Carbohydrate Polymers 87 (2012) 980–986

Contents lists available at SciVerse ScienceDirect

Carbohydrate Polymers

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

Review

Gum ghatti: A promising polysaccharide for pharmaceutical applications

Anand S. Deshmukh[a,*], C. Mallikarjuna Setty[b], Aravind M. Badiger[c], K.S. Muralikrishna[a]

[a] Department of Pharmaceutical Research, Shree Dhanvantary Pharmacy College, Kim, Kudsad Road, Surat, Gujarat 394110, India
[b] Department of Pharmaceutics, Saraswathi College of Pharmaceutical Sciences, Yethbarpally, Andhra Pradesh, India
[c] Shree Dhanvantary Pharmaceutical Analysis and Research Center, Kim, Surat, Gujarat 394110, India

ARTICLE INFO

Article history:
Received 6 April 2011
Accepted 31 August 2011
Available online 14 September 2011

Keywords:
Gum ghatti
Hydrogels
Gatifolia

ABSTRACT

Gum ghatti (*Anogeissus latifolia*) or Indian gum is a complex non-starch polysaccharide. It has been widely employed in food, pharmaceuticals, paper and other industries primarily due to its excellent emulsification and thickening property. Other applications of gum ghatti are inadequately investigated owing to lack of information on it. Researchers in the recent years have shown a great interest in exploring its molecular structure and functional properties. This article is aimed at discussing the structural features, functional properties and applications of gum ghatti with an emphasis on its pharmaceutical potential.

Contents

1. Introduction

The polysaccharide gums represent one of the most abundant industrial raw materials and have been the subject of intensive research over comparable synthetic materials due to their sustainability, biodegradability and safety (Rana et al., 2011). Gum ghatti or Indian gum is a non-starch polysaccharides, originates from India and the main species is *Anogeissus latifolia* (Combretaceae, Myrtales), a large deciduous tree found in dry areas (Glicksman, 1983; Meer, 1980; Meer, Meer & Gerard, 1973). It is a plant exudate, that has been long in use and whose name is derived from the word Ghat, which means a mountain pass, given to the gum possibly because of its ancient mountain transportation routes (http://www.megamic.com/gumghatti.html, 2010).

Gum exudes naturally, darkened often by non-carbohydrate contaminants, and the dried product is sifted and ground in the usual manner. In the past, its quality and supply could not be guaranteed; hence it has not been established as a major tree gum in food products (Amar et al., 2006). Regulatory status in USA as "Generally Recognized as Safe" (GRAS) since 1976 was based on tests for toxicity, mutagenicity, and teratogenicity, but the European Union subsequently demanded more detailed evaluation of the safety of these gums as food additives, and lack of the required information

Abbreviations: GRAS, generally recognized as safe; ^{13}C NMR, carbon 13 nuclear magnetic resonance; 2D NMR, two-dimensional nuclear magnetic resonance; COSY, correlation spectroscopy; TOCSY, total correlation spectroscopy; HMQC, heteronuclear multiple-quantum correlation; HMBC, heteronuclear multiple bond correlation; FS, soluble fraction; cP, centipoises; HPSEC, high-performance size exclusion chromatography; MALLS, multi-angle laser light scattering; P_s, percentage swelling; ABC, potassium persulphate-ascorbic acid; MBA, methylene-bis-acrylamide.

* Corresponding author. Tel.: +91 9726609206; fax: +91 2621231077.
E-mail address: anand4ds@rediffmail.com (A.S. Deshmukh).

0144-8617/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.carbpol.2011.08.099

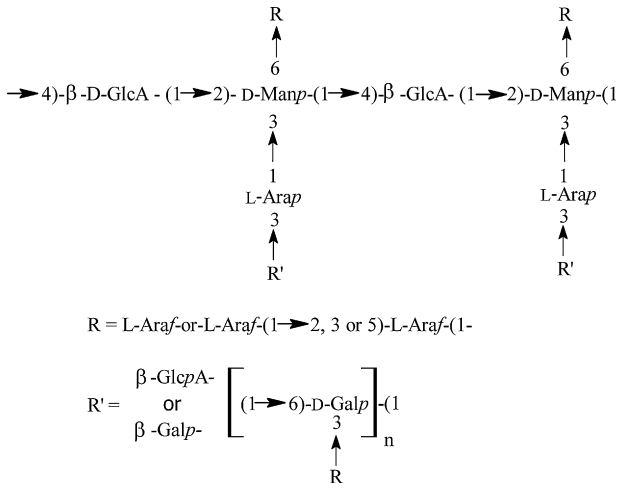


Fig. 1. Structural feature of gum ghatti.

has resulted in the deletion of gum ghatti from European lists of approved additives (BeMiller, 1973; Glicksman, 1983).

The quality has now been improved and its emulsification mechanism is also clarified (Ido et al., 2008; Katayama et al., 2008). Its acceptance in food in Japan, Latin America and other countries, have made it an alternative hydrocolloid for the food industry as a thickener and emulsifying agent (Castellani, Al-Assaf, Axelos, Phillips, & Anton, 2010). Renewed interest in gum ghatti is mainly due to its excellent emulsification properties (Castellani, Al-Assaf, et al., 2010; Castellani, Gaillard, et al., 2010; Jefferies, Konadu, & Pass, 1982; Jefferies, Pass, & Phillips, 1977; Jefferies, Pass, Phillips, & Zakaria, 1978; Kaur, Singh, & Singh, 2009) which is probably better than gum Arabic (Ido et al., 2008). The GRAS status of gum ghatti is tempered by very low maximum usage allowances (Glicksman, 1983; Meer, 1980; Meer et al., 1973). Moreover, the cost is favorable and comparable with that of gum Arabic.

In the recent years its molecular structure and functional properties has been duly investigated. Pharmaceutically, gum ghatti so far, has been investigated to limited applications in the dosage form design (as emulsifier, thickener and binder). But a new research has shown some promising applications of gum ghatti. In light of the above, the present article is aimed at providing a comprehensive review of the molecular structure, functional properties and promising applications with particular emphasis on pharmaceutical applications of gum ghatti.

2. Structure

The molecular structure of gum ghatti has been extensively studied by Aspinall and co-workers from 1955 to 1965 and others (Aspinall, Auret, & Hirst, 1958a, 1958b; Aspinall, Bhavanandan, & Christensen, 1965; Aspinall, Hirst, & Wickstrøm, 1955; Tischer, Iacomini, Wagner, & Gorin, 2002). It is found to have extremely complex arrays of neutral sugar units (Galp, Araf, and Arap) and GlcA, attached to a molecular core of alternating β-D-GlcA and D-Man residues, the former linked through O-4 and the latter through O-2. Fig. 1 displays the arrangements of constituent units as shown by various fragmentation and methylation analyses and Smith degradation experiments (Aspinall et al., 1955, 1958a, 1965). The periodicity of acidic groups in the main chain is an important feature, and there are others scattered through the periphery. (1,3)- and (1,6)-linked Gal units occupy side chains, and the structure is complicated by D-Man residues present as double branch-points.

Nature of the substituent(s) at O-4 of the –GlcpA– units was determined as 6% of rhamnose in the polysaccharide that might contribute substantially to its structure as an α-Rhap-(1→4)-β-GlcpA-group, which is common in plant gum polysaccharides (Delgobo, Gorin, Tischer, & Iacomini, 1999; Menestrina, Iacomini, Jones, & Gorin, 1998; Tischer, Gorin, & Iacomini, 2002).

The structure present in the gum polysaccharide and its accompanying free, reducing oligosaccharides was duly investigated using methylation and ^{13}C NMR analyses on the high-arabinose, acidic polysaccharide of gum ghatti and the products obtained on three successive controlled Smith degradation products. The studies have shown that the side chains contain mainly 2-O- and 3-O-substituted Araf units. The second degradation eliminated the remaining α-Araf units and their β anomers became evident. The proportion of Galp units gradually increased in the form of non-reducing end Galp although 3,6-di-O- and 3,4,6-tri-O-substituted Galp units diminished. After three degradations, groups with consecutive 3-O-substituted β-Galp units were formed and the proportion of periodate resistant 3-O and 2, 3,-di-O-substituted Manp units was maintained. As a guide to side chain structures in the polysaccharides, seven of the ten free reducing oligosaccharide fractions present in the gum were isolated and examined (NMR, ESIMS and methylation analysis). Characterization of α-Araf-(1→2)-Ara and three Ara-containing oligosaccharide fractions containing 2-O- and 3-O-substituted units gave, respectively, ESIMS molecular ions arising from Ara_2, β-Araf oligosaccharides with four units, β-Araf oligosaccharides with seven units, and Hex_2-Ara_4. The α-Rhap-(1→4)-GlcA, α-Rhap-(1→4)-β-GlcpA-(1→6)-Gal, and α-Rhap-(1→4)-β-GlcpA-(1→6)-β-Galp-(1→6)-Gal represented other side chains (Tischer, Iacomini, et al., 2002).

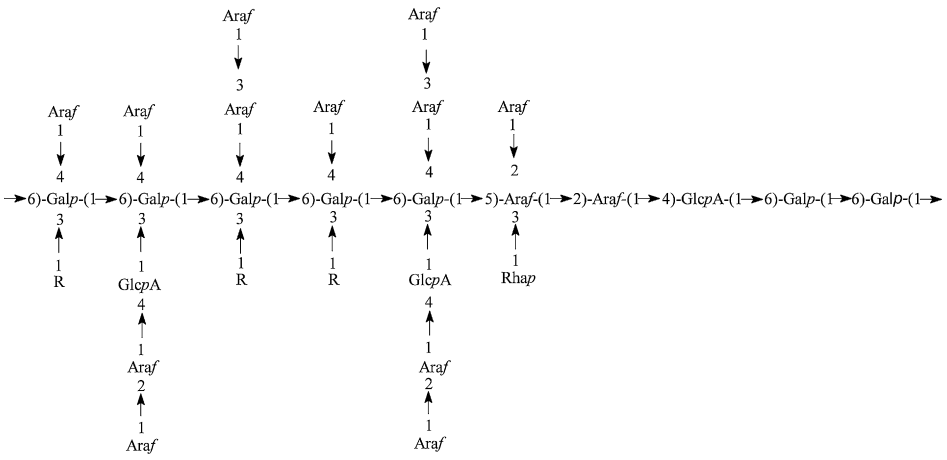
Recently Kang et al. (2010a), have carried an extensive research work to elucidate a structure of gum ghatti by fractioning it into four fractions—F50, F65, F80 (as 50%, 65% and 80% precipitate) and FS (supernatant of F80) by gradual ethanol precipitation. Preliminary structure analysis revealed that F50, F65 and F80 had similar molecular structure, whereas FS had a rather different structure, but higher protein content.

Fraction F80 was chosen as a representative to elucidate the main structure of gum ghatti using methylation analysis and 2D NMR spectroscopy, including homonuclear $^1H/^1H$ correlation spectroscopy (COSY, TOCSY) and heteronuclear $^{13}C/^1H$ multiple-quantum correlation experiments (HMQC, HMBC). A result concluded that F80 is a highly branched polysaccharide. The terminal sugar residues are about 40.8% of total sugars and majority of the terminal units are α-L-Araf, with a small amount of T-GlcpA, T-Arap, T-Rhap and T-Galp. About 14.2% of the total sugar residues were →6)-β-D-Galp-(1→ branched at 3rd and 4th positions. The linear portion of the arabinogalactan was composed of →4)-GlcpA(1→,→6)-Galp(1→and→2)-L-Araf-(1→linkages. The proposed structure of F80 is shown in Fig. 2 (Kang et al., 2010a).

The structure of soluble (FS) fraction (Fig. 3) was investigated using methylatione-GC–MS, ^1D (^1H, ^{13}C) and 2D (COSY, TOCSY, HMQC and HMBC) NMR spectra. It appeared to have a globular structure and was made up of rhamnose, arabinose, galactose, and glucose in a molar ratio of 2.3:72.9:16.4:8.6 with 4.6% protein and 2% of uronic acid. Molecular structure of FS was proposed to be a highly branched polysaccharide with small amount of acetyl substitution (Kang et al., 2010b).

3. Functional properties

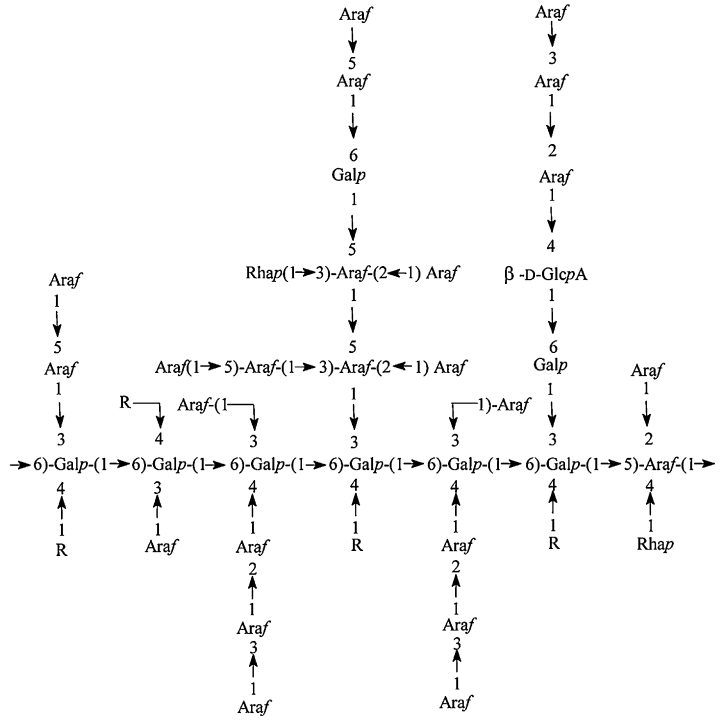
Ghatti gum is light yellow to brown colour powder, available in a various grades (Table 1) depending upon its viscosity and solubility (http://www.megamic.com/gumghatti.html, 2010). Its general characteristics are presented in Table 2 (Drytech, 2009). A great deal of work has been carried out by various researchers



R is one of the following groups:

→3)-β-D-Galp-(1→,→5)-β-D-Araf-(1→,→2,3-Manp1→, T-α-L-Araf 1→, T-GlcAp 1→and T-L-Arap 1→

Fig. 2. Proposed structure of F80 fraction from gum ghatti.



R can be represented by the following groups:

→2,3-Manp 1→ ,→ 3,4-Glcp 1→ ,→ 4-Galp 1→ , T-α-L-Araf 1→ , T-GlcpA 1→ , T-Galp→ and T-L-Arap 1→

All the galactose are in-β- D form, all the arabinose and rhamnose are in α-L form

Fig. 3. Proposed structure of gum ghatti fraction FS.

Table 1
Technical specifications of different grades of ghatti gum.

Sr. No.	Grade	Ash content (max)	Moisture (max)	Viscosity of 10% dispersion at 25 °C on RVT Brookfield Viscometer at 24 h
1	Gum Ghatti Soluble Grade I	2.5%	12%	Typically below 400 cP
2	Gum Ghatti Soluble Grade II	3–4%	12%	Typically 400–500 cP (slightly higher than soluble grade)
3	Gum Ghatti No.1 Grade III	3–4%	12%	1000–2500 cP
4	Gum Ghatti No.2 Grade IV	3–4%	12%	Above 2500 cP

Table 2
General characteristic properties of ghatti gum.

Physical appearance	Pale yellow to light brown, free flowing powder
Loss on drying	NMT 10
Optical rotation	−30 to −40°
Colour of slurry	Light brown
Specific gravity	1.02–1.10
Clarity of solution	Slightly hazy
pH (25% solution)	4.0–4.5
Heavy metals	20 ppm

to understand the functional properties of gum ghatti. Gum ghatti is not completely soluble at concentrations of ≥5% in water, but forms colloidal dispersions. This limited solubility makes it impossible to attain the concentrations reached with gum Arabic.

The viscosity of dispersions is variable from one batch of gum to another: for example, the viscosity of a 10% dispersion of grade 1 and 2 gum ghatti (Table 1) varies between 30–400 cP and 400–500 cP, respectively (http://www.megamic.com/gumghatti.html, 2010). This can be attributed to the presence of two fractions in the gum: one soluble in cold water, the other forming a dispersible gel. The viscosity attained in the water varies with the proportion of the latter, which is 10–30 times more viscous than the soluble fraction. The gel forming component, which was found in proportions varying between 8 and 23% (w/w) in four different commercial batches of the gum, can be dissolved to some extent (∼20% of the total) by stirring the gum at 92 °C for about 2 h, but complete dispersion requires maceration. This produces stable dispersions of concentration up to 50 g/L at room temperature, up to 90 g/L if maceration is preceded by heating the suspension to 92 °C. Thus, viscosity of gum ghatti solutions can be made more reproducible by such treatment or by blending gum samples from different commercial batches in ratios determined by the proportions of the gelling component in each batch (Jefferies et al., 1977).

The two fractions of gum ghatti show remarkable difference in physical properties; this may be a consequence of chemical heterogeneity of the gum (Jefferies et al., 1978). Variations in the length or degree of branching of the polysaccharide chains could well produce marked differences in solubility and viscosity between the two fractions. However, further investigation of these fractions, including potentiometric titration and determination of acyl groups and cations (Na^+, K^+, Ca^{2+} and Mg^{2+}) showed no appreciable differences in the proportion of uronic acid (cf. gum tragacanth) or the degree of acylation of the polysaccharides (cf. gum karaya). Both fractions were largely in salt form (the proportion of free acid was <10% in both), and the only significant difference revealed by this study lay in the proportions of the different cations present. Whereas the soluble fraction contained Ca^{2+}, Mg^{2+}, K^+ and Na^+ in the mass ratio 80:7:40:1, that is, Ca^{2+} constituted ∼62% of the total metal ion content, the dispersible gel fraction was largely a calcium salt, containing no Na^+ and very small proportions of Mg^{2+} and K^+ (respectively, 4 and 2%, w/w, of the total metal). These results suggest that the higher viscosity and lower solubility of the gelling fraction are due to aggregation, through interaction between the divalent Ca^{2+} ion and anionic groups on different molecules, as is well-known in the case of alginates (Williams, 1982). In view of the comparatively low molecular mass (Mn 11,860) indicated by osmotic pressure measurements (Glicksman, 1969, 1983) of the soluble fraction, the much higher viscosity of the dispersible gel indicates very extensive aggregation.

Removal of Ca^{2+}, by precipitation with sodium carbonate, reduces the viscosity of gum ghatti dispersions; this effect is not reversed on subsequent addition of Ca^{2+} which, on the contrary, further decreases viscosity owing to the usual effect of divalent cations on charge distribution in the polyelectrolyte. In this respect, the behavior of gum ghatti contrasts with that of alginates and of the gum of *Khaya grandifoliola* (Aslam et al., 1978), for which viscosity lost on removal of naturally occurring Ca^{2+} is restored on addition of Ca^{2+}, though the decrease due to shielding of charges is observed after the concentration of added Ca^{2+} exceeds approximately twice that in the original sample. Gum ghatti seems to differ from these other polysaccharides.

The effects of other cations, and of pH, on the viscosity of gum ghatti dispersions (Glicksman, 1983; Meer, 1980; Meer et al., 1973) differ little from those observed with gum Arabic. Addition of sodium salts decreases the viscosity (Glicksman, 1983; Jefferies et al., 1978), as does change in pH outside the range at which viscosity is maximal (∼6–8) (Glicksman, 1983; Jefferies et al., 1978; Meer, 1980; Meer et al., 1973). There is a relationship between pH and viscosity over pH range of 2–12. The maximum viscosity is achieved at pH 8 (above this pH the sols tend to become stringy) and drops sharply on both sides (http://www.megamic.com/gumghatti.html, 2010).

In contrast to gum Arabic (Goycoolea et al., 1995), the viscosity of gum ghatti dispersions increases with time (e.g., for a 5% dispersion, pH 5.6, at 25 °C, the viscosity rose from 93 to 104 cP after 1 week, to 112 cP after 2 weeks (Meer, 1980; Meer et al., 1973)).

This is probably due to increase in the degree of aggregation of the polysaccharide molecules. The effect of this evidently outweighs that of any depolymerization due to glycosidic fission, to which the polysaccharide backbone of gum ghatti, containing uronic acid residues, will be more resistant than the arabinogalactan framework of gum arabic.

The overall molecular shape of gum ghatti is generally described (Glicksman, 1983; Meer, 1980; Meer et al., 1973) as rod-like, and therefore chain entanglements producing structural viscosity, and consequently pseudoplasticity, occur at relatively low concentrations. Gaia et al. (1981) have demonstrated that the rheology of gum ghatti dispersions ranging in concentrations from 2 to 5% can be described by a power law equation. In terms of a proposed correlation (Frost et al., 1984) of perceived sliminess food products containing gum ghatti differ very little in this respect from those containing gum Arabic at low concentration (Mitchell, 1979).

Gatifolia, a commercial gum ghatti, was studied for its structural, thermal and rheological characteristics (Kaur et al., 2009). The molecular weight (MW) and R_g (radius of gyration) were calculated to be approximately 8.94×10^7 g/mol and 140 nm, respectively, using high-performance size exclusion chromatography (HPSEC) and multi-angle laser light scattering (MALLS). Gum ghatti solution exhibited pseudoplastic behavior which became more prevalent with increasing concentrations. Gum ghatti also displayed time dependent shear thickening behavior and showed negative hysteresis. Under the measurement conditions at the range of frequencies and temperatures studied, the gum did not behave as typical viscoelastic gel.

Recently, the fractionation, chemical and physical characterization of processed gum ghatti (Gatifolia SD) was carried out and identified the source of its surface activity (Kang et al., 2011c). Four fractions were separated using the gradual ethanol precipitation method. With the increase of alcohol concentration, the chemical composition of the fractions exhibited a pattern: arabinose content increased, but the galactose, protein and uronic acid contents decreased in the order of: F50 (50% ethanol precipitate), F65 (65% ethanol precipitate), F80 (80% ethanol precipitate) and FS (the supernatant after 80% ethanol precipitation). Rheologically gum ghatti and its fractions exhibited Newtonian flow behavior until gum concentrations reached to 20% (w/v), at which point gum ghatti showed some shear thinning. At the same shear rate and concentration, the apparent viscosities of these fractions decreased in the order: F50 > F65 > F80 > FS. When compared at same concentration, the FS fraction had the highest surface activity relative to the Gatifolia SD, the other fractions and even gum

Table 3
Emulsion properties of acid hydrolyzed gums (US Patent 3891620, Cushman & Schick). Acid hydrolysis of natural gums-effectiveness as wax emulsifiers.

Example	Gums	Untreated wt.%	Treated[a] wt.%	Appearances	Emulsion properties viscosity cP.	Shear stability (g)
1	Ghatti	1.0		Fluid	1600–2200	2.40–2.70
2	Ghatti		1.0	Fluid	250	3.05
3	Ghatti		2.0	Fluid	1070	2.23
4	Arabic	1.0		Fluid	900	3.24
5	Arabic		1.0	Fluid	30	1.77
6	Arabic		1.5	Fluid	90	1.25
7	Tragacanth	1.5		Solid	–	–
8	Tragacanth		1.5	Visc. fluid	–	–
9	Alginic acid		1.5	Fluid	650	1.55
10	Waxy maize		1.5	Fluid	690	1.32

[a] Acid hydrolyzed with 1% hydrochloric acid for 30 min prior to emulsifying wax–water mixture.

Arabic. Monosaccharide composition and preliminary structural analysis showed that the branching of the polymer increased in the order of F50, F65 and F80. The degree of branching levels, protein and uronic acid content could be responsible for the different solubility of the fractions in alcohol. However, the molecular structure of FS is significantly different from the other fractions. FT-IR spectroscopy revealed no esterified carboxyl group in gum ghatti.

4. Applications

Literature, research articles and patents reveal several applications of ghatti gum in pharmaceuticals and allied areas.

4.1. Emulsifying agent

The gum ghatti has been reported to have an excellent emulsification property due to its protenious molecular components, which binds to oil and which is probably better than gum Arabic (Ido et al., 2008). US patent demonstrated its application for preparing oil-in-water emulsion. This patent discloses that natural gums of molecular weight equal to or higher than of gum ghatti can be employed as emulsifying agent in acid-stable wax emulsions and oil-in-water emulsions, particularly, at reduced cost. Upon acid hydrolysis, various gums (Table 3) exhibit lower viscosities and improved emulsifying properties comparable to gum ghatti (Cushman & Schick, 1975). Whereas the high viscosity produced by the gum in solution makes it a superior stabilizer for dense pharmaceutical emulsions and suspensions like preparation of powdered, stable, oil-soluble vitamins (http://www.krystal-colloids.com/ghatti.html, 2008).

The preparation of the aqueous resole dispersions containing gum ghatti as interfacial agent was reported in another US patent (Harding & McCarthy, 1977). Invention discloses and demonstrates the usefulness and effectiveness of gum ghatti in the production of phenolic resole particles, which become very small and uniform in size, enhancing the utility of said dispersions in its end-use applications as coating and adhesives.

Gum ghatti is also been reported as an emulsifier and stabilizer in beverages, butter containing table syrups, petroleum and in non-petroleum waxes to form liquid and wax paste emulsions and flavor fixative for specific applications (http://www.krystal-colloids.com/ghatti.html, 2008).

4.2. Excipient in solid dosage form

Natural gums and polysaccharides attracted researchers for many years due to their usefulness in formulation of solid dosage forms (like tablets) and gum ghatti is no exception due to its GRAS status. Jain and Dixit (1988) studied various gums and their derivatives for their pharmaceutical applications, and found that gum ghatti can be used as a potential excipient (tablet binder).

In another study the role of gum ghatti was evaluated as new release modifier for zero-order release of diltiazem hydrochloride in 3-layered matrix tablets (Joshi et al., 2010). The gum ghatti was used as a matrix material in both core and barrier layer in various compositions, along with guar and xanthan gums to identify its effect. Tables 4 and 5 show the composition and kinetic parameter of various formulations. Their study revealed that gum ghatti alone could not retard the burst effect but could achieve zero-order release for 6 h. However, guar gum replaced partially with gum ghatti in barrier and core layer can successfully achieve a zero-order release profile for 9 h in 3-layered matrix tablets.

4.3. Hydrogels

Recently the term superabsorbent/intelligent/smart hydrogels has evoked an interest among researchers due to their swelling behavior, network structure, permeability, or mechanical strength in response to different internal and external stimuli and are being used to develop responsive drug delivery systems (Kulkarni et al., 2010).

Kaith et al. (2010a) have developed one such hydrogel system by graft copolymerization of mixtures of acrylamide and acrylonitrile with gum ghatti using ascorbic acid and potassium persulphate redox pair as an initiator and N,N′-methylene-bis-acrylamide as

Table 4
Composition of diltiazem hydrochloride 3-layered matrix tablets prepared by direct compression.

Core-layer				Barrier-layer (each)			
Formulation	Diltiazem HCl (mg)	Ghatti gum (mg)	Avicel (mg)	Ghatti gum (mg)	Xanthan (mg)	Guar gum (mg)	Avicel (mg)
F1	90	180	24	49	–	–	–
F2[a]	90	240	24	49	–	–	–
F3[b]	90	180	24	98	–	–	–
F4	90	180	24	–	49	–	–
F5[b]	90	180	24	–	98	–	–
F6	90	180	24	–	–	49	–

[a] Core-layer thickness increased.
[b] Barrier-layer thickness increased.
All the formulations have; 1% (w/w) magnesium stearate; 1% (w/w) talc.

Table 5
Kinetic parameters of all formulations.

First-order		Zero-order		KorsmeyerPeppas	
Formulation	r^2	Rate constant % mg/h	r^2	n-Value	r^2
F1	0.9519	11.76	0.9323	0.9896	0.9743
F2	0.9114	15.24	0.9812	0.7075	0.9023
F3	0.9969	12.78	0.9372	0.7288	0.9945
F4	0.9909	10.32	0.9797	0.7005	0.9849
F5	0.7574	7.68	0.9783	0.7565	0.9651
F6	0.9377	12.42	0.9935	0.9004	0.9305

Table 6
Thermal behavior of gum ghatti and Gg-cl-poly(AAm).

Sample code	TGA				DTA		DTG	
	IDT (°C)	1st stage decomposition, °C (wt.% loss)	2nd stage decomposition, °C (wt.% loss)	FDT, °C (residue left)	Exothermic peaks at different decomposition temp., °C (μV)		Decomposition temp., °C (rate of wt. loss in mg/min)	
					1st	2nd	1st	2nd
Gum ghatti	212.1	212.1–496.9 (65%)	496.6–590 (32.5%)	590	307.3 (18.7)	331.8 (21.1)	245.4 (0.625)	488.9 (1.875)
Gg-cl-poly (AAm)	160.7	160.7–572.1 (57.7%)	572.1–601.3 (5.5%)	601.3	443.3	588.4 (154.4)	379.2 (0.337)	580.5 (1.049)

IDT = initial decomposition temperature; FDT = final decomposition temperature; TGA = thermo gravimetric analysis; DTA = differential thermal analysis; DTG = differential thermo gravimetric.

an initiator via free radical mechanism (Kaith et al., 2010a). Water absorption capacity of modified gum ghatti was studied in deionized water as a function of percentage swelling (P_s) and effect of ionic strength and ionic charge of various cations, on the swelling (Fig. 4) of candidate polymer, in different chloride salt solutions were investigated. The synthesized polymer based hydrogel has shown decrease in P_s with increase in ionic strength and cationic charges. Study concluded that modification of gum ghatti has made it thermally more stable than an initial backbone polymer and improved its pharmaceutical profile and usability (behaved as a smart polymer by performing temperature and pH dependent absorption).

In another study, gum ghatti was modified into hydrogel under pressure by free radical initiation reaction using potassium persulphate–ascorbic acid (ABC) redox pair as an initiator and N,N′-methylene-bis-acrylamide (MBA) as cross-linker. Prepared hydrogel was found to be pH, electrical stimulus sensitive (DC/AC electric field responsive de-swelling behavior) and thermally more stable (Table 6) than the initial backbone polymer. This functionalized polymer is, thus, important from technological view point (Kaith et al., 2010b).

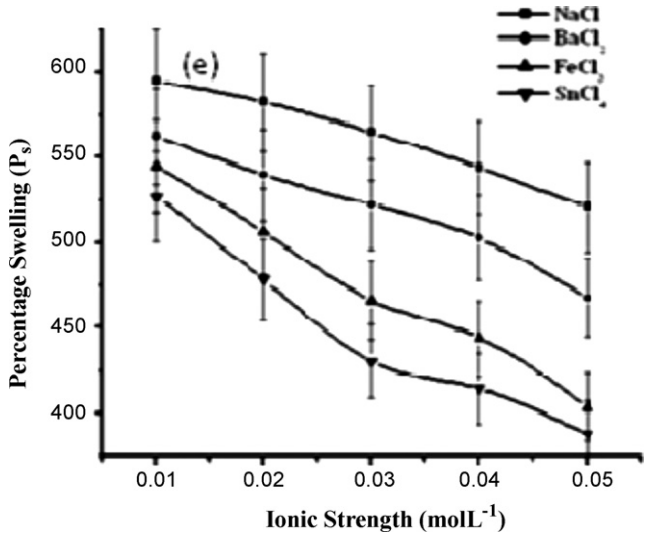


Fig. 4. Effect of ionic strength on swelling behavior (P_s) in different chloride salt solutions.

4.4. Miscellaneous

Williams (1982) in his research reported an adsorption of gum ghatti, a polyelectrolyte onto concentrated barium sulfate suspensions, which can be used as X-ray opaque media.

Investigation for inhibitory effects of plant polysaccharides on DNA restrictions (Hind III and EcoRI) revealed that in contrast to neutral polysaccharides, acidic polysaccharides like gum ghatti, carageenan, pectins, etc., were very inhibitory, even at low concentrations (Do & Adams, 1991).

Fermentation of mucin and plant polysaccharides (dietary fibers) by strains of bacteroides from human colon was duly investigated (Salyers, Vercellotti, West, & Wilkins, 1977). Some plant polysaccharides such as gum ghatti, gum Arabic, gum karaya and fucoidan were not utilized by any of the strains tested indicating varied ability among bacteroids species tested. Further 154 strains from 22 species of Bifidobacterium, Peptostreptococcus, Lactobacillus, Ruminococcus, Coprococcus, Eubacteriumand Fusobacterium which were present in high concentrations in human colon were investigated (Salyers, Vercellotti, & West, 1977) for their ability to ferment 21 different complex carbohydrates. Gum ghatti one of such polysaccharides was fermented by Bifidobacterium, Peptostreptococcus, Ruminococcus and Eubacterium.

The ability of edible gums to depress total liver lipids and activities of two hepatic enzymes (glucose-6-phosphate dehydrogenase and NADP-linked malic enzyme) was examined (Osilesi et al., 1988) during refeeding of 2 days starved rats. Ghatti gum fed as 4% of dry ingredient, occasionally with added water, in otherwise identical high glucose, nutritionally adequate diets, imparts little viscosity with water was found to be ineffective.

Idiotypes on galactan binding myeloma proteins and anti-galactan antibodies in mice were studied Antibodies with specificity for β-1,6-linked D-galactoses were induced in mice by immunization with ghatti gum (Mushinski & Potter, 1977).

Ghatti gum has also been found useful; as a binder in long-fibered light weight papers; As drilling mud conditioner and the acidizing of oil wells; in powdered explosives to improve resistance to water damage (http://www.krystal-colloids.com/ghatti.html, 2008).

5. Conclusion

Gum ghatti a unique polysaccharide is much accepted for its excellent emulsification property. A recent study revealed its complete molecular structure, which proved very useful in identifying its two fractions (soluble and gelling). Gelling property, surface activity and emulsification property is a result of these fractions. The different grades further possess different composition of these fractions and needed to be investigated for more specific applications. Gum ghatti is widely evaluated in food and certain biotechnology industries. Our literature survey revealed that pharmaceutically it received no or little attention and is still poorly investigated. For example as tablet excipient and as rate controlling matrix material. Moreover, other novel and very promising niches for application exists, but have not been completely developed. For example, a superabsorbent hydrogel act as smart/controlled delivery systems. In conclusion, a strong and obvious need exist to make further investigations on gum ghatti as potential polysaccharide for pharmaceutical applications.

Conflict of interest

No conflict of interest.

References

Amar, V., Al-Assaf, S. & Phillips, G. (2006). An introduction to gum ghatti: another proteinaceous gum. *Foods & Food Ingredients Journal of Japan*, *211*, 275–279.

Aslam, M., Pass, G. & Phillips, G. O. (1978). Properties of *Khaya grandifoliola* gum. *Journal of the Science of Food and Agriculture*, *29*, 563.

Aspinall, G. O., Auret, B. J. & Hirst, E. L. (1958b). Gum ghatti (Indian gum). Part III. Neutral polysaccharide formed on partial acid hydrolysis of the gum. *Journal of the Chemical Society*, 4408–4418.

Aspinall, G. O., Auret, B. J. & Hirst, E. L. (1958a). Gum ghatti (Indian gum). Part II. The hydrolysis products obtained from methylated degraded gum and the methylated gum. *Journal of the Chemical Society*, 221–230.

Aspinall, G. O., Bhavanandan, V. P. & Christensen, T. B. (1965). Gum ghatti (Indian gum). Part V. Degradation of the periodate-oxidised gum. *Journal of the Chemical Society*, 2677.

Aspinall, G. O., Hirst, E. L. & Wickstrøm, A. (1955). Gum ghatti (Indian gum). The composition of the gum and the structure of the two aldobiouronic acids derived from it. *Journal of the Chemical Society*, 1160.

BeMiller, J. N. (Ed.). (1973). *Quince seed, psyllium seed, flax seed, and okra gums, Industrial Gums*. New york: Academic Press.

Castellani, O., Al-Assaf, S., Axelos, M., Phillips, G. O. & Anton, M. (2010). Hydrocolloids with emulsifying capacity. Part 2. Adsorption properties at the n-hexadecane–water interface. *Food Hydrocolloids*, *24*(2–3), 121–130.

Castellani, O., Gaillard, C., Vié, V., Al-Assaf, S., Axelos, M. & Phillips, G. O. (2010). Hydrocolloids with emulsifying capacity. Part 3. Adsorption and structural properties at the air–water surface. *Food Hydrocolloids*, *24*(2–3), 131–141.

Cushman, D. R. & Schick, J. W. (1975). New Jersey Patent No. 3,891,620. U. S. Patent.

Delgobo, C. L., Gorin, P. A., Tischer, C. A. & Iacomini, M. (1999). The free reducing oligosaccharides of angico branco (*Anadenanthera colubrina*) gum exudate: An aid for structural assignments in the heteropolysaccharide. *Carbohydrate Research*, *320*(3–4), 167–175.

Do, N. & Adams, R. P. (1991). A simple technique for removing plant polysaccharide contaminants from DNA. *Biotechniques*, *10*(2), 162–166.

Drytech P., (I) Private, Ltd. (2009). *Product specification report (Production, Trans.)*. Mumbai, India: Drytech, P., (I) Private, Ltd.

Frost, J., Hegedus, E. F. & Glicksman, M. (1984). Objective characterization of hydrocolloid organoleptic properties. *Food Technology*, *38*(1), 118.

Gaıa, J. P., Desplanches, H. & Chevalier, J. L. (1981). Caracterisation rheologique de quelques hydrocolloides d'exsudats vegetaux. *Lebensmittel-Wissenschaft and Technologie*, *14*, 317.

Glicksman, M. (Ed.). (1969). *Gum technology in the food industry*. New York: Academic Press.

Glicksman, M. (Ed.). (1983). *Gum ghatti (Indian gum)*. Boca Raton: CRC Press.

Goycoolea, F. M., Morris, E. R., Richardson, R. K. & Bell, A. E. (1995). Solution rheology of mesquite gum in comparison with gum Arabic. *Carbohydrate Polymers*, *27*(1), 37.

Harding, J. & McCarthy, N. J. Jr. (1977). New Jersey Patent No. 4,026,848. U. S. Patent.

http://www.krystal-colloids.com/ghatti.html (2008). Retrieved December 4, 2008.

http://www.megamic.com/gumghatti.html (2010). Retrieved May 10, 2010.

Ido, T., Ogasawara, T., Katayama, T., Sasaki, Y., Al-Assaf, S. & Phillips, G. O. (2008). Emulsification property of GATIFOLIA (gum ghatti) used for emulsions in food products. *Foods and Food Ingredients Journal of Japan*, *213*, 365–372.

Jain, N. K. & Dixit, V. K. (1988). Studies on gums and their derivatives as binding agent. *Indian Journal of Pharmaceutical Sciences*, *50*, 113–114.

Jefferies, M., Konadu, E. Y. & Pass, G. (1982). Cation effects on the viscosity of gum ghatti. *Journal of the Science of Food and Agriculture*, *33*(11), 1152–1159.

Jefferies, M., Pass, G. & Phillips, G. O. (1977). Viscosity of aqueous solutions of gum ghatti. *Journal of the Science of Food and Agriculture*, *28*(2), 173–179.

Jefferies, M., Pass, G., Phillips, G. O. & Zakaria, M. B. (1978). The effect of metal ion content on the viscosity of gum ghatti. *Journal of the Science of Food and Agriculture*, *29*(2), 193–200.

Joshi, M. G., Setty, C. M., Deshmukh, A. S. & Bhatt, Y. A. (2010). Gum ghatti: A new release modifier for zero order release in 3-layered tablets of diltiazem hydrochloride. *Indian Journal of Pharmaceutical Education and Research*, *44*(1), 78–85.

Kaith, B. S., Jindal, R., Mittal, H. & Kumar, K. (2010a). Temperature, pH and electric stimulus responsive hydrogels from Gum ghatti and polyacrylamide—synthesis, characterization and swelling studies. *Der Chemica Sinica*, *1*(2), 44–54.

Kaith, B. S., Jindal, R. & Mittal, H. (2010b). Superabsorbent hydrogels from poly(acrylamide-co-acrylonitrile) grafted Gum ghatti with salt, pH and temperature responsive properties. *Der Chemica Sinica*, *1*(2), 92–103.

Kang, J., et al. (2010a). New studies on gum ghatti (*Anogeissus latifolia*). Part III. *Food Hydrocolloids*, 1–9. doi:10.1016/j.foodhyd.2010.11.020

Kang, J., et al. (2010b). New studies on gum ghatti (*Anogeissus latifolia*). Part II. *Food Hydrocolloids*, 1–8. doi:10.1016/j.foodhyd.2010.11.021

Kang, J., et al. (2011). New studies on gum ghatti (*Anogeissus latifolia*). Part I. *Food Hydrocolloids*, doi:10.1016/j.foodhyd.2010.12.011

Katayama, T., Ido, T., Sasaki, Y., Ogasawara, T., Al-Assaf, S. & Phillips, G. (2008). Characterization of the adsorbed component of gum ghatti responsible for its oil–water interface advantages. *Foods and Food Ingredients Journal of Japan*, *213*, 372–376.

Kaur, L., Singh, J. & Singh, H. (2009). Characterization of gum ghatti (*Anogeissus latifolia*): A structural and rheological approach. *Journal of Food Science*, *74*(6), E328–E332.

Kulkarni, R. V., Setty, C. M. & Sa, B. (2010). Polyacrylamide-g-alginate-based electrically responsive hydrogel for drug delivery application: Synthesis, characterization, and formulation development. *Journal of Applied Polymer Science*, *115*, 1180–1188.

Meer, G. (1980). Gum ghatti. In R. L. Davidson (Ed.), *Handbook of water-soluble gums and resins*. New York: McGraw-Hill (Chapter 9).

Meer, G., Meer, W. A. & Gerard, A. (1973). Gum ghatti. In R. L. Whistler, & J. N. BeMiller (Eds.), *Industrial gums*. New York: Academic Press.

Menestrina, J. M., Iacomini, M., Jones, C. & Gorin, P. A. J. (1998). Similarity of monosaccharide, oligosaccharide and polysaccharide structures in gum exudate of anacardium occidentale. *Phytochemistry*, *47*(5), 715–721.

Mitchell, J. R. (Ed.). (1979). *Rheology of polysaccharide solutions and gels*. London: Butterworths.

Mushinski, E. B. & Potter, M. (1977). Idiotypes on galactan binding myeloma proteins and anti-galactan antibodies in mice. *The Journal of Immunology*, *119*(6), 1888–1893.

Osilesi, O., Trout, D. L. & Knight, E. (1988). Hepatic responses to edible gums during refeeding of starved rats. *The Journal of Nutrition*, *118*(4), 462–468.

Rana, V., Rai, P., Tiwary, A. K., Singh, R. S., Kennedy, J. F. & Knill, C. J. (2011). Modified gums: Approaches and applications in drug delivery. *Carbohydrate Polymers*, *83*, 1031–1047.

Salyers, A. A., Vercellotti, J. R. & West, S. E. (1977). *Applied Environmental Microbiology*, *34*(5), 529–553.

Salyers, A. A., Vercellotti, J. R., West, S. E. & Wilkins, T. D. (1977). Fermentation of mucin and plant polysaccharides by strains of Bacteroides from the human colon. *Applied Environmental Microbiology*, *33*(2), 319–322.

Tischer, C. A., Gorin, P. A. J. & Iacomini, M. (2002). The free reducing oligosaccharides of gum Arabic: Aids for structural assignments in the polysaccharide. *Carbohydrate Polymers*, *47*, 151–158.

Tischer, C. A., Iacomini, M., Wagner, R. & Gorin, P. A. (2002). New structural features of the polysaccharide from gum ghatti. *Carbohydrate Research*, *337*, 2205.

Williams, P. A. (1982). *Adsorption of polyelectrolytes onto barium sulphate*. PhD Thesis, University of Salford.