Edible Coating for Preservation of Perishable Foods: A Review

Javeed Akhtar\textsuperscript{a}, P.K Omre\textsuperscript{b} and Z.R.A. Ahmad Azad\textsuperscript{c}

\textsuperscript{a}Research Scholar, Department of Post Harvest Process and Food Engineering, College of Technology, G.B. Pant University of Agriculture and Technology, Pantnagar (U.K), India.

\textsuperscript{b}Professor, Department of Post Harvest Process and Food Engineering, College of Technology, G.B. Pant University of Agriculture and Technology, Pantnagar (U.K), India.

\textsuperscript{c}Assistant Professor, Department of Food Technology, Jamia Hamdard University, Delhi-62, India.

*Corresponding Author: JaveedAkhtar
Email: er.jakhtar@gmail.com

Received: 04/08/2015
Revised: 17/09/2015
Accepted: 19/09/2015

Abstract

Technologists and entrepreneurs in food industry always produce novel products as per the demand of consumers whose preferences are growing towards ready-to-use foods. In this, fresh-cut fruits and vegetables are at the top of the list and are attracting a great deal of research in this area. In fact, fruit and vegetable market has grown up rapidly in recent years as a result of the changes in consumer preferences. Therefore, there is a need to discover advance techniques for preservation of processed food products as well as fresh food products like fruit and vegetables, which is of direct use to food industry. Edible coating is an environmentally friendly technology that can be applied to many food products to control moisture transfer, gas exchange or oxidation processes. Edible coatings can provide an additional protective coating to product; can give the same effect as modified atmosphere storage in modifying internal gas composition and it can incorporate several ingredients into the polymer matrix that can be consumed. However, edible coatings were not successful in some cases. The success of edible coatings for fresh products totally depends on the control of internal gas composition. Quality criteria for fruits and vegetables coated with edible films must be determined carefully and the quality parameters must be monitored throughout the storage period. In this review paper the main emphasis is given on preservation of fruits and vegetables using edible coating and its application for maintaining the quality of food products during storage.

Key words: Edible coating, Shelf life, Quality attributes, Perishable foods, Fruits and vegetables.

1. Introduction

Edible coatings are thin layers of edible material applied to the product surface in addition to or as a replacement for natural protective waxy coatings and to provide a barrier to moisture, oxygen, and solute movement for the food (Smith \textit{et al.}, 1987; Nisperos-Carriedo \textit{et al.}, 1992a; Guilbert \textit{et al.}, 1996; Lerdthanangkul and Krochta, 1996; Avena-Bustillos \textit{et al.}, 1997; McHugh and Senesi, 2000). They are applied directly on the food surface by dipping, spraying, or brushing to create a modified atmosphere (Guilbert \textit{et al.}, 1996; Krochta and Mulder-Johston, 1997; McHugh and Senesi, 2000). Because they will be consumed, the material used for the preparation of edible films and coatings should be generally regarded as safe (GRAS) (Park \textit{et al.}, 1994; Krochta and Mulder-Johston, 1997) approved by FDA and must conform to the regulations that apply to the food product concerned (Guilbert \textit{et al.}, 1996). An ideal coating is defined as one that can extend storage life of fresh fruits and vegetables without causing anaerobiosis and reduces decay without affecting their quality. Previously, edible coatings have been used to reduce water loss, but recent developments of formulated edible coatings with a wider range of permeability characteristics has extended the potential for fresh produce application (Avena-Bustillos \textit{et al.}, 1994; Park \textit{et al.}, 1994). Fruit-based coatings provide enhanced nutrition to products, which increases their market value (McHugh and Senesi, 2000). Edible and biodegradable coatings must meet a number of special functional requirements, for example, moisture barrier,
solute or gas barrier, waterlipid solubility, color and appearance, mechanical characteristics, nontoxicity, etc. The effect of coatings on fruits and vegetables depends greatly on temperature, alkalinity, thickness and type of coating, and the variety and condition of fruit and vegetable (Park et al., 1999). The functional characteristics required for the coating depend on the product matrix (low to high moisture content) and deterioration process to which the product is subjected (Guilbert et al., 1996).

Edible coatings can provide an additional protective coating for fresh products and can also give the same effect as modified atmosphere storage in modifying internal gas composition. Recently, several edible coatings for preserving fruits such as oranges, apples, and grapefruits were successfully applied. But, in some cases, edible coatings were not successful. In fact, fruit quality was deteriorated. The success of edible coatings for fresh products totally depends on the control of internal gas composition. This article is designed to help develop systematic means of selecting edible coatings to maximize quality and shelf life of fresh fruits and vegetables. Methods will be introduced to select edible coatings based on their gas permeation properties relative to controlling internal gas composition of target products (Park, 1999). Major losses in quality and quantity of fresh fruits occur between harvest and consumption (Sparks, 1976). Savings obtained through reduction of postharvest fruit losses is regarded as a hidden harvest (Spurgeon, 1976). Through a better understanding of the respiration process of fresh fruits, several techniques have been developed that are successful in extending shelf life. Controlled atmosphere storage and modified atmosphere storage have been used for preserving fruits by reducing their quality changes and quantity losses during storage. Edible coatings on fresh fruit can provide an alternative to modified atmosphere storage by reducing quality changes and quantity losses through modification and control of the internal atmosphere of the individual fruits.

2. Characteristics of Edible Film

The ideal edible film should have the following characteristics:

a) Contain no toxic, allergic and non-digestible components
b) Provide structural stability and prevent mechanical damage during transportation, handling, and display.
c) Have good adhesion to surface of food to be protected providing uniform coverage.
d) Control water migration both in and out of protected food to maintain desired moisture content.
e) Provide semi-permeability to maintain internal equilibrium of gases involved in aerobic and anaerobic respiration, thus retarding senescence.
f) Prevent loss or uptake of components that stabilize aroma, flavor, nutritional and organoleptic characteristics necessary for consumer acceptance while not inversely altering the taste or appearance.
g) Provide biochemical and microbial surface stability while protecting against contamination, pest infestation, microbe proliferation, and other types of decay.
h) Edible films and coatings maintain or enhance aesthetics and sensory attributes (appearance, taste etc.) of product.
i) Serve as carrier for desirable additives such as flavor, fragrance, colouring, nutrients, and vitamins.
j) Incorporation of antioxidants and antimicrobial agents can be limited to the surface through use of edible turns, thus minimizing cost and intrusive taste.
k) Last but not least be easily manufactured and economically viable.

Many type of material can be used for coating or wrapping various food products to increase shelf life of the food product that may be eaten along with food with or without further removal of coating is considered as an edible film or coating. Edible films provide additional layer or fortification of natural layers to prevent moisture losses and quality changes, while selectively permitting for controlled exchange of various gases, namely oxygen, carbon dioxide, and ethylene, which are involved in respiration processes. A coating or film can also provide surface resistance and prevent loss of other quality components of food product. Therefore, the thickness of coating or film can be used as less than 0.3 mm. Depending on oxygen level, respiration can be aerobic or anaerobic. Respiration activity of a product is influenced by storage temperature, type of processing, oxygen to carbon dioxide ratio, and absolute value of oxygen concentration itself. If a wax layer is applied, oxygen content of the internal atmosphere will decrease as a function of thickness of the layer, while carbon dioxide content and anaerobic respiration will rise (Eaks and Ludi, 1960). As a thumb rule, when oxygen level drops below 3%, anaerobic respiration will start replacing the Krebs cycle, with the resulting glycolytic pathway releasing unacceptable flavors and causing other problems, such as changes in colour and texture.

In addition, food texture is also a fundamental feature determining product acceptability, appearance and textural changes being very tightly linked markers...
of food deterioration (Cantwell and Suslow, 2002). Both appearance and texture of a fruit or vegetable tissue strictly depend on genetic, environmental, postharvest handling and storage factors. Therefore, the precise knowledge of the processes leading to the appearance and textural modifications is of crucial importance in developing effective approaches to counteract them and, hence, to improve quality and shelf-life of these products. Most of the changes occurring in fresh-cut fruits and vegetables represent an extension of the normal ripening events leading to their softening, although they are also specifically influenced by the tissue cutting and wounding. Product maturity at the time of processing mostly affects the shelf-life of fruits since they become increasingly soft and susceptible to transport and handling damage during ripening (Beaulieu et al., 2004; Soliva-Fortuny et al., 2004; Lana et al., 2005). Hence, precise understanding of ripening related softening must be carefully taken into consideration when fresh-cut fruits are studied. Conversely, fresh-cut vegetables normally present minor problems because they generally have a much greater proportion of cells with thickened secondary walls and, consequently, are much firmer and less susceptible to deterioration. One most important advantage of using edible films and coatings is that several active ingredients can be incorporated into the polymer matrix and consumed with the food, thus enhancing safety or even nutritional and sensory attributes.

3. History of Edible Coating

Wax was the first edible coating used on fruits. The Chinese applied wax coatings to oranges and lemons in the 12th and 13th centuries (Hardenburg, 1967). Although the Chinese did not realize that the full function of edible coatings was to slow down respiratory gas exchange, they found that wax-coated fruits could be stored longer than non-waxed fruits. In the 1930s hot-melt paraffin waxes became commercially available as edible coatings of fresh fruits such as apples and pears. Erbil et al. (1986) reported that coating of peach surfaces with wax emulsions decreased water vapour and oxygen transmission, thus diminishing respiration rate and increasing shelf life of the fruit. Nisperos-Carriedo et al. (1990) and Baldwin et al. (1995) observed that oils or waxes and cellulose had similar effects of preventing spoilage and retaining fresh-picked quality for tropical fruits. Several attempts have been made to develop other materials that could be used to coat, produce and modify internal gas composition for short-term storage. El-Ghaouth et al. (1992) and Zhang and Quantick (1997) suggested that chitin and chitosan (deacetylated chitin) from marine invertebrates could be used for making a transparent film for application as an edible coating on fruits and vegetables. In (Lowings and Cuts, 1982), reported on an edible coating material that is non-phytotoxic, tasteless, odourless, and effective in preserving fruits. This coating material is a mixture of sucrose fatty acid esters (SFAE), sodium carboxymethyl cellulose, and mono- and di-glycerides. SFAE was originally developed as an emulsifier. However, it has been established that the ripening of fruits be retarded by a coating of SFAE. SFAE mixtures have been commercially available since the 1980s, for coating fruits and vegetables, under the trade names `TAL Pro-long' and Semper fresh. Park et al. (1994) applied zein coating on the surface of tomatoes and reported that the film coating delayed colour change, weight loss and maintained firmness during storage.

4. Preparation of Edible Films/Coating and Its Application

Edible films or coating can provide either clear or milky coatings, but consumers generally favour unseen, clear coatings. Coatings can be obtained in various ways:

a) By dipping the product into, or by brushing or spraying it with solution containing film ingredients, so as to deposit the film directly on food surface (Gontard and Guillbert, 1996), or

b) By creating standalone film from solution or through thermo formation for subsequent covering of food surface.

The simplest way to apply a film is directly from solution. Depending on concentration of coating solution, the product will absorb an appropriate amount of coating material necessary to form the desired layer, which when dried, forms a protective layer at the food surface. In most cases, some plasticizer needs to be added to coating solution to keep the developing film from becoming brittle. Possible food grade plasticizers are glycerol, mannitol, sorbitol and sucrose. If coating cracks, movement of various components will increase by orders of magnitude, resulting in mass flow instead of diffusion. Coatings should have good adhesion to rough surfaces (Hershko et al., 1996).

Application of a uniform film or coating layer to cut fruit and vegetable surfaces is generally difficult. Better uniformity can be promoted by adding surfactants to solution to reduce surface tension. This strategy will also reduce the superficial and in turn reduce water loss (Roth and Loncin, 1984). In one standard process, carboxymethyl cellulose (CMC) powder was applied to cut fruit surfaces. The CMC adsorbed moisture within pores of the surface, causing the CMC to swell, which not only prevented loss of moisture, but also provided a barrier against oxygen to prevent enzymatic discoloration (Delong and Shepherd,
1972). Coatings derived from non-aqueous media, such as applying an alcohol solution of shellac to candy, result in another level of complexity. For safety reasons the finished coating layer should not contain any solvent residue. Thus, during large scale operation, disposal of exhaust gases may present environmental challenges. Should a free-standing film he required, it can be prepared from solution by evaporation. It should be pointed out that characteristics of stand-alone films might differ from those of films created on food surfaces (i.e., those produced by dipping in or spraying). Films obtained through evaporation were found to have lower water vapour permeability than those prepared by spraying (Pickard et al., 1972). Varying rate and temperature of evaporation may result in creation of films with differing characteristics. For example, polymer chains may he prematurely immobilized before reaching their optimal structure (by accelerated drying) to affect permeability (Reading and Spring, 1984; Greener, 1992).

When zein films were obtained from solution after drying at 51°C for 10 mm, plasticizer was needed to obtain a non-brittle material (Kanig and Goodman, 1962). In contrast, drying at 35°C for 24 h yielded flexible zein films without addition of plasticizer (Guilbert, 1986; 1988). Films can also be formed by cooling concentrated solutions. However rate of cooling can again result in amorphous, crystalline, or polymorphic films with differing permeabilities. The characteristics of a polymorphic film may be further modified by tempering (Landman et al., 1960). Formation of flexible and stretchable films was also reported from molten acetylated monoglyceride (Feuge et al., 1953). When films, comprised of pectin or alginate, are prepared by evaporation from watersoluble components, they are subject to re-dissolution in water or destruction in high humidity conditions. This problem can he avoided by cross-linking polymers at the film surface. Various reactions can be employed to achieve enhanced covalent bonding (e.g., treatment with formaldehyde); however such reactions can create new chemical structures that might necessitate approval by FDA. The most acceptable cross-linking method involves ionic interaction between polymer chains via multivalent ions to form ionomers. While most synthetic films have higher tensile strength than typical edible films, ionomers are exceptions (Paviath et al., 1999).

For ionomers, tensile strength of their films is dependent on number of available bonding locations. Ionomer cross-linked films can be used as wrapping materials or, in case of water solubility, as bags that dissolve when immersed in water during food preparation (e.g., soup). In such cases, films do not have to be thin, because they will disappear before tasting and can further act as thickening agents within the food product. This aspect is especially important from an environmental perspective, where disposal is not necessary (becomes consumed as part of the food). Commercial synthetic materials are not generally biodegradable, while edible films typically are. Thus, edible films provide an ideal solution for minimizing packaging waste on-board ships during long voyages, during which maritime regulations forbid throwing of any refuse overboard. While most synthetic commercial packages possess average life times of 200 years in a marine environment, edible films decompose readily providing an environment-friendly solution. Thermoformation is rarely used to create edible films, because most edible components cannot be moulded at elevated temperatures without causing irreversible structural changes to the material. Hydroxypropylmethyl cellulose and polylactic acid, two biodegradable thermoplastics, are rare exceptions.

Any protein-containing cysteine, such as gluten, hair or chicken feather, represents interesting thermoplastic biomaterials, depending on level of cysteine content. When these materials are treated with reducing agents, such as sodium sulfite, disulfide bonds can he cleaved at 90-100°C. This bond cleavage lowers protein molecular weight allowing the material to flow under slight pressure without decomposition. The reduced disulfide bonds can then easily reform resulting in a strong, pliable material (Pallos et al., 2006).

Packaging issues are further complicated by strong demand for convenience foods. With fast moving lifestyles of today, consumers desire to spend less time in the kitchen preparing meals. True, an apple can be eaten as a whole fruit but to use it in an apple pie or fruit cocktail, non-edible and/or unappetizing parts of the fruit need to be removed. Consumers do not generally want to waste time with so-called light processing of foods (i.e., skinning and pitting fruits, slicing vegetables, skinning chickens, or just cleaning food surfaces). At the same time, consumers expect appetizing appearance and mouth-watering flavour. Preparation processes can be tedious and time-consuming. In small-scale commercial operations, such as cafeterias, automatic processing machines can now do much of the light processing work, but cost of such machinery is still too high for typical home kitchens. On the other hand, large-scale commercial processing in a centrally-located factory provides both economic and environmental benefits. In this setting, energy costs are minimized by scale of operation, disposal and/or utilization of waste is carried out efficiently at centralized locations, and volume (cost) benefits are achieved. However, removal of a food from its natural state and environment also accelerates undesirable changes that can lead to deterioration of appearance, texture, and taste. We have all likely had the experience of biting into an apple, setting it down for a few -
Natural skin does not hermetically seal fruit torn its surroundings. Rather it maintains optimal gas exchange equilibrium to protect against weight loss, discoloration, loss of flavour and texture, among other attributes. While such products are still subject to...

minutes, and then observing how quickly the exposed surface has turned brown. Extensive browning is apparent on apple slices within 30 mm, though surface discoloration begins to occur even after just a few minutes (Bolin et al., 1964).

Fig 1: Browning and softening between uncoated and coated apple and potato samples after 10 days of storage at 4°C.

Fig 2: Process Flow chart of edible coating of fruits
various aerobic and anaerobic respiratory processes, these processes are maintained in proper balance by natural skin. However, when fruit or vegetable is cut or even just mechanically damaged. Cell wall membranes are disrupted, initiating a cascade of various enzymatic processes. Even minimal mechanical damage incurred during handling and transportation stimulate increased formation of ethylene causing physiological disorders and deterioration i.e. increased cell permeability, loss of compartmentalization, and increased enzyme activities (Hyodo et al., 1978). Change in the rate of migration of oxygen, carbon dioxide, and ethylene can result in anaerobic fermentation and increased ripening. Even the way in which fruits are cut can make a difference. For example, formation of a white, unappetizing layer on carrot surfaces can be prevented by peeling them with a sharp blade (Bolin and Huxsoll, 1991). Water knife cutting can also decrease slicing-related issues (Becker and Gray, 1992). Cut surfaces increase chances for growth of microorganisms, causing multiple-fold increase in respiration (Maxey, 1982). Increased respiration rates open up possibilities for cascading biochemical changes, such as degradation of carbohydrates, activation of dormant biological pathways, and facilitation of new, additional enzymatic activities (Uritani and Asahi, 1980) which may induce production of unusual metabolites.

5. Quality Changes of Edible Coated Fruits and Vegetables

Edible coatings may serve as carriers also for a wide range of food additives, including anti-browning agents, colorants, flavors, nutrients, spices that not only extend the shelf-life of the products, but also improve their safety and acceptability (Cagri et al., 2004). An example derives from the fresh-cut carrots, one of the most consumed vegetables, whose marketing is limited by their fast physiological changes during storage, developing characteristic odors of anaerobic catabolism due to higher respiration rate and microbiological deterioration. Thus, minimally processed carrots quickly lose their firmness and bright orange color and develop a white blush on the surface, thereby reducing consumer acceptability (Barry-Ryan et al., 2000). It was recently demonstrated that dipping into a hydro-alcoholic solution after fresh-cut carrot coating with sodium alginate, followed by a final packaging into a micro-perforated polypropylene film under passive or active MAP, prevents dehydration and microbial proliferation, delays the respiratory activity and enhances the quality of the product stored at 4°C (Mastromatteo et al., 2012). In addition, from the sensory point of view, coated carrots were appreciated for about two weeks, whereas all the uncoated ones were refused after only two days.

6. Conclusion

It is concluded that, edible coating is very effective and efficient method for preservation of fruits and vegetable. Therefore, this can be used for quality control of fruits and vegetables during the storage and transportation. The quality of food can be preserved with edible coating and to extend the shelf life of highly perishable products using edible coating. Therefore, the edible coatings saves the preservation cost as compare to low temperature or other method of preservation. It is also environment friendly method of preservation of food for long time.

References


Akhtar et al...Edible Coating for Preservation of Perishable Foods: A Review


