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Article in "Imperial Journal of Interdisciplinary Research (IJIR) · December 2016



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Imperial Journal of Interdisciplinary Research (IJIR)
Vol-3, Issue-1, 2017
ISSN: 2454-1362, http://www.onlinejournal.in

# Application of Edible Coatings on Fruits and Vegetables

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***Abstract:*** *Many techniques have been studied in order to extend the shelf life of fresh produce (fruits and vegetables), for example, low temperature and high relative humidity, controlled and modified atmosphere packaging/storage, etc. however, each has advantages and disadvantages. The maintenance of the quality of fresh produce is still a major challenge for the food industry. Research on edible coatings and films has been intense in recent years. Edible coatings have many advantages over other techniques, but only when the coated produces are stored at proper temperatures, which depends on the commodity. They can act as moisture and gas barriers, control microbial growth, preserve the colour, texture and moisture of the product and can effectively extend the shelf life of the product. All fruits and vegetables have a natural waxy coating on their surface, which conserves water. Wiping of fruits or abrasions by wrapping paper is sufficient to impair the protective action of waxy layer and increases the rate of respiration of fruits. The most common ingredients of coating are described and diverse coating material used in fruits and vegetables is discussed in this review.*
***Keywords:*** *Edible coatings, Fruits, Vegetables,*

## 1. Introduction

All fruits and vegetables have a natural waxy coating on their surface, which conserves water. Wiping of fruits or abrasions by wrapping paper is sufficient to impair the protective action of waxy layer and increases the rate of respiration of fruits. Hence, a protective coat on fruits and vegetables is given by application of extra continuous or discontinuous film on them.

The idea of using edible coatings has also been obtained from skin of fruits and vegetables (Goldstein et al., 1992). These are thin layer of edible materials which restrict loss of water, oxygen and other soluble material of food (Bourtoom, 2008).

The coating is an integral part of the food which can be eaten as a part of the whole food product (McHugh and Krochta, 1994). Edible coatings can offer the following advantages to the fresh fruits and vegetables industry: a) improved retention of colour, acids, sugar and flavour components; b) maintenance of quality during shipping and storage; c) reduction of storage disorders; and d) improved consumer appeal (Nisperos-Carriedo et al., 1991). Edible coatings have also a high potential to carry active ingredients such as anti-browning agents, colorants, flavours, nutrients, spices and antimicrobial compounds that can extend product shelf life and reduce the risk of pathogen growth on food surfaces (Vargas et al., 2008; Ricardo et al., 2012). During the last few decades a range of formulations of edible coating have been developed which are widely used in fruits and vegetable industries.

In this review article the properties of main coating ingredients and use of diverse coating materials in fruits and vegetables to increase shelf life has been discussed.

## 2. Materials Used for Edible Coating

Generally, coatings can be divided into proteins, lipids and carbohydrates, alone or in combination (Zaritzky, 2011). They act as barriers to moisture and oxygen during handling and storage and do not solely retard food deterioration but also enhance its safety due to their natural biocide activity or the incorporation of antimicrobial compounds (Cha and Chinnan, 2004). Different types of coating material are discussed here under.

### 2.1. Lipid Based Coatings

Lipids include a group of hydrophobic compounds, which are neutral esters of glycerol and fatty acids. They also include "waxes", which are esters of long-chain monohydric alcohols and fatty acids (Hernandez, 1994). Lipid coatings are good barriers to moisture loss. In addition to preventing water loss, lipid coatings have been used to reduce respiration, thereby extending shelf life, and to improve appearance by generating a shiny product in fruits and vegetables. Coatings that include lipid solids up to 75% can be used to improve coating performance without diminishing moisture-barrier properties (Martin-Polo et al., 1992). The effect of lipid based edible coatings used on fruits and vegetables is summarized in Table-1. Different lipid coating materials are discussed below.

**2.1.1. Oils.** Sources of edible oils are paraffin oil, mineral oil, castor oil, acetylated monoglycerides, and vegetable oils, (peanut, corn, and soy) have been used alone or in combination with other ingredients to coat food products (Hernandez, 1994).

**2.1.2. Waxes.** Wax coatings are naturally found on fruit and vegetable surfaces, where they help prevent moisture loss, especially in the dry humid season (Tharanathan, 2003). Preservation of fresh and dry fruits and nuts by was coatings have been practiced since time immemorial. Paraffin, carnauba, beeswax and candelilla wax (an oily exudate of the candelilla plant grown in USA/Mexico) have been used to coat food products, alone or in combination with other ingredients. Paraffin wax is a distillate of crude petroleum (Bennett, 1975) and is used for coating raw fruits and vegetables.

Several attempts had been made to develop edible wax from bio-based materials culminating in products like semperfresh and jonfresh (Yang et al., 2010), kafirin from sorghum (Gao et al., 2005), and bemul-wax from cassava starch (Afolabi and Oloywde, 2012). The bio-wax (bemul-wax), developed from liquefied cassava starch and bees wax was reported to be comparable to the Indian's commercial wax "waxol" for shelf-life extension of mandarin oranges (Afolabi et al., 2003). Its ability to preserve both the nutritional and sensory qualities of four months low temperature stored sweet oranges has also been reported (Afolabi, 2009). Bemul-wax and its coated products may be considered safe for consumption from elemental point of view. It may also be a good source of health beneficial minerals (Afolabi and Oloywde, 2012). Afolabi and Oloyede, (2011) reported the effect of the bemul-wax on some spoilage and defence-related enzymes in ambient temperature stored sweet potato. Carnauba wax is the exudates of Brazilian palm tree leaves (*Copernica ceirifera*) has a very high melting point and is used as an additive to other waxes to increase toughness and luster (Hernandez, 1991). Beeswax or "white wax" is secreted by honeybees, and candelilla wax is exudates of the candelilla plant (*Euphorbia antisphilitica*).

**2.1.3. Fatty Acids and Monoglycerides.** Fatty acids and monoglycerides are used in coatings mainly as emulsifiers and dispersing agents. Fatty acids are generally extracted from vegetable oils, while monoglycerides are prepared by trans-esterification of glycerol and triglycerol (Hernandez, 1994).

**2.1.4. Resins.** Resins are a group of acidic substances that are produced and secreted as a wound response by specialized plant cells of tree and shrubs. Synthetic resins are petroleum based products (Hernandez, 1994). Shellac resins are secreted by the insect Laccifer lacca found in India. Shellac is composed of aleuritic and shellac acids (Griffin, 1979), is compatible with waxes, and gives coated product a high gloss appearance. Shellac and other resins have relatively low permeable to gases and moderate permeability to water vapour (Hagenmaier and Shaw, 1992). Application of shellac- based waxes reduces internal $O_2$ levels, and increases internal $CO_2$ (Petracek et al., 1998) and ethanol levels (Hagenmaier and Baker, 1994).

**Table 1. Applications of lipid based coatings on fresh fruits and vegetables.**

| Produce | Coatings Types | Effect on Produce | References |
|---|---|---|---|
| Guava | Palm oil | Resisted the leaching effects | Suhaila- Mohammed et al., 1992 |
| | Semperfresh | Less decay | Combrink et al., 1990 |
| | Waxol | Best fruit quality, better the organoleptic properties, increased shelf life, highest acidity and TSS under the treatment with 6 to 9 % | Jagadeesh and Rokhade, 1998 |
| | Carnauba wax | It delayed ripening and reduced the water loss and decay incidence. Little effect on TSS, total titratable acidity, and ascorbic acid | Jacomino et al., 2003; Kore and Kabir, 2011 |
| Citrus | Beeswax and Larding (coated fruit with fat) | Retard water loss, prevent desiccation | Labuza & Contrereas-Medellin, 1981 |
| Mango | Carnauba Wax | Effective in retarding fruit ripening, retaining fruit firmness, and improving fruit quality attributes including levels of fatty acids and aroma volatiles | Dang, 2008 |
| | Carnauba Wax | Reduced weight loss, and shrivel; increase shelf | Oosthuyse, 1997 |

| | | | |
|---|---|---|---|
| | | life; increase ground skin colouration | |
| | Semperfresh and *A. vera* gel (1:1 or 100%) | Slightly delayed fruit ripening but reduced fruit aroma volatile development | Dang, 2008 |
| Apple | Wax, oil | Increased the shelf life. | Sabir et al., 2004 |
| | Paraffin wax + beeswax + soybean oil + CMC | Decreased soluble solids, titratable acidity and ascorbic acid loss; increase storage life up to 34 days. | Torgul and Arslan, 2005 |
| | Candelilla Wax | Prolongs and improves the shelf life, excellent antifungal barrier inhibiting the growth of natural phytophatogenic fungal strains and slow weight loss | Ochoa et al., 2011 |
| Peach | Wax | Reduced the rate of physico-chemical changes; retained the best quality | Chaynika et al., 2005 |
| Passion fruit | Carnauba wax | Lower the fresh matter loss percentage and higher the relative water retention; peel percentage decreased and pulp and pulp/peel percentages increased | Mota et al., 2006 |
| Banana | Semperfresh | Extended the green life, delayed ripening | Chukwu et al., 1995 |
| Pomegranate | Oil + starch | Reduced softening of arils, weight loss and % of browning index, loss of vitamin C, loss of anthocyanin and delayed microbial decay | Oz and Ulukanli, 2012 |
| Walnuts and Pine nuts | Whey protein isolate + Pea starch (PS) + Carnauba wax | Prevent oxidative and hydrolytic rancidity, improved their smoothness and taste and improved sensory characteristics | Mehyar et al., 2012 |
| Huanghua pears | shellac | Retaining texture (especially for brittleness); also maintained higher POD activity and lower activities of cell wall hydrolases such as PE, PG, and cellulase | Zhou et al., 2011 |
| Tomato | Semperfresh | Delayed ripening, retained higher TSS: acid ratio in storage | Kabir et al., 1994 |
| | Stayfresh | Delayed ripening, loss of firmness and reduced PLW | Shashikala et al., 2002 |
| | Mineral oil wax | Preserving the quality and extending the shelf life, reduced the weight and firmness losses | Dávila-Aviña et al., 2011 |
| Green pepper | Semperfresh | Retaining higher contents of Vit. 'C' and total 'chlorophyll' | Ozden and Bayindirli, 2002 |
| | Mineral oil | Reduced moisture loss, maintaining fruit firmness and fruit freshness | Lerdthanangkul and Krochta, 1996 |
| Pointed gourd | Semperfresh | Reduced physiological loss in weight and shrinkage | Chakraborty et al., 2002 |

## 2.2. Protein Based Coatings

Sources of proteins used in edible coatings of plant derived include corn zein, wheat gluten, soy protein, milk proteins and animal derived proteins like collagen, keratin and gelatin (Zhang and Mittal, 2010). Most protein films are hydrophobic and, therefore, do not present good barriers to moisture. However, dry protein films such as zein, wheat gluten, and soy present relatively low permeability's to $O_2$ (Gennadios et al., 1993). Protein-based films have impressive gas barrier and mechanical properties compared with those from lipids and polysaccharides (Ou et al., 2004). The effect of different protein based edible coating on fruits and vegetables are presented in tabular form (Table 2). The different types of proteins that are used as coatings are discussed:

### 2.2.1. Milk Protein

Milk protein products include casein (80% of total milk protein) and whey (20% of total milk protein), and combination of both (Maynes and Krochta, 1994).

**2.2.1.1. Casein.** Milk proteins and especially sodium caseinate (NaCas) are effective as edible coatings since they provide a high nutritional added value, good taste, show excellent functional properties and are filmogenic (Fuchs et al., 2008). Sodium caseinate is a mixture of casein monomers and small aggregates formed after removing the colloidal calcium phosphate from casein micelles, and can form films from aqueous solutions due to its random coil structure and its ability to form weak intermolecular interactions. Sodium caseinate has been extensively investigated because of its emulsifying properties (Lorenzen, 2007).

Furthermore, the mechanical and water barrier properties of sodium caseinate films might be considerably improved at the casein isoelectric point, by calcium cross linking (Avena-Bustillos and Krochta, 1993), or by the addition of lipophilic molecules (Fabra et al., 2008). However, sodium caseinate has not been studied as a film matrix to carry and deliver active or bioactive molecules.

**2.2.1.2. Whey protein.** Whey is a byproduct of cheese manufacturing that contains approximately 7% dry matter. In general the dry matter includes 13% proteins, 75% lactose, 8% minerals, about 3% organic acids, and less than 1% fat. In general these whey proteins are used as additives in the agro-food industry, such as the athletic drinks (Onwulata, 2008). Viable edible films and coatings have been successfully produced from whey proteins; their ability to serve other functions, viz. carrier of antimicrobials, antioxidants, or other nutraceuticals, without significantly compromising the desirable primary barrier and mechanical properties as packaging films, will add value for eventual commercial applications (Jooyandeh, 2011; Ramos et al., 2012). Whey protein coating helped to improve the shelf life of, for example, peanuts, by retarding the lipid oxidation causing rancidity (Khwaldia et al., 2004). In addition, those edible films were reported not to modify the sensory attributes of the coated good or its aspect, while providing some health benefits for the consumer (Onwulata and Peter, 2008). The developed whey protein formulations had excellent barrier properties almost comparable to the ethylene vinyl alcohol copolymers (EVOH) barrier layer conventionally used in food packaging composites, with an oxygen barrier (OTR) of <2 [cm3(STP)/(m2d bar)] when normalized to a thickness of 100 μm (Schmid et al., 2012).

**2.2.2. Collagen and Gelatin.** Collagen is the major component of skin, tendon, and connective tissues and it is the most prevalent and widely distributed fibrous protein in the animals (Tharanathan, 2003). This material is partially digested with acid or enzymes to produce edible collagen casings.

Gelatin is formed from the partial hydrosis of collagen (Jongjareonrak et al., 2006) and has gained more attention as edible films for its abundance and biodegradability. Gelatin structure obtained from mammalian sources (Saxena et al., 2005), and more recently from fish skins (Yang and Wang, 2009). The most abundant sources of gelatin are pig skin (46%), bovine hide (29.4%) and pork and cattle bones (23.1%) (Gómez-Guillén et al., 2011).

**2.2.2.1. Wheat Gluten.** The gluten complex is a combination of gliadin and glutenin polypeptiodes with some lipid and carbohydrate components (Gennadios et al., 1994). It is soluble in aqueous alcohol, but alkaline or acidic conditions are required for the formation of homogeneous film-forming solutions (Gennadios et al., 1993a). These films have high water permeability but are good barriers to $O_2$ and $CO_2$ (Gontard et al., 1993).

**2.2.2.2. Corn Zein.** Zein is prolamine derived from corn gluten and is soluble in alcohol. It has been used as a substitute for shellac because of its high gloss appearance, faster drying rate, and increased stability during storage (Gennadios and Weller, 1990). Corn-zein and sucrose fatty acid ester coatings have been applied successfully on fresh fruits and vegetables, such as apples, bananas and tomatoes, as oxygen and water vapor barriers for extending their shelf lives (Park et al., 1994a).

**2.2.2.3. Soy Protein.** Soy protein is available as concentrate (70% protein) or isolates (90% protein). Film formation is enhanced by heating, which partially denatures the protein, allowing formation of disulfide bonds. This was shown to lower water vapour permeability. In Asia, films are formed from heated soy milk and are used for wrapping food products (Gennadios et al., 1994).
The properties of soy protein films may be improved by blending with starch, sodium alginate, whey protein isolation, etc. (Tang et al., 2003). Soya Protein Isolate (SPI) is abundant, inexpensive, biodegradable, and nutritional raw material. It is a mixture of proteins with different molecular properties. Among them, the 7 and 11 S fractions that make up about 37% and 31% of the total extractable protein have the capability of polymerization (Cao et al., 2007).

**2.2.3. Surimi.** Surimi obtained from the stabilized myofibrillar fish proteins, has been reported to exhibit the film-forming ability (Paschoalick et al., 2003; Shiku et al., 2003). However, the film properties were governed by many factors including pH, plasticizers, etc. Recently, the transparent and flexible edible/biodegradable films were made from frozen threadfin bream surimi (Prodpran and Benjakul, 2005). The properties of films from surimi produced from tropical fish were affected by the pH used to solubilize the proteins, which directly influenced the proteolysis of muscle proteins (Prodpran and Benjakul, 2005).

**Table 2. Applications of protein based coatings on fresh fruits and vegetables.**

| Produce | Coatings Types | Effect on Produce | References |
|---|---|---|---|
| Cherry | Gelatine film | Lowest moisture loss | Lim et al., 2011 |
| | Zein | Accelerated ripening and fungal deterioration | Carvalho-Filho et al., 2006 |
| | Soy protein isolate (SPI) | Decrease the acidity | Lim et al., 2011 |
| Kiwifruit | Whey protein concentrate and rice Bran oil | Preserved the color, firmness, taste, and the overall acceptability of the fruits, slow down the increase of acidity and weight loss | Hassani et al., 2012 |
| Apple | Calcium caseinate and whey protein | Delayed browning | Tien et al., 2001 |
| | Carrageenan + whey protein Concentrate | Maintained the original colour during storage without changes in sensory properties. | Lee et al., 2003 |
| | Whey protein concentrate + beeswax | Reduced surface browning | Perez-Gago et al., 2006 |
| | Galactomannans and collagen blends | Lower the CO2 production and the O2 consumption by approximately 50% | Lima et al., 2010 |
| Mango | Galactomannans + collagen | Effective in less $O_2$ consumption and $CO_2$ production | Lima et al., 2010 |
| Tomato | Corn-Zein | Delayed colour changes and ripening; reduced firmness loss and weight loss; extended the shelf life; inhibited ethanol production | Park et al., 1994 |
| Zucchini | Casein proteins | Reduced water loss | Avena-Bustillos et al., 1994 |
| Eggplant | Soy protein + beeswax | Prevent softening of the tissues and reducing browning of the tissue, | Ghidelli et al., 2010 |
| Potato | Calcium caseinate and whey protein | Delayed browning | Tien et al., 2001 |
| Bell peppers | Calcium caseinate and whey protein | Effective gas barriers to internal carbon dioxide and oxygen, inhibited color changes and reduced decay | Lerdthanangkul and Krochta, 1996 |
| Carrots | Sodium caseinate and stearic acid | lower whitish index and could help moisturize the carrot surface | Avena-Bustillos et al., 1994 |

## 2.3. Carbohydrate Based Coatings

Carbohydrates are used in food systems as thickeners, stabilizers, gelling agents, and emulsifiers (Ganz, 1977). Polysaccharide films have relatively low permeability to gases, but little resistance to water vapour transfer. Such coatings have been used to retard moisture loss of some foods during short term storage. Carbohydrate films can be effective in shining of surfaces and separating of product in packaging (Debeaufort et al., 1998). The role of carbohydrate based coating on fruits and vegetables is summarized in Table 3. Different types of carbohydrate based coatings are discussed below.

**2.3.1. Cellulose.** Cellulose derivatives are polysaccharides composed of linear chains of β (1–4) glucosidic units with methyl, hydroxypropyl or carboxyl substituents (Dhanapal et al., 2012). Only four cellulose derivative forms are used for edible coatings or films: Hydroxypropyl cellulose (E463; HPC), hydroxypropyl methylcellulose (E464; HPMC), Carboxymethylcellulose (E466; CMC) or Methyl cellulose (E461; MC). However, cellulose derivative films are poor water vapour barriers because of the inherent hydrophilic nature of polysaccharides and they possess poor mechanical properties (Gennadios et al., 1997).

**2.3.2. Pectin.** Pectin is complex group of plant-derived polysaccharides found in middle lamella of plant cells (Nisperos-Carriedo, 1994). It is composed of D-galacturonic acid polymers with varying degree of methyl esterification. Coatings made with pectin materials generally have high water vapour transmission rates (Schultz et al., 1949) due to their hydrophilic nature. Pectin could provide a soft and shiny coat. It restricted the loss of nutrients and volatile materials during storage and transport. In addition, contamination of product by microorganisms could be controlled by pectin film. Separating of product in its package is the most important characteristics of this film (Salvatori et al., 1998).

**2.3.3. Sucrose ester.** Most formulations of sucrose ester have been based on one or more esters, a carrier, sodium carboxymethyl cellulose, or an antifoamant preparation of mono and diglycerides of fatty acids (Curtis, 1988). Sucrose polyester (SPE) coating delayed ripening in banana

(Banks, 1983), pears (Chen, 1986) and apple (Chu, 1985).
Semperfresh is an important formulation of earlier SPE products, which is use in USA, UK and in some other European countries for delaying ripening of fruits and vegetables (Drake et al., 1987).

**2.3.4. Chitin/Chitosan.** The application of edible coatings based on chitosan or caseinates is interesting because of its high nutritional quality, excellent sensory properties, and adequate protection of food products from their environment (Pereda et al., 2010; Mendes de Souza et al., 2010).

Chitosan is a modified, natural nontoxic biopolymer derived by deacetylation of chitin (poly- β-(1→4)-N-acetyl-D-glucose-amine), a major component of the shells of crustacean such as crab, shrimp, and crawfish (Maghsoudlou et al., 2012; Sitanggang et al., 2012). Recently chitosan has attracted notable interest due to its biological activities, including antimicrobial (Tsai et al., 2004), antitumor (Tokoro et al., 1988), antioxidative (López-Caballero et al., 2005), and hypocholesterolemic functions (Sugano et al., 1992) and it has bacteriostatic and bactericidal properties. For this reason, chitosan is a highly recommended polymer for the production of edible film coatings (Chien et al., 2007). Methylation of the polymer resulted in a twofold resistance to $CO_2$ (Baldwin, 1994). Chitosan, a high molecular weight cationic polysaccharide, has been shown to be fungicidal against several fungi (Kendra et al., 1989) and also shown antibacterial properties (Moller et al., 2004).

Incorporation of green tea extract (GTE) into chitosan films improved mechanical and water vapor barrier properties and enhanced polyphenolic content and antioxidant activity of the films (Siripatrawan and Harte, 2010).

**2.3.5. Starch.** Starch, composed of amylose and amylopectin, is primarily derived from cereal grains like corn (maize), with the largest source of starch (Dhanapal et al., 2012). Different sources of starch e.g. corn, potato, cassava and cereals etc. can be used (Dhanapal et al., 2012). Generally the varieties which contain high amylase starches can be utilized for edible film formation. Starch is the major carbohydrate reserve in plant tubers and seed endosperm where it is found as granules, each typically containing several million amylopectin molecules accompanied by a much larger number of smaller amylose molecules (Walstra, 2003). Amylose is responsible for the film forming capacity of starch (Romero-Bastida et al., 2005). High amylose starch films have been made that are flexible, oxygen impermeable, oil resistant, heat-sealable, and water soluble.

**2.3.6. *Aloe vera.*** *Aloe vera* is a tropical and subtropical plant that has been used for centuries for its medicinal and therapeutic properties (Eshun and He, 2004). *Aloe vera* contains malic acid-acetylated carbohydrates (including β-1, 4 glucomannans) that demonstrated anti-inflammatory activity (Esua and Rauwald, 2006). Recently, there has been increasing interest for the use of *A. Vera* gel as an edible coating material for fruits and vegetables driven by its antifungal activity (Rodriguez de Jasso et al., 2005). Valverde et al. (2005) reported that this edible coating was able to reduce the initial microbial counts for both mesophillic aerobic and yeast and molds in cv. Crimson Seedless table grapes.

In general, the positive effect of this edible coatings is based on their hygroscopic properties, which enables formation of $O_2$ and $CO_2$ and creating modified atmosphere (MA) and acting as moisture barrier between the fruit and the environment, and thus reduced weight loss, browning, softening, and growth of yeast and molds (Morillon et al., 2002). .

**2.3.7. Alginate.** Alginate is a polysaccharide isolated from marine brown algae (Phaeophyceae) is finding increasing use in the food industry as texturizing and gelling agents (Mancini and McHugh, 2000; Yang and Paulson, 2000). Alginate is a salt of alginic acid, a polymer of D-mannuronic acid and L-guluronic acid. Alginate has unique colloidal properties and can form strong gels or insoluble polymers through crossed linking with $Ca^{2+}$ by post-treatment of $CaCl_2$ solution. Such biopolymer-based films can keep good quality and prolong shelf life of foods by increasing water barrier, preventing microbe contamination, maintaining the flavour and texture of the fresh-cut fruits. Such coatings increase moisture, and reduce perception of warmed over flavour induced by lipid oxidation (Rhim, 2004).

**2.3.8. Carrageenan.** Carrageenans are water-soluble polymers with a linear chain of partially sulphated galactans, which present high potentiality as film-forming material extracted from the red-sea weed (Dhanapal et al., 2012) and protects against moisture loss by acting as a sacrificial moisture layer (Kester and Fennema, 1986). It consist of a family of sulfonated polysaccharides of D-glucose and 3, 6-anhydro-D-galactose. Recently, carrageenan films were also found to be less opaque than those made of starch.

**Table 3. Applications of carbohydrate based coatings on fresh fruits and vegetables.**

| Produce | Coatings Types | Effect on Produce | References |
|---|---|---|---|
| Guava | Dextrons | Better properties as gas barrier, increase size, colour, aroma, water content | Quezada-Gallo et al., 2005 |
| | Potato Starch | Did not affect the pH, titratable acidity, and sugars, soluble and total pectin, firmness, and values of chlorophyll a and b | Boas et al., 2005 |
| | Cellulose | Slowed softening, but fruits did not develop as much colour, had a lower soluble solids, and more prone to surface blackening | McGuire and Hallman, 1995 |
| Papaya | *Aloe vera* gel | Control PLW, ripening process (chemical changes, colour development and softening of fruit tissue) and decay, increase the shelf life | Marpudi et al., 2011 |
| Cherry | Carboxy-methylcellulose | Reducing water loss, decrease the acidity | Lim et al., 2011 |
| | *Aloe vera* gel | Prevent loss of moisture and firmness, control respiratory rate and maturation development, delay oxidative browning and reduce microorganism proliferation | Martinez-Romero et al., 2006; Ahmed et al., 2009 |
| Banana | Gum arabic and Chitosan | Delayed color development and reduced the rate of respiration and ethylene evolution, maintaining the overall quality | Maqbool et al., 2011 |
| Pineapple | Chitosan | Extends the shelf-life | Talens et al., 2012 |
| | Sodium alginate and gellan gum | Control weight loss, preserve flesh firmness, and slow the respiration rate at 10±1°C and 65% RH | Azarakhsh et al., 2012 |
| | Alginate | Helped to retain internal liquids | Montero-Calderon et al., 2008 |
| Apple | *Aloe vera* gel | Delayed the loss of total phenolics and ascorbic acid | Serrano et al., 2006 |
| | | Delayed the weight loss, colour changes, accelerated softening and ripening, rachis browning, and high incidence of berry decay, extend the storage life and reduce the initial microbial counts | Valverde et al., 2005 |
| | Carboxymethyl cellulose (CMC) | Delayed browning more effectively when was applied in an edible coating than in an aqueous solution | Baldwin et al., 1996 |
| | Lemongrass + oregano oil + vanillin incorporated in apple puree-alginate edible coating | Reduced native psychrophilic aerobes, moulds and yeast. Ethylene production in the coated apples remained below 50 $\mu L\ L^{-1}$. Lemongrass (1.0-1.5%) and oregano (0.5%) reduced >4 log CFU/g of inoculated *Listeria innocua* | Rojas-Grau et al., 2007 |
| | Cinnamon + clove + lemongrass essential oils (Eos) incorporated in alginate-based edible coating | Effectively maintained the physicochemical characteristics for more than 30 days, decreased the respiration rate, and reduced the *Escherichia coli* O157:H7 population by about 1.23 log CFU/g at day 0, and extended the microbiological shelf life by at least 19 days. The addition of EOs at 0.7% (vol/vol) or their active compounds at 0.5% (vol/vol) into the EC increased its antimicrobial effect, reduced *the E. coli* O157:H7 population by more than 4 log CFU/g, and extended the microbiological shelf life > 30 days. | Raybaudi-Massilia et al., 2008b |
| Grapes | *Aloe vera* gel | Prevent loss of moisture and firmness, control respiratory rate and maturation development, delay oxidative browning and reduce microorganism proliferation | Martinez-Romero et al., 2006; Ahmed et al., 2009 |
| | HPMC (Hydroxypropyl-methylcellulose) | It slowed down weight losses and controlled the oxygen consumption, had a better microbial safety | Pastor et al., 2011 |
| Melon | Alginate | Inhibited the microbial growth and reduced up to 3.1 log CFU/g after 30 days of storage | Raybaudi-Massilia et al., 2008a |

| | | | |
|---|---|---|---|
| | Methylcellulose | Reduced the growth *of mesophilic aerobes*, *psychrotrophs*, yeast and moulds and maintained the growth of *E. coli, Staphylococcus aureus*, *Salmonella* sp. <10 CFU/g | Krasaekoopt and Mabumrung, 2008 |
| Strawberry | Chitosan–lemon essential oil | Slowed down the respiration rate and extend shelf-life at 5$^o$ C | Perdonesa et al., 2012 |
| | Starch | Inhibited the growth of mesophilic aerobes, mold and yeast counts | Garcia et al., 2001 |
| | 1% Chitosan | Prevented microbial growth and reduced fruit weight changes | Campaniello et al., 2008 |
| Mango | Cashew gum | Acts as a barrier to mass transport and reduced weight loss | Souza et al., 2010 |
| | Mango pieces | Postponed weight loss, quality deterioration and prevented microbial growth | Chien et al., 2007 |
| Litchi | Chitosan | Delay in weight change, quality deterioration and organoleptic characteristics and effectively reduced microbial population followed by expansion shelf life at 1$^o$ C | Dong et al., 2004 |
| Pear | Methylcellulose | Prolonged shelf-life by retarding browning | Olivas et al., 2003 |
| | Alginate, gellan | Prevented browning for 2 weeks | Oms-Oliu et al., 2008 |
| | Chitosan | Reduced the growth of *Alternaria kikuchiana* and *Physalospora piricola* | Xianghong et al., 2010 |
| Pistachio Nuts | Chitosan | Inhibited the growth of the *Aspergillus*, prevented moisture absorption and weight change | Maghsoudlou et al., 2012 |
| Tomato | Chitosan | Resulted in firmness, less decay and less red pigmentation than the control | El-Ghaouth et al., 1992 |
| Broccoli | Chitosan | Reduced all microbiological population, extended shelf life | Moreira Mdel et al., 2011 |
| Garlic | Agar-agar + 0.2% chitosan + 0.2% acetic acid | Lower moisture loss, inhibited filamentous fungus and aerobic mesophilic, reduced respiration rate, lower the water vapor transmission | Geraldine et al., 2008 |
| Carrot | Chitosan | Improved appearance and preserved the better colour and mechanical response | Vargas et al., 2008 |
| | Starch coating | Enhances the efficiency of osmotic dehydration and increased the solid content by more than 30% | Lević et al., 2008 |
| Artichoke seeds | Chitosan | Reduced the activity of various fungi and increased plants growth | Khalid et al., 2010 |

## 3. Conclusion

Edible coatings improve the external and internal quality characteristics of diverse commodities and also reduce dehydration and oxidation as well as the resulting undesirable changes in colour, flavour, and texture. Waxes and other coatings delay ripening and senescence of fresh produce and can increase the microbial stability. Coatings show promise as environment-friendly quarantine treatments. It is comparatively low cost, easily handled post harvest treatment technology from point of view of producers as well as commercial users. Most coating materials are produced from renewable, edible resources and can be manufactured from waste products that represent disposal problems for other industries. More research and development efforts are required to develop edible coatings and also edible films that have good packaging performance besides being economical.

## 4. References

[1] Afolabi I.S. 2009. The preservative efficacies of bemul-wax coatings in combination with calcium chloride dip on low temperature stored *Citrus O. Sinensis*. Biokemistri. 211: 9-16.

[2] Afolabi I.S., Baskaran R., Asha M.R., Aravinda-Prasad B., Ramana K.V.R. 2003. Development of edible coating 'bio-emulsion' for shelf life extension of mandarin oranges. Proc. 5th International Food Convention at Mysore, India, pp. 188-189.

[3] Afolabi I.S., Oloyede O.B. 2011. Biochemical response of sweet potato to bemul-wax coating combined with calcium chloride treatment during ambient storage. Afr. J. Biotechnol. 1014: 2724-2732.

[4] Afolabi I.S., Oloyede O.B. 2012. Mineral Compositions of an Edible Emulsion Bemul-Wax from Cassava *Manihot esculentum* Starch. British J. Appl. Sci. Technol. 21: 16-22.

[5] Ahmed A.J., Singh Z., Khan A.S. 2009. Postharvest *Aloe vera* gel coating modulates fruit ripening and

quality of 'Arctic Snow' nectarine kept in ambient and cold storage. Int. J. Food Sci. Technol. 44: 1024-1033.

[6] Avena-Bustillos R.J., Krochta J.M, Saltveit M.E., Rojas-Villegas R., Sauceda-Perez J.A. 1994. Optimization of edible coating formulations on zucchini to reduce water loss. J. Food Eng. 21: 197-214.

[7] Avena-Bustillos R.J., Krochta J.M. 1993. Water vapor permeability of caseinate based edible films as affected by pH, calcium cross linking and lipid content. J. Food Sci. 58: 904–907.

[8] Azarakhsh N., Osman A., Ghazali H.M., Tan C.P., Mohd Adzahan N. 2012. Optimization of alginate and gellan-based edible coatings formulations for fresh-cut pineapples. Int. Food Res. J. 191: 279-285.

[9] Baldwin E.A. 1994. Edible coatings for fruits and vegetables: Past, present and future. In: Krochta J.M., Baldwin E.A., Nisperos-Carriedo M.O. (Eds.), Edible Coatings and Films to Improve Food Quality, Lancester. USA: Technomic Pub. Co. pp. 25-64.

[10] Baldwin E.A., Nisperos M.O., Chen X., Hagenmaier R.D. 1996. Improving storage life of cut apple and potato with edible coating. Postharvest Biol. Technol. 9: 151-163.

[11] Banks N.H. 1983. Evaluation of methods for the determining interval gases in banana fruit. J. Exp. Bot. 34: 871.

[12] Bennett H. 1975. Industrial Waxes. New York: Chemical Pub. Co. Vol. 1.

[13] Boas B.M.V., Nunes E.E., Silva W.A.da, Boas E.V. de B.V., Siqueira H.H. de, Pereira J. 2005. Post-harvest quality of 'Pedro Sato' guavas coated with potato starch film. Rev. Bras. Armaz. 301: 91-96.

[14] Bourtoom T. 2008. Review Article: Edible films and coatings: characteristics and properties. Int. Food Res. J. 153: 237-248.

[15] Campaniello C.A., Bevilacqua M., Sinigaglia M.R. 2008. Chitosan: Antimicrobial activity and potential applications for preserving minimally processed strawberries. Food Microbiol. 25: 992-1000.

[16] Cao N., Yuhua Fu., He J. 2007. Preparation and physical properties of soy protein isolate and gelatin composite films. Food Hydro. 21: 1153–1162.

[17] Carvalho-Filho C.D., Honorio S.L., Gil J.M. 2006. Post harvest quality of cherry cv. Ambrunes using edible coatings. Revi. Bra. Frut. 282: 180-184.

[18] Cha D.S., Chinnan M. 2004. Biopolymer-based antimicrobial packaging: a review. Crit. Rev. Food Sci. Nutr. 44: 223- 237.

[19] Chakraborty K., Ray S.K.D., Kabir, J. 2002. Influence of semperfresh coating on storage life of pointed gourd *Trichosanthes dioica* Roxb. J. Inter. 6: 486-489.

[20] Chaynika G., Thakur K.S., Kaushal B.B.L. 2005. Effect of various post harvest treatments on the storage quality of peach cv. July Elberta. Acta Hort. 696: 509-517.

[21] Chen P.M. 1986. Annual Report: Postharvest physiology of pome fruit in 1985. Mid-Columbia Experiment Station. Oregon State Univ. Hood River OR.

[22] Chien P., Sheu. F., Lin H. 2007. Coating citrus *Murcott tangor* fruit with low molecular weight chitosan increases postharvest quality and shelf life. Food Chem. 100: 1160–1164.

[23] Chien P.J., Sheu F., Lin H.R. 2007. Quality assessment of low molecular weight chitosan coating on slices red pitayas. J. Food Eng. 19: 736-740.

[24] Chu C.L. 1985. Post storage application of TAL Pro-long on apples from controlled atmosphere storage. Hortsci. 21: 267.

[25] Chukwu E.U., Olorunda A.O., Ferris R.S.B. 1995. Extension of ripening period of Musa fruit using calcium chloride infiltration, Semperfresh and brilloshine 1 coating. Musa Afr. 8: 14-15.

[26] Combrink J.C., Kock S.L. de., Eeden C.J. Van. 1990. Effect of post harvest treatment and packaging on the keeping quality of fresh guava fruit. Acta Hort. 275: 639-645.

[27] Curtis G.J. 1988. Some experiment with edible coatings on the long term storage of citrus fruits. In: Goren R. Mendel K. (Eds.), Proc. 6th Intern. Citrus Cong., Weikershein: Margraf Scientific Books, D-6992. pp. 39-44.

[28] Dang K.T.H. 2008. Edible coatings influence fruit ripening, quality, and aroma biosynthesis in mango fruit. J. Agric. Food Chem. 564: 361-1370.

[29] Dávila-Aviña J., Esteban de Jesús, Villa-Rodríguez J., Cruz-Valenzuela R., Rodríguez-Armenta M., Espino-Díaz M., Ayala-Zavala J.F. 2011. Effect of edible coatings, storage time and maturity stage on overall quality of tomato fruits. Amer. J. Agric. Biol. Sci. 61: 162-171.

[30] Debeaufort F., Quezada-Gallo J.A., Voilley A. 1998. Edible films and coatings: tomorrow's packaging: a review. Crit. Rev. Food Sci. Nutr. 38: 299-313.

[31] Dhanapal A., Sasikala P., Rajamani L., Kavitha V., Yazhini G., Shakila Banu M. 2012. Edible films from Polysaccharides. Food Sci. Qual. Manag. 3: 9-17.

[32] Dong H., Cheng L., Tan J., Zheng K., Jiang Y. 2004. Effects of chitosan coating on quality and shelf life of peeled litchi fruit. J. Food Eng. 64: 355–358.

[33] Drake S.R., Fellman J.K., Nelson J.W. 1987. Postharvest use of sucrose polyester for extending the shelf life of stored golden delicious apples. J. Food Sci. 52: 685-690.

[34] El-Ghaouth A., Ponnampolam R., Castalgne F., Arul J. 1992. Chitosan coating to extend the storage life of tomatoes. Hortsci. 27: 1061-1018.

[35] Eshun K., He Q. 2004. Aloe Vera: a valuable ingredient for the food, pharmaceutical and cosmetic industries a review. Crit. Rev. Food Sci. Nutr. 44: 91-96.

[36] Esua M.F., Rauwald J.W. 2006. Novel bioactive maloyl glucans from *Aloe vera* gel: isolation, structure elucidation and *in vitro* bioassays. Carbo. Res. 273: 355-364.

[37] Eum H.L., Hwang D.K., Linke M., Lee S.K., Zude M. 2009. Influence of edible coating on quality of

plum *Prunus salicina* Lindl. cv. 'Sapphire'. Eur. Food Res. Technol. 229: 427-434.
[38] Fabra M.J., Talens P., Chiralt A. 2008. Tensile properties and water vapour permeability of sodium caseinate films containing oleic acid–beeswax mixtures. J. Food Eng. 85: 393–400.
[39] Fuchs S.J., Mattinson D.S., Fellman J.K. 2008. Effect of edible coatings on postharvest quality of fresh green asparagus. J. Food Proc. Pres. 32: 951-971.
[40] Ganz A.J. 1977. Cellulose hydrocolloids. In: Graham H.P. (Ed.), Food Colloids. Westport: Ct, AVI Pub. Co. 383 pp.
[41] Gao C., Taylor J., Wellner N., Byaruhanga Y.B., Parker M.L., Clare-Mills E.N., Belton P.S. 2005. Effect of preparation conditions on protein secondary structure and biofilm formation of kafirin. J. Agric. Food Chem. 532: 306–312.
[42] Garcia M.A., Martino M.N., Zaritzky N.E. 2001. Composite starch-based coatings applied to strawberries *Fragaria ananassa*. Nahrung/Food. 45: 267-272.
[43] Gennadios A., Hanna M.A., Kurth L.B. 1997. Application of edible coatings on meat, poultry and seafoods: a review. Leb. Wiss. Technol. 30: 337-350.
[44] Gennadios A., McHugh T.H., Weller C.L., Krochta J.M. 1994. Edible coatings and films based on proteins. In: Krochta J.M., Baldwin E.A. Nisperos-Carriedo M.O. (Eds.), Edible Coatings and Films to Improve Food Quality, Lancaster: Technomic Publishing Co. p. 201.
[45] Gennadios A., Weller C.L. 1990. Edible films and coatings from wheat and corn proteins. Food Technol. 4410: 63-69.
[46] Gennadios A., Weller C.L., Testin R.F. 1993. Temperature effect on oxygen permeability of edible protein- based films. J. Food Sci. 58: 212.
[47] Gennadios A., Weller C.L., Testin R.F. 1993a. Modification of physical and barrier properties of edible wheat gluten-based films. Cere. Chem. 70: 426-9.
[48] Geraldine R.M., Soares Nilda de F.F., Botrel D.A., Gonçalves Leticia de A. 2008. Characterization and effect of edible coatings on minimally processed garlic quality. Carbo. Poly. 723: 403-409.
[49] Ghidelli C., Sanchís E., Argudo C.R., Mateos M., del Río M.A., Pérez-Gago M.B. 2010. Application of soy protein-beeswax edible coating with antioxidants: effect reducing enzymatic browning of fresh-cut eggplants. Proc. VI International Postharvest Symposium, Acta Hort. 8773, pp. 591-596.
[50] Goldstein J.L., Newbury D.E., Echlin P., Joy D.C., Romig A.D., Lyman C.E., Fiori C., Lifshin E. 1992. Scanning Electron Microscopy and X-Ray Microanalysis, 2ed New York: A Division of Plenum Publishing Corporation, pp. 571-599.
[51] Gómez-Guillén M.C., Giménez B., López-Caballero M.E., Montero M.P. 2011. Functional and bioactive properties of collagen and gelatin from alternative sources: A review. Food Hydro. 25: 1813-1827.
[52] Gontard N., Duchez C., Cuq J.L., Guilbert S. 1993. Edible composite films of wheat gluten and lipids: water vapor permeability and other physical properties. Int. J. Food Sci. Technol. 29: 39-50.
[53] Griffin W.C. 1979. Emulsions. In: Kirk-Othmer Encyclopedia of Chemical Technology, 3rd ed., New York: John Wiley and Sons, 8: 913-916.
[54] Hagenmaier R.D., Baker R.A. 1994. Wax micro emulsions and emulsions as citrus coatings. J. Agric. Food Chem. 42: 899-902.
[55] Hagenmaier R.D., Shaw P.E. 1992. Gas permeability of fruit coating waxes. J. Amer. Soc. Hort. Sci. 117: 105.
[56] Hassani F., Garousi F., Javanmard M. 2012. Edible coating based on whey protein concentrate-rice bran oil to maintain the physical and chemical properties of the kiwifruit *Actinidia deliciosa*. Trakia J. Sci. 101: 26 34.
[57] Hernandez E. 1991. Edible coatings from lipids and resins. In: Krochta J.M., Baldwin E.A., Nisperos-Carriedo M.O. (Eds.), Edible Coatings and Films to Improve Food Quality, Pennsylvania: Technomic Publishing Co. Inc. pp. 279-303.
[58] Jacomino A.P., Ojeda R.M., Klude R.A., Scarpare Filho J.A. 2003. Post-harvest conservation of guavas through carnauba wax emulsion application. Rev. Bra. Frut. 253: 401-405.
[59] Jagadeesh S.L., Rokhade A. 1998. Effect of post harvest treatments on keeping quality of guava *Psidium guajava* L. fruits cv. Sardar-1. Kar. J. Agric. Sci. 114: 1003-1008.
[60] Jongjareonrak A., Benjakul S., Visessanguan W., Prodpran T., Tanaka M. 2006. Characterization of edible films from skin gelatin of brown stripe red snapper and big eye snapper. Food Hydro. 204: 492–501.
[61] Jooyandeh H. 2011. Whey Protein Films and Coatings: A Review. Pak. J. Nutr. 103: 296-301.
[62] Kabir J., Ghosh B., Dutta S.K., Mitra S.K. 1994. Postharvest use of edible coatings on shelf life of tomato. Indian Food Pack. 49: 25-28.
[63] Kendra F.D., Christian D., Hadwiger L.A. 1989. Chitosan oligomers from *Fusarium solani*/ pea interactions, chitinase/β-glucanase digestion of sporelings and from fungal wall chitin actively inhibit fungal growth and enhance disease resistance. Physiol. Mol. Plant Pathol. 35: 215-230.
[64] Kester J.J., Fennema O.R. 1986. Edible films and coatings: a review. Food Technol. 40: 47.
[65] Khalid Z., Ursúa B., Maté J.I. 2010. Application of bioactive coatings based on chitosan for artichoke seed protection. Crop Prot. 29: 853-859.
[66] Khwaldia K., Ferez C., Banon S., Desobry S., Hardy J. 2004. Milk proteins for edible films and coatings. Crit. Rev. Food Sci. Nutr. 444: 239-251.
[67] Kore V.T., Kabir J. 2011. Influence of waxing and polyethylene packaging on shelf life of guava. Crop Res. 411, 2 and 3: 98-102.
[68] Krasaekoopt W., Mabumrung J. 2008. Microbiological evaluation of edible coated fresh-cut cantaloupe. Kasetsart J. Nat. Sci. 42: 552-557.
[69] Krochta J.M., Avena-Bustillos R.J., Cisneros-Zevallos L.A., Saltveit M.E. 1993. Optimization of edible coatings on minimally processed carrots

using response surface methodology. Trans Amer. Soc. Agric. Eng. 363: 801-805.

[70] Labuza T., Contrereas-Medellin. 1981. Prediction of moisture protection requirements for foods. Cereal Food World. 26: 335.

[71] Lee J.Y., Park H.J., Lee C.Y., Choi W.Y. 2003. Extending shelf life of minimally processed apples with edible coatings and antibrowning agents. Leb. Wiss. Technol. 36: 323-329.

[72] Lerdthanangkul S., Krochta J.M. 1996. Edible coating effects on postharvest quality of green bell peppers. J. Food Sci. 611: 176-179.

[73] Lević L.B., Koprivica G.B., Mišljenović N.M., Filipčev B.V., Šimurina O.D., Kuljanin T.A. 2008. Effect of starch as an edible coating material on the process of osmotic dehydration of carrot in saccharose solution and sugar beet molasses. *APTEFF* 39: 29-36.

[74] Lim R., Stathopoulos C.E., Golding J.B. 2011. Effect of edible coatings on some quality characteristics of sweet cherries. Int. Food Res. J. 184: 1237-1241.

[75] Lima Á.M., Cerqueira M.A., Souza B.W.S., Santos Ed Carlos M., Teixeira J.A., Moreira R.A., Vicente A.A. 2010. New edible coatings composed of galactomannans and collagen blends to improve the postharvest quality of fruits- Influence on fruits gas transfer rate. J. Food Eng. 97: 101-109.

[76] López-Caballer M.E., Gómez-Guillén M.C., Pérez-Mateos M., Montero P. 2005. A chitosan-gelatin blend as a coating for fish patties. Food Hydro. 19: 303-311.

[77] Lorenzen P.C. 2007. Effects of time/temperature-conditions of pre-heating and enzymatic cross-linking on thermo-functional properties of reconstituted dairy ingredients. Food Res. Intern. 40: 700-708.

[78] Maghsoudlou A., Maghsoudlou Y., Khomeiri M., Ghorbani M. 2012. Evaluation of anti-fungal activity of chitosan and its effect on the moisture absorption and organoleptic characteristics of pistachio nuts. Intern. J. Adv. Sci. Eng. Inf. Technol. 24: 65-69.

[79] Mancini F., McHugh T.H. 2000. Fruit-alginate interactions in novel restructured products. Food / Nahrung. 443: 152-157.

[80] Marpudi S.L., Abirami L.S.S., Pushkala R., Srividya N. 2011. Enhancement of storage life and quality maintenance of papaya fruits using *Aloe vera* based edible antimicrobial coating. Indian J. Biotechnol. 10: 83-89.

[81] Martinez-Romero D.L., Alburquerque N., Valverde J.M., Guillen F., Castillo S. 2006. Post harvest cherry quality and safety maintenance by *Aloe vera* treatment: A new edible coating. Postharvest Biol. Technol. 39: 93-100.

[82] Martin-Polo M., Voilley A., Blond G., Colas B., Mesnier M., Floquet N. 1992. Hydrophobic films and their efficiency against moisture transfer. 2. Influence of the physical state. J. Agric. Food Chem. 40: 413.

[83] Maynes J.R., Krochta M. 1994. Properties of edible films from total milk protein. J. Food Sci. 59: 909.

[84] McGuire R.G., Hallman G.J. 1995. Coating guavas with cellulose or carnauba based emulsion interferes with post-harvest ripening. Hortsci. 302: 294-295.

[85] McHugh T.H., Krochta J.M. 1994. Milk protein based edible films. Food Technol. 481: 97-107.

[86] Mehyar G.F., Al-Ismail K., Han J.H., Chee G.W. 2012. Characterization of edible coatings consisting of pea starch, whey protein isolate, and carnauba wax and their effects on oil rancidity and sensory properties of walnuts and pine nuts. J. Food Sci. 772: 52-59.

[87] Mendes de Souza P., Fernández A., López-carballo G., Gavara R., Hernandez- Muñoz P. 2010. Modified sodium caseinate films as releasing carriers of lysozyme. Food Hydro. 244: 300-306.

[88] Moller H., Grelier S., Pardon P., Coma V. 2004. Antimicrobial and physicochemical properties of chitosan-HPMC-based films. J. Agric. Food Chem. 52: 6585-6591.

[89] Montero-Calderon M., Rojas-Grau M.A., Martin-Belloso O. 2008. Effect of packaging conditions on quality and shelf-life of fresh-cut pineapple *Ananas comosus*. Postharvest Biol. Technol. 50: 182-189.

[90] Moreira Mdel R., Ponce A., Ansorena R., Roura S.I. 2011. Effectiveness of edible coatings combined with mild heat shocks on microbial spoilage and sensory quality of fresh cut broccoli *Brassica oleracea* L. J. Food Sci. 766: 367-74.

[91] Morillon V., Debeaufort F., Blond G., Capelle M., Voilley A. 2002. Factors affecting the moisture permeability of lipid-based edible films: a review. Crit. Rev. Food Sci. Nutr. 42: 67- 89.

[92] Mota W.F. da, Salomao L.C.C., Neres C.R.L., Mizobutsi G.P., Neves L.L. de M. 2006. Use of carnauba wax and plastic film on post-harvest conservation of the yellow passion fruit. *Revista-Brasileira-de-Fruticultura* 282: 190-193.

[93] Nisperos-Carriedo M.O. 1994: Edible coatings and films based on polysaccharides. In: Krochta J.M., Baldwin E.A. Nisperos-Carriedo M.O. (Eds.), Edible coatings and films to improve food quality, Lancaster, PA: Technomic Publishing Company. pp. 305-335.

[94] Nisperos-Carriedo M.O., Baldwin E.A., Shaw P.E. 1991. Development of an edible coating for extending postharvest life of selected fruits and vegetables. Proc. of the Florida State Horticultural Society, 104: 122-125.

[95] Ochoa E., Saucedo-Pompa S., Rojas-Molina R., Heliodoro de la Garza, Charles-Rodríguez A.V., Aguilar C.N. 2011. Evaluation of a candelilla wax-based edible coating to prolong the shelf-life quality and safety of apples. Amer. J. Agric. Biol. Sci. 61: 92-98.

[96] Olivas G.I., Rodriguez J.J., Barbosa-Cánovas G.V. 2003. Edible coatings composed of methylcellulose, stearic acid and additives to preserve quality of pear wedges. J. Food Proc. Pres. 27: 299-320.

[97] Oms-Oliu G., Soliva-Fortuny R., Martin-Belloso O. 2008. Edible coatings with antibrowning agents to maintain sensory quality and antioxidant properties of fresh-cut pears. Postharvest Biol. Technol. 50: 87-94.

[98] Onwulata C.H.P. 2008. Whey processing, functionality and health benefits, IFT Press Series,

Variation: IFT Press Series, Wiley- Blackwell, Ames, Iowa, USA.
[99] Onwulata C.I.H., Peter J. 2008. Whey Processing-Functionality and Health Benefits, vol. 1, Iowa, USA: Wiley-Blackwell, Ames.
[100] Oosthuyse S.A. 1997. Effect of waxing and a number of waxes on weight loss, shelf life and fruit quality of mangoes after four week of cool-storage. Yearbook South Afr. Mango Growers Assoc. 17: 105-110.
[101] Ou S.Y., Kwok K.C., Kang Y.J. 2004. Changes in in-vitro digestibility and available lysine of soy protein isolate after formation of film. J. Food Eng. 643: 301-305.
[102] Oz A.T., Ulukanli Z. 2012. Application of edible starch-based coating including glycerol plus *Oleum nigella* on arils from long-stored whole pomegranate fruits. J. Food Proc. Pres. 361: 81–95.
[103] Ozden C., Bayindirli Z. 2002. Effects of combinational use of controlled atmosphere, cold storage and edible coating application on shelf life and quality attributes of green peppers. Eur. Food Res. Technol. 2144: 320-326.
[104] Park H.J., Chinnan M.S., Shewfelt R.L. 1994. Effect of corn-zein film coating on the storage life of tomatoes. J. Food Proc. Pres. 18: 317-31.
[105] Park H.J., Chinnan M.S., Shewfelt R.L. 1994a. Edible coating effects on storage life and quality of tomatoes. J. Food Sci. 593: 568-570.
[106] Paschoalick T.M., Garcia F.T., Sobral P.J.A., Habitante A.M.Q.B. 2003. Characterization of some functional properties of edible films based on muscle proteins of Nile tilapia. Food Hydro. 17: 419-427.
[107] Pastor C., Sánchez-González L., Marcilla A., Chiralt A., Cháfer M., González-Martínez C. 2011. Quality and safety of table grapes coated with hydroxyl-propyl-methyl-cellulose edible coatings containing propolis extract. Postharvest Biol. Technol. 601: 64-70.
[108] Perdonesa A., Sánchez-Gonzáleza L., Chiralt A., Vargas M. 2012. Effect of chitosan–lemon essential oil coatings on storage-keeping quality of Strawberry. Postharvest Biol. Technol. 70: 32-41.
[109] Pereda M., Aranguren M.I., Marcovich N.E. 2010. Caseinate films modified with tung oil. Food Hydro. 248: 800-808.
[110] Perez-Gago M.B., Serra M., del Rio M.A. 2006. Color change of fresh-cut apples coated with whey protein concentrate-based edible coatings. Postharvest Biol. Technol. 39: 84-92.
[111] Petracek P.D., Montalvo L., Dou H., Davis C. 1998. Postharvest pitting of ‘Fallglo’ tangerine. J. Amer. Soc. Hort. Sci. 123: 130-135.
[112] Prodpran T., Benjakul S. 2005. Effect of acid and alkaline solubilization on the properties of surimi based film. Songklanakarin J. Sci. Technol. 27: 563-574.
[113] Quezada-Gallo J.A., Gramin A., Pattyn C., Diaz-Amaro M.R., Debeaufort F., Voilley A. 2005. Biopolymers used as edible coating to limit water transfer, colour degradation and aroma compound 2-Pentanone lost in Mexican fruits. Acta Hort. 6823: 1709-1716.
[114] Ramos O.L., Fernandes J.C., Silva S.I., Pintado M.E., Malcata F.X. 2012. Edible films and coatings from whey proteins: a review on formulation, and on mechanical and bioactive properties. Crit. Rev. Food Sci. Nutr. 526: 533-52.
[115] Raybaudi-Massilia R.M., Mosqueda-Melgar J., Martin-Belloso O. 2008a. Edible alginate-based coating as carrier of antimicrobials to improve shelf-life and safety of fresh-cut melon. Intern. J. Food Microbiol. 121: 313-327.
[116] Raybaudi-Massilia R.M., Rojas-Grau M.A., Mosqueda-Melgar J., Martin-Belloso O. 2008b. Comparative study on essential oils incorporated into an alginate-based edible coating to assure the safety and quality of fresh-cut Fuji apples. J. Food Prot. 71: 1150-1161.
[117] Rhim J.W. 2004. Physical and mechanical properties of water resistant sodium alginate films. Leb. Wiss. Technol. 373: 323-330.
[118] Ricardo D., Andrade O.S., Osorio F.A. 2012. Atomizing Spray Systems for Application of Edible Coatings. Compr. Rev. Food Sci. Food Saf. 113: 323-337.
[119] Rodriguez de Jasso D., Hernandez-Castillo D., Rodriguez-Gracia R., Angulo-Sanchez J.L. 2005. Antifungal activity in vitro of *Aloe vera* pulp and liquid fraction against pathogenic fungi. Ind. Crops Prod. 21: 81-87.
[120] Rojas-Grau M.A., Raybaudi-Massilia R.M., Soliva-Fortuny R.C., Avena-Bustillos R.J., McHugh T.H., Martin-Belloso O. 2007. Apple pureee alginate edible coating as carrier of antimicrobial agents to prolong shelf-life of fresh-cut apples. Postharvest Biol. Technol. 45: 254-264.
[121] Romero-Bastida C.A., Bello-Pérez L.A., García M.A., Martino M.N., Solorza-Feria J., Zaritzky N.E. 2005. Physicochemical and microstructural characterization of films prepared by thermal and cold gelatinization from non-conventional sources of starches. Carbo. Poly. 602: 235-244.
[122] Sabir S.M., Shah S.Z.A., Abida-Afzal. 2004. Effect of chemical treatment, wax coating, oil dipping and different wrapping materials on physicochemical characteristics and storage behaviour of apple *Malus domestica* Barkh. Pak. J. Nutr. 32: 122-127.
[123] Salvatori D., Andres A., Albors A., Chiralt A., Fito P. 1998. Structural and compositional profiles in osmotically dehydrated apple. J. Food Sci. 634: 606-610.
[124] Saxena A., Sachin K., Bohidar H.B., Verma A.K. 2005. Effect of molecular weight heterogeneity on drug encapsulation efficiency of gelatin nano-particles. Colloids and Surfaces B: Biointerfaces 45: 42-48.
[125] Schmid M., Dallmann K., Bugnicourt E., Cordoni D., Wild F., Lazzeri A., Noller K. 2012. Properties of whey-protein-coated films and laminates as novel recyclable food packaging materials with excellent barrier properties. Intern. J. Pol. Sci. 7 pp, DOI:10.1155/2012/562381.
[126] Schultz T.H., Miers J.C., Owens H.S., Maclay W.N. 1949. Permeability of pectinase film to water vapor. J. Phy. Coll. Chem. 53: 1320.
[127] Serrano M., Valverde J.M., Guillén F., Castillo S., Martínez-Romero D., Valero D. 2006. Use of *Aloe*

*vera* gel coating preserves the functional properties of table grapes. J. Agric. Food Chem. 5411: 3882-3886.

[128] Shasahikala P., Suresh C.P., Dhua R.S., Kabir J. 2002. Influence of stayfresh on shelf life of tomato. Haryana J. Hort. Sci. 31: 300-301.

[129] Shiku Y., Hamaguchi P.Y., Tanaka M. 2003. Effect of pH on the preparation of edible films based on fish myofibrillar proteins. Fish Sci. 69: 1026-1032.

[130] Siripatrawan U., Harte B.R. 2010. Physical properties and antioxidant activity of an active film from chitosan incorporated with green tea extract. Food Hydro. 24: 770-775.

[131] Sitanggang A.B., Sophia L., Wu H.S. 2012. Mini Review: Aspects of glucosamine production using microorganisms. Int. Food Res. J. 192: 393-404.

[132] Souza M.P., Cerqueira M.A., Souza B.W.S., Teixeira J.A., Porto A.L.F., Vicente A.A. 2010. Polysaccharide from *Anacardium occidentale* L. tree gum Policaju as a coating for Tommy Atkins mangoes. Chem. Papers. 644: 475-481.

[133] Sugano M., Yoshida K., Hashimoto M., Enomoto K., Hirano S. 1992. Hypocholesterolemic activity of partially hydrolyzed chitosans in rats. In: Brine C.J., Sandford P.A., Zikakis J.P.(Eds.), Advances in Chitin and Chitosan, London, UK: Elsevier. pp. 472-478.

[134] Suhaila M., Khan M.M.K., Idris A.Z., Salmah., Azizah O. 1992. Effect of various surface treatments palm oil, liquid paraffin, Semperfresh or starch surface coatings and LDPE wrapping on the storage life of guava *Psidium guajava* L. at $10^0$C. Acta Hort. 321: 786-794.

[135] Talens P., Pérez-Masía R., Fabra M.J., Vargas M., Chiralt A. 2012. Application of edible coatings to partially dehydrated pineapple for use in fruit-cereal products. J. Food Eng. 112: 86–93.

[136] Tang R., Du Y., Zheng H., Fan L. 2003. Preparation and characterization of soy protein isolate–carboxymethylated konjac glucomannan blend films. J. Appl. Pol. Sci. 888: 1095-1099.

[137] Tharanathan R.N. 2003. Biodegradable films and composite coatings: past, present and future. Trends Food Sci. Technol. 14: 71-78.

[138] Tien C.L., Vachon C., Mateescu M.A., Lacroix M. 2001. Milk protein coatings prevent oxidative browning of apples and potatoes. J. Food Sci. 664: 512.

[139] Tokoro A., Tatewaki N., Suzuki K., Mikami T., Suzuki S., Suzuki M. 1988. Growth-inhibitory effect of hexa-N-acetylchitohexaose and chitohexaose against Meth-A solid tumor. Chem. Pharmac. Bull. 36: 784-790.

[140] Torgul H., Arslan N. 2005. Carboxy-methyl cellulose from sugar beet pulp cellulose as a hydrophilic polymer in coating of apple. J. Food Sci. Technol. 422: 139-144.

[141] Tsai G., Zhang S., Shieh P. 2004. Antimicrobial activity of a low molecular weight chitosan obtained from cellulose digestion of chitosan. J. Food Prot. 67: 396-398.

[142] Valverde J.M., Valero D., Martínez-Romero D., Guillén F., Castillo S., Serrano M. 2005. Novel edible coating based on *Aloe vera* gel to maintain table grape quality and safety. J. Agric. Food Chem. 5320: 7807-13.

[143] Vargas M., Chiralt A., Albors A., González-Martínez C. 2008. Effect of chitosan-based edible coatings applied by vacuum impregnation on quality preservation of fresh-cut carrot. Postharvest Biol. Technol. 512: 263-271.

[144] Walstra P. 2003. Physical chemistry of foods. In: Walstra P. (Ed.), Marcel Dekker, New York, 807 pp.

[145] Xianghong M., Lingyu Y., John F., Kennedy T. 2010. Effects of chitosan and oligochitosan on growth of two fungal pathogens and physiological properties in pear fruit. Carbo. Poly. 10: 83-84.

[146] Yang E., Zhao Y., Qian M.C. 2010. Effect of edible coating on volatile compounds of hardy kiwifruit during storage. Flavor and Health Benefits of Small Fruits ACS Symposium Series, 1035, Chapter 6, pp. 79–94. DOI: 10.1021/bk-2010-1035.ch006.

[147] Yang H., Wang Y. 2009. Effects of concentration on nano structural images and physical properties of gelatin from channel catfish skins. Food Hydro. 23: 577-584.

[148] Yang L., Paulson A.T. 2000. Effects of lipids on mechanical and moisture barrier properties of edible gellan film. Food Res. Intern. 33: 571-578.

[149] Zaritzky N. 2011. Edible coatings to improve food quality and safety. Food Engineering Interfaces Food Engineering Series, Part 5, pp. 631-659, DOI: 10.1007/978-1-4419-7475-4_27.

[150] Zhang H., Mittal G. 2010. Biodegradable protein-based films from plant resources: A review. Env. Prog. Sust. Ene. 292: 203-220.

[151] Zhou R., Li Y., Yan L., Xie J. 2011. Effect of edible coatings on enzymes, cell- membrane integrity, and cell-wall constituents in relation to brittleness and firmness of Huanghua pears *Pyrus pyrifolia* Nakai, cv. Huanghua during storage. Food Chem. 124: 569-575.