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April-June 2023

INTERNATIONAL JOURNAL OF MEDICAL, PHARMACEUTICAL AND BIOLOGICAL SCIENCES

eISSN : 2832-787X, pISSN : 2832-7888

Review Article	Volume-3	Issue-1	Article ID: 0050

LOCUST BEAN GUM: A COMPREHENSIVE REVIEW

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Received: 20 April 2023 / Revised: 10 June 2023 / Accepted: 27 June 2023 / Available online: 30 June 2023

ABSTRACT

Locust bean gum (LBG), sourced from the seeds of the carob tree, Ceratonia siliqua, is a versatile polysaccharide highly valued in the food industry for its functional properties. This comprehensive review delves into the chemical composition, functional attributes, and diverse applications of LBG in various food products. Notably, LBG's molecular conformation in aqueous solutions influences its solubility and rheological behaviour, while its synergistic interactions with other biopolymers expand its utility. Moreover, LBG's amenability to modification through derivatization or crosslinking opens avenues for novel applications in biopharmaceutical and industrial sectors. These advancements offer promising prospects, including controlled release and gelling capabilities, as well as potential uses in encapsulation, drug delivery, packaging, and catalysis. Importantly, the biodegradable and non-toxic nature of LBG-based products aligns with sustainability goals, contributing to the development of eco-friendly solutions in line with considerations of raw material sourcing, modification processes, and end-product destinations.

Keywords – Locust Bean Gum, Seeds, Phytochemistry, Applications.

1. INTRODUCTION

Locust bean gum, also known as carob gum, is a natural polysaccharide widely utilized in the food industry for its thickening, stabilizing, and gelling properties. Extracted from the endosperm of carob seeds, locust bean gum primarily consists of galactomannans, with a mannose to galactose ratio typically ranging from 3:1 to 4:1. Its solubility and rheological properties in aqueous solutions are influenced by its molecular conformation. LBG exhibits synergistic interactions with other biopolymers such as xanthan gum and carrageenan. Moreover, this hydrocolloid can be easily modified through derivatization or crosslinking. These modified LBG products find applications beyond the food industry, including as encapsulation and drug delivery systems, packaging materials, batteries, and catalyst supports in various biopharmaceutical and industrial sectors. Given that the new derivatized or crosslinked polymers based on LBG are predominantly biodegradable and non-toxic, their utilization, either alone or in combination with other biopolymers, promotes the development of environmentally friendly products. This approach considers the sustainability of raw materials, the chosen modification methods, and the ultimate disposal of the products.

Locust bean gum (LBG) offers diverse functional properties crucial for various food applications. Firstly, it acts as a thickening and stabilizing agent, enhancing viscosity and preventing phase separation, thereby improving the overall texture of food products.

Secondly, LBG's hydrocolloidal nature enables effective water binding, leading to better moisture retention in food items. Lastly, under specific conditions, LBG can undergo gelation, contributing to the structural integrity and mouthfeel of food products. These versatile properties make LBG a valuable ingredient in the food industry [1].

2. PHYTOCHEMISTRY

LBG is a neutral polysaccharide composed of linear chains of mannose units with attached galactose side groups, which confer upon it thickening, stabilizing, and gelling capabilities [2]. The ratio of mannose to galactose, termed M/G ratio, influences its solubility and properties, with LBG typically exhibiting an M/G ratio of approximately 4:1 [3]. However, variations in cultivar, growth conditions, and manufacturing practices contribute to polydispersity in LBG, affecting its solubility and molecular weight [4]. Solubility of LBG is influenced by the M/G ratio, with higher galactose content enhancing solubility [5]. Despite its hydrophilic nature, LBG displays limited solubility due to aggregation of unsubstituted mannose regions, particularly in cold water [6]. Various studies have reported on solubilization patterns and temperature-dependent solubility of LBG [7]. Derivatization strategies have been explored to enhance solubility, including sulfate, carboxylate, and aminate derivatives [8].

3. APPLICATIONS IN PHARMACEUTICALS, FOOD & HEALTHCARE

i) Superdisintegrant: Orodispersible tablets containing 100 mg of nimesulide were prepared by the direct compression method. The prepared tablets were evaluated against the standard superdisintegrant, i.e., crosscarmellose sodium. Disintegration time of tablets containing 10 % locust bean gum was found to be 13 seconds [9].

ii) Thickener: Locust bean gum is widely used in dairy products, including ice cream, ketchup, fruit juices, and pudding powder [10].

iii) Oral Controlled Delivery: Metoprolol tartrate granules were prepared using different ratios of drug: gum. The ratio of 1:2 Drug: Gum was most similar to Meto-ER as the reference standard [11]. iv) As a Coating Agent: Locust bean gum was used in coating to reduce moisture loss in sausage and garlic-flavored sausage [12].

v) Binder: The Atorvastatin calcium spheroids were formulated using 1% w/w locust bean gum suspension. Locust bean gum can be used as an alternative binder with a 1% w/w concentration to produce spheroids better physico-mechanical properties and promising drug dissolution profile [13]. vi) Stabilizer: Strong stabilizer is used at 0.1–0.2% levels in ice creams [14].

vii) Food Applications:

- Edible films/coating: Locust bean gum has been used to form edible films/coatings due to its edibility and biodegradability, reducing the negative effects of minimal processing on fresh-cut fruits.

- Beverages: Locust bean gum solutions are stable over a wide range of pH, making it a unique stabilizer and thickener in most beverages.

- Bakery Products: The addition of locust bean gum to wheat flour suspension improves the pasting temperature and increases viscosity, water absorption capacity, and dough development time of wheat flour dough.

- Noodles: Incorporation of locust bean gum in noodles dough improves the dough rheology and textural characteristics of cooked noodles.

- Ice Cream: Locust bean gum, alone or in combination with guar gum, is used in frozen dairy products for desired textural properties such as viscosity enhancement and ice recrystallization inhibition [15].

viii) Health Benefits:

- In Diabetes: Locust bean gum can alter the rate of carbohydrate degradation during digestion, likely to have beneficial effects on postprandial blood sugar and insulin levels [16].
- In Cardiovascular Disease: Recent studies on gums as dietary fiber reported their protective effect on cardiovascular disease.
- Incorporation of gums such as guar gum and locust bean gum as dietary fiber in the diet can be beneficial in reducing inflammation and inflammatory bowel diseases, Crohn's disease, and ulcerative colitis [17].

4. BIOPHARMACEUTICAL APPLICATIONS

In recent decades, polysaccharides have emerged as promising materials in the biopharmaceutical field due to their diverse functionalities and biocompatibility. Locust bean gum, as a member of the galactomannan group, possesses appealing characteristics for biopharmaceutical applications, particularly its high gelling capacity. In controlled release systems, locust bean gum has demonstrated potential as a matrix material, enabling the delivery of drugs at predetermined rates to targeted biological sites [18, 19]. Furthermore, its physicochemical properties and compatibility with other biomaterials have facilitated the development of synergistic formulations with enhanced performance and efficacy. Moreover, the biodegradability of locust bean gum offers opportunities for its use in in vivo applications, where controlled degradation is desirable to minimize tissue irritation and promote tissue regeneration [20].

5. EXTRACTION

The extraction of LBG can proceed following different methods. First, the removal of the seeds from the pod must be performed mechanically. After that, to eliminate the hull, diverse procedures are available, such as roasting, acid extraction, water extraction, mechanical processes, or by swelling and freezing. The endosperm is then milled and pulverized under different conditions to remove the remaining husk. The endosperm is a mixture of polysaccharides, proteins, and other impurities, which necessitates a purification step, and this can be performed by precipitation coupled with dialysis. After dissolving the powder in water, the addition of an alcohol such as ethanol, methanol, or isopropanol; a copper complex or a barium-complex produces the precipitation of the galactomannan. Azero et al. studied different purification techniques and their impact on the physicochemical properties of the formed gum, and they showed better inter- and intramolecular associations for LBG for the one filtered over the centrifuged product. Isopropanol decreases the content of ashes and proteins and produces a more stable solution due to the elimination of enzymes and impurities. Dakia et al. compared two types of processes: the first one using water, removing the different seed layers by letting the seed swell in boiling water, and the germ removed after drying the seed; the second one by an acidic extraction. The seed is macerated in H_2SO_4/H_2O 60/40 (v/v) at 60 °C for 1 h. The carbonized hull is removed by washing for 2 min with a metallic sieve. After drying the seeds, they are crushed to release and remove the germ. Both procedures mill and sift the endosperm using the same conditions. Some physicochemical differences arise between the LBGs coming from the two processes: acid extraction produces better thickening properties, while water extraction is responsible for a higher solubility at high temperatures, for example [21-32].

6. LBG DERIVATIVES

6.1 Modifications of Functional Groups

Galactomannan polysaccharides, including LBG, are easily derivatized through chemical reactions involving sulfation, carboxylation, or acetylation. While these derivatization processes typically involve the use of hazardous chemicals and solvents, they yield non-toxic and biodegradable matrices. Braz et al. explored various modifications of LBG, including sulfation using SO_3DMF, resulting in modified polysaccharides suitable for forming solid spherical beads when mixed with chitosan, offering promise for antigen delivery. Carboxylation of LBG, achievable through reactions with TEMPO and NaBr, as well as grafting of quaternary ammonium salts using GTMA and HCl, have also been reported. Complexes formed with these modified LBG materials and reverse-charged polysaccharides show potential for drug delivery applications. Additionally, LBG can be carboxymethylated using monochloroacetic acid, yielding an efficient drug delivery matrix with a good degree of substitution, albeit with decreased viscosity and molar mass. This carboxymethylated LBG (CMLBG) has been deemed safe for internal use and can be utilized in controlled oral drug delivery systems, either alone or in combination with other materials such as alginate. Furthermore, LBG derivatives have been prepared by incorporating inorganic components such as palladium or gold nanoparticles, offering applications in catalysis and sensing, respectively. Grafting of polyacrylamide, methyl acrylate, acrylic acid, and polyethyleneimines onto LBG has also been achieved through various chemical reactions, expanding its utility in drug delivery and textile applications. Lastly, LBG-based superabsorbent polymers have been developed through network structures formed via irradiation, offering potential applications in absorbent materials [33-45].

6.2 Crosslinking Reactions

Glutaraldehyde has been identified as a potential crosslinker for LBG, either alone or in combination with chitosan, enabling the formation of matrices suitable for drug delivery applications with sustained release properties. Citric acid has also been investigated as a crosslinker for LBG, facilitating solventless reactions with basic catalysts to produce crosslinked networks exhibiting remarkable swelling behavior and dye sorption capabilities. Functionalization of these networks with β-cyclodextrin enhances specific interactions between sorbates and LBG, while the addition of lignin further increases sorption capacity. Another crosslinking method involves UV curing of swollen LBG with citric acid and an acidic catalyst, resulting in the formation of crosslinked products suitable for various applications. The protonation of hydroxyl groups during this process indicates crosslinking primarily occurs at the C6 carbon site of mannose and galactose residues. Additionally, studies have explored the disintegration behavior of tablets produced from these crosslinked materials [46-54].

7. CONCLUSION

Locust bean gum stands as a versatile and valuable ingredient in both the food and biopharmaceutical industries, offering functional benefits such as thickening, stabilizing, and controlled release. Its natural origin, diverse applications, and potential health benefits underscore its significance in food manufacturing and drug delivery systems. However, further research is warranted to explore its functional properties, optimize its applications, and ensure regulatory compliance in both sectors.

In conclusion, locust bean gum (LBG) stands out among galactomannans due to its high mannose-to-galactose ratio and minimally branched structure, requiring heat for full hydration. While LBG does not gel independently, it forms gels when combined with other hydrocolloids, making it an effective stabilizer and thickening agent in the food industry. Classified as a soluble fiber, LBG offers non-digestible properties further enhancing its utility in various food applications. Beyond its traditional use in food, recent exploration has focused on producing environmentally friendly matrices using LBG, either alone or in combination with derivatives. These materials, created through physical entanglements or chemical crosslinking reactions, find applications in diverse fields such as packaging, biopharmaceutical devices, batteries, and catalysts. Despite its excellent properties, the relatively low production volume of LBG, coupled with increasing demand, has led to market shortages. Given the lengthy cultivation period of carob trees, meeting growing demand solely through tree planting is not feasible. Consequently, alternative hydrocolloids are being explored as replacements for LBG, often used in combination to meet industry needs. This raises questions about the satisfaction level of these substitutes and the potential for LBG to be reserved for more specialized applications. This review underscores two key characteristics of LBG: its synergistic interactions with other biobased polymers, expanding its application range, and the potential for derivatization and crosslinking to explore new possibilities. Such advancements hold promise for unlocking the full potential of locust bean gum across various sectors.

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