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Guar gum: A promising natural polysaccharides for various applications

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Abstract
Guar gum, a natural polysaccharide derived from the seeds of *Cyamopsis tetragonoloba*, is widely recognized for its versatile applications across various industries. Its structural properties, including high molecular weight and water solubility, enable its use in food, pharmaceuticals, cosmetics, and wastewater treatment. Modified derivatives, such as hydrogels, films, and composites, enhance its functionality for specific purposes like drug delivery, packaging, and adsorption. Guar gum's biodegradability, non-toxicity, and economic availability make it a sustainable choice for industrial innovations.

Keywords: Guar gum, polysaccharide, hydrogels, food additives, drug delivery, wastewater treatment, biodegradable polymers, industrial applications.

Introduction

Guar gum which is also known as Guaran or Cluster bean is the cheapest source of galactomannan [1]. It is obtained from the seed endosperm of *Cyamopsis psoraloides*, a plant height of 0.6 m with 5-12.5 cm length pod size [1, 2]. It is grown in few countries like India, South Africa, Australia, Pakistan and some southern part of USA [3]. Out of all producer countries 90% of Guar gum is cultivated in India and Pakistan only and out of which India produces 80% and is the largest trading country all over the world [4, 5]. The gum obtained from seed endosperm is odorless, appears whitish yellow in color with high molecular weight. It is insoluble in organic solvents such as alcohols and ketones except in formamide. Water is the only important solvent in which it dissolves to form a viscous solution [4-8]. Structurally, it consists of long polymeric chain of D-mannose units linked by β (1 4) glycosidic linkage attached with side chain of D-galactose units alternatively through α (1 6) glycosidic linkage [4-11] in 1:2 ratio as shown in Fig 1.

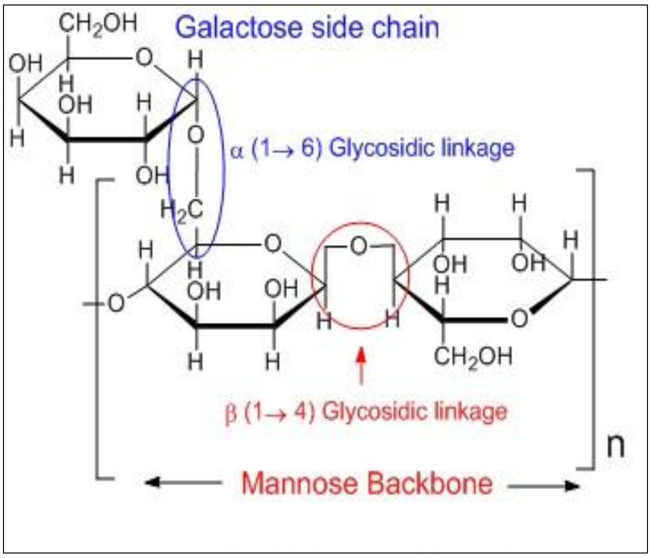


Fig 1: Structure of guar gum

In addition to carbon, hydrogen and oxygen it contains small amounts of nitrogen, phosphorus and ash as represented in Table 1 Also, Presence of hydroxyl groups in polysaccharide backbone opens up the opportunity of its modification to synthesize many derivatives for diverse industrial applications [11-13].

Table 1: Chemical composition of guar gum

Sl. No	Constituents	Percentage
1	Nitrogen	0.67
2	Protein	3.5-4.0
3	Phosphorous	0.06
4	Ash	1.07
5	Water soluble polysaccharides	88.50

Various chemical tests (methylation, acid hydrolysis), analytical techniques (SEM, NMR, IR-spectroscopy), biological test (hydrolysis of selective enzymes), physical test (stress-strain measurement) are used to determine the chemistry and structure of polysaccharide [14, 15]. All its chemical properties depends on its constituents and structural features i.e. presence of hydroxyl group, degree of polymerization, chain length etc. [16]. From advanced analytical techniques average molecular mass of guar gum is determined and found to be between 10^6 to 2×10^6 gm/mol. It is insoluble in alcohols, hydrocarbons, esters, and fats and is soluble in water only. Solubility of guar gum in water is due to the presence of 85% water soluble part. i.e. mannose and galactose units contain hydroxyl group which in water forms a highly viscous solution [17].

Guar gum attains high viscosity in less time in both hot and cold water even at room temperature whereas; other natural gums take prolonged heating to attain the same solution properties characteristics. Rate of hydration and viscosity of guar gum is dependent on features such as pH, temperature, concentration, dispersion and presence of other foreign substances. Owing to its high viscosity, gelling, non toxic, easy available properties, it is popular choice among researchers to use it in various industrial applications. Guar gum attains highest hydration at pH 8-9 and lowest at pH <4 and >10. Temperature is also another factor which influences the viscosity of guar gum. At high temperature hydration rate is more than compared to low temperature but prolonged heating effects the interaction of guar gum and water molecule by changing the order of water molecule around guar gum and thus results in decrease in rate of hydration and viscosity [18, 19]. Presence of hydroxyl groups helps guar gum to form hydrogen bonds with water molecule in aqueous solution. In addition to mannose units, galactose units also expose the hydroxyl group which results to form highly hydrated colloidal system [6]. Presence of sugar and salt molecule also affects the hydration rate and property of guar gum. Sugar molecule competes with guar gum for hydration and thus decreases its viscosity whereas salt molecules increase the intermolecular interaction and thereby enhances the rate of hydration. Due to this excellent property guar gum is used as a dispersant and coagulant in organic and inorganic solutions respectively [20].

Guar gum processing

India is the leading country and exporter of guar gum sharing about more than 85% of global production. It is obtained from guar seeds, a legume plant that is cultivated and grown in semi-arid region of Gujarat, Rajasthan and Haryana. Guar seeds are subjected to many mechanical processes such as screening, milling, dehusking, roasting, polishing and grinding etc. for the extraction of guar gum powder. Step wise procedure is shown in Scheme 1.1.

Split formation

Guar seeds are collected, processed and split into two halves. Further, germ and the hull are scrapped off mechanically to obtain endosperm.

Screening of split

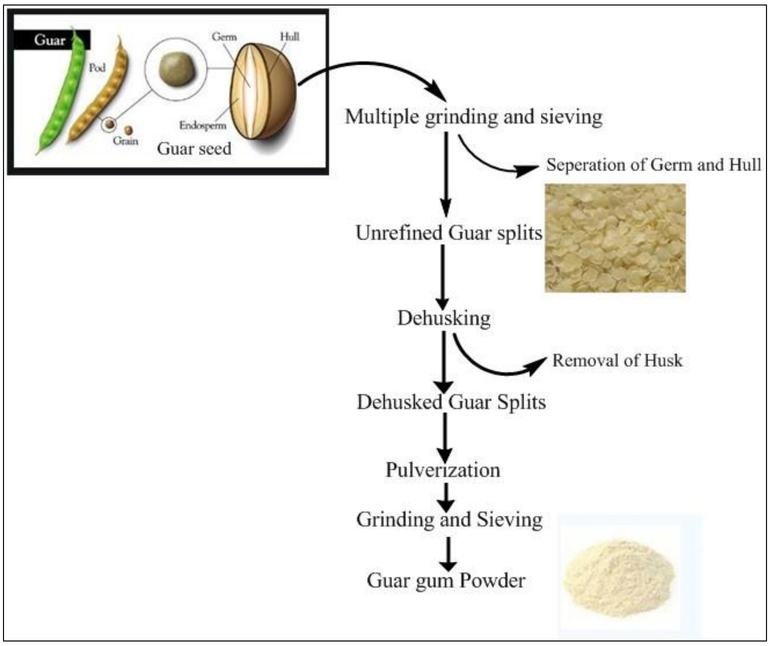
It is one of the important step in guar gum processing to obtain guar gum powder. In this step split formed are screened and selected for further process. The selected splits are cleaned and allowed to prehydrate. Prehydrating the splits is important as it decides the hydration rate of final product.

Pulverization

Endosperm obtained from the screened splits are then pulverized and purified followed by grounding to obtain a powder.

Sieving

Grounded powder is sieved to obtain a desired and required mesh.



Guar gum and its derivatives

Guar gum based hydrogels

Hydrogel is a highly complex three dimensional polymer formed as a result of crosslinking between the monomeric units. These hydrogels have the ability to absorb and hold water which makes them pertinent to be used in different fields and applications. Many crosslinking agents such as EGDMA, glutaraldehyde, methylbisacrylamide are used to synthesize these polymers. They are capable to form intermolecular bond with hydroxyl group present in the monomeric unit. Three dimensional voids formed within the polymer can entrap and hold water molecule. Degree of crosslinking and polymerization decides the nature and water holding capacity of hydrogel. Many guar gum based hydrogels are reported as far.

Guar gum hydrogels crosslinked with other natural gums such as xanthan, agarose, starch, alginate etc. have been reported for many applications with immense potential. In 2007 George *et al.* reported a hydrogel based on guar gum crosslinked with alginate for controlled release of a protein drug [21]. They crosslinked both polysaccharides due to their non toxic nature and high stability at even high pH range. This hydrogel had some limitations. On rapid dissolution, immediate release of protein drug was observed which enters the intestine [21]. Recently, in 2016 guar gum and nano sized bentonite clay based hydrogel was proposed by Maity and Ray for the removal of chromium from synthetic waste water. For the initial concentration 200 mg/L, they reported a maximum adsorption capacity of 182.4 mg/g, which make the synthesized hydrogel to be used in large industrial scale for wastewater treatment [22]. In 2018, guar gum grafted acrylic acid crosslinked with EGDMA based hydrogel was reported by Nandkishore *et al*. for controlled release of nutrients in soil. This hydrogel was fabricated for agricultural application with high porosity and water holding capacity of 800 ml water per gram of hydrogel [1]. All guar gum based hydrogel are nontoxic and biodegradable. Their degradation is dependent on oxygen content, pH of the system, humidity and temperature.

Both soil burial and composting methods are employed to check the biodegradability of guar gum hydrogels. In soil burial method samples are buried into the soil and degradation is studied in terms of weight loss whereas in composting samples are allowed to degrade by burying them in compost having various numbers of microbial species. Biodegradability of pure guar gum, different hydrogels like guar gum grafted with poly- acrylic acid and GG-g-p(AA-ipn-aniline) was studied by kaith *et al.* by both the methods [23]. They found that the samples were degraded completely in 7 days by soil burial method and within 14 days by compost technique.

Guar gum based films

Guar is also modified as film with the help of synthetic and natural polymers. The films are quite strong mechanically. They have found to posses antimicrobial properties also. Many guar gum based biocomposite films are reported so far in different applications with appreciable results. Biocomposite film based on guar gum and pea starch is reported for food packaging application with very good antimicrobial property [24]. Guar gum based metal nanocomposite with silver and copper is also reported with excellent oxygen barrier, thermomechnical and antibacterial characteristics. This film was synthesized by solvent casting technique for the application in food industries for food packaging [25]. Rao *et al.* also fabricated a chitosan and guar gum based film by casting method. The best film was obtained by standardizing the ratio of chitosan and guar gum in the range between 0% to 50% v/v. Properties such as opacity, oxygen permeability, transparency, rate of water vapour transmission, mechanical strength and antimicrobial activity were also studied and investigated. Film with 15% v/v guar gum composite showed the best result. This film was very less permeable to oxygen with very good tensile strength [26].

Application of guar gum and its derivatives

Guar gum being natural polysaccharide, non-toxic, and biodegradable with exceptional physicochemical properties is more suitable for modification. Guar gum and its derivatives have proven their worth in many industrial applications. Presence of glycosidic linkage makes it easily degradable by intestinal microbes and is used widely as a food product. In addition to this, its swelling property makes it suitable to be used in food as well as pharmaceutical industries to be as binder and dispersant respectively [27, 28]. Presence of hydroxyl group allows its modification to form many guar gum grafted derivatives, cross linked hydrogels, composites, nanocomposite films etc. Thus by controlling its inherent properties by different techniques, guar gum and its derivatives are used in various industrial applications [29-31].

Cosmetic industry

High solubility in both cold and hot water, film forming property, stability over wide pH range, characteristics to form highly viscous solution, non-toxic, biodegradable with economic and easy availability makes it useful for cosmetic industrial application. It is used in toothpaste to impart its flowing nature which makes toothpaste to extrude from tubes even when low force is applied. It is used as stabilizing agent and shaving cream. Guar gum also improvises facial skin [32] when used in cosmetic products. In cream and lotions, it acts as emulsifier and prevent from phase separation. Guar gum averts water loss and stabilises the emulsion system. At low temperature, in freeze thaw conditions, emulsion system of cold cream generally gets degraded, which is also prevented by the use of guar gum which acts as stabilizer and emulsifier in the system.

Food industry

Guar gum is one of the important and widely used natural polysaccharide, to be used in food industry. Properties like reduced rate of evaporation, high capacity of water retention, flexibility in freezing rate and its development in ice crystals after minor modification makes it exceptional excipient to be used in food products. Regulations to use guar gum as an additive is completely maintained by FAD (Food and Drug Administration). In chapatti, 0.75% is the permissible limit [33], where as 0.5% in bread and ice-cream [34, 35], 1.5% in pasta [36]. Function and permissible limit in many other products are tabulated in Table 2. In food products, it is used to improvise glazing, viscosity, moisture retention, gelation and bloom. In bakery industry, it reduces the moisture in dough and increases the product yield. It also prevents and reduces the penetration of fat into the dough. In dairy industry, it is used as thickener and helps in thickening of yoghurt and liquid cheese products. It is also used in ice-cream to improvise its consistency and texture. In beverage industry, guar gum is added in beverages to reduce and control the calories. Thus, it is preferred over other cellulosic gums like karaya, xanthan and tragacanth.

Table 2: Function of guar gum in various dietary products with their permissible dosage amount

Dietary product	Dose	Function	Reference
Chapatti	0.75%	Softness	[33]
Tomato ketchup	0.5-1.0%	Improving consistency	[37]
Fried products	0.5-1%	Decreasing oil uptake	[38]
Sausage	0.13-0.32%	Softness	[39]
Pasta	1.5%	Texture improvement	[36]
Cake	0.15%	Firmness	[40]
Yoghurt	2%	Texture improver	[41]

Drug delivery

In the past few years, guar gum and its modulated derivatives are extensively used in pharmaceutical industry for many drug formulation and drug delivery system. Swelling and binding properties in addition to emulsifier, thickener and stabilizer, make it suitable for pharmaceutical industry. Other than the above mentioned properties, its biodegradability and low cost are the driving force for its preference by drug and pharmaceutical industry. Guar gum derivatives are used as tablet matrix for targeted drug delivery. They can easily interact with mucus lining tissues and thereby increase the contact time and localization at targeted sites. Many derivatives like hydroxylmethyl guar gum, guar gum cross linked with glutaraldehyde, hydroxyethyl guar gum, guar gum conjugated with 4-vinyl-pyridine have been reported for novel targeted drug delivery system. Due to its high stability even under shear and stress, it is used as anti-hypersensitive drug system. Guar gum derivatives are used as tablet matrices for number of colon specific and anti inflammatory drugs [42] like metronidazole [43], indomethacin [44], mebendazole [45], albendazole [45], for their controlled release. Sodium trimetaphosphate cross linked guar gum succinic anhydride micro-particles were experimented as carrier for drug delivery. The material was found suitable due to its pH dependence and nontoxic nature. Guar gum based drug matrices are found to be pH and temperature sensitive in addition to percentage grafting in case of graft-co-polymers. For example, release of 5-ASA by GG-g-P(AM) decreases with the increase of percentage grafting [46], which is also seen in case of release of ketoprofen by ε-caprolactone grafted amphiphilic guar gum with maximum release in alkaline pH [47].

Some guar gum based derivatives used in pharmaceutical application are listed in Table 3.

Table 3: Guar gum based derivatives used in pharmaceutical application

Guar gum and its derivatives	Application	Reference
Carboxymethyl guar gum	Controlled transdermal release of diclofenac sodium	[48]
Alginate - guar gum hydrogel	Controlled delivery of protein drug	[21]
Fluoroacetic acid in guar gum	Medicine	[10]
Carboxymethyl guar gum	Wound healing	[49]
Carboxymethyl guar gum-g-gelatin	Biomedical	[50]
Chitosan and guar gum films	Antimicrobial properties	[26]

Wastewater treatment

Guar gum and its many derivatives are also used for the treatment of different waste water. It is modified by different synthetic polymers by grafting to form graft copolymer for the removal of suspended particles by flocculation. It is also fabricated as hydrogel to act as superadsorbent for the adsorption of many ionic dyes and heavy metal ions. Some of the derivatives are listed in Table 4 which are used in waste water purification.

Table 4: Guar gum and its various derivatives for water purification applications

Guar gum and its derivatives	Application	Reference
H-partially carboxymethylated guar gum-graft-methacrylic acid	Superabsorbing material	[18]
Guar gum with glycerol	Adsorption of fried potato chips	[38]

Summary

Guar gum, primarily produced in India and Pakistan, is an eco-friendly, non-toxic, and
biodegradable polysaccharide used extensively in industrial applications. Its unique physicochemical properties, such as high viscosity and water solubility, are exploited in
food for improving texture and shelf life, and in pharmaceuticals for controlled drug release. Derivatives like hydrogels, films, and composites are engineered for advanced applications, including waste management and biomedical uses. The paper highlights guar gum's chemical composition, processing, and modification techniques, emphasizing its role in sustainable development and its promising potential in emerging fields.

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