Production and Applications of Xanthan Gum, A Polymeric Material Obtained from Xanthomonas Campestris: A Mini Review

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ABSTRACT

Xanthan gum belongs to the category of naturally occurring exo-polysaccharide which owes its origin from the well-known bacterium *Xanthomonas campestris*. Its structure comprises D-Glucose, D-Mannose and D-Glucuronic acid units with a ratio of 2:2:1. Its use has been increased in day-to-day life and the present scenario shows its wide application, be it a food or non-food application. It is the constituent of more than 90% of the cosmetic products used in daily life. Along with this, its use as an adsorbent has also increased widely and it has imprinted its identity in the field of wastewater treatment, dye removal and drug delivery. This review covers the method of its production and applications in different fields such as food, industries, agriculture, and cosmetics.

Keywords: Xanthan gum, Production, Applications

1 Introduction

Gum is a public terminology often used for hydro polysaccharide-based hydrogels having an attraction for water by exhibiting clinging features for water. They also exhibit the same for various organic/inorganic materials. Gums are an offshoot of multifarious plants. Gums, however, are polymers of carbs. Polysaccharides show omnipresence in living forms, exhibiting a range of idiosyncratic physical as well as chemical properties [1]. They work as construction equipment for the huge kingdom of plants, as energy reservoirs, as adhesives, and as information-carrying agents too. Microbial polysaccharides have consistent repetition of sugars such as, glucose, galactose, fructose, mannose, etc. They are prevalent in the present engineering era as stabilisers, thickeners, gelling agents and also as emulsifiers. Their role comprises providing end products with boosted stability or superior features on use and increasing dispensation efficacy [2]. There are a number of natural materials that are used in wastewater treatment[3], [4].

Dextran was the pioneer polysaccharide obtained from microbes discovered in the 1940s to undergo commercialization. Xanthan gum, another microbial polysaccharide, came into light in 1963 at the Northern Regional Research Centre (now known as The National Centre for Agricultural Utilization Research) of the United States Department of Agriculture (USDA). It was the second one [5]. The toxicological and safety properties of this gum for its application in the food and pharmaceutical sector are widely investigated. Xanthan gum, formed from the bacterium *Xanthomonas campestris* was expansively explored because of its property of allowing supplementation of supplementary natural and synthetic water-loving gums. It is available only as food material in the United States. However, it is comparatively luxurious for being used as an individual carbon source in glucose with the very strict purity for foods.

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2 Structure

This polysaccharide, Xanthan gum, is formed via aerobic fermentation of sugar from *Xanthomonas campestris*. Its use is prominent as a food additive due to its hydrocolloid structural modifier characteristics. It is mainly composed of D-Glucuronic acid, pyruvated D-mannose, 6-O-acetyl D-mannose, and 1,4-D-Glucose as shown in Figure 1[6], [7]. Xanthan gum produced from the above-mentioned strain has been considered as a food additive by the US Food and Drugs Administration (FDA). It captures great interest because of its fascinating rheological characteristics unnoticed for other polymers. *Xanthomonas campestris* is an aerophilic mycobacterium, so its cultivation becomes calm in the laboratory having an optimum growth temperature of 25–30 °C and pH of 6-8 and within 2-3 days.

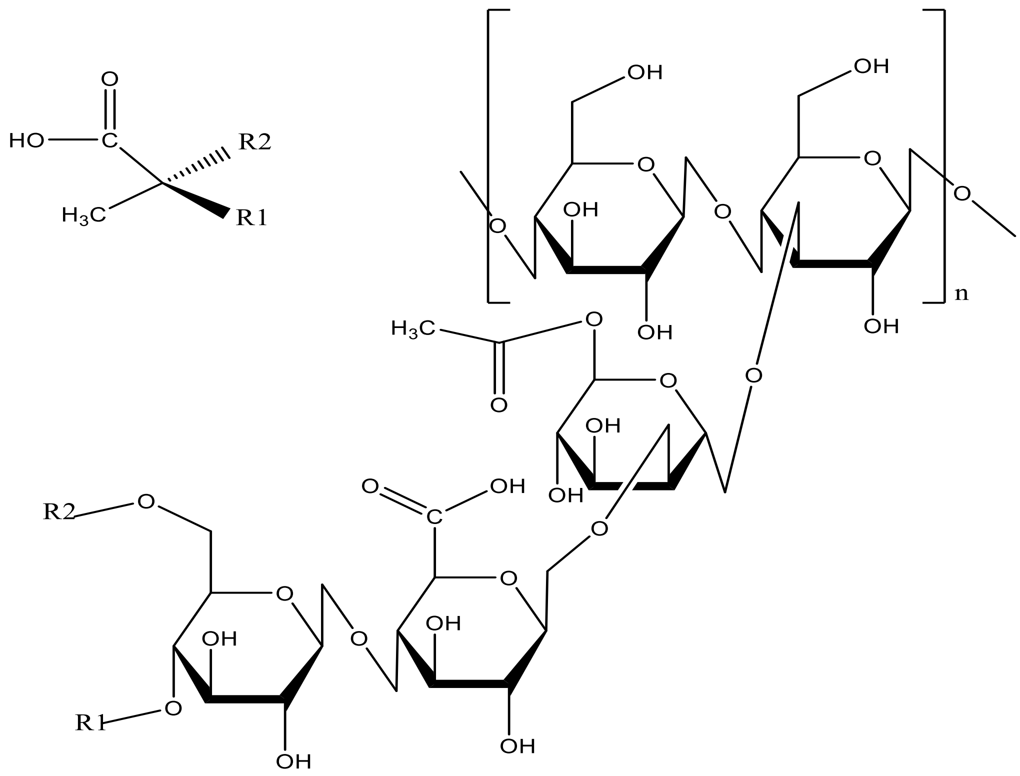

Figure 1: *Chemical structure of xanthan gum*

3 Properties

Xanthan gum is soluble in aqueous medium under hot or cold conditions. However, it desires rigorous mixing on coming in contact with water to prevent lump formation. They form non-Newtonian solutions and are extremely pseudoplastic. This pseudoplastic behaviour improves sensory abilities like flavour release, mouth feel, etc. in dietary goods and promises higher mixing, pouring and pumping ability. The three-dimensional system formed due to the side chains marks it an effective preservative for suspensions and emulsions [8]. For regulating the looked-for drift behaviour, xanthan gum has often been used for amalgamation with diverse hydrocolloids. Such communications among hydrocolloids prove to be of distinct marketable value offering novel functionalities at lower quantities and cheaper costs.

The helically organised structure of xanthan gum with its well-organized shape shields it from being depolymerized and accounts for its salt stability[9], [10]. Hence, salt is required for its optimal functionality. Xanthan gum shows activity at wide-ranging pH values. This accounts for acidic food applications like fruit systems and salad dressings. Xanthan gum is fully biodegradable owing to its natural origin. It is a steady thickener-cum-stabilizer, owing to its activity in highly enzymatic conditions. Xanthan gum is indigestible in humans and accounts for lowering the calorific value of foods and improvement in their passageway via gastrointestinal region. The calorific value of xanthan gum is nearly 0.6 kcal/g.

The key solution features which are responsible for xanthan gum's diverse applications can thus be summarised as follows:

i. Structure of xanthan gum in solution phase, low-shear viscosity, even at lower amount.
ii. Obtained yield.
iii. Highly pseudoplastic nature, i.e., high shear thinning.
iv. Increased viscosity with salt.
v. Maintenance of viscosity at high temperature and lower salt concentrations.
vi. Stability over a wide pH range.
vii. Thermo-reversible gelation and increase in synergistic viscosity on combining with other gums [11].

4 Production

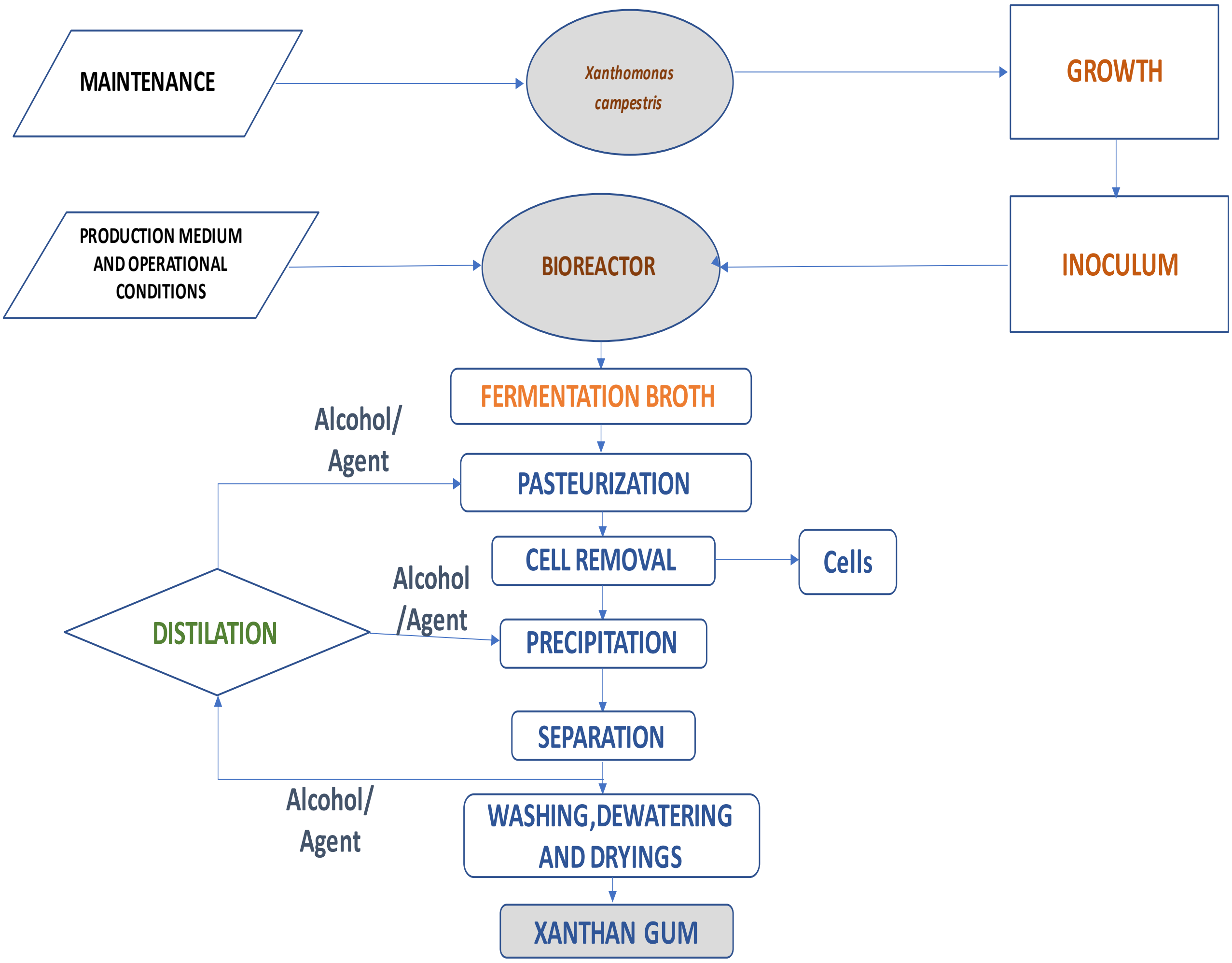

Figure 2: *Common procedure for xanthan gum production*

Xanthan Gum production is brought about by diverse *Xanthomonas* sp. bacterium via aerobic fermentation. Industrial scale microbial production of XG is shown in Figure 2 [12]. Initially, a previously well-preserved culture of known amount is revitalized for the purpose of obtaining inoculum by growing on solid substrates or in liquid media and is then headed towards bioreactors. Numerous operational factors play a significant role in this process like type and mode of operation of bioreactor, medium ingredients, temperature, pH, and concentration of oxygen[13]– [16]. Followed by the fermentation process, obtained broth encompasses XG along with bacteria, and other chemicals. For regaining XG, removal of the microbial cells by employing the centrifugation or filtration methods is brought about. The obtained material, then precipitated by regulating the solvents and pH is followed by salt addition. After precipitation, it is washed, dewatered, and dried to get packed in the containers with lower water permeable nature.

5 Applications of Xanthan gum

5.1 Food based applications

The foremost applications of this gum are as thickening and suspending agents in the food industry. Based on the toxicological tests, the United States Food and Drug Administration has approved the use of Xanthan gum in human food. Modern day foods require exceptional texturization, viscosity, flavour release, appearance, and water-control properties [17]. Xanthan gum is useful for expansion of all these assets and in controlling the rheology of ultimate food products too. It exhibits more Newtonian characteristics with pseudoplastic properties in solutions than other gums[2], [18], [19].

- Bakers: In the production of bakery products, this gum has an application of increasing water binding capacity at the time of baking and storage. It also out spreads their shelf life. It can also be used as a replacement in soft baked goods for egg white without disturbing appearance and sense of taste. It also subsidizes smoothness, retaining and recipe lenience for biscuits, muffins, cakes, and bread mixing batter. The addition to hot or cold bakery products aids in fillings of cream and fruit, improves flavour and texture extending to shelf steadiness, freeze–thaw steadiness and control of syneresis. It also progresses volume, reduces calorie baked foods and provides with gluten-free breads.

- Dairy blends: Xanthan gum acts as an outstanding stabilizer for milk and related products. Alike blends find use in dessert puddings, acidified milk gels by providing them with optimal viscosity, long standing stability, enhanced heat transfer at the time of processing, boosted flavour releasing, heat-shock shield, and ice-cubes regulation. It solidifies cottage cheese coverings by giving moral drainage control too.

- Beverages: Xanthan gum embodies beverages and squashes, along with units of fruit flesh which supports in sustaining suspension, providing better look and consistency. It also donates to instant and ample solubility at low pH. In dry-mix beverage bases, it offers boosted superiority to the re-formed drink accompanying hasty viscosity expansion.

- Dressings: Xanthan gums shows stability towards salt, bases as well as acid, efficacy at lower concentrations and high pseudoplastic rheology in production of an ideal stabilizer providing brilliant long-term emulsion firmness with moderately persistent viscosity at a wide range of temperature. It can also act as a semi-replacement to starch imparting a looked-for body, texture, and freeze–thaw stability with better flavour.

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- Pet food: Xanthan gum accompanied with other gums produces a homogeneous crystallized product. As liquid milk replacers for pets, it is used for stabilizing the suspension of insoluble constituents.
- Syrups and toppings: Chocolate toppings and buttered syrups comprising this gum have admirable constancy and drift qualities for their higher viscosities, thick appearance, and enticing over foodstuffs like ice cream, pancakes, etc. Frozen non-dairy lashed topping essences are composed of stable texture, more teemed with exceptional freeze–thaw stability.
- Relish: The addition of this gum to relish progresses its weight and effectively eradicates liquor loss at the time of handling.
- Sauces and gravies: Lower amounts of this gum deliver sauces with higher viscosity and gravies at both acidic and neutral pH. Viscosity is extremely stable to change in temperature and for long-standing storage which help them provide brilliant flavour to hot foods.

5.2 Industry based applications

Industrial mass produced from this gum competes for devising conditions like long-term holdup and stability of emulsion in alkaline, acidic, and salt solution, resistance to temperature, and pseudo plastic behaviour. This gum finds widespread applications in Chemical industries like, xanthan gum and locust bean gum's mixture used in deodorant gels, xanthan gum and borate gel in preparation of explosives, etc [2], [18], [19].

- Oil industry: In the petroleum industry, xanthan gum is used in oil drilling, rupturing, cleansing of pipelines, etc. Owing to admirable compatibility with salt, and thermal degradation resistance, it is also used in drilling fluids.
- Agricultural products: In the agricultural industry, xanthan gum's use in improving the flow-capability in fungicides, herbicides, and insecticides preparations by uniform suspension of the solid component. It helps control spray flow and clinging, increasing the duration of connection among pesticide and crop.
- Cleaners: Xanthan gum's drift assets and stability over a broad pH makes it an excellent thickener for products like, highly alkaline or acidic solutions, drain, tile, grout cleaners, removal of rust, metal oxide, removal of graffiti, toilet bowl cleaners, oven cleaners, and compounds used for cleaning of metals. It allows easy removal.

Table 1: *Summary of chemically modified XG with its different uses*

Chemically modified XG	Use	Ref
XG-g-EAT	Removal of Pb^{2+} ion	[20]
poly(XG-g-AAM-g-AA)	Removal of Cu^{2+} ion	[21]
XG-g-PAM/SiO_2 bionanocomposite	Removal of Pb^{2+} ion	[22]
Partially hydrolysed XG-g-PAM/SiO_2 bionanocomposite	Removal of Pb^{2+} ion	[23]
XG/Guar gum crosslinked polymer	Removal of Pb^{2+} ion	[24]

XG-g-P(AMPS)	Removal of Cu^{2+} ion	[25]
(XG-g-P(AMPS)/MMT) hydrogel composite	Removal of Cu^{2+} ion	[25]
XG-g- Poly(AA-co-AAM)/ Fe_3O_4	Malachite green dye removal	[26]
XG-PAM/SiO_2 composite	Congo red dye removal	[27]
XG-PAA/ Fe_3O_4	Methyl violet dye removal	[28]
XG-cl-PAA	Methylene blue dye removal	[29]
XG-cl-PAA/ reduced graphene oxide	Methylene blue & Methylene violet dye removal	[30]

- Coatings: The pseudo plastic properties of this gum offer admirable texture in paints as well as ceiling-tile coatings in order to ensure storage stability, comfort in application on wall and providing a finishing texture. It is also used to thicken latex paints and coatings.
- Paper: Xanthan gum finds use as a stabilizer for producing paper, paperboard, etc. to be used with food items particularly.
- Personal care: It advances the drift properties of creams, gels, shampoos, and liquid soaps enriching them with an unchanging, thick, and creamy lather. It is an outstanding binder for all types of toothpastes.
- Pharmaceutical applications: Xanthan gum stabilizes suspensions of various unsolvable constituents like that of, barium sulphate used in X-ray diagnosis, dextromethorphan used for preparation of cough remedy, etc.

5.3 Adsorbent based applications

The modified materials produced on introducing alteration in Xanthan Gum structure, like formation of crosslinkers, nanocomposites, hydrogels, etc., finds wide application as an adsorbent with an important role in the removal of heavy metals such as, Pb^{2+}, Cu^{2+}, etc., dye removal like that of methylene blue, crystal violet, etc., as well as in drug delivery shown in Table 1.

6 Conclusion

The mass-market for xanthan gum owes to food and industry. Major researches elucidated that the factors like microbial availability and starting material rates used for its manufacture. Still, there are several problems to be dealt with for producing cost-efficient and performance-effective xanthan gum. The processes used for producing effective xanthan gum from inexpensive raw materials should get more attention. Future studies should be directed towards the lowering of cost of production and expanding the application since xanthan gum's potential is undermined and still can be expanded by more practice.

7 Declarations

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