International Journal of Biological Macromolecules 60 (2013) 83–92

Contents lists available at SciVerse ScienceDirect

International Journal of Biological Macromolecules

journal homepage: www.elsevier.com/locate/ijbiomac

Review

Galactomannan: A versatile biodegradable seed polysaccharide

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ARTICLE INFO

Article history:
Received 26 April 2013
Accepted 16 May 2013
Available online 23 May 2013

Keywords:
Major galactomannans
Polysaccharides
M/G ratio

ABSTRACT

Polysaccharides have been finding, in the last decades, very interesting and useful applications in the biomedical and, specifically, in the biopharmaceutical field. Galactomannans are a group of storage polysaccharides from various plant seeds that reserve energy for germination in the endosperm. There are four major sources of seed galactomannans: locust bean (*Ceratonia siliqua*), guar (*Cyamopsis tetragonoloba*), tara (*Caesalpinia spinosa* Kuntze), and fenugreek (*Trigonella foenum-graecum* L.). Through keen references of reported literature on galactomannans, in this review, we have described occurrence of various galactomannans, its physicochemical properties, characterization, applications, and overview of some major galactomannans.

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1. Introduction to polysaccharides

Seed polysaccharides are one of the most important categories of plant-originated gums used in the food industry, as they play important roles in both food processing and improving the mouth feel and texture of food products. The occurrence of polysaccharides in plant seeds is mainly in three forms: as nonstarch polysaccharide food reserve material (e.g., guar, locust bean, etc.), as mucilages in the seed coats (e.g., psyllium seed, flaxseed, yellow mustard seed, etc.), and as cell wall materials of seed cotyledons and endosperms (e.g., tamarind and soybean seeds). The chemical compositions, fine structures, and physical and functional properties of these polysaccharides can vary significantly with plant sources, growing environments, and method of production. Seed polysaccharides (nonstarch) are also an important source of dietary fiber, which may exhibit bioactivities such as reducing calorie intakes, controlling blood glucose and insulin levels, and reducing the risks of heart diseases and colon cancer [1].

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0141-8130/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.ijbiomac.2013.05.017

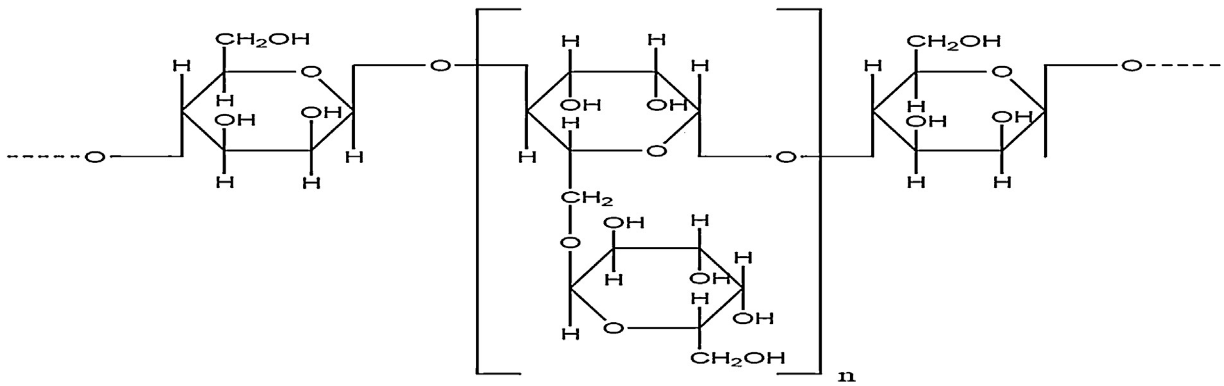

Fig. 1. General molecular structure of galactomannan.

Carbohydrate molecules have complex structures. These are the most abundant of the natural products and the source of all biological energy. Being poly functional in nature, these molecules participate in a multitude of chemical and biochemical reactions. They are composed of the polyhydroxy aldehydes, ketones, alcohols, acids and their simple derivatives as well as their polymers having linkages of the acetal type. Carbohydrates can be classified into *monosaccharides*, *oligosaccharides* and *polysaccharides*. Monosaccharides are the lower members of carbohydrates, which cannot be degraded by hydrolysis. Oligosaccharides and polysaccharides are polymers of monosaccharides and their derivatives, joined by acetal-type linkages. Oligosaccharides contain between 2 and 10 monosaccharide units, and polysaccharides contain more than 10 units.

Polysaccharides, also known as *Cinderella of biopolymers*, hold a wide range of different functions; sometimes they behave as energy storage materials and the well-known examples are starch, glycogen and some plant seed polysaccharides such as locust bean gum, guar gum, tara gum and panwar gum. Sometimes they contribute to the structural integrity and mechanical strength of plant tissues by forming a hydrated cross-linked three-dimensional network (pectins play this role in land plants while carrageenans, agar and alginate have an equivalent function in marine species). On the other hand, polysaccharides such as cellulose and chitin and, less frequently, xylans and mannans can generate hard, solid structures or tough fibers by close packing of the chains. Polysaccharides may also act as protective substances; protective polysaccharides are exemplified by the antigenic and immunogenic exocellular microbial polysaccharides-that are frequently highly specific for particular organisms or by the exudate gums from plants, which appear to provide a preventive function by sealing off the injured parts of the plant against bacterial infections [2].

2. Introduction to galactomannans

Galactomannans are heterogeneous polysaccharides composed by a β-(1–4)-D-mannan backbone with a single D-galactose branch linked α-(1–6) (Fig. 1) [3]. They differ from each other by the mannose/galactose (M/G) ratio. These gums are mostly obtained from the endosperm of dicotyledonous seeds of numerous plants, particularly the Leguminosae. The endosperm has several functions: it serves as food reserve for germinating seeds and it retains water, preventing the complete drying of the seeds [4,5]. There are four major sources of seed galactomannans: locust bean (*Ceratonia siliqua*), guar (*Cyamopsis tetragonoloba*), tara (*Caesalpinia spinosa* Kuntze), and fenugreek (*Trigonella foenum-graecum* L.). Among these, only locust bean and guar gums are of considerable industrial importance. The use of tara and fenugreek gums is limited due to availability and price. Other sources of galactomannans have also been explored in the literature, but no commercial potential can be expected in the near future [3].

Galactomannan is derived from the seeds of plant *C. tetragonolobus*, a pod bearing legume grown commercially in India, Pakistan and the southwestern United States. The seed is composed of hull (15%), germ (45%), and endosperm (40%). The ratio of D-mannopyranosyl to D-galactopyranosyl units is about 1.8:1. The average molecular weight of the Galactomannan is in the range of $1–2 \times 10^6$ Da [6]. Galactomannan forms viscous, colloidal dispersion when hydrated in water. It is being used as a viscosity builder and water binder in many industries such as textile, food, paper, petroleum, mining, explosives, and pharmaceuticals.

The molar ratio of galactose to mannose varies with plant origin but is typically in the range of 1.0:1.0–1.1, 1.0:1.6–1.8, 1.0:3.0, and 1.0:3.9–4.0 for fenugreek, guar, tara, and locust bean gums, respectively. The conformation of the 1→4-linked β-D-mannan backbone is similar to that of cellulose, so that it does not dissolve in water. The galactose side groups are considered to sterically disturb the interchain association and crystallization, thereby imparting certain water solubility to the galactomannans. As a result, the solubility of the galactomannans increases with the degree of galactosyl substitution: fenugreek and guar gums are readily dissolved in cold water, but heating is needed to reasonably solubilize locust bean gum in water.

The two main groups of galactomannan polysaccharides are those derived from (a) the endosperm of plant seeds, the vast majority of which originate in the *Leguminosae*, and (b) microbial sources, in particular, the yeasts and other fungi.

3. Occurrence

The majority of galactomannans originate from *Leguminosae* family. 70 species of the *Leguminosae* have been identified containing galactomannans (Table 1). True galactomannans, as defined by *Aspinall* (that is, those mannans containing more than 5% of D-galactose) have also been extracted from members of *Annonaceae*, the *Convolvulaceae* and the *Palmae*, *Ebenaceae* and *Loganiaceae* as shown in Table 2. The general procedure to obtain galactomannans from seeds combines extraction and purification processes. Briefly, the seed hull is removed from the seeds and the germ is separated from the endosperm. The most used separation procedures are: filtration, sifting and in some cases (e.g., lab scale) they are separated manually. The endosperm is dissolved in water (at temperatures that can range between 20 and 120 °C), followed by a precipitation step using alcohol (in a ratio water:alcohol that can range between 1:1 and 1:3). No effects of the alcohol on galactomannans' structure have been reported [6,7].