Chapter

Edible Coating

Kofi Owusu-Akyaw Oduro

Abstract

Postharvest losses are rampant due to lack of proper storage conditions and handling of the fresh food products. The perishable nature of fruits and vegetables makes their shelf life limited due to some extrinsic factors such as some environmental conditions and preservation conditions as well as some intrinsic factors such as respiration rate, ethylene production and transpiration. Among the other postharvest technologies available, edible coatings seems to be one novel method which has been verified to have a positive and safe approach to extending the shelf life of products. This type of packaging is made from various natural resources like polysaccharide, protein and lipid materials. Edible packaging materials can be divided into two main groups including edible coatings and edible films. It has so many benefits such as serving as a moisture barrier, oxygen scavenger, ethylene scavenger, antimicrobial properties among others. Different methods of application of the edible coating on the food materials include; dipping, spraying, brushing, layer by layer among others. There have been several verifications of the positive impact of edible coatings/films on pome fruits, Citrus fruits, Stone fruits, tropical and exotic fruits, berries, melon, tomatoes and others.

Keywords: postharvest technology, edible coating/films, water loss, shelf life

1. Introduction

The global production of fruits keep increasing as a result of the rise in the population demand, elevation in the living quality standard and the increase in health awareness of fresh food products especially fruits and vegetables. This is because fruits and vegetables play vital roles in healthy nutrition due to their vitamins, minerals, antioxidant content among others. According to FAOSTAT [1], within about 10 years, the production of fruits which include drupes, berries, pome fruits, melons and tomatoes increased from 2,587,570 in 2007 to 34,622,004 metric tonnes in 2017. However food production has been reported by Alexandratos and Bruinsma [2] that it should be increased by 60% in 2050. Thus the increase in production is needed in parallel with the growth of the global population. However, postharvest losses which result in the degradation of quantity and quality of the fruits after harvest constitute a serious challenge.

Though these fruits have very high nutritional values, they are highly perishable due to their high moisture content and nutritional value leading to the development of undesirable characteristics as well as issues of food safety. These fresh food products are susceptible to dehydration, mechanical injury, environmental stress, pathological breakdown and enzymatic attacks which leads to some nutritional, functional and sensorial losses and production of off flavour and also posing a level of threat in terms of possessing a level of toxicity. There is a level of reduction of the edible quality of the food products due to biochemical changes, physiological ageing and microbial infections during storage and transportation.

Therefore the gas composition greatly affects the shelf life of the products. Extension of the supply time of fruits and vegetables besides preserving their quality would have economic profits [3]. In this regard, post-harvest practices aiming to maintain the physicochemical composition during storage must be adopted.

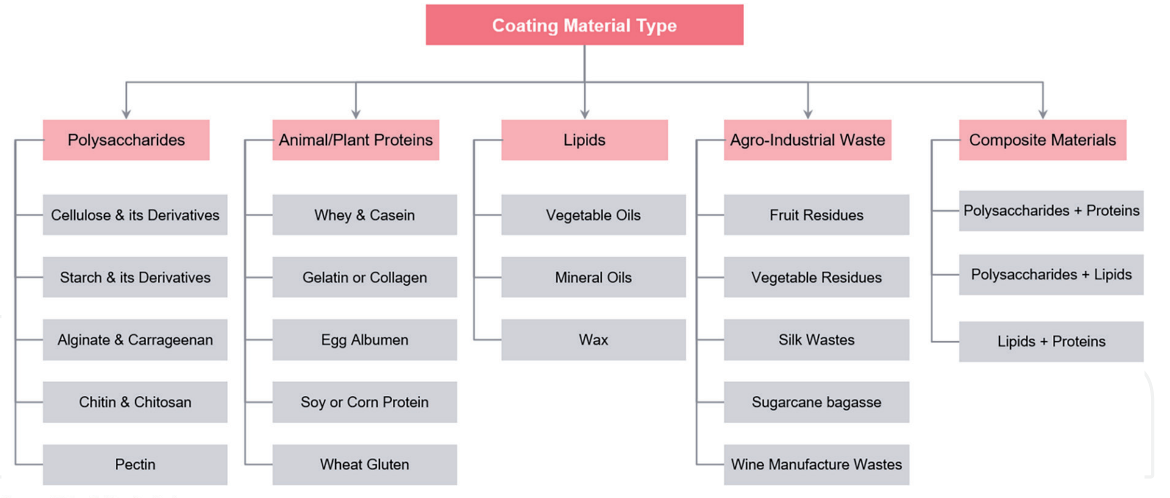
Fruits are either climacteric or unclimacteric. The latter cannot ripen once removed from the plant but the former can ripen after being picked and produce more ethylene which makes them more susceptible to spoilage. Thus to inhibit the rate of deterioration of these fruits, these is a need to alter the gaseous environment or control it. For instance making use of packaging materials with low water vapour and oxygen permeability to reduce respiration but not too low oxygenated environment which can lead to anaerobic respiration which can also produce off-flavours.

Although MAP and CA technologies can be regarded as the most effective methods with extensive and successful applications, they are quite expensive and chemical treatments on the other hand have potential levels of toxicity. Low temperature storage might also lead to chilling injury and heat treatment also leads to nutrient losses, decreased weight, flavour and vitamin losses [4]. One novel postharvest technology to circumvent these limitations is the use of edible coating which can control and inhibit the deteriorative changes as well as increasing the shelf life of the products. Edible coating/films is a good candidate to help solve the cases of postharvest losses since it has mechanical, thermal, antimicrobial and even antioxidant properties.

Edible coating or films are biopolymers that are hugely being investigated for the packaging and preservation of food. Edible packaging materials are a type of packaging that could be eaten and have the biodegradable ability also provides a barrier against moisture, gases and solute movement. Edible coatings are usually made from biodegradable materials such as Lipid-, Protein- or Polysaccharide-based materials. This packaging material is either used via a film or using coating. The latter is usually in liquid form whiles the former usually forming a thin layer around the food product. Edible coatings can be defined as a thin layer of edible and environmentally friendly materials that could be consumed and provide a barrier to gases, microbes and moisture to food products. Application of these films is simple, eco-friendly, highly safe and low priced which makes it promising for preserving food products.

There has been several research works on the impact of edible coating on the physiological and microbial stability of some fresh produce. For instance, Li et al. [5] verifies that application of Cinnamaldehyde as an edible coating on banana showed a significant decrease in the weight loss and ripening rate of the banana. Also, application of protein isolate with organo-clay MMT on minimally processed papaya sliced also demonstrated a lower microbial growth and lower mass loss [6]. An increasing interest in edible films/coatings is an outcome of growing consumer awareness on healthy foods, and also due to negative impacts of non-biodegradable synthetic packaging materials on the environment.

Edible coatings/films helps to improve the appearance of horticultural produce by giving shine, hiding scars, suppressing decay and physiological disorder developments [7]. Edible coatings can be generally classified into three main groups; Protein-based edible coatings, Polysaccharide-based coatings and lipid-based coatings. The choice of active agents depends on the characteristics of the product and the type of polymeric matrix in the coatings. Active or functional compounds; Antioxidants, antimicrobials, nutrients, vitamins, anti-browning agents, enzymes and probiotics that could be applied into coating matrix to help preserving products quality.

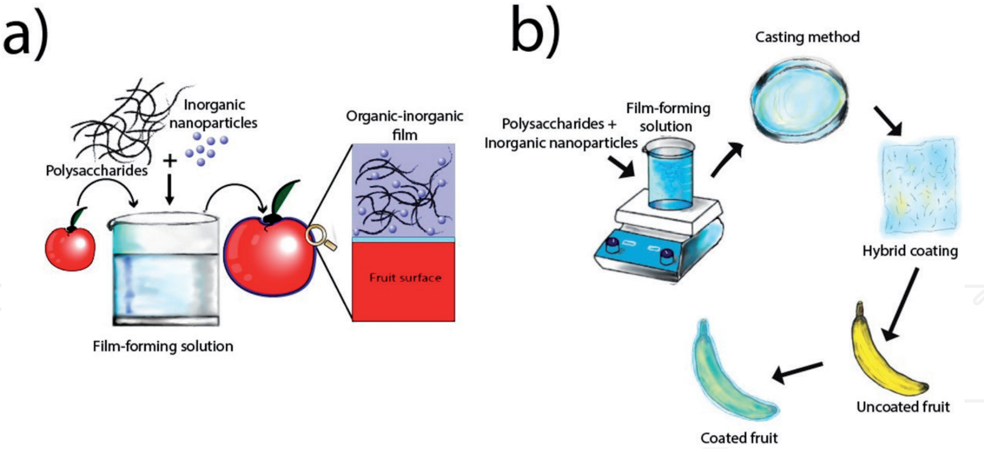


Source: FutureBridge Analysis

2. Classes of edible coating

2.1 Coatings based on Polysaccahrides

Polysaccharides are natural polymers used extensively to produce edible coating or films. Examples of polysaccharides used in the production of these films include; Pectin, cellulose, starch, chitosan, alginates and pullulan. Polysaccharides are the basic coatings that are considered to be an effective blocker of oxygen because of its ordered structure including a hydrogen network. However, polysaccharides form a poor barrier against water vapour because of its hydrophilic nature. They are usually used to improve the shelf life of meat products, vegetables, fruitc.



2.1.1 Starch

Starch is a polysaccharide that is composed of two different molecules which are amylose which is a linear polymer and amylopectin which is a highly branched polymer. Starch is widely used in coatings for food materials since it is abundant in nature and has a low cost. Several studies have been carried out to improve physicochemical and optical properties of starch-based edible films using Aloe Vera. Coatings based on starch are odourless and colourless. They possess less oxygen permeability and have an oil-free appearance. They can make an important contribution to decrease in the respiration rate for the fresh fruits and vegetables.

2.1.2 Chitosan

Natural chitin can go through a process called deacetylation to form Chitosan which is a polysaccharide that can be used in edible coating of food materials [8]. Chitosan is mostly used in coating materials for fruits and vegetables because of its antioxidative and antimicrobial properties. It is non-toxic, biodegradable, biocompatible and microbe-resistant, chitosan is currently attracting considerable attention and its scientific testing at a large scale is in progress to explore its possible applications in different fields [9]. Chitosan are partial permeable coatings and films, which can control the interior structure by diminishing transpiration rates and retarding ripening in foods and vegetables [10].

2.1.3 Alginate

Alginate is an unbranched polysaccharide and is composed of sodium salt of alginic acid that is derived from some species of brown algae. Alginates are indigestible natural polysaccharides acquired from seaweed and have been reported to be a stabilising and thickening in the food market. It has good film forming properties as it can form gels through crosslinking with divalent cations like Ca2+. For this reason, alginate finds interesting application for coating fresh and processed food items [11].

2.1.4 Gellan gum

Gellan gum consists of repetitive units of tetrasaccharides, and it is a well-recognised biopolymer due to its functional properties, eg) good hardness, high transparency, smooth surfaces and reduced water vapour permeability.

2.2 Pullulan-based coatings

Pullulan is a polysaccharide which is usually a thickener that may form effective films. The use of pullulan edible films and coatings in combination with chitooligosaccharide which has antibacterial properties and glutathione which is also a powerful reducing agent. This makes it effective in increasing the shelf life of various food products.

2.2.1 Cellulose

Cellulose is also a linear chain polysaccharide which is a major component of plant cell wall which has a large number of intra-molecular hydrogen bonds causing its water insolubility with highly associated crystalline structure [12]. The native cellulose has very low water solubility properties and is a less suitable film forming material. However, various chemically modified forms of cellulose like carboxymethyl cellulose, methylcellulose, hydroxypropyl cellulose and hydroxypropylmethyl cellulose are quite suitable for film and coating applications.

2.2.2 Carboxymethyl cellulose

An anionic linear and long chain compound that consists of glucopyronosyl units with high molecular weight providing strength and structural integrity in edible coatings. They exhibit excellent oxygen, aroma, and oil barrier and anti-senescence properties.

2.2.3 Pectin

Pectin, main compound of plant cell walls found in middle lamella of plant cells. They are complex heteropolymers made up of D-galacturonic acid units that may present variations in composition, structure and molecular weight [13].

2.3 Protein-based coatings

Proteins generally occur in the form of globular proteins or fibrous proteins. Fibrous proteins are insoluble in water and generally play the role of a basic structural element of animal tissues, they are also soluble in aqueous solutions of salt, bases or acids and perform different activities in living systems. Various types of globular proteins such as corn zein, whey protein, wheat gluten and soy protein are involved in edible coatings/ films. A dispersion or protein solution is taken into consideration to create coatings and films, and the solvent that is taken into consideration for playing this role is generally restricted to ethanol water combinations, or simply water or ethanol.

Protein-based coatings which include the use of casein, gluten and soy protein serve as good oxygen blockers and thus help preserve the food products from any deteriorative reactions. Proteins are reported to impart good mechanical properties and gas barrier properties.

2.4 Corn zein-based films and coatings

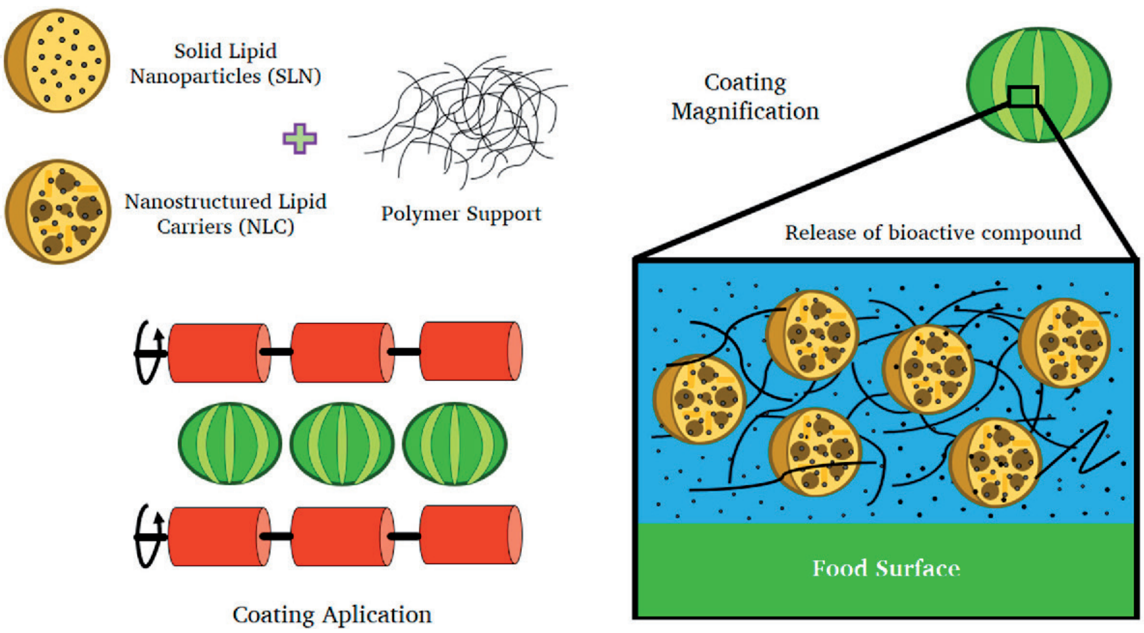
Corn is a major source of zein which is a prolamin protein that can be dissolved in 70–80% ethanol and hydrophobic in nature. Edible coating made from zein shows very good film properties. They are good moisture blockers than other films.

2.5 Gelatin-based coatings and films

Gelatin is a hydrophobic protein usually found in wheat which is also a globular protein and also used in some edible coatings/films due to its low cost and availability. Gelatin coatings usually depict good transparency, mechanical and barrier properties and can be manufactured via an extrusion or casting process. The nature of the gluten has significant impact on its filming properties.

2.6 Lipid-based coatings and films

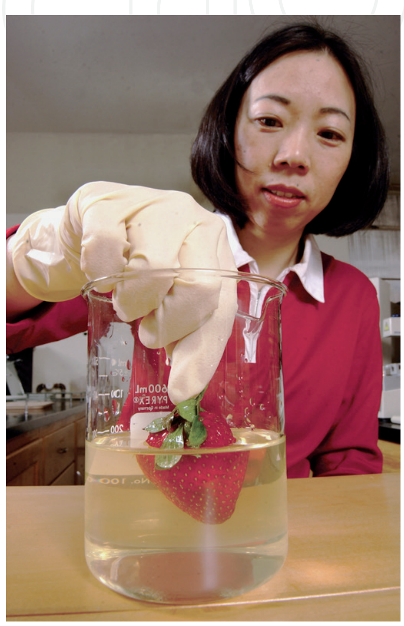
Lipids are naturally hydrophobic in nature making them very good materials to be used in edible coating since they can help resolve moisture migration into the fresh food product which can cause some significant deteriorative changes in the food material. Some example of lipids used in edible coatings include wax and paraffin [14].



3. Methods of application of edible coating/films

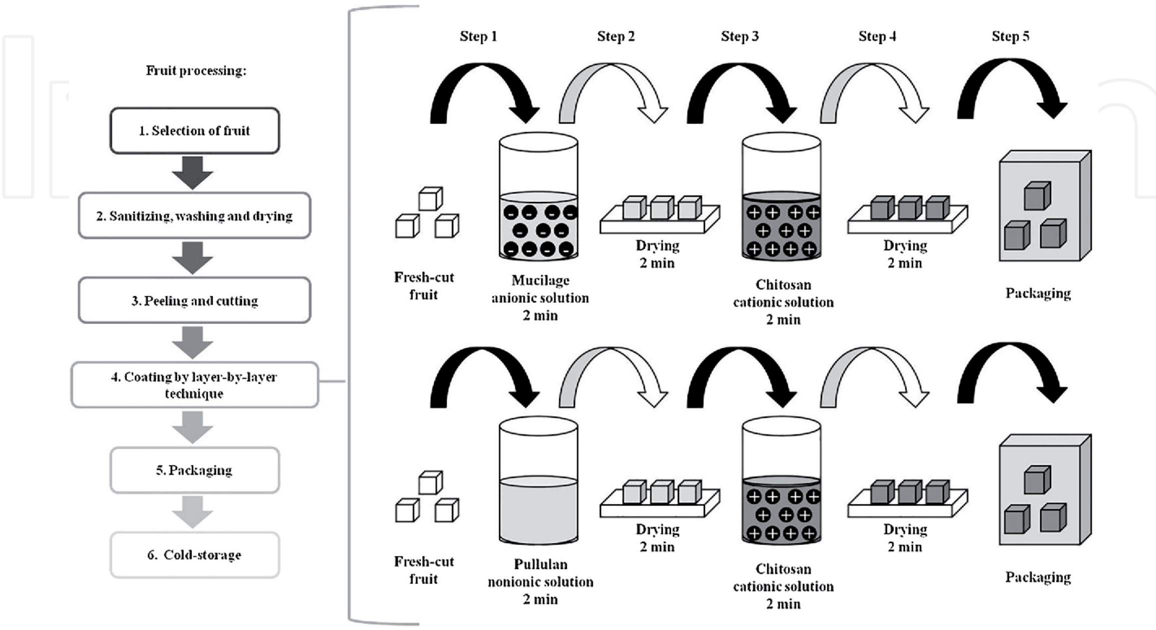
3.1 Dipping

This technique is the oldest commercial technique but still relevant until now. The concept of dipping technique is by immersing the fresh food produce into the coating solution to allow complete wetting of the surface of the food material. After that the coating solution is drained out to remove excess coating from the food surface. Finally the fruit is dried to form a well intact coating with the food surface. This can be applied to a wide range of viscous coating solutions.



3.2 Layer by layer method

Layer by layer method is based on alternate deposition of oppositely charged polyelectrolytes that result in a more effective control of the coating properties and functionality. This method leads to the production of several layers of the films which can help to improve the effectiveness of the edible coating.

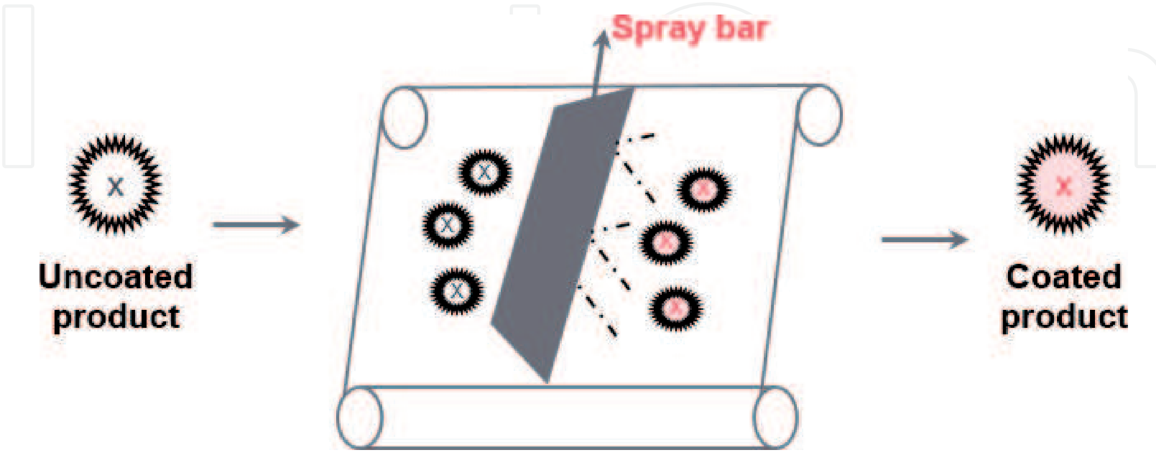


3.3 Vacuum impregnation technique

Vacuum impregnation technique is a further advancement of the dipping method. The difference is having a vacuum environment during fruit dipping. That is, instead of dipping the food material in a normal dipping tank, the fresh food is submerged in an airtight vacuum application. The food material is subjected to atmospheric restoration while it remains immersed in the coating solution under atmospheric pressure.

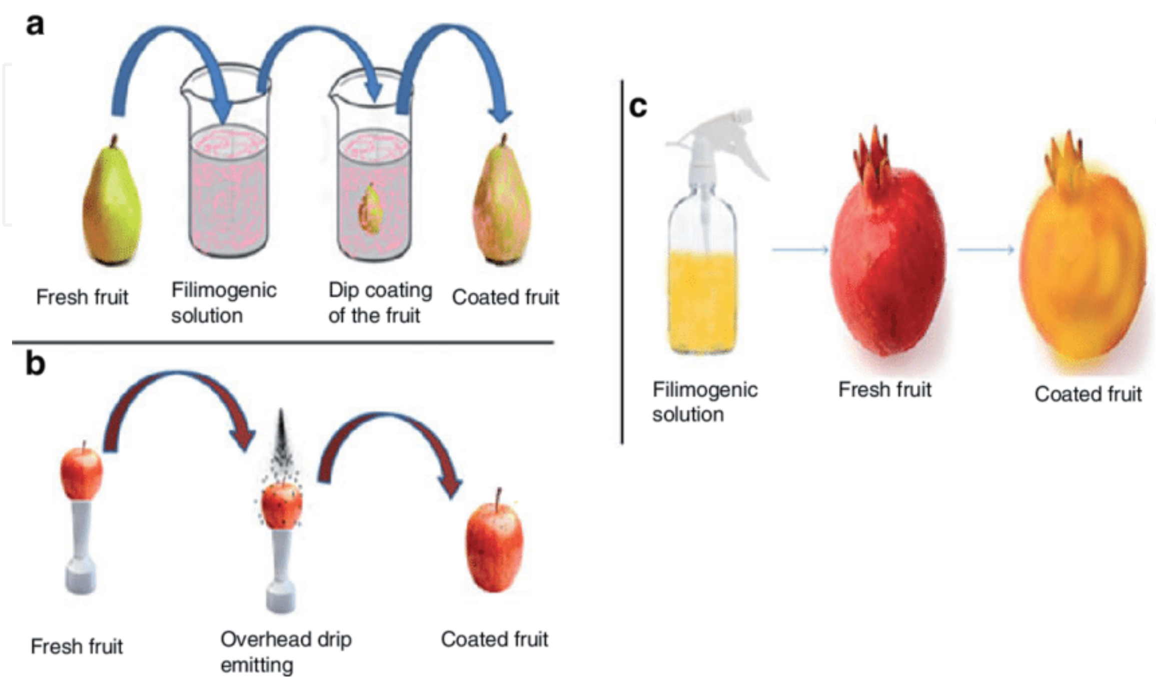
3.4 Spraying method

Spraying method is more suitable for less viscous coating solutions which can be sprayed at high pressure. Formation of polymeric coating using spraying system is affected by drying time and temperature. The advantage of applying the spraying technique is, the surface area of the liquid coating increase through the formation of droplets and distribution over the fruit surface.



3.5 Foaming and dripping method

Foaming and dripping method are considered as traditional methods in coating application. These methods are now gaining low popularity among researchers and industrial practitioners in fruit industries. With the dripping technique, the coating is being applied directly to the fruit surface using brushes However with the foam application, a foaming agent is added to the coating. Then, compressed air is blown into the air of applicator tank. Extensive tumbling action is applied to break the foam for uniform distribution.



4. Benefits of edible coatings/films

4.1 Moisture barrier

These films prevent moisture loss, aroma loss or water uptake by the food material or even penetration of oxygen which produces a good storability condition for these food products, Edible coating enhance the texture and improves the product appearance and prolong the shelf life by creating semi-permeable barriers. Emamifar and Bavaisi [15] developed a bio-nanocomposite coating with sodium alginate and nano-ZnO and applied it on strawberry. The results revealed a significant weight retention than those without the films. Again Titanium and silver nanocomposite packaging displayed same results on mangoes [16].

4.2 Oxygen scavengers

The presence of oxygen can have considerable detrimental effects on some packaged fresh food products. Some edible films have been found to contain some oxygen scavengers and humidity control systems which play an important role in reducing gases contributing to the spoilage of fruits and vegetables. Resende et al. [17] indicated that the coating of chitosan/cellulose nonofibril minimises the oxygen diffusion, decreases respiration and delays strawberry oxidation by ascorbic acid reaction.

4.3 Ethylene scavenger

Ethylene control in storage time plays a significant role in extending the shelf life of the fresh produce. Kaewklin et al. [18] determined the ethylene control activity of chitosan-TiO2 nanocomposites on tomato showed lower levels of ethylene concentration.

4.4 Antimicrobial properties

One of the main contamination reasons for fruit and vegetable is the lack of proper packaging. An antimicrobial active packaging system loaded with antimicrobial agents can be applied to minimise the spoilage of fresh produce to control their microbial growth. Some studies also proved this as strawberries coated with 1.5% sodium alginate and nano ZnO showed the lowest growth of micro-organisms. The Antimicrobials in the edible coatings enhance the shelf life and safety of fruits and vegetables by preventing microbial growth and damages [19]. Some of the antimicrobial substances include organic acids such as citric acid and lactic acid, Microbial bacteriocins like Lactic acid bacteria and some polypeptides such as lysozymes [20].

4.5 Antibrowning and antioxidant properties

Enzymatic browning in minimally-processed fruits and vegetables is linked to discoloration and discoloration of phenolic compounds catalysed by polyphenol oxidase (PPO) enzyme, which converts polyphenolic substrates to dark pigments in the presence of oxygen. Edible coating especially incorporated with antibrowning substances can control PPO activity, and in the other hand, can provide a strong barrier for oxygen. The antibrowning substances mostly used are ascorbic acid, thiol-containing compounds (cysteine and glutathione), carboxylic acids (citric and oxalic acid), phenolic acids and resorcinols. These reduce o-quinones resulted from the action of PPO enzymes, back to their phenolic substrates [21].

5. Texture modifiers for inhibition of physical damages

Pectolytic enzymes leads to the loss of firmness in fruit tissues and so any attempt to inhibit this enzyme's activity will result in firmness retention. Application of edible coatings containing active substances called texture enhancers could minimise the textural softening of fruits and vegetables during storage. These compounds retard plygalacturonase activity and preserve structural integrity of membrane. To control softening phenomena in fresh-cut fruits calcium salts are commonly used and considered as firmness retainers.

6. Nutraceuticals for preservation of nutritional quality

Nutraceuticals enhance the nutritional profile of low-micronutrient products; Minerals, vitamins and bioactive compounds are potential Nutraceuticals compounds that can be incorporated in formulation of active coatings to enhance the nutritional value of some fruits and vegetables, where these micronutrients are present in low quantities [22].

7. Application of edible coating/films on some selected food products

7.1 Apple

Apple which is a Pome fruit has undergone various research studies which proves the effectiveness of edible coating in the preservation of this fruit. For instance a research finding by Guerreiro et al. [23] showed a significant reduction of microbial load on the food product and resulted in a prolonged shelf life.

7.2 Citrus

FAOSTAT [1] reported that citrus is one of the main crops in the world with a total production of 18.9 million tonnes in 2017. Similar to the other fresh produce, postharvest losses are the major problem in the citrus production chain. Arnon et al. [24] developed a by-layer polysaccharides-based edible coating for mandarins using CMC as the internal layer whiles the chitosan was used as the external layer. The result demonstrated that the quality of the citrus fruits such as the gradient of the glossiness and peel colour were evenly improved.

7.3 Mango

Mango which is also a drupe fruit along with cherries and peaches have shown some significant improvement in terms of its shelf life upon the addition of edible coating/film materials n it. Though Mango is most preferred due to its appealine organoleptic properties it has been shown to undergo rapid deterioration after harvest.

Paladines et al. [25] investigated the impact of roseship oil with aloe vera gel von deferring ripening and preserving the postharvest quality of a number of stone fruits. The results indicated that the aloe Vera coating inhibited the formation of ethylene, decreased the respiration rate and delayed the changes the fruit colour and firmness. Again studies using guar gum and ginseng extract on sweet cherry showed a significant delay in the production of malondialdehyde [26].

7.4 Berries

Berry fruits such as blackberry are commonly used in the human diet either fresh or in processed form. Berries are small fruits that contain high antioxidant benefits. Several studies have been on the integrity of edible nano-coatings of curcumin and limonene liposomes integrated with methyl cellulose and its impact on the quality of strawberries and this showed the coating was found to be effective in regulating fungal decay in strawberries [27].

7.5 Melon

Carvalho et al. [28] stated that most of the cultivated melons are eaten as value added particularly fruits, especially for fresh-cut products. Though these food products have been found to deteriorate quite easily due to various biochemical processes, a lot of research has proven the effectiveness of edible coating in inhibiting the deteriorative changes [29].

7.6 Tomatoes

Tomatoes are one of the most vulnerable food products in the world due to their delicate structure. This obviously makes storage of these food products quite difficult since they even undergo rapid deteriorative changes after harvesting. There have been some successful findings on the positive impact of edible coatings on the shelf life of Tomato (**Table 1**).

Coating material	Food product	Impact on product	References
Alginate and chitosan	Guava	Improved shelf life	Arroyo *et al.* [30]; S. Panahirad et al. [31]
Glycerol and carnauba wax with aloe vera	Mango	• Delayed loss of firmness and weight • Less changes in colour, pH and Brix value • Controlled rate of respiration	Peres et al. [32]; Maan et al. [33]
Pectin	Tomatoes	• Weight loss retention • Delay in ripening index	Abebe *et al.* [34]; B. Manringgal et al. [35]
Carboxyl methylcellulose	Avocado	• Firmness and weight loss retention • Reduce the respiration rate • Antimicrobial • Increase the shelf life	Tesfay *et al.* [36]; Manringgal *et al.* [35]
Gelatin, Guar, Chitosan	Barhi date	Extended the shelf life of Barhi date fruits in comparison with the control sample	Abu-Shama *et al.* [37]; N.A. Al-Tayyar *et al.* [38]
Beewax, Chitosan	Strawberries	• Prevention of fungal infection, reduced weight loss and respiration rate	Velickova *et al.* [39]; N.A. Al-Tayyar *et al.* [38]

Table 1.
Impact of edible coating materials on food products.

Application of edible coatings have demonstrated a positive result in terms of improving the shelf life and preserving the quality of tropical fruit. Edible coatings have been added to pitaya [40], soursop [41], pineapple [42], papaya [43], banana [44], longan [45], and guava [46].

8. Conclusion

Edible coating is a very interesting field of study that could revolutionise the postharvest industry as we know it. These materials are biodegradable, eco-friendly and has less to no negative impact on the food product. There has been so many proven evidences on the positive impact of edible coatings and films on some food products.

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