Article

Gums and Mucilages Therapeutic and Pharmaceutical Applications++

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Introduction

Gums and mucilages are the most commonly available plant ingredients with a wide range of applications in pharmaceutical and cosmetic industries. Industrial gums and mucilages, which, for the most part, are water-soluble polysaccharides, have enormously large and broad applications in both food and non-food industries. Their use depends on the unique physicochemical properties that they provide, often at costs below those of synthetic polymers. The gums and mucilages are frequently used as thickening, binding, emulsifying, suspending and stabilizing agents in pharmaceutical industries. They have also been used as matrices for sustained release of drugs. Gums and mucilages are interesting polymers for the preparation of pharmaceutical formulations, because of their high water-swellability, non-toxicity, low cost and free availability. Gums and mucilages are polysaccharides or complex carbohydrates containing one or more monosaccharides or their derivatives linked in a bewildering variety of linkages and structures. They are condensation polymers. The term gum refers to polysaccharide hydrocolloids, which do not form a part of cell wall, but are exudates or slimes and are pathological products. Mucilages are part of cell and are physiological products. In recent years, these polysaccharides have evoked tremendous interest in pharmacy, medicine and food technology. This article presents an overview of biological, therapeutic and pharmaceutical applications of important polysaccharides.

++ This article is based on authors' studies carried out in their laboratory on some plants discussed in table 2 of this paper.

Classification of Gums and Mucilages

The gums and mucilages can be classified according to their nature or occurrence into the following groups:

1. Exudates (gum arabic, gum acacia)
2. Seed Gums (guar gum, carob gum)
3. Plant Extracts (pectin, starch, cellulose and hemicellulose)
4. Seed Mucilages (***Plantago ovata***, ***Ocimum*** species)
5. Seaweed Extracts (Agar-agar, carrageenan, alginates)
6. Polysaccharides from animals (chitin, chitosan)
7. Microbial Exudates (dextran, xanthan gum)

Chemical Nature of Gums and Mucilages

Gums and mucilages, because of their polysaccharide nature, produce an indefinite number of monosaccharides on hydrolysis. Depending on the type of hydrolysis products obtained, they can be further classified into pentosans (e.g. xylan) and hexosans (e.g. starch, cellulose).

Gums are pathological products consisting of calcium, potassium and magnesium salts of complex substances known as 'polyuronides'. Mucilages are physiological products related to gums, but they are generally sulfuric acid esters, the ester group being a complex polysaccharide. Both gums and mucilages are closely related to hemicelluloses in composition, except that the sugars produced by hemicelluloses are glucose, mannose and xylose, whereas those produced by gums and mucilages are galactose and arabinose.

Identification of the constituent sugar units in a polysaccharide is done by hydrolysis using dilute mineral acids, followed by separation of liberated

monosaccharides using different chromatographic techniques. Estimation of total carbohydrate content of a polysaccharide and also the content of monosaccharides can be done by phenol-sulfuric acid method.

The mode of linkage between the monosaccharides can be determined by methylation, periodate and lead tetra-acetate oxidation. Graded hydrolysis technique can be used to get a spectrum of oligosaccharides, which can be further analyzed to get information on sequence of different sugar residues. NMR and mass spectroscopy techniques can also be used for structural elucidation of gums and mucilages.

Therapeutic Applications

A number of fungi, plants, bacteria and algae produce a variety of polysaccharides, which exhibit different types of therapeutic actions. Some of the important therapeutic activities exhibited by these polysaccharides include anticoagulant, hypoglycaemic, anti-tumour, immunoregulating, anti-inflammatory, wound healing, and antilipemic activities. Some important polysaccharides and their therapeutic actions are given in Table 1.

1. Anticoagulant Activity

Heparin, an effective anticoagulant, is a sulfated amino polysaccharide. Hence, using analogies, sulfated polysaccharides are being investigated for anticoagulant activity. Many sulfated polysaccharides from marine algae have shown anticoagulant activity.

Table 1- Therapeutic Activities of Polysaccharides

Sl. No.	Source	Chemical Nature	Therapeutic Activity	Remarks
1	*Padina povina / Padina tetrastromatica* Hauck.	Sulfated polysaccharides composed of glucuronic acid, fructose, xylose, mannose, glucose, galactose and sulfates	Anticoagulant Activity	The activity was found to be higher than heparin
2	*Cladophora socialis*	Sulfated polysaccharides	Anticoagulant Activity	It was found to promote blood coagulation below certain concentration, whereas, above this concentration, anticoagulant activity is observed
3	*Caulerpa taxifolia* (Vahl) J. Ag.	Sulfated polysaccharides	Anticoagulant Activity	Activity was comparable with dextran sulfate
4	*Chaetomorpha antennina* (Bory) Kutz.	Sulfated polysaccharides	Anticoagulant Activity	Activity was comparable with dextran sulfate
5	*Artemisia herba*	Acidic polysaccharide composed of galacturonic acid and rhamnose	Anticoagulant Activity	Perhaps, it is the only polysaccharide without sulfate groups showing anticoagulant activity
6	*Saccharum officinarum* Linn.	Saccharans A to E obtained from non-sucrose portion of juice	Hypoglycaemic Activity	Saccharans B and E were found to be better than other saccharans
7	*Atractylodes japonicum* (Rhizome)	Polysaccharide fractions, viz., Atractan A, B and C	Hypoglycaemic Activity	Attractan A exhibited hypoglycaemic activity in mice
8	*Abelmoschus glutinotextilis* (Root)	Mucilage with repeating structure (1→4)-O-β-(D-glucopyranosyl uronic acid)-(1→3)-O-α-(D-galactopyranosyl uronic acid)-(1→2)-O-α-L-rhamno pyranose	Hypoglycaemic Activity	Hypoglycaemic activity was observed in normal mice

Sl. No.	Source	Chemical Nature	Therapeutic Activity	Remarks
9	***Abelmoschus manihot* (Linn.) Medic.** (Root)	Mucilage with similar structure as above one	Hypoglycaemic Activity	Hypoglycaemic activity was observed in normal mice
10	***Abelmoschus esculentus* (Linn.) Moench** (Immature fruit and root)	Mucilage with similar structure as above one	Hypoglycaemic Activity	Hypoglycaemic activity was observed in normal mice
11	***Abelmoschus moschatus* Medic.** (Root)	Mucilage with similar structure as above one	Hypoglycaemic Activity	Hypoglycaemic activity was observed in normal mice
12	***Alcea rosea* Linn.** syn. *Althaea rosea* (Linn.) Cav. (Root)	Mucilage with similar structure as above one	Hypoglycaemic Activity	Hypoglycaemic activity was observed in normal mice
13	***Althaea officinalis* Linn.** (Root and leaf)	Mucilage with similar structure as above one	Hypoglycaemic Activity	Hypoglycaemic activity was observed in normal mice
14	***Hibiscus syriacus* Linn.** (Leaf)	Mucilage with similar structure as above one	Hypoglycemic Activity	Hypoglycaemic activity was observed in normal mice
15	***Plantago asiatica* Linn.** (Seed)	Deacylated Mucilage	Hypoglycaemic Activity	Remarkable hypoglycaemic activity in mice
16	***Lilium japonicum* Thunb.** (Bulb)	Glucomannans	Hypoglycaemic Activity	Hypoglycaemic activity was observed in mice
17	*Basidomycetes* (fungi)	Polysaccharides – Lentinan, Schizophyllan	Anticancer Activity	Useful in cancer immunotherapy
18	***Grifola umbellata***	Glucans with common unit (1→3)-β-D-gluco pyranose-(1→3)-β-D-glucopyranose	Anticancer Activity	-----
19	***Ganoderma lucidum* (Leyss.) Karst.**	Glucans with same structure as above	Anticancer Activity	-----

2. Hypoglycaemic Activity

Many mucilages obtained from plants of *Liliaceae*, *Dioscoriaceae*, *Malvaceae* and *Plantaginaceae* families have been reported to possess good hypoglycaemic activity in normal mice and diabetic mice. Considerable activity is reported for mucilages belonging to *Malvaceae*. The mechanism of this activity is yet to be established.

3. Anti-tumour Activity

Sulfated polysaccharides, including carrageenan, are reported to inhibit tumour metastasis in rat test systems by inhibiting the action of tumour cell derived heparanases involved in membrane crossing. In general, soluble D-glucans have been reported to be active anti-tumour agents. Introduction of palmitoyl and phosphate groups into polysaccharides improves the anti-tumour activity.

4. Immunoregulator Activity

Plant polysaccharides offer an important source of immunostimulants. High molecular structure and presence of uronic acid are important features for immunostimulant activity. Many marine polysaccharides including carrageenans exhibit immunostimulating activity. For example, carrageenans have been shown to act as human T-cell mitogens, induce T-cell suppressor activity in mice, modify lymphocyto migration via specific receptors and stimulate the population of mouse B-cells.

5. Anti-inflammatory and Wound-healing Activity

Polysaccharides from plants, fungi and bacteria have shown anti-inflammatory activity in case of carrageenan

Sl. No.	Source	Chemical Nature	Therapeutic Activity	Remarks
20	***Lensinus edodes*** (Edible mushroom)	Polysaccharide lentinan β-(1→3)-linked linear glucan	Anticancer Activity	Strong anti-tumour activity against sarcoma-180 implanted in mice and complete regression of tumour
21	***Angelica acutiloba***	Water-soluble heteropolymer containing uronic acid, hexose and peptide	Immuno-stimulating Activity	Primary antibody response to sheep erythrocytes was augmented markedly by intraperitonial injection of the polymer
22	***Astragalus mongholicus*** **Bunge** (Roots)	Polysaccharide composed of glucose, galactose and arabinose	Immuno-stimulating Activity	Wide variety of immunological effects were observed in mice
23	***Acanthopanax senticosus***	Polysaccharides – Glucan and Heteroxylan	Immuno-stimulating Activity	Enhanced Phagocytosis
24	***Brahea serrulata*** **H. Wendl.** syn. *Sabal serrulatum* Schult.	Polysaccharide, acidic in nature	Anti-inflammatory Activity	Inhibited carrageenan paw edema at very low doses
25	***Aloe vera*** **Linn.** (leaf)	Polysaccharide containing galactose, glucose, mannose, arabinose and rhamnose	Anti-inflammatory Activity	The activity was observed at dose which was 1/3 of that of indomethacin
26	*Fungi, marine invertebrates and insects*	Chitosan	Wound healing and antilipemic activity	-----

induced paw edema. They are reported to reduce paw edema, but do not influence the proliferative phase of inflammation. Some of the polysaccharides are reported to have healing activity in gastric mucosa of rats with experimental ulcers.

6. Antilipemic Activity

Sulfated polysaccharides such as carrageenan have shown hypocholesterolemic activity. Chitosan has also shown antilipemic activity. Unfortunately, large doses of these polysaccharides are needed to show the activity, which can not be tolerated by humans.

Pharmaceutical Applications of Gums and Mucilages

Gums and mucilages possess a complex, branched polymeric structure because of which they exhibit high cohesive and adhesive properties. Such properties are highly useful in pharmaceutical preparations. Hence, gums and mucilages find diverse applications in pharmacy. They are ingredients in dental and other adhesives and as bulk laxatives. These hydrophilic polymers are useful as tablet binders, disintegrants, emulsifiers, suspending agents, gelling agents, stabilizing agents, thickening agents, protective colloids in suspensions and sustaining agents in tablets. Naturally available mucilages are preferred to synthetic materials due to their non-toxicity, low cost and free availability. Pharmaceutical applications of some gums and mucilages that are used commercially as adjuvants in pharmaceutical formulations, and some gums and mucilages under research in our laboratories are summarized in Table 2.

1. Application of gums and mucilages in tablet formulation

Gums and mucilages find applications in tablet formulation as binders because of their adhesive nature. They impart cohesiveness to the powder mass and convert them into granules, which are further compressed into tablets. They can also be used as disintegrants in tablets. The disintegrant property of gums and mucilages is due to their ability to absorb water and swell. They can swell up to 5

Abelmoschus esculentus (Linn.) Moench.

times their original volume and this swelling leads to breakage of tablets into smaller pieces, which in turn improves the dissolution rate. The gum from ***Abelmoschus esculentus* (Linn.) Moench.** has been reported as a binder for poorly water-soluble drugs such as sulphaguanidine, to improve their solubility.

2. Gums and mucilages as emulsifying and suspending agents

Gums and mucilages can act as emulsifying and suspending agents. They can effectively stabilize the emulsions via interfacial adsorption and the subsequent formulation of condensed films of high tensile strength that resist coalescence of droplets. They stabilize oil/water emulsions by forming a strong multimolecular film round each oil globule and thus retard the coalescence by the presence of a hydrophilic barrier between the oil and water phases.

Natural gums and mucilages increase the strength of the hydration layer formed around the suspended particles, through hydrogen bonding, and molecular interactions. Since these agents do not reduce the surface and interfacial tension, they function best in the presence of wetting agents. Gums and mucilages are also frequently used as protective colloids or thickeners. Natural gums and mucilages are hydrophilic colloids, which form dispersion with water and increase the viscosity of continuous phase, so that the solid particles remain suspended in it for a sufficient long time to measure a uniform dose.

3. Gums and mucilages as sustaining materials in dosage forms

Gums and mucilages can be used for sustaining the drug release. They have been used in tablets, suspensions, or as matrix systems for sustaining the drug release. These polymers, when come in contact with water, get hydrated and form a gel. The drug release from this gel will be usually diffusion controlled and hence the release will be sustained over a prolonged time. Many gums and mucilages such as guar gum, xanthan gum, karaya gum, ***Azadirachta indica* A. Juss.** gum and mucilages from ***Cassia tora* Linn.**, ***Ocimum americanum* Linn.** syn. *O. canum* Sims., ***Lepidium sativum* Linn.**, ***Asparagus racemosus* Willd.**, ***Colocasia esculenta* (Linn.)**

Asparagus racemosus Willd.

Colocasia esculenta (Linn.) Schott.

Schott., ***Aloe vera*** **Linn.**, ***Alcea rosea*** **Linn.** syn. *Althaea rosea* (Linn.) Cav. and ***Althaea officinalis*** **Linn.** have been reported to sustain the drug release from matrix tablets.

4. Gums and mucilages as coating agents

Many gums and mucilages act as good coating agents, which can sustain the drug release, or can protect the drug from degradation in stomach. The mucilage from drumstick polysaccharide (***Moringa oleifera*** **Lam.** syn. *M. pterygosperma* Gaertn.) has been reported to be a good film-coating polymer for paracetamol granules, which retarded the drug release from the granules when used at 2% concentration. As the number of coatings increased, the drug release was found to reduce.

5. Application of gums and mucilages in microencapsulation

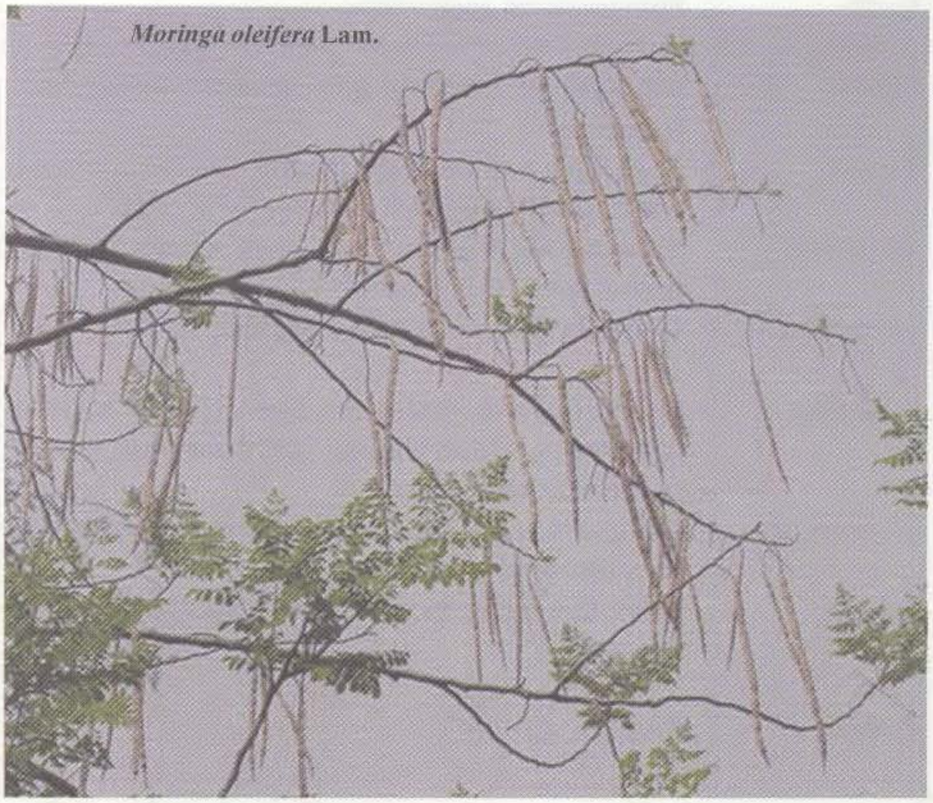
The gums and mucilages, because of their coating ability, find application in microencapsulation of drug particles for sustaining the release. Gums from ***Acacia nilotica*** **Delile**, ***Acacia senegal*** **Willd.** and amizo gum have been studied for their microencapsulating properties using spray-drying technique. Among the three, ***A. nilotica*** gum is reported to be a better microcapsulating agent.

6. Gums and mucilages as gelling agents

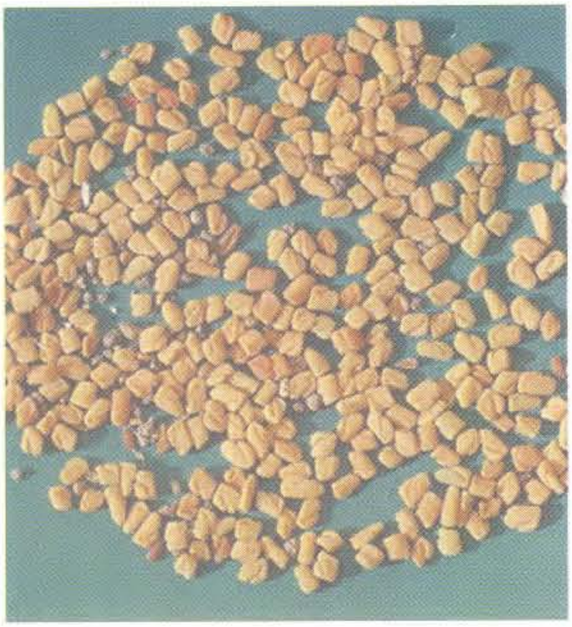
Gums and mucilages find application in the formulation of pharmaceutical gels. Gums and mucilages can form gels either alone or in combination with others. Gelling is a result of numerous inter and intra molecular associations to produce a three-dimensional network, within which the water molecules are entrapped. Such associations are brought about by either physical (pH change, altering temperature) or chemical (addition of suitable reagents) treatments. The mechanism of gelation in acidic polysaccharides such as pectin is different. In this case, the macromolecular chains are widely hydrogen bonded and as a result, junction zones are formed between hydrogen-bonded segments of chains. In alginic acid, the gel formation occurs as a result of interaction with calcium ions. Galactomannans interact synergistically with xanthan gum or carrageenans to form elastic gels.

Even though a variety of structures are involved with gel networks, most of the pharmaceutical gels are random coil networks, the mechanism of which is rooted in the polymer-polymer and polymer-solvent interactions. The strength of gel network increases with increase in

Borassus flabellifer **Linn.**



Moringa oleifera Lam.



Trigonella foenum-graecum **Linn.** Plant *(top)* seeds *(left)*

polymer concentration. This reduces the interparticle distance, which subsequently leads to chain entanglement and further development of crosslinks.

The utilization of natural gums and mucilages as base for pharmaceutical gels is a new concept, which is developed in our laboratory. The mucilages from palm fruit (***Borassus flabellifer*** **Linn.**), fenugreek seeds (***Trigonella foenum-graecum*** **Linn.**), ***Colocasia esculenta*** **(Linn.) Schott**, ***Ocimum basilicum*** **Linn.** seeds have been studied so far, for their gelling properties in our laboratory. The results are found to be favourable.

Conclusion

Systematic investigation of natural polysaccharides and their derivatives can lead to interesting discoveries in the fields of therapeutic and industrial research. There are still several plant polysaccharides that are not investigated so far and studies on such sources can make significant contribution in this direction.

Table 2- Pharmaceutical Applications of Gums and Mucilages

Name	Source	Family	Pharmaceutical Applications
Gum Tragacanth	***Astragalus . gummifer*** **Labill.**	Fabaceae	Suspending and emulsifying agent, demulcent and emollient in cosmetics
Gum Acacia	***Acacia arabica*** **Willd.**	Fabaceae	Suspending and emulsifying agent, binder in tablets, demulcent and emollient in cosmetics
Karaya gum	***Sterculia urens*** **Roxb.**	Sterculiaceae	Suspending and emulsifying agent, dental adhesive, sustaining agent in tablets, bulk laxative
Sodium alginate	***Macrocytis pyrifera***	Lessoniaceae	Suspending agent, gelation for dental films, stabilizer
Agar-agar	***Gelidium amansii***	Gelidiaceae	Suspending and emulsifying agent, gelling agent in suppositories, surgical lubricant, tablet disintegrants, medium for bacterial culture, laxative
Carrageenan	***Chondrus crispus*** **(Linn.) Stackh.**	Gigartinaceae	Gelling agent, stabilizer in emulsions and suspensions, in tooth paste, demulcent and laxative
Guar gum	***Cyamopsis tetragonoloba*** **(Linn.) Taub.**	Fabaceae	Binder, disintegrant, thickening agent, emulsifier, laxative
Locust bean gum	***Ceratonia siliqua*** **Linn.**	Fabaceae	Thickener, stabilizer

Name	Source	Family	Pharmaceutical Applications
Xanthan gum	***Xanthomonas lempestris***		Suspending agent, emulsifier, stabilizer in tooth paste and ointments
Pectin	***Citrus aurantium*** **Linn.**	Rutaceae	Thickening, suspending and protective agent, carrier in microspheres
Ispagol mucilage	***Plantago . psyllium*** **Linn.,** ***Plantago ovata*** **Forsk**	Plantaginaceae	Cathartic, lubricant, demulcent, laxative, sustaining agent and binder, transdermal film forming agent
Fenugreek mucilage	***Trigonella foenum-graecum*** **Linn.**	Fabaceae	Gelling, tablet binder and sustaining agent, emollient and demulcent
Gum ghatti	***Anogeissus latifolia*** **Wall.**	Combretaceae	Binder, emulsifier, suspending agent
Linseed mucilage	***Linum usitatissimum*** **Linn.**	Linaceae	Sustaining agent in tablets
Abelmoschus mucilage	***Abelmoschus esculentus*** **(Linn.)Moench.**	Malvaceae	Binder in tablets
Tamarind seed polysaccharide	***Tamarindus indica*** **Linn.**	Fabaceae	Binding, emulsifier, suspending and sustaining agent
Mesquite gum	***Prosopis juliflora*** **Dc.**	Fabaceae	Binding and sustaining agent
Asario mucilage	***Lepidium sativum*** **Linn.**	Brassicaceae	Suspending and emulsifying agent
Satavari mucilage	***Asparagus racemosus*** **Willd.**	Apocynaceae	Binding and sustaining agent in tablets
Drumstick mucilage	***Moringa oleifera*** **Lam.**	Moringaceae	Suspending, emulsifier and film forming agent
Cashew gum	***Anacardium occidentale*** **Linn.**	Anacardiaceae	Suspending and binder transdermal film forming agent
Aloe mucilage	***Aloe species***	Liliaceae	Gelling agent
Neem gum	***Azadirachta indica*** **A. Juss.**	Meliaceae	Suspending and binder, transdermal film forming agent
Coco yam mucilage	***Colocasia esculenta*** **(Linn.) Schott**	Araceae	Binding ,emulsifying and suspending agent
Basil seed mucilage	***Ocimum basilicum*** **Linn.**	Lamiaceae	Gelling, binding, sustaining and transdermal film forming agent
Badam gum	***Prunus amygdalus*** **Batsch**	Rosaceae	Binding, sustaining and transdermal film forming agent