ASSOCIATION FOR AGRICULTURE
ENVIRONMENT AND BIOTECHNOLOGY

REVIEW PAPER

Edible Film – Sources, Application and Properties: A Review

Sagar Nagnath Hundekari[1] and Shrikant Baslingappa Swami[2*]

[1]Department of Agricultural Process Engineering, College of Agricultural Engineering and Technology, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist Ratnagiri, Maharashtra, India

[2]Department of Post-Harvest Engineering, Post Graduate Institute of Post-Harvest Technology and Management, Killa-Roha. Dist: Raigad (Maharashtra State) (Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli-Campus Roha) India

*Corresponding author: swami_shrikant1975@yahoo.co.in

ABSTRACT

Edible films has received considerable attention in recent years because of their advantages including use as edible packaging materials over synthetic films. This could contribute to the reduction of environmental pollution because they are made from natural resources and they are degradable. By functioning as barriers, such edible films can feasibly reduce the complexity and thus improve the recyclability of packaging materials, compared to the more traditional non-environmental friendly packaging materials, and may be able to substitute such synthetic polymer films. New materials have been developed and characterized by scientists, many from abundant natural sources that have traditionally been regarded as waste materials. The objective of this review is to provide a comprehensive introduction to edible films by providing resource materials, reviewing their properties and describing methods of their applications and potential uses.

Keywords: Edible film, sources, properties of edible films, applications of film

The last decade have seen an explosion in the research devoted to the development of new biodegradable materials, essentially to protect the environment (Bourtoom, 2008), by curtailing the widespread use of non-biodegradable films as packaging material. Biodegradable films and coatings have been particularly considered in food preservation, because of their capacity to decompose early, and also being environmentally not harmful. Among all biopolymers, starch is being investigated as a potential material for biodegradable films due to its low cost, renewability and good mechanical strength (Xu *et al*. 2005).

There has been growing interest in bio based polymer packaging products made from raw materials and originating from natural, agricultural, marine and livestock raising and renewable sources. Edible films and coatings prepared from polysaccharides, proteins and lipids have a variety of advantages over synthetic materials due to their biodegradability, edibility, biocompatibility and environmentally friendly (Ozdemir and Floros, 2004). These packaging materials moreover can serve as a carrier for nutrients, anti - browning agents, flavours and colourants to improve food quality and functionality and other active ingredients such as antimicrobial and antifungal compounds for extending product shelf life and reducing the risk of pathogen growth. These aims have been achieved with maintaining effective concentration of active compounds on food surfaces. This type of packaging that is an innovative concept

in food industries is named "Active Packaging" (Tooraj Mehdizadeh *et al.* 2012).

The main mission of food packaging is to maintain the quality and safety of food products during storage and transportation, and to broaden their shelf-life by avoiding unlikeable circumstances, such as hazardous microorganisms and their corresponding toxins, external physical forces, chemicals compounds, sunlight, permeable volatile compounds, oxygen and moisture (Bradley *et al*. 2011). In order to accomplish such a mission, packaging materials should arrange for physical protection and establish appropriate physiochemical and microbiological situations to products that are indispensable to achieve an acceptable endurance, as well as uphold the quality-safety issues of food items (Rhim *et al*. 2013).

In the view of the predictable dwindling of fossil resources and of the severe environmental problems caused by the massive use of conventional packaging there is a considerable and growing interest in biodegradable materials obtained from natural polymers. In particular, polysaccharides, such as cellulose, chitin, chitosan, starch, etc., are considered as the key raw materials for the production of chemicals and materials for the bio refineries of the future (Belgacem, 2008).

Proteins are widely used to form edible films. Protein-based edible films show satisfactory gas barrier or mechanical properties. Guilbert *et al*. Park and Cuq *et al*. indicated that proteins (*e.g.* zein, wheat gluten, albumin, keratin and gelatin) are better gas barriers than polysaccharides (*e.g.* pectin, methylcellulose, hydroxyl propylcellulose and starch) due to their unique structure and high intermolecular binding potentiality (Falguera *et al.* 2011).

Natural polymers can be an alternative source for packaging development due to their palatability and biodegradability (Siracusa *et al.* 2008). For the development of food packaging when seaweed based polysaccharides films reinforced with organically modified or unmodified nano clay an improvement in mechanical strength of the film was observed (Martins *et al.* 2013). Moreover, strong inhibitory

activity against foodborne pathogens in seaweed based food packaging is developed by incorporating natural or synthetic antimicrobial agents like grapefruit seed extracts, silver nanoparticles etc. Through the vast literature survey, it can be concluded that additives like nonmaterial and antimicrobial component effectively improves various properties of composite films. Besides food packaging, seaweed based composites are also studied for pharmaceutical applications owing to its excellent properties (Kanmani and Rhim, 2014).

Edible film is a thin layer of edible, used in food wrapping manner, dipping, brushing, or spraying to provide selective detention against displacement gas, water vapour, and dissolved materials as well as protection against mechanical damage. Theoretically, the material must have properties of edible films resist moisture loss product, has a selective permeability to certain gases, controlling the movement of dissolved solids to maintain the natural colour pigments and nutrients, as well as a host of additives like dyes, preservatives and flavour enhancer that improves the quality of foodstuffs (Gennadios and Weller, 1990).

The food packaging technologies are improving consistently in response to the demands of modern society, as well as the industrial production trends toward fresh, mildly preserved, convenient, delicious, safe, wholesome and quality food products with a longer shelf life (Realini and Marcos, 2014). Recently, the passive role of food packaging has changed from simple preservation and containment methods to include such aspects as safety, convenience, point of purchase marketing, material reduction, environmental concerns and tamper-proofing (Han, 2014). Emerging concepts of active and smart packaging technologies provide all these functionalities and numerous other innovative solutions for prolonging the shelf life and improving the quality of food products (Kerry, 2014).

The concept of edible films and coatings represents a stimulating route for creating new packaging materials. This is because edible films and coatings are available with a wide range of properties that can

help to alleviate many problems encountered with foods. Edible films can be produced from materials with film forming ability. However, potential functions and applications of the films and coatings warrant increased considerations. The selected coating formulations can reduce gas transfer rates and can be therefore important tools to extend shelf life of foods. A good choice of the coating formulation is essential for the durability and maintenance of the coating on the food products. The determination of wettability is therefore fundamental for the correct application of edible coatings (Aruna Dhanapal *et al.* 2012).

SOURCES OF EDIBLE FILM

Edible films and coatings are usually classified according to their structural material (Falguera *et al.* 2011). Main molecule groups as sources for EF and EC are polysaccharides, proteins and lipids. Fig. 1 shows possible sources for EF and EC.

Biopolymers have multiple film-forming mechanisms, including intermolecular forces such as covalent bonds (e.g., disulfide bonds and cross linking) and electrostatic, hydrophobic, or ionic interactions. For the resulting films or coatings to be edible, the film-forming mechanism involved in fabrication should be an appropriate food process: pH modification, salt addition, heating, enzymatic modification, drying, use of food-grade solvents, or reactions with other food-grade chemicals. The nature of edible packaging films, which is rigid and brittle, causes limitations in food applications. Therefore, to over-come film's brittleness and also to increase the workability and flexibility of these films, various types of plasticizers have been widely used (Parra *et al.* 2004). These film structures are brittle due to extensive interactions between polymer molecules. Mechanical properties could be improved by doping some hydrophilic and hygroscopic plasticizer which can attract water molecules, as a result of having interactions between plasticizer–biopolymer instead of between biopolymer–biopolymer. The addition of plasticizers affects not only the elastic modulus and other mechanical properties, but also the resistance of EF and EC to permeation of vapours and gases (Krochta, 2002).
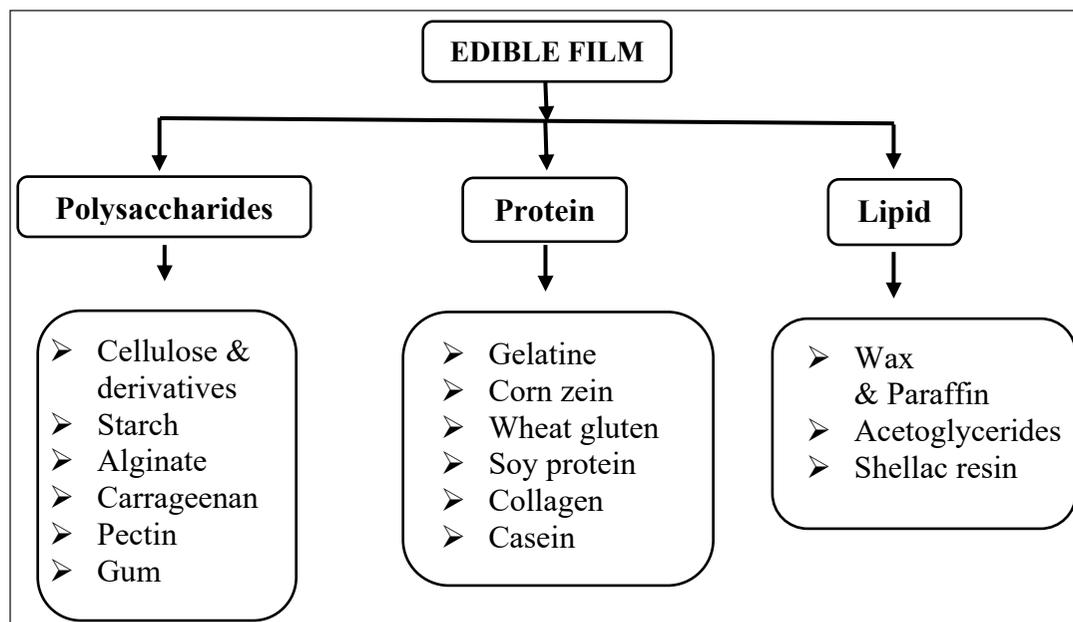

Fig. 1: Edible Films Used in Food Packaging (Falguera *et al.* 2011)

Polysaccharides

Polysaccharides used for edible films or coatings include cellulose, starch derivatives, pectin derivatives, seaweed extracts, exudate gums, microbial fermentation gums and chitosan. Polysaccharides are generally very hydrophilic resulting in poor water vapour and gas barrier properties. Although coatings by polysaccharide polymers may not provide a good water vapour barrier, these coatings can act as sacrificing agents retarding moisture loss from food products (Bourtoom, 2008).

1. Cellulose and derivatives

Cellulose is composed of repeating D-glucose units linked through ß-1, 4 glycosidic bonds. In its native state, the hydroxymethyl groups of anhydroglucose residues are alternatively located above and below the plan of the polymer backbone. This results in very tight packing of polymer chains and a highly crystalline structure that resists salvation in aqueous media. Water solubility can be increased by treating cellulose with alkali to swell the structure, followed by reaction with chloroacetic acid, methyl chloride or propylene oxide to yield carboxymethyl cellulose (CMC), methyl cellulose (MC), hydroxypropyl cellulose (HPMC) or hydroxypropyl cellulose (HPC). MC, HPMC, HPC and CMC film possess good film-forming characteristic; films are generally odourless and tasteless, flexible and are of moderate strength, transparent, resistance to oil and fats, water-soluble, moderate to moisture and oxygen transmission (Krochta and Mulder-Johnson, 1997). MC is the most resistant to water and it is the lowest hydrophilic cellulose derivatives however, the water vapour permeability of cellulose ether film is still relatively high. MC and HPMC have the ability to form thermally induced gelatinous coating; they have been used to retard oil absorption in deep frying food products. MC could be applied as coating on confectionery products as barrier to lipid migration (Nelson and Fennema, 1991). A number of researchers have investigated composite films composed of MC or HPMC and various kinds of solids, such as beeswax and fatty acids. Many of these have water vapour permeability comparable to low density polyethylene (LDPE). These composite films were all polymer-lipid bilayer formed from aqueous ethanolic solutions of cellulose ether fatty acids (Bourtoom, 2008). Fig. 2 shows the Chemical structure of Cellulose.
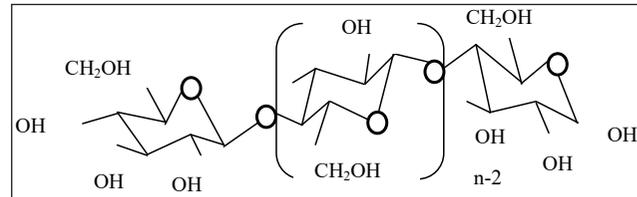

Fig. 2: Chemical structure of Cellulose

2. Chitin and chitosan

Chitin is the second most abundant naturally occurring biopolymer (after cellulose) and is found in the exoskeleton of crustaceans, in fungal cell walls and other biological materials. It is mainly poly (ß-(1-4)-2-acetamide-D-glucose), which is structurally identical to cellulose except that secondary hydroxyl on the second carbon atom of the hexose repeat unit is replaced by an acetamide group. Chitosan is derived from chitin by deacetylation in the presence of alkali. Therefore, chitosan is a copolymer consisting of (ß-(1-4)-2-acetamido-D-glucose and (ß-(1-4)-2-acetamide-D-glucose units with the latter usually exceeding 80%. Chitosan are described in terms of the degree of deacetylation and average molecular weight and their importance resides in their antimicrobial properties in conjunction with their cationicity and their-forming properties (Muzzarelli, 1996). Fig. 3 shows the chemical structure of Chitosan.
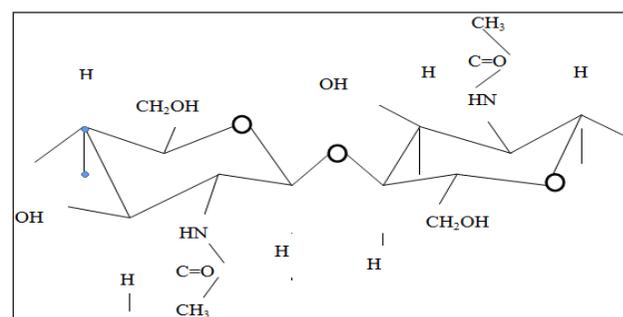

Fig. 3: Chemical structure of Chitosan

Chitosan can form semi-permeable coatings, which can modify the internal atmosphere, thereby delaying ripening and decreasing transpiration rates in fruits and vegetables. Films from aqueous chitosan are clear, tough, flexible and good oxygen barriers. Carbon dioxide permeability could be improved by methylation of polymers (Kalplan *et al*. 1993).

3. Starch

Starch is a polymeric carbohydrate composed of anhydroglucose units. This is not a uniform material and most starches contain two types of glucose polymers: a linear chain molecule termed amylase and a branched polymer of glucose termed amylopectin (Rodriguez *et al*. 2006). Starches are often used in industrial foods. They have been used to produce biodegradable films to partially or entirely replace plastic polymers because of its low cost and renew ability, and it has good mechanical properties (Xu *et al*. 2005). High amylose starch such as corn starch is a good source for films formation, free-standing films can be produced from aqueous solution of gelatinized amylose and drying. Normal corn starch consists of approximately 25% amylose and 75% amylopectin. Mutant varies of corn are produced which contain starch with up to 85% amylose (Whistler and Daniel, 1985). Fig. 4 shows the chemical structure of Amylose.
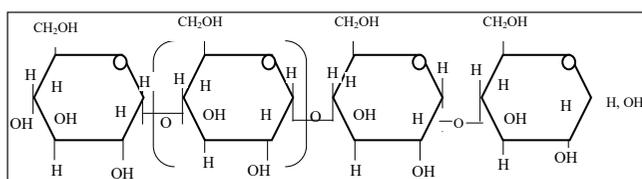

Fig. 4: Chemical structure of Amylose

Mark *et al*. (1966) reported that films produced from high amylose corn starch (71% amylose) had no detectable oxygen permeability at RH levels less than 100%. This was true for both unplasticized and plasticized (16% glycerol) films. This result is surprising in light of the fact that addition of plasticizers and absorption of water molecules by hydrophilic polymers increase polymer chain mobility and generally lead to increased gas permeability (Banker *et al*. 2000). Partial etherification

of high-amylose starch with propylene oxide, to yield the hydroxypropylated derivative, improves water solubility.

4. Alginate

Alginates are derived from seaweeds and possess good film-forming properties that make them particularly useful in food applications (Nisperos-Carriedo, 1994). Alginate has a potential to form biopolymer film or coating component because of its unique colloidal properties, which include thickening, stabilizing, suspending, film forming, gel producing, and emulsion stabilizing. Divalent cations (calcium, magnesium, manganese, aluminum, or iron) are used as gelling agents in alginate film formation. Desirable properties attributed to alginate films, include moisture retention, reduction in shrinkage improved product texture, juiciness, colour, and odour of foods. Edible films prepared from alginates form strong films and exhibit poor water resistance because of their hydrophilic nature (Borchard, 2005). Fig.5 shows the chemical structure of Alginate.
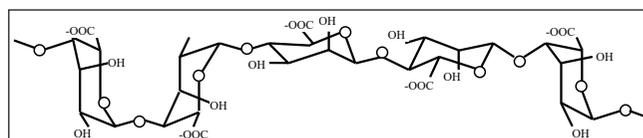

Fig. 5: Chemical structure of Alginate

5. Carrageenan

Carrageenans are water-soluble polymers with a linear chain of partially sulphated galactans, which present high potentiality as film-forming material. These sulphated polysaccharides are extracted from the cell walls of various red seaweeds (Rhodophyceae). Fig. 6 shows the chemical structure of Carrageenan.
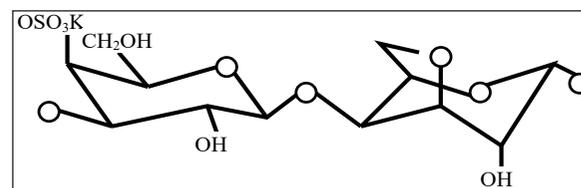

Fig. 6: Chemical structure of Carrageenan

Carrageenan film formation includes a gelation mechanism during moderate drying, leading to a three-dimensional network formed by polysaccharide - double helices and to a solid film after solvent evaporation (Karbowiak, 2006) Recently, carrageenan films were also found to be less opaque than those made of starch (Ribeiro, 2007).

6. Pectin

Pectins are a group of plant-derived polysaccharides that appear to work well with low moisture foods, but are poor moisture barriers (Baldwin *et al.* 1997). Pectin (E440) is a heterogeneous grouping of acidic structural polysaccharides, found in fruit and vegetables and mainly prepared from citrus peel and apple pomace. This complex anionic polysaccharide is composed of β-1,4-linked D-galacturonic acid residues, wherein the uronic acid carboxyls are either fully (HMP, high methoxy pectin) or partially (LMP, low methoxy pectin) methyl esterified. Fig. 7 shows the chemical structure of Pectin.
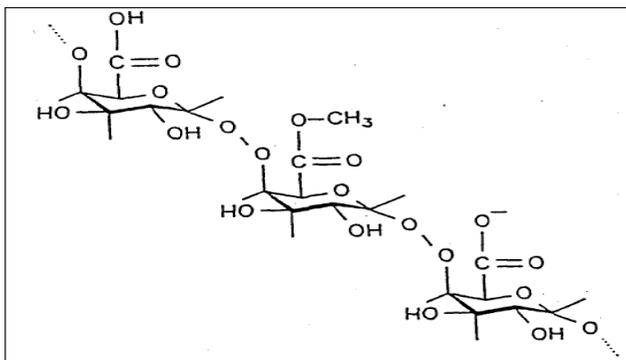

Fig. 7: Chemical structure of Pectin

7. Gums

Gums in edible-film preparation are used for their texturizing capabilities. All gums are polysaccharides composed of sugars other than glucose. Gums are differentiated into three groups (Williams, 2000): exudate gums (gum Arabic; mesquite gum), the extractive gums (from endosperm of some legume seeds or extracted from the wood: guar gum) and the microbial fermentation gums (xanthan gum). In edible-forming preparations, guar gum (E 412) is used as a water binder, stabilizer and viscosity builder. Gum arabic (E 414), owing to its solubility in hot or cold water, is the least viscous of the hydrocolloid gums. Xanthan gum (E 415) is readily dispersed in water; hence high consistency is obtained rapidly in both hot and cold systems. A blend of guar gum, gum arabic and xanthan gum provided uniform coatings with good cling and improved adhesion in wet batters. The mesquite gum forms films with excellent water vapor barrier properties when small amounts of lipids are added in their formulation (Diaz-sobac, 2002).

Protein films

In their native states, proteins generally exist as either fibrous proteins, which are water insoluble and serve as the main structural materials of animal tissues, or globular proteins, which are soluble in water or aqueous solutions of acids, bases or salts and function widely in living systems. Fibrous proteins are fully extended and associated closely with each other in parallel structures, generally through hydrogen bonding, to form fibres (Scope, 1994). Several globular proteins, including wheat gluten, corn zein, soy protein, and whey protein, have been investigated for their film properties. Protein films are generally formed from solutions or dispersions of the protein as the solvent/carrier evaporates. Generally, proteins must be denatured by heat, acid, base, and/or solvent in order to form the more extended structures that are required for film formation. Once extended, protein chains can associate through hydrogen, ionic, hydrophobic and covalent bonding. Increased polymer chain-to-chain interactions result in films that are stronger but less flexible and less permeable to gases, vapours and liquids. Polymers containing groups that can associate through hydrogen or ionic bonding result in films that are excellent oxygen barriers but are susceptible to moisture. Thus, protein films are expected to be good oxygen barriers at low relative humidity. Various types of protein have been used as edible films. These include gelatin, casein, whey protein, corn zein, wheat gluten, soy protein, mung bean protein, and peanut protein (Bourtoom, 2008).

1. Gelatin films

Gelatin is obtained by controlled hydrolysis from the fibrous insoluble protein, collagen, which is widely found in nature as the major constituent of skin, bones and connective tissue. Gelatin is composed of a unique sequence of amino acids. At approximately 40°C, gelatin aqueous solutions are in the sol state and form physical, thermo reversible gels on cooling. During gelation, the chains undergo a conformational disorder–order transition and tend to recover the collagen triple-helix structure (Ross-Murphy, 1992). Gelatin films could be formed from 20-30% gelatin, 10-30% plasticizer (glycerine or sorbitol) and 40-70% water followed by drying the gelatin gel. Gelatin is used to encapsulate low moisture or oil phase food ingredients and pharmaceuticals. Such encapsulation provides protection against oxygen and light, as well as defining ingredient amount or drug dosage. In addition, gelatin films have been formed as coatings on meats to reduce oxygen, moisture and oil transport (Gennadios *et al.* 1994). Fig. 8 shows the chemical structure of Gelatin.
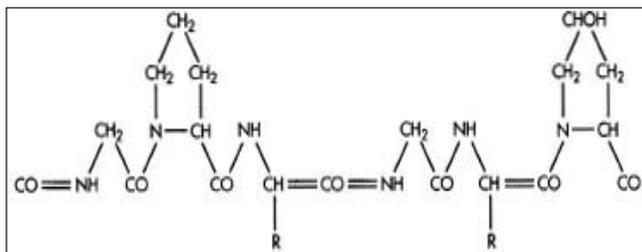

Fig. 8: Chemical structure of Gelatin

2. Corn zein films

Zein is the most important protein in corn. It is a prolamin protein and therefore dissolves in 70–80% ethanol. Zein is a relatively hydrophobic and thermoplastic material. Zein has excellent film forming properties and can be used for fabrication of biodegradable films. The zein bio-film is formed through the development of hydrophobic, hydrogen and limited disulfide bonds between zein chains. Edible films can be formed by drying aqueous ethanol solution of zein (Dickey and Parris, 2001, 2002). Formation of films is believed to involve

development of hydrophobic, hydrogen and limited disulfide bonds between zein chains in the film matrix. The resulting films are brittle and therefore require plasticizer addition for increasing flexibility. Zein films are relatively good water vapour barriers compared to other edible films. Water vapour barrier properties can be improved by adding fatty acids or by using a cross-linking reagent. But when cross-linking agents are used, the edibility of those films is of concern. Zein coating have also shown an ability to reduce moisture and firmness loss and delay colour change (reduce oxygen and carbon dioxide transmission) in fresh tomatoes (Shukla and Cheryan, 2001).
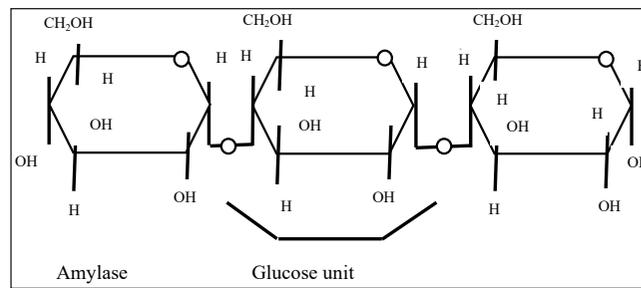

Fig. 9: Chemical structure of corn zein

3. Wheat gluten films

Wheat gluten is a general term for water-insoluble proteins of wheat flour which is composed of a mixture of polypeptide molecules, considered to be globular proteins. Cohesiveness and elasticity of gluten give integrity to wheat dough and facilitate film formation. Wheat gluten contains the prolamine and glutelin fractions of wheat flour proteins, typically referred to as gliadin and glutenin, respectively. While gliadin is soluble in 70% ethanol, glutenin is not. Although insoluble in natural water, wheat gluten dissolves in aqueous solutions of high or low pH at low ionic strength. Edible films can be formed by drying aqueous ethanol solution of wheat gluten. Cleavage of native disulfide bonds during heating of film-forming solutions and then formation of new disulfide bonds during film drying are believed to be important to the formation of wheat gluten films structure, along with hydrogen and hydrophobic bonds. Addition of plasticizer such as glycerin in

gluten films is necessary to improve film flexibility. However, increasing film flexibility by increasing sorbitol content reduces film strength, elasticity and water vapour barrier properties (Gontard *et al*. 1994). Gennadios and Weller (1992) confirmed the effect of wheat gluten purity on film appearance and mechanical properties, i.e., a greater purity gluten results in a stronger and clearer films. Herald *et al*., (1995) investigated the effect of plasticizer size of wheat gluten; films prepared from spray-dried wheat gluten were stronger than films from flash-dried which had larger sized particles. When used as a coating on grade A-quality shell eggs, the egg quality was maintained for 30 days. Tensile strength of gluten films can be improved by using a cross-linking agent such as glutaraldehyde, or heat curing at 80°C (Gennadios and Weller, 1992; Koelsch *et al*. 1992). Pochat-Bohatier *et al*. (2005) determined the influence of relative humidity on carbon dioxide sorption in wheat gluten films. The results showed that the permeability was based on the rise of CO_2 solubility and diffusivity with the increase in RH. The increase in the water content of wheat gluten improves the affinity between carbon dioxide and the protein matrix, leading to outstanding sorption values for high RH. Fig. 10 shows the chemical structure of wheat gluten.
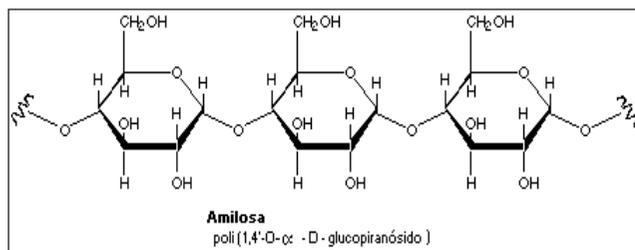

Fig. 10: Chemical structure of wheat gluten

4. Soy protein films

The protein content of soybeans (38-44%) is much higher than the protein content of cereal grain (8-15%). Most of the protein in soybeans is insoluble in water but soluble in dilute neutral salt solutions. Soy protein is high in asparagine and glutamine residues. Both conglycinin and glycinin are tightly folded proteins. While the extent of disulfide cross-linking of conglycinin is limited due to only two to three cysteine groups per molecule, glycinin contains 20 intramolecular disulfide bonds. Alkali and heating both cause dissociation and subsequent unfolding of glycinin due to disulfide bond cleavage. Edible films based on soy protein can be produced in either of two ways: surface film formation on heated soymilk or film formation from solutions of soy protein isolate (SPI) (Gennadios and Weller, 1992). Soymilk is produced by grinding soybeans with water followed by separation of milk from extracted soybeans. To form films from both soymilk and SPI, (a) heating of film solutions to disrupt the protein structure, cleave native disulfide bonds and expose sulfhydryl groups and hydrophobic groups, and then (b) formation of new disulfide, hydrophobic and hydrogen bonds during film drying are believed to be important to the formation of soy protein film structure (Subirade *et al*. 1998). Fig.11 shows the chemical structure of soy protein.
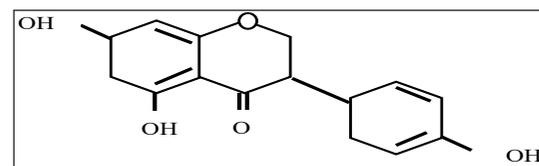
Fig. 11: Chemical structure of soy protein

5. Collagen

Collagen is the most commercially successful edible protein film. Films based on high concentrations of hydrolysed collagen produce films with more homogeneous surfaces (Fadini *et al*. 2013). Collagen fibre and collagen powder were also shown to be suitable for the production of biocomposite films in a system where the fibres act as filler, exerting a reinforcement effect (Wolf *et al*. 2009). Fig. 12 shows the chemical structure of Collagen.

Fig. 12: Chemical structure of Collagen

6. Casein

Casein molecules easily form transparent, flexible, tasteless films from aqueous solutions without further treatment. Due to a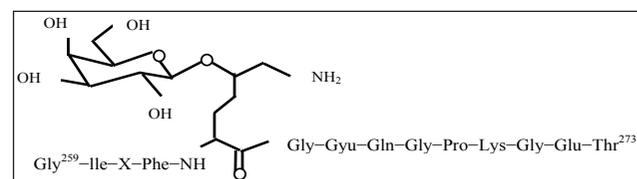 high number of polar groups casein films excellently adhere to different substrates and prevent migration of O_2, CO_2 and aromas (Arrieta *et al.* 2013). Decreased film solubility in water and improved mechanical properties were obtained through buffer treatments at the isoelectric point of these films by cross linking the protein using irradiation through the use of transglutaminase, Trametes hirsute laccase, and *Trichoderma reesei* tyrosinase enzyme or by the use of a chemical cross linker such as formaldehyde, DL-glyceraldehyde, glutaraldehyde, or glyoxal (Mendes de Souza *et al.* 2010). Main disadvantage of casein is its relatively high price. Fig. 13 shows the Chemical Structure of Casein.
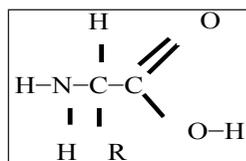
Fig. 13: Chemical structure of Casein

Lipid films

Lipid compounds utilized as protective coating consist of acetylated monoglycerides, natural wax, and surfactants. The most effective lipid substances are paraffin wax and beeswax. The primarily function of a lipid coating is to block transport of moisture due to their relative low polarity. In contrast, the hydrophobic characteristic of lipid forms thicker and more brittle films. Consequently, they must be associated with film forming agents such as proteins or cellulose derivatives generally, water vapour permeability decrease when the concentration of hydrophobicity phase increases. Lipid-based films are often supported on a polymer structure matrix, usually a polysaccharide, to provide mechanical strength (Debeaufort *et al*. 1993).

1. Waxes and paraffin

Paraffin wax is derived from distillate fraction of crude petroleum and consists of a mixture of solid hydrocarbon resulting from ethylene catalytic polymerization. Paraffin wax is permitted for use on raw fruit and vegetable and cheese. Carnauba wax is an exudate from palm tree leaves (*Copoernica cerifera*). Beewax (white wax) is produced from honeybees. Candelilla is obtained from candelilla plant. Mineral oil consists of a mixture of liquid paraffin and naphtheric hydrocarbon (Hernandez, 1994). Waxes are used as barrier films to gas and moisture (skin on fresh fruits) and to improve the surface appearance of various foods (e.g., the sheen on sweet). If applied as a thick layer, they must be removed before consumption (certain cheese); when used in thin layers, they are considered edible. Waxes (notably paraffin, carnauba, candellila and bee wax) are the most efficient edible compounds providing a humidity barrier. Fig. 14 shows the chemical structure of wax.
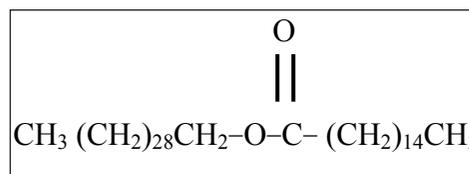
Fig. 14: Chemical structure of wax

2. Acetoglyceride

Acetylation of glycerol monosterate by its reaction with acetic anhydride yields 1-stearodiacetin. This acetylated monoglyceride displays the unique characteristic of solidifying from the molten state into a flexible, wax-like solid (Feuge *et al*. 1953). Most lipids in the solid state can be stretched to only about 102% of their original length before fracturing. Acetylated glycerol monostearate, however, can be stretched up to 800% of its original length water vapour permeability of this film is much less than that of polysaccharide films with the exception of methyl cellulose or ethyl cellulose. Acetylated monoglyceride coatings have been used on poultry and meat cuts to retard moisture loss during storage (Kester and Fennema, 1986). Fig. 15 shows the chemical structure of Acetoglyceride.

Fig. 15: Chemical structure of Acetoglyceride

3. Shellac resins

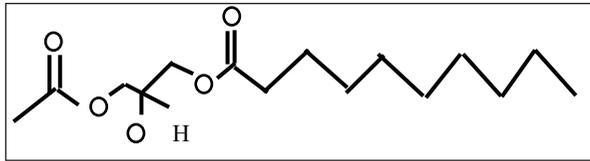A shellac resin is a secretion by the insect Laccifer lacca and is composed of a complex mixture of aliphatic alicyclic hydroxyl acid polymers. This resin is soluble in alcohols and in alkaline solutions. Shellac is not a GRAS substance; it is only permitted as an indirect food additive in food coatings and adhesives. It is mostly used in coatings for the pharmaceutical industry and only few studies have been reported on foods (Hernandez, 1994). Rosins which are obtained from the oleoresins of the pine tree are residues left after distillation of volatiles from the crude resin. Resin and its derivatives are widely used in coating for citrus and other fruits. These coatings were designed primarily to impart high-gloss at the time of inspection by the buyer, usually after application of the coating. When coatings are applied to fruit, they form an additional barrier through which gases must pass. Because coatings differ in gas permeance and ability to block openings in the peel, they have different effects on gas exchange. Citrus fruits with shellac and wood resin-based coatings generally have lower internal O_2, higher internal CO_2 and higher ethanol content than fruits with wax coatings (Hagenmaier and Baker, 1993). Fig. 16 shows the chemical structure of Shellac resin.
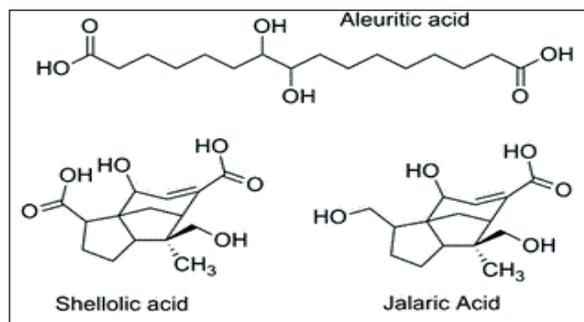
Fig. 16: Chemical structure of Shellac

METHODS OF APPLICATION OF EDIBLE FILM AND COATINGS

1. Dipping

Nowadays, dipping is a common method for applying coatings on fruits and vegetables (Vargas, 2008). The coating is made by dipping in a coating solution with properties such as density, viscosity and surface tension, as well as food withdrawal speed from the coating solution (Generally the food was dipped into the film-forming solutions between 5 and 30 second (Cisneros-Zevallos, 2003). Fig. 17 shows the method of applying coating of fruits and vegetables.
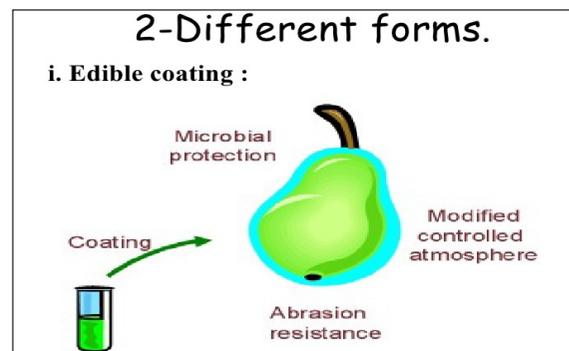
Fig. 17: Dipping

2. Brushing

However, the brushing method for the application of film solution to fresh beans and strawberries was found to be better than wrapping and dipping methods in terms of reducing the moisture loss (Ayranci, 1997). Fig. 18 shows the brushing method.

Fig. 18: Brushing

3. Spraying

In the food industry, coating by spraying is the conventional method generally used when the coating forming solution is not very viscous. Indeed, highly viscous solution cannot be or very easily sprayed. Thus only dipping techniques can be applied giving high thickness to the coating. Initially, in the case of plan jet, the spray exits the nozzle as a two dimensional sheet of fluid. This sheet then breaks up into a series of cylindrical ribbons which eventually undergo the same type of breakup as laminar capillary jets (Stone, 1994). The control of the final drop size and therefore of the quality of the coating depend on spray gun and nozzle temperature, air and liquid flow rate, humidity of incoming air and of the polymer solution. Nowadays, programmable spray systems are available for automation during such operations. Classic spraying system can produce a fine spray with relatively drop-size distribution up to 20 µm. Furthermore, other different factors are critical in the formation of polymeric films by spraying systems, such as drying time, drying temperature, drying method, etc. (Bergeron, 2003). Fig. 19 shows the coating by spraying.

Fig. 19: Spraying

4. Solvent Casting

Solvent casting is the most used technique to form hydrocolloid edible films. Water or water– ethanol solutions or dispersions of the edible materials are spread on a suitable substrate and later dried. During drying of the films, solvent evaporation leads to a decrease in solubility of the polymer until polymer chains align themselves to form films. The choice of the substrate is important to obtain films, which can be easily peeled without any damage after the solvent is evaporated. Generally, the films are air-dried during several hours in the ventilated oven (Bergeron, 2003). Optimum moisture content (5–10% w/v) is desirable in the dried film. Film structures depend on the drying conditions (temperature and relative humidity), wet casting thickness as well as the composition of the casting solution. Fig. 20 shows the solvent casting to form hydrocolloids edible film.

Fig. 20: Solvent casting

5. Extrusion

The application of extrusion technology to edible films, such as starch films, is another choice (Guan and Hanna 2006). The extrusion process is based on the thermoplastic properties of polymers when plasticized and heated above their glass transition temperature under low water content-conditions. The extrusion processing of polymer products often need the addition of plasticizers such as polyethylene glycol, sorbitol in an amount of 10% to 60% w/w .In comparison with the solvent casting method, the extrusion method is attractive for industrial processes since it does not require solvent addition and a time of evaporation.

PROPERTIES OF EDIBLE FILM

1. Polysaccharides film

Table 1 shows the Polysaccharides based Edible film. Moreno *et al.* (2015) determine some properties of starch based edible film and reported that the incorporation of proteins affected the structural and physical properties of potato starch films, while modifying their thermal behaviour and increasing the glass transition temperature. Their incorporation especially that of lactoferrin, greatly increased the film's brittleness, regardless of the films water content, although they enhance the water vapour and oxygen barrier properties, whatever the age of the film. The thermal degradation of blend films and isolated proteins occurred at temperatures of over 250°C, which means that blend starch films can be thermo processed, according to their thermoplastic properties and used for the plastics industries. Also they reported that thickness, tensile strength, elongation at break and water vapour permeability of potato starch film are 0.060±0.001 cm, 22.50 Mpa, 10 %, 6.4±0.08 g.mm/kpa.h.m² respectively.

Mostafavi *et al.* (2015) determine some properties of gum based edible film and reported that there was a distinct synergism between the two gums at all mixing ratios. FTIR spectra showed the existence of non-covalent intermolecular interactions between gums. The surface tensions of binary solutions were significantly lower than those of individual gums which is advantageous for coating applications. They also reported that thickness, tensile strength, elongation at break, water vapour permeability and moisture content of bean gum film are 0.475 cm, 20.28±2.07 Mpa, 1.12±0.27 %, 0.30±0.2 g.mm/kpa.h.m² and 13.07±0.36 respectively.

Farhan and Mohd Hani (2016) studies some properties of carrageenan film and reported that increased moisture content, water solubility and water vapour permeability were found in films plasticized with 25–30% of glycerol and 30% of sorbitol as compared to the control film. Films were more transparent and their oil permeability was reduced when the plasticizers concentration increased from 20–30%. Films plasticized with sorbitol were more effective oxygen barriers than films plasticized with glycerol. They also reported that thickness, tensile strength, elongation at break, water vapour permeability, moisture content and Film Solubility of Carrageenan film are 0.079±0.001 cm, 47.42±2.72 Mpa, 8.09±1.34 %, 4.32 ±0.41 g.mm/kpa.h.m² and 49.5 ±1.9 respectively.

Chaichi, *et al.* (2016) determine some properties of pectin based edible film and reported that the optimum result was obtained through the Nano composite film with 5% Crystalline Nano cellulose (CNC) in terms of mechanical and water vapour

Table 1: Properties of Polysaccharides based Edible film

Sl. No.	Properties of Film / Type of Film	Thickness (cm)	Tensile Strength (Mpa)	Elongation at Break (%)	WVP (g.mm/ kpa.h.m²)	Film Solubility (%)	MC (%)	Source
1	Potato Starch	0.060± 0.001	22.50	10	6.4±0.08			Moreno *et al.* (2015)
2	Bean Gum	0.475	20.28±2.07	1.12±0.27	0.30±0.2		13.07±0.36	Mostafavi *et al.* (2015)
3	Carrageenan	0.079±0.001	47.42±2.72	8.09±1.34	4.32 ±0.41	49.5 ±1.9		Abdulaal Farhan and Norziah Mohd Hani (2016)
4	Pectin		13.15 ±0.001	40	5	9.3±0.001	31.02	Chaichi *et al.* (2016)
5	Chitosan	0.076 ±0.0005	48.00 ±2.75	25	4.2 ±0.02	17.73±0.11	21.88	Jun Mei *et al.* (2013)
6	Cellulose	0.067	34.5	7.2	4.54 ±0.18			Jaqueline Oliveira de Moraes *et al.* (2015)
7	Alginate	0.098±0.01	0.562±0.15		74.50±4.94		16.23±0.97	Keshaw Ram Aadil *et al.* (2016)

properties as the tensile strength increased up to 84% and water vapour permeability decreased by 40%. They reported that tensile strength, elongation at break, water vapour permeability, Film Solubility and moisture content of Pectin film are 13.15 ±0.001 Mpa, 40 %, 5.00 g.mm/kpa.h.m², 9.3±0.001, 49.5 ±1.9 and 31.02 respectively.

Jun Mei *et al.* (2013) determine some properties of chitosan based edible film and reported that the incorporation of perilla oil resulted in a decrease in moisture content, solubility and mechanical properties. High water vapour permeability (WVP), good transparency and low solubility were observed with the addition of glycerol. They reported that thickness, tensile strength, elongation at break, water vapour permeability, Film Solubility and moisture content of chitosan film are 0.076 ±0.0005 cm, 48.00 ±2.75 Mpa, 25 %, 4.2 ±0.02 g.mm/kpa.h.m², 17.73±0.11, and 21.88 respectively.

Jaqueline Oliveira de Moraes, *et al.* (2015) determine some properties of cellulose based edible film and reported that the tape-casting technique allows for the preparation of films with much larger dimensions than those produced via classical casting. The spreading thickness and drying temperature of starch glycerol- cellulose fibre suspensions significantly influence the properties of the resulting films. They reported that thickness, tensile strength, elongation at break and water vapour permeability of Cellulose

& its derivative film are 0.067 cm, 34.5 Mpa, 7.2 % and 4.54 ±0.18 respectively.

Aadil *et al.* (2016) reported that the Acacia lignin has good potential to be blended into alginate film to synthesize active antimicrobial, antioxidant biodegradable film. Alginate films incorporated with lignin had significantly lower water solubility (up to 26%) and tensile strength (TS, 0.146 MPa). Infrared spectroscopy suggested that lignin interacts with alginate by hydrogen bonding. Mechanical and thermal properties of films vary as a function of lignin content, showing optimum values for films modified with 20% (w/v) lignin. Hence, the use of lignin-alginate (LA) film could be a useful for maintaining the quality and shelf life of food and non-food product. They reported that thickness, tensile strength, film solubility and moisture content of alginate film are 0.067 cm, 34.5 Mpa, 7.2 % and 4.54 ±0.18 respectively.

2. Protein film

Table 2 shows the protein based edible film. Musso., *et al.* (2016) reported some properties of Gelatine based edible film. They reported that thickness, tensile strength, elongation at break, water vapour permeability, Film Solubility and moisture content of gelatine film are 0.062 ±0.001 cm, 2.6 ±0.2 MPa, 163.3±13.10 %, 1.14±0.08 g.mm/kpa.h.m², 36.8±0.06, and 16.90 respectively. Sreedath Tulamandi *et al.* (2016)

Table 2: Properties of Protein based Edible film

Sl. No.	Properties of Film / Type of Film	Thickness (cm)	Tensile Strength Mpa)	Elongation at Break (%)	WVP (g.mm/ kpa.h.m²)	Film Solubility (%)	MC (%)	Source
1	Gelatin	0.062± 0.001	2.6±0.2	163.3±13.10	1.14±0.08	36.8±0.06	16.9	Musso. *et al.* (2016)
2	Soy protein	0.1186	5.13±0.9	28.11±0.22	7.52±0.14	72.20±0.23	13.07±0.36	Sreedath Tulamandi *et al.* (2016)
3	Casein	0.015±0.03	10.9	65.4	1.09 ±0.14	85.28 ±5.33	21.73±0.92	Nahal Aliheidari *et al.* (2013)
4	Wheat gluten		4.9±1.0	28.2±6.3	1.75±0.01			Ansorena *et al.*(2016)
5	Zein corn	0.011 ±0.0005			2.0 ±0.13		5.7±0.2	Escamilla-Garcia *et al.* (2013)
6	Collagen		2.61	24.74	0.52			Fadini *et al.* 2015)

reported some properties of Soy protein based edible film. They reported that thickness, tensile strength, elongation at break, water vapour permeability, Film Solubility and moisture content of Soy protein film are 0.1186 cm, 5.13±0.9 Mpa, 28.11±0.22 %, 7.52±0.14 g.mm/kpa.h.m^2, 72.20±0.23, and 13.07±0.36 respectively. Nahal Aliheidari *et al.* (2013) reported some properties of Casein based edible film. They reported that thickness, tensile strength, elongation at break, water vapour permeability, Film Solubility and moisture content of casein film are 0.015 ±0.03 cm, 10.9 Mpa, 65.4 %, 1.09±0.14 g.mm/kpa.h.m^2, 85.28±5.33, and 21.73±0.92 respectively.

Ansorena, *et al.* (2016) reported some properties of Wheat gluten based edible film. They reported that tensile strength, elongation at break and water vapour permeability of wheat gluten film are 0.015 ±0.03 cm, 4.9±1.0 Mpa, 28.2±6.3 % and 1.75±0.14 g.mm/kpa.h.m^2 respectively. Escamilla-Garcia *et al.* (2013) reported some properties of Zein corn based edible film. They reported that thickness, water vapour permeability and moisture content of zein corn film are 0.011 ±0.0005 cm, 2.0±0.13 g.mm/kpa.h.m^2, and 5.7±0.2 % respectively. Fadini, *et al.* (2015) reported some properties of Collagen based edible film. They reported that tensile strength, elongation at break and water vapour permeability of Collagen film are 2.61 Mpa, 24.74 % and 0.52 g.mm/kpa.h.m^2 respectively.

3. Lipid film

Table 3 shows the lipid based edible film. Delane *et al.* (2014) studied some properties of Wax based edible film and reported that water vapour permeability and water solubility were decreased by carnauba wax,

indicating that the presence of carnauba wax may be interesting for applications which require good water barrier and resistance and carnauba wax presented plasticizing effect on the composite films, lowering glass transition temperature, and decreasing film strength and stiffness while enhancing elongation. They reported that tensile strength, elongation at break, water vapour permeability and Film Solubility of wax film are 0.76 Mpa, 136.25 %, 3.26 g.mm/kpa.h.m^2 and 80.19 respectively.

Phan The *et al.* (2008) determine some properties of Shellac based edible film and reported that the incorporation of Polyethylene glycol (plasticizer) into shellac improves the flexibility that prevents the defects in structure and reinforces the adhesion between the shellac and the cohesive-structural layer. The use of plasticizer weakly affects the WVP of bilayer membranes; however, the surface hydrophobicity as well as the liquid water adsorption rate is comparable to that of non-plasticized shellac layer. Furthermore, PEG increases the stretchability of bilayer membranes. Either being plasticized or not, shellac layer could improve significantly the functional properties of bilayer barriers and give a promising use as biopackaging. Also they reported that thickness, tensile strength, elongation at break, water vapour permeability and Film Solubility of shellac film are 0.0187±0.039 cm, 12.83 Mpa, 5.26 % and 1.13±0.64 g.mm/kpa.h.m^2 respectively.

Sitthiphong Soradech *et al.* (2012) also studied some properties of Shellac based edible film. The formation of the composite film not only improved the mechanical properties of shellac but also enhanced the efficiency of film coating by the modification of

Table 3: Properties of Lipid based Edible film

Sl. No.	Properties of Film / Type of Film	Thickness (cm)	Tensile Strength Mpa)	Elongation at Break (%)	WVP (g.mm/kpa.h.m^2)	Film Solubility (%)	MC (%)	Source
1	Wax		0.76	136.25	3.26	80.19		Delane. *et al.* (2014)
2	Shellac	0.084±0.0039	12.83	5.26	1.13±0.64			Phan The *et al.* (2008)
3	Shellac	0.0187±0.01	15.8	33.4	9.46 ±0.46	54.24 ±2.10	15.12±1.22	Sitthiphong Soradech *et al.* (2012)

different concentrations of hydrocolloid polymer to suit with the type of coating substrate. Hence the knowledge of composite film could make beneficial contributions to the various applications in film coating for the food and pharmaceutical industries. They reported that thickness, tensile strength, elongation at break, water vapour permeability, Film Solubility and moisture content of shellac film are 0.0187±0.01cm, 15.8 Mpa, 33.4 %, 9.46±0.46 g.mm/ kpa.h.m², 54.24±2.10, and 15.12±1.22 respectively.

CONCLUSION

1. Edible films has received considerable attention in recent years because of their advantages including use as edible packaging materials over synthetic films. This could contribute to the reduction of environmental pollution because they are made from natural resources and they are degradable.

2. By functioning as barriers, such edible films can feasibly reduce the complexity and thus improve the recyclability of packaging materials, compared to the more traditional non-environmental friendly packaging materials, and may be able to substitute such synthetic polymer films.

3. New sourches have been discussed have been developed and characterized by scientists, many from abundant natural sources that have traditionally been regarded as waste materials.

REFERENCES

Abdulaal, F. and Mohd Hani, N. 2016. Characterization of edible packaging films based on semi-refined kappa-carrageenan plasticized with glycerol and sorbitol, *Food Hydrocolloids,* doi: 10.1016/j.foodhyd.2016.10.034.

Al-Hassan A.A. and Norziah, M.H. 2011. Starch gelatin edible films: Water vapour permeability and mechanical properties as affected by plasticizers. *Food Hydrocolloids,* **26**: 108-117.

Arrieta, M.P., Peltzer, M.A., Lopez, J., Garrigos, M.C., Valente, A.J.M. and Jimenez, A. 2013. Functional properties of sodium and calcium caseinate antimicrobial active films containing carvacrol. *Journal of Food Engineering,* **121**(1): 94-101.

Aruna, D., Sasikala, P., Lavanya, R., Kavitha, V., Yazhini, G.M. and Banu, S. 2012. Edible films from Polysaccharides. *Food Science and Quality Management,* **3**: 151-162.

Baldwin, E.A., Nisperos-Carriedo, M.O. and Baker, R.A. 1995. Use of edible coatings to preserve quality of lightly (and slightly) processed products. *Critical Reviews in Food Science and Nutrition,* **35**(6): 509

Banker, G.S., Gore, A.Y. and Swarbrick, J. 2000. Water vapour transmission properties of free polymer films. *Journal of Pharmacy and Pharmacology,* **18**: 173-176.

Belgacem, M.N. and Gandini, A. 2008. Monomers, polymers and composites from renewable resources. *Elsevier.,* **1**: 132-143.

Borchard, W., Kenning, A., Kapp, A. and Mayer, C. 2005. Phase diagram of the system sodium alginate/water: A model for biofilms. *International Journal of Biological Macromolecules,* **35**: 247–256.

Bourtoom, T. 2008. Edible films and coatings: characteristics and properties *International Food Research Journal,* **15**(3): 237-248.

Casariego, A., Souza, B.W.S., Vicente, A.A., Teixeira, J.A., Cruz, L. and Dıa, R. 2008. Chitosan coating surface properties as affected by plasticizer, surfactant and polymer concentrations in relation to the surface properties of tomato and carrot. *Food Hydrocolloids,* **22**: 1452–1459.

Chaichi, M., Hashemi, M., Badii, F. and Mohammadi, A. 2016. Preparation and characterization of a novel bionanocomposite edible film based on pectinandcrystalline nanocellulose. *Carbohydrate Polymers* http://dx.doi. org/10.1016/j.carbpol.09.062

Cisneros-Zevallos, L. and Krochta, J.M. 2003. Whey protein coatings for fresh fruits and relative humidity effects. *J. Food Science,* **68**(1): 176-181.

Debeaufort, F., Martin-Polo, M. and Voilley, A. 1993. Polarity homogeneity and structure affect water vapor permeability of model edible films. *Journal of Food Science,* **58**: 426-434.

Delane C. Rodrigues, Carlos Alberto Caceres, Halisson L. Ribeiro, Rosa F.A. de Abreu,Arcelina P. Cunha, Henriette M.C. Azeredo. 2014. Influence of cassava starch and carnauba wax on physical properties of cashew tree gum-based films, *Food Hydrocolloids,* **38**: 147-151.

Diaz-Sobac, R., Garcia, H.S., Beristain, C.I. and Vernon-Carter, E.J.J. 2002. *Food Process. Pres.* Gennadios, A.; Hanna, M.A.; Kurth, B. (1997) *LWT-Food Sci. Technol.*

Dickey, L.C. and Parris, N. 2001. Ethanolic extraction of zein from maize. *Industrial Crops and Products- an International Journal* 13: 67–76.

Dickey, L.C. and Parris, N. 2002. Serial batch extraction of zein milled maize. *Industrial Crops and Products an International Journal,* **15**: 33–42.

Bradley, L. Castle, Q. Chaudhry, 2011. Applications of nanomaterials in food packaging with a consideration of opportunities for developing countries, *Trends in Food Science & Technology*, **22**(11): 604-610.

Elsabee, M.Z. and Abdou, E.S. 2013. Chitosan Based Edible Films and Coatings: A Review. *Materials Science and Engineering,* **33**: 1819–1841.

Escamilla-Garcia S.M., Calderon-Domingueza, G., J.J. Chanona-Pereza,R.R. Farrera- Rebolloa, J.A. Andraca-Adameb, I. Arzate-Vazquezb, J.V. Mendez-Mendezb, L.A. Moreno-Ruiz. 2013. Physical and structural characterisation of zein and chitosan edible films using nanotechnology tool. *International Journal of Biological Macromolecules,* **61**: 196– 203.

Ewelina Basiak, Frederic Debeaufort, Andrzej Lenart. 2015. Effect of oil lamination between plasticized starch layers on film properties. *Food Chemistry*, **54**(5): 452-460.

Ezeohal, S.L. and Ezenwanne, J.N. 2013. Production of Biodegradable Plastic Packaging Film from Cassava Starch. *IOSR Journal of Engineering (IOSRJEN),* **3**(10): 14-20.

Fadini, A.L., Rocha, F.S., Alvim, I.D., Sadahira, M.S., Queiroz, M.B., Alves, R.M.V. and Silva, L.B. 2013. Mechanical properties and water vapour permeability of hydrolysed collagen–cocoa butter edible films plasticised with sucrose. *Food Hydrocolloids,* **30**(2): 625–631.

Falguera V., Quinterob J.P., Jimenez A., Munoz J.A. and Ibarz, A. 2011. Edible films and coatings: Structures, active functions and trends in their use. *Trends in Food Science & Technology,* **22**(6)*:* 292-303.

Feuge, R.O., Vicknair, E.J. and Lovegren, N.V. 1953. Modification of vegetable oils. XIII. Some additional; properties of acetostearin products. *Journal of the American Oil Chemists' Society,* **30**: 283.

Gennadios, A. and Weller, C.L. 1992. Tensile strength increase of wheat gluten films. ASAE paper no. 92-6517. In International Winter Meeting American Society of Agricultural Engineers, December 15-18, 1992. Nashvill, TN.

Gennadios, A., Brandenburg, A.H., Weller, C.L. and Testin, R.F. 1993. Effect of pH on properties of wheat gluten and soy protein isolate films. *Journal of Agricultural and Food Chemistry*, **41**: 1835-1839.

Gennadios, A., McHugh, T.H., Weller, C.L. and Krochta, J.M. 1994. Edible coating and films based on protein. *In:* Krochta, J.M., Balwin, E.A. and Niperos-Carriedo, M.O. (Eds.). Edible Coatings and Films to Improve Food Quality, p. 201-277. Lancaster. Basel: Technomic Publishing.

Ghasemlou, M., Khodaiyan, F., Oromiehie, A. and Yarmand, M.S. 2011. Development and characterization of a new biodegradable edible film made from kefiran an exopolysaccharide obtained from kefir grains. *Food Chemistry*, **127**(4)*:* 1496–1502.

Guilbert, S. 1986. Technology and application of edible protective films. *In:* Mathlouthi, M. (Ed.), Food packaging and preservation, p. 371–394. London, UK: Elsevier Applied Science.

Guilbert, S., Gontard, N. and Gorris, G.M. 1996. Prolongation of the shelf-life of perishable food products using biodegradable films and coatings, *LWT-Food Sci. Technol.,* **29**: 10–17.

Hagenmaier, R.D. and Baker, R.A. 1993. Reduction in gas exchange of citrus fruit by wax coatings. *Journal of Agricultural and Food Chemistry*, **41**(2): 283-287.

Han, J.H. and Gennadios, A. 2005. Edible films and coatings: a review. In: J. Han, *Innovations in Food Packaging* (pp. 239-259): Elsevier Science & Technology Books.

Han, J.H. 2000 Antimicrobial food packaging. *Food Technology,* **54**: 56–65.

Han, J.H. 2014. A review of food packaging technologies and innovations. *In:* J.H. Han (Eds.), *Innovations in food packaging* (pp. 3-12). San Diego, USA: Academic Press.

Herald, T.J., Gnanasambanadam, R., Mcguire, B.H. and Hachmeister, K.A. 1995. Degradable wheat gluten films: preparation, properties and applications. *Journal of Food Science*, **60**: 1147-1156.

Hernandez, E. 1994. Edible coating from lipids and resins. *In:* Krochta, J.M., Balwin, E.A. and Niperos-Carriedo, M.O. (Eds.). Edible Coatings and Films to Improve Food Quality, pp. 279-303. Lancaster. Basel: Technomic Publishing.

Hulda, N.M. and Carlos, R.F. 2011. Mechanical and water vapour permeability properties of biodegradables films based on methylcellulose, glucomannan, pectin and gelatin Ciênc. *Tecnol. Aliment. Campinas,* **31**(3): 739-746.

Jaqueline Oliveira de Moraes, Ana Silvia Scheibe, Bruno Augusto, Mattar Carciofi, Joao Borges Laurindo. 2015. Conductive drying of starch-fiber films prepared by tape casting: Drying rates and film properties. *LWT - Food Science and Technology,* **64**: 356-366.

Jimin Guo, Liming Ge, Xinying Li, Changdao Mu and Defu Li. 2014. Periodate oxidation of xanthan gum and its crosslinking effects on gelatin-based edible films, *Food Hydrocolloids,* **39**: 243-250.

Jun, M., Yilin, Y., Yan, W. and Yunfei, L. 2013. Characterization of edible starch–chitosan film and its application in the storage of Mongolian cheese. *International Journal of Biological Macromolecules,* **57**: 17– 21.

Kaplan, D.L., Mayer, J.M., Ball, D., McCassie, J., Allen, A.L. and Stenhouse, P. 1993. Fundamental of biodegradable polymer. *In* Ching, C., Kaplan D. and Thomas E. (eds.). Biodegradable Polymers and Packaging, p. 1-42. Lancaster: Technomic Publishing.

Karbowiak, T., Debeaufort, F., Champion, D. and Voilley, A. 2006. Wetting properties at the surface of iota-carrageenan-

based edible films. *Journal of Colloid and Interface Science,* **294**: 400–410.

Kanmani, P. and Rhim, J.W. 2014. Development and characterization of carrageenan/grapefruit seed extract composite films for active packaging. *Int. J. Biol. Macromolecules,* **68**: 258–66.

Keshaw, R.A., Dolly, P. and Jha, H. 2016. Improvement of physicochemical and functional properties of alginate film by Acacia lignin, *Food Packaging and Shelf Life, pp.* 25–33.

Kester and Fennema. 2008. Edible films and coatings: characteristics and properties. *International Food Research Journal,* **15**(3): 237-248.

Kerry, J.P. 2014. New packaging technologies, materials and formats for fast-moving consumer products. *In* J.H. Han (2ⁿᵈ Eds.), *Innovations in food packaging* (549-584) USA: Academic Press.

Kinsella, J.E., Damodaran, S. and German, B. 1985. Physiochemical and functional properties of isolated proteins with emphasis on soy proteins. *In* Altschul, A.M. and Wilcke.

Koelsch, C.M. and Labuza, I.P. 1992. Functional, physical and morphological properties of methyl cellulose and fatty acid-based edible film barriers. *LWT- Food Science and Technology,* **25**: 404-411.

Krochta, J.M. and Mulder-Johnston, C.D. 1997. Edible and biodegradable polymer films: challenges and opportunities. *Food Technology,* **51**(2): 61-74.

Krochta, J.M. 2002. Proteins as raw materials for films and coatings: definitions, current status and opportunities. In *Protein-based films and coatings.* Ed. A. Genadios, CRC Press, Boca Raton, pp. 1-41.

Krochta, J.M., Baldwin, E.A. and Nysperos-Car-riedo, M. 1994. Edible coatings and films to improve food quality, CRC Press, Boca Raton, pp. 1-7, 25-101, 189-330.

Krull, L.H. and Inglett, G.E. 1971. Industrial uses of gluten. *Cereal Science Today,* **16**(8): 232-261.

Landry, J. 1997. Comparison of extraction methods for evaluating zein content of maize grain. *Cereal Chemistry,* **74**(2): 188–189.

Maria R. Ansorena, Francisco Zubeldia , Norma E. Marcovich. 2016. Active wheat gluten films obtained by thermoplastic processing, *LWT - Food Science and Technology,* pp. 47-54.

Mark, A.M., Roth, W.B., Mehltretter, C.L. and Rist, C.E. 1966. Oxygen permeability of amylomaize starch films. *Food Technology,* **20**: 75-80.

Martins, J.T., Bourbon, A.I., Pinheiro, A.C., Souza, B.W., Cerqueira, M.A. and Vicente, AA. 2013. Biocomposite films based on κ-carrageenan/locust bean gum blends and clays:physical and antimicrobial properties. *Food Bioprocess Technol.,* **6**(8): 2081–92.

Mendes de Souza, P., Fernandez, A., Lopez-Carballo, G., Gavara, R. and Hernandez-Munoz, P. 2010. Modified sodium caseinate films as releasing carriers of lysozyme. *Food Hydro-colloids,* **24**(4)*:* 300–306.

Moreno, Olga., Atares, Lorena. and Chiralt, Amparo. 2015. Effect of the incorporation of antimicrobial/antioxidant proteins on the properties of potato starch films. *Carbohydrate Polymers* http://dx.doi.org/10.1016/j.carbpol.2015.07.047

Mostafavi, F.S., Kadkhodaee, R., Emadzadeh, B. and Koocheki, A. 2015. Preparation and characterization of tragacanth locust bean gum edible blend films, *Carbohydrate Polymers,* http://dx.doi.org/10.1016/j.carbpol.2015.11.069

Musso, Y.S., Salgado, P.R. and Mauri, A.N. 2016. Smart edible films based on gelatin and curcumin, *Food Hydrocolloids,* doi: 10.1016/j.foodhyd.2016.11.007.

Muzzarelli, R.A.A. 1996. Chitosan-based dietary foods. *Carbohydrate Polymer,* **29**: 309-316.

Gontard, N., Guilbert, S. and Cuq, J.L. 1993. Water and glycerol as plasticizers affect mechanical and water vapor barrier properties of an edible wheat gluten film, *J. Food Sci.,* **58**: 206–211.

Nahal, A., Mahboubeh, F., Reza, A., Mehran, G. and Zahra Emam- Djomeh. 2013. Comparative evaluation on fatty acid and Matricariarecutita essential oil incorporated into casein-based film. *International Journal of Biological Macromolecules* **56**: 69– 75.

Nelson, K.L. and Fennema, O.R. 1991. Methylcellulose films to prevent lipid migration in confectionery products. *Journal of Food Science,* **56**: 504-509.

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

Ozdemir, M. and Floros, J.D. 2004. Active food packaging technologies. *Crit. Rev. Food Sci. Nutrition,* **44**: 185- 193.

Park, H.J. 1991. Edible coatings for fruit and vegetables: Determination of gas diffusivities, prediction of internal gas composition and effects of coating on shelf life. Georgia, USA: University of Georgia, Ph.D. Thesis.

Park, H.J., Chinnan, M.S. and Shewfelt, R.L. 1994b. Edible corn-zein coatings storage life tomatoes. *Journal of Food Processing and Preservation,* **18**: 317-333.

Parra, D.F., Tadini, C.C., Ponce, P. and Lugao, A.B. 2004. Mechanical properties and water vapour transmission in some blends of cassava starch edible films. *Carbohydrate Polymers,* **58**(4): 475-481.

Patzsch, K., Riedel, K. and Pietzch, M. 2010. Parameter Optimization of Protein Film Production Using Microbial Transglutaminase. *Bio-macromolecules,* **11**(4): 896-903.

Petersen, K., Nielsen, P.V. and Bertelsen, G. 1999. Potential of bio based materials for food packaging. *Trends Food Science Technology*, **10**: 52-68.

Pochat-Bohatier, C., Sanchez, J. and Gontard, N. 2005. Influence of relative humidity on carbon dioxide sorptionin wheat gluten films. *Journal of Food Engineering,* **77**: 983–991.

Ponce, A.G., Aroura, S.I. and Del-Valle, C.E. 2008. Antimicrobial and antioxidant activities of edible coatings enriched with natural plant extracts: *In vitro* and *In vivo* studies. *Postharvest Biol. Tec.*, **49**: 294-300.

Realini, C.E. and Marcos, B. 2014. Active and intelligent packaging systems for a modern society. *Meat Science,* **98***: 404–419

Rhim, J.W. 2011. Effect of clay contents on mechanical and water vapour barrier properties of agar-based nanocomposite films. *Carbohydrate Polymer*, **86**(2): 691–9.

Rhim, J.W., Wang, L.F. and Hong, S.I. 2013. Preparation and characterization of agar/silver nanoparticles composite films with antimicrobial activity. *Food Hydrocolloid,* **33**(2): 327–35.

Rhim, J.W., Park, H.M. and Ha, C.S. 2013. Bio-nanocomposites for food packaging applications, *Progress in Polymer Science,* **38**(10): 1629-1652.

Rodriguez, M., Oses, J., Ziani, K. and Mate, J.I. 2006. Combined effect of plasticizers and surfactants on the physical properties of starch based edible films. *Food Research International*, **39**: 840-846.

Ross, P.I. 1987. Gelatin. *In:* Mark, H.F., Bikales, N.M., Overberger C.G., Menges, G. and Kroschwitz, J.I. (Eds.). Encyclopedia of polymer science and engineering, volume 7: Fibers, optical to hydrogenation, p. 488. New York: Wiley-Interscience.

Ross-Murphy, S.B. 1992. Structure and rheology of gelatin gels-Recent progress. *Polyme.,* **33**(12): 2622–2627.

Sarmah K., Das, P., Das, D. and Sarmah, T.C. 2015. Evaluation of Biodegradable Films from Tapioca Starch. *Journal of Agricultural Engineering,* **52**(3).

Saiful, Siti, S. and Salman. 2013. Preparation and characterization edible film The 2nd International Conference on Multidisciplinary Research (ICMR) 2013 October 2-4, 2013, Banda Aceh, Indonesia packaging from carrageenan.

Salame, M. 1986. Barrier polymers. *In:* Bakker, M. (Ed.). The Wiley Encyclopedia of Packaging Technology, p. 48-54. New York: Johh Wiley and Sons.

Sallam, K.I. 2007. Antimicrobial and antioxidant effects of sodium acetate, sodium lactate, and sodium citrate in refrigerated sliced salmon. *Food Control,* **18**: 566–575.

Sandford, P.A. 1989. Chitosan: commercial uses and potential application. *In:* Skjak-Braek, G., Anthosen, T. and Sandford, P. (Eds.). Chitin and Chitosan: Source, Chemistry,

Biochemistry, Physical Properties, and Application, p. 51-69. New York: Elsevier Applied Science.

Scope, R.K. 1994 Separation by precipitation. *In* Scope, R.K. (Ed.), Protein purification; Principles and practice, p. 71-101. New York: Springer-Verlag.

Shukla, R. and Cheryan, M. 2001. Zein: The industrial protein from corn. *Industrial Crops and Products an International Journal,* **13**: 171–192.

Siracusa., Rocculi., Romani & Rosa. 2008. Strategies for Evaluation of Edible Coating Formulations -Applications on Food Quality and Safety, p. 8-14.

Sitthiphong Soradech, Jurairat Nunthanid, Sontaya Limmatvapirat, ManeeLuangtana-anan. 2012. An approach for the enhancement of the mechanical properties and film coating efficiency of shellac by the formation of composite films based on shellac and gelatin, *Journal of Food Engineering,* **108**: 94–102.

Sothornvit, R., and Krochta, J.M. 2000. Plasticizer Effect on Oxygen Permeability of β-Lacto- globulin Films. *Journal of Agricultural and Food Chemistry,* **48**(12): 6298–6302.

Sreedath, T, Visvanathan, R, Syed S.H. Rizvi, Rekha S. Singhal, Sanjay Kr. Chattopadhyay and Saha, N.C. 2016. A biodegradable and edible packaging film based on papaya puree, gelatin, and defatted soy protein, *Food Packaging and Shelf-Life,* 60–71.

Stone, H.A. 1994. Dynamics of drop deformation and breakup in viscous fluids. *Annu. Rev. Fluid Mech.*, **26**: 65-102.

Subirade, M., Kelly, I., Gueguen, J. and Pezolet, M. 1998. Molecular basis of film formation from a soybean protein: Comparison between the conformation of glycinin in aqueous solution and in films. *International Journal of Biological Macromolecules,* **23**: 241-249.

Tooraj Mehdizadeh, Hossein Tajik, Seyed Mehdi Razavi Rohani, Abdol Rassol Oromiehie. 2012. Antibacterial, antioxidant and optical properties of edible starch chitosan composite film containing Thymus kotschyanus essential oil. *Veterinary Research Forum,* **3**(3): 167-173.

Vargas, M., Albors A, Chiralt, A. and Gonzalez-Martinez. 2006. Quality of cold-stored strawberries as affected by chitosan–oleic acid edible coatings. *Postharvest Biology and Technology,* **41**: 164–171.

Vasconez, M.B., Flores, S.K., Campos, C.A., Alvarado, J. and Gerschenson, L.N. 2009. Antimicrobial activity and physical properties of chitosan-tapioca starch based edible films and coatings. *Food Research International,* **42**: 762–769.

Veena, D., E. Naga Mallika, G. Vijayabhaskar Reddy and Sudheer, K. 2015. Quality of Edible Polymer Films Incorporated With Plant Essential Oils. *International Journal of New Technologies in Science and Engineering,* **2**(2).

Whistler, R.L. and Daniel, J.R. 1985. Carbohydrate. *In* Fennema, O.R. (Ed.). Food Chemistry, p. 69. New York: Marcel Dekker.

Williams, P.A., Phillips, G.O. Audic, J.L. and Chaufer, B. 2010. Caseinate based biodegradable films with improved water resistance, *Journal of Applied Polymer Science,* **117**(3): 1828-1836.

Williams, P.A. and Phillips, G.O. 2000. *In:* Handbook of hydrocolloids; Phillips G.; Willians P.; Ed.; CRC Press, Cambridge, England, 2000; pp 1-19.

Wirongrong Tongdeesoontorn, Lisa J Mauer, Sasitorn Wongruong, Pensiri Sriburi, Pornchai Rachtanapun. 2011. Effect of carboxymethyl cellulose concentration on physical properties of biodegradable cassava starch-based films. *Chemistry Central Journal,* **5**: 6.

Wolf, K.L., Sobral, P.J.A. and Telis, V.R.N. 2009. Physicochemical characterization of collagen fi-bers and collagen powder for self-composite film production. *Food Hydrocoloids,* **23**(7)*:* 1886–1894.

Wong, D.W.S., Camirand, W.M. and Pavlath, A.E. 1994. Development of edible coatings forminimally processed fruits and vegetables. *In:* J.M. Krochta, E.A. Baldwin, & M.O. Nisperos-Carriedo (Eds.), Edible coatings and films to improve food quality (pp. 65–88). Lancaster, PA: Technomic Publishing Company.

Xu, X.Y., Kim, K.M., Hanna, M.A. and Nag, D. 2005. Chitosan-starch composite film: preparation and characterization. Industrial Crops and Products. *An International Journal,* **21**: 185-192.