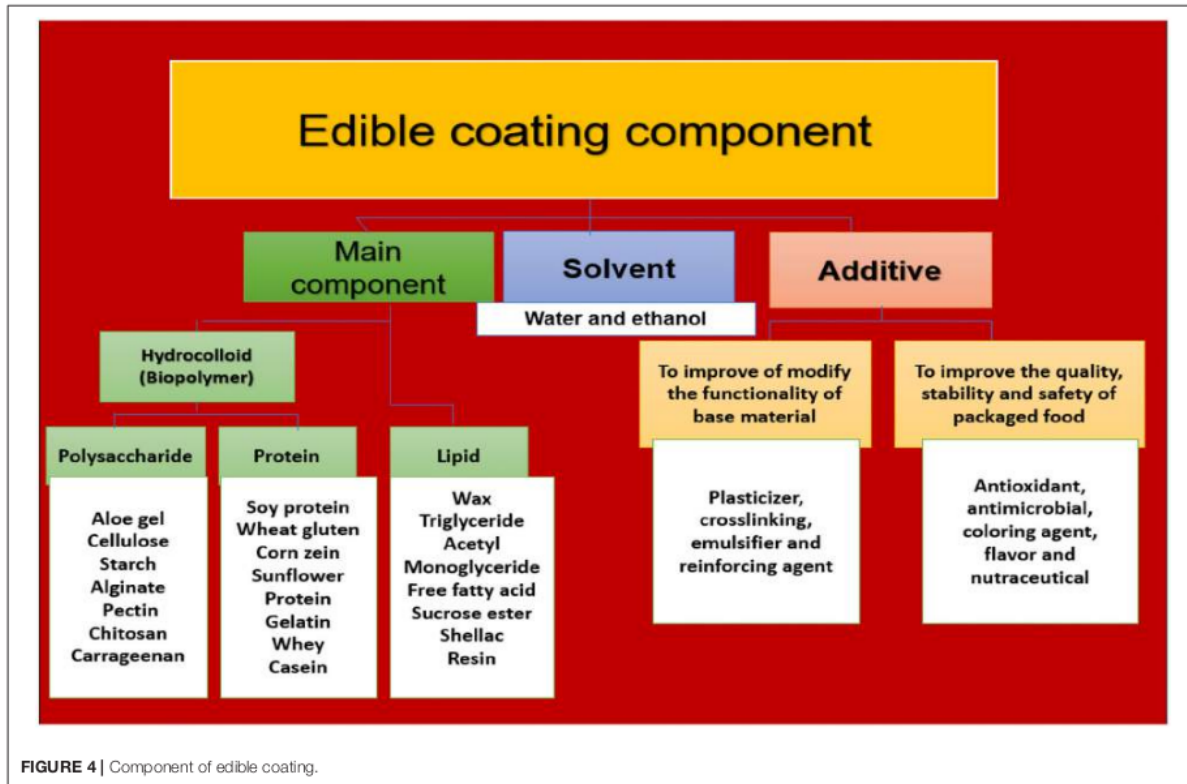


FIGURE 4 | Component of edible coating.

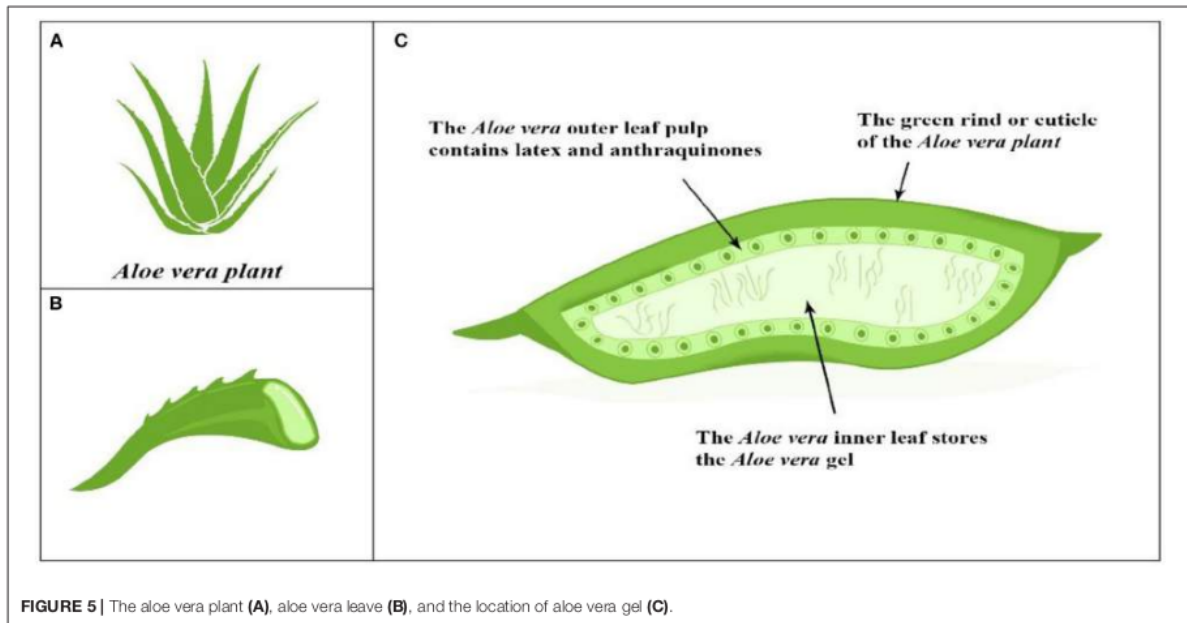


FIGURE 5 | The aloe vera plant (A), aloe vera leaf (B), and the location of aloe vera gel (C).



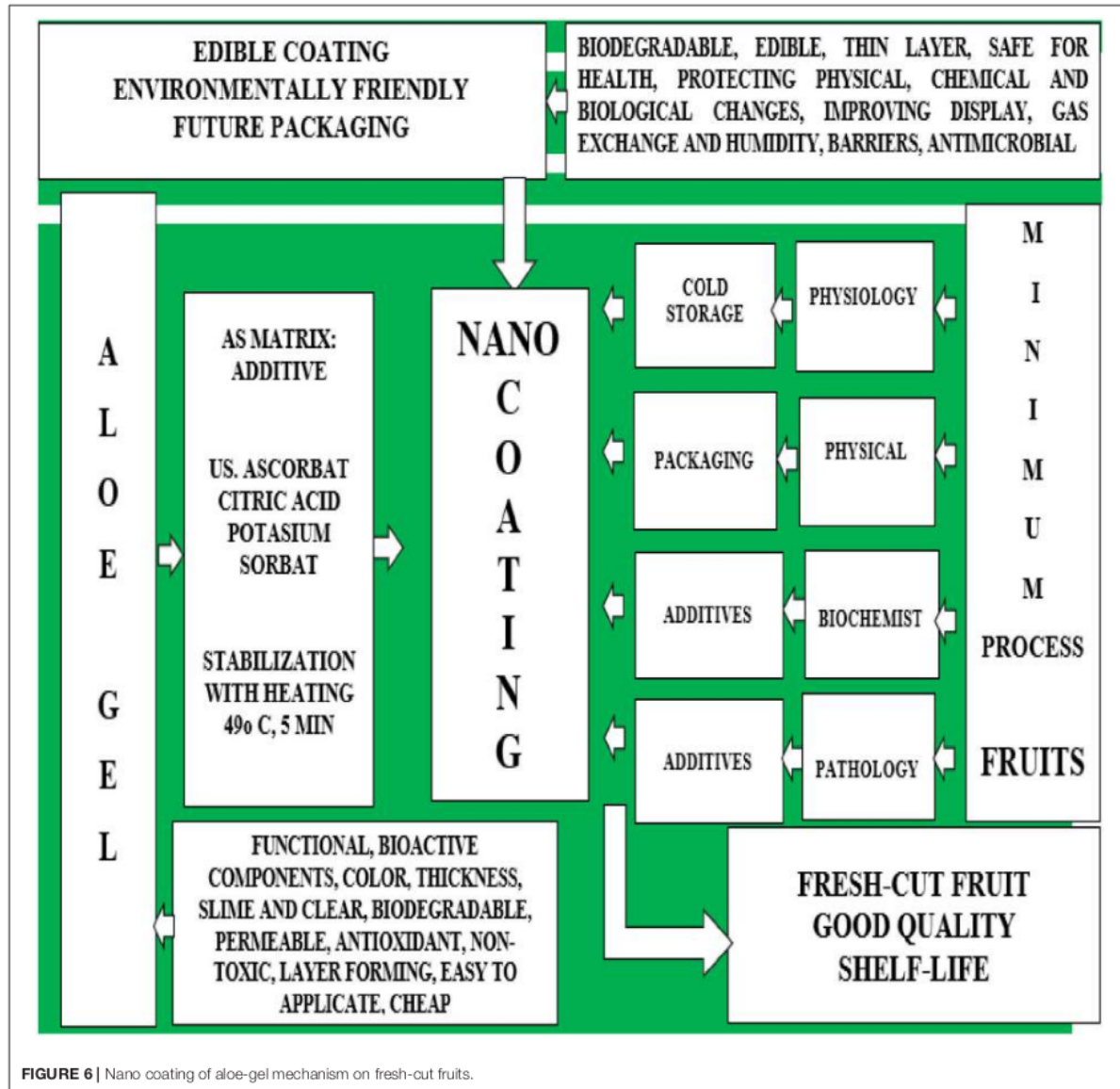


FIGURE 6 | Nano coating of aloe-gel mechanism on fresh-cut fruits.

to remove dirt and bacteria on the surface. At the fileting stage, a thick green outer layer is removed to produce a gel filet. Fileting surgery must be completed within 36 h after the leaves are harvested. The gel is further processed through the stages of filtration, sterilization, and stabilization (Hasan et al., 2021). It is reported that the enzyme glucose oxidase can be added to remove oxygen and inhibit the growth of aerobic bacteria (Kornecki et al., 2020). Moreover, ultraviolet (UV) irradiation followed by ultra-filtration is an effective way to sterilize Aloe-gel (Bassey et al., 2021). Gel extraction from leaves is sometimes carried out by adding cellulose, treating it with activated carbon for purification, as well as removing aloin and anthraquinones

that have a laxative effect. Centrifugation methods have also been found to be effective in the Aloe-gel extraction process. The centrifugal action breaks the chain of sugar molecules surrounded by gel molecules, producing a gel without more fiber (Rehman et al., 2020).

Aloe-gel extraction must be followed by sterilization and stabilization measures because the processing stage can alter the properties of polysaccharides, affect the original structure, as well as cause changes in the physiological and pharmacological properties. Measures that can be taken to avoid changes in the physicochemical properties are to be stored in a dark and cold place as well as chemically stabilizing with additives



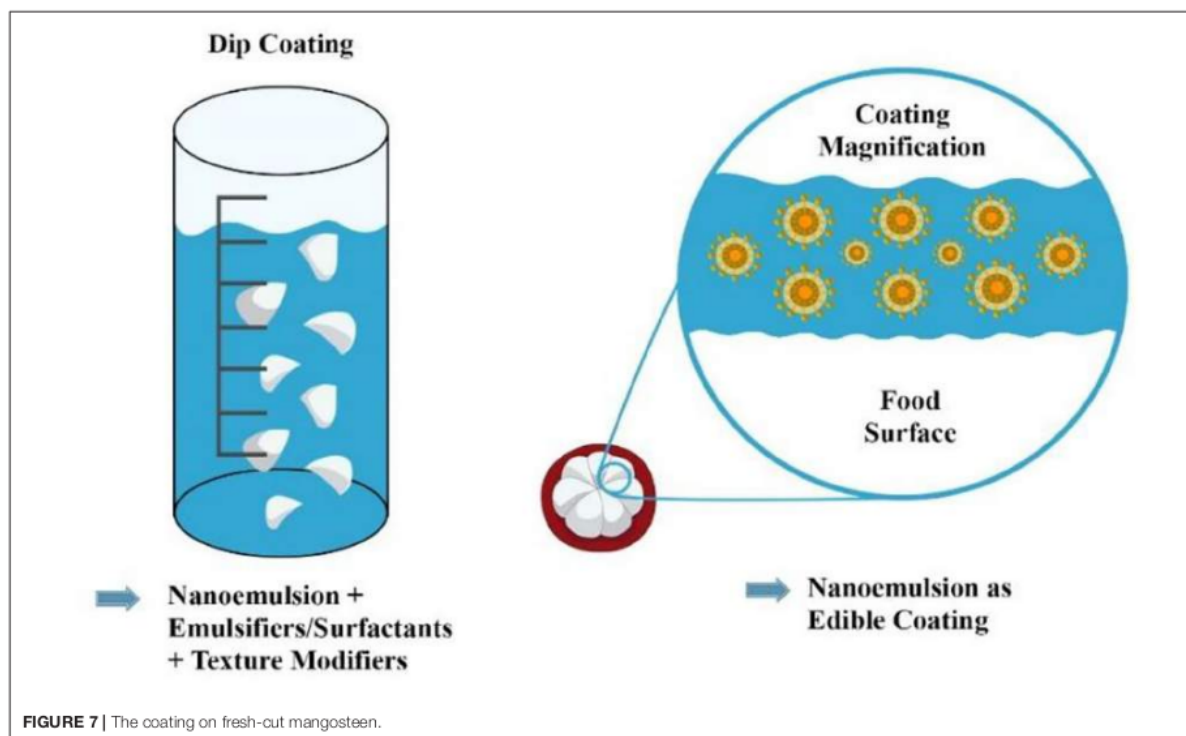


FIGURE 7 | The coating on fresh-cut mangosteen.

(Rehman et al., 2020; Suriati et al., 2020a; Sonawane et al., 2021).

## STABILIZATION OF ALOE VERA GEL

The stability of Aloe-gel is greatly affected by air, light, heat, and microbes when it is not immediately stored in the refrigerator. When the gel comes into direct contact with air and light, its color is pink and eventually becomes brown. Heat and light greatly catalyze this reaction which is also affected by the sugar content. The older the age of the aloe plant, the more sugar content is reduced, thereby turning into a less active polysaccharide (Sánchez et al., 2020). The stabilization process can be carried out with proper processing, heating treatment, and the addition of preservatives and other additives such as sodium benzoate, potassium sorbate, citric acid, and vitamin E. Some other chemicals that have a supporting function include ascorbic acid which potentially reduces the activity of polyphenol oxidase, potassium sorbate as an antimicrobial, or the addition of calcium chloride to improve texture (Nascimento et al., 2020; Rodríguez et al., 2020; Tkaczewska, 2020; Manzoor et al., 2021).

Stabilization of aloe-gel can also be performed with the addition of ascorbic acid ranging from 0.05–0.5% followed by one or more standardization ingredients. Among others are citric acid (0.01–0.5%), sorbitol powder 1–6%, sodium benzoate (0.05–0.5%), acetyl alcohol (0.001–0.05%), and color stabilizers such as tocopherol or vitamin E (0.006–0.01%). The addition of citric

acid and ascorbic acid tends to reduce the activity of polyphenol oxidase, while potassium sorbate acts as an antimicrobial (Ochoa-Velasco et al., 2021; Ong et al., 2021). Aloe-gel must be stored in a dark-colored glass container to avoid the influence of light on sensitive bioactive agents (Suriati et al., 2020c). The capacity to form coatings and biodegradable capabilities make aloe-gel an important alternative to petroleum-based materials that are used as food packers. Furthermore, the barrier capability, mechanical resistance, and thermal properties of polymers are important characteristics to explain their potential use as food-packing materials. Time, temperature, and sterilization are also important for maintaining the bioactive molecules of aloe vera (Cui et al., 2020; Deshi et al., 2021).

## ADDITIVES IN EDIBLE COATINGS

15 Additives are ingredients that are intentionally added to food in small amounts, to improve appearance, taste, and texture, as well as extend shelf life. Additionally, it can increase the nutritional value such as proteins, minerals, and vitamins but must not affect the texture, taste, and aroma of the final product (Galus et al., 2021; Ochoa-Velasco et al., 2021; Salgado-Cruz et al., 2021). One of the additives that have the potential to be incorporated with edible coatings is citric acid which is a crystalline or white powder-shaped organic compound with the chemical formula  $C_6H_8O_7$  (2-hydroxy acid 1,2,3-tricarboxylate) (Marghmaleki et al., 2021). The properties include: being easily

soluble in water, odorless, tasting very acidic, and tending to melt when decomposed. Citric acid is a deflating agent that inhibits tanning because it can complex copper ions which act as catalysts, lower the pH to inactivate the enzyme polyphenol oxidase (PPO) (Díaz-Montes and Castro-Muñoz, 2021; Kumar N. et al., 2021). Besides, it is a natural preservative that is safe to consume and the acid content serves to prevent the growth of bacteria and fungi (Bhat T. A. et al., 2021; Galus et al., 2021; Xu Y. et al., 2021). Citric acid can also be used to regulate acidity or food preservatives, as well as to prevent tanning in fruits (Marghmaleki et al., 2021).

Meanwhile, ascorbic acid is one of the chemical compounds in the form of whitish-yellow crystal powder that is soluble in water and has antioxidant properties. Soaking apples in solution on ascorbates can reduce the activity of polyphenol oxidase (Marghmaleki et al., 2021). Manzoor et al. (2021), reported that fresh-cut kiwi treated with an ascorbic acid solution effectively prevents browning during storage, while Liguori et al. (2021) argued that it can maintain the quality of strawberries during cold storage. Xu L. et al. (2021) also stated that ascorbic acid can control enzymatic browning in green food and conventional apples in China. The results showed that ascorbic acid was more effective at reducing browning. A study was also conducted to evaluate the potential of citric and

ascorbic acid as anti-browning ingredients in fresh-cut kiwi fruit (Bhat T. A. et al., 2021). At higher concentrations, ascorbic acid is more effective in maintaining fruit quality than citric and can reduce browning.

Antimicrobial ingredients such as sorbic acid can be used to prevent microbes on fresh-cut fruit. This is because sorbic acid is odorless and tasteless up to a usage rate of 0.3%. It is chemically known as 2,4-hexadecenoic acid and is commonly used in the form of potassium sorbic salts, has a broad spectrum of inhibiting yeast, but is not effective in inhibiting bacteria. Furthermore, potassium sorbate is classified as an unsaturated fatty acid used to inhibit the growth of mold (Cheng et al., 2020; Abdollahzadeh et al., 2021; Wangprasertkul et al., 2021). It is powdery and the granules are white or slightly yellowish-brown, and odorless. A rise in potassium sorbate concentration will increase the inhibitive force of microbial growth, hence, organic acids are formed slightly. The use of sorbic acid and salt varies depending on the type of food (Abdollahzadeh et al., 2021).

Calcium chloride ( $\text{CaCl}_2$ ) is a salt that is white, odorless, colorless, inflammable, and stored in an airtight container due to its hygroscopic nature (Sathiyaseelan et al., 2021; Sultan et al., 2021). The properties include great solubility and a source of calcium ions in solutions.  $\text{CaCl}_2$  can maintain the



**TABLE 1** | Aloe-gel in coating solution for fresh-cut fruits.

No	Fresh-cut fruit	Particle size	Coating solution	Source
1	Mangosteen	Nano	50% Aloe-gel in 1 min immersion time	Suriati et al., 2021a
2	Mango	Nano	0.15% additive in 50% Aloe-gel	Suriati et al., 2020d; Luh Suriati et al., 2021
3	Rambutan	Nano	50% in 3 min immersion time	Suriati, 2021
4	Strawberry	Non-nano	75% Aloe-gel in 1 min immersion time	Suriati and Singapurwa, 2020; Suriati and Suardani, 2021; Suriati et al., 2021b

quality of fresh-cut fruit as well as suppress the process of ripening or the treatment of sugar into organic acids. Furthermore, the immersion treatment in the solution preserves the firmness of the fruit tissue and extends shelf life. It also stiffens the structure of the cell wall of lamella by slowing the activity of polygalacturonate, as well as maintaining the structural and functional integrity of the membrane system (Bhat V. G. et al., 2021; Díaz-Montes and Castro-Muñoz, 2021; Mohd Suhaimi et al., 2021; Sultan et al., 2021). The ions bind to pectic and galactosemic acids to form calcium pectin cross-bonds that strengthen molecular bonds between constituents and maintain the firmness of the fruit cell wall (Muñoz-Almagro et al., 2021).  $\text{CaCl}_2$  exogenous slurs can also delay the tanning and softening reaction of logan fruit as well as increase apple's fresh-cut firmness during cold temperature storage.

## NANO-COATING OF ALOE-GEL

Nanotechnology is a science that has become quite popular and attract massive attention in the last few decades. Meanwhile, nanoparticles include the design, characterization, production, and application of a material, tool, or system at the nanoscale of 0.1–100 nm (Kehinde et al., 2021; Lu et al., 2021). They have received significant attention in the food sector, including nano ingredients, nano-emulsions, and nano-coatings (Sathiyaseelan et al., 2021). The advantages of using nano-coatings are:

- 1) **Antimicrobial ability:** Nano-coatings can interact directly with microbial cells, penetrate cell membranes, oxidize cell components, or produce secondary products that cause damage (Lu et al., 2021). They are also used to extend the shelf life of food that are easily damaged by microbial activity such as meat and its processed products, as well as minimally processed foods, etc. (Hu et al., 2020; Prakash et al., 2020).
- 2) **Improvement of mechanical properties** such as flexibility, durability, temperature, and humidity. This is related to the interaction between nano-coating additives and the matrix, the movement of air and gas is increasingly difficult because of the tortuous path (Praseptianga et al., 2021). Nano-coating mechanism tends to also reduce matrix (Salgado-Cruz et al., 2021).

- 3) **Improved emulsion system.** The advantage of nano-coating is that the droplets are much smaller which causes a decrease in the gravitational force, and prevents sedimentation, cream formation, and flocculation to improve the emulsion system. Tools commonly used include high-pressure homogenizer, ultrasonic disruptor, and high-speed blender (Prakash et al., 2020; Wang et al., 2020).
- 4) **Bioavailability:** Nano-coating is expected to increase bioavailability to improve the absorption of bioactive components. The very fine and small size of the material causes an increase in the higher solubility rate and even dispersal (Suriati et al., 2022).

The use of nano-coating for aloe-gel has great potential to provide new, innovative, and better results in horticultural productivity, post-harvest, processing efficiency, packaging, food quality, and safety through the detection of microbes that are harmful to human health (Ghasemi and Niakousari, 2020; Hu et al., 2020). Currently, the application in food products makes a significant contribution to the delivery of bioactive compounds. This is because nano-coating of Aloe-gel can increase the bioavailability and control the release of active ingredients, as well as inhibit chemical reactions thereby reducing the impact on the sensory properties of the product. Nano-coating of Aloe-gel mechanism on fresh-cut fruit as **Figure 6**.

Nano-coating of aloe-gel produces a larger surface area which has the potential to increase the solubility, absorption, and availability of biologically active compounds as well as controlled release. Subsequently, the small particle size culminates in new physicochemical properties, such as surface area, reactivity, and color, which are very different from conventional-sized materials. Several studies reported that nano-coating of Aloe-gel is used for a wide variety of products. According to Suriati et al. (2020c) and Salgado-Cruz et al. (2021), it can be applied to fresh handling, processing, preservation, and improving the functional properties of food to maintain the physical quality or freshness, and chemical quality of a product. Moreover, nano-coating has been widely developed and applied to the surface of fresh fruit to maintain its quality and shelf life. Wang et al. (2020) showed that the active application of chitosan nano-composite can maintain the nutritional content of the coating material as well as extend shelf life, produce a better appearance, and prevent mold growth. The extraction, formulation, and application of aloe vera gel on fresh-cut mangosteen, mango, and rambutan fruits are presented in **Table 1**, **Figures 7, 8**.



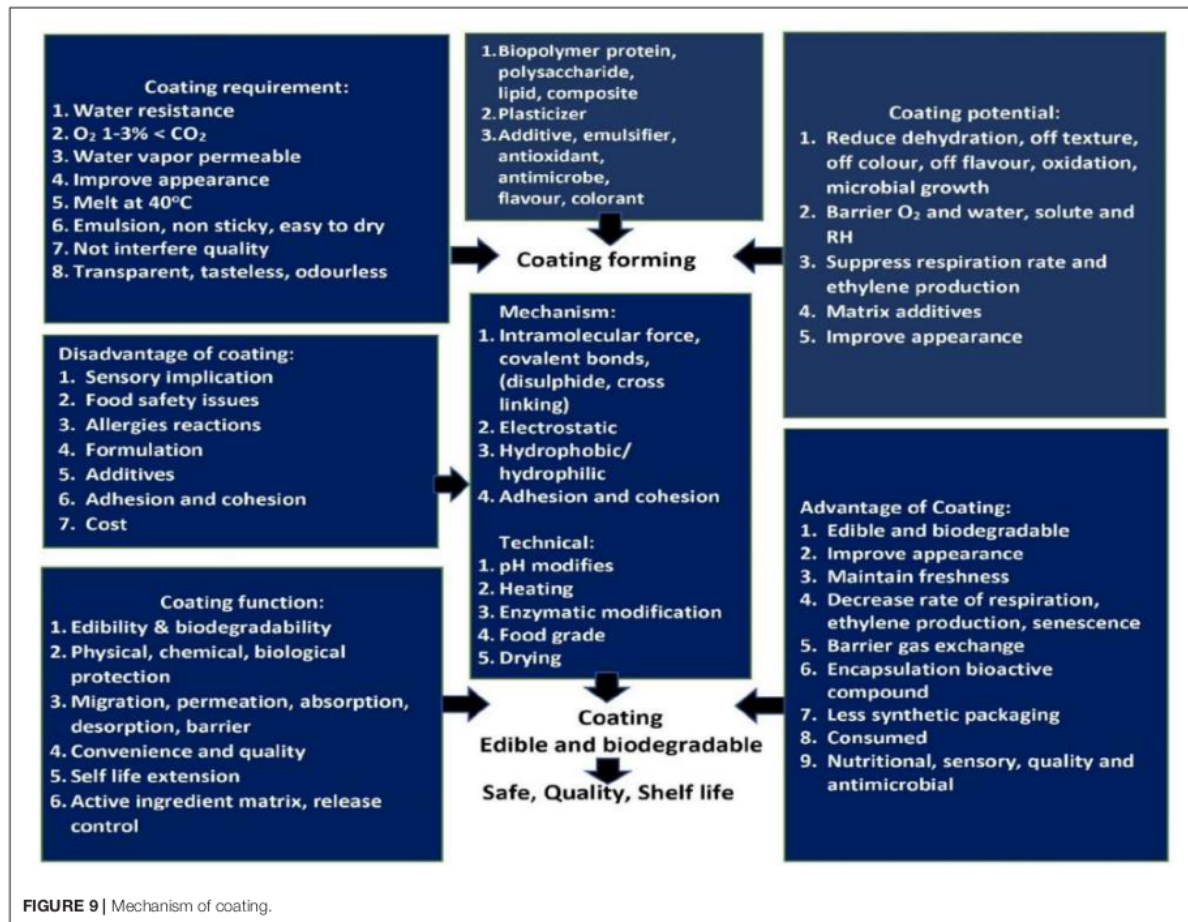


FIGURE 9 | Mechanism of coating.

## FUTURE PERSPECTIVES AND OTHER STUDIES ON NANO-COATING OF ALOE-GEL

The packaging system in the future is expected to effectively close the small pores and have a good response to the environment such as changes in temperature, air, and humidity. Additionally, future packaging trends must be biodegradable and have antimicrobial capabilities. Nano-coating of aloe-gel can be used as an alternative packaging material and is expected to increase the added value of food products as shown in Figure 9. They are applied to control the ripening process of fruit, maintain freshness and safety, as well as to detect contaminants/pathogens, and food expiration dates (Singh et al., 2020).

## CONCLUSION

The edible coating is the future and environmentally friendly alternative to synthetic packaging because it is biodegradable, exists in the form of a thin layer that is edible, safe for health,

inhibits physical, biological and chemical changes, improves the appearance, acts as a barrier of gas exchange, as well as maintains moisture and antimicrobial abilities. Meanwhile, aloe-gel consists of polysaccharides, namely acemannan and glucomannan, that contain several bioactive components applicable as edible coatings. The characteristics include transparent, thick, slimy, clear, biodegradable, permeable to  $O_2$ , antioxidant, low toxicity, forms layers, affordable, as well as easy to apply and obtain. The easy-to-dilute weakness can also be overcome by the process of stabilization, sterilization, the addition of antioxidants and fillers, control of the extraction process, odorization, modification of the atmosphere, and storage temperature. Furthermore, the size of the particle determines the effectiveness of the coating process on the fresh-cut fruit. Nano-coating can be used to overcome the difficulty in the adhesion of coating materials on surfaces of fresh-cut fruits. Based on the results, there is a need to develop simple and efficient processing techniques to improve the quality of the product, as well as maintain all-natural bioactive chemical components to increase the quality and ability of an edible coating. Quality criteria for fresh-cut fruits processed with nano-coating must be determined rigorously



and monitored throughout the storage period. The use of aloe-gel nano-coating incorporated with additives can maintain the quality of fresh-cut fruits.

## ETHICS STATEMENT

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

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## AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

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