Biomedical applications of marine based polysaccharides-an overview

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ABSTRACT

Polysaccharides are polymeric compounds composed of monosaccharide units bridged by glycosidic linkages. Cellulose and chitin are the two marine based linear polymers majorly used for structural support in plants and animals, respectively. Among the marine plant sources of carbohydrates, seaweeds are the most abundant source of polysaccharides viz.., alginites, agar and agarose, carrageenans, cellulose and amylase, playing a major role in biomedical and pharmaceutical applications including drug delivery. Similarly, marine animals, crustaceans in specific are the huge resources for chitin and chitin based products which have already been proven their biomedical significance. In addition to the intrinsic biocompatibility (inducing osteogenic, adipogenic, and chondrogenic differentiation in stem cells and wound healing), these resources are economically feasible and cost-effective. Other important properties of these marine polysaccharides include biodegradability, controllable biological activity and their ability to form hydrogels as they maintain therapeutic plasma concentrations in the surrounding tissues or in circulation for a longer period of time. Several researchers studied these polysaccharides in medical applications considering the huge unmet need. A combination of marine plant and animal polysaccharides could generate biocompatible composites that suit the oral medicine environment. The current review can be resource information on collective applications of marine polysaccharides and their applications in medicine and also focuses on various perspectives of these polymers in biomedical applications.

Key words: Alginites; carrageenans; chondrogenic; polysaccharide; seaweeds

INTRODUCTION

Polysaccharides are long chain polymers consisting of more than two monosaccharides linked by glycosidic bonds. Polysaccharides can be divided in to two categories starch - derived polysaccharides and nonstarch polysaccharides. These are the natural carbohydrates cheap carbohydrate food source & occupies first position in availability[1]. Polysaccharides are widely distributed in nature and are comparatively cheap, non-toxic, eco-friendly, with different origins, plant origin, animal origin and microbial origin. The different chemical properties of these polysaccharides made them versatile materials which are used for many different applications. Some important properties are holding of H2O, binding, thickening, gelling, suspending, emulsifying, as well as formation of films and pharmaceutical industries. These characteristics have opened avenues to be utilized in different industries such as cosmetics, drilling, explosives, food, paper, textiles, petroleum, medical, and pharmaceutical industries. The properties of these polysaccharides can be enhanced by interactions with monomers and polymers, mainly due to their capabilities to form synergistic interactions of the numerous -OH groups availability.

Four important polysaccharides, starch, chitin, glycogen, and cellulose, are composed of glucose. Starch and glycogen serve as short-term energy stores in plants and animals, respectively. Chitin and cellulose serve as characteristic component of the cell walls of different organisms (fungi, arthropods, crustaceans, and insects). The glucose monomers are linked by a glycosidic bond. The physico-chemical characteristics of these polysaccharides play an important role in several applications in various fields.

CELLULOSE

Cellulose is the most abundant organic polymer on earth, since it is the main component of plant cell walls[2]. Wood, paper, and cotton are the most common forms of cellulose. The glucose units in cellulose are linked by β glycosidic bonds[3] showing in figure 1, different than α glycosidic bonds found in glycogen and starch. Cellulose has more hydrogen bonds between adjacent glucose units, both within a chain and between adjacent chains, making it a tougher fiber than glycogen or starch. This is why wood is so tough.

Figure : 1. Chemical Structure of Cellulose

Cellulose has many uses, works as a gelling agent because of its cellulose's properties of holding on to water. It is also used as an anti cake agent, stabilizer, thickener and dispersing agent. Water cannot enter crystalline cellulose but dry cellulose absorbs water and it becomes flexible. 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. Most papers are made of cellulose. The most important role of cellulose is that it is the major constituent of paper and cardboard and of textiles made from cotton, linen, and other plant fibers.

Cellulose can also be converted into cellophane, a thin transparent film, and into rayon, an important fiber that has been used for textiles. Both cellophane and rayon are identical to cellulose in chemical structure. They are known as "regenerated cellulose fibers" and are usually made from viscose, a viscous solution made from cellulose. In the laboratory, cellulose is used as the stationary phase for TLC (thin layer chromatography). It is the raw material in the manufacture of nitrocellulose (cellulose nitrate). Cellulose is used in the laboratory as a stationary phase for thin layer chromatography. Cellulose fibers are also used in liquid filtration, sometimes in

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immune responses by intake of seaweeds, and the effects have been mainly attributed to sulfated polysaccharides constituting the cell sources of nutrients such as minerals for people living in the area. Asian areas, including Japan. They might have been invaluable seaweeds have long been utilized as food materials especially in substances collectively known as hydrocolloids or phycocolloids. Starch is also used as an excipient, as tablet disintegrant or as binder.

**CHITIN**

Chitin is a linear homopolysaccharide (long chain bio polymer) an important structural molecule comprising of N-acetyl-glucosamine $\alpha$ as shown in figure 2, derivative of glucose and second most abundant organic compound, main ingredient in the exoskeleton of many arthropods, crustaceans and is the main component of cell walls in fungi, radulas of mollusks etc.$^{[9]}$. Like cellulose, it is indigestible by vertebrate animals having biomedical significance. Chitin has also been used as surgical thread, making it very valuable.

Chitin is a good inducer involved in plant defense mechanisms for controlling diseases, also been assessed as a fertilizer that can improve overall crop yields, also used in industry in many processes.$^{[10]}$. Examples of the potential uses of chemically modified chitin in food processing include the formation of edible films and as an additive to thicken and stabilize foods.$^{[11]}$. Processes to size and strengthen paper employ chitin and chitosan.$^{[12]}$. The chitin subunits form beta-glycosidic linkages similar to those formed by glucose molecules in cellulose. In fact, the only chemical difference from cellulose is the replacement of a hydroxyl group at the second carbon, thus be described as cellulose, but simply with a different group at the second carbon.

**STARCH**

Starch is the most common carbohydrate in the human diet and is contained in many staple foods like cereals (rice, wheat, and maize) and the root vegetables which is major source of animal diet, consisting of a large number of glucose units joined by glycosidic linkages showing in figure 3. This polysaccharide is produced by most green plants as an energy store. Starch generally contains 75 to 80% amylopectin and 20 to 25% amylose by weight depending on the plant.$^{[13]}$. Glycogen, the glucose store of animals, is a more branched version of amylopectin. In the pharmaceutical industry, starch is also used as an excipient, as tablet disintegrant or as binder.

**SEAWEEDS**

Major source of the polysaccharides are extracted from marine algae well known seaweeds (red, brown and green algae). Seaweeds are the most abundant source of polysaccharides viz., alginates, agar and agarose, carrageenans, cellulose and amylase. These are gelatinous substances collectively known as hydrocolloids or phycocolloids.$^{[14]}$. Seaweeds have long been utilized as food materials especially in Asian areas, including Japan. They might have been invaluable sources of nutrients such as minerals for people living in the area. Recently, much attention has been paid to the enhancement of immune responses by intake of seaweeds, and the effects have been mainly attributed to sulfated polysaccharides constituting the cell walls of seaweeds.$^{[15]}$. They are used as a food source, fertilisers, bioethanol and biogass production. Seaweed is a major ingredient in toothpaste, cosmetics and paints. Alginites and carrageenan are used in industrial products such as paper coatings, adhesives, dyes, gels, explosives and in processes such as paper sizing, textile printing, hydro-mulching and drilling.$^{[16]}$. Sulfated saccharides from both red and green algae have been known to inhibit some DNA and RNA enveloped viruses.$^{[17]}$. Products employing seaweed and its extracts total about $6$ billion annually, $5$ billion of which comes from direct consumption of the algae as a foodstuff.

**ALGINATE**

Alginate is an anionic polysaccharides and commonly available in cell wall of seaweed. It forms a viscous gum with water and having capacity to absorb water around 200-300 times of its own weight. Alginate, the mannuronic acid and glucuronic acid-constituted polysaccharide from brown seaweed (Phaeophyceae), including Laminaria hyperborean, Laminaria digitata, Laminaria japonica, Ascophyllum, & Macrocystis pyrifera.

**BIOMEDICAL APPLICATIONS OF ALGINATE**

Alginate forms mild gelation by addition of divalent cation $\text{Ca}^{2+}$ and has been extensively studied and applied as a biomaterial in wound healing, tissue engineering, orthopaedics, and dental implant surgery because of its low toxicity, relatively low cost, good biocompatibility, and osteoconductivity.$^{[18]}$. The thickening, gel-forming and stabilizing property of alginate adds it amongst the most widely used biopolymer with broader range of applications including tissue engineering, drug delivery, biosensor, and wound dressing, preparation of dental impression media.

**CARRAGEENANS**

Carrageenan, an anionic sulfated polysaccharides, has straight chain backbones of alternating 3-linked $\beta$-$\text{D}$-galactopyranose, 4-linked $\alpha$-galactopyranose residue. Several of its $\alpha$-galactose residues may exist in the form of 3, 6-anhydro derivatives, these derivatives may be substituted by ester sulfate, methyl groups and pyruvic acid acetals, and sometimes monosaccharide. The residue 3, 6-anhydro-$\alpha$-D-
Galactose is necessary for gel formation by carrageenan. Carrageenans have been extensively studied marine derived polysaccharides in drug delivery, tissue engineering, and wound healing applications.

**Use of polysaccharides in Dentistry**

Dentistry involves in the study of diagnosis, prevention, and treatment of diseases, disorders and conditions of the oral cavity, and of adjacent and related structures and tissues, particularly in the maxillofacial (jaw and facial) area mainly associated with teeth. The majority of dental treatments are carried out to prevent or treat the diseases. Common treatments involve the restoration of teeth, extraction or surgical removal of teeth, scaling and root planning and endodontic root canal treatment.

Seaweeds can be used in the preparation of fluoridated toothpastes and also acts as a stabiliser in toothpastes. According to American dental Association, thickening materials include seaweed colloids, mineral colloids and natural gums. Interestingly it has been recently found that certain bacteria (*Bacillus licheniformis*) that live on the surface of raw seaweeds secrete enzymes that help to clear dental plaque when applied as an ingredient in toothpastes.

**Other uses of polysaccharides**

Polysaccharides have promising applications in various clinical settings because of vide variety of biological activities, highly heterogeneous and complex structure. Polysaccharides have several roles. Polysaccharides such as starch, glycogen, and dextrins are all stored in the liver and muscles to be converted to energy for later use. Amylose and Amylopectin are polysaccharides of starch, used in dairy industries as a thickener for cream and milk desserts, stabilizer in sorbets, ice cream, in processed cheese, moisture retention and flavor enhancement, used in preparation of diabetic products, coffee whiteners, baby milk formulations, making of bakery products, icings and cake mixes and improving bread quality.

**REFERENCES**