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Guar gum: A comprehensive review of its potential applications in pharmaceuticals, biomedicine, and the food industry

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Abstract

Guar gum (GG) is a galactomannan obtained from the seeds of *Cyamopsis tetragonoloba* (L.) Taub., a plant belonging to the Leguminosae family. It is renowned for its remarkable viscosity in water, which is among the highest found in natural polysaccharides. Furthermore, guar gum is appreciated for its excellent biodegradability and biocompatibility. These attributes make it a versatile material utilized in various industries, such as textiles, food, petrochemicals, mining, paper, and explosives. Despite its advantages, the use of guar gum in pharmaceutical applications is restricted due to issues like variable viscosity, inconsistent hydration, solution instability, and susceptibility to microbial growth. To address these challenges, chemical modification of guar gum is necessary. Modified guar gum is widely applied in the pharmaceutical field for its viscosity-enhancing properties. It serves as a binder, a disintegrant in tablet formulations, and a controlled-release agent for drugs. This review explores the pharmaceutical uses of both unmodified guar gum and its derivatives.

1. Introduction

Food, cosmetics, the textile and paper industries are some of the fields where natural gums have a great application. These are essential components in the manufacture of ice cream, soft drink, pudding, flavored milk, jam, jelly, fruit spread, bread, biscuit, cosmetic, textile and papers. Natural gums or these gums which are extracted from plants are in excess supply, inexpensive and can be altered in structure chemically through suitable reagents (Nehra *et al*., 2022; Shouride *et al*., 2023; Sanjana *et al*., 2023). Natural gums are chemically polysaccharide or carbohydrate polymers of diverse forms such as algal (alginates and carrageenan), plant (cellulose, pectin and guar gum), microbial (*e.g.*, dextran and xanthan gum) and animal chitosan, hyaluronan, chondroitin and heparin These materials have particular characteristics and properties that make great structural and energy materials, adhesives, and information transport agents in plants and even other organisms. Gums and other polysaccharides of plant origin are obtained from various sources, roots (tapioca starch), tubers (potato starch), seeds (guar gum), plant cell walls (cellulose and pectin), and gum arabic (plant exudates) (Amiri *et al*., 2021; Ganiger *et al*., 2023).

Guar gum or cluster bean is often referred to as a galactomannin, which derives from the *C. tetragonolobus* seeds that fall under the Leguminosae family. Guar beans mostly grow in lengths of 0.6 meters at maximum height along with having average pods length ranging from 5 to 12.5 cm. The pods themselves contain around 5 or 6 tan colored seeds (Kumari *et al*., 2020; Chauhan *et al*., 2023). Compared to formamide, primordial remains organic solvents such as hydrocarbons, alcohols or even fats and esters become insoluble with guar beans. On the other hand, they are completely free and capable of mixing with water as they have a high molecular weight along with low concentration. To add onto that, a unique quality of gel formation enables guar beans to mix with cold water with ease (Eghbaljoo *et al*., 2022; Das *et al*., 2022). In chemically, guar gum is composed of mannose and galactose with a ratio of 2:1 or 1:6 and 1:4, respectively, in which the sugar molecules branched out in side chains. As a stable pH between 5-7 is considered to be a norm, this non-ionic answer does not affect pH fluctuations; however, altered pH levels and high temperatures will lead to its degradation. The economic significance of guar gum became apparent after galactomannan was discovered because it was the sticky part of seeds (Meftahizadeh *et al*., 2022).The principal producers of guar gum are India, Pakistan, China, the USA, Australia and Africa with India contributing 80% of global production. The nation produces between 1.5-3.5 million tons of crops each year with Rajasthan, Gujarat and Haryana being the primary sites. Due to the numerous industries employing guargum, it has been an important item of trade for many years. This article also presents a comprehensive review of the existing literature on recent trends in guar gum utilization, especially in drug delivery systems, medical domains, and other industries (APEDA, 2022).

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2. Chemistry of guar gum

Guar gum is a natural, non-ionic gum that makes up 41% of the dry weight and the acetone-insoluble solids found in its seeds. The endosperm's acetone-insoluble solids are mainly comprised of at least 75% galactomannan, while the remaining 12% includes pentosans, proteins, pectin, phytin, ash, and substances that are insoluble in dilute acids (Shanmukha *et al.*, 2022). The chemical composition of guar gum is usually detailed in the following table:

Table 1: Typical composition of guar gum

Constituent	Per cent present
Ash	1.07
Water soluble polysaccharide	86.50
Phosphorus	0.06
Water insoluble fraction	7.75
Protein	3.5 - 4.0
Alcohol soluble fraction	1.50

Guar gum typically has a moisture level of about 10 to 13% and is distinct among plant gums and mucilages in that it does not contain uronic acid, a component that has been observed in most of the substances. The galactomannan fraction of guar gum contains approximately 36.6% of D-galactose anhydride and 63.1% of mannose anhydride its composition has been determined by numerous methods, including chemical analysis (acid hydrolysis and methylation), analytical (chromatography and infrared spectroscopy) and physical methods (optical rotation, stress-strain tests, and X-ray diffraction) (Li *et al.*, 2023). The general structure of guar gum is shown in below figure.

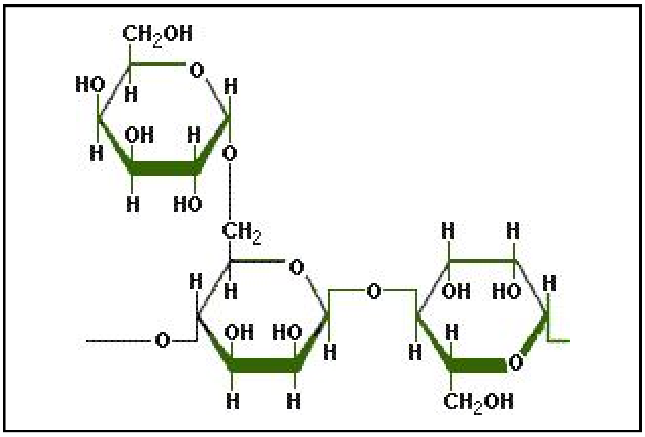

Figure 1: Structure of guar gum.

Guar gum consists of a linear chain of carbohydrate with an average molecular weight of about 220000. Its structure consists of a linear chain of D-mannose units linked together by $\beta(1\rightarrow4)$ glycosidic linkages with D-galactose units attached at interval positions through $(1\rightarrow6)$ glycosidic linkages. This structure gives a polymeric like structure of a backbone with mannose and randomly scattered galactose side chains with an average ratio of galactose to mannose of 1:2 (Kaur *et al.*, 2022). Guar gum has a wide range of characteristics that enhance its polymer properties, such as numerous hydroxyl groups that can be chemically modified to make various types of derivatives for industrial use. Galactomannan's functional properties and possible applications are determined by several characteristics including chain length, presence of cis-hydroxyl groups, steric hindrance, and degree of polymerization among others (Reis *et al.*, 2022; Dalei *et al.*, 2022).

3. Physicochemical properties of guar gum (Kirtil *et al.*, 2021; Verma *et al.*, 2022; Gasti *et al.*, 2021)

3.1 Physical properties

- Guar gum is nearly odourless and possesses a neutral, mild flavor. Its coloration varies from off-white to light yellow. The finely milled guar gum powder is available in different viscosities and particle sizes, customized for specific applications and viscosity requirements.
- The molecular weight of guar gum ranges from 200,000 to 300,000 daltons.
- Notable physical attributes include a refractive index of 1.2337, relative viscosity values between 0.20 and 0.47 in water and 0.37 to 0.56 in a 4% NaCl solution. The pH level is between 5.0 and 7.0, with optical density ranging from 0.035 to 0.050, and specific rotation varying from +28 to +76.
- It is soluble in both hot and cold water but remains insoluble in most organic solvents.
- Guar gum demonstrates significant intra- and intermolecular hydrogen bonding capabilities.
- Even at low concentrations, it shows remarkable settling properties, serving as a filter aid for the separation of organic and inorganic materials.
- As a non-ionic compound, it retains stability across a wide pH spectrum.
- Guar gum is compatible with various organic compounds, including certain dyes and food additives.
- Depending on the concentration, its solutions can act as emulsifying agents by minimizing the coalescence of oil droplets and stabilizing suspensions.

3.2 Chemical properties

- Guar gum serves as a cost-effective thickening and stabilizing agent, capable of hydrating in water to create highly viscous solutions with non-Newtonian flow characteristics.
- It exhibits greater solubility than badam gum due to a higher number of galactose branch points.
- In contrast to locust bean gum, guar gum does not form gels but maintains excellent stability during freeze-thaw cycles.
- It reduces ice crystal formation by decelerating mass transfer at the solid-liquid interface.
- The polymeric structure of guar gum contains numerous hydroxyl groups, which facilitate chemical modifications, allowing for the creation of derivatives that can regulate viscosity.

4. Extraction of guar gum

The hardness of the hull, embryo and endosperm is different from each other, which is utilized to separate the endosperm from the other parts of the guar seeds. This process includes several stages of grinding, sieving and other physical methods to the seed in order to break it apart and separate its components. The germ of the guar seed primarily contains protein and the endosperm is largely made of galactomannan. The endosperm that was separated from the husk is called guar split and is used to manufacture split endosperm powders for the production of gum (Madni *et al*., 2021). A schematic overview of the guar gum extraction process is depicted in Figure 2.

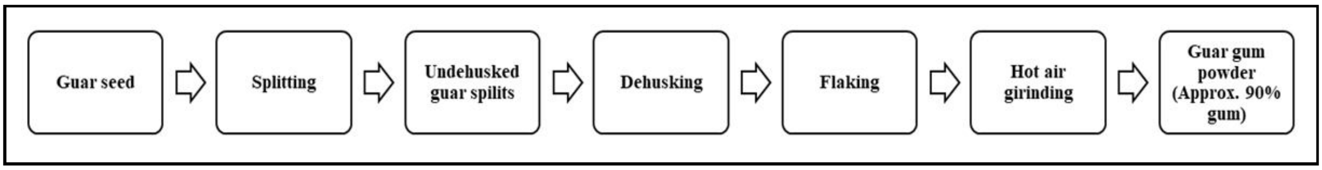

Figure 2: Extraction of guar gum from guar seed.

Singh *et al.* (2021) developed a protocol for the separation of guar endosperms that is quite extensive. For this procedure, they recommended soaking seeds in water while enzymatic activity is rendered ineffective by stirring providing heat to about 100°C for 30 min which Doris the enzymes and germs. Endosperm created *via* standard commercial extraction methods is not entirely clean as it has traces of hull and germ that can act as possible contaminants. However, because the hull and germ are consumable, to consider them as contaminants does not rank as a serious issue. Such imprecisions do not render guar gum unsuitable for use as a food additive. Usually, guar gum powder has the following composition: 75-86% of a solubilized galactomannan, 8-14% water, 5-6% protein, 2-3% fiber, and 0.5-1% ash. As a natural product, guar gum can differ in solubilization rate and viscosity from batch to batch (Sharahi *et al*., 2024) Application of guar gum and its derivatives spread across industries like oil and gas well fracturing, textiles, paper, food, cosmetics, explosives and mining. Guar gum is food or industrial grade depending on the levels of impurities and viscosity and other characteristics (Yavari *et al*., 2024). There are in fact a Joint Expert Committee on Food Additives (JECFA), Codex Alimentarius, and Bureau of Indian Standards (BIS) responsible for regulatory limits establishing grading and quality control standards for guar gum. These standards are very important in assuring the quality and suitability of guar gum for the different uses.

5. Guar gum in pharmaceutical industries

5.1 Guar gum in control drug release system

Guar gum is also commonly used as a taste masking agent in some formulations. It is reported that it successfully conceals the taste and the smell of unpleasant drugs which can help in achieving the desired drug kinetics in controlled release formulations. Furthermore, it has been shown to enhance the stability and bioavailability of a medication by serving as a protective coat during the coating of a tablet to allow for slow and sustained release of the drug of the tablet (Verma *et al*., 2021; Thombare *et al*., 2021; Amsa *et al*., 2022). Daud *et al.* (2021) synthesized transdermal patches employing. Sodium carboxymethyl guar as a polymeric matrix and other plasticers. Their investigations led to the conclusion that skin permeation enhancement with sodium carboxymethyl guar polymer is an effective. Garg *et al.* (2023) revealed that guar gum in compression-coated tablets for controlled release of indomethacin. In their results, swelling of moisture sensitive urethane elastomers was achieved by using guar gum, which showed good encapsulation of the drug during a simulated mouth to colon series, making it suitable for colonic drug delivery systems. In their study, Shi *et al.* (2021) noted that supplementation of polymeric hydroxyl propylmethyl MC, which is partially hydrolyzed, significantly reduced the presence of *Salmonella* in chickens by augmenting the composition of the gut microflora.

According to the Ashames *et al*. (2022), polyacrylamide was employed to modify the functional properties of gum through emulsification in an effort to improve its performance. The research deduced that nifedipine is pH dependent as non-Fickian laws governed the kinetics for release and pepsin solution proved to be favorable. On a parallel note, Yadav *et al.* (2021) suggested the potential use of guar gum stains in controlled oral drug delivery systems by formulating multiunit systems that provided sustained release of trimetazidine dihydrochloride. Guar gum has been used in the formulation of microspheres and tablets that have a metronidazole or 5-flurouracil active ingredient and promise to deliver the drug near the colon. Such medications had showed a localized action in the stomach and in the small intestine while a higher normal was recorded in the colon area, indicating the probabilistics of using the guar gum excipient for targeted drug delivery (Manna *et al*., 2024; Zarbab *el al*., 2023). Moutaharrik *et al.* (2024) carried out an experiment aiming tot coverance on studies around drug release systems of which guar gum and its derivatives were covered. Their studies illustrated how modified guar gum can enhance drug release profiles, particularly when used in formulations that require changes in the pH system. Also, formulations containing guar gum have been developed with diltiazem hydrochloride, zidovudine, diclofenac sodium and ibuprofen, among others; this expands its usefulness in the preparation of controlled and sustained release formulations. Guar gum, when combined with useful pre-formulations provides numerous benefits overall to the various pharmaceutical applications as an excipient. This includes improved stability, bioavailability and drug release when compared with other excipients. Its use in transdermal patches, targeted delivery systems, and sustained release systems are examples of new and innovative approaches in pipe filling drug systems.

5.2 Guar gum in treatment of diabetes

Guar gum and its derivatives have been elaborately studied and synthesized because they are believed to assist in the control of blood sugar, blood fats, and diabetes. Guar gum, in large doses, has been shown to mitigate the postprandial hyperglycemic and hyperinsulinaemia in some patients which makes it quite useful during diabetes management (Alaeian *et al*., 2023). Awan *et al*. (2024) revelled that guar gum was incorporated in the daily diets of 25 diabetic participants in a period of between five to seven days. Home-diet results including urinary glucose excretion were normalized to decreased concentrations of 46 per cent or more than two third in the diet group and 54 per cent in the diet group in places where juices were served. This also means that guar gum, a carbohydrate which is gel-forming and non-absorbable, has a lot of potential when coupled with other treatments for diabetes management regardless of the treatment given or the amount of insulin administered. Geng *et al.* (2023) combined pectin and guargum to evaluate its impact on lipid level and insulin level of those female patients with type 2 diabetes. Their findings also indicated that less total cholesterol and triglycerides were achieved as a result of administration of a fiber blend of 17 g of guar gum with 5.9 g water soluble in some water. This fiber blend proved effective in reducing lipid levels without significantly impacting HDL-cholesterol.

Xu *et al.* (2022) evaluated the effects of postprandial guar meal with altered depolymerization of collagen on blood glucose, insulin, and c-peptide and gastric inhibitory polypeptide (GIP) in subjects with non insulin dependent diabetes mellitus (NIDDM). They found an improvement in postprandial glycemia and insulin plasma concentration but did not find any related change in the C-peptide concentrations. Thus, modified and depolymerized guar may assist diabetics with improved blood sugar control. Bakshi *et al.* (2022) observed glucose intolerance amelioration and hypetriglyceridemic response reduction after GGH administration to rats on a high fructose diet. They suggested that this SCFA beneficial application is due to being a result of fermentation of GGH by microbes in large intestine. Koyyada *et al.* (2021) were interested in the effects of guar gum on male rats diabetic with streptozotocin. Their test results showed that in the case of this diet with the addition of guar gum, serum cholesterol, triacylglycerols, LDL-C and atherogenic index were decreased significantly. In addition, the blood glucose of diabetic rats treated with guar gum was significantly lower after 28 days compared to treatments with no other medication or glibenclamide. The study also noted enhancements in body weight and food consumption among the rats treated with guar gum.

In a clinical trial conducted by Mondal *et al.* (2024), the effects of soluble fiber derived from partially hydrolyzed guar gum (PHGG) were assessed in individuals with type 2 diabetes and metabolic syndrome (MetS). The incorporation of 10 g of PHGG daily into the standard diet resulted in favorable changes in cardiovascular and metabolic parameters, including reductions in waist circumference (WC), HbA1c, urinary albumin excretion (UAE), and trans-fatty acid levels. The findings concluded that PHGG can have a beneficial effect on cardiovascular and metabolic risk factors in patients with type 2 diabetes and MetS.These investigations highlight the promising role of guar gum and its derivatives in diabetes management, lipid profile improvement, and overall metabolic health enhancement.

5.3 Guar gum in treatment of cancer

Guar gum as well as its derivatives were researched to find their potential in the treatment of cancer especially Colorectal cancer which is among the most common and fatal forms of cancer worldwide (Sriram *et al.*, 2023). Guar gum has been investigated in drug delivery systems designed for targeted therapy in the colon of patients suffering from colorectal cancer (Zarbab *et al.*, 2023; Kang *et al.*, 2020). Luo *et al.* (2020) used methotrexate (MPX) in their research on the treatment of colorectal cancer by crosslinking glutaraldehyde-guar gum microspheres using glutaraldehyde cross linking agents. Their outcomes ascertained at a primary level that the incorporation efficiency for MTX was high with the crosslinked gum. *In vitro* drug release studies turning the US Pharmacopeia paddle type dissolution apparatus concluded that in fact all the dissolution patterns were dependent on the ratios of guar gum and MS. These results indicate that crosslinked MS would be a candidate for Site specific MTX delivery into colon which is required for the treatment of colorectal cancer. Haqasif *et al.* (2021) on the other hand conducted an analysis on the bowel regulating effects of PHGG or partially hydrolyzed gum and its potential chances of increasing the risk of developing cancer in the colon. Their research involved monitoring the effects of PHGG consumption on nine healthy female participants by assessing the weight, moisture content, and texture of their stools. The outcomes demonstrated that PHGG enhanced fecal moisture and improved stool texture, albeit with some variability among individuals. This study underscores the potential of PHGG to support bowel health, which may contribute to lowering the risk of colorectal cancer. Dalei *et al.* (2023) modified both guar gum as C-glycosylated derivatives and sulfated derivatives to test these based on their cancer chemopreventive and anti-inflammatory properties. According to their findings, modified guar gum derived compounds were able to inhibit cancer promoting enzymes, including cytochrome P450 1A (CYP1A) but stimulated detoxifying enzymes such as glutathione-S-transferases (GSTs). Such findings complements other studies which advocate for modified guar gum in cancer prevention and its use as functional food.

Jana *et al.* (2020) developed CH-GG-g-AAm polymarized resin microspheres semi-IPNMs from chitosan and guar gum-g-acrylamide for drug delivery. Glutaraldehyde crosslinked these microspheres and the anticancer drug used was 5-fluorouracil (5-FU). The in vitro release studies indicated that 5-FU irradiation from these microspheres was sustained above 12 h with influence from polymer ratios, crosslinking, and drug concentration. Pasupathy *et al.* (2024) investigated guar gum-based matrix tablets for the delivery of curcumin, an anticancer agent. They formulated three variations of curcumin using different concentrations of guar gum and assessed the tablets for hardness, friability, drug content uniformity, and in vitro release. The drug release was evaluated in simulated gastric, intestinal, and colonic fluids, utilizing rat caecal contents to mimic the colonic environment. The formulation with 40% guar gum (F-1) exhibited the highest drug release (91.1%) after 24 h in the presence of rat caecal contents, indicating that guar gum may serve as an effective carrier for delivering curcumin to the colon for the treatment of colon cancer.These investigations highlight the potential of guar gum and its derivatives as promising drug delivery systems for the targeted treatment of colorectal cancer, facilitating localized and sustained drug release within the colon.

5.4 Guar gum as hydrogel

There is an increasing trend towards using drug delivery systems based on hydrogels made out of guar gum and its derivatives due to their ability to target specific sites in patient's body in a controlled manner. The encapsulation of diverse pharmaceuticals due to the copolymerization of various monomers with guar gum crosslink may act as an effective strategy that sustains and targets the localized drug release (Iqbal *et al.*, 2020). Songara *et al.* (2021) reported the development of a crosslinked low-swelling guar gum hydrogel with potential for verapamil hydrochloride and nifedipine colon targeting. The *in vivo* experiments conducted on rats showed that the crosslinked guar gum form is an effective vehicle to deliver the drugs to the site of action in the colonic region where it can biodegrade *via* enzymatic action indicating its role in site specific therapy. Batool *et al*. (2023) reported the synthesis of crosslinked polyacrylamide-guar gum copolymer microspheres with glutaraldehyde containing two coupled antihypertensive drugs verapamil hydrochloride and nifedipine convection. Their data confirmed that the degree of crosslinking and drug concentration along with drug type used were among the determinants for the rate of drug release. This research highlighted the potential of guar gum-based hydrogels for controlled drug delivery, particularly for both hydrophilic and hydrophobic compounds. Dallabrida *et al.* (2024) did further experiments on glutaraldehyde crosslinked guar gum hydrogels for use as colon specific drug delivery systems and their results showed that the hydrogel discs have a high potential for drug loading in conjunction with drug release, and the profiles of the released drug were influenced by buffer conditions and pH. It was observed that higher levels of glutaraldehyde in the formulation improved drug release demonstrating the importance of crosslinking in the control of the drug delivery.

Khan *et al*. (2020) studied the use of pH sensitive alginate-guar gum hydrogels cross linked with glutaraldehyde for controlled release of protein based drugs. It was specifically found that these hydrogels showed restriction of drug release under acidic pH conditions (simulating stomach) but there was adequate release at neutral pH (simulating intestines), thereby directing delivery of the protein drug to mainly the intestines. Maiti *et al*. (2021) formulated photo-polymerized derivatives of guar gum-methacrylate with different levels of methacrylation and molecular weights. These hydrogels demonstrated effective proliferation of endothelial cells, suggesting their potential application in cell-based therapies and advancing drug delivery research. Devi *et al*. (2024) investigated acrylic acid, maleic anhydride and polyquaternium-7), that also produced acryloyl guar gum (AGG) hydrogels, regarding their ability to act as pro-drugs carriers (l-tyrosine and l-DOPA). The pH responsiveness of the hydrogels results in reversible transitions allowing controlled release of the pro-drugs at separate pH settings. Lopez *et al.* (2022) prepared pH-sensitive hydrogels based on poly (vinyl alcohol) and acrylic acid-graft-guar gum. These hydrogels were used for the delivery of the anti-tuberculosis drug isoniazid and displayed controlled release at acidic and neutral pH, with longer release time than the intrinsic plasma half-life of the drug. Singh *et al*. (2020) emulsion technique synthesized crosslinked polyacrylamide-grafted guar gum hydrogels. These hydrogels exhibited responsiveness to pH and ionic strength, showing enhancement of the swelling in alkaline conditions. Studies reporting the release of information about common antihypertensive medications such as diltiazem hydrochloride and nifedipine, indicate that the drug release profiles were influenced by the pH of the surrounding medium. Dalei *et al*. (2021) grafted acrylic acid onto guar gum *via* gamma radiation to develop guar gum-based hydrogels. The resulting hydrogels responded rapidly to pH and temperature variation. These hydrogels can be applied for drug delivery and other applications due to biocompatibility, biodegradability, and cost-effectiveness. Collectively, these studies underscore the adaptability of guar gum-based hydrogels for controlled and targeted drug delivery, positioning them as promising candidates for various pharmaceutical applications.

5.5 Guar gum in treatment of other disease

Therapeutic uses of guar gum and its derivatives include monotherapy to treat/challenge various gastrointestinal conditions, including cholera, functional constipation, and diarrhoea, as well as its use in some eye-drop formulations (Wang *et al*., 2021). Accordingly, Alaeian *et al*. (2023) reported in an 18 day intervention study that 11 healthy men were given three different fiber supplements (enzymatically modified guar gum, maltodextrin and soy polysaccharides) at mealtimes (no details given on their individual compositions). Interestingly, improvements in gastrointestinal function were observed across all studies, highlighting the potential benefits of guar gum for digestive wellness. Fetting *et al*. (2022) examined the role of partially hydrolyzed guar gum (PHGG) in relieving constipation in 15 constipated females for 3 weeks. The results demonstrated that PHGG improved the consistency, moisture content, and bacterial composition of feces, affirming its positive impact on constipation, which is often linked to insufficient dietary fiber intake.Takayama *et al*. (2021) studied how PHGG, sold as BENEFIBER, affects the absorption of glucose, amino acids like arginine, and fats. In a double-blind trial with 10 healthy men, they found that PHGG did not interfere with normal absorption and had no side effects, proving it to be a safe dietary supplement. Huang *et al*. (2020) looked at hydrolyzed guar gum's impact on hormone levels, the respiratory quotient (RQ), and feelings of fullness during a weight-loss program. Their results showed that hydrolyzed guar gum helped with weight loss by promoting a sense of satiety. Oliveira *et al*. (2023) researched the impacts of PHGG, glucomannan, highly methoxylated pectin, and water-insoluble cellulose on lipid profiles and immunoglobulin production in rats. They found that soluble fibers like guar gum and pectin significantly lowered cholesterol, phospholipid, and triglyceride levels while boosting IgA production.

Reider *et al.* (2020) studied on phosphorylated guar gum hydrolysate (PGGH) in ovariectomized rats demonstrated that PGGH preserved calcium absorption in the intestines without estrogen. This indicates its potential to help maintain bone density and overall bone health.Pi *el al*. (2024) examined modified guar gum's effects on appetite and weight loss in 28 overweight men. Their trial showed that adding guar gum to a semi-solid meal effectively reduced appetite and led to significant weight loss compared to other methods. Minor *et al.* (2023) studied PHGG's ability to reduce diarrhea caused by sugar substitutes like maltitol and lactitol. They found that PHGG significantly decreased diarrhea rates, showing its usefulness for digestive issues related to sugar alcohols. El-Shafei *et al.* (2021) created sulfonated degraded guar gum by treating it with chlorosulfonic acid. They learned that at 2500 mg/l, sulfated guar gum significantly lowered cholesterol, LDL, and fibrinogen levels, suggesting potential benefits for cholesterol management and heart health. Bogdanoyic *et al.* (2024) evaluated PHGG for treating functional constipation in hospitalized patients, finding it effective in relieving symptoms and improving bowel movements. Gutierrez-Reyes *et al.* (2022) studied PHGG's role in preventing arterial thrombosis and high lipid levels in hamsters eating a high-fat diet. Their results indicated that PHGG increased antioxidant protein levels, reducing oxidative stress and protecting arteries. These studies highlight the diverse benefits of guar gum and its derivatives for various digestive problems and overall cardiovascular health, making it an important option for many health issues.

6. Guar gum in food industry

Guar gum is a widely used ingredient in the food industry, appreciated for its affordability and safety. It plays a vital role in many food applications, such as holding water, reducing evaporation, changing freezing rates, controlling ice crystals, and modifying texture. Guar gum also participates in various chemical processes, making it versatile in food production (Madni *et al*., 2021). The U.S. Food and Drug Administration (FDA) regulates guar gum, classifying it as a generally recognized as safe (GRAS) ingredient when used at levels below 2%. It serves multiple purposes in food products, acting as a gelling, thickening, and binding agent, as well as helping with emulsification and stabilization. Guar gum increases water retention and boosts the fiber content in foods (Tahmouzi *et al*., 2023). In baked goods, guar gum helps dough retain moisture and prevents fat absorption, leading to better texture and longer shelf-life. For pastry fillings, it stops weeping, keeping the crust crisp. In dairy products, it thickens milk, yogurt, and liquid cheese, ensuring ice cream and sherbets have a smooth consistency while reducing ice crystal formation in frozen items. It also acts as a binder and stabilizer in ice cream, extending its freshness (Jiang *et al*., 2023). In meat products, guar gum improves binding and enhances the appearance and stability of dressings, sauces, ketchups, and canned soups. Within the candy industry, it helps manage thickness, gel formation, shine, and moisture retention. In drinks, it modifies viscosity and can help lower calorie counts. As a non-caloric fiber source, it is also found in dietary supplements (Chang *et al*., 2020). Guar gum is also commonly used in animal feed, especially pet food, due to its safety and nutritional benefits. When mixed with other gums like gum tragacanth, karaya gum, xanthan gum, and cellulosic gums, it can greatly enhance viscosity and overall product quality (Bhat *et al*., 2022).

6.1 Bakery goods and pasta

Bakery products, including different types of bread, biscuits, cakes, and donuts use a broad range of additives including GG (Rosell *et al*., 2001). GG is used in a wide range of food items and beverages. This is especially possible due to the fact that guar is deemed "generally recognized as safe". As a hydrocolloid GG serves the purpose of controlling the rheology and the water absorption of the batter or the dough. This helps in improving the mixing as well as recipe tolerance while also helping in ensuring longer product shelf life through moisture retention while preventing syneresis in frozen products such as bread and controlling spreadability (Ribotta *et al*., 2004). Adding GG to wheat bread dough results in a substantial increase in the loaf volume once it has been baked. Additionally, Kohajdová and Karovièová (2008) conducted an experiment that used a range of hydrocolloids such as gum arabic, methyl 2-hydroxyethyl cellulose, xanthan gum and GG to understand its effect on baked items. As these compounds were added there was an increase in both the water absorption and stability of the dough. The shelf-life of baked items such as bread was indeed impacted and it was noted that with bread being stored for up to 72 h and cellulose derivatives being used, the shelf-life was shorter.

Guar gum (GG) is a valuable ingredient for improving bread-making due to its unique properties. It effectively reduces the staling of baked goods, keeping the crumb softer for longer (Kohajdová and Karovièová, 2008). GG is also popular in cakes, donuts, and biscuits, particularly among children, because it enhances their nutritional value. Using GG as a fat replacement can elevate the quality and sensory experience of these products (Salehi, 2019). Research shows that GG can be used in low-fat biscuits and cakes (Chugh *et al*., 2013). Rice cakes made with a mix of xanthan and guar hydrocolloids without fat or emulsifiers tend to be firmer, likely due to the thickened crumb structure (Turabi *et al*., 2008). In gluten-free baking, GG boosts nutritional content and improves texture (Encina-Zelada *et al*., 2019). Moradi *et al*. (2021) examined how adding GG improves gluten-free bread. Their findings indicated that GG enhances adhesion, porosity, and elongation while reducing firmness and specific volume. The optimal formulation, involving 1% GG with potato flour, showed good quality for potential industrial use. Adding a small amount of GG (2% - 5%) to products like breakfast cereals, pasta, and snacks can increase production efficiency and maintain texture during storage. GG helps control starch retrogradation, improving shape and crunchiness (Shaikh *et al*., 2008). Additionally, GG fortifies cereal bars by retaining moisture and binding ingredients for better texture. A study by Sandhu *et al*. (2015) found that incorporating GG into pasta dough strengthened the dough and enhanced its properties.

6.2 Dairy products

GG is a versatile ingredient used in many dairy products for various purposes. It can influence crystallization, prevent separation, improve freezing and thawing, and stabilize foam. By keeping fat and water evenly mixed, GG helps maintain a consistent texture in products like cheese, yogurt, coconut milk, ice cream, and milkshakes (Gujral *et al*., 2002). The inclusion of GG powder and other thickening agents is vital for the creamy texture of ice cream. When combined with other hydrocolloids like carrageenan, GG works well in ice creams processed at high temperatures. This combination helps reduce ice crystal formation, ensuring that products like ice cream and yogurt stay creamy and stable (Heyman *et al*., 2010). However, GG and xanthan gum should not be mixed due to their different viscosity characteristics; xanthan gum is used in thinner applications. Guar gum is also added to yogurt to stabilize it and can help create low-fat versions (Lee and chang, 2016). Research indicates that adding GG significantly improves the texture of yogurt. GG can replace fat in low-fat yogurt, decreasing water separation and enhancing texture to match that of full-fat products. Consumers accept low-fat products made with GG as a fat substitute (Demirci *et al*., 2014).

GG plays a role in improving cheese by managing water content and reducing separation. Studies have shown that using GG and gelatin can enhance the texture and properties of ricotta cheese, resulting in better gel strength when combined (Pirsa *et al*., 2018). Guar gum is also used to create a smooth texture in doogh, a yogurt-based drink. Research found that the best formulation was achieved with specific amounts of quince seed mucilage and GG (Rather *et al*., 2015). The study observed significant changes in the sensory and physical qualities of doogh based on the factors tested (Lyly *et al*., 2009).

6.3 Meat products

Guar gum is widely used in the meat industry as a fat replacement as well as in edible films to improve shelf life and extend the shelf life of meat products. A study by Foegeding and Ramsey (1986) demonstrated that low-fat frankfurters made with GG were stable in quality compared to other fat substitutes. Andres *et al*. (2006) investigated how xanthan and GG can be used as hydrocolloids in preparing low-fat chicken sausages, and it was demonstrated that these products would retain acceptable quality even after being stored for 6 months.

Another experiment was conducted on preparing low-fat goshtaba (a traditional Indian meat product), and it was determined that adding a 0.5% gum mixture (a 1:1 ratio of GG to xanthan gum) resulted in a low-fat product with similar sensory and textural properties to those of a high-fat product when it came to sensory and textural quality (Rather *et al*., 2015).

Guar gum absorbs water in the gut, producing a mild laxative effect (Feiner, 2006). As a result of its performance in water binding, GG is soluble in cold and hot water, making it easy to be absorbed. As a thickening agent in processed meat products, it primarily controls syneresis in the products, prevents fat migration during storage, and regulates viscosity and rheology (Mudgil *et al*., 2014). An algin/ calcium and a salt/phosphate structure beef roll containing GG have been shown to exhibit an improved water-holding capacity (Shand *et al*., 1993). Further, hydrocolloid gums (GG) store water and create a gel network, which enhances their juiciness over time (Gupta and Variyar, 2018). It was investigated whether GG and carrageenan could replace phosphate in processing pork sausages. In addition to increasing water-holding capacity, the hydrocolloid compounds also reduced cooking loss. Compared to the control sausages, hardness, cohesiveness, and chewiness were well maintained. Furthermore, phosphate-free sausages were stable for extended periods (Park *et al*., 2008).

Regarding the importance of textural characteristics of meat products, the effects that can be obtained from supplementing lowfat, high-moisture meat batters with kappa-carrageenan, GG, xanthan, locust bean gum, methylcellulose, and a kappa-carrageenan/ locust bean gum combination have been assessed by Foegeding and Ramsey (1986). The texture profile analysis revealed changes in the texture properties of GG-based batter samples, which was better than controls. It was also found that low-fat frankfurters were just as acceptable as control frankfurters after sensory evaluation (Foegeding and Ramsey, 1986). Goswami *et al*. (2018) demonstrated that most physicochemical characteristics of lowfat carabeef cookies were significantly changed as GG levels were increased. They found that most physicochemical characteristics changed markedly as GG levels increased. There was an improvement in the sensory scores, including the texture profile, the color profile, and the flavor profile. Despite this, no significant difference was observed in hardness.

6.4 Sauces and dressings

In salad dressing, the inclusion of a thickener like GG at 0.2% to 0.8% of the total weight helps improve texture. Its ability to disperse in cold water and work well with acidic mixtures makes it effective (Mudgil *et al*., 2014). Thicker water phases in salad dressings can reduce the separation of oil and water. Research has explored using GG as a thickener in pickles and relishes, offering an alternative to tragacanth (Burrell, 1958). GG provides qualities that other hydrocolloids cannot, and it dissolves more readily in cold water compared to konjac glucomannan, which poses challenges in products like cold drinks and salad dressings (Ran *et al*., 2022). A study by the American Chemical Society showed that GG significantly improved the thickness of tomato ketchup compared to other thickeners like carboxymethyl cellulose and sodium alginate. GG also minimizes serum loss and improves flow in ketchup, making it a valuable thickening agent (Gujral *et al*., 2002). Additionally, research evaluated how different concentrations of GG, carboxymethyl cellulose, and xanthan gum affected the stability and texture of béchamel sauce. The results showed that adding these hydrocolloids increased the consistency and reduced syneresis, leading to better quality (Heyman *et al*., 2010). Studies on the texture and flow properties of GG-based sauces indicate that these properties reflect food quality (Burrell, 1958). For example, mustard sauce displayed weak gel-like behavior and strong shear-thinning characteristics under force. Various attributes were assessed, including springiness and hardness, revealing a strong link between GG and texture (Wang *et al*., 2016). Shen *et al*. (2022) enriched mayonnaise with pea protein and GG, resulting in greater emulsion stability and improved emulsifying and flow properties. Hydrocolloid thickeners are commonly used to manage the flow and texture of ketchup. Shah *et al*. (2007) showed that tomato ketchup thickened with GG and xanthan gum had significantly improved consistency. Additionally, xanthan gum and GG led to the most considerable reductions in serum loss and flow. Similarly, Sahin and Ozdemir (2004) found that GG-based ketchup samples had a higher consistency than those thickened with tragacanth, carboxymethyl cellulose, and xanthan gum.

6.5 Beverage industry

Gums are widely used in the beverage industry for various purposes, such as thickeners and viscosity enhancers. Among them, GG is the safest option. Some studies link carrageenan to inflammation and digestive problems in both animals and humans, although the evidence remains unclear (Shen *et al*., 2022). Regulatory bodies like the FDA and the European Food Safety Authority have classified carrageenan as safe for consumption. GG is also simpler to extract and produce compared to carrageenan, which involves a more complex process (Sow *et al*., 2018). When combined with xanthan gum, GG improves the viscosity of food systems. Its stability at lower pH levels and solubility in cold water makes it suitable for beverages. Being tasteless and odourless (Thombare *et al*., 2016), GG does not alter the flavor or smell of drinks. It is typically used in diet beverages at concentrations between 0.10% and 0.12% and can stabilize pulp in juices, requiring 0.25 to 0.75%. This helps keep carrot juice clear for up to six months at room temperature and can also stabilize musk melon juice (Ulu, 2006).

In fermented milk beverages, hydrocolloids like gum arabic and GG maintain quality and replace fat. Research shows that adding different hydrocolloids, especially GG, enhances firmness, pH, viscosity, protein content, and adhesiveness while reducing syneresis (Wang *et al*., 2016). The fat content significantly affects texture, supported by visual microstructure analysis. Besides being a source of soluble fiber, GG contributes to digestive health. Healthy, non-diabetic volunteers showed lower peak glucose levels after consuming drinks containing GG (Wolf *et al*., 2003).

7. Conclusion

Guar gum (GG) is a type of polysaccharide found in the seeds of the *C. tetragonoloba* plant, which belongs to the Leguminosae family. In recent years, these natural substances have gained attention for their useful applications in medicine and pharmaceuticals. GG has a history of use in drug delivery systems due to its thickening, gelling, and stabilizing properties. As the need for more efficient drug delivery methods grows, there is a greater demand for specialized polymers. Although the field of polymer-based drug delivery is still emerging, researchers are increasingly focusing on modifying GG to improve how long and accurately drugs are released. The unique qualities of GG, such as its versatile chemistry, availability, and wide range of uses, have made it a popular subject for research. This flexibility suggests that GG could be an important material for developing new drug delivery systems. Ongoing studies into GG and its derivatives are expected to lead to innovative solutions for delivering drugs more effectively.

8. Future prospects

The research analyses the guar gum parent market, derived market, intermediaries market, raw material market, and substitute market are all evaluated to better prospect the guar gum powder market outlook. Geopolitical analysis, demographic analysis, and porter s five forces analysis are prudently assessed to estimate the best guar gum market projections. Recent deals and developments are considered for their potential impact on guar gum powder's future business. Other metrics analyzed include the threat of new entrants, threat of new substitutes, product differentiation, degree of competition, number of suppliers, distribution channel, capital needed, entry barriers, govt. regulations, beneficial alternative, and cost of substitute in guar gum powder market. Guar gum trade and price analysis helps comprehend guar gum international market scenario with top exporters/suppliers and top importers/customer information. The data and analysis assist our clients in planning procurement, identifying potential vendors/clients to associate with, understanding guar gum price trends and patterns, and exploring new guar gum powder sales channels. The research will be updated to the latest month to include the impact of the latest developments such as the russia-ukraine war on the guar gum market.

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Conflict of interest

The author declares no conflicts of interest relevant to this article.

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