Chapter

Gums—Characteristics and Applications in the Food Industry

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Abstract

Gums, or polysaccharides, are complex carbohydrates, soluble in water, which can form gels and mucilages. They have high molar mass and can be formed by galactose, arabinose, rhamnose, xylose, galacturonic acid, among others. They have gelling characteristics, thickening, moisture retention, emulsification and stabilization. Polysaccharides are widely used in the formulation of food products, due to their wide versatility. Its diversity of applications is closely linked to its chemical structures. The characterization of structural molecules allows the knowledge of the properties of polysaccharides or glycoconjugates. In this sense, this chapter addresses knowledge about chemical, molecular, rheological, thermodynamic characteristics that are extremely important to identify the use and applications of polysaccharides in the context of elaboration and innovation in the food industry.

Keywords: gum, hydrocolloids, carbohydrate

1. Introduction

The food and beverage industries face increasingly challenging scenarios, as they need to meet consumers' desires, and use ingredients that are natural, and that fulfill their technological roles in processed foods. Among these ingredients, gums and hydrocolloids are the compounds most widely used as agents of innovation in the food industry.

Gums, also known as hydrocolloids or polysaccharides, are very versatile biopolymers, extensively used in the food sector as ingredient or additive, which fulfill several technological and, sometimes, nutritional functions. This versatility is intrinsically related to their molecular composition, which gives these polysaccharides certain properties such as gelling, thickening, moisture retention, emulsification, and stabilization. In the food industry, they are widely used in confectionery, as ice cream stabilizers, food emulsions, in the microencapsulation of flavors and dyes, clarifiers, and beverage stabilizers.

Therefore, information on the molecular structure, thermal stability, interaction with water, and rheological behavior are essential knowledge for prospecting and developing applications for each type of polysaccharide, whether isolated or in mixtures.

Another important fact, in this sense, is the constant search for new sources of polysaccharides that might have similar and/or better effects than those already known. This is important because it also shows regional valorization, source of income, and new business opportunities.

Thus, this chapter aims to discuss the physical, chemical, and molecular knowledge of polysaccharides, in addition to their versatility of applications in the food industry.

2. Gums: origin and definition

The term gum is generally used to define hydrophilic or hydrophobic molecules of high molar mass, which have colloidal properties [1]. Classified according to origin, behavior, and chemical structure, gums can be derived from plant seed endosperm (guar gum) [2], plant exudates (tragacanth), shrubs or trees (gum arabic, karaya gum, cashew gum) [2–5], algae extracts (agar) [6], bacteria (xanthan gum), animal source (chitin), and others [7–10].

Vegetable exudates are fluids that flow spontaneously from trees, due to adaptations to climatic conditions (physiological gummosis) or in response to any injury suffered, whether mechanical, such as cutting, or by the action of microorganisms, which dry out when exposed to air [11].

Hillis [12] describes in detail the differences between exudates from tree trunks, specifically the differences between resins and gums, and their formation. The author defines resins as materials composed largely by terpenoids, and that may contain phenolic compounds (coumaric, caffeic, and ferulic acids), with few fatty acids and glycerides. They may be formed within plastids present in epithelial cells of plants [13] or even synthesized in spherosomes, both in resin duct cells and in parenchymal cells [14].

Hillis [12] also defines gums as products composed mainly of complex carbohydrates, soluble in water, which can form gels and mucilages. They have high molar mass and can be formed by galactose, arabinose, rhamnose, xylose, galacturonic acid, and other compounds. In some species, they are secreted by organelles present in the bark or between barks, whose main function is protecting the plant from injuries caused by cuts or microbial attack [15–17].

The interest in gums exuded from plants is due to their structural properties and respective functions in food, pharmaceutical, cosmetic, textile, and biomedical products [18]. Water-soluble gums, also known as hydrocolloids, can have various applications such as: dietary fibers, texture modifiers, gelling agents, thickeners, stabilizers, emulsifiers, coatings, films, and as encapsulants [19, 20]. There has been a strong trend towards replacing synthetic materials by natural gums due to their non-toxicity, low cost, safety, and availability [21].

3. Structural aspects of gums

All the properties and applications of gums are closely linked to their chemical structures. Gums can be formed by numerous sugars, in their main chains and/or side chains, and can be more or less branched, which determines, in general, their complexity [15].

Among the most well-known and commercialized gums [22], the gum arabic, produced by the species *Acacia senegal*, presents in its structure a main chain formed by β-D-galactopyranose joined by bonds (1➔3), alternated by highly branched bonds (1➔6), and shows lateral chains constituted by 4-O-methyl-glucuronic acid (1.5%), glucuronic acid (17.5%), galactose (39%), arabinose (28%), and rhamnose (14%) [23]. Anderson; Hirst; Stoddart [24] proposed the structure presented in **Figure 1** for acacia gum. The authors indicated, as possible replacement units, those represented by the radical "R": (L-Araf); (L-Araf 1➔3 L-Araf); (β-L-Arap 1➔3 L-Araf);

(L-Araf 1➔3 L-Araf 1➔3 L-Araf); (β-L-Arap 1➔3 L-Araf 1➔3 L-Araf); (β-D-Galp 1➔3 L-Araf). Arabinofuranoside is Araf, arabinopyranoside is Arap, and galactopyranoside is Galp. The radicals "R" are not shown in **Figure 1B**.

Gum ghatti is also important among exudate gums because of its high emulsifying capacity [25]. It is extracted from the trunk of *Anogeissus latifolia*, an abundant tree in India [26]. Its molecular structure is formed by a main chain of (1➔6)-β-Galactose bonds, whose branches at positions O-3 and O-4 are replaced, consisting of ➔2)-Araf-(1➔4)-GlcpA-(1➔6)-Galp-(1➔6)-Galp-(1➔. The terminal

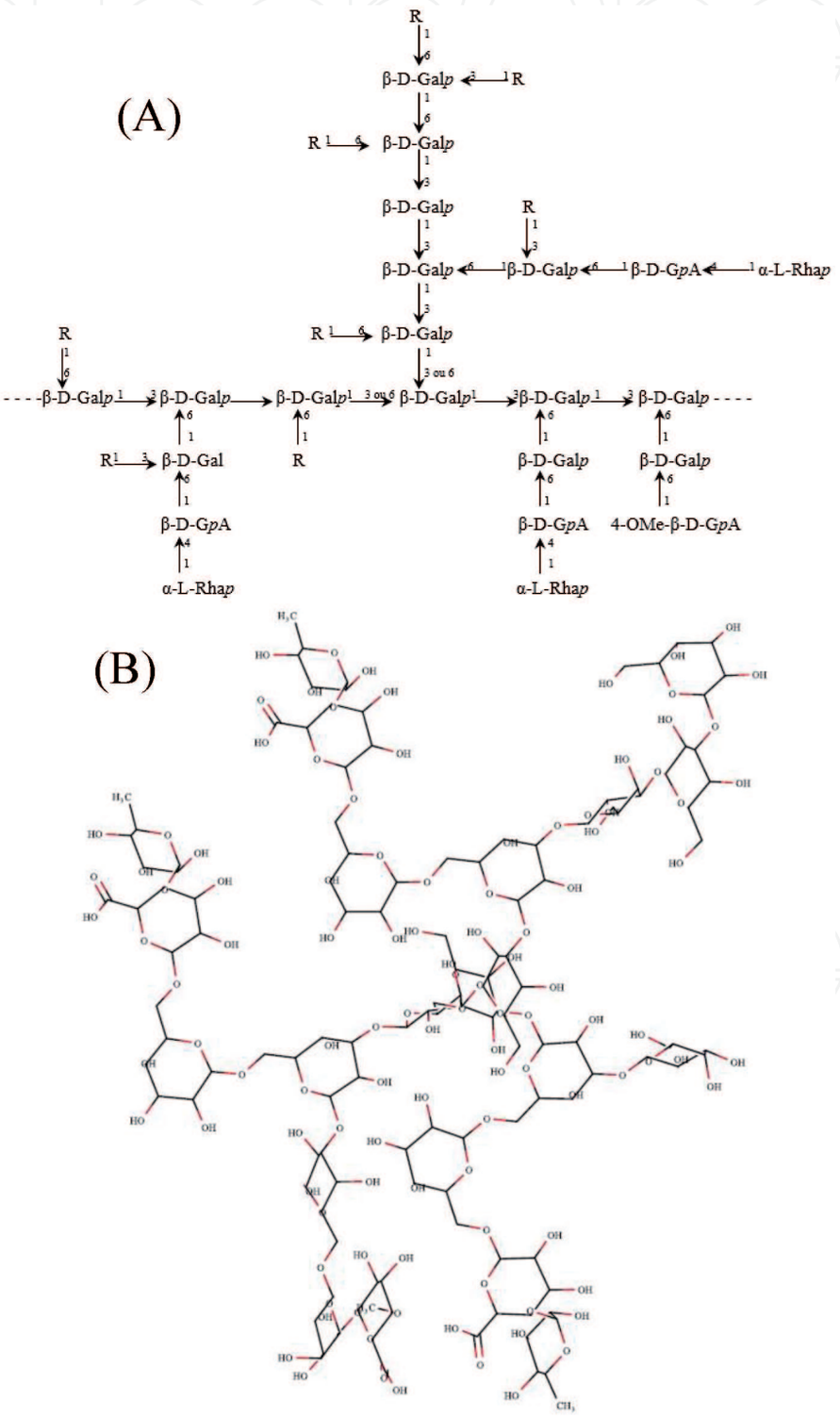

Figure 1.
*Structural fragment of gum arabic (*Acacia senegal*). (A) Scheme and (B) three-dimensional structure referring to the fragment shown.*

lateral chains are formed by residues of arabinofuranoside (Araf) and occasionally by rhamnopyranoside (Rhap), arabinopyranoside (Arap), galactopyranoside (Galp) or glucuronopyranoside (GlcpA) [27, 28]. The structure of gum ghatti is shown in **Figure 2**.

Karaya gum is also on the list of exudates from commercially interesting plants, and is extracted from *Sterculia urens* tree. Structurally, it is a complex, partially acetylated polysaccharide, composed of 55–60% of rhamnose and galactose, 8% of acetyl groups, and 37–40% of uric acid residues (galacturonic and glucuronic acids) [29]. Its structure can be seen in **Figure 3**.

3.1 Gum structure of exudates from arecaceae family species

The Arecaceae (Palmae) family consists of a large variety of monocot plants found predominantly in tropical and subtropical environments, mostly in South America, and contains 457 palm species distributed in 50 genera [30, 31].

Nussinovitch [26] described, in general, three types of gum from plants of the Arecaceae family, with sensory information about them. According to the author, *Borassus flabellifer* palm gum is a black glassy exudate, which swells and is insoluble in water; *Cocos nucifera* L. gum has coloration ranging from light brown to red, and in water, it presents certain insolubility, forms gel, and has low adhesiveness; *Corypha utan Lam*. gum has sweet odor and brown coloration, being used in medicine.

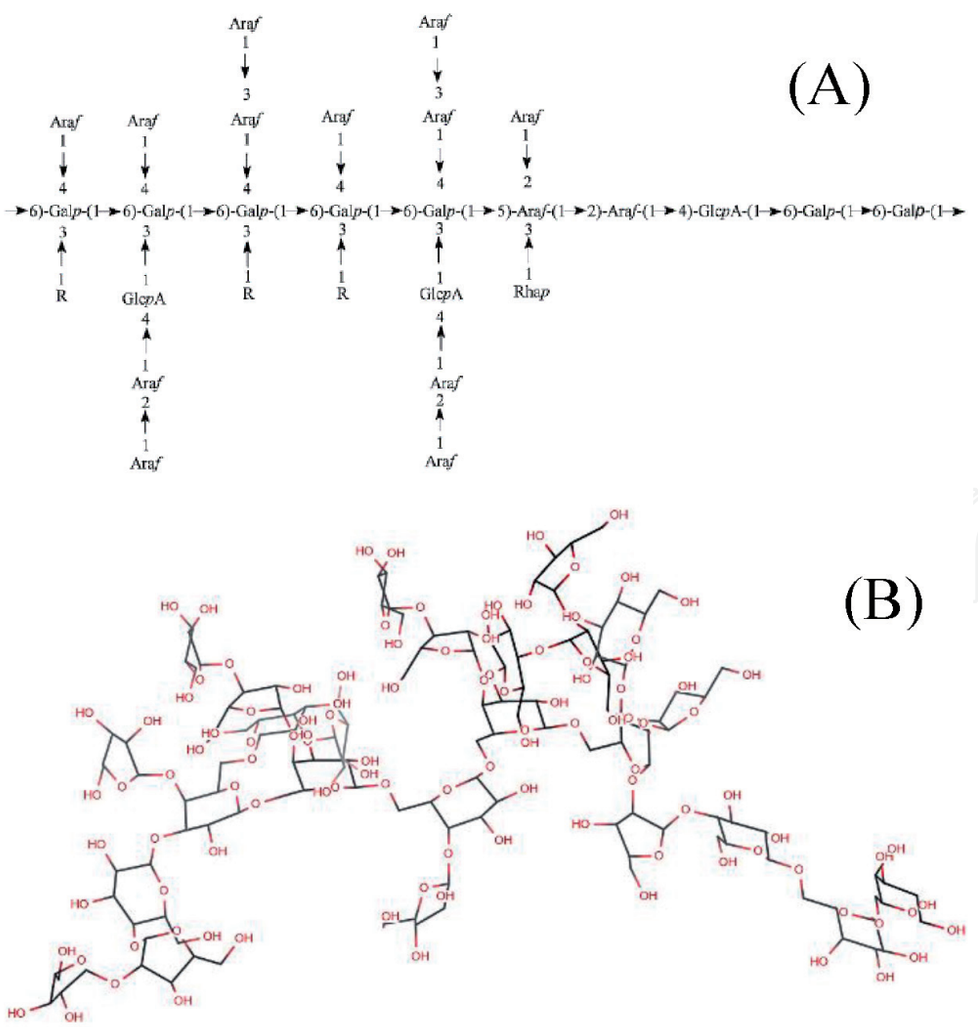

Figure 2.
Structural fragment of gum ghatti. (A) Scheme and (B) three-dimensional structure referring to the fragment shown.

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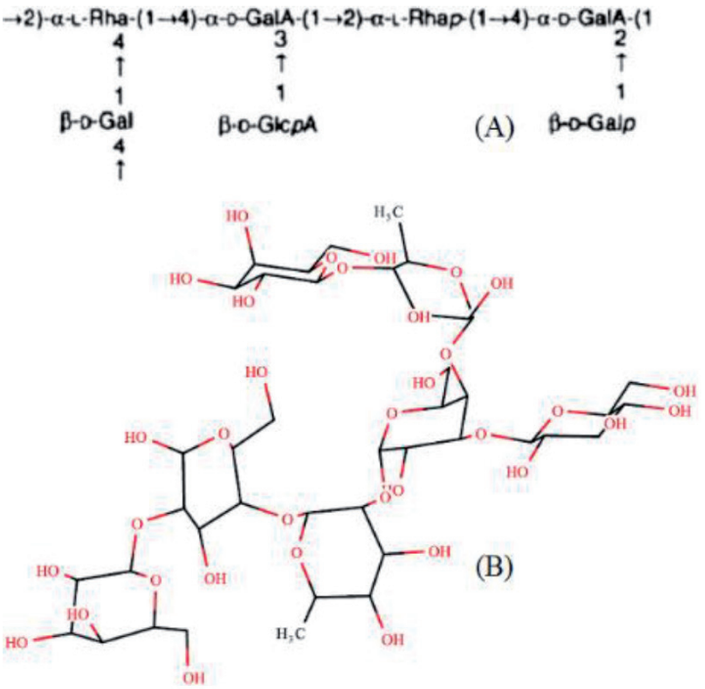

Figure 3.
Structural fragment of karaya gum. (A) Scheme and (B) three-dimensional structure referring to the fragment shown.

Gums from exudates of Chinese fan palm trunk (*Livistona chinensis*) [32] and jerivá (*Syagrus romanzoffiana*) [33] were presented as heteroxylans, whose main chain is joined by β-(1➔4) bonds, highly substituted at O-2 and O-3 positions by units of arabinose, xylose, and terminal fucose, as shown in **Figure 4**.

The exudate from Uricuri palm (*Scheelea phalerata*) was also identified by Fernanda F. Simas et al., [34]. The authors found a water-insoluble polysaccharide with a branched structure. Units of Xylp (~8%) were replaced at O-2, whereas Araf units (12%) were replaced at O-3. They also found non-reducing units of Araf (15%), Fucp (fucopyranose - 10%), Xylp (4%), and Arap (6%) as side chains attached to the main chain composed of Xylp units joined by β-(1➔4) bonds, which were replaced at 3-O-(9%), 2-O-(13%), and 2,3-di-O-(13%) positions.

The structure of the gum obtained from coconut tree trunk exudate (*Cocos nucifera*) was elucidated by Simas-Tosin et al., [35]. This gum is a glucurono-arabinoxylan composed of Fuc, Ara, Xyl, and GlcpA at molar ratio of 7:28:62:3.

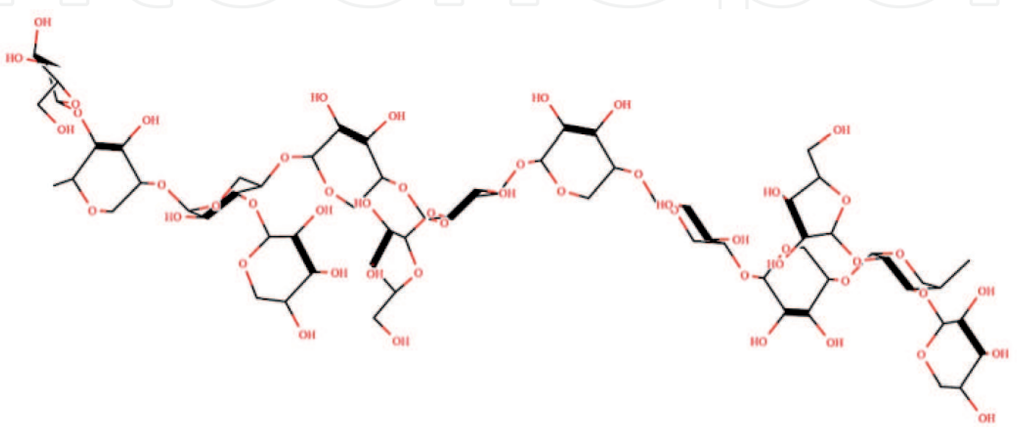

Figure 4.
Three-dimensional representation of the heteroxylan present in Scheelea phalerata *(Uricuri) palm gum, with β-(1➔4) bonds. Main chain branches are substituted at O-2 or O-3 positions by arabinose and xylose units.*

Non-reducing units substituted at 3-O (Araf - 8%); 3,4-di-O-(15%); 2,4-di-O (5%); and 2.3.4-tri-O (Xylp 17%) positions were also found, attached to a main chain composed of Xylp joined by β-(1➔4) bonds.

4. Gum characterization

4.1 Spectroscopic methods for gum characterization

"Structure is the key to everything in chemistry. The properties of a substance depend on the atoms it contains and how these atoms are bound. Less obvious, but very powerful, is the idea that someone with knowledge of chemistry can look at the structural formula of a substance and say several things about its properties" [36]. "Looking at the structural formula" inevitably refers to the use of techniques that assist in the chemical and structural knowledge of organic molecules, and in this context, spectroscopic techniques can be a very important tool to fulfill such function [37].

In order to know the properties of polysaccharides or glycoconjugates, it is essential to elucidate and characterize the structural and dynamic aspects of their molecules [38]. Carbohydrate chemistry can rely on one of the most efficient spectroscopic techniques for investigating organic compounds in solution: Nuclear Magnetic Resonance (NMR), which has advanced methods, and becomes essential in the characterization of polysaccharides with complex structures [39, 40].

The commonly used NMR techniques are hydrogen (^{1}H), carbon-13 (^{13}C), homonuclear correlations (^{1}H-^{1}H), COSY (homonuclear Correlation Spectroscopy), and ^{13}C-^{1}H HMQC (Heteronuclear Multiple Quantum Coherence) [41].

The elements that are most common in organic molecules (carbon and hydrogen) have isotopes (^{1}H and ^{13}C) capable of providing NMR spectra rich in structural information. A proton nuclear magnetic resonance spectrum (1H NMR) provides information about the environments of the various hydrogens present in a molecule. A carbon-13 nuclear magnetic resonance spectrum (^{13}C NMR) does the same for carbon atoms [36, 38].

NMR spectrum of coconut trunk gum (*Cocos nucifera*), obtained by alkaline extraction, presented approximately 10 signs in the anomeric region, which reveals a complex structure. The signals made reference to the presence of L-Araf (δ 108.6–107.0); α-Arap (δ 103.1); β-Xylp (δ 101.6), and also α-Fucp and α-Glcp units (δ 100.5–99.2), bonded to C-4. Reducing terminals were bonded to C-5 [35].

Peach gum (*Prunus persica*) was also considered as a complex molecule, as it shows 8 signs in the anomeric region (δ 110–90). The main sign in δ 103.2 refers to β-D-Galp units in the main chain, and the sign in δ 102.8 suggests the presence of β-D-GlcAp. In the substituted carbon region, the signs in δ 84.1 and δ 82.0–82.5 refer to C-3 of the replaced units α-L-Araf and β-D-Galp 3-O-, respectively [42]. These are examples that demonstrate that the NMR technique is an indispensable tool for the knowledge of polysaccharides and their properties.

Another technique widely used for the structural identification of polysaccharides, even before the advent of NMR, is the Fourier-Transform Infrared Spectroscopy (FTIR) [36]. Although NMR gives more information about the structure of an unknown compound, infrared is important because it can identify certain functional groups. Structural units, including functional groups, vibrate in characteristic ways, and this sensitivity to group vibrations forms the basis of infrared spectroscopy [43].

Molecular movements are described by two types of vibrations: deformation and stretching (**Figure 5**). The deformation causes a bond angle change that can occur in or out of the molecular plane of symmetry; and the stretching is a linear

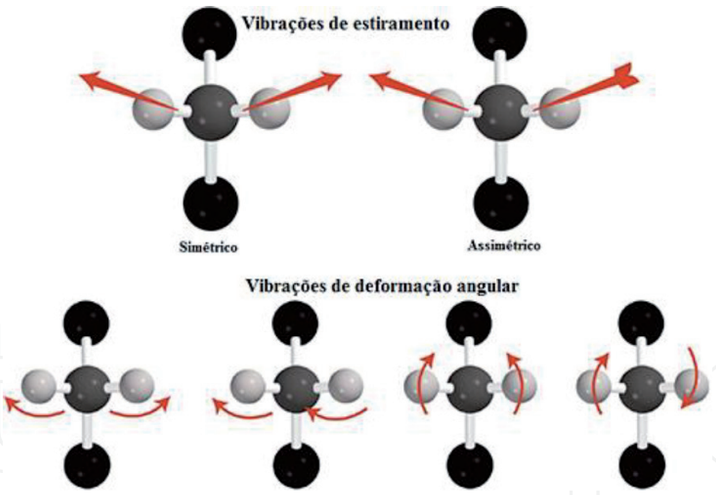

Figure 5.
Aspects of the molecule vibrations observed in infrared spectroscopy.

intermittent movement so that the interatomic distance changes constantly. It can be symmetrical or asymmetrical [44].

When irradiated by infrared light, the atoms of the molecular structure of a given sample absorb it. The vibration or rotation will depend on the type of chemical bond formed by these atoms B [45, 46]. **Table 1** shows some bands of infrared

Bands	Associated vibrations	Possible assignments to bands	References
≈1650 and 1550 cm^{-1}	ν(C=O) γ(CN) δ(NH) $(CCN)_{deform.}$ ν(C=C) $ν(COO^-)$	Amide I and II of proteins, respectively	[47–50]
1640–1600 and 1420 cm^{-1}		Carboxylic acids deprotonated in uronic acid	[48, 50]
1444, 1371, 975–978, and 923 cm^{-1}	$δ(CH_3)$ $(CH)_{deform.}$ δ(CO) δ(NH) δ(C–O) $δ(OH)_{COOH}$ ν(C–O–C) ν(CN)	Methyl ester groups (CH_3) in pectins	[51]
1280 and 1220 cm^{-1}		Methyl ester groups (CH3) in pectates	[51]
1280–1260 cm^{-1}		Phenolic esters bonded to cell walls groups	[52]
≈1230 cm^{-1}		Amide III of protein secondary structures	[49, 52]
Fingerprint region in polysaccharides			[53]
1155–1038 cm^{-1}	ν(C–O–C) ν(C–OH) ν(C–O) ν(C–C) $ν(O–CH_3)$ (CH_3) $(C_1–H)$ δ(OH) δ(CCH) δ(COH)	Galactan attached to main chain β 1➔6 Galp	[53]
1141–1039 cm^{-1}		Arabinans connected to the main and side chains of Araf	[53]
1139–985 cm^{-1}		Arabinogalactans linked to the main chain of β 1➔3 Galp, and side chain of α 1➔3 Araf (8%) and β 1➔6 Galp (92%)	[53]
1140–975 cm^{-1}		Arabinogalactan-rhamnoglycan attached to the main chain β 1➔6 Galp (24%) and α 1➔4 Rhap (42%), and side chain of α-Araf and α 1➔5 Arap (34%)	[53]
900–870 cm^{-1}		B-type bonds between monosaccharides	[54, 55]

Table 1.
Infrared Fourier transform bands in plane (δ); out of plane (γ) and stretching (ν), and assignments related to functional groups.

spectroscopy and their respective functional groups present in polysaccharides. It is also possible to see that FTIR can provide information on important functional groups in polysaccharides in the fingerprint region [44, 46].

In polysaccharides, the infrared spectroscopy can be used to qualitatively observe possible structural changes. Quelemes et al., [56] demonstrated the structural change in cashew gum when submitted to quaternary ammonium reagent, which also improved some properties such as biocompatibility and antimicrobial action. FTIR was also efficient to demonstrate that the interaction of gum arabic and chitosan was formed by electrostatic complexes, a result of the interaction between functional groups ($NH3^+$ and –COO-) of both macromolecules. Also, it improved viscoelastic characteristics at different pH's, demonstrating its complex versatility for use as food additives [57].

4.2 Thermal analysis of gums

Most polymers, synthetic or natural, suffer degradation when subjected to thermal stress [58]. This is attributed to chain depolymerization, point splits, or even the elimination of low molecular weight fragments, which cause mass loss due to the increase in temperature [59]. They cause thermal effects related to physical or chemical changes, and are associated with thermodynamic events [58]. These changes in energy and mass can be measured by thermogravimetry (TG), derivative thermogravimetry (DTG), differential thermal analysis (DTA) and differential scanning calorimetry (DSC), which make it possible to obtain information such as changes in the crystalline structure, reaction kinetics, melting and boiling point, glass transition, and others [60]. Changes in mass as a function of temperature and/or time [61] and continuous registration of mass subjected to heating or cooling [62] are definitions attributed to thermogravimetry.

Being the combination of an electronic microbalance and an oven, associated with a linear temperature programmer, thermogravimetric analysis consists of submitting a known mass of sample inside a crucible, suspended by a platinum wire, to a programmed temperature gradient, for a predefined time, which is automatically registered, simultaneously with the sample mass [63].

In DTG, the mass variation derivative (dm/dt) is registered as a function of temperature or time. In this method, the levels observed in TG are replaced by peaks that delimit areas which are proportional to the changes in mass suffered by the sample and can indicate the exact initial temperatures and maximum speed of reactions. DTG allows a clear distinction of successive reactions (not detected by TG), by quantitative determinations of loss or gain of mass which are associated with the peak areas [60].

DSC and DTA are analyses that measure energy gradients between the sample and a reference material subjected to controlled temperature. DSC is a calorimetric method in which energy differences are measured, whereas in DTA, temperature differences between the sample and the reference material are registered [59]. DTA provides a qualitative analysis of the thermal events experienced by the sample, whereas DSC is able to quantify such events because it measures the heat flow through a temperature gradient [64].

Changes in composition, food processing temperatures or ingredients result in changes in phase transitions of the product [65]. Quantifying the variables involved in these phenomena, such as temperature or thermodynamic quantities, is important for understanding processes such as evaporation, dehydration, and freezing [66]. Being the responsible for plasticizing effects and important component of food, water and its state transitions (gaseous or crystalline) guide such processes, and can also be used to describe the effects of temperature on physical properties [59].

4.3 Gum rheology

Natural polymers are of particular interest in rheological studies [67]. Their thickening, emulsifying, gelling, and stabilizing properties, which enable them to be used in food, pharmaceutical, and cosmetic industries are supported by a series of inter and intramolecular association mechanisms inherent to each polymer. Such mechanisms lead them to particular applications in different processes and products [68].

Gum arabic *(Acacia senegal)* 3% (m/v), originating from African regions such as Sudan, Senegal, and Mali, has typical behavior of a liquid. Sanchez, Renard, Robert, Schmitt, & Lefebvre, [69] investigated G' and G" in gum arabic, where G' is the storage modulus and indicates the portion of energy (from the applied voltage) that is temporarily stored during the test, and it provides information on the elastic characteristic of the fluid. On the other hand, G" is the loss modulus, which indicates the portion of energy used to initiate flow. It is irreversibly transferred in the form of heat and provides information on the viscous characteristics of the fluid [70]. The authors state that gum arabic presented a viscous modulus (G') greater than its elastic modulus (G'), but after 5 hours of rest, gel characteristics were identified, consequently showing a more elastic structure [69].

Acacia tortuosa gum, originating from species located in South America (Venezuela) (15% m/v), presented elastic modulus (G') greater than its viscous modulus (G"), indicating the occurrence of a gel material that became progressively weaker with increasing temperature [71]. In both studies, gums showed transition from Newtonian to non-Newtonian behavior with increasing concentration. Also, the influence of inter and intramolecular structural interactions as agents responsible for rheological changes was observed [69, 71].

The emulsifying and rheological characters of chemically modified gum arabic (*Acacia senegal*) (esterified with octenyl succinic anhydride (OSA) at different concentrations) was measured by [72]. The study revealed that the gum presented an increase in its emulsifying capacity and a gradual increase in apparent viscosity with increasing OSA content, indicating satisfying emulsion stability and potential use as microencapsulant. The electrostatic interaction between gum arabic and soy protein β-conglycinin was the mechanism that improved the flocculating action of *Acacia senegal*, in addition to providing greater elasticity at the oil/water interface of the gum, consequently improving its emulsifying capacity [73]. The interaction of gum arabic with native tapioca starch also provided improved product elasticity and adhesiveness [74]. Chenlo, Moreira, & Silva, [75], studied the rheology of aqueous dispersions of tragacanth gum and guar gum (10 g/L) during storage for 47 days. In general, the apparent viscosity decreased significantly ($\alpha = 0.05$) for both systems at low values of $\dot{\gamma}$ ($< 10s^{-1}$) and remained constant above this value. The decrease in viscosity was lower for tragacanth gum and lasted until the 15th day, whereas for guar gum, the decrease occurred until the 20th day.

Mixtures of corn starch (5% m/m) and locust bean gum (0; 0.125; 0.25; 0.50; and 1% m/v) were rheologically evaluated by Hussain, Singh, Vatankhah, & Ramaswamy, [76], who found that the addition of locust bean gum at low concentrations (0.125%) made the mixture behave as a liquid at low oscillatory frequencies (0.1 to 10 rad/s). It also presented increased elasticity, with typically solid behavior at concentrations of 0.5 to 1%, at higher frequencies (15 to 100 rad/s). Thus, locust bean gum has potential to specifically modify the structure and texture of corn starch products.

The research results showed that there are many variables that influence the rheological characteristics of gums. Among them, the fine chemical structure of the polysaccharide, their interactions, and molecular conformations can be highlighted, which confirms the importance of characterizing the structure of new gums.

5. Thermodynamic relations between gums and water

The functions derived from the physical and chemical properties of gums are closely related to the interactions of polysaccharides with water. The relationship between the water content of a product and its relative humidity at equilibrium, at constant temperature, can be expressed by characteristic curves called moisture sorption isotherms [77, 78]. In fact, the thermodynamic properties of sorption, such as water-solute affinity and spontaneity of the sorption process provide a better understanding of the water-solute equilibrium that is present in the product [79]. In addition, they facilitate the definition of order and disorder existing in water-solute systems [80].

The differential enthalpy or isosteric heat of sorption defines the amount of heat released or absorbed in the sorption process at constant pressure, and is used as an indicator of the binding force between the water and solutes of the product [81]. When the free water latent heat of vaporization is added, the integral isosteric heat of sorption is obtained, which is the total energy necessary to transfer the water molecules in the vapor state to a solid surface, or vice versa [79, 82]. Also, the differential entropy of a material is proportional to the number of available sorption sites, corresponding to a specific energy level, and indicates the mobility state of the water molecules present in the product [81]. Entropy describes the degree of disorder and randomness in the movement of water molecules, and has been used to explain how water sorption in biological materials occurs [83].

Thermodynamic properties, such as enthalpy and entropy, are necessary to design a process and to qualitatively understand the water state at a certain food surface. Alterations in enthalpy provide the energy variation of the interaction between water molecules and the adsorbent. Entropy, in contrast, may be associated with the binding or repulsion of forces and, consequently, with the spatial arrangement of the water-adsorbent relationship. Thus, entropy characterizes the degree of order or disorder existing in the water-adsorbent system [84]. Gibbs free energy, in turn, is influenced by the thermodynamic properties enthalpy and entropy, and indicates the energetic spontaneity of the water-adsorbent interaction, providing the availability of process energy. If the value of this property is negative, the process is spontaneous, and if it is positive, the process is nonspontaneous. In systems with many constituents, such as food and polysaccharides, Gibbs-free energy depends not only on pressure and temperature, but also on the amount of each component [80].

6. Gum applications

The applications of gums from plant exudates are very diversified, and can be present in various areas of the food industry: confectionery (lollipops, chocolates, jelly beans, pastilles, and others), in which there is a high sugar content and low humidity; to prevent sugar crystallization; in salad dressings (thickeners and emulsion stabilizers) [85]; in frozen products (pasta, popsicles, ice cream) [1]; in dehydrated products, such as juices obtained by spray drying, protecting important compounds such as vitamin C, anthocyanins, and improving solubility, or also as microencapsulants for colors, flavors, and oils [86]; in wine clarification; flavor fixatives and emulsifiers; and in beverages and meat products [87, 88] (**Table 2**).

In adhesion functions, gums are used as fixatives of skin bioelectrodes, dentures, ostomy devices, and transdermal membrane systems, which perform controlled release of drugs through the skin [7, 89, 90]. They are used as adhesive materials in wood-based industry, and obviously, in adhesive industries in general [91]. Gums have applicability in the pharmaceutical area as emulsifiers and reducing agents for suspended particles, laxatives, in the preparation of antiseptics, binders for tablets

Common name	Scientific name	Main chemical compounds	Application	Reference
Gums from fruits				
Date palm mucilage	*Phoenix dactylifera*	Fructose, sucrose, mannose, glucose, and maltose	Anti-cancer action	[105]
"Erva Baleeira" Mucilage	*Cordia obliqua*	Arabinose, galactose, and pyrralinose	Expectorant, tablet binder, emulsifier	[106]
Jackfruit	*Artocarpus heterophyllus*	Galactomannan, starch	Suspension stabilizer, emulsifier, binder, mucoadhesive	[107, 108]
Gums from seeds				
Tamarind gum	*Tamarindus indica*	Glucose:xylose:galactose (3:2:1)	Tablet formulation, biodegradable support for controlled drug release (colon), bioadhesive	[109, 110]
Fenugreek mucilage	*Trigonella foenum-graceum*	Galactomannan	Textural and sensory properties of soup powder/ anthocyanin encapsulation	[111, 112]
Locust bean gum	*Ceretonia Siliqua*	D-galacto-D-manoglycan, cellulose, galactomannan	Superdisintegrant in controlled drug delivery system	[113, 114]
Tara gum	*Caesalpinia spinosa*	Mannose:Galactose (3:1)	Smart food packaging	[115]
Gleditsia triacanthos gum	*Gleditsia triacanthos*	Galactomannan	Matrix formulation for tablets	[116]
Cassia tora Mucilage	*Cassia tora*	Arabinose and glucose	Suspension stabilizer, binder	[117]
Flamboyant gum	*Mimosa scabrella*	Mannose:Galactose (3.65:1)	Dietary fiber, probiotic viability in milk drink	[118]
Guar gum	*Ocimum americanum*	Xylose, arabinose, rhamnose, and galacturonic acids	Guar gum nanocomposite films	[119]
Gums obtained from tree trunks exudates				
Albizia stipulata Boiv. gum	*Albizia stipulata* Boiv.	Arabinose, galactose, and rhamnose	Antioxidant properties	[120]
Almond gum	*Prunus amygdalus*	Aldobionic acid, L-arabinose, L-galactose, and D-mannose	Emulsifier, suspension stabilizer, binder, thickener	[121]
Cashew gum and cashew nut gum	*Anacardium occidentale*	Galactose, arabinose, rhamnose, glucose, glucuronic acid	Encapsulation of a lipid shrimp waste extract, anti-inflammatory effect	[86, 122]

Common name	Scientific name	Main chemical compounds	Application	Reference
Cherry gum	*Prunus avium*	Arabinogalactan	Coating film	[123]
Raphia hookeri gum	*Raphia hookeri*	Mannose and galactose	Aluminum anti-corrosion agent in acid medium	[124]
Tragacanth gum	*Astragalus gummifer*	D-galacturonic acid, D-galactose, L-fucose (6-deoxy-L-galactose), D-xylose, L-arabinose, and L-rhamnose	Catalyst in the production of nanoparticles	[125]
Gum kondagogu	*Cochlospermum gossypium*	Rhamnogalacturonan	Production of biocompatible and antimicrobial scaffold for bandages	[126]
Gums obtained from leaves				
Cocculus hirsutus mucilage	*Cocculus hirsutus*	Polysaccharides and gelatinous materials	Binding agent, gelling agent (drugs)	[127]
Hibiscus mucilage	*Hibiscus rosa-sinensis*	L-rhamnose, D-galactose, Dgalactouronic acid, and D- glucuronic acid	Controlled drug release	[128, 129]
Gums obtained from microorganisms				
Curdlan gum	*Agrobacterium* spp.	Glucose	Food additive, thickener, gelling agent	[130]
Gellan gum	*Sphingomonas* spp.	Glucose, rhamnose, and glucuronate	Emulsion stabilizer, ophthalmic hydrogel	[131, 132]
Cholic acid	*Escherichia coli*	Fucose, glucose, glucuronate, and galactose	Viscosity enhancer	[130]
Xanthan gum	*Xanthomonas spp.*	D-glucose, D-mannose, and glucuronic acid	Carotenoid encapsulation for use in yogurts	[133]
K30 antigen	*Escherichia coli*	Mannose, galactose, and glucuronate	Viscosity enhancer/ controlled drug release	[130]
Gums obtained from tubers				
Konjac glucomannan	*Amorphophallus konjac*	D-Glucose and D-mannose	Gelling agent, controlled drug release	[134, 135]
Taro	*Colocasia Esculenta*	Galactose and arabinose	Gelling agent, mucoadhesives	[136]

Table 2.
Applications of gums from various origins.

and pills, and in the cosmetics area (perfume fixers, skin cleansers, and repellents) [92–95]. Also, in the medical field, gums are used to control osmotic pressure, in addition to having activity against *Leishmania amazonensis* and antifungal properties [96].

The most recent studies have shown that the versatility of gum use has increased. The beverage industry, for instance, is always seeking products with greater stability. Some polysaccharides are excellent stabilizers, such as tara gum, which is often used to stabilize casein aggregation in dairy drinks, improving phase separation. This occurs because tara gum makes it difficult to approach casein molecules, providing greater stability and improving the sensory acceptance of the product [93].

Carrageenan gum, xanthan gum, guar gum, sodium alginate, carboxymethyl cellulose, gum arabic, and pectin were tested to prevent the formation of turbidity, caused by protein-polyphenol complexation, in packaged beverages. Among them, pectin, xanthan gum, and guar gum showed the best results [94]. These polysaccharides, when present in low concentrations: 0.5, 0.05, and 0.01 mg/mL, compete with proteins to bind polyphenols, which decrease protein-polyphenol aggregation; or they can form a ternary complex (protein-tannin-polysaccharide) to increase the solubility of protein- polyphenol systems. This mechanism promotes the reduction of unwanted turbidity in such products [95].

The use of gums and polysaccharides in film production is also an area of great concentration of studies. Active, functional, and biodegradable packagings are examples which may have antibacterial activity.

Tragacanth gum, for instance, showed excellent results in the production of nanocomposite biofilms, and can be applied in the prevention of lipid oxidation in high-fat foods, with antimicrobial action and excellent responses to biodegradability tests [96] [97]. In addition, chemically modifying the gums to improve their hydration control, gel formation, and swelling can also be an interesting way to use these polysaccharides to produce biodegradable films, which have a good response in prolonging food quality [98].

Gums can offer great innovation opportunities for the food sector. Its use is reported in wastewater treatment and in the production of nanoemulsions, and micro and nano encapsulation of dyes, essential oils, and probiotics [99–104].

Therefore, it is important to encourage the search for new sources of gums and polysaccharides from biodiversity, as their applicability and benefits can and, obviously, should be explored.

7. Conclusion

Gums have incredible versatility and are a rich source of innovation in food formulations and elaborations in the industry. They can be used both in isolation and in mixtures and can be modulated to deliver not only taste and nutrition, but also a new consumption experience, whether due to texture or applied technology. It is important that new sources of these carbohydrates are increasingly known, as there is still much to explore in this area.

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