



ISSN: 2456-0057

IJPNPE 2019; 4(1): 2441-2447

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www.journalofsports.com

Received: 02-09-2018

Accepted: 06-10-2018

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A review on gum polysaccharides and biological action in human beings

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Abstract

Polysaccharides are composed of many monosaccharide residues that are joined one to the other by *O*-glycoside linkages. The great diversity of structural features of polysaccharides, which originates from difference in the monosaccharide composition, linkage types and patterns, chain shapes, and degree of polymerization, dictates their physical properties including solubility, flow behaviour, gelling potential, and surface or interfacial properties. The structural diversity also dictates the unique functional properties exhibited by each polysaccharide. Polysaccharides, which are commercially available for use in food and non-food industries as stabilizers, thickening and gelling agents, crystallization inhibitors, and encapsulating agents etc., are called hydrocolloids or gums. Polysaccharide gums occur in nature as storage materials, cell wall components, exudates, and extracellular substances from plants or microorganisms. Exudate gums are obtained as the natural exudates of different tree species and exhibit unique properties in a wide variety of applications. This review covers the chemical structure, occurrence and production of the different gums. It also deals with the size and relative importance of the various players on the world market. Furthermore, it gives an overview of the main application fields of the different gums, both food and non-food. Now a day's many of scientists and researches are interested about the synthesis of the nanoperticals about these gums and study their applications as well as different kinds of their functions. The information presented in this review is helpful in exploring and understanding the different gum polysaccharides and their structures, different types of activities.

Keywords: Exudate gums, stabilizers, thickening, crystallization inhibitors, encapsulating agents

Introduction

Exudate gums are polysaccharides produced by plants as a result of stress, including physical injury and/ or fungal attack. They are amongst the oldest natural gums: about 5,000 years ago they were already being used as thickening and stabilizing agents. The three major exudate gums—gum arabic, gum tragacanth, and gum karaya—possess a unique range of functionalities ^[1]. They have been important items of international trade in the food, pharmaceutical, adhesive, paper, textile, and other industries for centuries. Generally, these gums are structurally related to arabinogalactans, galacturonans, or glucuronomannans. They all contain a high proportion of glucuronic or galacturonic acid residues.

Gum arabic is the oldest and best known of all natural gums. It is exuded from the bark of *Acacia nilotica* trees which was called the "Gum Arabic tree", ^[2] in the present day, gum Arabic is predominantly collected from two related species, namely *Acacia Senegal* ^[3] and *Vachellia (Acacia) seyal*, that grow primarily in Africa. The thorny trees grow to a height of 7 to 8 meters, and the gum is obtained by cutting sections of the bark from the tree. Its use can be traced back to the third millennium B.C., the time of the ancient Egyptians. Early Egyptian fleets shipped gum arabic as an article of commerce. It was used as a pigment binder and adhesive in paints for making hieroglyphs, and ancient inscriptions refer to it as *kami*. Furthermore, it was used as a binder in cosmetics and inks and as an adhering agent to make flaxen wrappings for embalming mummies.

Gum tragacanth is a natural gum obtained from the dried sap of several species of middle Eastern legumes of the genus *Astragalus*, including *A. Adscendens*, *A. Gummifer*, *A. Brachycalyx*, ^[4, 5] and *A. Tragacanthus*. Some of these species are known collectively under the common names "goat's thorn" and "locoweed". The gum is sometimes called Shiraz gum, shiraz gum elect or gum dragon. Iran is the biggest producer of the best quality of this gum.

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It is collected by hand, then graded, milled, and sifted to remove impurities. Gum tragacanth contains a water-soluble fraction and water-insoluble fraction and the water-soluble fraction is accounted for 30 to 40% of the total gum.

Gum karaya is a vegetable gum produced as exudates by trees of genus *Sterculia*. Chemically, gum karaya is an acid polysaccharide composed of the sugars – galactose, rhamnose and galacturonic acid. It is used as a thickener and emulsifier in foods, as laxative, and as denture adhesive. It is also used to adulterate Gum tragacanth due to their similar physical characteristics [6]. Gum karaya is defined by JECFA as: 'a dried exudation from the stems and branches of *Sterculia urens* Roxburgh and other species of *Sterculia* (Fam. Sterculiaceae) or from *Cochlospermum gossypium* A.P. De Candolle or other species of *Cochlospermum* (Fam. Bixaceae) [7].

Gum Ghatti is the amorphous translucent exudate of the *Anogeissus Latifolia* tree of the Combretaceae family. The tree occurs throughout the greater part of India; more commonly in the dry deciduous forests. It is a large erect deciduous tree, 9-15 meters (sometimes 24 m) with a smooth light colored bark. The tree is leafless during the whole of the cold season; new leaves in April-May. The gum, locally called *Dhavda* when first exuded is in a soft plastic form. The colour varies from whitish yellow to amber depending on factors like the proximity of the tear to the bark, the length of time it has remained on the tree before being picked and the age of the product in storage. It is also an excellent emulsifier and has been used to replace gum Arabic in more complex systems, e.g.; gum ghatti is used as an emulsifier and stabilizer in beverages and butter-containing table syrups. Gum ghatti is used to encapsulate and stabilize oil-soluble vitamins. It is also used as a binder in making long-fibered, light weight papers.

Gum Katira [8, 9] has assumed great importance in recent years and exported annually from India for use in the cigar paste and ice-cream industry. The gum is sweet, thermogenic, anodyne, sedative and useful [10] in cough, diarrhoea, dysentery, pharyngitis, gonorrhoea, syphilis and trachoma. It is exudate of the *Cochlospermum religiosum* which is a small or medium sized, deciduous, soft wooded tree. The tree occurs all over India from Garhwal to west sub- Himalayan tracts to West- Bengal, Bihar, Orissa and Decan peninsula. This gum is pale and semi-transparent, insoluble in water, but swells into a pasty transparent mass with water.

Chemical structures

Table 1: Main Botanical and Structural Characteristics of Exudate gums [11]

Gum	Species of Origin	General Structure
Gum Arabic	<i>Acacia senegal</i>	Substituted acidic arabinogalactan
Gum Tragacanth	<i>Astragalus gummifer</i>	Mixture of arabinogalactan And glycano-rhamnogalacturonan
Gum Karaya	<i>Sterculia urens</i>	Glycano-rhamnogalacturonan
Gum Ghatti	<i>Anogeissus latifolia</i>	Glycano-glucuronomannoglycan

The chemical composition of these gums is complex and varies to some extent depending on the source and its age. Therefore, it is not possible to provide defined structural

formulas of these biopolymers.

Gum Arabic

Gum Arabic is a low viscosity gum and its solutions exhibit Newtonian flow behaviour even at high concentrations. It is extremely soluble in water and the solubility can be as high as 55%. The highly branched molecular structure and relatively low molecular weight of this polymer are responsible for these properties. Another unique feature of gum Arabic is its covalent association with a protein moiety. Gum Arabic is a surface active gum that is able to stabilize oil-in-water emulsions. The protein-rich high molecular weight fraction of gum Arabic is preferentially adsorbed onto the surface of oil droplets while the carbohydrate portion inhibits flocculation and coalescence by electrostatic repulsions and steric forces. Gum arabic is a branched, neutral or slightly acidic, complex polysaccharide obtained as a mixed calcium, magnesium, and potassium salt. The structure of gum Arabic is relatively complex. The main chain of this polysaccharide is built from (1→3) and (1→6) – linked β-D- galactopyranosyl units along with (1→6)- linked β-D-glucopyranosyl uronic acid units. Side branches may contain α-L-rhamnopyranose, β-D-glucuronic acid, β-D- galactopyranose, and α-L-arabinofuranosyl units with (1→3), (1→4), and (1→6) glycosidic linkages.

Table 2: Analytical data for the gum obtained from *Acacia Senegal* [12]

Parameter	Range
Moisture content (%)	12.5–16.0
Specific rotation	–32.7 ° to –27.0 °
Nitrogen (%)	0.22–0.39
Protein (%)	1.5–2.6
Galactose (%)	39–42
Arabinose (%)	24–27
Rhamnose (%)	12–16
Glucuronic acid (%)	15–16
Equivalent mass (Da)	1,118–1,238

The characteristics may vary significantly, depending on the geographical origin and age of the trees, climatic conditions, soil environment, and even on the place of exudation on the tree [13, 14]. Because of its heterogeneous nature, gum arabic was described by Anderson and Stoddart [15] as heteropolymolecular, on the one hand having a variation in monomer composition and/or in the linking and branching of the monomer units and on the other hand having a molecular mass distribution.

Gum Tragacanth

Gum tragacanth is a complex, highly branched, heterogeneous polysaccharide, naturally occurring as a slightly acidic calcium, magnesium, and potassium salt. The composition of the gum obtained from different *Astragalus* species shows considerable variation. Hence, commercial gum tragacanth is a highly variable product. In table-3 the composition of Turkish samples of gum tragacanth from the two commercially most important species (*A. microcephalus*, *A. gummifer*) are compared. Important differences are found in sugar composition, methoxyl content, and relative proportion of soluble and insoluble components.

Analytical data for the exudates from Turkish *Astragalus* species [16].

Table 3: The sugar composition was assessed after hydrolysis

Parameter	<i>Astragalus microcephalus</i>	<i>Astragalus gummifer</i>
Loss on drying (%)	12.7	9.9
Total ash (%)	3.2	2.9
Nitrogen (%)	0.58	0.46
Total protein (%)	3.65	2.84
Methoxyl (%)	3.3	0.9
Ratio of soluble: insoluble components	65:35	40:60
Galacturonic acid (%)	11	3
Galactose (%)	14	23
Arabinose (%)	37	63
Xylose (%)	22	5
Fucose (%)	12	2
Rhamnose (%)	4	4

Gum tragacanth consists of two fractions. Tragacanthic acid or bassorin is insoluble in water, but has the capacity to swell and form a gel. The other fraction is called tragacanthin and is water-soluble. The water soluble fraction is a highly branched neutral polysaccharide composed of (1→6)-linked D-galactosyl backbones with L-arabinose side chains joined by (1→2), (1→3), and /or (1→5)-linkages. The water-insoluble fraction (~60 to 70%), is tragacanthic acid which is consisted of D-galacturonic acid, D-galactose, L-fucose, D-xylose, L-arabinose and L-rhamnose. It has a (1→4)-linked α -D-galacturonopyranosyl backbone chain with randomly substituted xylosyl branches linked at the 3 position of the galacturonic acid residues. It is the most viscous natural water-soluble gum and is an excellent emulsifying agent with good stability to heat, acidity, and aging.

Gum karaya

Gum karaya is a complex, partially acetylated polysaccharide obtained as a calcium and magnesium salt. It has a branched structure and a high molecular mass of approximately 16×10^6 Da [17]. The backbone of the gum consists of α -D-galacturonic acid and α -L-rhamnose residues. Side chains are attached by 1,2-linkage of β -D-galactose or by 1,3-linkage of β -D-glucuronic acid to the galacturonic acid of the main chain. Furthermore, half of the rhamnose residues of the main chain are 1,4-linked to β -D-galactose units [18]. The chemical composition of gum samples obtained from different *Sterculia* species and from different places of origin was found to be quite similar [19, 20]. Commercial gum karaya contains about 13–26% galactose and 15–30% rhamnose, which is considerably higher than the rhamnose content of other commercial exudate gums. However, the protein content of about 1% is lower than that of other exudate gums. Gum karaya contains approximately 40% uronic acid residues and 8% of acetyl groups, from which free acetic acid is released on aging. Due to the presence of these acetyl groups, native gum karaya is insoluble and only swells in water [21]. Le Cerf *et al.* [17] distinguished three fractions in gum karaya, based on their solubility in water. Only 10% of the native gum was solubilized in cold water, increasing to 30% in hot water. After deacetylation with dilute ammonia, 90% of the native gum dissolved in water. The equivalent weight of the deacetylated-soluble fraction was higher than that of the cold-water-soluble fraction. This indicates that only lower-molecular-weight molecules are able to dissolve in cold water, while deacetylation leads to the solubilization of material of higher molecular weight [17].

Table 4: The sugar composition was assessed after hydrolysis

Parameter	Range
Protein (%)	Lower than 1% of other Exudate gum
Galactose (%)	13–26
Rhamnose (%)	15–30
Uronic acid (%)	40
Acetyl group (%)	8
Equivalent mass (Da)	16×10^6

Gum Ghatti

Gum Ghatti is a complex polysaccharide of high molecular weight. It occurs in nature as a mixed calcium, magnesium, potassium and sodium salt. Complete hydrolysis has shown that it is composed of L-arabinose, D-galactose, D-mannose, D-xylose and D-glucuronic acid in a molar ratio of 10:6:2:1:2 plus traces less than 1% of 6-deoxyhexose. Gum Ghatti does not dissolve in water to give a clear solution but rather over 90% of the gum disperses in water to form a colloidal dispersion. At the same time it does not form a true gel. It forms viscous solutions at concentrations of about 5% or higher and exhibits typical non-Newtonian behaviour. Gum Ghatti is a moderately viscous gum lying intermediate between Arabic and Karaya. This viscosity profile gives it a unique status in the spectrum of hydrocolloids. The emulsifying properties of Gum Ghatti are excellent and considered to be better than Gum Arabic and thus used in more difficult-to-handle systems. The normal pH of the dispersion is 4.8. Gum Ghatti solutions are sensitive to alkali. Viscosity increases sharply with pH upto a maximum at about pH 8 and above that the solutions tend to become stringy.

Gum Katira

In 1953, E.L. Hirst *et al.* [22] first time attempted to establish the structure of the polysaccharide of this gum and showed that, it consists of equimolecular proportion of L-rhamnose, D-galactose and D-galacturonic acid, together with traces of a ketohexose. From methylatyon study, he established the presence of the fragments; terminal L-rhamnose, terminal D-galactose, 1,2 linked L-rhamnose, 1,4-linked D-galactose, 1,2,4-linked L-rhamnose and a mixture of methylated uronic acid but no detailed structure was established. In 1962, Aspinall *et al.* [23] again attempted to establish the detailed structure. He observed the presence of 1,2,4-linked D-galacturonic acid in the inner chain of this polysaccharide with similar residues of neutral sugars. But in recent years, the detailed structure of this polysaccharide was established [24].

active properties and acts as a thickener in the continuous water phase, thus stabilizing the emulsion and providing long shelf-life. In low-calorie, an oil-free dressing, gum tragacanth is used to imitate the creamy mouthfeel and body of dispersed oil droplets. In fish and citrus oil emulsions with a long shelf-life, gum tragacanth is used in combination with gum arabic. It has been used in the pharmaceutical and personal care industries as an emulsifier and stabilizer in medicinal emulsions, jellies, syrups, ointments, lotions, and creams. It is also used in milkshakes as a viscosity control agent, providing

texture and stabilizing incorporated air [40]. Improve dietary glucose tolerance [58]. Research has revealed the water-soluble fiber in it may help people with diabetes by slowing the adsorption of sugars by the small intestine. In pharmaceutical industry-it is used as binder or as disintegrator in tablets; main ingredient in some bulk forming laxative. Folic acid conjugated guar gum nanoparticles are established recently which is used for targeting methotrexate to colon cancer [59].

Table 6: Maximum usage levels (%) of gum tragacanth permitted in accordance with the FDA Code of federal regulations

Food (as served)	Percentage	Function
Baked goods and baking mixes	0.2	Emulsifier, emulsifier salt, formulation aid, stabilizer/thickener
Condiments and relishes	0.7	Emulsifier, emulsifier salt, formulation aid, stabilizer/thickener
Fats and oils	1.3	Emulsifier, emulsifier salt, formulation aid, stabilizer/thickener
Gravies and sauces	0.8	Emulsifier, emulsifier salt, formulation aid, stabilizer/thickener
Meat products	0.2	Formulation aid, stabilizer/thickener
Processed fruits and fruit juices	0.2	Emulsifier, emulsifier salt, formulation aid, stabilizer/thickener
Other food categories	0.1	Emulsifier, emulsifier salt, formulation aid, stabilizer/thickener

Gum Karaya

Due to its acid stability, high viscosity, and suspension properties, gum karaya is well suited for stabilizing low pH emulsions, such as sauces and dressings [41]. In French dressings, gum karaya functions as a stabilizer, increasing the viscosity of the aqueous phase of the oil-in-water emulsion [42]. In cheese spreads, gum karaya is used as a binder to provide texture and spreadability and to prevent water separation. In salads, the gum acts as a stabilizer and prevents the weeping of the water from the oil-in-water emulsion [43]. It is also incorporated in aerated dairy desserts and whipped cream, where it acts as a foam stabilizer. Gum karaya significantly reduces the bioavailability of calcium in milk-based foods, as demonstrated by [44].

Table 7: Maximum usage levels (%) of gum karaya permitted in accordance with the FDA Code of federal regulations

Food (as served)	Percentage	Function
Frozen dairy desserts and mixes	0.3	Formulation aid, stabilizer/thickener
Milk products	0.02	Stabilizer/thickener
Soft candy	0.9	Emulsifier, emulsifier salt, stabilizer/thickener
Other food categories	0.002	Formulation aid, stabilizer/thickener

Most gum karaya is consumed in the pharmaceutical industry, where it is used in diverse applications. It functions as an adhesive in leakproof sealing rings for post-surgical drainage pouches or ostomy bags [45, 46, 47]. Powdered gum karaya is widely applied on dental plates as an adhesive [48]. When brought in contact with the moist surfaces of the mouth, the gum does not dissolve but swells and provides a more comfortable and tighter fit of the plate. Furthermore, it is very resistant to bacterial and enzymatic degradation. In tampons, gum coatings form a gelatinous medium in contact with body fluids, preventing irritation of the mucous membranes and facilitating removal after use [49]. Deacetylated gum karaya is used as a binding agent in the production of long-fiber, lightweight papers [20]. It effectively prevents the fibers from forming flocks and keeps them homogeneously distributed, resulting in a lightweight sheet of improved formation and strength. The gum is deacetylated in order to expose more active carboxyl and hydroxyl groups and improve the

association with the cellulose fibers. For textile applications, the solubility of gum karaya is increased by cooking an aqueous dispersion under pressure. It is then used as a thickening agent for the dye in direct color-printing on cotton fabrics.

Gum Ghatti

Following are some of the applications of Gum Ghatti:

- As an emulsifier and stabilizer in beverages and butter containing table syrups.
- As a flavour fixative for specific applications.
- Used in the preparation of powdered, stable, oil-soluble vitamins.
- As a binder in long-fibered light weight papers.
- As an emulsifier of petroleum and non-petroleum waxes to form liquid and wax paste emulsions.
- Used in combination with polyacrylamide to aid in the polymerization and formation of uniform and discrete prills of cross-linked polystyrene.
- Used as drilling mud conditioner and the acidizing of oil wells.
- Used in powdered explosives to improve resistance to water damage.

Gum Katira

This gum has assumed great importance in recent years and exported annually from India for use in the cigar paste and ice-cream industry [8, 9]. The gum is sweet, thermogenic, anodyne, sedative and useful [10] in cough, diarrhoea, dysentery, pharyngitis, gonorrhoea, syphilis and trachoma. Recently, green syntheses of gold nanoparticles (AuNPs) are established using aqueous solution of a hetero polysaccharide, extracted from the gum [50]. These gold nanoparticles function as an efficient heterogeneous catalyst in the reduction of 4-nitrophenol. This gum has also been applied as excipient in drug delivery devices and may have the potential of exploration in novel drug delivery development [51].

Some other common gums

Mucilage gums: These gums are very viscous polysaccharides extracted from seeds or soft stem of plants: examples are okra mucilage (from *Hibiscus esculentus*), psyllium (from *Plantago* species), yellow mustard (from *Sinapis alba*), and flax mucilage (from *Linum usitatissimum*).

All of them are acidic polysaccharide with structures somewhat related to some of the exudates gums. Their utilization in certain food products is increasing due to their functional properties (viscosity, gelation, water binding) as well as to their bio-active role in prevention and treatment of certain diseases.

Xanthan gum: Xanthan gum is an extracellular polysaccharide produced by the bacterium *Xanthomonas campestris* [52]. It is used as food additive and rheology modifier, [53] commonly used as a food thickening agent (in salad dressings etc.) and a stabilizer (in cosmetics products etc.). It is composed of pentasaccharide repeat units, comprising glucose, mannose and glucuronic acid in the molar ratio 2:2:1 [54]. The primary structure of xanthan consists of the cellulose-like backbone of (1→4)-linked β-D-Glcp residues substituted, at O-3 of alternate glucose residues, with a trisaccharide. The trisaccharide consists of the β-D-Manp- (1→4)- β-D- Glcp A- (1→2)-α-D- Manp-(1→unit). Non-carbohydrate substituents include the acetyl group at O-6 of the inner Manp residue and the pyruvate group at O-4,6 of the terminal Manp.

Gellan gum: Gellan gum is a DE acetylated form of the extracellular bacterial polysaccharide from *Aurimonas elodea*. It was initially identified as a substitute gelling agent at significantly lower use level to replace agar in solid culture media for the growth of various microorganisms [55]. Its initial commercial product with the trademark as 'GELRITE' gellan gum, was subsequently identified as a suitable gelling agent in various clinical bacteriological media. It has a repeating tetrasaccharide sequence of →3)-β-D-Glcp-(1→4)-β-D-GlcpA- (1→4)- β-D-Glcp- (1→4)-α-L- Rhap- (1→unit). In the native form gellan has anL-glycerol substituent on O-2 of the (1→3)-linked glucose and an acetyl group on some of the O-6 atoms of the same residue; both groups are normally lost during commercial extraction. It is used as gelling agents in desert jellies, dairy products, and sugar confectionery. Gellan gum can also be used to prepare structured liquids [56].

Guar gum: Guar gum, also called guaran, is a galactomannan. It is primarily the ground endosperm of guar beans. Chemically, guar gum is a polysaccharide composed of the sugars galactose and mannose. The backbone is a linear chain of β- (1→4)-linked mannose residue to which galactose residues are (1→6)-linked at every second mannose, forming short side-branches. This gum, as a water-soluble fiber, acts as a bulk-forming laxative, so is claimed to be effective in promoting regular bowel movements and relieving constipation and chronic related functional bowel ailments, such as diverticulosis, Crohn's disease, colitis and irritable bowel syndrome. Guar gum has been considered of interest in regard to both weight loss and diabetic diets. It is a thermogenic substance [57]. Some studies have found guar gum to

Conclusions

This paper presented a review of the industrially most relevant exudate gums: gum Arabic, gum karyya, and gum tragacanth. This review covers the chemical structure, occurrence and production of the different gums. It also deals with the size and relative importance of the various players on the world market. Furthermore, it gives an overview of the main application fields of the different gums, both food and non-food. Recently, many of scientists and researchers are

interested in these different gum polysaccharides because of their good stabilizing properties. Gum karyya used as a biotemplate using green synthesis of copper oxide nanoparticles which is shown as antibacterial properties [60]. Again, gum of *Cochlospermum gossypium* used also as a template for the green synthesis of silver nanoparticles and also shown antibacterial application [61]. Some of gums are used as magnetic nano-absorbent [62]. Gum Xanthan / Fe₃O₄ based nanocomposite hydrogel are used as adsorption of methyl violet from aqueous solution [63]. Gum Xanthan / Silica hybrid nanocomposite are used as absorbent for removal of Congo red dye from aqueous solution [64]. Ultimately, the pharmaceutical industry as also as food and non-food industry may provide new markets for chemically modified these gum polysaccharides and help develop new generations of polysaccharides with more beneficial biological activities.

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