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Importance of edible coating on fruits and vegetables: A review

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Abstract
Edible coating extends the post-harvest life of fresh fruits and vegetables. It is used to improve food appearance and provide safety to the food by its environmental friendly nature. It may be obtained from both animal and vegetable sources. Nature of edible coating may be of protein, lipid, polysaccharide, resin alone or in combination. It acts as a barrier for moisture and gases during processing, handling and storage. It reduces food deterioration and enhances safety by their activity or by incorporation of antimicrobial compound. Other advantages of using edible coating is to reduce packaging waste, to extend the shelf life of fresh and minimally processed product and protect it from harmful environmental effect by maintaining the transfer of oxygen, carbon dioxide, moisture, aroma and taste compound in a food system. According to this review, Edible Coatings extends shelf life, reduce water and moisture loss, delayed ripening process and also prevent microbial growth specifically in fresh fruits and vegetables.

Keywords: Triclosan, TCS, determination, detection, sensor

Introduction

Edible coating is used to improve food appearance and provide safety to the food by its environmental friendly nature. It may be obtained from both animal and vegetable sources. Coating may be of protein, lipid, polysaccharide, resin, nature alone or in combination. They act as a barrier for moisture and gases during processing, handling and storage. It reduces food deterioration and enhances safety by their activity or by incorporation of antimicrobial compound. Other advantages of using edible coating is to reduce packaging waste, to extend the shelf life of fresh and minimally processed product and protect it from harmful environmental effect by maintaining the transfer of oxygen, carbon dioxide, moisture, aroma and taste compound in a food system. Edible coating may carry functional ingredient such as antioxidants, nutrients and flavor to enhance food stability, quality, functionality and safety. Fruits and vegetables are generally coated by dipping in, brushing or by spraying with edible material so that a semi permeable membrane is produced on the surface by which it suppress the respiration rate, controls moisture loss and provides other function (Raghav *et al*., 2016) [58, 59]

Huge post-harvest losses of fruits and vegetables are a matter of grave concern for any country whose economy is agriculture based. But this is a general phenomenon happening in almost every developing country. Fruits and vegetables are highly perishable commodities that require to be handled with much care to minimize losses. Because of their high moisture content horticultural crops are inherently more liable to deteriorate especially under tropical conditions. They are biologically active and carry out transpiration, respiration, ripening and other biochemical activities, which result in quality deterioration. Losses during post harvest operations due to improper storage and handling are enormous and can range from 2050 percent in developing countries (Kader, 1992). During peak seasons when horticultural crops arrive in plenty at the market, prices slump bringing the farmer less profit. These stocks are carelessly handled due to lack of appropriate storage and transport facility. There should be enough processing industries to utilize the surplus. Moreover the varieties available need to be suitable for processing. Here agriculture may be characterized as disjointed. Production is not linked with marketing. With perishable crops like fruits and vegetables, storage, packaging, transport and handling technologies are practically non-existent in most developing countries. Hence considerable amount of produce is wasted. Every crop is worthy of its investment only when it is utilized completely without losses. The quality of the harvested fruits and vegetables depends on the condition of growth as well as physiological and biochemical changes they undergo after harvest. Fruits and vegetable cells are still alive after harvest and continue their physiological activity. The post harvest quality and storage life of fruits appear to be controlled by the maturity. If the fruits are harvested at right maturity their quality is excellent.

The main components of our everyday foods (e.g., proteins, carbohydrates and lipids) can fulfill requirements for preparation of edible films. As a general rule, fats are used to reduce water transmission; polysaccharides are used to control oxygen and other gas transmission, while protein films provide mechanical stability. These materials can be utilized individually or as mixed composite blends to form films provided that they do not adversely alter food flavor. A major objective in preparing films for many foods (e.g., fresh fruit and vegetables) is to ensure that the generated films afford physical and chemical properties necessary to maintain transmission of various gases and liquids at the same rates as they occur within their native systems. Chemical structures of the three major components used to prepare films differ widely, and therefore attributes that each component contributes to overall film properties are different too.

Respiration plays a very significant role in the post harvest life of the fruits. In most fruits the rate of respiration increases rapidly with ripening as in climacteric fruits when senescence and deterioration of the fruits begin. To extend the post harvest life of the fruits and delay ripening, its respiration rate should be reduced as far as possible. Ethylene, produced by some fruits as they ripen, promotes additional ripening of produce. Thus an understanding of the factors which influence the rate of respiration and ripening is indispensable to developing appropriate post harvest technologies. Recently edible films have been developed to extend the shelf life of fruits and vegetables. This environment friendly technology wraps the film closely around the fruit preventing respiration and transpiration, thus slowing down senescence. Studies have shown that these films can be incorporated with nutrients or preservatives and are functional in various ways. With demand for more natural foods, biopreservatives are being added to the films making it more wholesome for the consumer.

Edible coating should

- not contain any toxic, allergic substance and should be digestible
- liable to mechanical damage during handling, display and transportation
- have good adhesion property
- have good water barrier properties
- provide semi permeability to maintain internal equilibrium of gases which is involved during anaerobic and aerobic respiration, thus retarding senescence
- not affect the nutritional and organoleptic properties of fruit and vegetable
- be capable of being used as a carrier for desirable additives such as flavor, nutrients, coloring and vitamin
- have antimicrobial and antibacterial properties
- be easily manufactured and economically viable

Requirements from a Coating Material

The characteristics required from an edible coating depend on the specific requirements of the product to be coated, including the primary degradation modes to which it is most susceptible. Fresh and minimally processed fruits have complex requirements concerning packaging systems, since such products are still metabolically active. The main requirements for a fruit coating are described in the following:

1. Moderately low permeability to oxygen and carbon dioxide in order to slow down respiration and overall metabolic activity, retarding ripening and its related changes. On the other hand, the metabolic activity must not be reduced to a degree that creates anaerobic conditions, which promote physiological disorders and accelerate quality loss (Kester and Fennema 1986; Debeaufort *et al*., 1998) [38, 18]. Edible coatings for fruits should control the ripening by reducing oxygen penetration in the fruit rather than by decreasing CO2 and ethylene evaporation rates, that is to say, the CO2/O2 permeability ratio (related to selectivity) should be as high as possible. Proteins and polysaccharide coatings present much higher ratios (from 10 to 25) than those of conventional plastic films (lower than 5.73) (Debeaufort *et al*., 1998) [18]. The decreased metabolic activity provided by edible coatings has also been known to retard softening changes (Conforti and Zinck, 2002; Zhou *et al*., 2011) [16, 76], which result from the loss of turgor pressure and degradation of cell walls, contributing to a decrease in fruit brittleness and firmness (Zhou *et al*., 2008) [77]. The degradation of cell wall structure has been attributed to activity of enzymes such as pectin methylesterase, cellulase, and polygalacturonase on polysaccharides present in the cell wall (Goulao and Oliveira, 2008) [29].
2. Low water vapor permeability in order to retard desiccation (Garcia and Barret, 2002) [26]. In the case of minimally processed fruits, this is especially difficult, since the product surface usually has a very high water activity, which tends to decrease the performance of hydrophilic coatings (Hagenmaier and Shaw, 1992) [8].
3. Sensory inertness or compatibility. Edible coatings were traditionally supposed to be tasteless so would not interfere with the flavor of the product (Contreras-Medellin and Labuza, 1981) [17]. Alternatively, they may have sensory properties compatible with those of the food. For instance, fruit purees have been studied as film-forming edible materials (McHugh *et al*., 1996; Senesi and McHugh, 2002; Rojas-Graü *et al*., 2006, 2007a; Azeredo *et al*., 2009) [50, 66, 61-62, 5] which can be used as edible coatings for fruits due to the presence of filmforming polysaccharides in their compositions.

Edible coating for fruits and Vegetables

Biopolymer such as lipids, polysaccharide, protein and resin are common coating forming materials that can be used alone or in combination. The functionality of coating is greatly influenced by physical and chemical characteristics of polymer (Sothornvit 2000). Coating material selection is based on water solubility, hydrophilicity and hydrophobicity nature, ease in formation of coatings and sensory properties.

Lipid based coatings

Lipid compounds include neutral lipids of glyceride which are esters of glycerol and fatty acid and waxes which are esters of long chain monohydric alcohols and fatty acids. Resins are a group of acidic substances that are secreted by special plant cell into long resin duets or canals in response to injury or infection in many trees and shrubs (Debeaufort *et al*., 1998) [18]. Edible lipids are neutral lipids, waxes and resin which are traditional coating material for fresh produce and provide effective moisture barrier property and also improve surface appearance (Hernandez 1994; Morillon 2002) [53].

Waxes (carnauba wax, beeswax, paraffin wax and other) are commercially used as protective coating for fresh fruits and vegetables. It reduces moisture loss and surface abrasion during fruit handling (Lawrence 1983) [41]. Generally wax coatings are resistant to moisture loss as compared to lipid and non lipid coating (Schuttz 1949; Landmann 1960) [40]. Wax coating is effective on citrus, apple, mature green tomato, cucumber and other vegetables such as asparagus, beans, carrots, eggplant, okra, sweet potatoes and turnip (Hardenburg 1967) [34] where shiny surface is desired.

Shellac and other resin based coatings have lower permeability to O_2 , CO_2 and ethylene gas. Shellac coating dries fast and provides shiny surface on the coated produce (Baldwin 1994) [9]. Resins coating are fairly effective for water loss.

Beneficial properties of lipid based coatings include good compatibility with other coating agents and have high water vapour and gas barrier properties as compared to polysaccharide and protein based coating (Greener and Fennema 1992) [30-31]. Lipid based coating gives greasy surface and undesirable organoleptic properties such as waxy taste and lipid rancidity (Robertson, 2009) [60].

Polysaccharide based coating

Polysaccharide coating have been produced from starch and starch derivatives, cellulose derivative, alginates, carrageenan, various plant and microbial gums, chitosan and pectinates (Nisperos 1990). These coatings reduce respiration rate of fruits and vegetables (Motlagh 1988) [54]. Due to its hydrophilic nature it has high gas barrier property.

(a) Starch and its derivative

Starch is a natural polysaccharide used for food hydrocolloid (Whistler 1965) [73] because of its high functionality and relatively low cost. Starch film is generally transparent, odourless, tasteless and colorless and has low permeability to O_2 .

Dextrin is derived from starch and has smaller molecular size and used in coating formation. Dextrin coating has better resistance to water vapour as compared to starch coating (Allen 1963) [2]. Pullulan is an extracellular polysaccharide of starch which is edible and biodegradable. Pullulan films are colourless, odourless, and tasteless and show high O_2 barrier properties. Pullulan coating has been applied for preserving strawberries and kiwi fruits (Diab 2001) [20]. Starch coating is effective for fruits and vegetables because they have high respiration rate.

(b) Cellulose and its derivative

Cellulose is a structural material of plant cell walls (Nisperos 1994) [9]. Cellulose derivative shows excellent film forming property but they are too expensive for large scale application. Most common cellulose derivatives are carboxymethyl cellulose (CMC), methyl cellulose (MC), hydroxypropyl cellulose (HPC) and hydroxypropyl methyl cellulose (HPMC). These are water soluble polysaccharide, non ionic and compatible with surfactants.

CMC is the most important cellulose derivative for food application. Edible coatings produced from CMC, MC, HPC and HPMC are applied on some fruit and vegetables for providing barrier to oxygen, oil or moisture transfer (Morgan 1971) [52] and also for providing better adhesion (Dziezak 1991) [22]. CMC coating maintains the firmness and crispness of apple, peaches and carrots when used in dry coating process (Mason 1969) [49], preventing the flavour loss of some fruit and vegetable and reduce oxygen uptake without any increase in carbon dioxide level in internal environment of coated apples.

(c) Seaweed extracts

Alginates are the major structural polysaccharides of brown seaweed, also known as Phaeophyceae. Alginate consists of good film forming property, transparent and soluble in water. Alginates have low permeability to oil and fats but have high permeability to water vapour (Valero *et al*., 2013) [71]. It also act as a sacrificing agent. Alginates have good adhesion property. Calcium alginate coatings enhance the quality of fruits and vegetables by retarding shrinkage, oxidative rancidity, moisture migration and oil absorption. It reduces weight loss and improves appearance and colour (Hershko 1998) [36].

Carrageenan is extracted from several red seaweeds mainly *Chrondrus crispus* (Whistler 1985) and it is complex mixture of polysaccharide. Carrageenan based coating reduces moisture loss and oxidation of apple slices (Lee *et al*., 2003) [42-43]. It inhibits microbial growth. It reduces moisture loss from grape fruit (Bryan 1972) [11].

(d) Chitosan

It is a linear polymer of 2-amino-2-deoxy-βD-glucan, is a deacetylated form of chitin. It is a naturally occurring cationic biopolymer (Bemiller 1965, Davis 1988). It is a shell component of crab and shrimp, skeletal substances of invertebrates and cell wall constituent of fungi and insects (Raghav *et al*., 2016) [58, 59]. Chitosan is one of the best coating material for fresh produce because of its excellent film forming properties, antimicrobial activity and its compatibility with other substances such as minerals, vitamins and antimicrobial agents (Li 1992; Shahidi 1999) [67]. Chitosan based coating delay ripening and decreased respiration rate of fruits and vegetables and retard weight loss, colour wilting and fungal infection in cucumber and tomatoes (EI Ghaouth 1991) [23].

(e) Aloe vera

Aloe vera is a tropical and subtropical plant. Aloe vera contains medicinal and therapeutic properties and has been used for centuries (Eshun 2004) [24]. Aloe vera gel is used as edible coating for fruit and vegetables. It has antifungal properties (Saks 1995) [64]. Aloe vera gel based edible coatings prevent moisture loss and retains firmness, decreases respiration rate, delays oxidative browning and reduces the growth of microorganisms in table grapes (Valverde 2005) [37].

Protein based edible coating

Edible coating can be made from animal protein (such as milk protein) and plant protein (such as zein, soy protein and wheat protein). They show excellent oxygen, carbon dioxide and lipid barrier properties particularly at low RH (Lin *et al*., 2007) [46]. Protein based edible coatings are brittle and susceptible to cracking. Protein based edible coating shows poor water barrier properties (Mohamoud and Savello 1992) [51].

(a) Plant origin

Zein and soy protein are the two main plant origin protein and they are used as edible coating for fruits and vegetables. Zein is the storage protein of corn and comprises of 45 to 50% of the protein in corn. Zein based coating has lower permeability to water vapour as compared to other protein based coatings (Krochta 1992) [39]. It has lower permeability to O_2 and CO_2 as compared to polysaccharide and polysaccharide/lipid composite coatings (Greener 1989).

Soy protein concentrate (SPC) or Soy protein Isolate (SPI) is produced from defatted protein and contain 65 to 72% and 90% protein respectively (Mounts 1987). Soy protein based edible coating shows bad resistance to moisture because of its hydrophilic characteristics. Soy protein based coating exhibits good barrier properties to O_2 at low RH.

(b) Animal origin

Whey protein and Casein are the main milk protein. They are used as edible coating for fruit and vegetables. Casein comprises 80% of the total milk protein (Chen 1995) [13]. Casein films are transparent, flavourless, and flexible and are attractive for food applications. Whey proteins comprise 20% of the total milk protein. Whey proteins are purified to produce whey protein concentrate. It can have 25 to 80% protein content or whey protein isolate has 90% protein content. Whey protein films show good oxygen barrier properties in low and intermediate relative humidity.

Commercial application of edible coating

The impact of cellulose edible coating having different pH on lightly processed carrot was studied by Li and Barth (1998). Their study showed that lower pH EC had highest CO_2 and lowest O_2 concentration. A study was conducted by Baldwin *et al.,* (1999) [8] to determine the impact of edible coating produced from polysaccharide and carnauba wax on mango fruit. Their results indicated that polysaccharide was less permeable to respiratory gas such as O_2. Both coatings delayed ripening and improved appearance. Therefore it can be concluded that shelf life was extended by both coatings. Water loss was also comparatively reduced by carnauba wax and polysaccharide coatings.

According to Yaman and Bayoindiri (2002) studied the impact of edible coating such as Semperfresh TM on cherries. Their study suggested that this coating reduce weight loss and increase firmness, ascorbic acid content, titratable acidity and skin color of cherries. It also prolonged the shelf life of cherries. According to Lee *et al.,* (2003) [42-43] and Bai *et al.,* (2003) [6-7] studied the impact of edible coating on slices apples and variety of apples. The coating produced from carageenan and whey protein concentrate reduced the respiration rate, reduced firmness loss and extended the shelf life of apple slices. Another study was conducted on coating made from shellac wax, candelilla wax and shellac with carnauba wax. Shellac coating showed maximum fruit gloss, highest CO_2, lowest O_2 and least loss of firmness for all varieties of apples (Delicious, Fuji, Braeburn and Granny Smith). This study was done by Bai *et al.,* (2003) [6-7] to determine the impact of zein edible coating on Gala apples. Zein coating extended the shelf life of apples and also maintained the quality by decreasing respiration rate.

Impact of methyl cellulose and polyethylene glycerol edible coating on fresh apricot and green peppers was studied by Ayranei and Tunc (2004) [3]. Water loss rate was lower in fresh apricot coating and green pepper coating. Vit. C loss was reduced by this coating. Chitosan based edible coating on strawberries and red raspberries reduced decay incidence and weight loss and also delayed the change in color, pH and titratable acidity was studied by Han *et al.,* 2004. Dipping mango fruit in carboxymethyl cellulose (CMC) improved the visual quality and delay firmness loss was studied by Plotto *et al.,* 2004 [57]. The effect of edible coating on cucumber based on polyvinyl alcohol, chitosan, lithium chloride and sodium benzoate was studied by Zhang *et al.,* 2004 [75]. This coating inhibit respiration and chlorophyll breakdown. It also reduces soluble solid content and inhibits polyphenol oxidase activity.

Prickly pear cactis mucilage edible coating improved the shelf life of strawberries. This coating maintains color, texture and sensory quality of fruit was studied by Delvalle *et al.,* (2005). The study conducted by Tanada Palmu *et al.,* (2005) [70] and Maftoonazad *et al.,* (2005) [47] stated that methyl cellulose edible coating slowed down respiration rate, prevented firmness loss and color of avocados and the wheat gluten coating enhanced the shelf life of strawberries and also maintained the quality. It also reduced weight loss and maintained the firmness of strawberries.

Durango *et al.,* (2006) [21], Hernandez Mumz *et al.,* (2006) [35] and Martmez Romero *et al.,* (2006) [48] suggested that edible coating improve the quality of fruits. First study concluded that the starch chitosan edible coating used on minimally processed carrot controlled the growth of mesophilic aerobes, yeast, molds and psychrotrops. Second study concluded that chitosan combined with calcium gluconate edible coating increase the shelf life of strawberries by reducing respiration activity, delaying ripening and reducing fruit decay due to senescence. Third study concluded that Aloe vera based edible coating maintained sweet cherry quality and safety during postharvest treatment. Aloe vera coating reduce respiration rate, weight loss and color change and decreased softening and ripening of strawberries. It also decreased microbial populations.

Impact of trehalose edible coating on minimally processed apple slices was studied by Albanese *et al.,* 2007 [1]. It showed that coating reduced browning phenomena and lowered whitening index (WI) and hue values. It also reduced weight loss and organic acid. In another study on impact of chitosan coating on mango slices (Chien *et al.,* 2007) [14] the coating increase the shelf life and maintained the quality by reducing weight loss and inhibiting the growth of microorganisms. According to Chlebowska *et al.,* (2007) [15] pullulan edible coating reduced the apple mass loss and increased the shelf life. The study conducted by Perez Gago *et al.,* (2005) [56] edible coating based on whey protein isolate (WPC), hydroxypropyl methylcellulose (HPMC), bee wax and carnauba wax applied on apple slice stated that whey protein isolate had antibrowning effect. Bee wax decreased enzymatic browning of the fruit.

Impact of pectin, plant gum and starch on two resins such as Thompson seedless and Shahani was evaluated by Ghasemzadeli *et al.,* 2008. The study concluded that pectin had better color, texture and flavour. It also maintains the firmness of fruit. Edible coating based on calcium caseinate, chitosan and semperfresh TM improved the quality and increase the storage life of hardy kiwi fruit (Fisk *et al.,* 2008) [25].

In a study on effect of agar agar based coating on minimally processed cloves it was observed that filamentous fungus and aerobic measophilic were inhibited and the coating resulted in reduction of respiration rate of clove (Geraldine *et al.,* 2008) [27]. Impact of mango edible film on fresh mango quality and shelf life during storage was evaluated (Sothornvit and Rodsamran 2008) [68]. Film provided good oxygen barrier properties and had enough mechanical strength. The film decreased weight loss and increased ripening time period. It also prolonged the shelf life of the mangoes. The impact of modified atmosphere packaging and honey dip treatment as edible coating on minimally processed grapes was evaluated by Sabir Ali *et al.,* (2011). Their study stated that it reduced weight loss of berries. It also maintained the quality of minimally processed grapes by retarding quality loss and berry decay. Result showed that honey dip edible coating act as barrier to moisture and resist to water vapour diffusion during the cold storage and gave good adherence to berry surface. Impact of hydroxypropylmethylcellulose (HPMC) coating on grapes was evaluated by Pastor *et al.,* (2011) [55]. The study concluded that HPMC coating extended the shelf life of grapes and inhibiting the growth of microorganism. Effect of Aloe vera gel edible coating on green grapes was evaluated by chauhan *et al*., (2014) [12]. According to their study coating reduced weight loss, browning, cracking and also inhibited the growth of bacteria and fungi in berries. Coating showed beneficial effects in terms of delaying rachis browning and maintained the visual aspects of berries without any adverse effect on aroma, taste or flavours. Impact of gellan based edible coating on fresh cut pineapple was evaluated by Azarakhsh *et al*., (2014). The study concluded that gellan coating reduced weight loss, slow down respiration rate and maintained firmness and color. It also maintained the quality of fresh cut pineapples. Effect of coating based on dewaxed shellac and Aloe vera on tomato fruit was evaluated by Chauhan *et al.,* (2015). Their study stated that they contain optimum barrier properties towards O_2 , CO_2 and water vapour and they effectively prevented anaerobiosis. It also prolonged the shelf life of tomatoes. Impact of composite coating comprises of xanthan gum, olive oil and antioxidants on table grapes was studied by Baraiya *et al.,* (2016) [10]. The study concluded that this coating reduced weight loss, slow down respiration rate and delayed firmness. Shelf life of grapes was extended by this coating. According to Sogvar *et al.,* (2016) studied the impact of edible coating such as aloe vera with ascorbic acid on strawberries. Their study suggested that coating reduced weight loss and inhibiting the growth of mesophilic yeast and molds. This coating enhanced the shelf life of strawberries.

Applying Methods of Edible Coating

Edible coatings should be applied on fruits and vegetables by different methods. These methods are

a) Dipping
b) Brushing
c) Extrusion
d) Spraying
e) Solvent casting

The dipping method is used widely for applying edible coatings on fruits and vegetables, in this method Fruits and Vegetables are dipped in coating solution for 5-30 sec. It is easy to apply on mostly fruits. While Brushing method gives good result, Edible Coatings applied on generally, Beans and highly perishable Fruits and Vegetables such as strawberry, berries. Other three methods spraying, extrusion and solvent castings are also used in food industry. Extrusion method depends on thermoplastic properties of edible coatings; it is best technique for applying of EC for industrial purpose as compared to other methods (Valverde *et al.,* 2005) [37].

Conclusion

Edible coatings alone or as carriers of useful additives serve many functions for all types of food products. They improve the external and internal quality characteristics of diverse commodities. Coatings can reduce dehydration and oxidation as well as the resulting undesirable changes in color, flavor, and texture. Waxes and other coatings delay ripening and senescence of fresh produce and can increase the microbial stability of lightly processed fruits, vegetables, and some processed products. Coatings show promise as environment-friendly quarantine treatments. Most coating materials are produced from renewable, edible resources and can even be manufactured from waste products that represent disposal problems for other industries. According to this review, Edible Coatings extends shelf life, reduce water and moisture loss, delayed ripening process and also prevent microbial growth specifically in fresh fruits and vegetables.

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