INTRODUCTION

Now a day, the awareness of consumers towards eating and its health benefits to maintain good health is increasing. Preventing illness by diet is a unique opportunity for innovative so-called functional foods. These products often present new challenges to the food technologist. Existing and new ingredients need to be incorporated into food systems, in which they slowly degrade and lose their activity, or become hazardous, by oxidation reactions. Ingredients can also react with components present in the food system, which may limit bioavailability, or change the colour or taste of a product. In many cases, microencapsulation can be used to overcome these challenges.

Microencapsulation is the envelopment of small solid particles, liquid droplets or gases in a coating. Microcapsules are small (1–1000 μm) and can have many morphologies. In general, one can distinguish between mononuclear capsules, which have one core enveloped by a shell, and aggregates, which have many cores embedded in a matrix.

The shell or matrix materials are usually polymers. These carrier materials are commonly referred to as the internal phase, the core material, the filler or the fill. The encapsulation material is known as the external phase, the shell, coating or membrane. Bioactive compounds in foods are chemically unstable.

These compounds are undergoes degradation, migration, transformation and they may lose their bioactivity during storage, food processing or food packaging or transportation.

Carrier materials can be made from a variety of polysaccharides (i.e. cellulose, starch, chitin alginates, pectin), proteins (i.e. gelatine, corn zein, wheat gluten, soy protein, casein, keratin, collagen, whey), lipids (i.e. wax and oil based coating, fatty acids and mono-glycerides, reis and rosins, emulsions, composite bilayer coating consisting of polysaccharides, protein and lipids).

The paper will be focused on different carrier materials used for encapsulation of bioactive food components.

Carrier/Encapsulating Materials of Different Origins

Encapsulant materials like proteins, carbohydrates and lipids are depicted in Table 1, which may be used in alone or in combination to improve efficiency. The materials chosen as encapsulants are typically film forming, pliable, odourless, tasteless and non-hygroscopic. Solubility in aqueous solvent or ability to exhibit a phase transition, such as melting or gelling, are sometimes attractive, depending on the processing requirements for production of the microencapsulated ingredient and for when it is incorporated into the food product. Other additives, such as emulsifiers, plasticisers or defoaming agents, are sometimes included in the formulation to tune the final product’s characteristics. The encapsulant materials may also be modified by physical or chemical means in order to achieve the desired functionality of the microencapsulation matrix. The choice of encapsulant materials is therefore dependent on a number of factors, including its physical and chemical properties, its compatibility with the target food application and its influence on the sensory and aesthetic properties of the final food product.

Carbohydrates Based Encapsulating Materials

The ability of carbohydrates to form gels and glassy matrices has been exploited for microencapsulation of bioactive. Starch and starch derivates have been widely used for the delivery of sensitive ingredients through food. Chemical modification has made a number of starches more suitable as encapsulating for oils by increasing their lipophilicity and improving their
emulsifying properties. Starch that was hydrophobically modified by octenyl succinate anhydride had improved emulsification properties compared to the native starch\textsuperscript{10-11}. Acid modification of tapioca starch has been shown to improve its encapsulation properties for carotene, compared to native starch or maltodextrin\textsuperscript{12}. Physical modification of starches by heat, shear and pressure has also been explored to alter its properties\textsuperscript{13}, and the modified starch has been used in combination with proteins for microencapsulation of oils\textsuperscript{14}. Carbohydrates used for microencapsulation of carotene, from sea buckthorn juice by ionotropic gelation using furcellaran beads, achieved encapsulation efficiency of 97%\textsuperscript{15}. Interest in using cyclodextrins and cyclodextrin complexes for molecular encapsulation of lipophilic bioactive cores is on-going, especially in applications where other traditional materials do not show good activity, or where the final application can accept the cost of this expensive material. The majority of marketable applications for cyclodextrins have been for flavour encapsulation and packaging films\textsuperscript{16}. Proteins are used as encapsulating agents because of their excellent solubility in water, good gelforming, film-forming and emulsifying properties\textsuperscript{17-18}. Polysaccharides used for coatings food materials which includes cellulose, starch derivatives, pectin derivatives, seaweed extracts, exudates gums, microbial fermentation gums and chitosan. Polysaccharides are generally very hydrophilic resulting in poor water vapor 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\textsuperscript{19-20}.

**Cellulose and its Derivatives**

Cellulose is composed of repeating unit of D-glucose which are linked together by ß-1, 4 glycosidic bonds. In the structure of cellulose, the hydroxymethyl groups of anhydroglucose residues are alternately located above and below the plan of the polymer backbone. The polymeric chains and a highly crystalline structure of cellulose resist 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 (HPCM) or hydroxymethyl cellulose (HPC) (Figure 1B-1E). 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\textsuperscript{19}.

MC is the most resistant to water and it is the lowest hydrophilic cellulose derivatives\textsuperscript{15} 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\textsuperscript{20-21}. MC could be applied as coating on confectionery products as barrier to lipid migration\textsuperscript{22}. A number of researchers have investigated composite films composed of MC or HPMC and various kinds of solids, such as beeswax and fatty acids\textsuperscript{20,23-27}. 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\textsuperscript{28}.

**Chitin and Chitosan**

Chitin is the second most abundant naturally occurring biopolymer and is found in the exoskeleton of crustaceans, in fungal cell walls and other biological materials\textsuperscript{29}. 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 (Figure 2A). 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% (Figure 2B). Chitosans 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\textsuperscript{30}. 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\textsuperscript{31-32}. Carbon dioxide permeability could be improved by methylation of polymers. Butler\textsuperscript{33} observed that films from chitosan were rather stable and their mechanical and barrier properties changed only slightly during storage. Chitosan coatings are usually used on fruit and vegetable products like strawberries, cucumbers, bell peppers as antimicrobial coating\textsuperscript{34-35}, and on apples, pears, peaches and plums as gas barrier\textsuperscript{36-37}.

**Starch**

Starch is a polymeric carbohydrate made up of anhydrous glucose units. Starch is polysaccharides composed of a linear chain molecule termed amylase and a branched polymer of glucose termed amylopectin\textsuperscript{38}. Starches are mostly used in food industry. 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\textsuperscript{39}. 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 varieties of corn are produced which contain starch with up to 85% amylose (Whistler and Daniel, 1985). Mark\textsuperscript{39} 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. Partial etherification of high-amylose starch with propylene oxide, to yield the hydroxypropylated derivative, improves water solubility.

**Agar**

Agar is a hydrophilic colloid consisting of a mixture of agarose and agaropeptin that have the ability to form reversible gels simply by cooling a hot aqueous solution. Agar gel melts on heating and resets on cooling. Typical gel temperatures of agar for 1.5% solution are in the range 35-45°C because of its ability to form very hard gels at very low concentrations and the simplicity of the extraction process, agar has been used extensively as a gelling agent in the food industry. However, in despite its biodegradability and its enormous gelling power, agar has been few used as edible film due to a poor aging. Indeed, both photo-degradation and fluctuations in ambient temperature and humidity alter agar crystallinity, leading to formation of micro-fractures and polymer embrittlement. However, it was reported that agar-based film displays a better moisture barrier properties than cassava starch film. The influence of agar on the structure and the functional properties of emulsified edible films have been recently studied by Phan. Gelled agar chains can stabilize film-forming emulsion to create a macro network. This macro network entraps flattened lipid particles improving barrier performance by increasing tortuosity. The mechanical properties of agar-hydrogenated vegetable oil emulsified films are comparable with some protein and Low-density polyethylene (LDPE) films.

**Alginate**

Alginate is an indigestible biomaterial produced by brown seaweeds (Phaeophyceae, mainly Laminaria) therefore it may also be viewed as a source of dietary fibre. 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. An attractive feature of alginate solutions is the gelling capacity in presence of Calcium. Edible films prepared from alginate form strong films and exhibit poor water resistance because of their hydrophilic nature. The water permeability and mechanical attributes can be considered as moderate compared to synthetic films.

Alginate edible-films are appropriated to load additives and antibacterial compounds. Good results are obtained applying probiotics and oil compounds such as garlic oil and oregano oil. A mixture of starch and alginate to form edible film has been studied by Wu achieving to improve the mechanical properties of film.

**Carrageenans**

Carrageenans are water-soluble polymers with a linear chain of partially sulfated galactans, which present high potentiality as film-forming material. These sulfated polysaccharides are extracted from the cell walls of various red seaweeds (Rhodophyceae). Different seaweeds produce different carrageenans. The positions and numbers of sulfate ester groups are important because they are, together with the anhydrogalactose bridge, responsible for carrageenan functionality and determine a classification in three major types: κ, λ and ι. κ- and ι-carrageenans contain the 3,6-anhydro units and are used as gelling agents because of their property to produce thermo-reversible gels on cooling below the critical temperature. λ-Carrageenan, with only sulfatedgalactose groups and no anhydrogalactose bridge, is a thickening polymer. The use of carrageenans as edible films and coatings already covers various fields of the food industry such as application on fresh and frozen meat, poultry and fish to prevent superficial dehydration, sausage-casings, dry solids foods, oily foods, etc. Carrageenan film formation includes this gelation mechanism during moderate drying, leading to a three-dimensional network formed by polysaccharide double helices and to a solid film after solvent evaporation. Recently, carrageenan films were also found to be less opaque than those made of starch.

**Gums**

Gums in edible-forming preparation are used for their texturizing capabilities. All gums are polysaccharides composed of sugars other than glucose. Gums are differentiate in three groups exudates gums (gum Arabic; mesquite gum), the extractive gums (come 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 is used as a water binder, stabilizer and viscosity builder.

Gum arabic, owing to its solubility in hot or cold water, is the least viscous of the hydrocolloid gums. Xanthan gum 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 coating based from mesquite gum preparation and applied to Persian limes provided a lowest physiological weight loss, best dark shade green colour retention and unaltered physicochemical parameters to Persian limes. The mesquite gum forms films with excellent water vapour barrier properties when small amounts of lipids are added in their formulation. Film-forming polymers based on gum Arabic, showed to be an inhibitor of after-cooking darkening of potatoes.

**Pectin**

Pectin 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. Commercial extraction causes extensive degradation of the neutral sugar-containing side chains. With Chitosan, HMP or LMP forms excellent films. Indeed, the cationic nature of chitosan offers the possibility to take advantage of the electrostatic interactions with anionic polyelectrolytes, such as pectin. The effect of antimicrobial plant essential oils such as oregano, lemon grass, or cinnamon oil at different concentrations, on physical properties of apple puree-pectin based edible coatings was reported by Rojas-Grau. It is also interesting to point out the application of LMP based edible coatings as a pre-treatment in osmotic dehydration for obtaining better dehydration efficiency. Finally, an investigation demonstrated the prevention of crumb ageing of dietetic sucrose-free sponge cake when a pectin-containing edible film was used. This sponge cake had better preserved freshness, especially up to the fifth day of storage.

**Protein Based Encapsulant Materials**

Protein-based microcapsules can be easily rehydrated or solubilised in water, which often results in immediate release of the core. Proteins are often combined with carbohydrates for microencapsulation of oils and oil-soluble components. In the manufacture of encapsulated oil powders, encapsulation efficiency was higher when the encapsulation matrix was a mixture of milk proteins and carbohydrates, compared to when protein was used alone. Soy protein-based microcapsules of fish oil have been cross-linked using transglutaminase to improve the stability of the encapsulated fish oil. Protein-based hydrogels are also useful as nutraceuticals delivery systems. The release properties of protein-based hydrogels and emulsions may be modulated by coating the gelled particles with carbohydrates. A model-sensitive core, paprika oleoresin, was encapsulated in microspheres of whey proteins and coated with calcium alginate to modify the core’s release properties. Whey protein-based hydrogels with an alginate coating altered the swelling properties of the gelled particles. The stability of these particles was improved at neutral and acidic conditions both in the presence and absence of proteolytic enzymes. Lipids are generally used as secondary coating materials applied to primary microcapsules or to powdered bioactive cores to improve their moisture barrier properties.

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 fibers. The globular proteins fold into complicated spherical structures held together by a combination of hydrogen, ionic, hydrophobic and covalent (disulfide) bonds. The chemical and physical properties of these proteins depend on the relative amounts of the component amino acid residues and their placement along the protein polymer chain. 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. The solvent/carrier is generally limited to water, ethanol or ethanol-water mixtures. 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. The chain-to-chain interaction that produces cohesive films is affected by the degree of chain extension and the nature and sequence of amino acid residues. Uniform distribution of polar, hydrophobic, and/or thiol groups along the polymer chain increase the likelihood of the respective interactions. Increased polymer chain-to-chain interactions resulted 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.

**Gelatin**

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. The characteristic features of gelatin are high content of the amino acids glycine, proline and hydroxyproline. Gelatin also has a mixture of single and double unfolded chains of hydrophilic character. At approximately 40°C, gelatin aqueous solutions are in the sol state and form physical, thermoreversible gels on cooling. During gelation, the chains undergo a conformational disorder–order transition and tend to recover the collagen triple-helix structure. Gelatin films could be formed from 20-30% gelatin, 10-30% plasticizer (glycerin 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 content.
dosage. In addition, gelatin films have been formed as coatings on meats to reduce oxygen, moisture and oil transport\textsuperscript{109}. 

**Zein**

Zein is the most important protein in corn. It is a prolamin protein and therefore dissolves in 70–80% ethanol\textsuperscript{110,111,112}. Zein is a relatively hydrophobic and thermoplastic material. The hydrophobic nature of zein is related to its high content of non-polar amino acids\textsuperscript{113}. 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\textsuperscript{114}. Edible films can be formed by drying aqueous ethanol solution of zein\textsuperscript{115}. Formation of films is believed to involve development of hydrophobic, hydrogen and limited disulfide bonds between zein chains in the film matrix\textsuperscript{116}. The resulting films are brittle and therefore require plasticizer addition for increasing flexibility\textsuperscript{117}. Zein films are relatively good water vapor barriers compared to other edible films\textsuperscript{114}. Water vapor 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\textsuperscript{118}. Zein coating have also shown an ability to reduce moisture and firmness loss and delay color change (reduce oxygen and carbon dioxide transmission) in fresh tomatoes\textsuperscript{119}.

**Gluten**

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\textsuperscript{120}. Although insoluble in natural water, wheat gluten dissolves in aqueous solutions of high or low pH at low ionic strength\textsuperscript{121}. Edible films can be formed by drying aqueous 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\textsuperscript{122}. Addition of plasticizer such as glycerin in gluten films is necessary to improve film flexibility (Gennadios). However, increasing film flexibility by increasing sorbitol content reduces film strength, elasticity and water vapor barrier properties 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\textsuperscript{122}. Herald 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\textsuperscript{123}. 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, Koelsch 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\textsubscript{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\textsuperscript{125,126}.

**Soy Protein**

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. Thus, soy protein belongs to the globulin classification\textsuperscript{125}. Soy protein is globular in nature and is further classified into 2S, 7S, 11S and 15S fraction according to relative sedimentation rates\textsuperscript{125}. The principal components are the 7S (conglycinin) and (glycinin) fractions, both of which have a quaternary (subunit) structure\textsuperscript{124}. 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\textsuperscript{127}. Alkali and heating both cause dissociation and subsequent unfolding of glycinin due to disulfide bond cleavage\textsuperscript{127}. 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)\textsuperscript{128}. 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 sulphhydryl 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\textsuperscript{129,130}. The use of soy protein in the formation of films or coatings on food products has been investigated\textsuperscript{131-135}.

**Whey Protein**

Whey protein isolate produces totally water-soluble coatings but heat denatured solutions of whey protein isolate produce coatings in which the protein is insoluble. Industrially produced whey protein concentrate (WPC) have a protein content between 25 and 80% whereas the whey protein isolate (WPI) have protein content above 90%\textsuperscript{136,137}. Whey proteins have been the subject of intense investigation over the past decade or so\textsuperscript{138}. Whey proteins can produce transparent, flexible, colourless and flavourless films, with poor moisture barrier\textsuperscript{139,140}. Moreover protein-based films possess a good aroma barrier\textsuperscript{138,141}, and low oxygen permeability\textsuperscript{142}. Whey
protein films produced without addition of any plasticizers are very brittle therefore the addition of plasticizers provides flexibility to the films but also increases their water vapour permeability. Increased concentration of plasticizers in edible whey protein films will decreases tensile strength and Young’s modulus, but increased elongation. The water vapour permeability can also be improved by the incorporation of hydrophobic materials such as lipids. However, the incorporation of lipid materials into edible film formulations into films could adversely affect the sensory characteristics of films. The incorporation of antimicrobial agents into edible coating formulations is needed to obtain stronger inhibitory effect against microbial growth. Optimization of edible whey protein films containing sorbitol, beeswax and potassium sorbate concentrations for mechanical and optical properties was reported by Ozdemir and Floros. Recently WPI and mesquite gum (MG) are showed totally compatible to form solutions and films. Indeed, the incorporation of different amounts of MG on the WPI allowed to obtain composite films with improved flexibility without increasing plasticizer content and consequently without affecting negatively others characteristics such as water vapour permeability.

**Lipid based Encapsulant Materials**

Lipids can also be incorporated in an emulsion formulation to form a matrix or film around the bioactive core. The increasing demand for food-grade materials that will perform under the different stresses encountered during food processing has spurred the development of new encapsulant materials. Understanding the glass transition temperature of various polymers (e.g. proteins and carbohydrates) and their mixtures is also becoming important as this can influence the stability of the encapsulated core. The low water mobility and slow oxygen dispersal rates in glassy matrices can improve stability of bioactives. It is possible to exploit thermally induced transitions between proteins and polysaccharides and then to use the modified materials for encapsulation. Hydrogels formed by heat treatment of lactoglobulin chitosan have been investigated, and it has been suggested that under controlled conditions these complexes may be useful for microencapsulation of functional food components. Maillard reaction products formed by interactions between milk proteins and sugars or polysaccharides have been used as encapsulant matrices to protect sensitive oils and bioactive ingredients.

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 vapor permeability decrease when the concentration of hydrophobic phase increases. Lipid-based films are often supported on a polymer structure matrix, usually a polysaccharide, to provide mechanical strength.

**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 (Copernicacerifera). Beewax (white wax) is produced from honeybees. Candelilla is obtained from candelilla plant. Mineral oil consists of a mixture of liquid paraffin and naphthery hydrocarbon. 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 onswert). 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, candelilla and bee wax) are the most efficient edible compounds providing a humidity barrier.

**Acetoglyceride**

Acetylation of glycerol monostearate by its reaction with acetic anhydride yields 1-steaodiacetin. This acetylated monoglyceride displays the unique characteristic of solidifying from the molten state into a flexible, wax-like solid. 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 vapor 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.

**Shellac Resins**

Shellac resins are a secretion by the insect Lacciferlaconia and are 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\textsuperscript{160}. 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\textsuperscript{160}. High ethanol content, in turn, is an indication of off-flavor\textsuperscript{161-163}. Shellac- and wood resin-based coatings also tend to increase prevalence of post-harvest pitting\textsuperscript{161}.

### Table 1: Encapsulating Materials for Food Application

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<th>Lipid and Waxes</th>
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### Table 2: Carbohydrate based Encapsulating Materials and their Applications

<table>
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<td>Encapsulation of antioxidant agents in fruits</td>
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<tr>
<td>1. N-acetylcystein and glutathione</td>
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<td>2. ascorbic acid and citric acid</td>
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<td>3. Tea polyphenols</td>
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<td>Encapsulation of antimicrobials agent in</td>
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</tr>
<tr>
<td>1. Cinnamon, palmarosa and lemongrass oils</td>
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<tr>
<td>2. Lemongrass, oregano oil and vanillin</td>
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<td>Encapsulation of flavours</td>
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<tr>
<td>1. Linoleic acid and isoleucine</td>
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<td>Encapsulation of probiotics</td>
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<td>1. Bifidobacterium lactis</td>
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<td>2. Lactobacillus acidophilus</td>
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<td>3. Lactobacillus acidophilus</td>
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<td>4. Lactobacillus rhamnosus</td>
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<td>5. Lactobacillus acidophilus</td>
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<tr>
<td>Carrageenans</td>
<td>application on fresh and frozen meat</td>
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<tr>
<td>poultry and fish, sausages-casting</td>
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<td>dry solid foods, oily foods</td>
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<tr>
<td>Gums</td>
<td>Applied on potatoes</td>
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<tr>
<td>Pectins</td>
<td>Edible coating for fruits</td>
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</table>
CONCLUSION

The bioactive components of food are undergoing changes due to heat, light, and oxygen. The decomposition of these components may be overcome by the encapsulation.

Various encapsulating materials are used for encapsulation of bioactive components of foods. These materials are mainly based on carbohydrate, protein, and lipids. These materials can be used for encapsulation to prevent oxidation and decomposition which was occurred due to heat and light.

This paper will be beneficial to research scientist and R & D persons to find out the best encapsulating materials for bioactive food components.

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