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Hydrocolloids in Food Industry

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1. Introduction

Hydrocolloids or gums are a diverse group of long chain polymers characterized by their property of forming viscous dispersions and/or gels when dispersed in water. These materials were first found in exudates from trees or bushes, extracts from plants or seaweeds, flours from seeds or grains, gummy slimes from fermentation processes, and many other natural products. Occurrence of a large number of hydroxyl groups noticeably increases their affinity for binding water molecules rendering them hydrophilic compounds. Further, they produce a dispersion, which is intermediate between a true solution and a suspension, and exhibits the properties of a colloid. Considering these two properties, they are appropriately termed as 'hydrophilic colloids' or 'hydrocolloids'.

Hydrocolloids have a wide array of functional properties in foods including; thickening, gelling, emulsifying, stabilization, coating and etc. Hydrocolloids have a profound impact on food properties when used at levels ranging from a few parts per million for carrageenan in heat-treated dairy products to high levels of acacia gum, starch or gelatin in jelly confectionery. The primary reason behind the ample use of hydrocolloids in foods is their ability to modify the rheology of food systems. This includes two basic properties of food systems that is, flow behavior (viscosity) and mechanical solid property (texture). The modification of texture and/or viscosity of food systems helps modify its sensory properties, therefore hydrocolloids are used as significant food additives to perform specific purposes. It is evident that several hydrocolloids belong to the category of permitted food additive in many countries throughout the world. Various food formulations such as soups, gravies, salad dressings, sauces and toppings use hydrocolloids as additives to achieve the preferred viscosity and mouth feel. They are also used in many food products like ice-creams, jams, jellies, gelled desserts, cakes and candies, to create the desired texture.

In addition to the functional attributes, future acceptance and, possibly, positive endorsement may derive from the recognition that fibers contribute many physiological benefits to the natural function and well-being of the body.

The aim of this chapter of the book is to highlight the importance of the hydrocolloids in food industry.

2. Functional properties

2.1 Viscosity enhancing or thickening properties

The foremost reason behind the ample use of hydrocolloids in foods is their ability to modify the rheology of food system. The modification of texture and/or viscosity of food

system helps to modify its sensory properties, and hence, hydrocolloids are used as important food additives to perform specific purposes. The process of thickening involves nonspecific entanglement of conformationally disordered polymer chains; it is essentially polymer-solvent interaction (Philips et al., 1986). Hydrocolloids that have been used as thickening agents are shown in Table 1. The thickening effect of produced by the hydrocolloids depends on the type of hydrocolloid used, its concentration, the food system in which it is used and also the pH of the food system and temperature. Ketchup is one of the most common food items where the hydrocolloid thickeners are used to influence its viscosity (Sahin & Ozdemir, 2004).

The question that arises is how hydrocolloids thicken solution. In dilute dispersion, the individual molecules of hydrocolloids can move freely and do not exhibit thickening. In concentrated system, these molecules begin to come into contact with one another; thus, the movement of molecules becomes restricted. The transition from free moving molecules to an entangled network is the process of thickening.

The viscosity of polymer solutions is influenced significantly by the polymer molecular mass. In addition to molecular mass effects, the hydrodynamic size of polymer molecules in solution is significantly influenced by molecular structure. Linear, stiff molecules have a larger hydrodynamic size than highly branched, highly flexible polymers of the same molecular mass and hence give rise to a much higher viscosity.

2.2 Gelling properties

Swollen particulate forms of gelled hydrocolloids are particularly useful as they combine macroscopic structure formation with an ability to flow and often have an attractive soft solid texture, which is especially sought in food applications, all at high water contents (>95%). There is a potential opportunity for particulate hydrocolloid systems to replace chemically cross-linked starches based on appropriate structuring, processing, and molecular release properties without the need for chemical treatment.

The characteristics of gel particles, and the application for which they are used, will depend on the type of hydrocolloid, the network formation mechanism and the processing method used for particle formation (Burey et al., 2008).

Hydrocolloid gel networks form through entwining and cross-linking of polymer chains to form a three-dimensional network. The mechanism by which this interchain linking occurs can vary (Djabourov, 1991).

Hydrocolloid gelation can involve a hierarchy of structures, the most common of which is the aggregation of primary interchain linkages into “junction zones” which form the basis for the three-dimensional network characteristic of a gel.

Various parameters such as temperature, the presence of ions, and the inherent structure of the hydrocolloid can affect the physical arrangement of junction zones within the network.

2.3 Surface activity and emulsifying properties

The functionality of hydrocolloids as emulsifiers and/or emulsion stabilizers correlates to phenomena such as: retardation of precipitation of dispersed solid particles, decreased creaming rates of oil droplets and foams, prevention of aggregation of dispersed particles, prevention of syneresis of gelled systems containing oils and retardation of coalescence of oil droplets. It is believed that gums will adsorb (onto solid or liquid surfaces) very slowly, weakly and with very limited surface load if at all. The hydrocolloids were classified according to their activity at the interface. Gum Arabic is probably the most studied

hydrocolloid that proved significant surface activity. Gum arabic is the only gum adsorbing onto oil-water interfaces and imparting steric stabilization. Other gums such as galactomannans, xanthan, pectin, etc. have been known to reduce surface and interfacial tensions, to adsorb onto solid surfaces and to improve stability of oil-in-water emulsions. Micro crystalline cellulose (MCC) is an example of a hydrocolloid with no solubility in water that adsorbs mechanically at the interface.

It well documented that gum arabic, a natural polysaccharide, has excellent emulsification properties for oil-in-water emulsions. An excellent example of its use is in cloudy emulsions, as opacity builders for citrus beverages (Connolly et al. 1988). Related the significance of protein components presenting in gum arabic to its emulsifying properties. It seems that the protein-hybrid in gum arabic meets all the necessary requirements in a capacity similar to emulsifying proteins (such as casein, or soy protein) via its numerous adsorption sites, flexibility, conformational change at the interface and the entropy gain (solvent depletion). Gum arabic works by reducing the oil-water interfacial tension, thereby facilitating the disruption of emulsion droplets during homogenization. The peptides are hydrophobic and strongly adsorb on to the surface of oil droplets, whilst the polysaccharide chains are hydrophilic and extend out into the solution, preventing droplet flocculation and coalescence through electrostatic and steric repulsion forces.

Microcrystalline cellulose is also able to stabilize the oil-in-water emulsions. Its strong affinity for both the oil and the water results in precipitation and some orientation of the solid particles at the oil-in-water interface (Philips et al., 1984). It was proposed that the colloidal network of the free MCC thickens the water phase between the oil globules preventing their close approach and subsequent coalescence. Therefore, the MCC provides long term stability (Philips et al., 1990).

As the galactomannans structure gives no suggestion of the presence of any significant proportion of hydrophobic groups, it is generally assumed that this type of hydrocolloid functions by modifying the rheological properties of the aqueous phase between the dispersed particles or droplets. It has been suggested that these gums stabilize emulsions by forming liquid crystalline layers around the droplets. It should be noted that this putative adsorption of the gum to the oil-water interface is reportedly rather weak and reversible. That is, the associated emulsion stability is lost on diluting the aqueous phase of the emulsion with water (Dickinson, 2003).

Pectin is another class of hydrocolloid whose emulsifying character has attracted attention in recent years. While citrus and apple pectin is normally used as low-pH gelling or thickening agents (are not effective as emulsifying agents), sugar beet pectin does not form gels with calcium ions or at high sugar concentrations. Due to its higher protein content, sugar beet pectin is considerably more surface-active than gum arabic, and it is very effective in stabilizing fine emulsions based on orange oil or triglyceride oil at a pectin/oil ratio of 1:10 (Williams et al., 2005).

2.4 Hydrocolloids as edible films and coatings

An edible film is defined as a thin layer, which can be consumed, coated on a food or placed as barrier between the food and the surrounding environment. The most familiar example of edible packaging is sausage meat in casing that is not removed for cooking and eating. Hydrocolloids are used to produce edible films on food surfaces and between food components. Such films serve as inhibitors of moisture, gas, aroma and lipid migration. Many gums and derivatives have been used for coating proposes. They include alginate,

carrageenan, cellulose and its derivatives, pectin, starch and its derivatives, among others. Since these hydrocolloids are hydrophilic, the coatings they produce have nature limited moisture barrier properties. However, if they are used in a gel form, they can retard moisture loss during short term storage when the gel acts as sacrificing agent rather than a barrier to moisture transmission. In addition, since in some cases an inverse relationship between water vapor and oxygen permeability has been observed, such films can provide effective protection against the oxidation of lipid and other susceptible food ingredient. The hydrocolloid edible films are classified into two categories taking into account the nature of their components: proteins, polysaccharides or alginates. Hydrocolloidal materials, i.e. proteins and polysaccharides, used extensively for the formation of edible films and coatings are presented in Table 1 (Hollingworth, 2010).

	Film forming material		Principal function
Polysaccharide	Agar		Gelling agent
	Alginate		Gelling agent
	Carrageenan		Gelling agent
	Cellulose derivatives	CMC HPC HPMC MC	Thickener Thickener and emulsifier Thickener Thickener, emulsifier and gelling agent
	Chitosan		Gelling agent Antimicrobials
	Gum	Arabic gum Guar gum Xanthan gum	Emulsifier Thickener Thickener
	Pectin		Gelling agent
	Starches		Thickener and gelling agent
protein	Gelatin	Bovine gelatin Fish gelatin Pig gelatin	Gelling agent Gelling agent Gelling agent

Table 1. Hydrocolloidal materials that have been studied extensively for the formation of edible films and coatings in foods.

2.5 Hydrocolloids as fat replacers

The changes in modern lifestyle, the growing awareness of the link between diet and health and new processing technologies have led to a rapid rise in the consumption of ready-made meals, novelty foods and the development of high fiber and low-fat food products. Calorie-dense materials such as fats and oils may be replaced with 'structured water' to give healthy, reduced-calorie foods with excellent eating quality. In particular, numerous hydrocolloid products have been developed specifically for use as fat replacers in food. This has consequently led to an increased demand for hydrocolloids. As an example, the Italian dressing includes xanthan gum as a thickener and the 'Light' mayonnaise contains guar gum and xanthan gum as fat replacers to enhance viscosity.

The traditional approach is the partial replacement of fat using starches which, when dissolved in water, create stable thermo-reversible gels. Soft, fat-like gels can be created by conversion modifications to the degree necessary to produce thermo-reversible, spreadable gels. Typically, 25–30% solids, i.e. starch in water, form an optimal stable structure for fat replacement. New generation fat replacers are tailored to mimic more closely the many and complex properties of fats or oils in a particular application. These are referred to as fat mimetics. Maximising the synergies of functional ingredients such as hydrocolloids generally in combination with specific starch fat mimetics can mean that 100% fat reduction is achievable (Phillips & Willians, 2000).
Based on the particle gel characteristics of inulin, it can be concluded that inulin functions as a fat replacer but only in water-based systems. When concentrations exceed 15%, insulin has the ability to form a gel or cream, showing an excellent fat-like texture. This inulin gel is a perfect fat replacer offering various opportunities in a wide range of foods. Each inulin particle dispersed in the water phase of any food system will contribute to the creaminess of the finished food. Inulin is also destined to be used as a fat replacer in frozen desserts, as it processes easily to provide a fatty mouth-feel, excellent melting properties, as well as freeze–thaw stability, without any unwanted off-flavor.

3. Origins and structures of hydrocolloids

3.1 Plant hydrocolloids

3.1.1 Cellulose and derivatives

Cellulose is the most abundant naturally occurring polysaccharide on earth. It is the major structural polysaccharide in the cell walls of higher plants. It is also the major component of cotton boll (100%), flax (80%), jute (60 to 70%), and wood (40 to 50%). Cellulose can be found in the cell walls of green algae and membranes of fungi. Acetobacter xylinum and related species can synthesize cellulose. Cellulose can also be obtained from many agricultural by-products such as rye, barley, wheat, oat straw, corn stalks, and sugarcane. Cellulose is a high molecular weight polymer of (1→4)-linked β-D-glucopyranose residues. The β-(1→4) linkages give this polymer an extended ribbon-like conformation. The tertiary structure of cellulose, stabilized by numerous intermolecular H-bonds and van der Waals forces, produces three-dimensional fibrous crystalline bundles. Cellulose is highly insoluble and impermeable to water. Only physically and chemically modified cellulose finds applications in various foodstuffs (Cui, 2005).

3.1.1.1 Microcrystalline cellulose

Microcrystalline cellulose (MCC) is purified cellulose, produced by converting fibrous cellulose to a redispersible gel or aggregate of crystalline cellulose using acid hydrolysis. Microcrystalline cellulose is prepared by treating natural cellulose with hydrochloric acid to partially dissolve and remove the less organized amorphous regions of this polysaccharide. The end product consists primarily of crystallite aggregates. MCC is available in powder form after drying the acid hydrolysates. Dispersible MCC is produced by mixing a hydrophilic carrier (e.g., guar or xanthan gum) with microcrystals obtained through wet mechanical disintegration of the crystallite aggregates (Cui, 2005). These colloidal dispersions are unique when compared to other soluble food hydrocolloids. They exhibit a variety of desirable characteristics including suspension of solids, heat stability, ice crystal control, emulsion stabilization, foam stability, texture modification and fat replacement (Imeson, 2010).

3.1.1.2 Carboxymethylcellulose

Carboxymethylcellulose (CMC) is an anionic, water-soluble polymer capable of forming very viscous solutions. CMC is prepared by first treating cellulose with alkali (alkali cellulose), and then by reacting with monochloroacetic acid. The degree of substitution (DS) with the carboxyl groups is generally between 0.6 to 0.95 per monomeric unit (maximum DS is 3), and occurs at *O*-2 and *O*-6, and occasionally at *O*-3 positions.

3.1.1.3 Methylcellulose and its derivatives

Methylcellulose (MC) has thickening, surface activity (due to hydrophobic groups), and film forming properties. MC is prepared by treating alkali cellulose with methyl chloride. Other MC derivatives are also available, of which hydroxypropylmethylcellulose (HPMC) has been widely used. The reagent for HPMC is mixture of methyl chloride and propylene oxide. These two cellulose derivatives are non-ionic.

3.1.2 Hemicelluloses

Hemicelluloses are a heterogeneous group of polysaccharides constituting the cell walls of higher plants; these polysaccharides are often physically entangled, covalently and/or noncavalently bonded to cellulose and lignins. The structure of hemicelluloses may vary depending on their origin, but they can be divided into four groups based on composition of their main backbone chain:D-xylans with (1→4)-linked β-D-xylose; D-mannans, with (1→4)-linked β-D mannose; D-xyloglucans with D-xylopyranose residues attached to the cellulose chain; and D-galactans with (1→3)-linked β-D-galactose. The first three groups are very similar to cellulose in having the main chain backbone linked via (1→4) diequatorial linkages and capable of adopting extended ribbon conformations. Most of the hemicelluloses, however, are substituted with various other carbohydrate and noncarbohydrate residues, and unlike cellulose, they are heteropolysaccharides. This departure from uniformity because of various side branches renders them at least partially soluble in water (Cui, 2005).

3.1.2.1 Mannans and galactomannans

The cell walls of seeds are especially rich in mannans and galactomannans. D-Mannans, found in tagua palm seeds, have a backbone composed of linear (1→4)-linked β-D-mannose chains. The best known D-galactomannans, locust bean, guar, and tara gums have the same linear mannan backbone but they are substituted with α-D-Gal*p* side units linked to O-6. The degree of substitution in galactomannans, which profoundly affects their solution properties, differs in galactomannans extracted from various plants (Table 2) (Cui, 2005).

Widely used galactomannans are from the carob tree (*Ceratonia siliqua*), named as locust bean gum (LBG) or carob bean gum (CBG), and the guar plant (*Cyamopsis tetragonoloba*), namely guar gum (Philips & Williams, 2000). The ratio of D-mannosyl to D-galactosyl units is about 1.8:1 in guar gum and 3.9:1 in LBG. Guar gum containing galactose content of 33-40% (w/w) is soluble in water of 25°C. The rate of dissolution of guar gum increases with decreasing particle size and with increasing temperature. In the case of LBG, with the larger part containing galactose contents of about 17-21% (w/w), it needs a heat treatment during 10 min at 86-89°C under stirring to dissolve in water. Like most hydrocolloids, both guar gum and LBG shows pseudoplastic, or shear-thinning, behavior in solution. The degree of pseudoplasticity increases with both concentration and molecules weight.

Galactomannan	Species of Origin	Man:Gal Ratio
Locust bean gum	Ceratonia siliqua	3.5
Senna gum	Senna occidentalis	3.5
Guar gum	Cyamopsis tetragonolobus	1.6
Tara gum	Caesalpinia spinosa	1.3
Fenugreek gum	Trigonella foenum graecum	1

Table 2. Botanical Origin and Main Structure Features of Galactomannans

3.1.2.2 Xyloglucans

Xyloglucans, like cellulose, have linear backbones of (1→4)-linked β-D glucopyranoses. Numerous xylopyranosyl units are attached along the main backbone. In many plant xyloglucans, the repeating unit is a heptasaccharide, consisting of a cellotetraose with three subtending xylose residues (Phillips & Williams, 2000). Some xylose residues may carry additional galactosyl and fucosyl units. A few plants may have arabino- instead of fucogalactosylgroups attached to the xylose residues. One of the best characterized is the xyloglucan from the cotyledons of the tamarind seed (*Tamarindus indica*) (Shirakawa et al., 1998).

3.1.2.3 Glucomannans

Glucomannans are linear polymers of both (1→4)-linked β-D-mannose and (1→4)-linked β-D-glucose residues. Glucomannans are obtained from dried and pulverized root of the perennial herb *Amorphophallus konjac*. Acetyl groups scattered randomly along the glucomannan backbone promote water solubility. Konjac glucomannan is a high molecular weight polymer (>300 kDa) which can form viscous pseudoplastic solutions. It can form a gel in the presence of alkali.

3.1.2.4 Arabinoxylans

D-Xylans are composed of (1→4)-linked β-D-xylopyranoses with various kinds of side branches, the most common being 4-*O*-methyl-D-glucopyranosyl uronic acid linked mostly to *O*-2 of β-Xyl*p* units and α-L-Araf linked to *O*-3 of β-Xyl*p* units. The amount of arabinose and glucuronic acid in glucuronoarabinoxylans may vary substantially, ranging from substitution at almost all Xyl*p* to polymers having more than 90% of unsubstituted β-Xyl*p* units. Many cereal (wheat, barley, rye, oats) arabinoxylans do not carry glucuronic acid units.

3.1.2.5 β-D-Glucans

β-D- Glucans are high molecular weight, viscous polysaccharides. Mixed linkage (1→3), (1→4) β-D-glucans are present in the grass species, cereals, and in some lichens (e.g., *Cetraria islandica*). Cereal β-D-glucans contain predominantly (1→4) linked β-D-Glc*p* units (~70%) interrupted by single (1→3)-linked β-D-Glc*p* units (~30%). The distribution of β-(1→4) and β-(1→3) linkages is not random; this leads to a structure of predominantly β-(1→3)-linked cellotriosyl and cellotetraosyl units. There are also longer fragments of contiguously β-(1→4)-linked glucose units (cellulose fragments) in the polymer chain. The main source of

food β-D-glucans are the kernels of oats, barley, wheat, and rye. β-D- glucans have been ascribed cholesterol and blood glucose lowering properties.

3.1.2.6 Arabinogalactan

Arabinogalactan is a major D-galactan obtained from soft-woods such as pine, larch, cedar, and spruce. This polymer has a main backbone of (1→3)-linked β-D-galactopyranosyl residues with β-(1→6)-linked disaccharides of β-D-Gal*p*-(1→6)-β-D-Gal*p* and α-(1→6)-linked disaccharides of β-L-Ara*f*-(1→3)-α-L-Ara*f*. Arabinogalactan is generally a highly branched polymer with arabinose and galactose ratio of 1:6. Commercially available arabinogalactan, obtained from the butt wood of Western larch, has a relatively low molecular weight of 15,000 to 25,000, little impact on viscosity, color, and taste. It is used as a low-calorie additive in beverages to increase the fiber content.

3.1.3 Pectins

Pectins are polysaccharide and are the major components of most higher plant cell walls; they are particularly prevalent in fruits and vegetables. Commercial pectins are prepared mostly from some by-products of the food industry, such as apple pulp, citrus peels, and sugarbeet pulp. Pectins are the most complex class of plant cell wall polysaccharides. They comprise of two families of covalently linked polymers, galacturonans and rhamnogalacturonans.

Galacturonans are segments of pectins with (1→4)-linked α-D-galactosyluronic acid residues in the backbone, such as those in the linear homogalacturonans, in the substituted xylogalacturonans and in rhamnogalacturonans type II (RG II) (Cui, 2005). The carboxylic acid groups in galacturonans may be methyl esterified; the degree of esterification has an important effect on the conformation and solution properties of these polymers. Based on the degree of esterification, pectins are divided into two categories: low methyl (LM) pectin that contains less than 50% methyl esters, and high methyl (HM) pectin with more that 50% methyl esters. Xylogalacturonans are relatively recently discovered subunits of pectic polysaccharides, present in storage tissue of reproductive organs of peas, soybeans, apple fruit, pear fruit, onions, cotton seeds, and watermelon. The rhamnogalacturonans type II have been found in the cell walls of many tissues of edible plants, such as apple (juice), kiwi, grape (wine), carrot, tomato, onion, pea, and radish. Rhamnogalacturonans type I (RG I) have a backbone composed of alternating (1→2)-linked α-L rhamnosyl and (1→4)-linked α-D-galacturonic acid residues. Depending on the source of pectins, 20 to 80% of rhamnose residues may be branched at *O*-4 with side chains which vary in length and composition. The side branches may be composed of arabinans, galactans and type I arabinogalactans. Pectins with type I arabinogalactans have been found in potato, soybean, onion, kiwi, tomato, and cabbage.

3.1.4 Exudate gums

Exudate gums are polysaccharides produced by plants as a result of stress, including physical injury and/or fungal attack. Gum arabic, gum tragacanth, gum karaya, and gum ghatti have been used by humans for many thousands of years in various food and pharmaceutical applications (Table 3). Generally, these gums are structurally related to arabinogalactans, galacturonans, or glucuronomannans. They all contain a high proportion of glucuronic or galacturonic acid residues (up to 40%).

Gum	Species of Origin	General structure	Viscosity	
			Concentration %	(Pas×10^{-3})[a]
Gum arbic	Acacia Senegal	Substituted acidic arabinogalactan	5.01	717
Gum tragacanth	Astragalus gummifer	Mixture of arabinogalactan and glycano-rhamnogalacturonan	1.0 3.0	1,000 >10,000
Gum karaya	Sterculia urens	glycano-rhamnogalacturonan	1.0 5.0	300,045,000
Gum ghatti	Anogeissus latifolia	glycano-glucuronomannoglycan	5.01	2,882,440

[a] Viscosity obtained at shear rates 10^{-S}

Table 3. Main botanical and structural characteristics exudates gums

3.1.4.1 Gum arabic

Acacia gum, also known as gum arabic, is a natural, vegetable exudate from acacia trees (primarily in Africa) known since antiquity and used for thousands of years in foods as an additive and ingredient, in the pharmaceutical industry and for technical purposes (Imenson, 2010). The thorny trees grow to a height of 7 to 8 meters, and the gum is obtained by cutting sections of the bark from the tree. The structure of gum arabic is relatively complex. The main chain of this polysaccharide is built from (1→3) and (1→6)-linked β-D-galactopyranosyl units along with (1→6)-linked β-D-glucopyranosyl uronic acid units. Side branches may contain α-Lrhamnopyranose, β-D-glucuronic acid, β-D-galactopyranose, and α-L-arabinofuranosyl units with (1→3), (1→4), and (1→6) glycosidic linkages. Gum arabic has a high water solubility (up to 50% w/v) and relatively low viscosity compared to other exudate gums. The highly branched molecular structure and relatively low molecular weight of this polymer are responsible for these properties. Another unique feature of gum arabic is its covalent association with a protein moiety. It is thought that the protein moiety rich in hydroxyproline (Hyp), serine (Ser), and proline (Pro) constitutes a core to which polysaccharide subunits are attached via Ara-Hyp linkages (the wattle blossom model). The protein moiety of gum arabic is responsible for the surface activity, foaming, and emulsifying properties of this polymer (Phillips & Williams, 2000).

3.1.4.2 Tragacanth gum

In the *European Pharmacopoeia* (6th edition, 2007), *gum tragacanth* is defined as 'the air-hardened gummy exudates, flowing naturally or obtained by incision from the trunk and branches of *Astragalus gummifer* Labillardiere and certain other species of *Astragalus* from western Asia (mostly in Iran, some in Turkey)'. Tragacanth gum contains a water-soluble fraction and a water-insoluble fraction and the water-soluble fraction is accounted for 30 to 40% of the total gum. The water soluble fraction (tragacanthin) is a highly branched neutral polysaccharide composed of 1→6-linked D-galactosyl backbones with L-arabinose side chains joined by 1→2-, 1→3- and/or 1→5-linkages. The water-insoluble fraction (~60 to 70%), is tragacanthic acid (bassorin) which is a water-swellable polymer and is consisted of D-galacturonic acid, D-galactose, L-fucose, D-xylose, L-arabinose and L-rhamnose. It has a

(1→4)-linked α-D-galacturonopyranosyl backbone chain with randomly substituted xylosyl branches linked at the 3 position of the galacturonic acid residues. In spite of the availability of alternative materials, the continued use of the gum is the result of its unique functional properties combined with a high degree of stability in a range of conditions.

3.1.4.3 Gum karaya

Gum karaya, also known as sterculia gum, is a branched acidic polysaccharide obtained from the exudates of the *Sterculia urens* tree of the Sterculiaceae family grown in India. The backbone chain is a rhamnogalacturonan consisting of α-(1→4)-linked D-galacturonic acid and α-(1→2)-linked-L-rhamnosyl residues. The side chain is made of (1→3)-linked β-D-glucuronic acid, or (1→2)-linked β-D-galactose on the galacturonic acid unit where one half of the rhamnose is substituted by (1→4) linked β-D-galactose.

3.1.4.4 Gum ghatti

Gum ghatti is an amorphous translucent exudate of the *Anogeissus latifolia* tree of the Combretaceae family grown in India. The monosaccharide constituents of gum ghatti are L-arabinose, D-galactose, D-mannose, D-xylose, and D-glucuronic acid in the ratio of 10:6:2:1:2, with traces of 6-deoxyhexose.

3.1.5 Mucilage gums

Mucilage gums are very viscous polysaccharides extracted from seeds or soft stems of plants; examples are psyllium (from *Plantago* species), yellow mustard (from *Sinapis alba*), and flax mucilage (from *Linum usitatissimum*). All of them are acidic polysaccharides with structures somewhat related to some of the exudate gums. Their utilization in certain food products is increasing due to their functional properties (viscosity, gelation, water binding) as well as to their bio-active role in prevention and/or treatment of certain diseases (Cui, 2005).

3.1.5.1 Psyllium gum

Psyllium gum can be extracted from seeds of the *Plantago* species. The gum is deposited in the seed coat; it is, therefore, advantageous to mechanically separate the outer layers from the rest of the seed before extraction. Psyllium gum can be extracted with hot water or mild alkaline solutions. The molecular structure of the gum is a highly branched acidic arabinoxylan. D-Glucuronic acid residues have also been found in this gum. Psyllium gum has a very high molecular weight (~1500 kDa) and does not completely dissolve in water. When dispersed in water, it swells and forms a mucilageous dispersion with gel-like properties. It is used primarily as a laxative and dietary fiber supplement in pharmaceutical and food industries.

3.1.5.2 Yellow mustard mucilage

Yellow mustard mucilage can be extracted from whole mustard seeds or from the bran. The mucilage contains a mixture of a neutral polysaccharide, composed mainly of glucose, and an acidic polysaccharide, containing galacturonic and glucuronic acids, galactose, and rhamnose residues. Detailed analysis of the neutral fraction of yellow mustard mucilage showed that it contains mainly (1→4)-linked β-D-glucose residues. The *O*-2, *O*-3, and *O*-6 atoms of the (1→4)-β-D-glucan backbone may carry ether groups (ethyl or propyl). Depending on the polymer concentration, yellow mustard mucilage can form either viscous solution of weak gels. When it is mixed with locust bean gum, however, the gel rigidity can

be increased substantially. It has been shown that the neutral (1→4)-β-D-glucan fraction of yellow mustard mucilage synergistically interacts with galactomannans. Yellow mustard is used in processed meat formulations and salad dressing as a stabilizer and bulking agent.

3.1.5.3 Flaxseed mucilage

Flaxseed mucilage can be easily extracted from the seeds by soaking them in warm water. The mucilage constitutes the secondary wall material in the outermost layer of the seed. Upon hydration of the seeds, it expands, breaks the mucilage cells, and exudes on the surface of the seeds. Flaxseed mucilage contains 50 to 80% carbohydrates and 4 to 20% proteins and ash. Flaxseed mucilage contains a mixture of neutral polysaccharides, composed mainly of xylose, arabinose and galactose residues, and acidic polysaccharides, containing galactose, rhamnose, and galacturonic acid residues. The neutral fraction of flaxseed mucilage has a backbone of (1→4)-linked β-D-xylopyranosyl residues, to which arabinose and galactosecontaining side chains are linked at *O*-2 and/or *O*-3.
The acidic fraction of flaxseed mucilage has a rhamnogalacturonan backbone with (1→4)-linked α-D-galacturonopyranosyl and (1→2)-linked α-L-rhamnopyranosyl residues. The ratio of neutral to acidic polysaccharides in flaxseed may vary substantially with their origin. Unfractionated flaxseed mucilage forms a viscous solution, but it is the neutral fraction that mainly contributes to the high viscosity and weak gel-like properties of this gum. Flaxseed mucilage has not yet been widely utilized mostly because of limited information about the structure and functional properties of this gum. Similar to other gums, flaxseed mucilage can be used as a thickener, stabilizer, and water-holding agent.

3.1.6 Fructans

Fructans are reserve polysaccharides in certain plants, either complementing or replacing starch. They can also be produced by certain species of bacteria. A main kind of fructans is inulin. Inulins are found in roots or tubers of the family of plants known as Compositae, including dandelions, chicory, lettuce, and Jerusalem artichoke. They can also be extracted from the Liliacae family, including lily bulbs, onion, tulips, and hyacinth. Inulin is a low molecular weight polysaccharide containing (2→1) linked β-D-Fru*p* residues.

3.2 Seaweed hydrocolloids

3.2.1 Alginates

Alginates constitute the primary structural polysaccharides of brown seaweeds (*Phaeophyceae*). The alginate molecules provide both flexibility and strength to the plants and these properties are adapted as necessary for growth conditions in the sea. The major species of seaweeds that produce alginates are *Macrocystis pyrifera,* grown primarily along the California coast of the USA, south- and north-western coasts of South America, and coasts of Australia and New Zealand. Other good sources of alginates are *Laminaria hyperborea*, *Laminaria digitata*, and *Laminaria japonica*, grown along the north Atlantic coast of the USA, Canada, France, and Norway. Alginates can also be synthesized by bacteria, *Pseudomonas aeruginosa* and *Azobacter vinelandii*. Alginates are unbranched copolymers of (1→4)-linked β-D-mannuronic acid (M) and α-L-guluronic acid (G) residues. If the uronic acid groups are in the acid form (–COOH), the polysaccharide, called alginic acid, is water insoluble. The sodium salts of alginic acid (–COONa), sodium alginates, are water soluble. The sequence of mannuronic and guluronic residues significantly affects the physicochemical properties of alginates. The ratio of β-D-mannuronic acid to α-L-guluronic

acid residues is usually 2:1, although it may vary with the algal species, the age of the plant as well as the type of tissue the alginates are extracted from (Cui, 2005). The main advantage of alginate as a gel former is its ability to form heat-stable gels which can set at room temperatures. In food applications, it is primarily gel formation with calcium ions which is of interest.

3.2.2 Carrageenans

Carrageenans are structural polysaccharides of marine red algae of the Rhodophyceae class. They are extracted mainly from *Chondrus crispus*, *Euchema cottoni*, *Euchema spinosum*, *Gigartina skottsbergi*, and *Iradaea laminarioides*. These red seaweeds grow mostly along the Atlantic coasts of North America, Europe, and the western Pacific coasts of Korea and Japan. Carrageenan extracted from seaweed is not assimilated by the human body, providing only fibre with no nutritional value, but it does provide unique functional characteristics that can be used to gel, thicken and stabilise food products and food systems. κ-carrageenans, ι-carrageenans, and furcellarans are linear polysaccharides whose backbone structure is based on a repeating disaccharide sequence of sulphate esters of (1→3) linked β-D-galactose and (1→4) linked 3,6-anhydro-α-D-galactose. They differ from each other in the number and position of sulphate groups. κ-carrageenans have one sulphate group per repeating disaccharide unit, positioned at C-4 of the β-D-galactopyranosyl residue, whereas ι-carrageenans have two sulphate groups, positioned at C-4 of the β-D-galactopyranosyl residue and C-2 of the 3,6-anhydro-α-D-galactopyranosyl residue. Furcellaran has a similar structure to κ-carrageenan, but it is less sulphated; only 40% of the β-D-galactopyranosyl residues carry the sulphate group at C-4. These two types of monosaccharide conformations, along with the presence of axial and equatorial glycosidic linkages, allow κ- and ι-carrageenans to assume a helical conformation. In solution, in the presence of some cations (K^+, Rb^+, Ca^{++}), the double helices of furcellaran, κ- and ι-carrageenans can aggregate and form gel. κ-carrageenan and ι-carrageenan form thermally reversible gels, which range in texture from firm and brittle to soft and elastic.

The functional properties of carrageenan gels, such as rigidity, turbidity, and tendency to syneresis (separation of water from gel upon aging), generally decrease with the increasing degree of sulphation in these polymers. λ-carrageenans constitute another group of the red seaweed polysaccharides. The repeating disacharide unit in λ-carrageenans consists of β-D-galactopyranosyl residue sulphated at C-2 (instead of C-4 as in ι- and κ-carrageenans) and 2, 6-di-*O*-sulfato-α-D-galactopyranosyl units (instead of 3, 6-anhydro-α-D-galactopyranosyl residue). λ-carrageenans are nongelling polysaccharides used as cold soluble thickeners in syrups, fruit drinks, pizza sauces, and salad dressings.

3.2.3 Agar

Agar constitutes another group of polysaccharides from red-purple algae of the *Rhodophyceae* class. The agar-yielding species of *Gracilaria* and *Gelidium* grow in the waters along the coast of Japan, New Zealand, South Africa, Southern California, Mexico, Chile, Morocco, and Portugal. Agar is a linear polysaccharide built up of the repeating disaccharide unit of (1→3)-linked β-D-galactose and (1→4)-linked 3,6-anhydro-α-L-galactose residues. In contrast to carrageenans, agar is only lightly sulphated and may contain methyl groups. Methyl groups, when present, occur at C-6 of the (1→3)-linked β-D-galactose or C-2 of (1→4)-linked 3, 6-anhydro-α-L-galactose residues. Agar, containing

3,6-anhydro-α-L-galactose residues, forms three-fold left-handed helices. These left-handed threefold helices are stabilized by the presence of water molecules bound inside the double helical cavity (Labropoulos *et al.*, 2002) and exterior hydroxyl groups allow aggregation of up to 10 000 of these helices to form microdomains of spherical microgels (Boral *et al.,* 2008).
The agar helix is more compact due to the smaller amount of sulphate groups. Agar is a well known thermo-reversible gelling polysaccharide, which sets at 30 to 40°C. Being less sulphated than furcellaran, and κ- and ι-carrageenans, agar can form strong gels, which are, subject to pronounced syneresis, attributed to strong aggregation of double helices (not weakened by the sulphate groups). The ability to form reversible gels by simply cooling hot, aqueous solutions is the most important property of agar. Gelation depends exclusively on the formation of hydrogen bonds, where the random coils associate to form single helices (Foord & Atkins, 1989) and double helices (Rees & Welsh, 1977).

3.3 Microbial hydrocolloids

3.3.1 Xanthan gum

Xanthan gum is an extracellular polysaccharide produced by the bacterium *Xanthomonas campestris*. The primary structure of xanthan gum consists of a cellulosic backbone of *β*-(1→4) linked D-glucose units substituted on alternate glucose residues with a trisaccharide side chain. The trisaccharide side chain is composed of two mannose units separated by a glucuronic acid (Melton *et al.*, 1976). Approximately half the terminal mannose units are linked to a pyruvate group and the non-terminal residue usually carries an acetyl group. The carboxyl groups on the side chains render the gum molecules anionic. The pyruvic acid content of xanthan can vary substantially depending on the strain of *X. campestris*, resulting in different viscosities of xanthan solutions.
Molecular modelling studies suggest that xanthan gum can assume a helical structure, with the side branches positioned almost parallel to the helix axis and stabilizing the structure. Xanthan gum forms very viscous solutions, and, at sufficiently high polymer concentration, it exhibits weak gel-like properties. It can form thermo-reversible gels when mixed with certain galactomannans (e.g., locust bean gum) or konjac glucomannan. Xanthan is widely used in foods because of its good solubility in either hot or cold solutions, high viscosity even at very low concentrations, and excellent thermal stability.

3.3.2 Pullulan

Pullulan is an extracellular homopolysaccharide of glucose produced by many species of the fungus *Aureobasidium*, specifically *A. pullulans*. Pullulan contains (1→4) and (1→6)-linked α-D-glucopyranosyl residues. The ratio of (1→4) to (1→6) linkages is 2:1. Pullulan is generally built up of maltotriose units linked by (1→6) with much smaller amount of maltotetraose units. The presence of (1→6) glycosidic linkages increases flexibility of pullulan chains and resulted in their good solubility in water compared with other linear polysaccharides (e.g., amylose) (Cui, 2005). Pullulan easily dissolves in cold or hot water to form a stable, viscous solution that does not gel. A pullulan solution is stable over a wide range of pH and is also relatively stable to heat (Imenson, 2010).

3.3.3 Gellan gum

Gellan gum is a fermentation polysaccharide produced by the microorganism *Sphingomonas elodea* (previously identified as *Pseudomonas elodea,* but later reclassified). Gellan gum is now

approved for food use in many countries including Australia, Canada, United States, Mexico, Chile, Japan, South Korea, and Philippines.
The molecular structure of gellan gum is a straight chain based on repeating glucose, rhamnose and glucuronic acid units. In its native or high-acyl form, two acyl substituents – acetate and glycerate – are present. Both substituents are located on the same glucose residue and, on average, there is one glycerate per repeat and one acetate per every two repeating unit (Kuo et al., 1986). In low-acyl gellan gum, the acyl groups are absent. Upon cooling of gellan solutions, the polysaccharide chains can assume double helices, which aggregate into weak gel structures (supported by van der Waals attractions). In the presence of appropriate cations (Na^+ or Ca^{++}), the double helices form cation-mediated aggregates, which leads to formation of strong gel networks. Acyl substituents present in native gellan interfere with the aggregation process, giving much weaker gels. In the branched variants of gellan, the side chains also interfere with the cation-induced aggregation, allowing only 'weak gel' formation.

3.4 Animal hydrocolloids

3.4.1 Chitin and chitosan

Chitin is a structural polysaccharide that replaces cellulose in many species of lower plants, e.g., fungi, yeast, green, brown, and red algae. It is also the main component of the exoskeleton of insects and shells of crustaceans (shrimp, lobster, and crab). The molecular structure of chitin is similar to that of cellulose, except that the hydroxyl groups at *O*-2 of the β-D-Glc*p* residues are substituted with *N*-acetylamino groups. Chitin forms a highly ordered, crystalline structure, stabilized by numerous intermolecular H-bonds. It is insoluble in water. However, when chitin is treated with strong alkali, the *N*-acetyl groups are removed and replaced by amino groups. This new water-soluble polysaccharide, called chitosan, contains, therefore, (1→4)-linked 2-amino-2-deoxy-β-D-glucopyranosyl residues. Chitosan is the only polysaccharide carrying a positive charge. It is not digested by humans and can be used as a dietary fiber.

3.4.2 Gelatin

Gelatin is a proteinaceous material obtained from animal connective tissue (collagen) using hydrolysis in acidic (type A) or basic (type B) solution followed by hot water extraction. Commercially, skins or bones of different animal species, such as beef, pork, fish and poultry, form the main raw material for gelatin production. The extracted gelatin is a group of molecules of different molecular weight (Imenson, 2010). The molecular weight profile depends on the process. The amino acid profile determines hydrogen bond formation and reactivity via side groups such as amine, imidazole, alcohol, amide and carboxylic acid. It hydrates readily in warm or hot water to give low-viscosity solutions that have good whipping and foaming properties. After cooling, the network of polypeptide chains associates slowly to form clear, elastic gels that are syneresis free.

3.5 Chemically modified hydrocolloids

Although all natural gums have inherently useful and uniquely functional properties, they also have inherent limitations and deficiencies which restrict their overall utilization. In many cases, these limitations can be removed by selective chemical modification and derivatization of the gum. In other cases, the overall functional properties can be improved by the chemical modification of the natural hydrocolloid.

Thus, while sodium alginate is quite soluble, it does not have good stability at low pHs. By treating alginates with propylene oxide to form propylene glycol alginate ester, a modified soluble alginate is formed that has exceptional stability under acidic conditions.
In a similar fashion, while normal guar gum is quite soluble in cold water, solubility can be greatly increased by forming the hydroxypropyl guar derivative, while simultaneously giving a greatly increased viscosity.
Pure cellulose is completely in soluble in water as well as being poorly absorptive in its native form. By chemical treatment to form cellulose ether compounds, such as methyl cellulose and hydroxypropyl cellulose, water solubility can be imparted, thus making a useful series of water soluble functional hydrocolloid polymers.

4. Hydrocolloids in the production of special products

4.1 Soft gelatin capsules

Liquid foods, as well as instant (soluble) coffee and other food powders, can be conveniently contained in a gelatin capsule (Maddox, 1971). The interior of the capsule contains a suitable instant food which dissolves or disperses promptly upon addition of water. The capsule is maintained in a dry form in a suitable enclosure, such as a hermetically sealed bottle, blister-pack packaging or the like, until use. Soft gelatin capsules are commonly used in food supplements. Gelatin is the basic capsule shell component and it is formulated with suitable ingredients to encapsulate a wide variety of materials. Gelatin's special properties are of particular interest in foods since it acts as a barrier and protects liquid capsule contents from the outside environment. On the one hand, gelatin acts as a physical barrier to bacteria, yeasts and molds. On the other, it provides a low-permeability membrane to gases. The gelatin shell is transparent, can be formed in a wide range of sizes and shapes and dissolves quickly in hot water, releasing its encapsulated liquid. The advantages of encapsulation are: portion control, easy use and storage, extended shelf-life, improved aesthetic appeal, the variety of sizes available, disposability and edibility, improved product aromatics versus time, and biodegradability. A wide range of filler materials can be encapsulated within these capsules, such as most vegetable oils, essential oils and fish oils, as well as suspensions of crystalline materials milled with oils. A few food applications are: real chicken broth capsules which retain and deliver flavor more effectively than the powder system, encapsulated lemon oil for meringue pie mix, mint essence capsules for the tinned goods market (Moorhouse & Grundon, 1994).

4.2 Liquid-core capsules

Liquid-core hydrocolloid capsules are liquids encapsulated in a spherical polymer membrane (Vergnaud, 1992). Production of these capsules included suspending cells in a sodium alginate solution, forming small spherical calcium alginate beads by cross-linking with calcium salt, and reacting with polylysine to create a polylysine alginate membrane around the bead. In the final stage, the bead's core, composed of calcium alginate gel, was solubilized, thus forming a liquid-core micro-capsule containing cells (Lim & Sun, 1980). With this procedure, cells could also be found in the membrane matrix, leading to the proposal of an approach to eliminate this possibility (Wong & Chang, 1991). In the latter approach, cells were entrapped in alginate-gel micro-spheres, which in turn were contained within larger beads, resulting in a greater distance between the cells and the surface of the larger alginate bead. Similar to (Lim and Sun's 1980) procedure, the surface of the larger

micro-sphere was reacted with poly-L-lysine and then with alginate to form a coating membrane. The contents of the micro-capsule were then liquefied with sodium citrate to remove the calcium from the array. The cells in the smaller entrapped gel micro-sphere were released and allowed to float freely in the liquid core of the resultant beads (Wong & Chang, 1991).

The contents of the capsule were either distilled water or sucrose solutions (2.5 and 30%, w/w), although other viscous liquids can be used. Beads with 0, 2 and 5% sucrose were produced by diffusion of sucrose out of liquid-core capsules containing 30% sucrose. The spherical shape of the capsule was retained after diffusion. Capsules with a higher hydrocolloid concentration within their membrane displayed more stress at failure (strength) and less brittleness than those with lesser solid membrane content. Following diffusion, capsules with 2 and 5% sucrose were weak compared to those with 30% sucrose; however, no membrane rupture was observed after incubation.

4.3 Jelly-like foods

Natural gums are used in the confectionary industry. At one time, guar was used for production of jellies (candies) and marshmallows, and gum arabic was used gum drops. The gum within the formulation served to form *jelly*, but an additional function was to prevent sugar crystallization and to emulsify fat, keeping it evenly distributed within the product (Furia, 1980). The gum powder swells and gels when added to water and heated. Its gels are thermally irreversible and unaffected by further addition of water and can be produced over a pH range of 2.0-9.5 in the presence of many food additives. The gels may be used to make novel food products consisting of a jelly-like skin with a liquid core, and canned jellies. The concentration of the polysaccharide in water must be greater than 1.5% for gel stability and less than 0.6% for taste acceptability. The gels are freeze-thaw stable and may be used to make an ice confection contained in an elastic gel skin (Anon, 1977).

4.4 Fruit products

A combination of compression and shearing forces is used to extract juice from fruits or vegetables. For pulp production, and in the case of grapes, tomatoes or other soft fruits, are heated, if necessary, to soften their tissues and pulp is forced through the perforations of the pulping equipment's screen, the size of which determines the consistency of the resultant product (Fellows, 2000). Unique uses of such fruit products (i.e. juice, pulp or puree) for production of soft viscous, fruit-based, membrane-coated items by a membrane were described decades ago. For example fruit juice, pulp or puree containing soluble Ca salt is extruded to form drops which are coated with a thin skin of alginate or pectate sol. The coated drops are exposed to an aqueous setting bath containing a soluble Ca salt (Sneath, 1975). Drops of aqueous fruit material are coated with an aqueous alginate or pectate solution and applied in a solution containing Ca or Al ions to gel the surface.

4.5 Frozen product

Frozen desserts are mixtures of ice crystals in flavored liquid syrup. The most common frozen dessert is ice cream. During the last 50 years, a huge change in the texture of ice-cream products has occurred.

Gum karaya can be used as a stabilizer in ice cream, ice milk, mellorine and related products. In ice pops and sherbets, formation of large ice crystals and syneresis can be prevented by including 0.2-0.4% gum karaya. Combinations of 0.15% gum karaya and 0.15%

LBG can be used successfully for ice pop stabilization. Karaya, as well as carrageenan, can be used as a binder and emulsifying agent in quantities of less than ~1%. The binders are used to absorb the water resulting from the ice during chopping. LBG is used in the food industry for its ability to bind and immobilize large amounts of water. This property helps inhibit ice crystal formation in frozen products, produce viscosity, modify texture and stabilize product consistency in the face of temperature changes (Glicksman, 1969). Sodium CMC in its highest purified form is used in many food applications. In frozen desserts (such as ice cream), cellulose gum inhibits the formation of ice crystals (Davidson, 1980). Gum arabic, because of its water-absorbing properties, gum inclusion inhibits the formation and growth of ice crystals. Other stabilizers, such as carrageenan and LBG, can be used for the same purposes (Glicksman, 1969). Guar gum is used in the food industry for its ability to bond and immobilize large amounts of water. This property contributes to inhibition of ice crystal formation, product texture, stabilization of product consistency to changes in temperature, and viscosity (Davidson, 1980).

Freezing often causes undesirable changes in foods, and hydrocolloids are used to improve their quality. To produce a high-quality ice cream, a blend of guar gum or CMC with a smaller amount of carrageenan may be used. If xanthan and guar gum are used instead, viscosity is lower and faster processing is obtained. Karaya gum has been used in the past as a stabilizer for frozen desserts, but has been replaced almost completely by other gums. Carrageenan, guar gum and CMC have also been used as stabilizers in other frozen products. In foods containing starch as the main ingredient, there is a tendency for water to exude from the gel. Thus starch-based products curdle and undergo syneresis (loss of water) after freezing and thawing. Modified starches have been developed to deal with the problem (Nussinovitch, 1997).

Frozen doughs are widely used in industrial bakeries to make baking more profitable. However, loaf volumes are usually smaller and quality poorer for breads baked from frozen doughs, especially in those with low fat content (Williams & Philips, 1998). Addition of hydrocolloids such as CMC, alginate, and different blends in quantities of up to 1.5% yielded higher total dough water content without changing baking properties. There were no obvious differences between analyzed samples or added hydrocolloid levels.

4.6 Candies

Candies are popular products among children and adults and their versatility is visually alluring as well as pleasing to the consumer. The confectionery industry uses gum arabic to a great extent, for crystallization prevention, as an emulsification agent of fat and as a glaze in candies, chewing gum. Gum arabic serves to coat the center of sugar-coated tablets. It is the main ingredient in gumdrops (regular and dietetic) and other chewy-type gums, where pectin or modified starches can also play a major role (Davidson, 1980). The incorporation of sorbitol, mannitol and gum arabic can produce dietetic candies. The higher the gum arabic content, the softer and chewier the candy.

4.7 Fabricated foods

Using fish, meat, fruit or vegetables as main ingredients within a matrix, which is usually produced from a gum, can create fabricated foods. Gums were incorporated into meat products to achieve better control of their texture, improve sliceability and increase yield. In some meat products, hydrocolloids are responsible for the undesirable broad dark striations (called tiger stripping), running parallel to the meat fibers (Williams & Philips, 1998). The swelling ability of the type of carrageenan used influences its activity within the product.

Semi-refined carrageenan (less swelling) improved performance in injected poultry by reducing the incidence of tiger stripping without reducing purge controls (Williams & Philips, 1998).
Fabricated fruit is easily manufactured with alginates. A gel is readily formed when a soluble calcium salt is added to a sodium alginate solution. This gel is stable over a wide range of temperatures, has excellent syneresis control, and is irreversible to heat. Possible uses for this fabrication concept include imitation cocktail cherries; imitation glazed fruit pieces for cakes, breads, cookies, ice cream and candy products; icing; and gelled products containing pureed fruit. Other hydrocolloids - carrageenan, gelatin (and recently gellan), and combinations of gums such as carrageenan and locust bean gum (LBG) - have been used to fabricate food products. Examples include reconstituted pimento strips (based on alginate and gum arabic), the aforementioned imitation caviar, and restructured fish and shellfish (Nussinovitch, 1997).
Use of sodium carboxymethyl cellulose (CMC) in food applications is on the rise, especially in developed countries where the popularity and convenience of fabricated foods has grown rapidly since the early 1950s. Hydroxypropylcellulose can also be used in fabricated foods to a large extent. Its useful properties are its ability to form solvent-soluble films and its surface-active stabilization (Davidson, 1980).

5. Health benefits of hydrocolloids

5.1 Hydrocolloid and the risk of cardiovascular disease (CVD)

Dietary fiber was briefly mentioned in the WHO report to reduce total and LDL cholesterol, and probably also to decrease the risk for cardiovascular diseases. Several studies have dealt with the association between dietary fiber intake and risk for cardiovascular disease. The main interest has been focused on effects of soluble fibers, such as different hydrocolloids, and thus on foods rich in soluble fibers. Both mixture of hydrocolloids and only one hydrocolloid were investigated. In one study, subjects with increased plasma cholesterol values were given a daily supplement of 15 g of psyllium, pectin, guar gum, and locust bean gum during 6 months (Jensen et al., 1997). The fibers were mixed in water and consumed with each of three major daily meals. In comparison with the control group given acacia gum, the total and LDL cholesterol values were significantly lower in the test group. After 8 weeks, the reductions in comparison with baseline were 6.4 and 10.5%, respectively, and about the same reductions were found at weeks 16 and 24. In another study, a combination of soluble fibers from psyllium, oats, and barley was given to men with hypercholesterolemia (Roberts et al., 1994). They consumed the fibers as a breakfast cereal (50 g containing 12 g of soluble fiber) for 6 weeks. In comparison with a control group given a breakfast cereal based on wheat, the total cholesterol and LDL cholesterol levels fell significantly in the test group, with 3.2 and 4.4%, respectively.
Psyllium has been extensively investigated in relation to its effects on CVD. As in the study of Anderson et al. (2000), the fiber preparations were mixed in water and taken before regular meals three times per day. A dose–response study was made by Davidson et al. (1998) using psyllium seed husk given in daily doses of 0, 3.4, 6.8, or 10.2 g for 24 weeks. The fibers were included in different foods like ready-to-eat cereals, bread, pasta, and snack bars. A change in LDL cholesterol (–5.3% in comparison to control) after 24 weeks consumption was only shown for the group that took the highest dose of psyllium husk-10.2 g/day. The reduction in LDL cholesterol was more pronounced in the beginning of the intervention (week 4) for all groups. Davidson et al. (1998) also investigated the lipid-lowering effect of psyllium in hypercholesterolemic children (6 to 18 years). They were given psyllium for 6 weeks and, after

a 6-week washout period, a control cereal. Consumption of psyllium gave a 7% reduction in LDL cholesterol compared with the control cereal.
Many human studies on guar effect on lipid metabolism have been conducted. The dose of guar gum was 10 g and it was taken three times a day for 6 weeks. In comparison with a placebo, the guar gum decreased the blood cholesterol and triglyceride levels and blood pressure significantly (Landin et al., 1992). The effect of guar gum on LDL metabolism seemed to be related to an increased LDL a polipoprotein B fractional catabolism. Modified guar gum has also been studied, and in one study partially depolymerized guar gum decreased the total cholesterol levels by 10%, which is a reduction similar to that found earlier for high molecular weight guar gum (Blake et al., 1997). The effects of solid or liquid guar gum and preparations with high or medium viscosity on lipid metabolism were followed in hypercholesterolemic subjects (Superko et al., 1988). Both solid and liquid guar gum preparations lowered the total and LDL cholesterol, but the high-viscosity preparation gave a larger reduction in blood lipid levels than the medium-viscosity preparation.
Pectin can be included in the diet as a supplement, but also as fruits, which often contain much pectin. In a study, subjects with hypertension were given guava fruits before meals during 12 weeks, and the effect on the blood lipids and blood pressure was followed (Singh et al., 1992). In comparison with a group that was not given guava, the total cholesterol, HDL cholesterol, triglycerides, and blood pressure decreased significantly. Several studies have also been done with different kinds of pectins. Dongowski & Lorentz (2004) gave diets containing pectin with different degrees of methylation (34.5, 70.8, and 92.6%) to rats for 3 weeks. The concentration of bile acids in the plasma decreased when pectin was given, and with increasing degree of methylation more bile acids were excreted with the feces.

5.2 Hydrocolloids and type 2 diabetes

It has been reported that dietary soluble fiber such as β-glucan, psyllium, and guar gum decreases glucose and insulin responses to carbohydrates if taken in sufficient amounts. A study comparing the effects over 6 months of barley bread, high in β-glucan, to white bread found that barley bread improved glycemic control compared with white wheat bread in 11 men with type 2 diabetes.97 Insulin responses were increased, which hypothetically could reflect recovered β-cell function. In men with diabetes and hypercholesterolemia participating in a crossover trial, 8 weeks of psyllium (15 g/day) decreased hemoglobin A_{1c} 6.1% (absolute change, 0.8%), with similar 6% decreases in fasting postprandial glucose (Anderson et al., 1999). Improved fasting and postprandial glycemic control was found in 11 type 2 diabetic patients taking 21 g/day of guar gum or placebo in a randomized double-blinded crossover trial (Aro et al., 1981). Small improvements in overall glycemic control and sizable improvements in postprandial glycemia after 4 weeks of treatment in a randomized controlled crossover trial were reported by Fuessl et al. (1987) Guar gum decreased fasting blood glucose from 11.4 to 9.5 mmol/l in 19 obese patients with type 2 diabetes who were enrolled in a randomized double-blind crossover trial (Lalor et al., 1990). Guar gum (15 g/day) has also improved long-term glycemic control and postprandial glucose tolerance in 15 type 2 diabetic patients treated with guar gum over an 8-week period (Groop et al., 1993). Viscosity is an important determinant of soluble hydrocolloid in retarding glycemic responses (Wood et al., 2000).

5.3 Hydrocolloids as laxative and antidiarrhea

The laxative activity of bulk forming substances has been known since the time of Hippocrates. Hydrocolloid fractions of psyllium and ispaghula are common bulk forming

laxative (Fingal & Feston, 1979). The fiber from foods, such as carrots, cabbage, apple, and bran compared to guar, produces very different responses in colon function 104. Fecal weight is increased more by a bran supplement than by guar supplement. The results from a study of digestion of hemicelluloses in humans suggest that arabinoxylan is not digested and perhaps may be the active component in laxation (Holloway et al., 1980). One hypothesis for judging the value of a bulk former as a laxative concerns its ability to hold water. However, some new evidence appears to contradict this. Since the greater the water holding capacity of a fiber source, the less the effect on fecal bulk (Stephen & Cummings, 1979).

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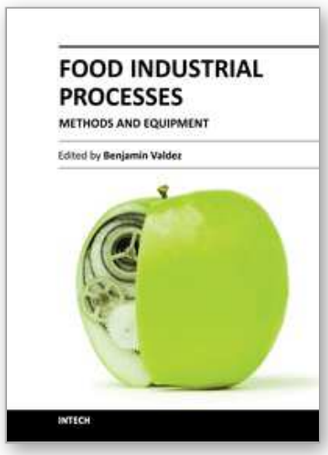
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The global food industry has the largest number of demanding and knowledgeable consumers: the world population of seven billion inhabitants, since every person eats! This population requires food products that fulfill the high quality standards established by the food industry organizations. Food shortages threaten human health and are aggravated by the disastrous, extreme climatic events such as floods, droughts, fires, storms connected to climate change, global warming and greenhouse gas emissions that modify the environment and, consequently, the production of foods in the agriculture and husbandry sectors. This collection of articles is a timely contribution to issues relating to the food industry. They were selected for use as a primer, an investigation guide and documentation based on modern, scientific and technical references. This volume is therefore appropriate for use by university researchers and practicing food developers and producers. The control of food processing and production is not only discussed in scientific terms; engineering, economic and financial aspects are also considered for the advantage of food industry managers.

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