Industrial Production of Xanthan Gum

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History

- Xanthan gum is a natural polysaccharide and an important industrial biopolymer.
- It was discovered in the 1950s at the Northern Regional Research Laboratories (NRRL) of the United States Department of Agriculture in the course of a screening which aimed at identifying microorganisms that produced water-soluble gums of commercial interest.
- The first industrial production of xanthan was carried out in 1960, and the product first became available commercially in 1964.

Why do Microorganisms Produce Gums?

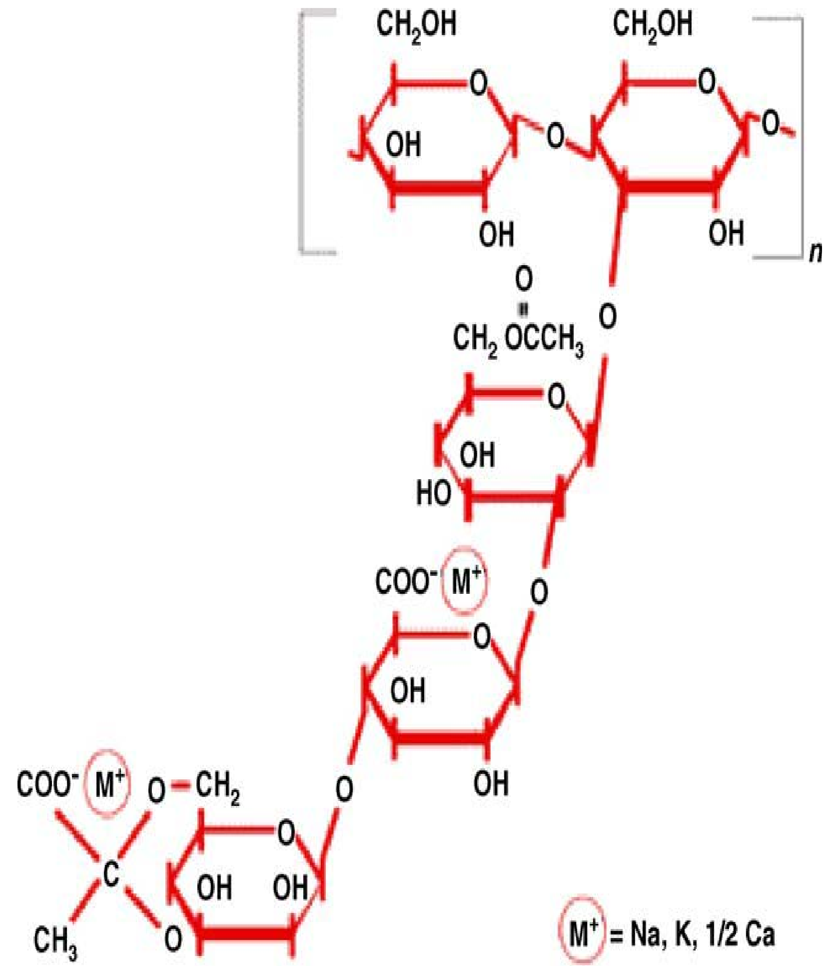
- Most phytopathogenic bacteria do not form spores. Many of them are resistant to desiccation and survive under dry conditions for more than 50 years at normal surrounding temperature.
- This is due to the protective layer of the ‘ooze’ or exudates produced by the bacteria.
- The layer is nothing but a coating of specific gum that is chemically a polysaccharide.
- This coating may act as a barrier against attack from bacteriophage, and also helps identification of appropriate sites on the host plant for colonization of the bacteria.

Xanthan Gum

- **Definition:** Xanthan gum is a high molecular weight polysaccharide gum produced by a pure culture fermentation of a carbohydrate with natural strains of *Xanthomonas campestris*, purified by recovery with ethanol or propane-2-ol, dried and milled.
- It contains D –glucose and D-mannose as the dominant hexose units, along with D-glucuronic acid and pyruvic acid, and is prepared as the sodium, potassium or calcium salt.
- The molecular weight must be approximately 1 MDa and the color must be cream.

Chemical Structure

- Xanthan gum is a heteropolysaccharide with a primary structure consisting of repeated pentasaccharide units formed by two glucose units, two mannose units, and one glucuronic acid unit, in the molar ratio 2.8:2.0:2.0.
- The glucoses are linked to form a β -1,4-D-glucan cellulosic backbone, and alternate glucoses have a short branch consisting of a glucuronic acid sandwiched between two mannose units.
- The side chain consists therefore of β-D- mannose-(1,4)-β-D-glucuronic acid-(1,2)-α-D-mannose.
- The terminal mannose moiety may carry pyruvate residues linked to the 4- and 6-positions.
- The internal mannose unit is acetylated at C-6.
- Acetyl and pyruvate substituents are linked in variable amounts to the side chains, depending upon which *X. campestris* strain the xanthan is isolated from.
- The pyruvic acid content also varies with the fermentation conditions
- This molecular weight distribution depends on the association between chains, forming aggregates of several individual chains. The variations of the fermentation conditions used in production are factors that can influence the molecular weight of xanthan.



Properties of xanthan gum

- Xanthan gum is highly soluble in both cold and hot water.
- Xanthan solutions are highly viscous even at low polymer concentrations.
- Xanthan is used as a thickener, and to stabilize suspensions and emulsions. The thickening ability of xanthan solutions is related with viscosity; a high viscosity resists flow.

Commercial Production

- **Most industries prefer batch instead of continuous (easy to control).**
- **Carbohydrate sources such as sucrose, sugarcane molasses and whey have been successfully used in the production medium. Whey also provides adequate nitrogen and some growth factors.**
- **Efficient conversion of carbon source to the desired polysaccharide production requires a high carbon to nitrogen ratio. Inorganic nitrogen sources like ammonium or nitrate salts are suitable, and a wide variety of complex nitrogen sources like yeast extract, soy-meal peptone and soybean whey are also useful for xanthan production.**
- **Phosphorus is usually added in the form of a phosphate buffer.**
- **A typical commercial production process starts with inoculums of *X. campetris* that are prepared in suitable fermentation medium in conventional batch processing using mechanically agitated vessels.**
- **The process is held at the following operating conditions:**
  - **Temperature approximately T = 28–30 ◦C**
  - **pH∼7,**
  - **the aeration rate must higher than 0.3 (v/v)**
  - **the specific power input for agitation higher than 1 kW/m3 (Adequately designed agitation is necessary to disperse the introduced air evenly throughout the medium. Agitation of the medium is useful for enhancing the rate of transport of nutrients across the cell membrane, which in turn supports the growth rate of the microorganism.)**

...Commercial Production

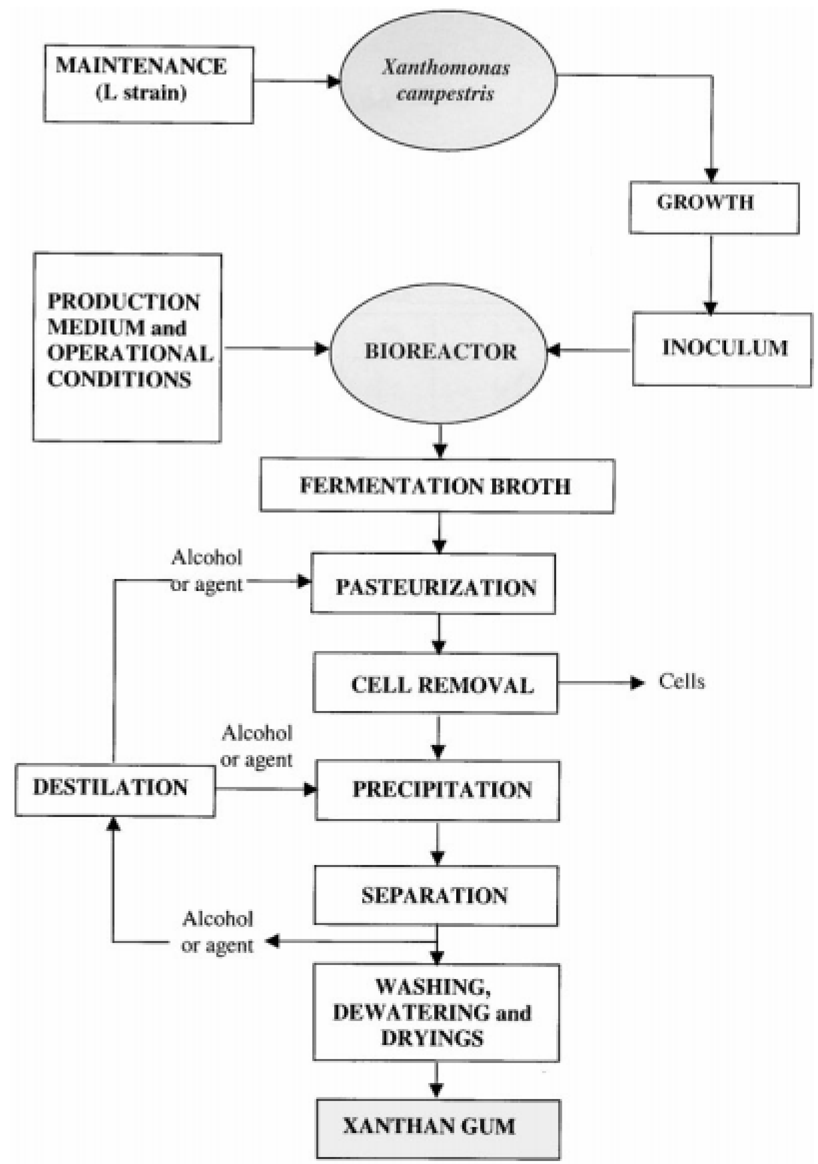
- The fermentation process is carried out for about 100 h and converts an approximately 50% of the glucose into the product.
- During the initial growth phase polysaccharide accumulation starts and continues after growth.
- The pH decreases during the fermentation due to the formation of organic acids.
- If pH falls below 5.0, the formation of xanthan drastically reduces.
- Thus, it is necessary to control the fermentation medium at the optimum pH of 7.0 using a buffer or addition of base during process.

… Commercial Production

Downstream processing:

- When industrial grade xanthan is required, the post fermentation process treatment may be started with pasteurisation on the fermented broth to sterile the bacterial and to deactivate the enzymes.
- This process usually uses a large amount of alcohol to precipitate the xanthan gum, and the precipitated xanthan gum is then sprayed dry or maybe re-suspended on the water and then re-precipitated.
- When cell-free xanthan gum is required, cells centrifugation is facilitated by diluting the fermentation broth to improve the cell separation (because of high viscosity due to xanthan gum).
- The cell separation by dilution process from highly viscous xanthan solution is a cost-intensive process. A favoured method is by adding alcohol and adding the salt would improve precipitation by creating reverse effect charges.
- Alcohol used for xanthan precipitation is recovered by distillation column.
- The dry xanthan gum is milled to the desired mesh sizes for control of disperse ability and dissolution rate as well as to get the handling much easier.

Outline of Xanthan gum production



Applications

Application	Properties
Food Industry	
Juice, drinks, chocolates, pickles, fruit pulp,	Suspending and thickening agent particulate suspension (for chocolate)
Canned food, jams, jellies, milk products	Shear thinning properties ensures favourableviscosity under processing conditions. Good gelling agent, easy pouring due to high pseudoplasticity.
Frozen foods, sauces, gravies	Provides favourable emulsion, suspension,stability and viscosity, improves freeze-thaw stability of starch thickened products.
Bakery products	For better texture to bread, mouth feel and release. Xanthan can replace gluten.
Cheese, creams, meat products, margarine	Combination of xanthan with plant gums like locust bean gum, guar gum is suggested

...Applications

Application	Properties
Industrial Chemicals	
Agriculture	Longer contact with crops, clings during spraying and controls drift of fungicide, herbicide, pesticide and fertilizers.
Paints and inks	Stabilizer, emulsifier for thixotropic paints, compatible with other thickeners and water based emulsion inks, prevents sagging and allows easy and even application.
Ceramics	Suspending agent for heavy particles in ceramics glazes. Maintains proper viscosity and lubricating power of suspension.
Paper manufacturing	Clay coating for paper finish. As a rheology modifier for high size press, roll coating.
Textile	Suspending agent for dyes, pigments, controlling agent for printing.
Abrasives, adhesives, polish, toothpastes, cosmetics, gelled explosives	Viscosity control, flow modifier,
Enhanced oil recovery	Flocculent, stable to pH and temperature changes and to high salt concentrations, effective lubricant, high pseudoplasticity, allows easy injectability.

Questions

- Write an essay on industrial production of xanthan gum
- Write properties and applications of xanthan gum
- Explain in brief the down stream processing steps