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Unveiling the Potential of Guar Gum in Food Applications

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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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.

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1. INTRODUCTION

Cluster bean *Cyamopsis tetragonoloba* (L.) is an annual legume crop mostly grown in arid and semi-arid regions under resource constrained conditions (Kumar, 2005). It is a deep-rooted plant known for high temperature and drought tolerance vegetable crop belongs to Leguminosae (Fabaceae) family (Kumar and Rodge, 2012). Time of sowing and arrangement of plants in rows and columns to make efficient use of natural resources like light, water, nutrients and space play an important role in cluster bean production (Punia et al., 2009b) as well as influence the plant growth cycle of cluster bean (Luqman et al., 2020) including seed germination, seedling emergence, vegetative plant growth, flowering, pod formation, grain filling and crop maturity. When the crop is sown early, the vegetative phase of the plants is prolonged compared to the reproductive phase depending on the atmospheric temperature and rainfall of the region (Ayaz et al., 2004). But when cluster bean seeds are sown late in the season, flowering occurs earlier and the plants cannot complete their normal vegetative phase (Ali et al., 2004). Increased temperatures stimulate the phenological cycle of plants (Laghari et al., 2021), leading to reduced crop yields (Zimmermann et al., 2017).

“The factors like annual rainfall, temperature and humidity of area are directly related to the cluster bean production” (Meena et al., 2014). “Sowing timing is an important factor in determining the yield of crops” (Meena and Meena, 2015). It is also cultivated for guar gum in Gujarat, Haryana and Punjab and for vegetable purposes in parts of Uttar Pradesh and Madhya Pradesh. The plant is also gaining importance in Maharashtra, Chhattisgarh and southern states like Karnataka, Tamil Nadu and Andhra Pradesh due to its diverse uses and economic benefits. The crop requires minimal input and thrives in sandy soils with moderate to intermittent rainfall, both as a sole crop and as an intercrop with pearl millet and sesame. Since it is a leguminous crop, it enhances soil health through symbiotic nitrogen fixation while being used 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.

Guar gum has a wide range of industrial applications, including food (bakery, processed cheese, pastry ices, noodles, meat, dressing and sauces, and beverages), textiles, oil and well drilling, mining, construction, explosives, paper, cosmetics and medicines (Vikaspedia 2022).

“Cluster bean pods are used as a vegetable. Galactomannans or guar gum, is a polysaccharide derived from guar” (Sabahelkheir et al., 2012). Cluster bean grain consists of germ (41-46%), endosperm (34-43%) and hull (13-18%) (Srivastava et al., 2011). In India, Rajasthan is the main cluster bean growing 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.

1.1 Properties of Gum

“Cluster bean gum consists of long, -D-mannopyranosyl units linked together the straight chains of -D-galactopyranose, is 4 glycosidic linkage” (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 D galactopyranose 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.

1.2 Physical Properties of Guar Gum

GG is obtained from the endosperm of the cluster bean seed *Cyamopsis tetragonolobus* and *Cyamopsis psoraloides*, family *Leguminosae*. It is separated from the hull and germ, which are then crushed into particles of different sizes (Bogdanova, Popov et al., 2017: Dehgani Soltani et al., 2021). The endosperm, embryo and shell constitute 45%, 40% and 15% of the seed, respectively (Feiner, 2006: Mayer et al., 1993). To obtain endosperm from guar seeds, the seeds must be placed in a two-stage mill. As the seeds come out of the mill still have the shell and embryo attached, the endosperm is heated to soften the shell and then reintroduced into the mill to completely remove the shell and embryo.

Next, the endosperm is powdered. The outer hull and germ are used as animal feed (Kapoor et al., 2013). The gum is white with a light grayish color and is a water-soluble, high-density polymer. Its mass is 22,000 Daltons and the heat resistance of guar gum is 80-95°C (Feiner, 2006, Maier et al., 1993). “Guar is widely used in the food industry, as 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, controls obesity and type 2 diabetes” (Dehghani Soltani et al., 2021).

1.3 Solubility

Guar gum soluble in polar solutions, including liquid ammonia, ethylene diamine, formamide, hydrazine and water. Guar's solubility in water is increased by a number of conditions, including rising temperatures, falling pH and reducing particle size; whereas, solubility is decreased by the presence of salt and sugar. (Maier et al., 1993). The concentration of galactomannan determines the rate of hydration; therefore, the concentration of the hydration rate (0.5%–1.2% w/v) increased as the concentration of galactomannan increased, but the rate of hydration also decreased at concentrations greater than 1.2% w/v. Particle size and distribution play a significant role in the guar hydration rate. (Wang et al., 2003).

1.4 Viscosity

The molecular size of the dissolved particles in the process determines a substance's viscosity, which is the internal resistance of its various components against jerks and displacement. Determining a solution's viscosity can reveal important details about the size, shape, and separation of molecules. The Brownian motion of the molecules in the inner layers of a liquid or semi-liquid system in the flow determines the resistance between the various layers. The size of the grain and number of macromolecules in the fluid structure are some of factors responsible for deciding the physical properties. Guar gums are used in a variety of food industries due to their ability to produce highly viscous products at low concentrations. Guar gum has a unique structure that, at high quantities, causes water to bind and increases viscosity. Because guar gum performs well at high concentrations and forms more structural bonds, its concentration increased until level group 3 produced cheese with a firm texture (Shendi EG. 2017).

1.5 Gelation

Gel formation is one of guar's essential characteristics. With both solid (elastic) and liquid (flow) qualities, the gel acts as a bridge between the two. Gelation is a phenomenon in which polymer chains crosslink to form a three-dimensional network that holds water within it, forming a rigid structure that can withstand water pressure under pressure and maintain that structure. Hydrocolloids utilize hydrophobic bonds, cation-based cross-links and hydrogen bonds to form gels. Temperature, pH, and guar concentration all impact the gel which guar forms. The optimal pH range for gel formation is 7.5–105. Numerous compounds, such as borate and transition metal ions, strengthen the cross-links with guar gum and improve its resilience, gelling power and consistency at high temperatures. (Maier et al., 1993).

1.6 pH and Thickening

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. When the pH value goes to less than three, the structure of glycosidic will be destroyed in guar and the viscosity will be decreased rapidly (Maier et al., 1993). According to research, the lowest viscosity rate occurs at pH 3.5 and the highest viscosity rate is observed between pH 6 to pH in Guar Gum (Zhang et al., 2005).

Since thickening is one of hydrocolloids' primary properties, they are used in various kinds of food industry sectors, such as sauces, jams, and more. The interweaving of hydrocolloid polymer chains with a solvent over the critical concentration is what causes this reaction. The thickening process is formed when molecules with less mobility join to create an interwoven network at critical concentrations. The type of polymer, charge density, temperature, humidity and food system type are some of the variables that influence this property. (Mahmood et al., 2017). GG has a tendency to form hydrogen bonds with water due to its hydroxyl groups and can be used as a stabilizer and thickener.

1.7 Salt and Sugar

The rheology of GG is very diverse, the important factors such as type, concentration of gum, solution pH, temperature and other additives will be responsible for the effect of salt and sugar on its rheology of guar gum. 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. The most often used stabilizers in the dairy sector to enhance the viscosity and appearance of products are hydrocolloids. Hydrocolloids are frequently used at concentrations between 0.1 and 0.5% and they have no direct effect on the taste or odor components of flavor (Ioanna and Gregory. 1990). Since the viscosity of guar gum solutions isn't changed by the acid levels present in fermented milk products, guar gum, a form of hydrocolloid is typically employed as a stabilizer for acidified milk products (Bassett, H. J. 1983 & Francis, P. S. 1961).

1.8 Chemical Properties

Guar gum, referred to as galactomannan, is a kind of polymer made up of two monosaccharide units: galactose and mannose. Guar gum's structural components are mannopyranosyl and galactopyranosyl. Two D-mannose units, β1−4 connected to the D-galactose unit, and α1−6 connected to each other mannose unit make up its structure. Galactose to D-mannose has a 1:2 ratio. (Srinivasan, 2020). This gum has been employed in a variety of sectors due to its hydroxyl groups and propensity to form hydrogen bonds. The solution becomes more viscous when galactose and mannose units mix with water molecules (Dehghani Soltani et al., 2021). The production of high-viscosity soluble gum can restrict its usage in the food business by causing viscosity, molecular weight loss, and molecular chain disruption by a variety of techniques, such as heat, alkali, ultrasonic, acid and enzyme. Since they are easy to utilize and can get guar with any molecular weight, the acid and enzyme techniques are employed in the interim. (Li et al., 2018).

1.9 Food Application

Guar gum is a unique food additive used in the food industry to stabilize food and provide fiber in a variety of food products (Morris 2010). Although it is a natural and affordable ingredient, both manufacturers and consumers prefer it. Because it alters the behaviour of water, an important component in many foods, it is utilized as an addition in a wide range of dishes. Guar gum, up to 0.75 g per kilogram of skim milk, can be used as a fat substitute to improve the texture and rheological qualities of Iranian White Cheese while lowering its energy level (Shendi EG, 2017). Guar's "generally recognized as safe" (GRAS) designation is upheld by Title 21 CFR 184.1339, which addresses permissible use levels and limitations in multiple goods. Guar gum significantly improves the texture of tomato ketchup compared to other hydrocolloids such as carboxymethyl cellulose, sodium alginate, gum acacia, and pectin. The incorporation of guar gum results in reduced serum separation and flow properties in tomato ketchup, establishing it as an innovative thickening agent for this condiment (Manisha et al., 2020).

1.10 Dairy Products

Guar gum's primary function in frozen goods is stability. Due to its ability to bind water, guar gum plays a significant part in stabilizing ice cream. Because high temperature short time (HTST) systems need hydrocolloids that can fully hydrate in a short processing time, its application in these processes is highly advantageous. Locust bean gum possesses all the qualities of the perfect gum, according to McKiernan (1957), but it hydrates slowly, which is not suitable for the HTST process. In continuous ice cream production, Julien (1953) found that using guar as a stabilizer produced good results. A 0.3% concentration level of guar gum is recommended for usage in ice cream mixes (Goldstein & Alter 1959a, b). It was also used into a mixed guar-carrageenan system created for the HTST process, along with carrageenan. When combined with other stabilizers, it can work better, much like locust bean gum (Weinstein 1958). Guar gum enhances the chewiness, body, texture, and resilience to heat shock of ice cream. When added to low-fat yoghurt at concentrations of 2–6%, partially hydrolyzed guar gum reduces syneresis and enhances its textural and rheological qualities, making it equivalent to full-fat yoghurt. (Brennan and Tudorica, 2008). However, only two food categories—baked goods and cheese—were found to use guar gum as a stabilizing and thickening agent (US food sector, 1977).

1.11 Processed Meat Products

Guar gum has a high water-holding capacity in both hot and cold water. As a result, it works incredibly well as a lubricant and binder when making sausage and stuffed meat products. It carries out particular tasks in processed meat products, such as regulating syneresis, preventing fat migration during storage, controlling the liquid phase's viscosity during processing and cooling, and preventing water from building up in the can during storage. Additionally, guar gum improves the regulate rheology as well as creaming stability of the emulsion made with egg yolk. (Ercelebi and Ibanoglu 2010)

1.12 Bakery Products

By incorporating guar gum to cake and biscuit dough, the dough becomes more machinable, allowing it to be easily removed from the mold and sliced without crumbling. It provides desired binding and film-forming qualities that reduce the penetration of fats and oils when added to doughnut batter at a rate of 1%. It has been discovered that guar gum and starch work well together to stop frozen pie fillings from drying out, shrinking, and cracking. (Werbin 1950). Guar gum significantly increases the volume of the baked loaf when added to wheat bread dough (Cawley 1964). By lowering the weight loss and retrogradation enthalpy, guar gum and xanthan gum prevent staling in gluten-free rice cakes (Sumnu et al. 2010). Similarly, by regulating the retrogradation of starch, guar gum also delays staling in chapati at both room temperature and chilled temperature (Shaikh et al. 2008).

2. CONCLUSION

Guar Gum used as a stabilizer and thickener in food industry. It is used in a drug delivery system including as a hydrogel. Other applications of guar gum in textiles and paper industries as a binding and emulsifying properties. The main challenges of guar gum production are a more fluctuations in cluster bean seed production as well the seed prices in market, processing technologies and minimum of value-added products from guar gum.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology.

Details of the AI usage are given below:

1. ChatGPT
2. Quillbot

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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