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Guar Gum A Potential Material For Pharmacological And Industrial Application

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Abstract

Cyamopsis tetragonoloba (L.) Taub, familiarly called guar, is a drought-tolerant leguminous crop, cultivated throughout the semi-arid and sub-tropical areas of the world. Plant pods, leaves, and stems possess a variety of pharmacological activities such as anti-diabetic, anti-alzheimer, anti-ulcer, antioxidant, anti-dengue, anti-cancer, and so on. Guar gum is a noval agrochemical refined from the seed endosperm of clusterbean; this complex polysaccharide is made of D-mannose and D-galactose monosaccharide units. This hydroxyl group-rich polymer establishes hydrogen bonds with water molecules, thus making it a good thickening and stabilising agent. Innocuous, budget-friendly, and easily available polysaccharides join other components in either functionalized or unmodified forms to create a variety of nanocomposites. These nanocomposites are used as an ingredient in the culinary, pharmaceutical, paper, textile, explosive, oil, and cosmetic industries and also for the removal of water impurities. The chemically modified guar gum is used in pharmaceuticals as a vehicle to carry drugs and for the adsorption or degradation of heavy metals, dyes, and organic pollutants. The Guar gum derivatives are also used as a green binder and separator for sodium and lithium ion batteries. This review is an effort to focus on the processing, pharmacological activities, and application of Guar gum and its nanocomposites.

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Keyword: Guar Gum; nanocomposites; pharmacological; pharmaceutical; Chemical derivative

Introduction

Cyamopsis tetragonoloba (L) Taub. belongs to family Fabaceae, the members of which are globally distributed and ranks third in terms of species abundance, beyond Asteraceae and Orchidaceae (1). The plant is a drought-tolerant crop distributed throughout the semi-arid and sub-tropical areas of the world. It is commonly known as guar or gawar, gwar ki phalli or clusterbean and is extremely significant from ethnobotanical perspective in both urban as well as indigenous population around the world. The crop has been grown all over India, but is most popular in the states viz. Rajasthan and Gujrat (2). Guar is an annual, summer plant that grows up to height of 2 to 4 feet and has coarse, erect, bushy morphology. The trifoliate leaves of the plant have pointed tips, saw-toothed margins and small in size. The raceme inflorescence bears purplish-white flowers, pods are hairy that are clustered together and are 3–4 inches long. There are varieties that are both tall and small. At young stage petals are white in color which gradually turn light pink as they start opening, finally the purplish white colored flowers are produced on maturity**(3).** Guar is a sun-loving plant, flourishing well in temperature ranges between 25-30 ^{o}C and regular rainfall is must for its optimum growth but is extremely sensitive to frost. The crop is planted in late July following the first rain, and harvested in late October. *C. tetragonoloba* was originated from the wild African species, *Cyamopsis senegalensis*, Arab traders probably brought the latter species from Africa to south Asia to use as a horse feed. The domesticated variety is mostly associated with India and Pakistan, where it has been raised as a vegetable for human consumption and as animal feed (4). The plant is also popular by several synonyms namely *Cyamopsis psoralioides* (Lam.) DC; *Dolichos psoraloides* Lam; *Psoralea tetragonoloba* L.; *Dolichos fabaeformis* L'Her; *Lopinus trifoliolatus* Cav; *Dolichos fabiformis* L'Her. (5). Guar has prominent traditional uses in ancient medical system like Ayurveda and siddha which are also mentioned in different ancient literature and used as a traditional remedy against inflammation, asthma, diabetes and as a hypolipidemic agent.

This herb of economic importance has been widely exploited for the gum, extracted from its seed endosperm and is becoming more and more popular because of its usage as both food and non-food item **(6)**. Guar gum (GG) powder is the most common form in which it is used as an ingredient in the culinary, pharmaceuticals, paper, textile, explosive, oil, and cosmetics industries. Galactomannan (gum) is a complex polysaccharide of D-mannose and D-galactose monosaccharides units Fig. 1. This hydroxyl group rich polymer establishes hydrogen bonds with water molecules, significantly thickening the solution, so having industrial applications primarily as a thickening and stabilizing agent (4,7). Being a natural polymer, guar gum possesses a number of intriguing qualities including biodegradability, biosafety, biocompatibility, and sustainability. There

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are numerous studies exemplifying several health promoting benefits of this leguminous crop like anti-diabetic, anti-cancerous, anti-inflammatory, cure against arthritis, cardiovascular diseases, and laxative effect. Nutritional analysis study of GG by George et al (2019) presented that it contains protein (5%), fat (0.7%), water (12%), galactomannan 80% /carbohydrate, and 2 % of acidic insoluble ash (8).

Area and production

In India, its production is recorded from North and North Western regions and also grown in certain neighboring areas of Pakistan. Guar is one of the largest produced commercial crop of India with export to more than 100 countries. India only produces 70-80% of total world production followed by Pakistan (15%) and remaining 5-10% produced by Australia, South Africa, and USA. Hence, India is the largest producer and exporter country of GG in the world. Approximately 40% of the world GG supply comes from the Jodhpur GG industries. According to economic survey of Rajasthan (2021-2022), the state singly contributes 78.62% of total India's production. Moreover, Bikaner, Shri Ganganagar, Hanumangarh, Churu, Barmer, Nagaur, Jaiselmer, and Jodhpur are major contributing districts in Rajasthan. Among these districts, Bikaner and Hanumangarh clench first position in terms of area wise production and higher yield/hectare, respectively. According to the export data report from the "Agriculture and Processed Food Product Export Development Authority (APEDA)" GG export increased by 12.42% from 2021 (2,34,871 MT) to 2022 (2,64,058) (9).

Extraction of guar meal and guar gum

Guar meal (GM) and GG are obtained from the seed of *C. tetragonoloba* and at commercial level, GG and GM are extracted by different mechanical processes. In one process, seeds are mainly separated in three parts namely seed coat, germ and endosperm. The innermost component, the embryo and the surrounding endosperm constitute roughly 43 to 47% and 35 to 42%, of the total seed weight, respectively whereas the outermost shell contributes up to 30 to 33 % to seed weight (10). First the germ part is separated from seed by numerous grinding and sieving process followed by dehusking the remaining part. Then separate the husk (hull) and split (galactomannan endosperm), the former component is used as cattle feed along with the isolated germ part. The protein rich husk is called as GM/guar churi/guar korma and split is passed through flacking, drying and milling operations to obtain GG powdered form. The procured powder is further refined by dissolution in water following filtration and alcoholic precipitation, this refined GG is known as extracted clarified GG Fig. 2 (11).Moreover, depending upon the mesh size, colour, hydration rate, and viscosity power, different types of GG are sold in the market(12). GM is actually a byproduct of GG industries. Wang et al (2000) findings suggested that GG formation might be stable under low pH processing conditions, particularly when low heat treatment was used (13). The 'clarified GG' that is easily accessible in the market can be typically standardized by adding sugar (14). The high water absorption capacity of the guar resulted into formation of high viscosity substances which get dispersed.

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The fundamental properties of GG are found to be significantly influenced by temperature like loses water encircling the gum polymer with rise in temperature (14-16).

Phyto-compounds and their pharmacological activities

Leaves, beans and seed of cluster bean contain protein, fibers, sugars, ascorbic acid galactomannans and tannins with different types of acids and alcohols **(17).** Guar meal is a protein rich module containing various essential and non-essential amino acids namely, lysine (1.66%), phenylalanine (1.53%), methionine (0.47%), arginine (4.76%), cysteine (0.52%), lucine (2.29%), glycine (2.11%), threonine (1.16%), isoleucine (1.19%), tryptophan (0.59%), alanine (1.65), valine (1.46%), aspartic acid (3.91%), proline (0.79%), glutamic acid (7.18%), and serine (1.75%)**(18)**. Wang and Morris, (2007) determined the quantity of various flavonoids in several guar seed accessions and found presence of kaempferol (14.460 mg), genistein (0.700 mg), diadzein (1.114 mg), and quercetin (0.553 mg) in good proportion. The polyphenol concentration in seed ranges from 0.69-1.26 %, flavonols (0.05-0.24%), gallotannins (0.5-0.21%), gallic acid (0.12-0.49%) and in leaves varies from 0.75-1.24% of total phenol, 0.25-0.24% hydroxycinnamic acid, and flavonols (0.18-0.84%) **(19)**. Coxon et al (1980) identified a tri-terpenoidal saponin from guar meal whereas the alcoholic extract of guar fruit and its GC-MS analysis revealed the presence of 34 phytochemicals from it **(20,21).** Among the several secondary metabolites reported, the most important one are saponins, contributing the antibacterial, antiprotozoal, and anticancer properties to this medicinal crop **(22).**

Applications of guar and its derivatives in various scientific fields

Pharmacological applications

The use of medicinal plant as a source of biologically active chemicals with therapeutic capabilities for the treatement of various ailments has been recorded over time by a wide range of individuals, *C. tetragonoloba* (L.) Taub is one of them. The various pharmacological activities have been tabulated in Table 1.

Drug delivery

In recent year, natural polysaccharides and their derivatives have become more popular in pharmaceutical formulations and disciplined drug release activities. GG has been utilized in tablet formulations as a binder and dissolving agent, while in liquid formulations it has been utilized as an emulsifier, stabilizer, thickener, and suspending agent (36), so GG is considered safe for oral ingestion. The muco-adhesive and antioxidant properties of GG strongly supported the use of this material for drug delivery (37, 38). However, natural GG is not very useful due to uncontrollable swelling, hydration, viscosity, and being vulnerable to microbial attack. These issues are solved by chemical modification of the functional OH group (8, 39-41,). The different derivatization methods include sulfation (42); carboxy-methylation (43, 44, 45); alkylation (46, 47); esterification (48); etherification; grafting; and cross-linking (8) of the OH group of GG. The different

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methods of chemical modification of GG are summarized in Fig. 3.

GG has been investigated several times as an antihypertensive, anti-cancer, and colon-specific drug delivery agent due to its stability under shear stress conditions (40, 50-52). Verma and Sharma (2021) discovered the various routes of GG based drug delivery, such as oral, transdermal, intravenous, buccal, and gene delivery (53).

Industrial Uses

GG and its derivatives are extremely important in different industries for their numerous applications. In the cosmetic, food, pharmaceutical, and biomedical sectors, many guar gum nanocomposite systems have demonstrated multifunctional features including thickening, emulsifying, fast solubility in water, strong biocompatibility, and biodegradability.

Petroleum industry: GG is used as ingredients in numerous formulations for better oil and gas recovery, fracturing fluids, corrosion inhibition, viscosity improvement, and water demulsification in oil emulsion (54).

Cosmetics: According to the International Cosmetic Ingredient Dictionary and Handbook, these six derivatives of glactomannons from Cyamopsis are used in cosmetics. Glactomannons mostly function as a viscosity improver and skin/hair conditioning agent in cosmetic products (55).

- Hydrolysed GG
- Carboxymethylhydroxypropyl GG
- Hydroxyalkyl hydroxypropyl GG
- Hydroxypropyl GG
- Hydroxypropyltrimonium Chloride GG
- Hydroxypropyl hydroxypropyltrimonium chloride GG

Paper industry: GG help in the overall paper making process. A little volume of GG was applied to break up lump cellulose pulp sludge to create uniform pulp sludge (52) GG replaces the hemicelluloses in sheet with a number of benefits, including good-quality sheet, enhance burst strength, increase thickness, decrease porosity, increase pick, improved finish, and fold strength. Further, in the paper industry, it is used because of its ability to bind and produce films.

Food industry: GG is widely used in the food industry because of its special functional characteristics like softness, improving texture, consistency, decreasing oil uptake, firmness, fat replacer, improving ice crystal size, decreasing serum loss, and improving dough in various food products (4) GG is used in various food products at a suitable level of dose, such Yoghurt 2.0%, pasta 1.5% , baked goods 1.0%, chapatti 0.75%, tomato ketchup 0.5-1.0%, bread 0.5% cake 0.15%, ice cream 0.5, etc (56-63).

Water purification: The paucity of clean water is the biggest issues that world is now facing. Due to the quick growth of industrialization numerous pollutants, including heavy metals (Cd^{+2}, Pb^{+}, Zn^{+2} etc.) dyes (rhodamine B, safranin, fast green and malachite green) and organic pollutant (fungicide, pesticides, and herbicides), are released into water sources without any prior treatment (64). GG and its number of derivatives are used as pollutant adsorbents into water sources (Table 2).

Conclusion

This guar and guar gum review covers the production area, extraction of GM and GG, phyto-compounds, pharmacological, pharmaceutical, and vast industrial applications. Plant have medicinal properties due to their large amounts of phenols and flavonoids. GG innocuous, budget-friendly, and easily available polysaccharides join other components in either functionalized or unmodified forms to create a variety of nanocomposites. Because of the abundance of hydroxyl groups, GG can be extensively functionalized in a variety of ways, resulting in a wide range of innovative and sustainable materials. Instinctive GG derivatives are genuinely used in therapy for various disorders. In medicines, it serves as a stabilizing, binding, emulsifying, and suspending ingredient for conventional dosage forms. Because of its biodegradability and water holding capacity, it can be used in the food, oil, cosmetic, explosive, paper, textile, and paint industries. GG and its derivatives are also used as binders and separators for Li or Na ion batteries.

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Statement of Declarations

Competing Interests

The author declares no conflict of interest. The manuscript has not been submitted for publication in another journal.

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Tables

Table 1: Identified phytochemicals and their pharmacological activities.

S. No.	Plant part	Phytochemical	Pharmacological activity	Description	References
1.	**Pods**	Flavonoid and phenolic compounds	Anti-diabetic	Pod extract (250 mg/Kg) body weight was used to lower blood glucose level in fasting rat therefore, showed hypoglycemic activity and hence can be utilized in type 2 diabetes treatment.	(23-25)
	Pods	Flavonoid and phenolic compounds	Anti-Alzheimer	Pod extract (100 or 200 mg/kg) with 2.5 mg/kg Donepezil (elevates acetylcholine level) administered orally for seven days. This increases acetylcholine level and decreases oxidative stress.	(26)
	Pods	Vitamin-A	Cure against ulcer	The pods extract (500 mg/kg) inhibit gastric acid secration and cure gastric lesions induced by indomethacin, hypothermic stress, pylorus ligation and various nacrotizing agent	(17,27)
	Pods		Antioxidant activity	Fiber-rich guar beans showed gastric and	(28)

				intestinal protecting behavior with respect to enzymatic antioxidant activity (catalase, superoxide dismutase, glutathione-s-transferase, glutathione reductase and GPX). The antioxidant effect were increased when it's complexed with 0.01% capsaicin. In a different study, it was reduced ethanol induced oxidative stress.	
	pods	Fatty acid , alkane and terpene alcohol	Anti-dengue	The supercritical extract of clusterbean inhibit 99.9% dengue-2 virus.	(29)
2.	**Leaves**		Anti-asthmatic	The leaves extract decrease blood leukocyte and eosiniphilia	(30)
3.	**Seeds**	flavonoid and Saponin content	Anti-Inflammatory	Seed of clusterbean was assessed for acute, sub-acute, and neurogenic inflammation. The extract of seed were used in quantity of 50 and 100 mg/kg against xylene induced ear edema and formaldehyde or carrageenan induced paw edema	(31)
	Seeds	Saponin and	Anti-coagulant	The sulfated derivatives of guar	(32,33)

		polyphenols		seed galactomannon is act as thrombin inhibitor	
	Seeds	Saponin	Anti-microbial	GG obtained modified /sulfated polysaccharide show antibacterial activity against bacteria at 200 µg/ml concentration	(34)
	Seeds	Saponin	Hemolytic	Saponin rich GM extract was tested against chicken blood for check hemolytic activity. only 100% MeOH fraction and its 16 minute peak sub fraction reveal Hemolysis	(22)
	Seeds	Saponin	Anti-cancer	The MCF-7 cell line's IC_{50} values of extract was determined to be 13.75 and 12.4 g/ml using the SRB and MTT technique respectively.	(35)

Table 2: Numerous modified GG-based nanocomposites materials (hydrogel adsorbents) for adsorbent and photo-catalytic degradation of various water impurities (65)

S. No.	Nanomaterial	Water pollutant (Dyes/metal ion)	Adsorption capacity (mggGU^{-2}) or Removal efficiency (%)	References
1.	Propanamide/2-acrilamido-2-methayl-1-propanesulphonic acid	Basic violet 1	92.10-96.25 %	(66)

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2.	Silver nanoparticles GG/acrylic acid	Methylene blue	833.33	(67)
3.	GG/ activated carbon nanocomposite	Congo red	831.82	(68)
4.	Galacylhydrazine modified guar gum (GG-GH)	Methylene blue, Methyl orange, Rhodamine B, Bromophenol blue	1522.2 868.83 1359.96 904.7	(69)
5.	Zno nanoparticles GG	Reactive red 195, Rhodamine B	70 72.96	(70)
6.	Aminated guar gum/graphene oxide	Methylene blue, Malachite green, Rhodamine B Cu(II)	90 % 98 % 75% 88 %	(71)
7.	acrylamide-co-sodium acrylate-co-acrylamido sodiumpropanoate GG	Mv Hg(II)	53.28 49.12	(72)
8	Ethyl acrylate GG	Ca(II) Mg(II)	-	(73)

9.	Polysaccharide base semi IPN	Pb (II) Hg(II)	116 86.4	(74)
10.	Salicylhydrazine GG	Ni(II) Co(II) Cr(II)	1272.4 748.86 521.81	(75)
11.	GLF-Bionanocomposites GG	Cr(II)	101	(76)
12.	GG-Nano zinc oxide	Cr(II)	55.56	(77)
13.	GG-polyacrylonitrile copolymer	Pb(II) Cu(II)	125 90.1	(78)
14.	GG grafted polyacrylonitrile template silica xerogel	Pb(II)	2000	(79)
15.	Starch/poly (alginic acid-cl-acrylamide)/Fe/Zn nanocomposite hydrogel	Malachite green fast green mixture	91% 82%	(80,81)
16.	GG- copper oxide nanocomposite	Malachite green	89%	(82)
17.	Fe^{o} @GG-cross-linked-soya lecithin nanocomposite hydrogel	Methyl violet	81%	(83)
18.	Chitosan-GG blend silver nanoparticles	Rhodamine 6 G, Reactive Red-141, Reactive blue-21, Mixture of RB + RH, RB + RR	100%	(84)
19.	GG-alginate@ Ag bionanocomposite	Methylene blue	92.33%	(85)

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20.	Borax-cross-linked GG-manganese dioxide composites	Methylene blue	99% oxidative decolouration	(86)

Figures

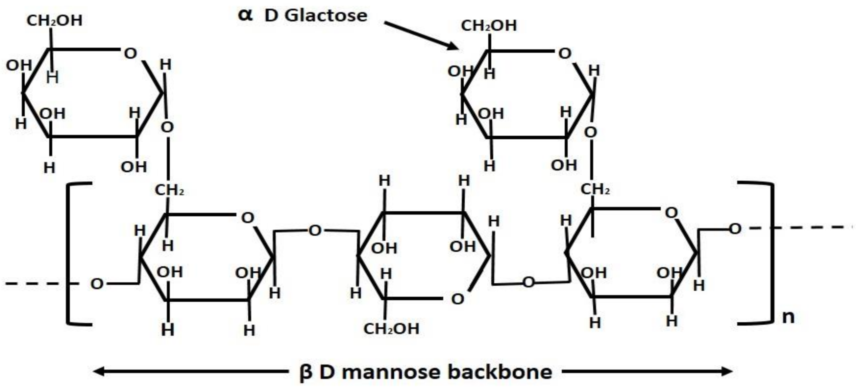

Fig. (1) Structure of guar gum.

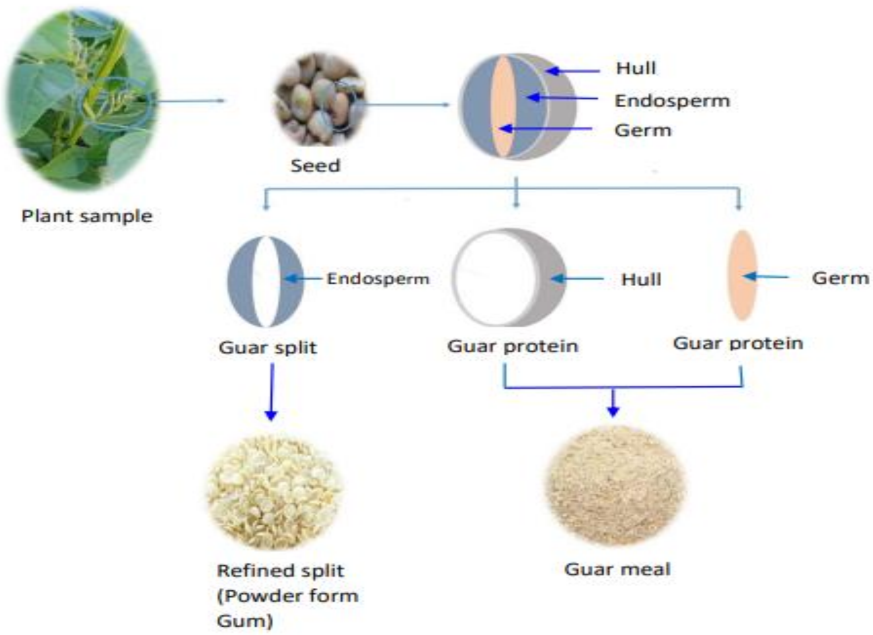

Fig. (2) Diagrammatic procedure of GG and GM extraction

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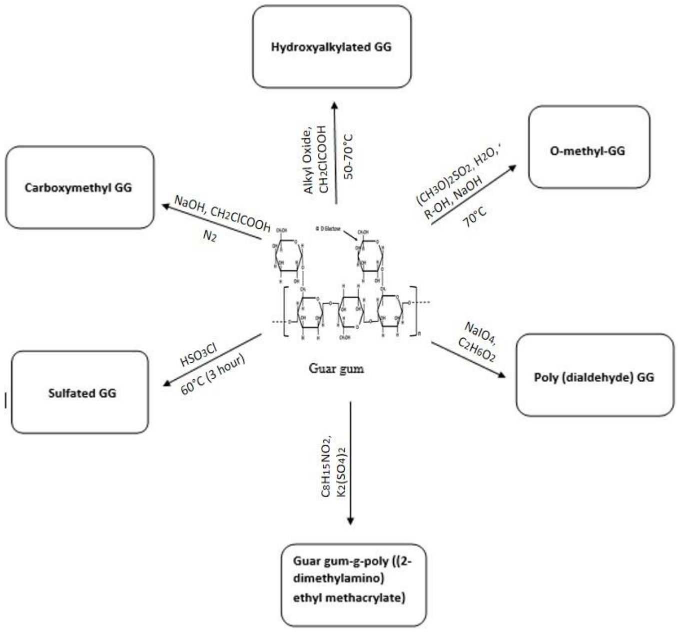

Fig. (3) Different methods of chemical modification of GG.