UNIT –2 Food Polysaccharides and their Applications

Structure

2.1 INTRODUCTION

In the last unit we read about the simple sugars i.e. monosaccharide, di/oligosaccharides. Continuing with our discussion on carbohydrates, in this unit we will focus on polysaccharides. You would be surprised to learn that polysaccharides can be produced from a wide range of sources namely plants, algae, microbes, yeast etc. You may already know that plants contain two main types of polysaccharides. They are the starch and non-starch polysaccharides (NSP) commonly referred to as *dietary fibre*. In addition food polysaccharides also include exudates gums, seed gums, microbial polysaccharides, algal polysaccharides. We shall learn about these food polysaccharides in this unit. What are the characteristics, properties and functions of food starches? What are modified starches? What is their role in our food? These are the issues discussed in the first part of this unit. Next, the unit focuses on non-starch polysaccharides (NSP), microbial polysaccharides, algal polysaccharides, exudates gums. Different food polysaccharides – their structure, properties and functionality - are described in this unit. You will find this unit quite comprehensive and perhaps a bit exhaustive. Read the contents carefully and make notes to facilitate your understanding of polysaccharides.

Objectives

After studying this unit you will be able to:

- define starches and modified starches
- explain the structural components and properties, functionality of starches in our food
- discuss the role of modified starches in the food industry and in home use
- present the classification of NSP
- describe the structure, properties and functions of different NSPs in our food.

2.2 CHARACTERISTICS AND FUNCTIONAL PROPERTIES OF NATIVE AND MODIFIED STARCHES

In this section we will read about starch and modified starches. We will first look at the structural components of starch and go on to talk about its properties and finally a detailed discussion on the varied uses of starch in our food. The next sub-section will focus on modified starches.

2.2.1 Starches

Can you name a few common food sources of starch in our diet? Yes potato, wheat, rice, corn (maize), tapioca, pasta etc. are some of the common food sources of starch in our diet. Table 2.1 presents the percentage of starch in some of the foods/food items.

Table 2.1: Starch percent in different foods

Food	Starch (%)
Baby foods	3-5
Beverages (bottlers emulsion)	0.2-0.3
Butter sauces	0.3-0.5
Cake mix and icing	0.3-0.5
Pourable	1.5-2.3
Spoonable	2.8-5.0
Gum candy	5-12
Harvard style beets	2-4
Marshmallows	0.5-1.0
Pie crust	0.5-1.2
Pie filling	3-5
Canned	4.5-6.5
Cooked	5-8
Instant	3-7

Starch is the major carbohydrate reserve in plant tubers and seed endosperm where it is found as granules. Starch is second only to cellulose in abundance as one of the main carbohydrates synthesized in plants. Starch also represents the primary energy source (60-80%) for many animals including humans. It's a very valuable ingredient to the food industry, owing to its versatility, consistent supply and relatively inexpensive cost. Starch is mainly used as a thickener but it can also function as an adhesive, binder, encapsulating agent, film former, gelling agent, water binder, texturizer, fat sparing agent with numerous other applications in the food and non food areas. We will learn about these various functions of starches in this section. But, first an understanding of its structure is important. Let us learn about the structure.

2.2.1.1 The Starch Granule – Structure and Characteristics

Starch is a polysaccharide, a chain of many glucose molecules. There are two types of glucose chains in starch. One is a simple chain called *amylose*, and the other is a complex branched form called *amylopectin* as indicated in figures 2.1(a) and 2.1(b).

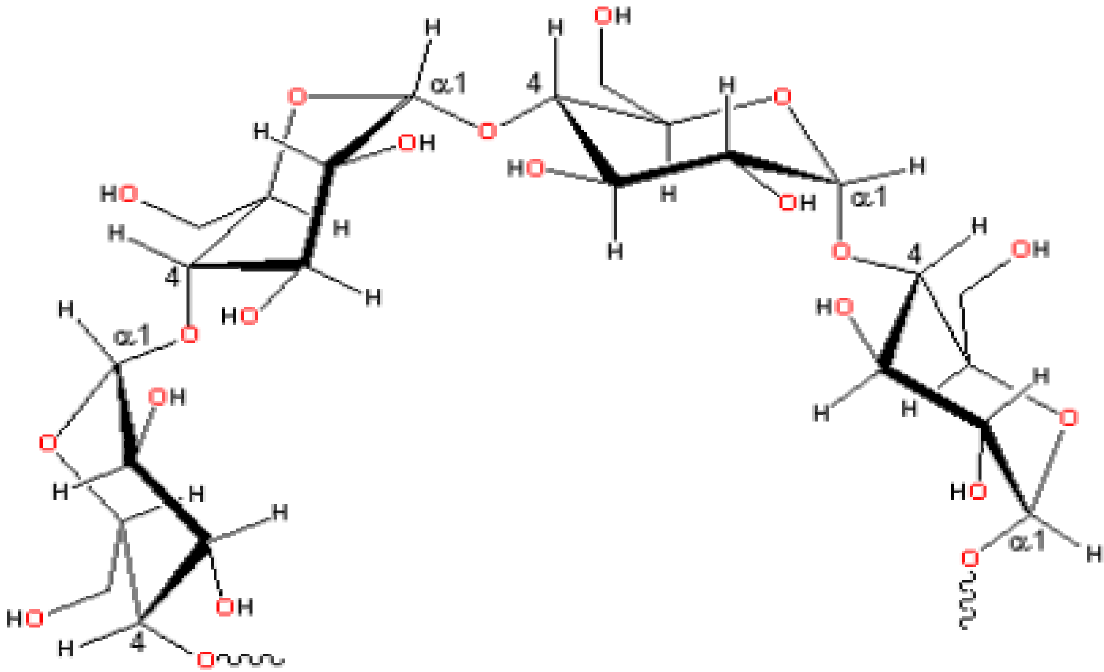

Figure 2.1(a): Representative Partial Structure of Amylose

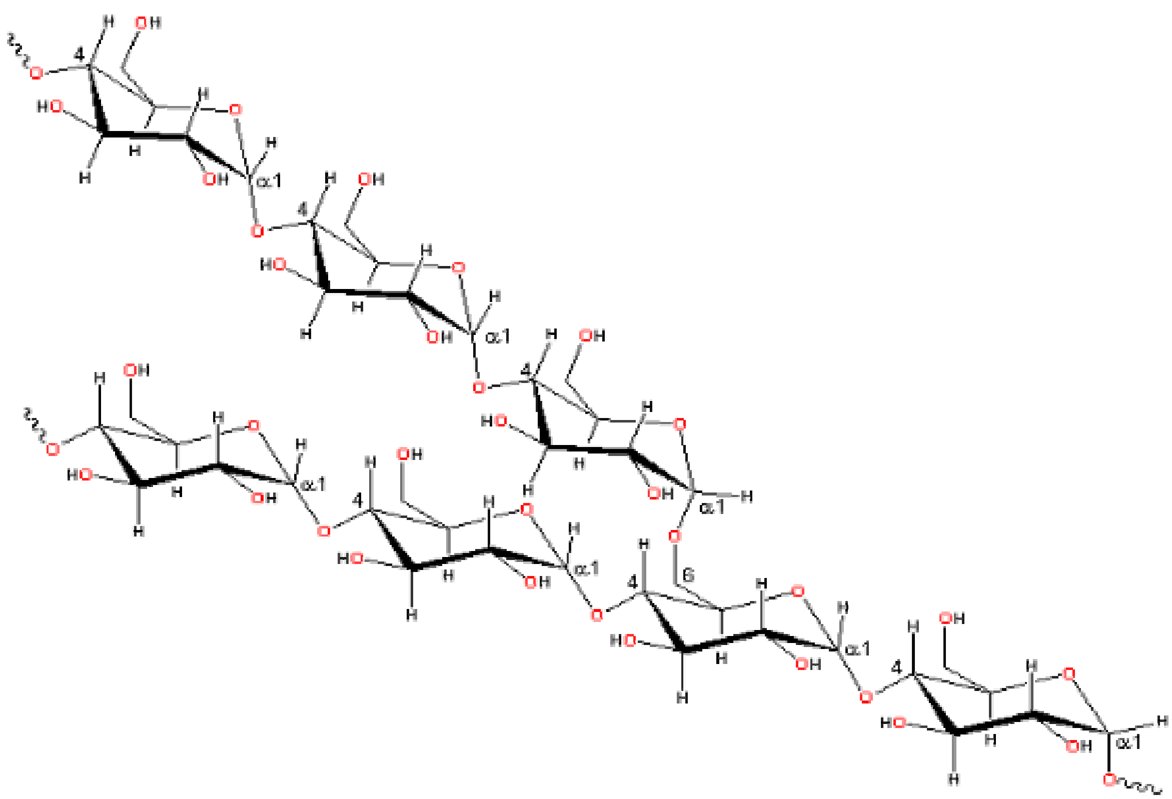

Figure 2.1 (b): Representative Partial Structure of Amylopectin

Starch granules, primarily, are made up of amylose (20-30%) and or amylopectin (70-80%) molecules arranged radially. Each granule typically containing several million amylopectin molecules, made up of several million glucose units, accompanied by a much larger number of smaller amylose molecules, made up of 500 to 20,000 glucose units in each chain. Amylopectin is the major component of most of the starches and is responsible for the organization of the granules. Amylopectin (without amylose) can be isolated from 'waxy' maize starch (is so termed because when the kernel is cut the new surface appears as vitreous or waxy), whereas amylose (without amylopectin) is best isolated after specifically hydrolysing the amylopectin with pullulanase.

Lets get to know a bit more about amylase and amylopectin, the building blocks of starch.

A. Amylose

Amylose molecules have molecular weights ranging from 10^4-20^6. Amylose can form an extended shape (hydrodynamic radius 7-22 nm) but generally tends to wind up into a rather stiff left-handed single helix or form even stiffer parallel left-handed double helical junction zones. The interior of the helix contains only hydrogen atoms and is lipophilic, while the hydroxyl groups are positioned on the exterior of the coil as can be seen in figure 1a. Most starches contain about 25% amylose. The two high amylose corn starches that are commercially available have apparent amylose contents of about 52% and 70-75%.

B. Amylopectin

Amylopectin forms a branched structure with about 30 glucose units in a chain between branches. There are usually slightly more 'outer' unbranched chains (called A-chains) than 'inner' branched chains (called B-chains) as indicated in figure 2.2(a). There is only one chain (called the C-chain) containing the single reducing group.

As indicated earlier, each amylopectin molecule contains up to two million glucose residues in a compact structure. The branched structure of the amylopectin makes the molecule somewhat striped in appearance, with the knotted branch points all in a row, and the smooth chains separating them. These molecules are so large that this stripped appearance shows up under the light microscope, forming what appears to be “growth rings” in the starch grain as can be seen in figure 2.2(b).

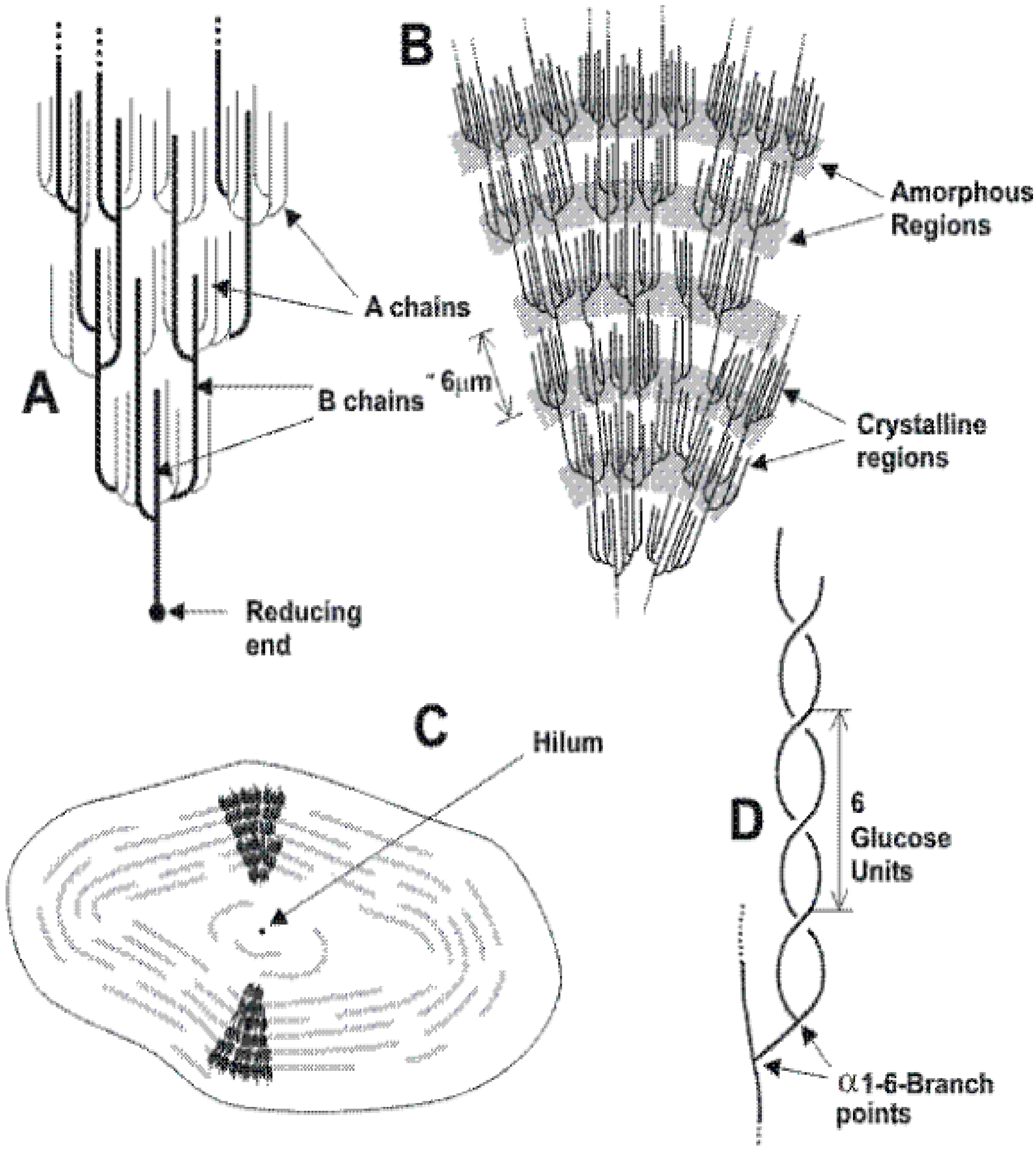

Figure 2.2: The amylopectin molecule

The salient properties of amylopectin and amylose are summarized in Table 2.2.

Table 2.2: Properties of Amylopectin and Amylose

Properties	Amylose	Amylopectin
General studies	Essentially linear	Highly branched
Average chain length(glucose residues)	20-25	20-30
Degree of polymerization	10-1000	10,000-100,000
Molecular weight	10^4-10^6	10^6-10^8
Reaction with iodine	Intense blue	Red violet
λmax (maximum of iodine starch complex)	Approx. 660nm	Approx.540nm
Conversion into maltose (%) a) with β-amylase b) with isoamylase, then with β-amylase	 Approx.100 Approx. 100	 Approx. 55 Approx.105
Iodine affinity (%)	19-20	1
Blue value	1-4	0.05
X-ray analysis	High degree of crystallinity	Amorphous
Solubility in water	Variable	Soluble
Stability in aqueous solution	Retrogrades readily	Stable

In plants, starch is packaged in granules, which vary in their shape and size, when isolated from different sources. The size of these granules varies from 2-150µ. The larger granule gelatinizes more easily while the smaller ones have better dispensability. In general, the granules from tubers are larger and spherical whereas those from cereals are small and polyhedric. The granules from legumes may be of kidney shaped.

With our knowledge of amylose and amylopectin let us move on to understand the properties of starches.

2.2.1.2 Starch Properties

Gelatinization and retrogradation are the basic properties of starches. What are these properties and its application in food industry, let's find out.

A. *Starch Gelatinisation*: Starch is insoluble in cold water but in warm water it swells until its gelatinization temperature begins to lose its structure and leaches out its constituents. This act of converting into a substance like jelly is called gelatinization. Gelatinization is a phenomenon which takes place in the presence of heat and moisture. Cooking the starch to 100^0 C disrupts H-bonding and causes swelling of the granule and solubilization of the constituent starch polymers. The suspension increases in viscosity, becomes less opaque and eventually forms a paste. This process is referred to as gelatinization. *During gelatinisation, water is absorbed and as a result, the starch granule swells irreversibly to several times of its size.*

Let us learn about starch gelatinization in more details. Undamaged starch granules are insoluble in cold water but can imbibe water reversibly i.e. they can swell slightly and then return to their original size on drying, when starch is heated with excess of water, the molecular order of the granule is gradually and irreversibly destroyed at the gelatinisation temperature, which is approximately in the range of 60-70°C for most of the starches. Amylose is preferentially leached out of the network and gets solubilized, however, some leaching of amylose can also occur prior to gelatinization. When further heated, starch granules are disrupted and partial solubilization is achieved. Total gelatinization usually occurs over a temperature range with larger granules generally gelatinizing first. At temperatures below 100° C, true molecular solution is not achieved and the swollen hydrated granules consisting of mainly amylopectin remain. Continued heating of starch granules in excess water results in further granule swelling, additional leaching of soluble components (primarily amylose) and eventually, total disruption of granules especially with the application of shear forces,. This phenomenon results in the formation of a starch paste. The melting temperature of the crystallites is 190°C. Gelatinization is an endothermic process (10 mJ/mg), i.e. a chemical reaction accompanied by the absorption of heat.

***B. Starch Retrogradatio**n:* The starch paste or solution obtained after the gelatinisation is not stable and generally produces a viscoelastic, firm and rigid gel. Structural transformation occurs during storage. As starch pastes are cooled and stored, the starch becomes progressively less soluble. In dilute solution, starch molecules will precipitate, with the insoluble material being difficult to redissolve by heating. *The collective processes of dissolved starch becoming less soluble are called retrogradation.*

Retrogradation of cooked starch involves constituent polymers, amylose and amylopectin, with amylose undergoing retrogradation at a much more rapid rate than does amylopectin. Upon cooling, the dispersed starch polysaccharides re-associate. Concentrated amylose solutions rapidly gel on cooling to room temperature. Subsequently, some of the amylose molecules slowly crystallize. The gel can only be melted at 160°C. The amylopectin with gelatinized granules can also crystallize but this association can be reversed by heating to 70°C. Thus after retrogradation of a starch-water mixture, a partially crystalline polymer system is again obtained.

After studying the structure, properties of starches we now move on to the functions of starches.

2.2.1.3 Functional Properties of Starches

You already know that starch is a major source of energy (calories) in grains and tubers, and foods made from them. However, when starch is added to products as an ingredient, it is the functional properties of the starch that are usually important, not the calories. Let us learn about these functional properties of starches.

Starches (being versatile and cheap) have an enormous number of food uses, including adhesive, bindings, clouding, dusting, film forming, foam strengthening, anti-staling, gelling, glazing, moisture retaining, stabilizing, texturizing and thickening applications as highlighted in Table 2.3.

Table 2.3: Functions of Starches

Functions of starch	Examples
Thickener	Puddings
	Sauces
	Pie fillings
Binder	Formed meats
	Breaded items
Encapsulation, Emulsion stabilizer	Flavours
	Bottlers emulsion
Coating	Candles
Water Binder	Cakes
Free flowing/ Bulking agent	Baking powder
Releasing agent	Candy making
Fat replacer	Salad dressing
	Baked goods
	Dairy products

Starch is the main thickener in gravies, sauces and puddings. You learnt under the properties that starch absorbs water, and becomes a gel when cooked. As the starch swells up with water, the amylose leaches out, and the amylopectin forms the gel. Some starches have higher amylopectin content, and make better gels than those containing lots of amylose. Remember, higher the amylose content lower is the swelling power and smaller is the gel strength for the same starch concentration. As a thickener (as opposed to a gel) it is the amylose that has the main function. The long water-soluble chains increase the viscosity, which does not change much with change in temperature. Amylose chains tend to curl up into helices (spirals) with the hydrophobic parts inside. This allows them to trap lipids (oils and fats) molecules inside the helix, as well as aroma molecules.

Because starches are so good at absorbing water and bulking/swelling up, they are important in the "mouth feel" of many food products, and are used as fat substitutes. Swelling power is determined after heating the starch in excess water and is the ratio of the wet weight of the sedimented gel formed to its dry weight. It will depend on the processing conditions (temperature, time, stirring, centrifugation) and may be thought of as its water binding capacity. This water binding ability of starches (high but relatively weak) can provide body and texture to food stuffs. Starches are added to processed meat (hot dogs, sausages etc.) as a filler, binder, moisture retainer, and fat substitute. They are used in extruded cereals, ready-to-eat breakfast cereals and snacks to hold the shape of the material.

A significant proportion of starch in the normal diet escapes degradation in the stomach and small intestine and is labeled *'resistant starch'* but this portion is difficult to measure and depends on a number of factors including the form of starch and the method of cooking prior to consumption. Resistant starch should be considered a dietary fiber and *can be defined as the sum of starch and products of starch degradation not absorbed in the small intestine of healthy individuals*. It serves as a primary source of substrate for intestinal microflora, which make important vitamins (and intestinal gas) and has several important physiological roles. Resistant starch has been categorized as physically inaccessible (RS_1), raw ungelatinized starch (e.g. in banana; RS_2), thermally stable retrograded starch (e.g. as found in bread, especially stale bread; RS_3) and chemically modified starch (RS_4). Many functional derivatives of starches are marketed including cross-linked, oxidized, acetylated, hydroxypropylated and partially hydrolyzed material. For example, partially hydrolyzed (i.e., about two bonds hydrolyzed out of eleven) starch (dextrin) is used in sauces to control viscosity.

So far we have studied about the native starches. You may have heard about modified starches. What are modified starches? The next section deals exclusively with modified starches- the types, characteristics and functions.

Check Your Progress Exercise 1

1. List a few applications of starches in the food industry.

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2. What do you understand by the terms retrogradation and gelatinization?

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3. Fill in the blanks:

(i) --------------------- component in the starch is responsible for the organization of starch granules.

(ii) The growth rings in the starch grain are due to -------------------------- .

(iii) The sum of starch and products of starch retrogradation not absorbed in the small intestine of healthy individuals is referred to as ------------------------------ .

(iv) The measurement of resistant starch depends upon ------------------------------------ --- .

(v) Swelling power of the starches is the ratio of --- -- .

2.2.2 Modified Starches

In your opinion, what would be an ideal starch for all industrial uses including in food use? Well, one would think an ideal starch for most of the foods should be able to produce a smooth texture with a heavy bodied consistency but no gel phase, have a bland flavour, give a clean transparent solution and paste, retain its thickening power at high temperature, high shear and low temperature. Unfortunately, native starches cannot satisfy this wide range of desirable properties. The shortcomings encountered for different applications could be the lack of free flowing properties of water repellence of the starch granules, insolubility or failure of the granules to swell and develop viscosity after cooking, cohesive or rubbery texture of the cooked starch particularly of waxy corn, potato and tapioca starch, the sensitivity of the cooked starch to breakdown during extended cooking when exposed to shear or low pH, the lack of clarity and the tendency of starch sols from conventional cereal starches to become opaque and gel when cooled etc.

The native starches are, therefore, modified to overcome one or more of the above shortcomings thus expanding the usefulness of starch for myriad of industrial applications. Food starches, which have one or more of their original characteristics altered by treatment in accordance with good manufacturing practice, are therefore, referred to as *modified starches.*

Food scientists have developed a number of modified starches by reactions on granular starches. What are these modifications? Let's find out.

2.2.2.1 Modification of Food Starches

Positive attributes of starches can be greatly improved and/or negative characteristics diminished by slight and relatively simple modifications. Modifications of native starch are designed to change one or more of the following properties:-

(i) Gelatinization temperature and cooking characteristics.
(ii) Solid viscosity relationships.
(iii) Retrogradation characteristics.
(iv) Ionic character.
(v) Resistance to changes in viscosity of pastes due to acid conditions, mechanical shear, high temperature.

Modification of native starch can be either physical or chemical. Chemical modification includes reaction of starch with acid or alkali and is called *acid modified starch and oxidized starch,* respectively. *Hydrolysis* was a commonly used method of modification since long time and vinegar as well as amylolytic enzymes were used for this treatment.

Starch modification can also be induced by modifying the processes of starch biosynthesis by targeting and manipulating specific enzymes using transgenic technologies, thus leading to the production of novel materials with dedicated commercial applications.

In the case of starches treated with heat in presence of acid or alkali, the alteration is a minor fragmentation; similarly, when the starch is bleached, the change is essentially in color only. Oxidation involves the deliberate production of carboxyl group in the molecule. Treatment with reagents, such as orthophosphoric acid results in partial substitution in the 2, 6 or 3 position of the anhydroglucose unit unless the 6-position is occupied for branching. In case of cross bonding, where a polyfunctional substituting agent such as phosphorous oxychloride connects two chains, the structure can be represented by starch –O-R-O- starch (where R=Cross bonding group and starch refers to the linear and/or branched structure). The commercial sample can be specified by the parameter specific for the particular type of modification and also may be further specified, as to the loss on drying, sulfated ash, protein and fat.

Improved performance of starches may be realized by physical and chemical modifications. The major physically modified starch is pre-gelatinised starch. It swells in cold water giving an instant paste. It is used in all cases where a cold water paste is needed such as in convenience foods. In applications requiring specific and narrow process and product requirements, chemically modified or "TAILOR MADE" food starches have been the most successful.

A brief summary of various modified starches is presented in Table 2.4.

Table 2.4: Preparation and properties of modified starches

	Product	Methods	Properties	Uses
1	Acid modified (Thin boiling)	Conc. Starch slurry + 1-3% acid; about 50^0C, 12 hr	Low paste viscosity, disintegrates easily, more soluble, higher GT, higher gel strength	Candy, textile laundry
2	Oxidized (thin boiling)	Slurry + alkaline sodium hypochlorite, pH 8-10, 21-38^0C	Lower GT, easy pasting, low paste viscosity, more soluble, cold sol fluid and clear	Oxidized starch has been applied in foods as coating and sealing agents in confectionery, as emulsifier, as dough conditioner for bread, as gum Arabic (a NSP) replacer and as binding agent in batter application.
3	Esters Acetate	Slurry + acetic anhydride; <50^0C	Lower GT, swells easily, higher peak viscosity, resistant to reassociation, cold sol fluid and clear, freeze thaw stable	Provides excellent stabilizing and thickening performance for use in baked, frozen, canned, dry foods, gravies etc.
4	Phosphate monoester (anionic)	Starch+ phosphate salt; 120-140^0C	-do-, Being ionic, susceptible to salts. At 0.07DS, swells in cold water.	Used as emulsifiers for vegetable oil in water systems and as pudding starches and thickening agents.
5	Ethers – Hydroxyethyl starch, hydroxypro-pyl starches	Slurry + alkali + ethylene oxide	-do- Ether linkage not cleaved by acid, alkali, oxidation, hence can be used under drastic conditons. Non-ionic, so unaffected	Hydroxypropyl starches find application as coffee whiteners, thickener in a multitude of food and food related products. The outstanding storage stability and freeze/thaw properties

			by electrolytes.	of these starches make them a premier product for the food industry.
6	Cationic starch Tertiary amino alkyl ethers	Slurry + halogenated or apoxy alkylamine + NaoH; 40-45^{0}C, 6-12 hr, then acid	-do- Active even at low pH. At 0.07 DS, swells in cold water. If very high DS, thermoplastic	Not often used for food purposes.
7	Cross bonded	Mixed anhydride phosphorous hypochlorite trimeta-phosphate, epichlorohydrin + alkali + heat.	Paste viscosity remarkable stable to cooking, temperature, acid, shear,'short' non-cohesive gel. If highly cross-linked, does not swell.	Because of commercially important viscosity-textural properties, it is often employed in conjunction with other types of modification such as oxidation, phosphorylation and esterification
8	Pre gelatinized	Slurry drum dried, extrusion	Swells in cold	All (convenience foods)

GT ; Gelatinisation temperature ***DS ; Degree of substitution***

A detailed discussion on the various uses of modified starches follows.

2.2.2.4 Uses of modified starches in food and confectionery industries

Visit a grocery shop and look out for products such as the instant desserts, jelly beans, salad dressings, tomato and pizza toppings, canned soups etc. You would be surprised to learn that all these and many such products have modified starches as ingredients. Modified starches are used in a variety of products. Many types are available and have different functions depending on the way in which the starch has been modified. Few examples of products containing modified starches and how it works is illustrated herewith.

Types of starches and their action

Product	Modified Starch	How it does work?
Instant Desserts	Enables the product to thicken without requiring heat.	Starch is added in a pre-gelatinized form which swells in cold water, thickening the product without the use of heat.
Jelly Beans	Produces a very strong gel coating.	Starch is treated with an acid to produce very strong gel. This forms the shell of the jelly bean.
Salad Dressing	Helps to stabilise an oil-in-water emulsion.	French dressing the hydrophobic part of the starch wraps around the oil droplet, so the hydrophilic (water loving) part of the starch is in contact with the water. This keeps the oil droplets suspended in the water.
Tomato and Pizza Toppings	Produces a gel which thickens on heating, preventing the topping from boiling over.	Starch is treated with a chlorine solution. This produces a get which thickens on heating and prevents the topping from spilling over. On cooling the topping flows.
Battered Fish	Improves the adhesion of the coating.	Oxidation of starch can improve its binding properties, which can be used to increase the stickiness of foods, such as batter applied to fish.
Canned Soups	Prevents the product from separating on standing.	Bonding starch with phosphate allows the starch to absorb more water and helps keep the ingredients of the soup together.

Uses of oxidised starches are further illustrated herewith.

Oxidised starch finds a number of uses in the food industry where a neutral tasting, low viscosity ‘body builder’ is required as in lemon curd manufacture, in salad creams and mayonnaises etc. Oxidised starch has been used to replace gum arabic a NSP, in gum-drop and pastille types of confectionary since it has good film forming properties.

Oxidised starches prepared from corn and waxy amaranth starch under conditions optimised for development for film forming ability were compared with gum arabic and a known substitute of gum arabic for encapsulation of a model flavour compound, vannilin. It was found that in making jelly and marmalade, the gelatinising rate and stability of the product was increased when 5% of sodium alginate was added to the oxidised starch. Attempts were made to replace gum arabic in gumdrops with oxidised waxy maize starch.

With the uses of modified starches, we come to an end on our discussion on native and modified starches. We will take up the next important constituent–non-starch polysaccharides (NSPs) – in the next section. Non-starch polysaccharides are primarily hydrocolloids. What do we mean by hydrocolloids? So then we start our discussion with an introduction to hydrocolloids in the next section. But first let's take a break. After the break answer the exercises given in check your progress exercise 2. This will help you consolidate your knowledge regarding modified starches.

Check Your Progress Exercise 2

1. What do you understand by the term 'modified starch'?

   ----

2. List a few shortcomings of native starches which make it unacceptable in certain food applications.

   ----

3. Give the uses of the following modified starches in food applications:

(i) Oxidized starch

(ii) Starch acetates

(iii) Starch phosphates monoesters

(iv) Hydroxypropyl starches

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4. Fill in the blanks:

(i) Native starches can be modified by the processes such as ---------------------------- -- .

(ii) ---------------------------- starch has applications in the production of convenience foods.

(iii) Specific reagents of --------------------------- starch have been approved by FDA to make paperboard.

2.3 FOOD HYDROCOLLOIDS – AN INTRODUCTION

What are food hydrocolloids? Food hydrocolloids are *hydrophilic polymers of vegetable, animal, microbial or synthetic origin that generally contain many hydroxyl groups and may be polyelectrolytes*. They are naturally present or added to control the functional properties of aqueous foodstuffs. Most important among these properties are viscosity (including thickening and gelling) and water binding but also significant are emulsion stabilization, prevention of ice recrystallization and organoleptic properties. Some of the important food hydrocolloids are listed below:

- Alginate
- Carboxymethyl Cellulose
- Guar gum
- Gum Arabic
- Xanthan Gum
- Carrageenan

All hydrocolloids interact with water, reducing the diffusion and stabilizing it. Interaction between hydrocolloids and water depend on hydrogen bonding and, therefore, on temperature in the same way as water cluster formation. Water binding affects texture and processing characteristics, prevents syneresis and may have substantial economical benefit. In particular, hydrocolloids can provide water for increasing the flexibility (plasticizing) of other food components. These can also affect ice crystal formation and growth so exerting a particular influence on the texture of frozen foods. Most of the hydrocolloids are used to increase viscosity, to stabilize foodstuffs by preventing settling, phase separation, foam collapse and crystallization.

Hydrocolloids are extremely versatile and are used for many other purposes including:

(a) Production of pseudoplasticity (i.e. fluidity under shear) at high temperatures to ease mixing and processing followed by thickening on cooling,
(b) Liquefaction on heating followed by gelling on cooling,
(c) Gelling on heating to hold the structure together (thermogelling), and
(d) Production and stabilization of multiphase systems including films

The hydrocolloids not only have the functional properties but also have nutritional characteristics. Most polysaccharide gums are not metabolized in the upper digestive tract but pass into the large intestine with little or no change. Some sugars get converted to short chain fatty acids that are eventually absorbed and metabolized. However most gums function as soluble dietary fibre and provide negligible calories. For this reason, these have been particularly useful in recent years as zero-calorie fat replacers, especially in high fat systems, such as dairy products and salad dressings. Gums are used in low calorie foods to thicken or improve body, cover flavours, provide bulk, aid in carbonation retention and control ice crystal formation.

Hydrocolloids, together with other dietary fibres are increasingly being seen as contributing to a number of health effects. Some of the hydrocolloids are common bulk forming laxatives. These are used to modify diarrhoea. Also, the symptoms of diverticular disease are alleviated by increasing intakes of dietary fibre. In a variety of diabetic subjects, both guar gum and pectin reduce blood glucose level and insulin response. Maximal response is observed in obese diabetics. The mechanism of action of dietary fibre in general, and gel forming polysaccharides in particular, on serum cholesterol through the binding of bile acids in the gut may impart hypocholesteremic effect i.e. cholesterol lowering effect of dietary fibre.

With the basic understanding about food hydrocolloids let us move on to the classification of hydrocolloids which is presented next.

2.3.1 Classification of Hydrocolloids

Hydrocolloids, based on their solubility, thickening and gelling properties in water, are categorized into two major classes. These are:

- Natural gums
- Modified or semi synthetic gums

A brief review follows.

A. Natural Gums: These are derived from various plant as well as microbial sources and are divided into the following four basic categories:

1. *Seaweed gums*: Agar, Alginate, Carrageenan
2. *Tree extracts*: Gum Arabic, Gum ghatti, Gum karaya, Gum tragacanth.
3. *Seed or root gums*: Guar gum, Locust bean gum
4. *Microbial fermentation gums*: Xanthan gum, Pullulan, Dextran, Curdlan

B. Modified or Semi-synthetic Gums: These are natural polymers, which are chemically modified to give a new product with improved functional properties. These also fall into several different areas but the most commonly used include: carboxymethyl cellulose, methyl cellulose, hydroxypropylmethyl cellulose, hydroxypropyl cellulose, ethyl hydroxyethylcellulose, microcrystalline cellulose, hydroxybutylmethyl cellulose.

Each gum has it own functional properties and is considered on individual basis for its use in food industries. The usefulness of most gums is based on their ability to modify the basic property of water. Some gums swell completely in water, while others swell partially and dissolve partially in water. Some dissolve in hot water, while others are soluble in cold water. These solutions or dispersions are important in food application because they add body or textures to a food product, thus imparting the proper thickness or gel character or mouth feel in a particular product. They help to stabilize the suspensions (solids dispersed in water), emulsions (oil dispersed in water), and foams (gas dispersed in water).

The use of the gums in various foods may affect the following functional properties:

1. Water-binding capacity
2. Rheological properties
3. Capacity to form film or gel
4. Osmotic pressure
5. Capacity to bind flavor compounds
6. Hygroscopicity
7. Chemical reactivity
8. Sweetening and taste enhancement
9. Resorption

These properties have numerous technological and application capabilities that include thickening, emulsification, stabilization of emulsions and foams flow properties, texture, softness retention, browning, fermentability, control of microbial and enzymatic modifications and stabilization of taste and flavor. Table 2.5 shows the multiple functions of the gums in the food industry:

Table 2.5: Functions of Gums

Function	Example
Adhesive	Bakery glaze
Binding agent	Sausages
Calorie control agent	Dietetic foods
Crystallization inhibitor	Ice cream, sugar syrups
Clarifying agent	Beer, wine
Clouding agent	Fruit juice
Coating agent	Confectionery
Emulsifier	Salad dressing
Encapsulating agent	Powdered flavors
Film former	Sausage casings, protective coatings
Flocculating agent	Wine
Foam stabilizer	Whipped toppings, beer
Gelling agent	Puddings, dessert
Molding	Gum drops, gelly candies
Protective colloid	Flavor emulsifiers
Stabilizer	Beer, mayonnaise
Suspending agent	Chocolate milk
Swelling agent	Processed meats
Thickening agent	Jams, pie fillings, sauces
Water binding (prevents syneresis)	Cheese, frozen foods
Whipping agent	Toppings, icings

Other than the classification based on their solubility, thickening and gelling properties in water, hydrocolloids are also classified based on their functions as indicated in Table 2.6.

Table 2.6: Classification of hydrocolloids by function

Hydrocolloids	Thickener	Gelling agent	Stabilizer
Guar gum	+	-	-
Locust bean gum	+	-	-
Pectin	-	+	+
Alginate	+	+	+
Agar	-	+	+
Carrageenan	-	+	+
Cellulose	+	-	-
Gum tragacanth	+	-	-
Gum arabic	+	-	-
Starches	+	-	+
Xanthan gum	+	-	+

The discussion above presented a detailed overview on the classification of hydrocolloids. It must be clear to you now that gum ghatti, gum karaya, gum tragacanth (classified as exudate gums) locust bean gum, guar gum (classified as seed gums) and pullulan, xanthan, curdlan, dextran etc.(microbial polysaccharides) along with conventional nonstarch polysaccharides such as cellulose, hemicellulose and pectin which are cell wall polysaccharides are all food hydrocolloids. Now let us study about each of these food hydrocolloids separately. We start our discussion with NSPs, particularly the plant cell wall polysaccharides.

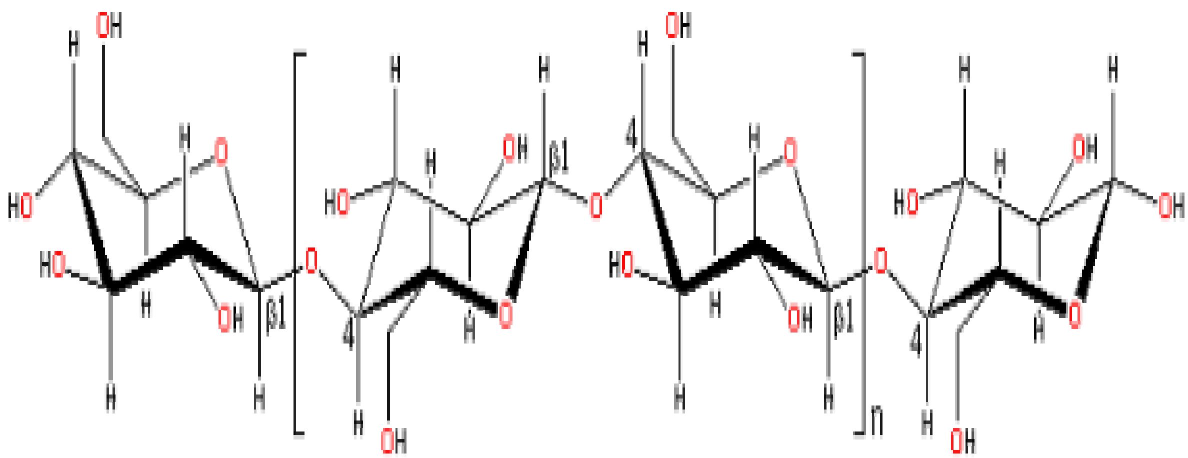
2.4 NON-STARCH POLYSACCHARIDES

Earlier in this unit we summarized the classification of carbohydrates. We presented a brief review on starch, a polysaccharide often termed as complex carbohydrate. Besides starch, a mixture of substances called non starch polysaccharide (NSP), also constitute carbohydrates. This section focuses on the study of NSP.

Dietary fibre, a term familiar to all of us, is also known as non-starch polysaccharides (NSP). It is the name given to a group of materials found in the cell walls of plants which give the plant its structure and form. It includes those carbohydrates that are not digested or absorbed, but pass through to the colon where bacteria ferment them for energy, thereby stimulating their growth. Because the term 'dietary fibre' describes a nutritional concept rather than a component of diet, it has been suggested that the term be phased out and replaced with the term 'NSP' but this has been difficult because the word fibre is so widely used. Examples of NSP include cellulose, pectin, gums, beta-glucans etc. In this section we will learn about these different non-starch polysaccharides. The major polysaccharides in the plant cell wall are cellulose, carboxymethyl cellulose, hemicellulose and pectin. Let's learn about them. We start with the plant cell wall polysaccharides, cellulose.

2.4.1 Cellulose

Cellulose is found in plants as microfibrils (2-20 nm diameter and 100–40,000 nm long). These form the structurally strong framework in the cell walls. Cellulose is mostly prepared from wood pulp. Structurally, cellulose is a β1→4 linked glucan, as you can see in the figure 2.3.



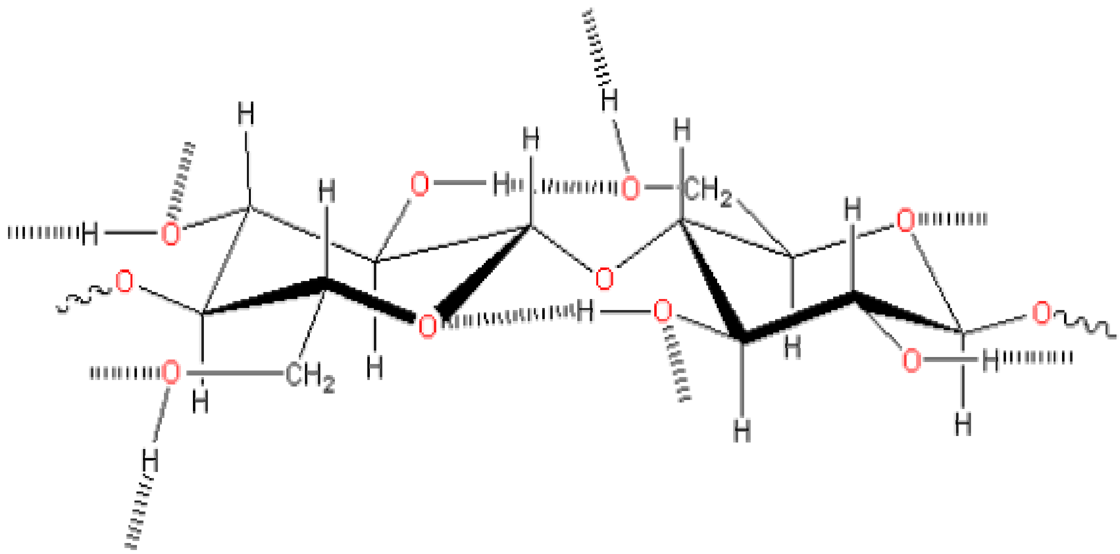


Figure 2.3: Structure of Cellulose

Let us take a close look at the functional properties of cellulose and how these serve an important role in various food applications.

Functionality

Cellulose has many uses as an anticaking agent, emulsifier, stabilizer, dispersing agent, thickener and gelling agent, but these are generally subsidiary to its most important use of holding water. Dry amorphous cellulose absorbs water becoming soft and flexible. Some of this water is non-freezing but most is simply trapped. Less water is bound by direct hydrogen bonding if the cellulose has high crystallinity but some fibrous cellulose products can hold on to considerable water in pores and its typically straw-like cavities. As such water is supercoolable, this effect may protect against ice damage. Cellulose can give improved volume and texture, particularly as a fat replacer in sauces and dressings but its insolubility means that all products will be cloudy.

Swelled bacterial cellulose (*eg. Acetobacter xylinum*) exhibits pseudoplastic viscosity, like xanthan gels but this viscosity is not lost at high temperatures and low shear rates as the cellulose can retain its structure. Where individual cellulose strands are surrounded by water, they are flexible and do not present contiguous hydrophobic surfaces.

About one third of the world's production of purified cellulose is used as the base material for a number of water-soluble derivatives with predesigned and wide ranging properties. Methylcellulose (made by methylating about 30% of the hydroxyl groups) is thermogelling i.e. forming gels above a critical. Such gels break down on cooling causing the minimum solubility for non-polar gases. Hydrophobic saccharides become less soluble as the temperature increases. This property is useful in forming films as barriers to water loss and for holding on to small gas bubbles. Hydroxypropyl cellulose possesses good surface activity but does not gel as it forms open helical coils. Another important derivative of cellulose is carboxymethylcellulose. Let us learn about its properties and food applications.

2.4.2 Carboxymethyl Cellulose (CMC)

CMC is a linear, long-chain, water-soluble, anionic modified polysaccharide. It is a derivative of cellulose formed by its reaction with alkali and chloroacetic acid. Its structure is presented in the figure 2.4. Purified CMC is a white to cream colored, tasteless, odorless and free-flowing powder. This latter characteristic is maintained only by adequate packaging, as the material readily absorbs atmospheric moisture.

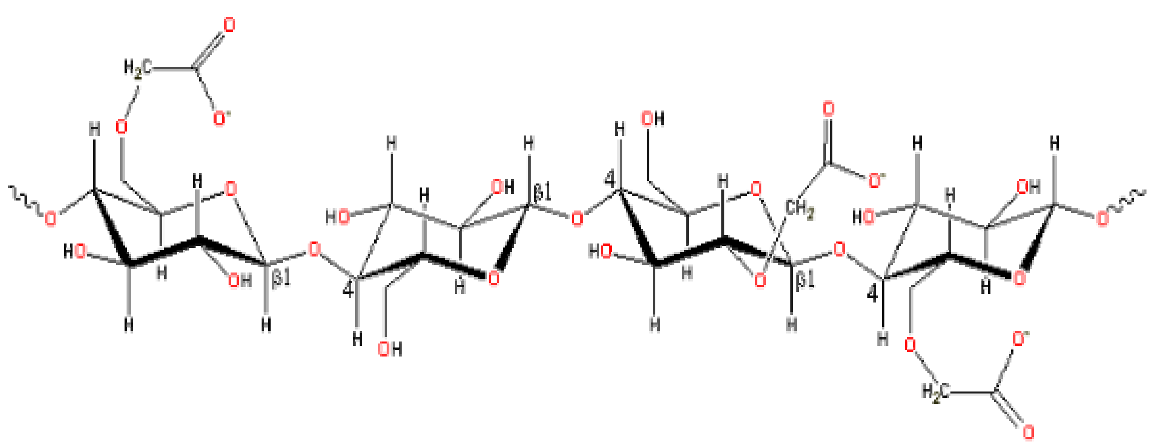


Figure 2.4: Structure of Carboxymethyl Cellulose

Let us look into the properties of CMC, to determine their usefulness in food applications.

Functionality

CMC is soluble in cold water and mainly used for controlling viscosity without gelling. As its viscosity drops during heating, it may be used to improve the volume yield during baking by encouraging gas bubble formation. Its control of viscosity allows uses as thickner, phase and emulsion stabilizer (e.g with milk casein), and suspending agents. CMC can be used for its water-holding capacity as this is high even at low viscosity, particularly when used as $Ca^{2}+$ salt. Thus it is used for retarding staling and reducing fat intake into fried foods.

CMC is compatible in solution with most common food ingredients including protein, sugar, starches and other hydrocolloids. Like other water-soluble gums it forms films by casting and evaporating the water from solutions and clear films may be obtained. Better strength and flexibility of such films result when they are prepared with high viscosity type CMC.

In common with other linear water-soluble polymers, cellulose gum solutions are pseudoplastic that is the viscosity decreases as the rate of shear increases. Some of the food applications of CMC are highlighted in Table 2.7.

Table 2.7: Food applications of CMC

Industry/Food	Function	Properties utilized
Baked goods	Adhesion, fat exclusion	Film formation, viscosity
Beverages	Body, texturizer, stabilizer	Rheological, dispersant
Frozen desserts	Texturizer, stabilizer	Crystal growth retarder, inhibition
Low fat, low calorie Foods	Fat & sugar substitute	Rheological
Milk & yoghurt drinks	Stabilization	Interaction with milk protein, dispersant
Pet foods	Binder, lubricant	Adhesion, rheological
Sauces, syrups & Toppings	Stabilization, thickening	Rheological

2.4.3 Hemicellulose

In plant cell walls, the most abundant compound present is α-cellulose with long fibers embedded in a matrix of cementing compounds (matrix polysaccharides). These compounds are alkali soluble and are called as hemicelluloses. They constitute about 20-30% of plant cell walls.

Hemicellulose is defined as a large polysaccharide, which helps give structure to plant cells. Hemicellulose gives fruits and vegetables crisp, chewy, fibrous characteristics that partially remain after cooking. Along with pectin, it forms an amorphous matrix in which cellulose fibrils from the plant cell walls are embedded. It has the chemical formula of $C_6H_{10}O_5$ and consists of a chain of D-xylose sugar units which has side chains of units of other sugars branching off it as shown in figure 2.5.

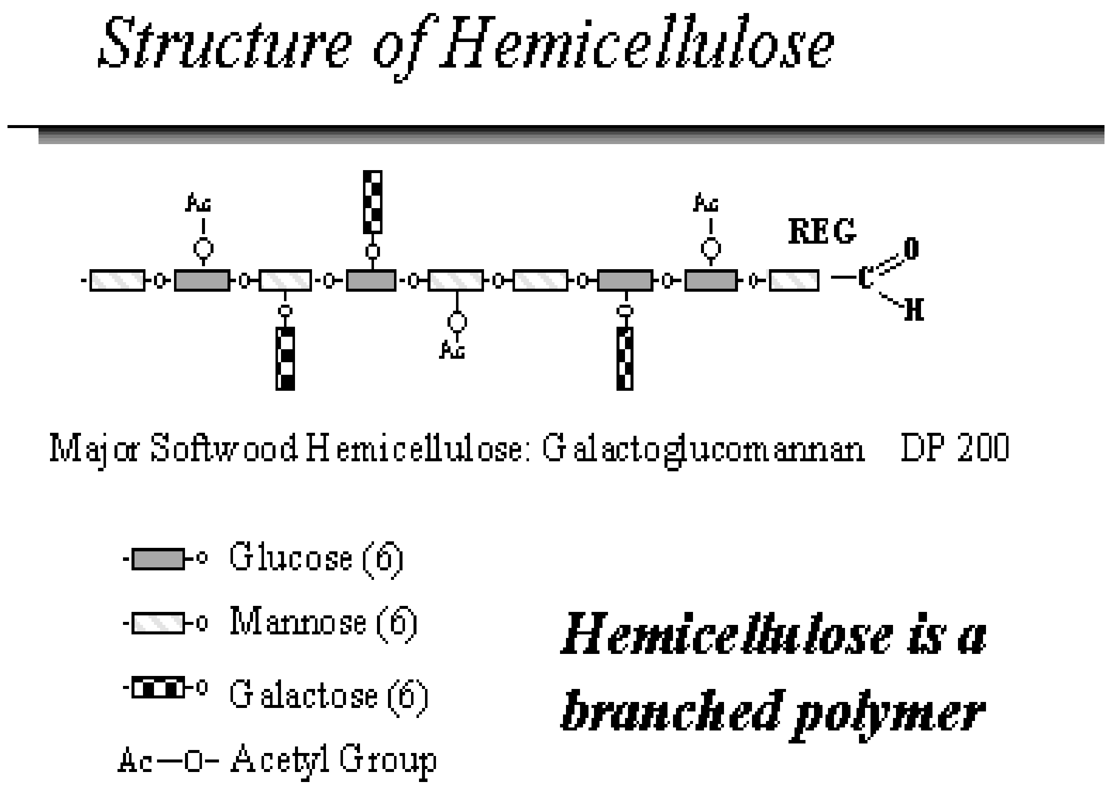


Figure 2.5: Structure of Hemicellulose

When compared with cellulose, it has lower degree of polymerization, more readily soluble in acid and alkali and non-fibrous. On hydrolysis, it predominantly yields xyloses and other monosaccharides. Hemicelluloses include xylan, glucuronoxylan, arabinoxylan, glucomannan and xyloglucan. It is easily hydrolyzed by dilute acid or alkali or enzyme hemicellulase (such as endo-xylanase, beta-xylosidase, and alpha-L-arabinofuranosidase for hemicellulose). Important sources of hemmicellulose include *seed coats of corn, cereal brans, wheat oats, barley and rice.* Other possible sources are *skins of sugar beets, potatoes and tomatoes.*

There are two forms of hemicellulose - *Hemicellulose A and B* - Hemicellulose A is precipitated upon neutralization of an alkaline extract, essentially linear polymers, while Hemicellulose B precipitates on addition of ethanol to the neutralized extract (to a final concentration of 60-70%). Now let's understand the various nutritional effects of hemicellulose, followed by its application in the food system.

Nutritional effects

Hemicelluloses are classified under the category of soluble dietary fibers. Hemicellulose is an indigestible complex carbohydrate that absorbs water. It is good for promoting weight loss, relieving constipation and controlling carcinogens in the intestinal tract. A commercial product (β-glucans based) possess the ability to reduce serum cholesterol. Oat and barley β-glucans when taken in foods reduce postprandial serum glucose levels; reduce insulin response and serum cholesterol levels. Hemicellulose can be converted to a number of value-added fermentation products such as fuel ethanol, xylitol, butanediol, and lactic acid.

Food Applications

The hemicelluloses find their application in food systems as emulsifer, stabilizer and binder in flavor bases, dressings and pudding mixes. These may also be used as a potential bulking agent. These are good source of dietary fiber and stimulate the immune system. Its properties suggest usefulness as a low-viscosity thickener and / or emulsion stabilizer, for eg. corn oil / water emulsions are stabilized by corn fiber gum. It also finds potential usefulness in pourable dressings. It may also act as a fat replacer / mimetic.

2.4.4 Pectin

The word pectin is derived from a *Greek* word which means to *"congeal or solidify*". Pectin is an acidic structural polysaccharide, found in fruit and vegetables and mainly prepared from 'waste' citrus peel and apple pomace (skin). Pectin is present as a structural polysaccharide in the middle lamella and primary cell wall of higher plants. Its structure is presented in the figures 2.6 (a) and (b). Pectin is a polygalacturonic acid ester along with rhamnose, arabinose and galactose.

Pectin is also industrially extracted from apple and citrus pomace and traded internationally in purified and standardized forms. There are three main types of pectin - Low Methoxy Pectin (<50% methylester groups), High Methoxy Pectin (>50% methylester groups) and amidated Pectin.

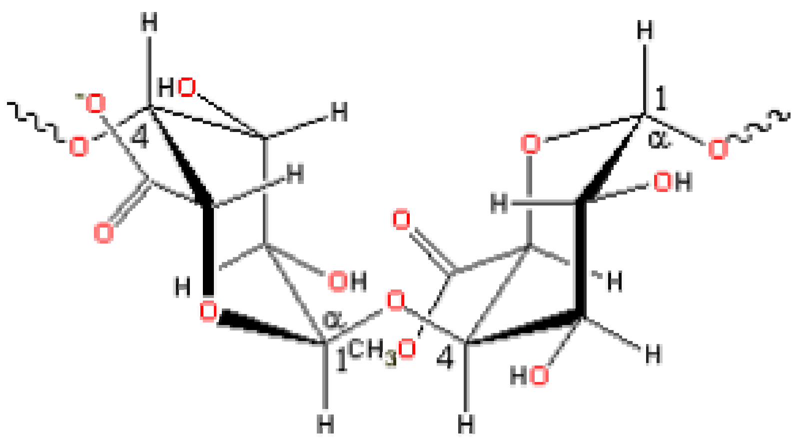


Figure 2.6 (a): Pectin: Smooth Structure

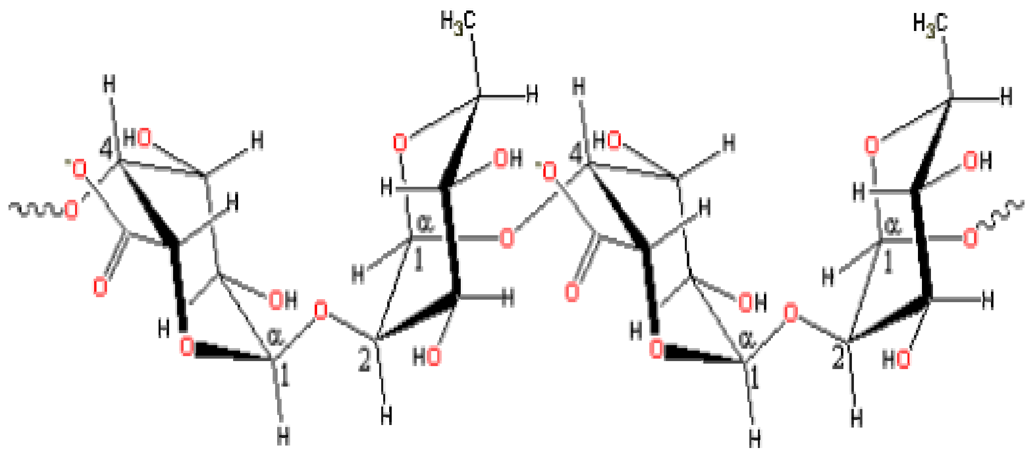


Figure 2.6 (b): Hairy Structure

Pectin is generally soluble in water and insoluble in most organic solvents. Pectin solutions show relatively low viscosities than other plant hydrocolloids and consequently has limited use as a thickener. Low-ester pectin forms gels in the presence of calcium and other divalent metal ions. These properties of pectin contribute to the functionality of pectin, which is discussed next.

Functionality

Pectins are mainly used as gelling agents, but can also act as a thickener, water binder and stabilizer. Low methoxyl pectins (<50% esterified) form thermoreversible gels in the presence of calcium ions and at low pH (3 - 4.5), whereas, high methoxy pectin's rapidly form thermally irreversible gels in the presence of sufficient (e.g. 65% by weight) sugars, such as sucrose and at low pH (<3.5). The lower the methoxy content, the slower is the setting. The degree of esterification can be reduced using commercial pectin methylesterase, leading to a higher viscosity and firmer gelling in the presence of Ca^{2+} ions. Highly acetylated pectin from sugar beet is reported to have considerable emulsification ability due to its more hydrophobic nature, but this may be due to associated protein impurities.

As with other viscous polyanions such as carrageenan, pectin may be protective towards milk casein colloids, enhancing the properties (foam stability, solubility, gelation and emulsification) of whey proteins whilst utilizing them as a source of calcium. Some food applications of pectin are summarized in table 2.8

Table 2.8: Food Applications of Pectin

Product group	Function of pectin	Pectin level (%)
Jams, jellies and preserves	Gelling agent, thickener	0.1-1.0
Bakery fillings and glazing	Gelling agent, thickener	0.5-1.5
Fruit preparations	Thickener, stabilizer	0.1-1.0
Fruit beverages and sauces	Thickener, stabilizer	0.01-0.5
Confectionery	Gelling agent, thickener	0.5-2.5
Diary products	Stabilizer, gelling agent	0.1-1.0

The discussion above focussed on dietary fibres, particularly the plant cell wall polysaccharides. It would be interesting for you to know that there are seven major categories of fibers including cellulose, hemicellulose, pectic substances, gums, mucilage, algal polysaccharides, and lignin. Cellulose, hemicellolose, pectin etc. are plant cell polysaccharides. Cellulose is the most common of these fibers. Gums are actually substances secreted by plants in response to injury. Mucilages are also water-soluble, and are used by plants to protect seeds. Algal polysaccharides are extracted from algae. These all are classified as dietary fibres (also referred to as non starch polysaccharides). Next, we shall focus on algal polysaccharides and learn about the different algal polysaccharides, their structure and function.

Check your Progress Exercise 3

1. Explain the following terms:

a) NSP

----

b) Food hydrocolloids

----

2. List a few important uses of food hydrocolloids.

----

3. What are the functional properties of gums that are considered to be important in food industries?

----

4. How does cellulose differs from starch?

----

5. Fill in the blanks:

a) The most important use of cellulose is its -------------------------------- .

b) The calcium salts of CMC, because of its water holding capacity, is used for ------ -- .

c) The food applications of hemicelluloses are -- --

d) The main types of pectin are --- --- .

2.5 ALGAL POLYSACCHARIDES

The main algal polysaccharides include agar, alginate and carrageenan. Let us get to know about them.

2.5.1 Agar

Agar is a polysaccharide found in the cell walls of some red algae and is unusual in containing sulfated galactose monomers. Certain marine algae of the class *Rhodophyceae,* called Red Sea weeds are the source of this polysaccharide. Some of the chief algal sources are *Gelidium cartilagineum, Gracilaria conferroides* and *Pteroclaia capillcea.* The structure and composition of the agar extract of *Gelidium amansii* showed that it is composed of two major fractions – *agarose*, a neutral polymer and *agaropectin,* a charged, sulfated galactan (Galactose, 3-6-anhydrogalactose). The ratios of these two polymers vary widely and the percentage of agarose in agar-bearing seaweeds ranges from 50% to 90%. The composition of agar is discussed herewith along with the structure as shown in the figure 2.7.

Composition: Agar we learnt consists of a mixture of agrose and agropectin. Agrose has a linear polymer structure consisting of alternating D-galactose and 3,6-anhydro-L-galactose as shown in figure 2.7. Agaropectin is a heterogeneous mixture of smaller molecules that occur in lesser amounts. Their structures are similar but slightly branched and sulfated, and they may have methyl and pyruvic acid ketal substituents

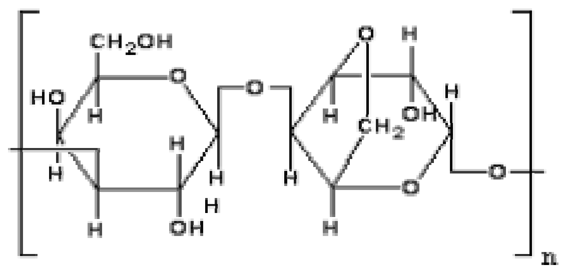


Figure 2.7: Structure of Agar and Agarose

We will briefly discuss the main properties of Agar, i.e. gelation and viscosity and its food applications next.

Agar we have learnt is a polysaccharide found in the cell walls of some red algae and is unusual in containing sulfated galactose monomers. It requires nothing but extraction and purification to become agar. It is sometimes chemically modified into agarose for special applications. Agarose is the gelling component. Agar added to media simply gels them into a convenient solid form. In tropical countries it is sometimes used as a gelatin substitute for "jelly-like" desserts, about which you shall read in the sub-section on food applications. Now let us learn about the gelation and viscosity properties of agar.

Gelation: Agar gels can be formed in very dilute solutions containing a fraction of 1% agar. In fact gelation is perceptible at concentrations as low as 0.04%. These gels are rigid, brittle, have well defined shapes and sharp melting and setting points. pH noticeably affects the strength of agar gels; as the pH decreases, gel strength weakens down to a pH of 2.5.

Viscosity: The viscosity at temperatures above its gelation point is relatively constant at pH values of 4.5 to 9.0 and is not greatly affected by age or ionic strength within the pH range 6.0 to 8.0. Once gelation begins, however, viscosity at constant temperature increases with time.

Having looked at the properties of agar, we move on to the food applications of agar.

Food Applications

The bakery industry has been the largest user of agar because of its heat- resistant gel properties. Confectionary products, such as agar jelly candies, marsh mallows and sweet potato-sugar-agar confections employ agar at 0.3 to 1.8% to give the desired technical effects. Agar is also used in the manufacture of canned meat, fish and poultry products to prevent damage to the contents during transit and storage. In dairy products, such as Neufchatel process cheese, cream cheese and fermented milk products improved textures and stability are obtained with the use of agar. Superiority of Agar over gelatin have been described in the fining of wines, juices and vinegar. Difficulties encountered in clarifying fruit wines by traditional method were overcome by using a 0.5% solution of agar or a 1% of solution of sodium alginate.

We move on to the next algal polysaccharide i.e. alginate next.

2.5.2 Alginate

Alginates are produced by brown seaweeds (*Phaeophyceae*, mainly *Laminaria*). Alginates or algin, is a generic term for the salts and derivatives of alginic acid. Alginate is a copolymer of 1 $\rightarrow$ 4 linked β-D-mannuronic acid (M) and α-L-guluronic acid (G). Figure 2.8 presents the structure of alginate. This acid polysaccharide or gum occurs as the insoluble mixed calcium, sodium, potassium and magnesium salt in the *Phaeophyceae* brown seaweeds.

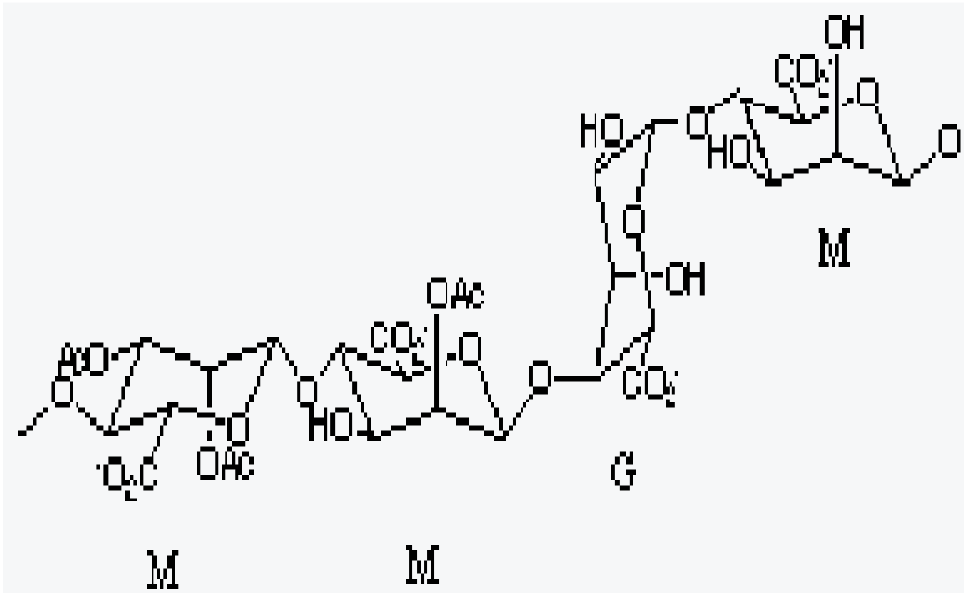


Figure 2.8: Structure of alginate

The commercially available alginates are white to cream coloured powders. 1% alginic acid solution gives a pH value of 2.9 while it is 2.3 and 7.5 for 1% solutions of propylene glycol and sodium alginate respectively. Alginic acid is essentially insoluble in cold or hot water, but it does swell quite strongly. Alginic acid salts (K, Na, NH_4+ Ca, and Na+ Ca) and propylene glycol alginates are soluble in cold or hot water and form stable solutions. The major properties of alginate include pH, solubility and viscosity.

Let us now focus on the various food applications of alginate.

Food Applications

One of the most unusual properties of the alginates has been the ability of soluble alginate salts to produce attractive, edible gels or jellies. This has been used for production of dry powder to give a quick setting gel. The sodium alginate stabilizers possess good water-holding properties, are readily dispersible in ice-cream mixes, and contribute good body properties and excellent texture production. Addition of sodium alginate (less than 0.5%) increased the viscosity of mixes significantly. The presence of sodium alginate also minimizes surface hardening and improves the texture of the processed cheese. The addition of about 0.15% sodium alginate is sufficient to thicken cream and to act as a stabilizer \upon whipping.

The oxidative rancidity in the quick frozen fish can be prevented by block freezing fish in alginate jelly. Alginate films when applied on edible meat as a coating composed of a slurry of corn starch and sodium alginate, enabled to improve the texture and juiciness and in some cases, color, appearance and odor as well. The film forming properties of calcium alginate has been used as a food packaging or coating material since it is edible in nature and it is more extensively being used as a synthetic sausage casing.

Sodium alginate helps in aiding cloud retention and inhibits clarification in orange squash and crush. It has been used as the most efficient stabilizer in the fermentable fruit milk beverages. Blend of alginate and phosphate is effective as a stabilizer for cocoa powder in chocolate milk drinks. In beer, this acts as an auxiliary fining agent for a perfect clarity. Propylene glycol alginate has the advantage of constant quality, unlimited availability and high resistance to acid degradation, hence been used for long in salad dressings.

Finally, we shall study about the third algal polysaccharide i.e. carrageenan.

2.5.3 Carrageenan

Carrageenan is a collective term for polysaccharides prepared by alkaline extraction (and modification) from red seaweed (*Rhodophycae*). Carrageenan is a sulfated galactose polymer. It's a β-D-galacto pyranose linked glycosidically through positions 1 and 3 to α-D-galactopyranose residues linked glycosidically through positions 1 and 4, as illustrated in the figure 2.9(a).

It was first produced commercially from the red algae, C*handrus crispus,* found along the northeast shores of the U.S and Canada and referred to as Irish mosh extract. Carrageenan is of 3 major types –kappa, iota and lambda as shown in the figure 2.9 (b). These not only vary in composition but also in properties

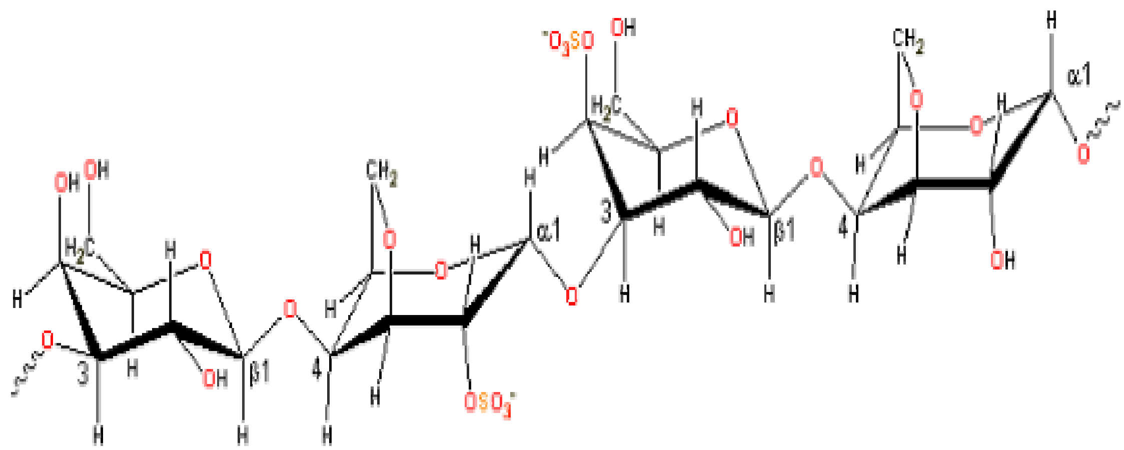


Figure 2.9(a): Structure of Carrageenan

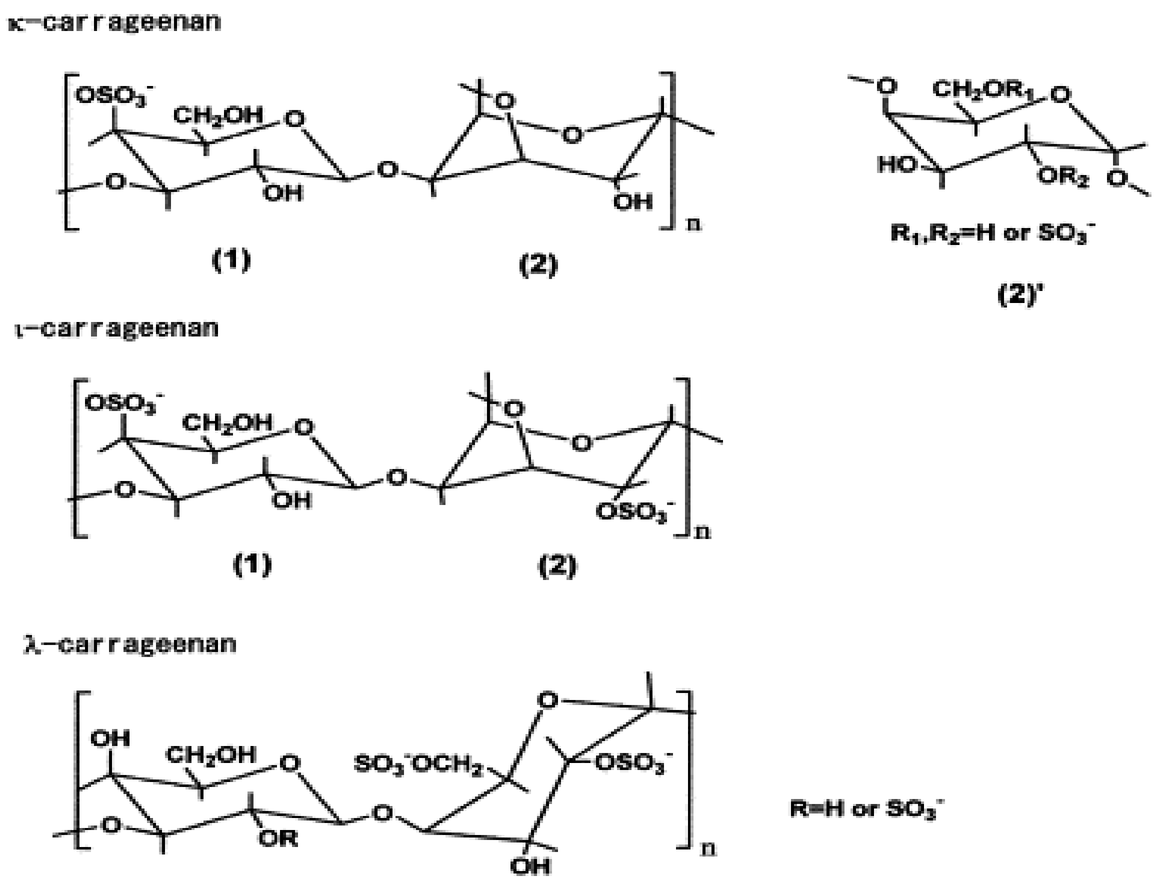


Figure 2.9 (b): Structure of various Carrageenans

We shall not go into the details of the properties of carrageenan in this section. Our focus here is to learn about the food applications of carrageenan. So let us get to know about these applications.

Food Applications

Carrageenan consists of a family of hydrocolloids, which have different properties and it has a wide variety of uses. Some examples of properties, which are important for food formulations, are:

- Gel clarity and high gelling temperatures, thus important in cake glazes and water dessert gels. Firm, quick setting gel, which is valued in, processed cheese system.
- Ability to adjust the texture and the melting point, thus provides the texture needed when carrageenans are used to replace fat in ground meats.
- Low hot viscosities at elevated temperatures, thus useful UHT systems.
- Increases milk solid contents thus makes system economical because of the interaction with milk protein.
- Synergism with locust bean gum and starch, this allows a variety of gel tortures, melting gels, and non-melting gels to be produced.
- Kappa-carrageenan used at a concentration of 0.02-0.03% holds cocoa particles in suspension and prevents cream separation.
- Lamda-carrageenan at a concentration of 0.05% produces thickening and stabilization.
- Sodium salts of Lamda and Kappa-carrageenan at a concentration of 0.01-0.035% gives improved dough characteristics and allows incorporation of higher levels of nonfat milk solids.

Our discussion on algal polysaccharides ends now. We shall learn about the seed gums next. But first let us recapitulate what we have learnt so far.

Check Your Progress Exercise 4

1. Fill in the blanks:

(i) -------------- , ------------- and ------------------ are the main algal polysaccharides.

(ii) The agar extract is composed of two major fractions ------------ and ---------------- .

(iii) -------------- is a copolymer of 1 $\rightarrow$ 4 linked β-D-mannuronic acid (M) and α-L-guluronic acid (G).

(iv) Carrageenan is a ---------------------- polymer.

(v) The three major types of carrageenan are -------------------, --------------------- and --------------- .

2. Discuss the food applications of the following:

(a) Agar

(b) Alginate

(c) Lamda and Kappa-carrageenan

2.6 SEED GUMS

Polysaccharides derived from plants and seeds have been in use for thousand of years. Seed gums are a group of polysaccharides with the following properties:

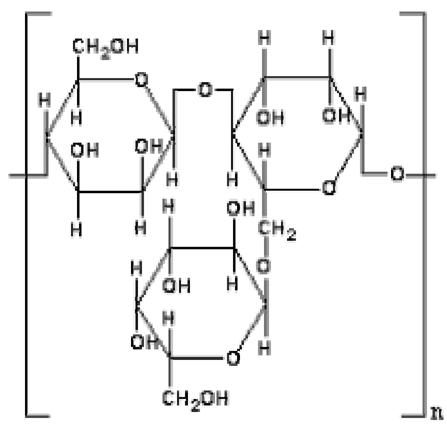
- Seed gums are light to dark cream colored amorphous powder characterized by forming viscous or clear solutions when dispersed or dissolved in cold or hot water.
- They produce low to high viscosity depending upon the source and manufacturing process. They have property of forming high viscosity even at low concentration (4500-8000 cP at 1% w/v) where cP=centipoise, measure scale of viscosity.

- Seed gums are stable over a wide range of pH(3-9). The nonionic nature of the polymer is responsible for almost constant viscosity of the solution.
- They have excellent compatibility characteristic with organic, inorganic substance including certain dyes and various constituents of food.
- They show effective settling (flocculation) properties even at lower concentration.

The common seed gums include locust bean gum and guar gum. We shall learn about these seed gums next.

2.6.1 Locust Bean Gum

Locust bean gum (also called Carob bean gum) is extracted from the seed (kernels) of the carob tree (*Ceratonia siliqua*). Structurally, locust bean gum is composed of Galactomannan galactose: mannose in a ratio of 1:4. Have a look at the figure 2.10 which indicates β-linked mannan (1 → 4) linkage and a side chain α (1→6) linkage.



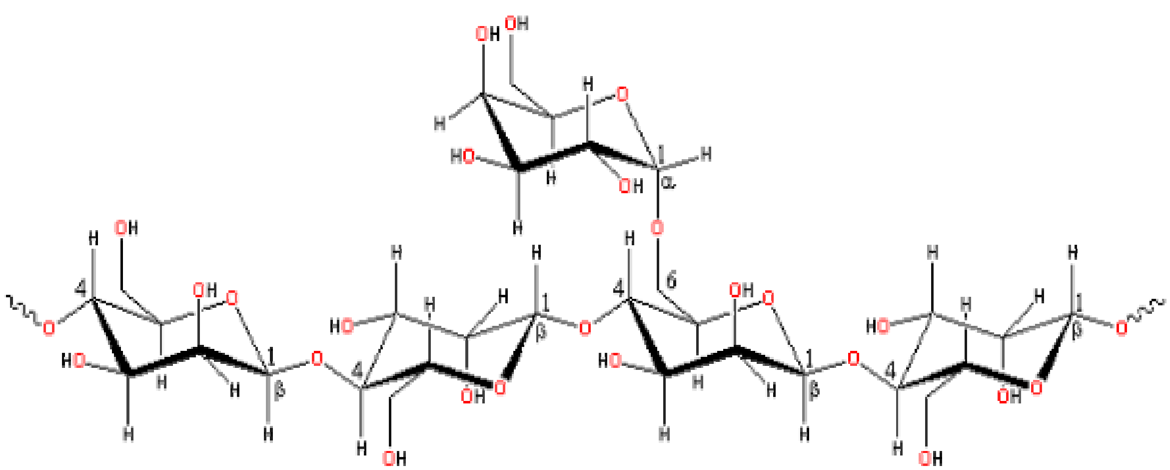


Figure 2.10: Structure of Locust Bean Gum (figure showing a section of the structure)

Properties

Locust bean gum is slightly soluble in room temperature water and must be heated to 75 to 85^{o}C for complete hydration and viscosity development. Maximum viscosity develops when the gum is heated to about 95°C, then cooled. Texture modification of carrageenan water gels is achieved through the incorporation of locust bean gum. Synergistic viscosity results from the combinations of locust bean and Xanthan gum. A thermally reversible gel is formed when locust bean gum and Xanthan are heated to above 130^{o}F and cooled.

Food Applications

Locust bean gum has multiple applications in food industry. Let us focus on a few of the important ones:

- Locust bean gum has been used as a basic ice cream stabilizer. The addition of carrageenan with locust bean gum results in homogenous ice cream mix dispersions. It specifically retards ice crystal growth by forming structured gel at solid/liquid interface
- Cream cheese and similar products are major outlet for locust bean gum. Besides controlling moisture in the end product, a unique texture effect is realized from the use of locust bean gum.
- Locust bean gum is used as an ingredient in specialty products such as salami, sausage and bologna. Due to the viscosity imparted by the gum, extrusion and stuffing is facilitated. The water retention property of the gum reduces finished product weight loss during storage.
- Bread flour supplemented with locust bean gum produces dough with constant properties and enhanced water-binding characteristics. Moreover, yields are improved and the baked products remain soft and palatable for a longer time.
- Syneresis-resistant dessert gels have been prepared from locust bean gum, potassium and calcium-sensitive carrageenans. In this, long storage times at accelerated temperatures resulted in a minimum of syneresis.

2.6.2 Guar Gum

Guar Gum is derived from seed of legume *Cyamopsis tetragonalobus* resembling soyabean plant. Guar gum is composed of Galactomannan Galactose : mannose in the ratio 1:2. Try and identify the following linkages as shown in the figure 2.11.

β 1 $\rightarrow$ 4 linked mannan backbone

α 1 $\rightarrow$ 6 linked galactose

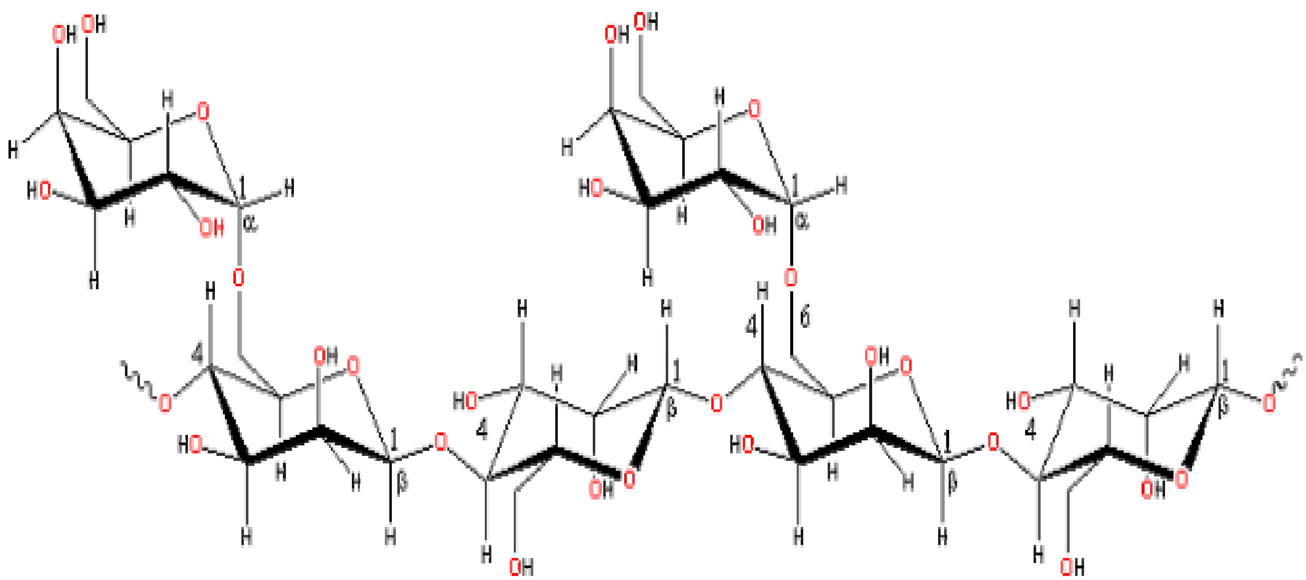


Figure 2.11: Structure of Guar Gum

The food applications of guar gum are highlighted next.

Food Applications

- Guar imparts smoothness to ice cream by promoting small ice crystals during the freezing process.
- Guar gum in the dressing of cottage cheese processing promotes curd integrity by friction reduction or turbidity, which allows the curd to slip during processing.

- Guar influences baked goods in both dough and finished product. Guar in tomato based sauces helps to maintain a desirable color as well as imparting body and stabilizing the system.
- Guar gum imparts a desirable gloss or sheen to canned pet foods. Removal of the pet food from the can is also facilitated by the friction reduction function of agar.

Check Your Progress Exercise 5

1. What are seed gums? What are its characteristic properties?

   ----

2. Enlist a few food applications of the following seed gums:

(a) Locust bean gum

(b) Guar gum

2.7 EXUDATE GUMS

Most exudates gums come from compounds produced when the plant is wounded and these substances seal the wound. Most widely used exudate gum is 'gum Arabic' exuded from wounded trees of Acacia. Gum ghatti, gum karaya and gum tragacanth are the other exudates gums. We will learn about these gums – their structure and function – in details next.

2.7.1 Gum Arabic

Gum Arabic or Gum Acacia is the oldest and best known of the natural gums. Gum Arabic is the natural exudate produced by various species of the thorny Acacia trees and the stems and branches of *Acacia Senegal* (L.) wild or of related species of Acacia. Gum arabic is a complex and variable mixture of arabinogalactan, oligosaccharides, polysaccharides such as Glucuronic acid and 4-O-methyl glucuronic acid and glycoproteins.

Let us now study more about this complex compound by understanding its properties.

Properties

Gum Arabic is unique among the natural hydrocolloids because of its extremely high solubility in water and can yield solutions of up to 55% concentrations. Solutions below 10% gum Arabic, show low viscosities and Newtonian rheology. The gum arabic is stable in acid solutions and products such as citrus oil emulsions exhibit good shelf stability. The addition of electrolytes to gum Arabic solutions results in a reduction of the viscosity even in a very dilute solution. This lowering is much more pronounced in more concentrated solutions. Gum Arabic is a very effective emulsifying agent because of its protective colloid functionality and has found wide spread use in the preparation of varied oil-in-water food emulsions over a wide pH range and in the presence of electrolytes without the need for a secondary stabilizing agent. Gum Arabic has broad range of compatibility with most gums and starches and with most carbohydrates and proteins as well. It is incompatible with few gums such as sodium alginate and gelatin.

Gum Arabic has multifarious food applications, which are highlighted herewith.

Food Applications

- A major use for gum Arabic is in the confectionery industry where it has two important functions; to retard or to prevent crystallization and to emulsify and keep the fatty components evenly distributed. It finds applications in confections like jujubes and pastilles, where the major content in high and the mixture content comparatively low.

- Gum Arabic is used widely in the soft drink industry as an emulsifier in the preparation of flavor emulsion concentration. Because of its protein component, gum arabic functions as an emulsifier and stabilizer in soft drink emulsion, a segment of the market that consumes 30% of the total gum supply. The functionality of inferior types of gum arabic for use in liquid emulsions could be improved by the addition of small amounts of whey protein concentrate selected for this purpose. The foam stabilizing abilities of Gum Arabic is used in beer and soft drinks to give the "Lace curtain" effect on the sides of the glass when the beer is consumed.
- Gum Arabic is used in the bakery industry for its comparatively low water-absorption properties. In addition, it has favorable, adhesive properties for use in glazes and toppings and imparts smoothness when used as an emulsion stabilizer.
- Gum Arabic has been used in preparing dry, powdered and stable oil-soluble vitamins for use as food supplements. The oil-soluble vitamins, gum Arabic, an anti-caking agent such as calcium or magnesium stearate, an antioxidant and a chelating agent were combined, dried, and pulverized to obtain a product in which the vitamins are stable.
- Gum Arabic has been used as a non-caloric bulking agent and bodying agent in diabetic foods and in low carbohydrate baked goods for dietetics.
- Gum Arabic, in combination with Xanthan gum in a 10:1 ratio, was used in preparing stabilized whipped or aerated low calorie products such as butter, margarine, toppings spreads, and frozen desserts.
- Gum Arabic has been used to solublize water-insoluble materials such as antioxidants, butylated hydroxyl anisole (BHA) is made water dispensable and soluble by coating one part BHA with one part of glyceryl mono-oleate and two parts gum arabic.
- Most dry package products, such as desserts and pudding mixes, beverage powders, cake mixes, soup bases, etc. contain encapsulated flavors to ensure flavor stability, longer shelf life and superior product quality. Such flavors are

made by various spray-drying methods in which a mixture or emulsion of the flavor and a gum in water are dried rapidly. The flavor becomes coated with a film of the gum, thereby sealing and protecting it from further change until it is released when in the final preparation of the food product.

2.7.2 Gum Ghatti

Gum ghatti, also known as Indian gum, is amorphous, translucent exudates of the *Anogeissus latifolia* tree of the C*ombretaceae* family. Gum Ghatti is composed of glucuronomannoglycan (uronic acid and mannose). The gum has a glassy fracture and the color of the exudates varies from very light brown to dark brown, with the higher colored material yielding a higher and better grade of gum.

In this, we will focus our attention on a very important property of gums referred to as 'viscosity' and the effets of pH. Gum ghatti does not form true aqueous solutions but form viscous dispersions in water (having a pH of about 4.8) at concentrations of about 5% or higher and exhibits typical non-Newtonian behaviour common to most hydrocolloids. The viscosity remains more or less constant upto pH 7 and then drops off gradually down to pH 12. At all pH values, viscosity increases noticeably overtime upon ageing. The gel fraction of ghatti, responsible for its viscous behaviour, is predominantly calcium salt. Removal of the calcium ions reduces the viscosity; however, the original viscosity cannot be restored by the addition of calcium ions.

As for the food applications of gum ghatti, in foods, it has been effectively used as an emulsifier and stabilizer in combination with lecithin in butter- containing pancakes and waffle syrups. It has also been used as a flavor fixative for specific applications.

2.7.3 Gum Karaya

Gum karaya (sterculia gum) is the dried gummy exudate from *Sterculia urens Roxburgh* and other species of *Sterculia (F*amily: Sterculiaceae) or from *Cochlospermun gossipium* or other species of C*ochlospermun kunth* (Family: Bixaceae). Gum karaya is also known as *Indian tragacanth*. Structurally, Gum Karaya is acetylated rhamnogalacturonan (rhamnose and galacturonic acid).

After having knowledge about the composition of gum karaya, let us study its properties and various food applications

Properties

Gum karaya is water-swellable rather than water-soluble and absorbs water very rapidly to form viscous colloidal dispersions at low concentrations. At higher concentrations (20 to 25%), gum karaya exhibits strong adhesive properties. Gum karaya dispersions are stable, however, will lose viscosity gradually if solutions are not preserved by the addition of preservatives.

Food Applications

- The water absorbing and water-holding capacity of Karaya, together with an excellent acid compatibility made it suitable for its use in the ice pops, water ices and sherbets.
- Karaya is very efficient in preventing the bleeding of free water (with dissolved flavor and color) and the formation of large ice crystals.
- Karaya has effective foam stabilization properties which have been employed in stabilizing packaged whipped cream products and other aerated dairy foods.
- Karaya has been used to prevent syneresis and improve the spreadability characteristics of cheese spreads. It is used as a good emulsion stabilizer for French style salad dressings, sometimes in conjunction with gum Arabic for improved effectiveness.
- Karaya in combination with alginate or carrageenan is used to retard staling of bread and other baked goods. In doughnut mixes, this gum combination improved the tolerance of the dough to over mixing and gave an improved product.
- In ground meat products, karaya provides good water holding and binding properties to yield products such as bologna with smooth, desirable textures and appearance.

2.7.4 Gum Tragacanth

Gum tragacanth, the exudation of *Astragalus* species, is defined as the "dried gummy exudate" obtained from *Astragalus gummifer Labillardiere*. Gum tragacanth is a mixture of the compounds arabinogalactan and glycanogalactouronan.

Properties

Gum tragacanth swells in water to give thick viscosity dispersions or pastes similar in texture to soft gels. The viscosity shows a sharp rise as the gum concentration increases, but deceases with increasing shear rates in typical pseudoplastic fashion. Rheologically, tragacanth show pseudoplastic behaviour, typical of most gums. In general, tragacanth is fairly stable over a wide pH range even at extremely acidic conditions (pH 2). For this reason it has been widely used in food products, such as salad dressings where stable viscosities at low pH are required. Gum tragacanth has well defined surface active properties and produces a rapid lowering of the surface tension of water at low concentrations, thus used as an emulsifying agent. Together with its viscous nature and acid stability, gum tragacanth promotes stable emulsions and is known as a very effective emulsifying agent. Gum tragacanth is compatible with most gum systems and viscosities are usually additive when it is used in mixed gum systems. Gum Arabic when added to gum tragacanth lowers the viscosity of gum tragacanth and produces emulsions with superior smooth quality citrus oil, cod liver oil, linseed oil and mineral oil. Preservatives are necessary in order to maintain long term shelf stability of gum tragacanth containing solutions and the choice will depend on the finished product and formulation. Glycerol or propylene glycol is an excellent preservative for many emulsions.

Food Applications

Gum tragacanth finds various food applications. These include:

- In dairy products, it functions as stabilizer in ice cream, ice pops and water ices, chocolate milk drinks, puddings and cheese.
- In bakery products (meringues, bakers' citrus oil emulsions, frozen pie fillings) dressings and sauces (salad dressing, syrups and toppings, white sauces and

gravies), beverages (soft drink with fruit pulp, fruit juices and nectars, dry beverage mixes), confectionery products (candy gels and jellies, caramels, nougats, candy glaze, gum drops, jujubes, pastilles) and in various dietetic foods it has useful applications.

Check Your Progress Exercise 6

1. List a few food applications of the following:

(a) Gum Arabic

(b) Gum karaya

(c) Gum tragacanth

----

2. Match the following:

	A		B
(i)	Gum Arabic	(a)	glucuronomannoglycan
(ii)	Gum Ghatti	(b)	arabinogalactan, oligo and polysaccharides
(iii)	Gum karaya	(c)	arabinogalactan and glycanogalactouronan
(iv)	Gum tragacanth	(d)	rhamnogalacturonan

2.8 MICROBIAL POLYSACCHARIDES

Many microorganisms produce polysaccharides that either remain attached to the cell wall (capsular polysaccharides) or are secreted into the extracellular fluid (exopolysaccharides). Some examples of microbial polysaccharides include xanthan gum, gellan gum, curdlan, pullulan. Let us get to know about these microbial polysaccharides.

2.8.1 Xanthan Gum

Xanthan gum is a microbial polymer prepared commercially in pure culture fermentation from *Xanthomonas campestris*. This polysaccharide was given the generic name xanthan gum. Xanthan gum, as shown in the figure 2.13, comprises of β-1 →4 linked glucan backbone and trisaccharide side chains consisting of β-D-mannose, β-D-glucuronic acid and 6-O-acetyl-α-D mannose. Pyruvic acid is linked to β-D-mannose as sugar ketal.

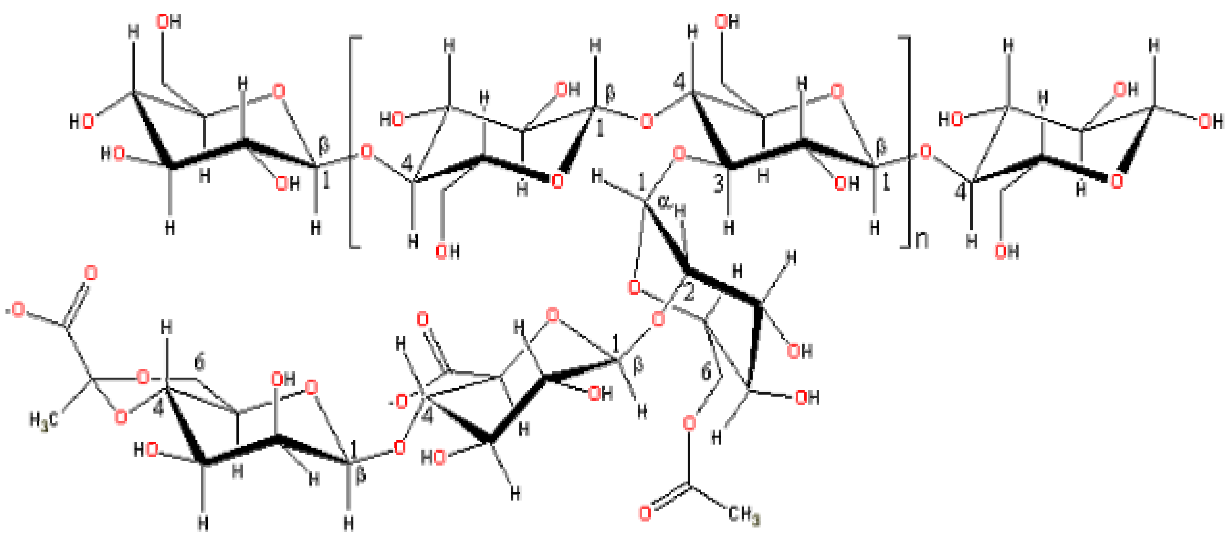


Figure 2.13: Structure of Xanthan Gum

Xanthan gum is completely soluble in hot or cold water. Solution of Xanthan gum at 1% or higher concentration appear almost gel like at rest, yet these pour readily and have a very low resistance to mixing and pumping. Xanthan gum solutions show excellent stability at 80^{o}C. This property has practical utility for hot foods, such as gravies.

Food Applications

- Xanthan gum is mainly considered to be non-gelling and used for the control of viscosity due to the tenuous associations, endowing it with weak-gel properties. It hydrates rapidly in cold water without lumping to give a reliable viscosity, encouraging its use as thickener, stabilizer, emulsifier and foaming agent. The consistent water holding ability may be used for the control of syneresis and in freeze-thaw situations. Its most important property being its very high low-shear viscosity coupled with its strongly shear-thinning character. The relatively low viscosity at high shear means that it is easy to mix, pour and swallow but its high viscosity at low shear lends stability to colloidal suspensions. Being relatively unaffected by ionic strength, pH (1 – 13) or temperature it may be used in such products such as salad dressings.

- Xanthan gum gives enhanced mouthfeel with full bodied taste**.**
- Due to its unusual heat stability, xanthan gum is very useful in heat processed food systems containing sauces and gravies.
- Canned tuna, chicken, ham, potato and macaroni salads have been formulated with retortable salad dressings containing xanthan gum. The addition of xanthan gum is able to maintain freeze-thaw stability for five or more cycles. The freeze-thaw stability of starch based salad dressings can be also maintained by the addition of 0.1% Xanthan gum.
- In tomato, pickle, onion or mustard relishes, xanthan gum is exceptionally effective in reducing liquor drainage. Neither the acid nor the salt content of these products is able to reduce the water holding abilities of xanthan gum.
- It is utilized for the stabilization of law calorie and other aerated desserts, instant milkshakes, breakfast drinks, soups and sauces. A bakery filling type product can be stabilized with a combination of xanthan gum, locust bean gum and 2% starch.
- In comparison with several other colloids, xanthan gum has a detectable depressing effect on the sweetness intensity of sucrose, while it has no effect on the taste of citric acid, saccharine, caffeine and sodium chloride.

2.8.2 Gellan Gum

Gellan is an exopolysaccharide consisting of β-D-glucose, β-D-glucuronic acid, α-L-rhamnose with acetate and glycerate groups, produced by the bacterium *Sphingomonas paucimobilis*. Its structure is presented in the figure 2.14.

It is currently being manufactured under patent in two different terms: *kelcogel* and *Gelrite.* The former is used as a thickener and gelling agent and the latter is used as a solidifying agent.

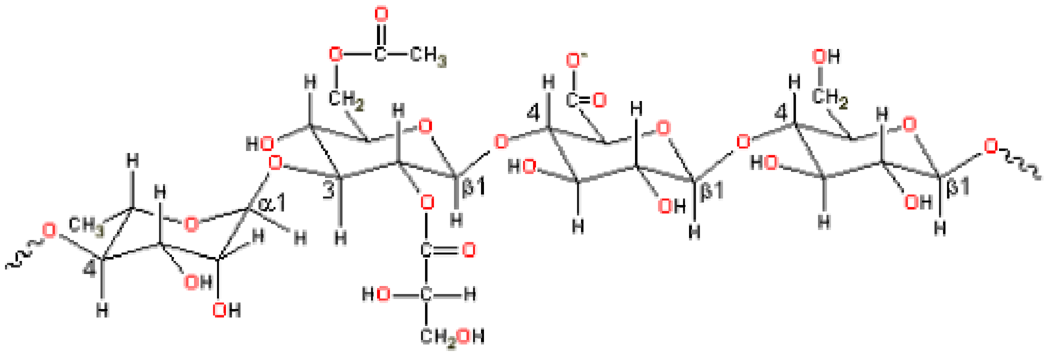


Figure 2.14: Structure of Gellan Gum

Functional properties

One of the most important features of gellan gums is its versatile texture which is defined in terms of hardness (measure of rupture strength), modulus (measure of gel firmness), brittleness (strain required to break the gel) and elasticity (measure of rubberiness). Gellan gels can be formulated to set with or without heating. The melting point can be either below or above 100^{o}C, allowing the design and production of both heat resistant gels and gels that should liquify during processing. At 15% sugar content gellan gum gels are crystal clear. Gellan can be easily and fully dissolved in water without any preparatory steps. Gellan can be easily combined with other gums/polymers, for example, gelations gels, which have pleasant organoleptic qualities but low melting point, can be stabilized satisfactorily when gellan is added to the mixture. Apart from native gellan, which has properties similar to xanthan-locust gum mixtures and thus rather limited uses, there are 3 types of modified gellan gum.

(a) High acetyl gellan (partially deacetylated), which provides a thermo reversible gel, fairly soft, elastic and non-brittle.

(b) Low acetyl gellan (highly deacetylated), which is preferred for most food applications, as it forms firm and brittle gels.

(c) High clarity gellan (highly deacetylated and clarified), which is suitable for some confectionery products where clarity is a crucial quality issue.

Applications

Gellan is a highly versatile food ingredient and has numerous applications in foods. The combination of gelatin with gellan, by comparison, produced gels with both pleasant organoleptic properties and thermal stability. Although alginate produces stable gels, gellan not only enhances thermal stability when used as gelling agent, but also provides excellent clarity, which is an important feature for some jellies or sugar icings. The addition of gellan in fruit and milk beverages has also proved to be very useful in forming stable, homogeneous products. Gellan can be utilized in confectionary and bakery products. Starch jellies, due to introduction of gellan reduces the setting time to 10-12 hour. In addition, gellan can prevent moisture fluctuations in sugary icings and toppings. Gellan can successfully replace pectins and are effective at lower concentrations. In these products, syneresis is minimized, while jams have good organoleptic characteristics and spread easily. Low solid and reduced calorie jams can also be prepared with only 0.15% of high clarity gellan, giving a jam with excellent sheen. The firm consistency of pie fillings and puddings can be obtained from gellan alone or in mixtures with modified starch. It can be used as a *stabilization and water-binding agent*, averting the "blanding effect" that starches can have as food flavour (i.e., starches generally tend to weaken the flavour release characteristics of food). Gellan gum offers significant thermal resistance during the pasteurization process. In dairy products like cheese, the interactions of gellan with milk proteins, especially caseins and whey lactoglobulins increased the total yield of cheese and reduced the loss of solids (mainly proteins) in the whey. Also, water retention during cheese making was enhanced after the addition of gellan to milk. Ice cream can be improved by the addition of gellan, where it acts as effective bulking agent.

2.8.3 Curdlan

Curdlan, a glucan with $(1\rightarrow3)$ is produced by bacterium *Alkaliqenus faecalis var. myogenes* and some related bacteria. It is a tasteless, odorless white powder, which swells upon the addition of water. Upon heating low concentrations of gum suspensions, a cloudy, opaque gel forms at temperatures above 80^{O}C. This gel is irreversible and is not affected by cooling heating or freezing. The gel will form over a wide pH range from 1.0 to 11.5 and tends to show syneresis upon ageing.

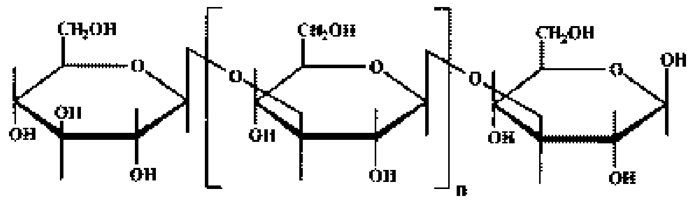


Fig. 1 Structure of curdlan.

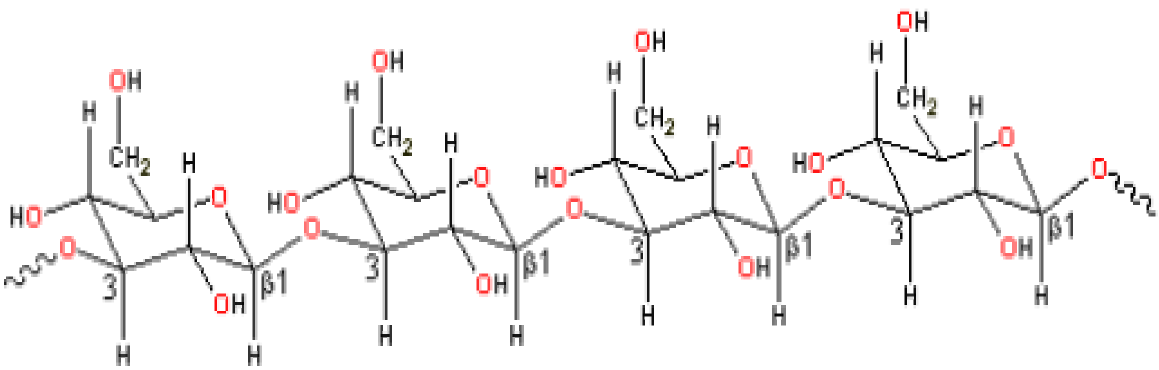


Figure 2.15: Structure of Curdlan

Food Applications

Curdlan has a variety of food applications as enumerated herewith:

a) Meat and Poultry

Curdlan makes meat and poultry products juicier and tenderer. It’s ideal for frozen products, like steak, burgers and fried chicken. It increases yield by reducing shrinkage. Curdlan prevents moisture loss and oil absorption in breaded and batter-coated meat and seafood products.

b) Dairy Products

Curdlan replaces fat while improving mouthfeel, texture, and appearance in frozen and cultured dairy products. It makes low-fat yogurts and cheeses creamier.

c) Miscellaneous

Curdlan, used with egg whites, improves texture and shape retention in noodles, especially in canned soups and macaroni products. Its gel will form tofu noodles that retain their shape when boiled or sauted. Curdlan imparts creamy mouthfeel to salad dressings, adds viscosity to non-fat varieties. It consists of 90% dietary fiber and is nutritionally inert, making it an excellent bulking agent for low- and no-fat foods.

2.8.4 Dextran

Dextran is a high molecular weight polysaccharide having α1→ 6, α1→ 3 linked glucans, as you can see in the figure 2.16. It is produced by the bacterial fermentation of sucrose by *Leuconostoc dextranicum* followed by partial depolymerisation and purification of the fermented mixture to produce a substance that is free of viable micro organisms.

Dextran is a fine, white powder that dissolves readily in hot or cold water to give a clean and viscous solution. It has good humectant and water–holding properties and imparts good bodying attributed to liquid systems.

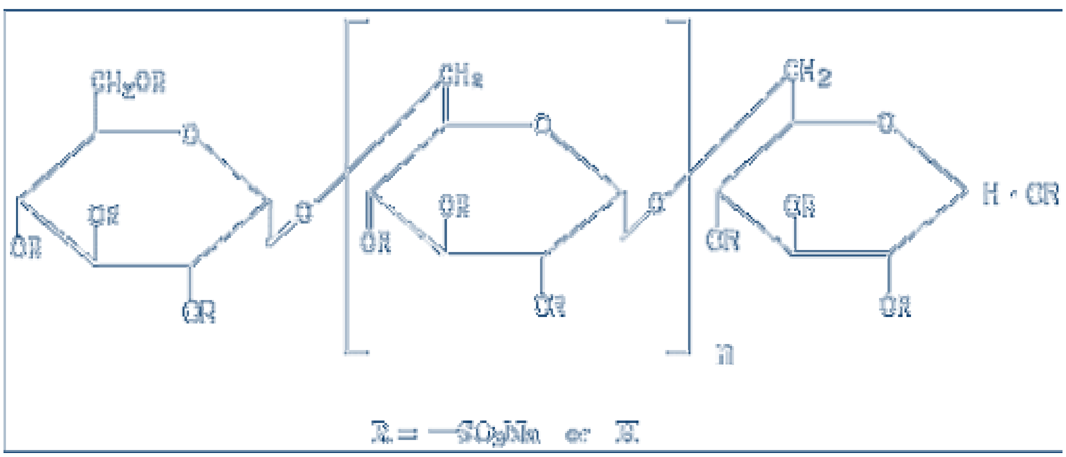


Figure 2.16: Structure of dextran sulphate sodium

Food Applications

Dextran can be used in food products, as it is capable of moisture retention and inhibition of crystallization of sugar. The properties of dextran as gelling agent and prevention of ice crystals in ice cream can also be exploited. It can be used as stabilizer in bakery, especially for soft bread. Use of dextran can also stabilize foam in beer and milk beverages.

2.8.5 Pullulan

Pullulan is a water soluble edible microbial polysaccharide consisting of Maltotriose units (α 1 $\rightarrow$ 6), as shown in the figure 2.12. It is produced by yeast *Aureobasidium pullulans.* It is a natural linear polysaccharide with maltotriose units. Pullulan is tasteless and odourless. Esterification of pullulan makes it water-soluble. The films made from this are odourless, impermeable to oxygen and resistant to grease. It cannot be degraded by human digestive enzymes and thus can be exploited in dietetic foods.

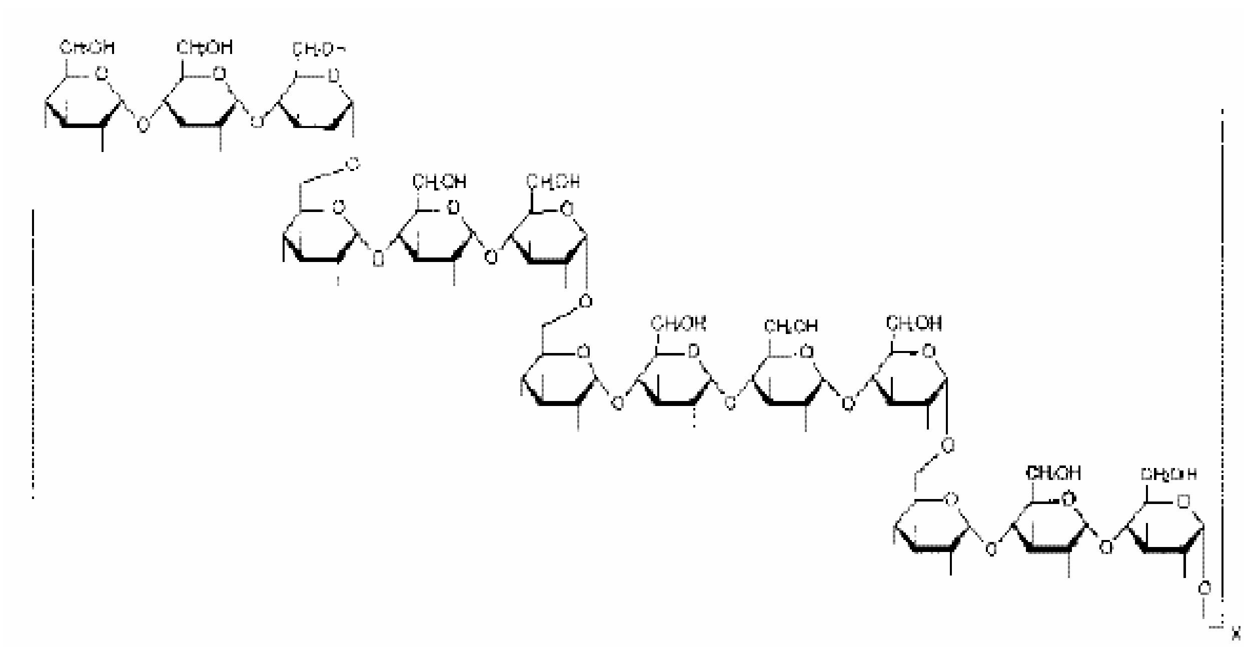


Figure 2.12: Structure of Pullulan

Food Applications

The food applications of pu;;alan include:

- Due to its oxygen barrier properties, it can be used as a packaging material for fat / oil containing food products.
- Pullulan can improve the viscosity of beverages, ice creams and sauces.

- It can also be used in the preparation of ham, sausages and other meat products for their quality and texture improvement.
- It can be used as ingredient of dietetic foods.

Check Your Progress Exercise 7

1. What are microbial polysaccharides? Name any two microbial polysaccharides.

   ----

2. List a few food applications of the following:

a) Xanthan Gum

   ----

b) Gellan Gum

   ----

c) Pullulan

   ----

d) Curdlan

   ----

3. List the types of Gellan gum.

2.9 LET US SUM UP

This unit focuses on food polysaccharides. Polysaccharides, as you are aware, are complex carbohydrates made up of monosaccharides units joined together in a linear or branched fashion. They are of two main types – starches and dietary fibre component. In addition food polysaccharides also include exudates gums, seed gums, microbial polysaccharides, algal polysaccharides.

Starches, we learnt, form the primary energy source for many animals, including humans. They are composed of a simple chain molecule called amylose (20-30%) and a complex branched form called amylopectin (70-80%) molecules. They have enormous number of uses including adhesive, binding, clouding, dusting, film forming, foam strengthening, getting, glazing, moisture retaining, stabilizing, texturizing and in thickening applications. Inspite of such wide-range application of starches, they suffer from various shortcomings. To overcome these and expanding usefulness of starch for a myriad of applications, modified starches are developed. The modified starches find its use in food and confectionery industries as instant desserts, salad dressings, toppings, canned soups etc.

Non-starch polysaccharides (NSP), is a group of materials found in the cell walls of plants. These include cellulose, hemicellulose, pectin etc. Gum ghatti, gum karaya, gum tragacanth (classified as exudate gums) locust bean gum, guar gum (classified as seed gums) and pullulan, xanthan, curdlan, dextran etc.(microbial polysaccharides) are the other food polysaccharides about which we learnt in this unit. All these polysaccharides have a variety of food applications. They function as gelling agent, prevent forming of ice crystals in ice cream, used as stabilizer in bakery etc.

2.10 GLOSSARY

Colloidal dispersion : a mixture containing particles larger than those found in a solution but small enough to remain suspended for a very long time.

Complex Carbohydrates	:	also known as polysaccharides, made up of many monosaccharide units joined together in a linear or branched fashion.
Depolymerization	:	the process of converting a polymer into its monomer or a mixture of monomers.
Diverticular disease	:	a disease characterized by small protrusion in the colon i.e. the large intestine
Emulsifier	:	an additive that promotes formation of a stable mixture or emulsion of oil and water
Encapsulated flavour	:	encapsulation involves the coating of a fine particle of an active core with an outer shell into small capsules. It prevents ingredients from reacting prematurely with their environment or degrading.
Esterification	:	the process of converting an acid into an alkyl or aryl derivative. Most frequently the process consists of the reaction of an acid with an alcohol in the presence of a trace of mineral acid as catalyst or the reaction of an acyl chloride with an alcohol. Esterification is the act or process of making ether; specifically, the process by which a large quantity of alcohol is transformed into ether by the agency of a small amount of sulphuric, or ethyl sulphuric, acidification and can also be accomplished by enzymatic processes
Etherification	:	the act or process of making ether; specifically, the process by which a large quantity of alcohol is transformed into ether by the agency of a small amount of sulphuric, or ethyl sulphuric, acid.
Extruded Starch	:	cereal products, that are prepared by pumping cereals through a small opening for instance, pasta, Ready-to-eat cereals etc.
Gums	:	food hydrocolloids, hydrophilic polymers which contain many hydroxyl groups. These are added to food products to provide a particular functional property
Hemicellulose	:	the second major constituent of plant cell wall
Humectant	:	property of moisture retention.
Monosaccharides	:	simplest form of carbohydrates which can not be further

hydrolysed into smaller units.

Organoleptic properties : the effect or impression produced by any substance on the organs of touch, taste, or smell, and also on the organism as a whole.

Pasteurization : partial sterilization of a substance using heat to destroy harmful organisms.

Pseudoplastic viscosity : A decrease in viscosity with an increase in shear rate.

Rheology : the science of the deformation and flow of matter. It is the branch of physics concerned with the flow and change of shape of matter, especially the viscosity of liquids.

Syneresis : Separation of liquid from a gel caused by contraction.

2.11 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. A few applications of starches in the foods industry include thickener, a fat sparing agent, adhesive, binder, encapsulating agent, film former, gelling agent, water binder, texturizer etc.

2.

- The realignment of the amylose and amylopectin and swollen starch granules to form a pocket is termed as retrogradation.
- The process of converting starch into a jelly-like substance is referred to as gelatinization.

3.

a) Amylopectin

b) glucose residues in a compact structure

c) resistant starch.

d) form of starch; method of cooking prior to consumption.

e) wet weight of the sedimented gel formed to its dry weight.

Check Your Progress Exercise 2

1. Modified starches are the food starches having one or more of their original characteristics altered by treatment in accordance with good manufacturing practices.

2. Lack of free-flowing properties of water repellence of the starch granules, insolubility or failure of the granules to swell and develop viscosity after cooking, cohesive or rubbery texture of the cooked starch, sensitivity of the cooked starch to breakdown during extended cooking, lack of clarity and formation of opaque gel are a few shortcomings of native starches which make it unacceptable in certain food applications.

3.

(i) Oxidized starch: Coating and sealing agent, emulsifier, dough conditioner for bread, binding agent as gum Arabic replacer, lemon curd manufacture, salad cream, mayonnaise.

(ii) Starch acetates: Stabilizer and thickener in baked, frozen, canned, dry foods and gravies.

(iii) Starch Phosphate monoesters: Emulsifying agent and thickening agent.

(iv) Hydroxypropyl starches: Coffee whiteners, thickener in a variety of food related products.

4.

a) Reaction with acid or alkali, hydrolysis, use of specific enzymes, treatment with reagents.

b) pregelatinized

c) cationic starches

Check Your Progress Exercise 3

1.

a) NSP or dietary fibre is the name given to a group of materials found in the cell walls of plants which gives the plant its structure and form.

b) Food hydrocolloids are the hydrophilic polymers of vegetable, animal, microbial or synthetic origin that generally contains many hydroxyl groups and may be polyelectrolytes.

2. A few important uses of food hydrocolloids are: to increase viscosity and to stabilize food products. Its other uses include use as laxatives, modifying diarrhoea, alleviation of the symptoms of diverticular disease, reduction in blood glucose level and insulin response and hypocholesterolemic effect.

3. The functional properties of gums that are considered to be important in food industries are:

- Ability to modify the basic property of water
- Helps to stabilize the suspensions, emulsions and foams.

4. Cellulose has β(1,4) linkages, which are not digested by human beings and unbranched structure.

5.

a) Water holding capacity

b) retarding, staling and reducing fat intake into the fried foods

c) emulsifier, stabilizer, binder, potential bulking agent, good source of fibre.

Check Your Progress Exercise 4

1.

(i) agar, alginate and carrageenan

(ii) agarose, agropectin

(iii) alginate

(iv) sulphated galactose

(v) kappa, iota and lambda

2. The food applications of the various cell wall polysaccharides are:

(a) Agar: Agar is used in the confectionary products, such as agar jelly candies, marsh mallows and sweet potato-sugar-agar. Agar is also used in the manufacture of canned meat, fish and poultry products to prevent damage to the contents during transit and storage. In dairy products, improved textures and stability are obtained with the use of agar. It is also employed in the fining of wines, juices and vinegar and clarifying fruit wines.

(b) Alginates: Soluble alginate salts produce attractive, edible gels or jellies. The sodium alginate stabilizers possess good water-holding properties. The presence of sodium alginate minimizes surface hardening and improves the texture of the processed cheese. The addition of about 0.15% sodium alginate is sufficient to thicken cream and to act as a stabilizer in ice-cream mixes. It prevents oxidative rancidity in the quick frozen fish and helps in aiding cloud retention and inhibits clarification in orange squash and crush.

(c) Lamda and Kappa-carrageenan: Lamda-carrageenan at a concentration of 0.05% produces thickening and stabilization. Sodium salts of Lamda and Kappa-carrageenan at a concentration of 0.01-0.035% gives improved dough characteristics and allows incorporation of higher levels of nonfat milk solids.

Answers to Check Your Progress Exercise 5

1. Seed gums are a group of polysaccharides with the following properties:
   - light to dark cream colored amorphous powder characterized by forming viscous or clear solutions when dispersed or dissolved in cold or hot water.
   - produce low to high viscosity depending upon the source and manufacturing process. They have property of forming high viscosity even at low concentration.
   - stable over a wide range of pH (3-9).
   - excellent compatibility characteristic with organic, inorganic substance including certain dyes and various constituents of food.
   - effective settling properties even at lower concentration.

2. The food properties of various seed gums are discussed as:

(a) Locust bean gum: Locust bean gum has been used as a basic ice cream stabilizer. It controls moisture and gives a unique texture effect to cream cheese and similar products. It is used as an ingredient in specialty products such as salami, sausage and bologna to facilitate extrusion and stuffing. Bread flour supplemented with locust bean gum produces dough with constant properties and enhanced water-binding characteristics. It helps to minimize syneresis in dessert gels.

(b) Guar Gum: Guar in tomato based sauces helps to maintain a desirable color as well as imparting body and stabilizing the system. It imparts a desirable gloss or sheen to canned pet foods.

Check Your Progress Exercise 6

1. The food properties of various exudate gums are discussed as:

(a) Gum Arabic: It retards or prevents crystallization and emulsifies, acts as an emulsifier. It has low water- absorption properties, favorable, adhesive properties and imparts smoothness. It is used in the preparation of dry, powdered and stable oil-soluble vitamins. It is used as a non-caloric bulking agent and bodying agent in diabetic foods. Also, it is used to solublize water-insoluble materials such as antioxidants, butylated hydroxyl anisole (BHA).

(b) Gum Karaya: It has water absorbing and water-holding capacity. It prevents the bleeding of free water and the formation of large ice crystals. It has foam stabilization properties, prevents syneresis and improves the spreadability characteristics of cheese spreads. In combination with alginate or carrageenan, it is used to retard staling of bread and other baked goods. In ground meat products, it provides good water holding and binding properties.

(c) Gum tragacanth: Gum tragacanth finds food applications as stabilizer in the dairy industry.

2.

(i) - (b)

(ii) - (a)

(iii) - (d)

(iv) - (c)

Check Your Progress Exercise 7

1. Microbial polysaccharides are microorganisms that produce polysaccharides. Some examples of microbial polysaccharides include xanthan gum, gellan gum, curdlan, pullulan.

2. The food properties of various microbial polysaccharides are discussed as:

(a) Xanthan gum: It is non-gelling and is used for the control of viscosity. It is used as a thickener, stabilizer, emulsifier and foaming agent. It has a consistent water holding ability. It gives enhanced mouthfeel with full bodied taste and unusual heat stability. In pickles and relishes, it is exceptionally effective in reducing liquor drainage. It is utilized for the stabilization of law calorie and other aerated desserts, instant milkshakes, breakfast drinks, soups and sauces.

(b) Gellan gum: It has pleasant organoleptic properties and thermal stability. It provides excellent clarity, prevent moisture fluctuations in sugary icings and toppings. It can be used as a stabilization and water-binding agent. Gellan gum offers significant thermal resistance during the pasteurization process. Also, it enhances water retention. It acts as effective bulking agent.

(c) Pullulan: Due to its oxygen barrier properties, it can be used as a packaging material for fat / oil containing food products. It is used to improve the viscosity of beverages, ice creams and sauces and also as ingredient of dietetic foods. Also, it is used in the preparation of meat products for their quality and texture improvement.

d) Curdlan: It finds its uses in the following food products:

- Meat and Poultry: It makes meat and poultry products juicier and tenderer; it is ideal for frozen products, prevents moisture loss and oil absorption.
- Dairy Products: It improves mouthfeel, texture and appearance in frozen and cultured dairy products; makes low-fat yogurts and cheeses creamier.

- Miscellaneous: Along with egg whites, it improves texture and shape retention in noodles, especially in canned soups and macaroni products. It imparts creamy mouthfeel to salad dressings, adds viscosity to non-fat varieties; an excellent bulking agent for low- and no-fat foods.

2. The three types of gellan gums are:

- High acetyl gellan (partially deacetylated)
- Low acetyl gellan (highly deacetylated)
- High clarity gellan (highly deacetylated and clarified).