__Minireview Article__

UNVEILING THE POTENTIAL OF GUAR GUM IN FOOD APPLICATIONS

Abstract

The multifaceted versatility of guar gum, derived from the cluster bean (*Cyamopsis tetragonoloba)*. Beginning with an overview of cluster bean production's agricultural significance and its sensitivity to environmental factors, the study delves into the chemical and physical properties of guar gum. Emphasis is placed on its molecular composition, solubility, viscosity, gelation and thickening capabilities, detailing the factors influencing these properties. The discussion extends to pH stability, interactions with salt and sugar and methods for molecular weight modification. Furthermore, the study examines guar gum's wide-ranging applications across industries, particularly in food, elucidating its role in dairy, processed meats and bakery products. Through a comprehensive analysis, this study offers insights into the diverse uses and importance of guar gum, highlighting its integral role in various fields and its potential for further exploration and innovation.

Key words: Cluster bean, Guar gum, Properties, Food application.

Introduction

Cluster bean *Cyamopsis tetragonoloba* (L.) is an annual legume crop mostly grown under resource constrained conditions in arid and semi-arid regions (Kumar, 2005). Cluster bean is a deep-rooted plant of Leguminosae (Fabaceae) family known for drought and high temperature tolerance (Kumar and Rodge, 2012). Sowing time and planting geometry play an important role in the production of cluster bean (Punia et al., 2009b). Sowing time affects the whole plant growth cycle (Luqman et al., 2020), including seed germination, seedling emergence, vegetative plant growth, flowering, pod formation, grain filling, and crop maturity. When crop is sown early, plants make its vegetative phase prolonged compared to reproductive phase depending upon atmospheric temperature and rainfall of area (Ayaz et al., 2004). But when the crop is sown late, flowering comes earlier and plants could not complete their normal vegetative phase (Ali et al., 2004). The increase in temperature accelerates the phenological cycle of plants (Laghari et al., 2021), leading to a decline in crop yield of crop (Zimmermann et al., 2017).

Therefore, cluster bean production is directly related to the annual rainfall, temperature and humidity of area (Meena et al., 2014). Sowing time plays a vital role in increasing or decreasing crop yield (Meena and Meena, 2015). It is also grown in Gujarat, Haryana and Punjab for guar gum and in some parts of Uttar Pradesh and Madhya Pradesh for vegetable purpose and is also gaining importance in Maharashtra, Chhattisgarh and southern states like Karnataka, Tamil Nadu and Andhra Pradesh due to its diversified uses and economic returns. The crop has low input requirement and grows well in sandy soils with moderate and intermittent rainfall both as sole and intercrops with pearl millet/moth bean/sesame. Since, it is a leguminous crop, it improves soil health through symbiotic nitrogen fixation and is also grown as a green manure and cover crop. Being consumed as a vegetable and cattle feed, thus, a valuable source of nutrition to humans and animals [19,20].

Guar gum has diversified industrial usages such as food (bakery, processed cheese, pastry ices, noodles, meat, dressing and sauces and beverages), textile, oil and well drilling, mining, construction, explosives, paper, cosmetics and pharmaceuticals (Vikaspedia 2022). Cluster bean pods are used as a vegetable. Galactomannans is a polysaccharide that is extracted from guar and known as guar gum (Sabahelkheir et al., 2012). Grain of cluster bean is made of germ (41–46%), endosperm (34–43%) and hull (13–18%) (Srivastava et al., 2011). In India, Rajasthan is the major cluster bean producing state followed by Haryana, Gujarat, Uttar Pradesh, Punjab and Madhya Pradesh (USDA, 2014). Based on 2011-12 statistics, Rajasthan and Haryana together contribute about 95% of the total cluster bean production in India.

Properties of gum

Cluster bean gum consists of long, -D-mannopyranosyl units linked togetherαstraight chains of -D-galactopyranose, isα4) glycosidic linkage. →-D (1βby an hexose that forms the side groups (Stephen, 1983). The ratio of mannose to galactose in galactomannan of cluster bean gum is approximately 2:1 (Robinson et al., 1982; Englyst and Cummings, 1988). Owing to the difficulty in determination of the single/exact molecular weight, its range is estimated to be 200,000 to 300,000 daltons (Glicksman, 1969). Galactomannan acts as a good water binder due to the binding of water molecules in the active sites of Dgalactopyranose and D-mannopyranose. Ability to form viscous dispersions or solutions in water is the most important characteristic of cluster bean gum powder. Viscosity of the guar gum powder varies with the particle size, and moisture.

Physical properties of guar gum

GG is obtained from the endosperm of the guar seed *Cyamopsis tetragonolobus* and *Cyamopsis psoraloides*, family *Leguminosae*, which was separated from the hull and germ and then ground into different particle sizes (Bogdanova Popov et al., [2017]; Dehghani Soltani et al., 2021) Endosperm, germ, and hull comprise 45%, 40%, and 15% of the seed, respectively (Feiner, 2006; Maier et al., 1993). To obtain endosperm from guar seeds, the seeds must be entered into two-level mills. The seeds coming out of the mill still have the hull and germ, so the endosperm is heated to soften the shell, and the endosperm is re-entered into the mill to remove the hull and the germ completely.

Next, the endosperm is powdered. The outer hull and germ, which is a meal, are used as animal feed (Kapoor et al., 2013). This gum is white and light grayish. Guar is a high-weight polymer soluble in water; its weight is reported to be 22,000 Daltons (Feiner, 2006, Maier et al., 1993). The thermal resistance of guar gum is between 80 and 95°C (Feiner, 2006, Maier et al., 1993). Guar is widely used in the food industry, it also emulsifies, and bind water to prevent ice crystal in a frozen product and postpone many liquid-solid systems. Also, various types of research have shown that this gum reduces blood cholesterol and controls obesity and type 2 diabetes (Dehghani Soltani et al., 2021).

Solubility

Guar gum dissolves in polar solutions such as water, hydrazine, formamide, ethylene diamine, and liquid ammonia. Various factors, such as increasing temperature and decreasing pH and particle size, increase the solubility of guar in water, while the presence of salt and sugar decreases solubility (Maier et al., 1993). The rate of hydration depends on the concentration of galactomannan; therefore, the concentration (0.5%–1.2% w/v) of the hydration rate accelerated with the increase in the concentration of galactomannan, but at concentrations higher than 1.2% w/v, the rate of hydration also decreased; particle size and its distribution are important factors in guar hydration rate (Wang et al., 2003).

Viscosity

The viscosity of a substance is the internal resistance of its different parts against jerking and displacement, and this quality depends on the molecular dimensions of the dissolved solids in the system. Studying the viscosity of a solution can provide useful information about the size, shape, and distance of molecules. The resistance between the different layers of a liquid or semi-liquid system in the flow is obtained due to the Brownian motion of the molecules in the inner layers. This important physical property depends on various factors, such as the size and number of macromolecules in the fluid structure. Gums have the ability to make products with high viscosity in low concentration and hence are used in various food industries.

Gelation

One of the most important properties of guar is gel formation. The gel is an intermediary between solid and liquid, which has both solid (elastic) and liquid (flow) properties. Gelation is a phenomenon that involves the cross-linking of polymer chains to form a three-dimensional network that traps water within it to form a rigid structure that resists flow stresses under pressure and maintains its structure. Hydrocolloids form gels through hydrogen bonds, cation-based cross-links, and hydrophobic bonds. The gel formed by guar depends on factors such as temperature, pH, and concentration of guar. The optimal pH range for gel formation is 7.5–105. Various compounds, including borate and transition metal ions, increase cross-links with guar gum and increase gelling power, viscosity, and resistance at high temperatures (Maier et al., 1993).

Thickening

One of the essential characteristics of hydrocolloids is thickening, which has led to their use in various food industries, including sauces, jams, etc. This process occurs due to the interweaving of hydrocolloid polymer chains with a solvent higher than the critical concentration. At critical concentrations, the molecules have less mobility and join together, creating an interwoven network and forming the thickening process. This feature depends on various factors such as polymer type, charge density, environmental conditions (temperature and humidity), and type of food system (Mahmood et al., 2017). Due to its hydroxyl groups, GG tends to form hydrogen bonds with water, which can be used as a stabilizer and thickener.

pH

Guar gum is stable in a wide range of pH due to its neutral structure. The highest water absorption occurs in the 8–9, and the lowest water absorption occurs at a pH >10 and <4. At pH <3, glycosidic structures of guar are destroyed, and the viscosity decreases rapidly (Maier et al., 1993). According to research, the lowest viscosity rate occurs at pH 3.5, while at pH 6 and 9, the highest viscosity rate is observed in GG (Zhang et al., 2005).

Salt and sugar

The rheology of GG is very variable, and the effect of salt and sugar on its rheology depends on various factors such as the type and concentration of gum, solution pH, temperature, and other additives. Sugar has positive and negative impacts on the rheology of GG. The addition of sugar enhances the water-holding capacity of guar gum by forming many hydrogen bonds, hence facilitating an increase in viscosity and consistency. On the other hand, sugar makes a stronger bond with gurami and increases the resistance of the solution against the flow.

Chemical properties

Guar gum, a galactomannan, is a polymer consisting of two monosaccharide units, mannose and galactose, called galactomannan. The structural units of guar gum include galactopyranosyl and mannopyranosyl. Its structure consists of two D-mannose units, $\beta 1 \rightarrow 4$ linked to the D-galactose unit $\alpha 1 \rightarrow 6$ linked to every second mannose unit. The ratio of galactose to D-mannose is 1:2 (Srinivasan, 2020). The presence of hydroxyl groups and its tendency to establish hydrogen bonds have used this gum in various industries. The interaction of galactose and mannose units with water molecules increases the viscosity of the solution (Dehghani Soltani et al., 2021). Production of high-viscosity soluble gum can limit the use of this gum in the food industry so that it can cause molecular weight loss, molecular chain, and viscosity by various methods, including heat, alkali, ultrasonic, acid, and enzyme. In the meantime, acid and enzyme methods are used because of their simplicity and the acquisition of guar with any molecular weight (Li et al., 2018).

Food application

In food industry, guar gum is used as a novel food additive in various food products for food stabilization and as fiber source (Morris 2010). It is liked by both manufacturer and consumer because it is economical as well as natural additive. It is used in variety of foods as an additive because it changes the behaviour of water present as a common component in various foods. Permissible use levels and limitations in various products are covered under Title 21 CFR 184.1339, affirming guar's "generally recognized as safe" (GRAS) status.

Dairy products

Main purpose of using guar gum in frozen products is stabilization. Guar gum has important role in ice cream stabilization because of its water binding properties. Its use in high temperature short time (HTST) processes is very favorable because such processes require hydrocolloids that can fully hydrate in a short processing time. According to McKiernan (1957) locust bean gum has all the properties of an ideal gum but it hydrates slowly which is not favorable in HTST process. Julien (1953) obtained satisfactory results with guar as stabilizer in continuous ice cream processing. Guar gum should be used in ice cream mix at a concentration level of 0.3% (Goldstein & Alter 1959a, b). It was also used in combination with carrageenan in a mixed guar-carrageenan system developed for HTST process. Like locust bean gum its performance can be improved when used in combination with other stabilizers (Weinstein 1958). Guar gum in ice cream improves the body, texture, chewiness and heat shock resistance. Partially hydrolyzed guar gum (at 2–6% concentration level) decreases syneresis and improves the textural and rheological properties of low-fat yoghurt comparable with full-fat yoghurt (Brennan and Tudorica 2008).

Processed meat products

Guar gum has strong water holding capacity in both hot and cold water. Hence, it is very effectively used as a binder and lubricant in the manufacturing of sausage products and stuffed meat products. It performs specific functions in processed meat products like syneresis control, prevention of fat migration during storage, viscosity control of liquid phase during processing and cooling and control of accumulation of the water in the can during storage. Guar gum also enhances the creaming stability and control rheology of emulsion prepared by egg yolk (Ercelebi and Ibanoglu 2010)

Bakery products

Addition of guar gum in cake and biscuit dough improves the machinability of the dough that is easily removed from the mold and can be easily sliced without crumbling. At 1% addition of in batter of doughnuts, it gives desirable binding and film-forming properties that decreases the penetration of fats and oils. Guar gum in combination with starch is found to be effective in prevention of dehydration, shrinking and cracking of frozen-pie fillings (Werbin 1950). In wheat bread dough, addition of guar gum results in significant increase in loaf volume on baking (Cawley 1964). Guar gum along with xanthan gum retard staling in gluten-free rice cakes by decreasing the weight loss and retrogradation enthalpy (Sumnu et al. 2010). Similarly, guar gum also retards staling in chapati at room temperature as well as refrigerated temperature by controlling retrogradation of starch (Shaikh et al. 2008).

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Reference

1. Anita Punia, arakesh Yadav, Pooja Aroea & Ashok chaudhury, 2009. Molecular morphological characterization of superior cluster bean (*cymposis tetragonoloba*) varities. Journal of crop science and biotechnology. Vol 12, 143 – 148
2. Eldaw, G.E., 1998. A study of guar seed and guar gum properties (Cyamopsis tetragonolabous). ETDE Web.
3. Heyne, E., & Whistler, R. L. (1948). Chemical composition and properties of guar polysaccharides1, 2. *Journal of the American Chemical Society*, *70*(6), 2249-2252.
4. Kumar H, J.C. Radha, C. Ranganathaiah, Siddaramaiah, 2007. Physio-mechanical and free volume behaviour of guar gum filled polyurethane/ polyacrylonitrile biodegradable composites. European polymer journal. Vol 43: 1580 – 1587
5. Kumar, D., & Rodge, A. B. (2012). Status, scope and strategies of arid legumes research in India-A review. *Journal of food legumes*, *25*(4), 255-272.
6. McCleary, B. V., & Prosky, L. (Eds.), 2001. *Advanced dietary fibre technology*. Oxford: Blackwell Science. Vol :63-76
7. Meena, H. N., Debarati Bhaduri, R. S. Yadav, N. K. Jain, and M. D. Meena. "Agronomic performance and nutrient accumulation behaviour in groundnut-cluster bean cropping system as influenced by irrigation water salinity." *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences* 87 (2017): 31-37.
8. Muhammad Luqman Hasan, Nur Afiqah Zainol Abidin, Alvinderpal Singh, 2018. The rheological performance od uar gum nd castor oil as additives in water beased drilling fluid. Science direct. Vol 5, 21810 – 21817
9. Muhammad Salman Farid, Rameesha Anjum, Sehar Anwar, Nawal Saeed, 2021. Role of active food packaging developed from microencapsulated bioactive ingredients in quality and shelf life enhancement. Journal of American science. Vol 17 (2): 12 – 28
10. Praveen Kumar Srivastava, Mukesh Kapoor, 2015. Recombinant GH – 26 endo-mannanase from bacillus sp. CFR 1601: Biochemical characterization and application in preparation of partially hydrolysed guar gum. Science direct. Vol 64: 809 – 816
11. Ranjit Singh, Himani Priya, Simmi Ranjan Kumar, Dipika Trivedi, Niranjana Prasad, Faraz Ahamad, Jeevitha Gada Chengaiyan, Shaffiuk Haque and Sandeep Singh Rana, 2024. Gum Ghatti: A comprehensive review on production, processing, remarkable properties, and diverse applications. ACS publication. Vol 9: 9974 – 9990
12. Robinson, Geoffrey, Simon B. Ross-Murphy, and Edwin R. Morris. "Viscosity-molecular weight relationships, intrinsic chain flexibility, and dynamic solution properties of guar galactomannan." *Carbohydrate Research* 107, no. 1 (1982): 17-32.
13. Sabahelkheir Murwan K, Abdalla Abdelwaha H and Nouri Sulafa H, 2012. Quality assessment of guar gum (endosperm) of guar (*cymposis tetragonoloba*). ISCA journal of biological sciences. Vol 1(1): 67 – 70.
14. Stephen, A. M. 1983. "Other plant polysaccharides." In *The polysaccharides*. Academic Press. 97-193
15. Tahmouzi, Sima, Heidar Meftahizadeh, Saba Eyshi, Amin Mahmoudzadeh, Behnam Alizadeh, Neda Mollakhalili-Meybodi, and Mehrnaz Hatami. "Application of guar (Cyamopsis tetragonoloba L.) gum in food technologies: A review of properties and mechanisms of action." *Food Science & Nutrition* 11, no. 9 (2023): 4869-4897.

16. Tobacman J.K, R.B Wallace, M.B Zimmerman, 2001. Consumption of carrageenan and other water soluble polymers used as food additives and incidence of mammary carcinoma. Vol 56, 589 – 598
17. Wang, Q., Ellis, P. R., & Ross-Murphy, S. B. (2006). Dissolution kinetics of guar gum powders—III. Effect of particle size. *Carbohydrate Polymers, 64*(2), 239-246.
18. Wang, T., Bae, M., Lee, J.-Y., & Luo, Y. (2018). Solid lipid-polymer hybrid nanoparticles prepared with natural biomaterials: A new platform for oral delivery of lipophilic bioactives. *Food Hydrocolloids*, 84, 581–592.
19. Sharma G, Sharma S, Kumar A, Ala'a H, Naushad M, Ghfar AA, Mola GT, Stadler FJ. Guar gum and its composites as potential materials for diverse applications: A review. Carbohydrate polymers. 2018 Nov 1;199:534-45.
20. Gupta S, Variyar PS. Guar gum: a versatile polymer for the food industry. InBiopolymers for food design 2018 Jan 1 (pp. 383-407). Academic Press.