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KELTROL[®] / KELZAN[®] **Xanthan Gum Book**

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KELTROL[®] / KELZAN[®] Xanthan Gum

8th
Edition

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I. Introduction

Polysaccharides are widely used to thicken or stabilize aqueous systems (Whistler and BeMiller 1993; Sandford and Baird 1983). In addition, some polysaccharides – or gums, as they are also called – can produce gels, act as flocculants, binders, film-formers, lubricants, and friction-reducers. Thus, polysaccharides will modify and control the rheological properties of aqueous systems.

Traditionally, industrial gums have been derived from botanical sources; however, other valuable polysaccharides are now obtained from microbial sources. **Table 1** lists some commercial gums. Included are several gum derivatives, such as propylene glycol alginate, hydroxypropyl guar, and a variety of cellulose.

In 1964, CP Kelco pioneered the production of polysaccharide gums by viscous fermentation and subsequently, commercialized xanthan gum. Since then, xanthan gum has been used in thousands of

applications by a multitude of industries. After extensive toxicological testing that verified its safety, xanthan gum was approved in the United States for general use in foods in 1969.

The first edition of this booklet was published in 1972. Since the time of the first edition, CP Kelco has expanded its manufacturing locations from San Diego, California to Okmulgee, Oklahoma, Danville, Pennsylvania, and Knowsley, England. As applications for xanthan gum have increased over the years, CP Kelco has also commercialized new biogums: gellan gum, rhamsan gum, welan gum and diutan gum, and is actively working to develop other hydrocolloids with unique properties.

CP Kelco is pleased to present this eighth edition of its xanthan gum booklet containing the most up-to-date scientific information on the polymer's properties and applications.

Table 1
Commercial Gums

Marine plants	Terrestrial plants	Microbial polysaccharides	Polysaccharide derivatives
Agar	Guar gum	Dextran	Carboxy methylcellulose
Alginates	Gum arabic	Gellan gum	Methyl hydroxypropyl cellulose
Carrageenan	Gum tragacanth	Rhamsan gum	Hydroxypropyl cellulose
Furcellaran	Karaya gum	Welan gum	Hydroxyethyl cellulose
	Locust bean gum	Xanthan gum	Propylene glycol alginate
	Pectin	Curdlan	Hydroxypropyl guar
	Tamarind seed gum	Pullulan	Modified starches

Production of Xanthan Gum

Xanthan gum is an exocellular heteropolysaccharide produced by a distinct fermentation process. The bacterium, *Xanthomonas campestris*, produces this gum at the cell wall surface during its normal life cycle by a complex enzymatic process; the gum is released into the surrounding medium.

The composition and structure of the xanthan gum produced by commercial fermentation is identical to the naturally occurring polysaccharide formed by

Xanthomonas campestris on plants belonging to the cabbage family, where it occurs naturally.

Xanthan gum is produced by aerobic submerged fermentation. The fermentation medium contains a carbohydrate (such as sugar), a nitrogen source, trace elements, and other growth factors.

The production of xanthan gum involves a multi-step inoculum preparation, followed by fermentation in large stainless steel tanks and, finally, product recovery (Figure 1). Fermentation equipment is sterilized before use, and strict aseptic techniques are followed to ensure a pure culture. Media composition, as well as fundamental requirements such as aeration, agitation, pH, and temperature, are precisely controlled to guarantee optimal results and reproducibility. After fermentation is complete, the broth is pasteurized to kill the organisms before the product is recovered. Typically, xanthan gum is recovered from the fermentation broth by alcohol precipitation. The alcohol is then removed, and the resultant product dried, milled, tested, and packaged.

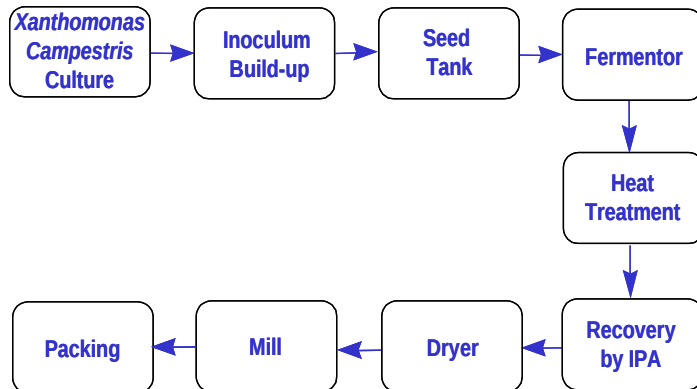


Figure 1. Xanthan gum production process

II. Structure and Properties of Xanthan Gum

Structure

Each xanthan gum repeat unit, shown in Figure 2, consists of five sugar residues: two glucose, two mannose, and one glucuronic acid (Jansson et al. 1975; Melton et al. 1976). The polymer backbone consists of 1, 4-linked β -D-glucose and is therefore identical in structure to cellulose. Trisaccharide side chains on alternating anhydroglucose units distinguish xanthan gum from cellulose. Each side chain comprises a glucuronic acid residue between two mannose units. At most of the terminal mannose units is a 4, 6-linked pyruvate moiety¹; the mannose nearest the main chain typically carries a 6-linked acetyl ester, or can also be unsubstituted.

Numerous studies have indicated a molecular weight for xanthan gum of approximately two million daltons, which corresponds to approximately two thousand repeat units per polymer molecule. However, values as high as 50 million have been reported (Dintzis et al. 1970). These differences are thought to be due to molecular aggregation.

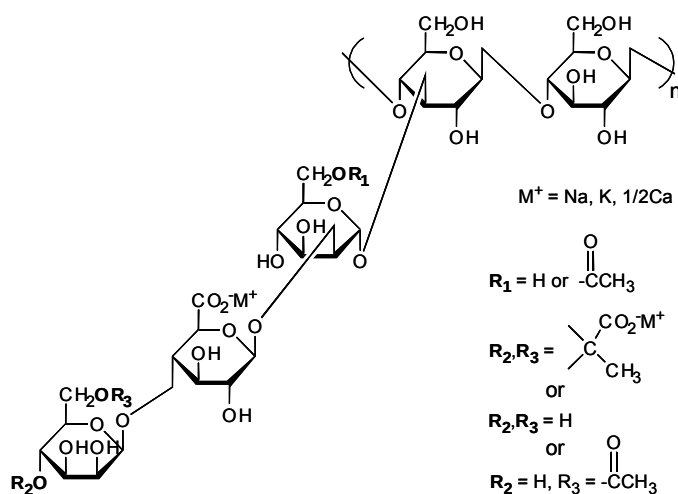


Figure 2. Structure of xanthan gum

¹ Non-pyruvylated mannose units can be substituted or can contain a 6-linked acetyl ester.

X-ray diffraction studies on oriented xanthan gum fibers (Moorhouse et al. 1977) identified the molecular conformation as a right-handed, fivefold helix with a rise per backbone disaccharide residue of 0.94 nm – i.e., a fivefold helix with a pitch of 4.7 nm (**Figure 3**). In this conformation, the trisaccharide side chain is aligned with the backbone and stabilizes the overall conformation by non-covalent interactions, principally hydrogen bonding.

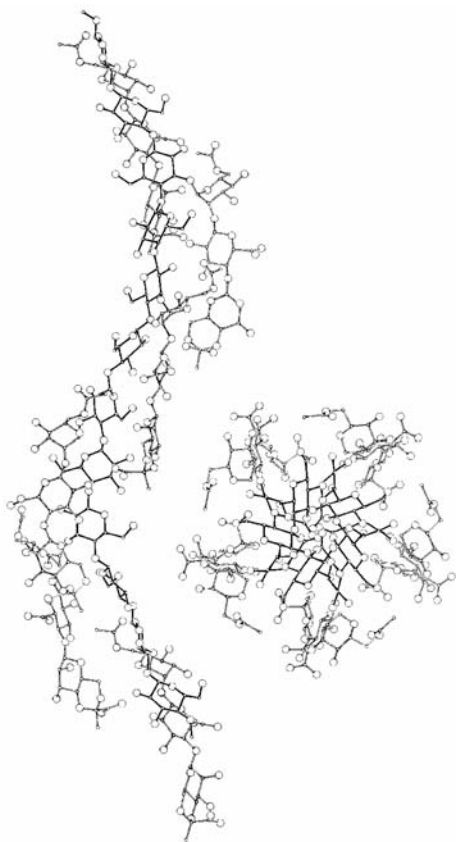


Figure 3. Helical conformation of xanthan gum viewed parallel and perpendicular to helix axis

A double helical structure composed of two entwined xanthan molecules is also consistent with the x-ray data.

Solution studies on the conformation of xanthan gum suggest a rod-like character with some degree of flexibility (Whitcomb and Macosko 1978). Holzwarth and Prestidge (1977) suggested a double or multi-stranded assembly, whereas Norton et al. (1984) argued for a single helical entity in solution.

Xanthan gum solutions at low ionic strength undergo a thermal transition that has been detected by a variety of physical methods. This transition was first demonstrated by Jeanes et al. (1961) as a sigmoidal change in viscosity of 1% salt-free solutions (T_m 55°C, 131°F). The subsequent work of Morris et al. (1977) showed that optical rotatory and circular dichroic transitions are coincident with the viscosity change, indicating a conformation transition of the molecule. These data are consistent with the unwinding of an ordered structure like a helix into a random coil, with a consequent decrease in effective hydrodynamic volume and, therefore, viscosity.

Intermolecular association among polymer chains results in the formation of a complex network of weakly bound molecules. These aggregates are progressively disrupted under the influence of applied shear. Heating a xanthan gum solution above the transition temperature results in "melting" of the ordered structure. This structure returns to its original state upon cooling, depending on the salt environment and the xanthan gum concentration (Norton et al. 1984).

Properties

Present knowledge of the structure and conformation of xanthan gum explains many of its unusual solution properties, which are summarized in **Table 2**.

Table 2
Properties of Xanthan Gum

Rheological properties	Stability/compatibility to:
High viscosity at low concentration	Ionic strength variations
High viscosity at low shear rates	Heat
High degree of pseudoplasticity	pH
High elastic modulus	Shear
Low degree of thixotropy	Enzymes
	Chemicals
	Salts
	Acids
	Bases

Xanthan gum solutions are highly pseudoplastic. When shear stress rate is increased, viscosity decreases. Upon the reduction of shear, initial viscosity is recovered in moments. Xanthan solutions are not thixotropic to a significant degree. Pseudoplasticity results from the high-molecular weight molecule, which forms complex molecular aggregates through hydrogen bonds and polymer entanglement. This highly ordered network of entangled, stiff molecules accounts for high viscosity at low shear rates and for the gum’s outstanding suspending properties. Shear thinning pseudoplasticity results from disaggregation of this network and alignment of individual polymer molecules in the direction of shear force. However, when the shearing ceases, aggregates reform rapidly. These features are shown schematically in **Figure 4**.

The ordered conformation is stabilized by hydrogen bonding, but destabilized by the repulsion between the negatively charged groups on the overlapping side chains. A low concentration of electrolyte enhances the ordered conformation of xanthan gum by reducing the electrostatic repulsion between carboxylate anions on the trisaccharide side chains. This stabilized helical structure is maintained with an increase in temperature, which explains why the viscosity of the xanthan gum solution is insensitive to temperature changes below the transition temperature.

As a result of the rigid helical conformation, xanthan gum viscosity is relatively insensitive to differences in ionic strength and pH. In contrast, other polysaccharides that are polyelectrolytes normally have a less-ordered, or random coil, conformation – a state, in which increasing or decreasing electrolyte levels adversely affect solution viscosities. Finally, protection of the backbone by the side chains results in the superior stability of xanthan gum compared to other polysaccharides when exposed to acids, alkalis, and enzymes. These structure/property relationships are summarized in **Table 3**.

Table 3
Structure/Property Relationships

Structural features	Properties
Complex aggregates, with weak intermolecular forces	High viscosity at low shear rates (suspension-stabilizing properties)
Rigid helical conformation, hydrogen-bonded	Temperature insensitivity and salt compatibility complexes, anionic charge on side chains
Backbone protected by large overlapping side chains	Stability to acids, alkalis, and enzymes

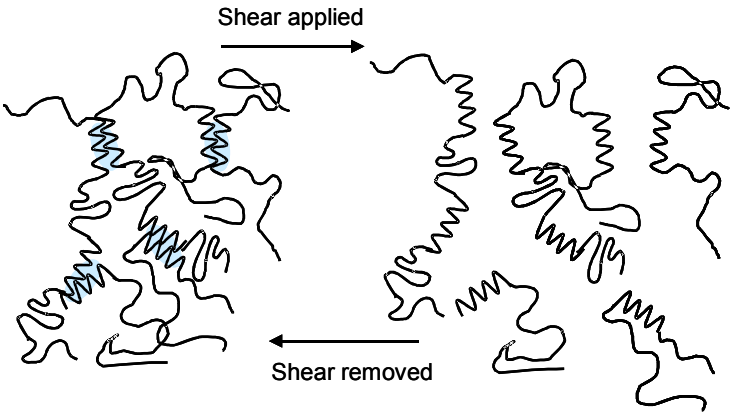


Figure 4. Schematic representation of the conformation change in xanthan gum solutions when shear is applied and removed

Viscosity/Concentration Relationship

Figure 5 shows the relationship between viscosity and concentration in xanthan gum solutions. At low concentrations xanthan gum displays the unusually high viscosities important to its suspension-stabilizing properties.

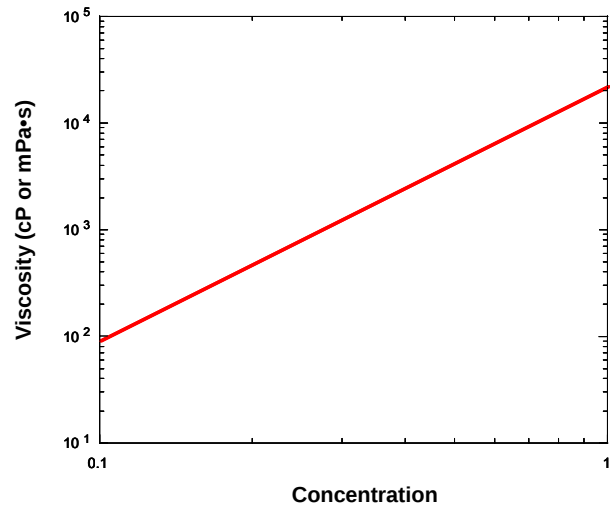


Figure 5. Xanthan gum viscosity vs concentration in standardized tap water

The rheological behavior shown in Figure 6a is important to many applications. The viscosity-vs-low shear-rate plot clearly shows xanthan gum’s high degree of pseudoplasticity. Pseudoplasticity is important in contributing good sensory qualities and flavor release to foods, as well as long term shelf stability of emulsifying and suspending.

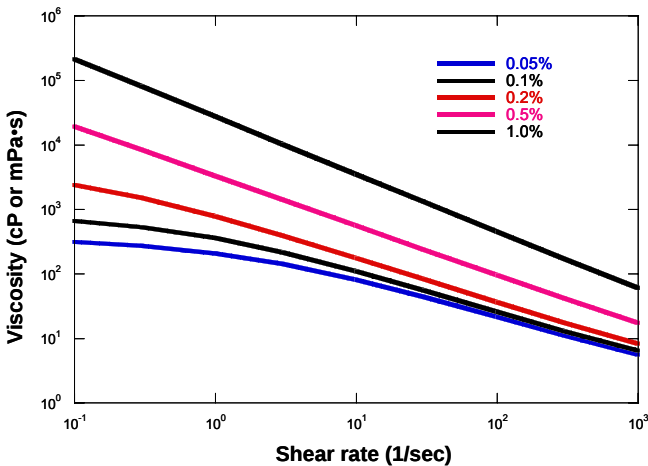


Figure 6a. Flow curve (viscosity vs shear rate) for xanthan solutions over a limited shear rate range. (Measured at 23°C in standardized tap water.)

Figure 6b shows the effect of shear rate on xanthan gum solutions when measured over a very wide range. Twelve orders of magnitude of shear rate are covered and xanthan gum shows pseudoplastic properties over most of the range. The 0.5% solution varied in viscosity from 1 million centipoise at low rates of shear to about 1.7 centipoise at the highest rates of shear. At both the highest and lowest shear rates there is evidence of a leveling off of the viscosity. These regions are known respectively as the upper and lower Newtonian regions. Nearly all polymeric thickeners will show this type of behavior providing data can be taken at the extremes of shear rate required.

Solutions of xanthan gum at 1% or higher concentration appear gel-like at rest, yet these same solutions pour readily and have a very low resistance to mixing and pumping. These same qualities are observed at typical use levels of about 0.1% to 0.3%. Low shear viscosity is responsible for xanthan gum’s effectiveness in stabilizing emulsions and suspensions against separation. The reduction in viscosity in response to increasing shear is important to the pourability of suspensions and emulsions, and to the efficacy of xanthan gum as a processing aid.

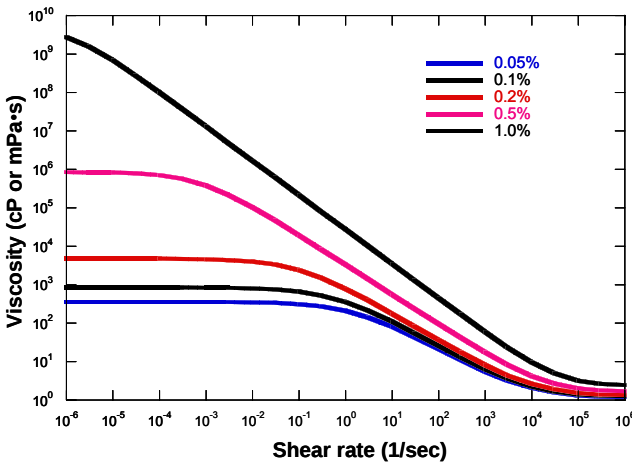


Figure 6b. Flow curve (viscosity vs shear rate) for xanthan solutions over a wide shear rate range. (Measured at 23°C in standardized tap water.)

Effect of Salts on Viscosity

How salts affect viscosity depends on the concentration of xanthan gum in solution. At or below about 0.25% gum concentration, monovalent salts such as sodium chloride cause a slight decrease in viscosity. At higher gum concentrations, viscosity increases with added salt. At a sodium chloride level of 0.1%, the viscosity plateau is reached, and further addition of salt has no effect on viscosity. These phenomena are illustrated in **Figure 7**.

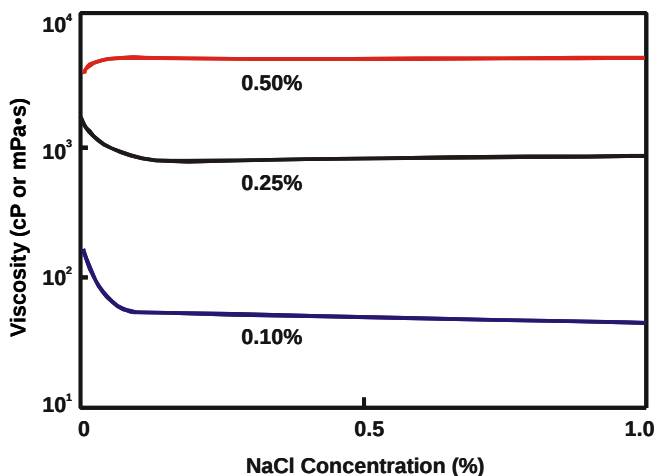


Figure 7. Viscosity vs. salt concentration for 0.1%, 0.25%, and 0.5% xanthan gum solutions²

Many divalent metal salts, including those of calcium and magnesium, have a similar impact on viscosity. To develop optimal rheological and uniform solution properties, some type of salt should be present; usually the salts found naturally in tap water are sufficient to generate these effects.

Effect of pH on Viscosity

Generally, pH has little effect on the viscosity of xanthan gum solutions (**Figure 8**). Uniform and high viscosity is maintained over the pH range 2-12, with some reduction at extreme pH values. However, differences in viscosity with pH are more evident at low concentrations of xanthan gum.

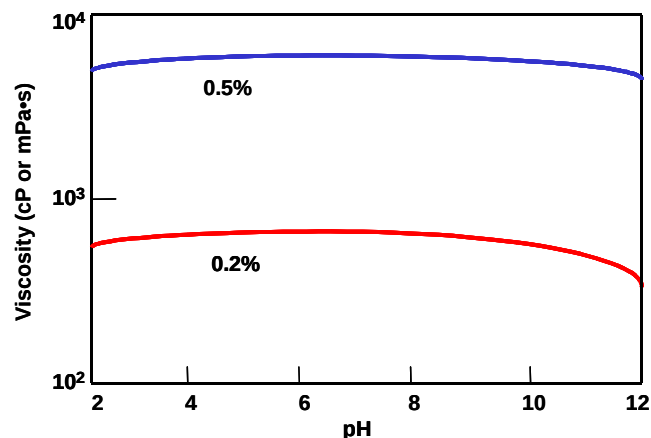


Figure 8. Viscosity vs pH for 0.2% and 0.5% xanthan gum in standardized tap water^{2, 3}

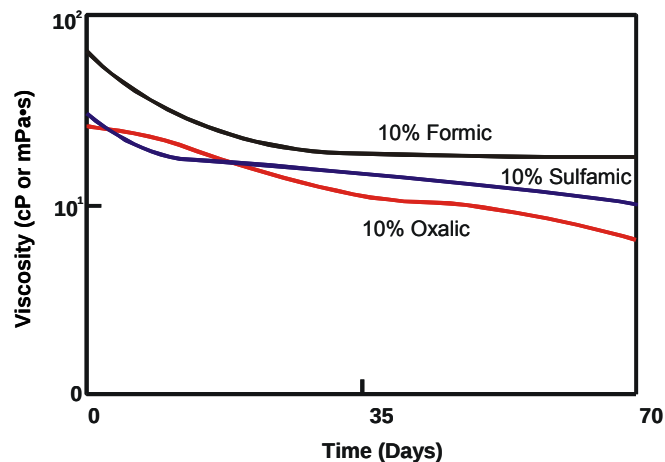


Figure 9. Viscosity vs time for 1% xanthan gum solutions containing 10% W/V of some typical weak acids; Brookfield LVT, 60 rpm

Xanthan gum solutions have excellent stability at low pH over long time periods. At ambient temperatures (20°C, 68°F), the viscosity of xanthan gum remains stable over time in the presence of some weak acids, as shown in **Figure 9**. After a slight decrease in viscosity during the first few days, solutions remained reasonably stable for the duration of a 70-day test period.

² Unless otherwise indicated, all viscosity data were obtained using a Brookfield® LVT viscometer at 3 rpm.

³ Standardized tap water is prepared by dissolving 1.00 g of NaCl and 0.15 g CaCl₂·2H₂O in 1 liter of deionized water.

Effect of Temperature on Viscosity

Xanthan gum solutions are unique in their ability to retain their viscosity until a definite "melting temperature" (T_m) is reached. At this temperature, the viscosity drops sharply due to a reversible molecular conformation change (Figure 10a). Figure 10b shows this melting temperature for several sodium chloride concentrations. Note that the sample prepared in with 5% NaCl has a melting temperature greater than 100°C. Upon cooling, all samples revert to their original high viscosity.

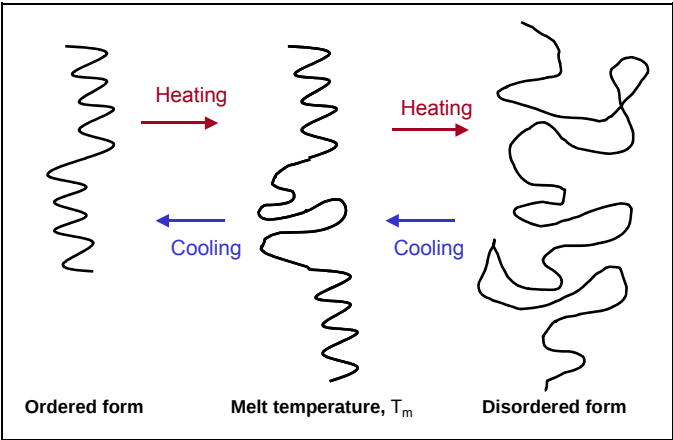


Figure 10a. Schematic representation of the conformation change in xanthan gum solutions with heating and cooling

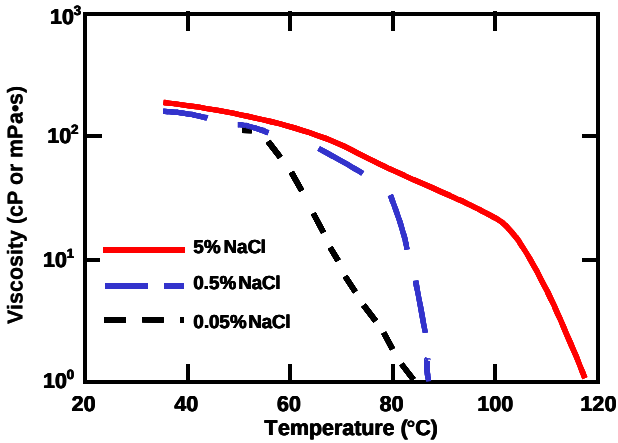


Figure 10b. Viscosity at 10(s-1) shear rate for 1% xanthan gum in 3 different NaCl concentrations

There is a predictable relationship between the T_m and the ionic strength of the xanthan gum solution. This is shown for sodium chloride in Figure 10c. By controlling the ionic strength, the user can vary T_m over a wide range. This, in turn, can alter xanthan gum solutions from being either thin or thick at elevated temperature.

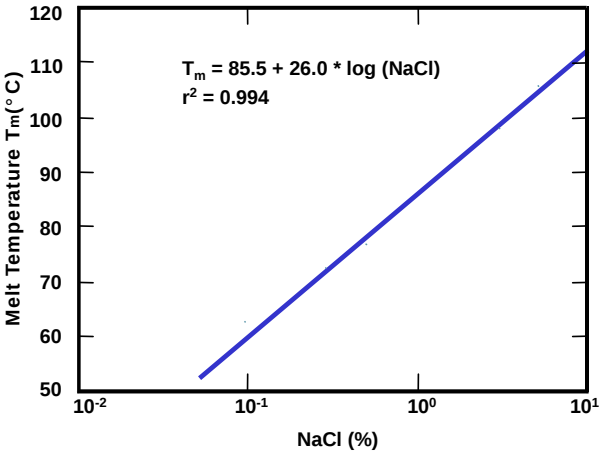


Figure 10c. Thermal melting temperature of 1.0% xanthan gum solutions as a function of sodium chloride concentration

III. Rheological Properties of Xanthan Gum Solutions

Xanthan gum's major value is its capacity to impart useful rheological properties to aqueous systems. A few definitions are needed to introduce the topic of rheology.

Figure 11 shows the forces acting on a liquid contained between a pair of one-square-meter plates that are one meter apart. The bottom plate is stationary, and the top plate moves horizontally at a rate of one meter per second. The amount of force required for this movement is commonly measured in Newtons.

Shear stress (τ) is defined as the force acting in the plane of the fluid. The units of shear stress are Newtons per square meter, also known as Pascals. Alternative units for shear stress are dynes per square centimeter and pounds force per square inch.

Shear rate ($\dot{\gamma}$) is defined as the velocity gradient of the fluid between the plates. It is determined by dividing the velocity of movement of the plates by the distance between them. In the case illustrated in **Figure 11**, the rate is one meter per second per meter of fluid, and is measured in reciprocal seconds (1/sec).

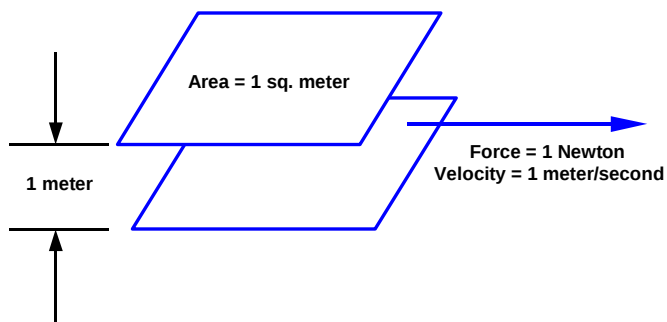


Figure 11. Fluid forces acting on a pair of parallel plates

Viscosity (η) is defined as the ratio of shear stress (τ) to shear rate ($\dot{\gamma}$). The units are Newton seconds per square meter, or Pascal seconds (Pa·s). Another common unit of viscosity is the poise (dyne second/centimeter²). One centipoise is equal to one milli-Pascal second.

Almost all polysaccharides produce fluids in which measured viscosity is a function of the shear rate. For fluids such as water, the measured viscosity is independent of the shear rate. These fluids are termed Newtonian. Plots of shear stress against shear rate are often used to illustrate the response of different fluids to applied forces as shown in **Figure 12a**. An alternative picture is shown by plotting apparent viscosity (the ratio of the shear stress to shear rate) against shear rate as shown in **Figure 12b**. The term apparent viscosity indicates that the measured viscosity is a function of shear rate.

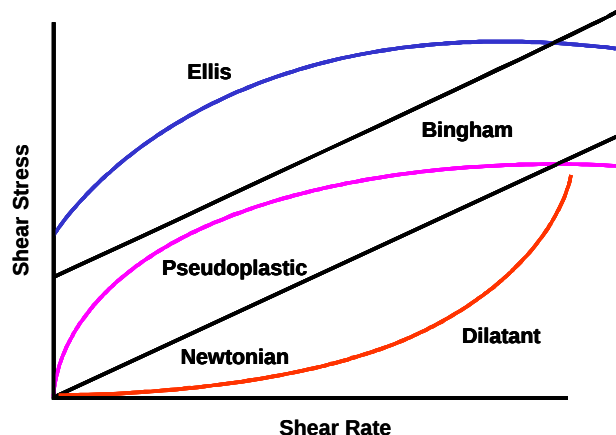


Figure 12a. Shear stress vs shear rate relationship for common types of flow behavior

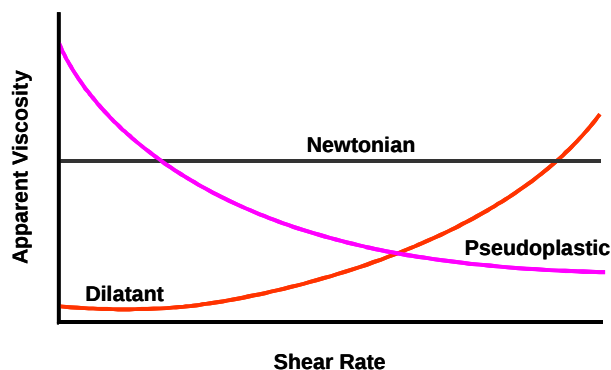


Figure 12b. Apparent viscosity vs shear rate relationship for common types of flow behavior

Most aqueous polysaccharide solutions display shear thinning flow, which is characterized by a decrease in apparent viscosity in response to increasing shear rate.

In contrast, some concentrated mineral suspensions in water exhibit dilatant behavior, i.e., they increase in viscosity with increasing shear. Some fluids have a critical shear stress, denoted yield value, which is defined as the shear stress that must be exceeded before flow can begin.

Newtonian flow is evidenced by a linear relationship between shear stress and shear rate; i.e., viscosity is independent of shear rate. If the fluid has essentially Newtonian flow after the yield value is exceeded, it is called a Bingham fluid (or Bingham plastic). An example is pigment paste for textile printing. If the fluid has a yield value and follows the pseudoplastic model, it is termed an Ellis fluid. This model is often used to describe xanthan gum solutions.

Fluids that decrease in viscosity under constant shear stress over a period of time, usually in seconds or fractions thereof, are called thixotropic. Many polysaccharide solutions, such as those of guar gum, carboxymethylcellulose, carrageenan, and starch are thixotropic. Under most conditions of use, xanthan gum solutions show no thixotropy.

Rheopectic flow, characterized by a viscosity increase at constant shear rate, is rare for polymer solutions, but certain solutions, such as high-solids clay and gypsum suspensions, exemplify this behavior.

Figure 13 illustrates these two time-dependent effects.

A viscometer that operates with one of three basic geometries – cone and plate, Couette (concentric cylinder), or capillary – may be used to measure the viscosity of a sample and obtain data in rheological terms (shear stress and shear rate).

In the case of the commonly used rates on the Brookfield viscometers with rotating discs, the shear fluids are a function of the distance from the center of the disc. The instruments are calibrated against standard viscosity oils and measurements made on them must always quote both rotation speed and spindle used. When measuring xanthan gum solutions, spindle type viscometrics will indicate a different viscosity when spindles are changed. This is normal and is due to the change in effective shear rate of each spindle.

Xanthan gum's main function is to suspend and stabilize the dispersion of solids, immiscible liquids, and gases in aqueous systems. For example, solids are suspended in oil drilling fluids, immiscible liquids in salad dressings and gases in whipped toppings. Each system consists of a continuous phase (water) and a dispersed phase (solid particle or air bubbles).

For an emulsion to be stable, the continuous phase must be viscous to prevent the disperse phase from coalescing. Adding xanthan gum increases viscosity at low shear rates, thereby ensuring that individual particles in the dispersed phase remain separate. Similar principles are important in suspensions of solids and gases.

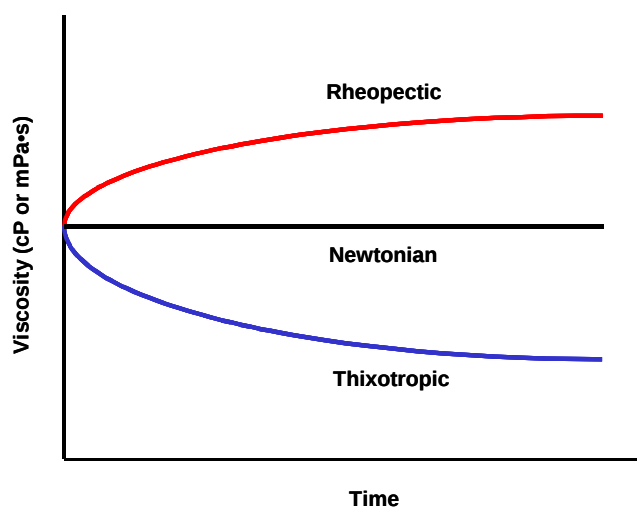


Figure 13. Time under constant shear rate

In **Figure 14** the viscosities of some common gums are compared over a range of shear rates relating to specific functions or processes. At low shear rates, solutions of xanthan gum have approximately fifteen times the viscosity of guar gum and significantly more viscosity than carboxymethyl-cellulose (CMC). This explains xanthan gum's superior performance in stabilizing suspensions. At about 100 1/sec, xanthan gum, CMC, and guar gum have similar viscosities. At shear rates above 100 1/sec, the viscosity of xanthan gum solutions drops sharply. This viscosity reduction has the benefit of making xanthan gum formulations easy to pump, spray, or spread.

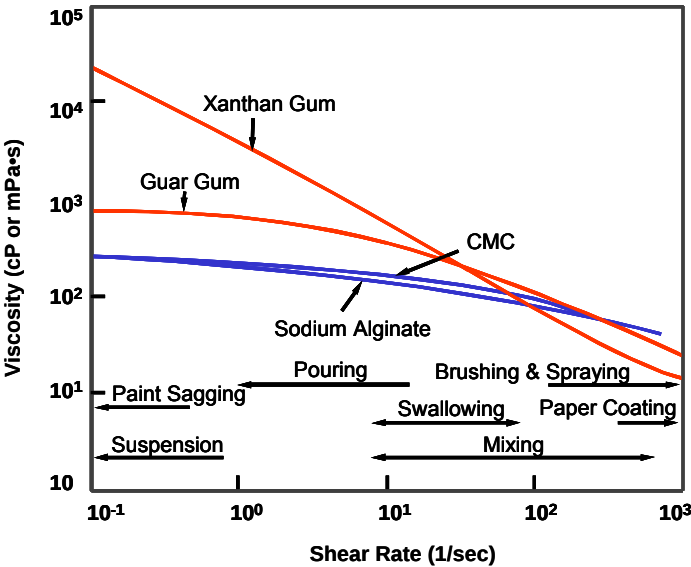


Figure 14. Effect of shear rate on the viscosity of 0.5% polymer solutions. Viscosity was measured with Rheometrics® Fluids Rheometer.

Viscoelasticity

Many materials possess both elastic (solid-like) and viscous (liquid-like) properties. Purely elastic solids deform under an applied stress; however, the deformation is completely recovered after the stress is removed provided the deformation is within the elastic limit of the material. Viscous materials flow under an applied stress, but this deformation cannot be recovered when the stress is removed. The rate at which the liquid flows is the deformation rate. Materials that exhibit intermediate behavior are termed viscoelastic. Xanthan gum solutions are viscoelastic. Because xanthan gum builds viscosity through inter-molecular association, as well as through molecular size, it is capable of suspending solids, yet still pours like a liquid. Most foods and industrial systems are viscoelastic to a certain degree.

The usual way to quantify viscoelastic properties is to measure elastic modulus (G') and viscous modulus (G'').

These are vector quantities phase shifted by 90°. A constant shear viscometer cannot differentiate between the viscous and elastic components, providing only apparent viscosity.

Figure 15 illustrates elastic and viscous moduli for two fluids. Both fluids will have the same steady-shear viscosity because the resultant vector of the two moduli is the same magnitude (same length in diagram). True viscoelastic measurements reveal the fluids are actually quite different. The elastic fluid derives a much greater proportion of its apparent viscosity from its elastic modulus. Conversely, the viscous fluid derives most of its viscosity from its viscous modulus. The elastic fluid would more effectively suspend insoluble particles or stabilize an emulsion.

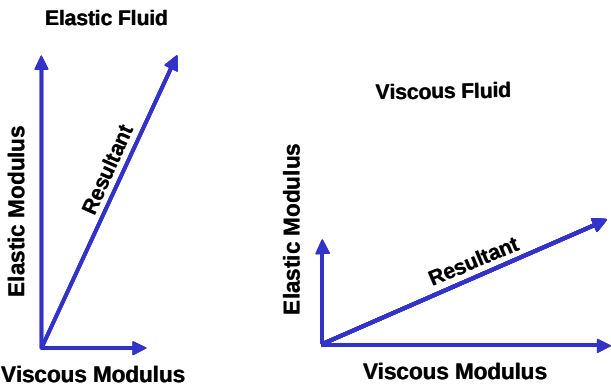


Figure 15. Elastic and viscous moduli for two fluids with the same measured viscosity

To measure these two quantities separately, a specially designed rheometer applies a sinusoidally varying strain, or deformation, to the sample. A transducer measures the resulting stress or force. For materials that are highly elastic, such as xanthan gum solutions, the stress and strain sine waves are in phase or nearly in phase. For mixture samples that are perfectly viscous, such as oils, the stress and strain will be 90° out of phase. Both characteristics are shown in **Figure 16**. Instruments commonly used for viscoelastic measurement include those made by Rheometrics Scientific, TA Instruments, Bohlin, Physica, Hacke and others.

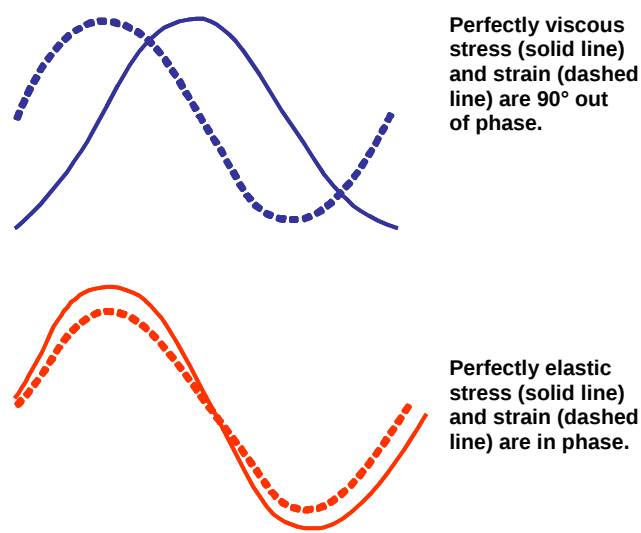


Figure 16. Viscous and elastic responses to an applied strain

The importance of elastic modulus is illustrated in **Figure 17**. Its data show how the elastic modulus changes with varying frequencies (similar to shear rates for the steady-shear samples). At low deformation rates, xanthan gum has 300 times higher elastic modulus than guar gum, and the difference is even greater between xanthan gum and the other gums. The more efficient and effective suspending properties of xanthan gum result from its high elastic modulus.

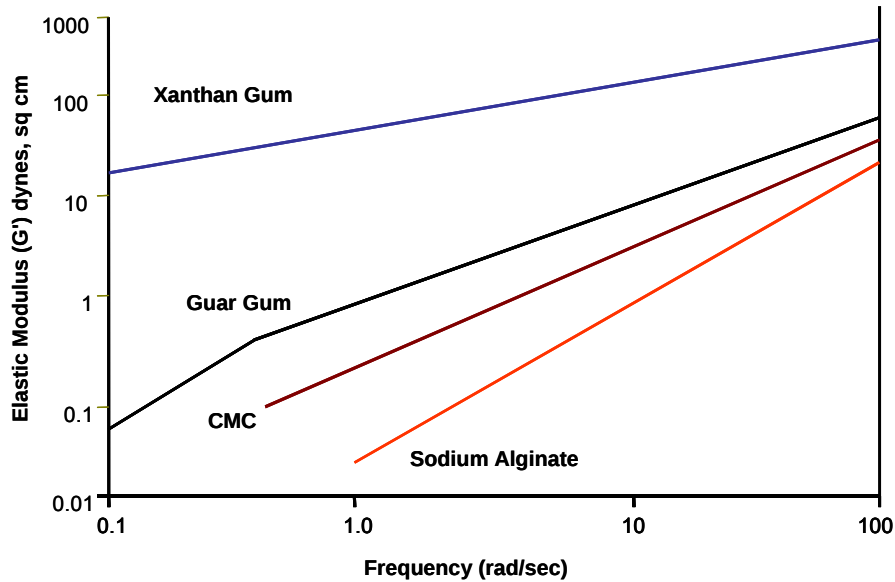


Figure 17. Elastic modulus versus frequency for various gums at 0.5% concentration, measured in standardized tap water

IV. Compatibility of Xanthan Gum Solutions

Xanthan gum solutions have excellent compatibility and stability in the presence of many chemicals, including enzymes. The data below illustrate xanthan gum’s compatibility with a variety of natural and synthetic materials. The concentrations shown are not necessarily the compatibility limits.

Acids

Xanthan gum dissolves in many acid solutions, although high shear mixing may be required to obtain full hydration. It is therefore recommended to dissolve xanthan gum in fresh water before adding acid. The compatibility of xanthan gum with mineral acids depends upon the type of acid and its concentration. The limiting concentration for any specific application depends on the formulation.

In the presence of most organic acids, the stability of standard xanthan gum is excellent. At elevated temperatures, however, acid hydrolysis of the polysaccharide is accelerated and lower viscosities result.

Table 4 shows the stability of xanthan gum in several organic and mineral acids at ambient temperatures.

Table 4
Compatibility and Stability of Standard Xanthan Gum Solutions with Acids

Acid	Acid concentration	Xanthan gum concentration	Viscosity retained
Acetic acid	20%	2%	100%
Citric acid	20%	1%	75%
Hydrochloric acid	5%	2%	80%
Phosphoric acid	40%	2%	100%
Sulfuric acid	10%	2%	80%
Tartaric acid	20%	1%	75%

Bases

Xanthan gum is compatible with a variety of basic compounds: for example, 10% sodium hydroxide, 5% sodium carbonate, 5% sodium phosphate, 5% sodium metasilicate, and concentrated ammonium hydroxide. Glucoheptonate should be included to inhibit gelation caused by calcium and other polyvalent

metal ions under these alkaline conditions and to inhibit metal catalyzed base hydrolysis. **KELZAN® AR** is a modified industrial grade xanthan gum product with even better alkali compatibility.

Salts

Xanthan gum solutions are stable in the presence of most salts, as shown in Table 5. In many cases, compatibility is limited only by the solubility of the salt. However, for any specific application, the limiting concentration depends upon other formulation components and variables, such as pH and temperature. Under highly alkaline conditions, polyvalent metal salts (including those of calcium) cause gelation or precipitation. This incompatibility can often be controlled or prevented by adding sequestrants such as glucoheptonates. Xanthan gum has unusually good compatibility with most divalent ions. It is best to hydrate the xanthan gum in fresh water prior to adding salt. If this is not possible, use **KELTROL® BT**, which is specially process to hydrate into high salt or low pH environments.

Table 5
Compatibility of 1% Xanthan Gum Solutions with Various Salts

Salt	Concentration
Ammonium chloride	30%
Barium chloride	15%
Calcium chloride	20%
Cupric chloride	15%
Magnesium chloride	15%
Potassium chloride	15%
Sodium chloride	15%
Zinc chloride	15%
Diammonium phosphate	10%
Disodium hydrogen phosphate	10%
Sodium bisulfite	15%
Sodium carbonate	5%
Sodium citrate	15%
Sodium sulfate	10%
Sodium tetraborate	15%

Data are based on solutions of 1% xanthan gum; pH was adjusted to neutral with dilute sodium hydroxide or hydrochloric acid. Good stability was observed at these salt concentrations.

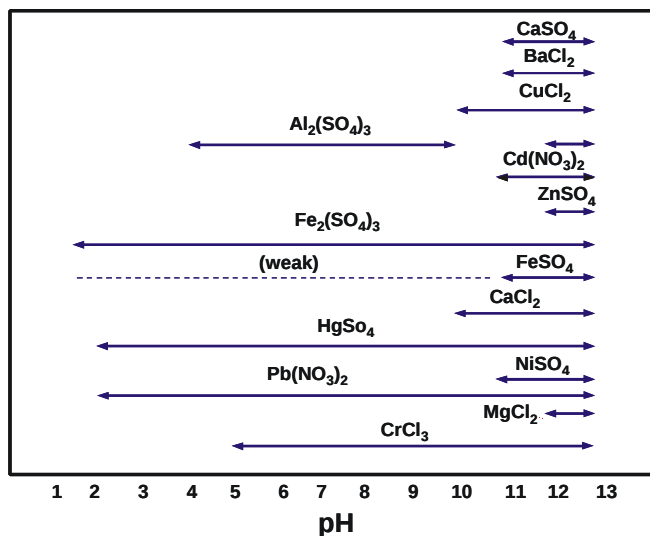


Figure 18. Xanthan gum interaction or gelation with polyvalent cations under different pH conditions

Figure 18 shows the pH range of xanthan gum reactivity for a number of metallic ions in solutions. The data were obtained with 1.0% xanthan gum solutions containing 0.5% metallic salt. The pH was adjusted with dilute sodium hydroxide or hydrochloric acid. No other additives were present, and gelation occurred within the pH boundaries noted for each ion.

In the presence of high concentrations of monovalent salts, gelation seldom occurs. Most divalent ions require a high pH for gelation, whereas trivalent ions may produce gels under neutral or even acidic conditions, depending upon the reactivity of the metal ion. The area of reactivity is specific for the metallic ion and xanthan gum concentrate involved; hence the type of anion seems to have little or no influence. Sequestrants normally have a greater affinity for divalent and trivalent cations than does xanthan gum, and thus can be used to control or prevent gelation with these ions. The presence of very low levels of borates (generally less than 300 ppm as boron) can cause gelation when other soluble salts are present. This can be avoided by increasing the boron ion concentration to above 300 ppm or by lowering the pH to 5 or below. The addition of ethylene glycol, sorbitol, or mannitol may also control this gelation.

Thickeners

Xanthan gum is compatible with most commercially available synthetic and natural thickeners. When xanthan gum is to be combined with cellulose derivatives, a special type of xanthan gum free of cellulase enzyme must be specified; other types may contain sufficient cellulase enzyme activity to depolymerize some cellulose derivatives. When xanthan gum is to be combined with starch in shelf-stable applications, a special type of xanthan gum,

free of amylase enzyme must be specified. Other types may contain sufficient amylase enzyme activity to break down starch.

Galactomannans

A synergistic interaction occurs between xanthan gum and galactomannans such as guar gum, locust bean gum, tara gum, and cassia gum. This interaction results in enhanced viscosity or gelation. Thus combinations of xanthan gum with galactomannans are valuable in applications where very high viscosity or gel formation is needed. All CP Kelco food-grade xanthan gum products and some specific industrial xanthan gum products are free of the hemicellulase enzyme that causes depolymerization of galactomannans.

Galactomannans are branched hydrocolloids, in which the mannose backbone is partially substituted by single-unit galactose side chains (Baker and Whistler 1975; Courtois and LeDizet 1966, 1970). The substitution pattern is not regular, and regions of the mannose backbone have no substituents.

Galactomannans with fewer galactose side chains and more unsubstituted regions react more strongly with xanthan gum. Thus locust bean gum, which has a mannose-to-galactose ratio of around 3.5:1, reacts more strongly with xanthan gum than does guar gum, which has a mannose-to-galactose ratio slightly less than 2:1.

It is assumed that the unsubstituted or "smooth" regions of locust bean gum are involved in the interaction. Xanthan gum contains disordered regions, and the gel that forms with locust bean gum comes from an interaction with these disordered regions. This results in a cross-linked, three-dimensional network. (These "smooth" or unsubstituted regions interact with the xanthan gum molecules shown in **Figure 19**.)

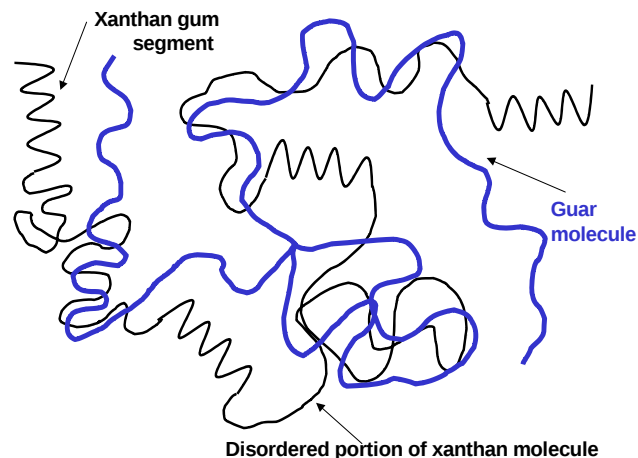


Figure 19. Schematic representation of the interaction between xanthan gum and galactomannan polymers

Elastic, cohesive gels are formed after combining approximately equal proportions of locust bean gum and xanthan gum at and above a total gum concentration of approximately 0.03% and then heating and cooling (Schuppner 1968). Below this concentration a synergistic viscosity increase occurs. The gel strength of xanthan gum/locust bean gum gels is highly dependent on the ratio of the two gums and on the pH of the gel system, as shown in **Figure 20**.

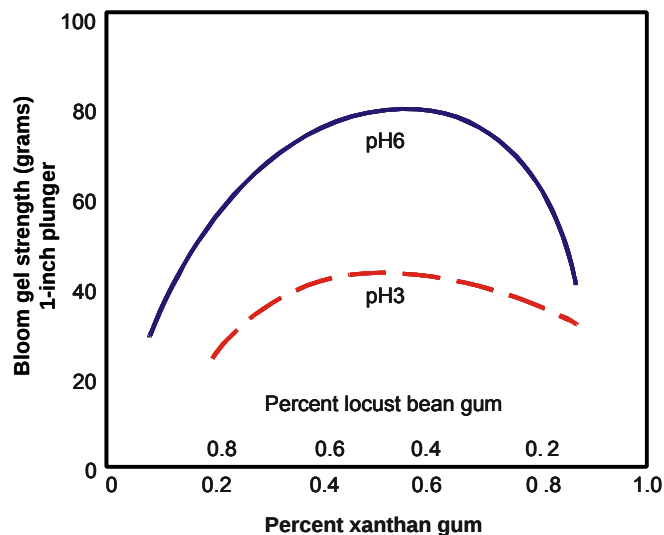


Figure 20. Gel strength of 1% xanthan gum/locust bean gum gel as a function of colloid ratio

Gels from xanthan gum and locust bean gum are elastic, cohesive, and non-brittle. Consequently, food product components such as proteins, starch, or other gums are usually included to produce a more desirable gel texture. Blends of xanthan gum and locust bean gum can be used effectively to modify the texture of agar, Kappa-carrageenan (Kovacs 1973) and gellan gum gels (Clark and Sanderson 1984). Cassia gum (Bayerlein et al. 1984) and tara gum (Glicksman and Farkas 1974) are structurally similar to locust bean gum and therefore interact with xanthan gum in much the same way. Xanthan gum can also modify the texture of konjak mannan gel, a glucomannan stereochemically similar to galactomannans (Dea et al. 1977).

Guar gum does not form gels with xanthan gum, but gives a synergistic increase in viscosity as evidenced by higher viscosities than predicted by theory for blends (**Figure 21**). The viscosity data were obtained by blending 0.5% solutions of the two gums at various ratios so that the total gum concentration remained constant. In some cases, a threefold synergistic viscosity increase was observed; however, the magnitude depends on many factors, such as pH and ionic environment. This synergism is most pronounced in deionized water and is reduced in the presence of salt (Clark 1987).

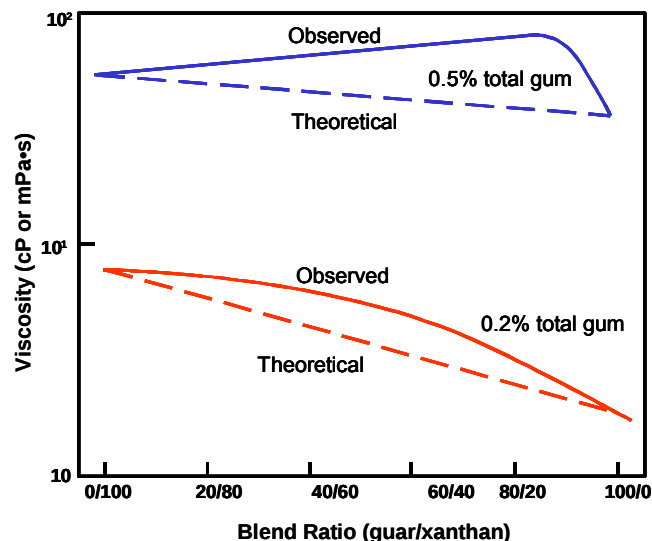


Figure 21. Theoretical (dashed line) and observed (solid line) viscosities for blends of guar and xanthan gum. Data were collected with Brookfield LVT viscometer using the 60 rpm speed at 25°C. The theoretical viscosity line comes from the assumption that non-interacting hydrocolloids will obey a log mean blending relationship.

Oxidizing and Reducing Agents

Strong oxidizing agents like persulfates, peroxides, and hypochlorites depolymerize xanthan gum. This reaction is accelerated by heat and is catalyzed by certain transition metals, such as ferrous ions.

Xanthan gum is generally stable in the presence of reducing agents.

Solvents

Aqueous solutions of xanthan gum will tolerate as much as 50% of water-miscible solvents. However, at higher alcohol concentrations, gelation or precipitation occurs. Examples of xanthan gum’s compatibility with organic solvents are shown in Table 6.

Table 6 Compatibility of 1% Xanthan Gum Solutions with Some Typical Solvents	
Solvent	Concentration
Acetone	20%
Glycerol	50%
Methanol	20%
Ethylene glycol	50%
Isopropanol	20%
Propylene glycol	50%
Benzyl alcohol	10%
Hexylene glycol	50%
Thiodiethylene glycol	50%
Triethanolamine	50%
Good stability is observed at the specified concentrations	

Surfactants

Xanthan gum is compatible with up to 20-40% nonionic surfactants. Anionic and amphoteric surfactants tend to salt out xanthan gum above a surfactant concentration of about 15-25%. Xanthan gum is an anionic polymer and therefore tends to be incompatible with cationic surfactants. This incompatibility can be controlled or prevented in certain cases by adding an electrolyte.

Xanthan gum has excellent compatibility with various concentrations of surfactants, as shown in Table 7. However, the compatibility should be tested under actual application conditions because other factors like the presence of acids, bases and salts may be influential.

Table 7 Surfactant Compatibility with KELTROL T Xanthan Gum at 0.25% wt Xanthan Gum in Standard Tap Water	
Upper Surfactant	Concentration
Sodium lauryl sulfate	20%
Ammonium lauryl sulfate	20%
Triethanolamine lauryl sulfate	20%
Ammonium laureth(3EO) sulfate	10%
Sodium lauryl polyoxyethylene(3EO) sulfonate	20%
Sodium C ₁₄ -C ₁₆ alpha-olefin sulfonate	15%
Sodium dodecyl diphenyl oxide sulfonate	5%
Sodium linear dodecyl benzene sulfonate	10%
Monosodium N-cocoyl L-glutamate	10%
Sodium lauroyl sarcosinate	5%
Disodium laureth sulfosuccinate	15%
Ammonium cocoyl isethionate	15%
Coco amido betaine	20%
Coco amidopropyl betaine	25%
Coco amidopropyl hydroxysultaine	25%
Lauryl dimethyl amine oxide	25%
Sodium N-lauroyl beta-iminodipropionate	10%
Linear alcohol ethoxylate(7EO)	25%
Linear alcohol ethoxylate(9EO)	30%
Secondary alcohol ethoxylate(7EO)	40%
Octyl phenol ethoxylate(HLB=14)	40%
Nonyl phenol ethoxylate(HLB=15)	40%
C ₉ -C ₁₁ alkyl polyglycoside	30%
Poly(oxyethylene)-20 sorbitan monostearate	5%
Ethylene oxide-propylene oxide block copolymer (HLB=19)	25%

V. Food Applications

In foods, xanthan gum provides stability and improves or modifies textural qualities, pouring characteristics and cling. In beverages, a slight increase in viscosity imparts the sensation of enhanced body without reducing flavor impact. Partially replacing high concentrations of starch in many food systems with xanthan gum contributes to a more pseudoplastic rheology. The benefits are improved flavor release and more pleasing texture.

The synergistic reactivity of xanthan gum with galactomannans further expands its application potential. Typical physical properties of **KELTROL® T** xanthan gum are shown in **Table 8**. Nutritional data are given in **Table 9**. **Table 10** lists CP Kelco’s broad range of xanthan gum products for food.

Table 8
Typical Physical Properties
of **KELTROL® T** Xanthan Gum ^a

Physical state	Cream to white powder
Mesh size	
Standard mesh	80 mesh (180 µm)
Fine mesh	200 mesh (75 µm)
Viscosity, 1% solution ^b in 1% KCl	1400 cP
Solubility	Hot or cold water
Moisture content	12%
Ash	10%
Color	70 minimum
Specific gravity	1.6
Bulk density ^c	40.0±5.0 lb/cu. ft.
Browning temperature	320°F (160°C)
Charring temperature	520°F (270°C)
Ignition temperature	†

^a CP Kelco Sales Specifications contain more detailed information.
^b 60 rpm, 25°C (77°F) Brookfield LVF viscometer, spindle 3.
^c 80 mesh product.
† Spontaneous combustion did not occur in an air environment.

Table 9
Typical Nutritional Data
for Food-Grade Xanthan Gum

All values are per 100 grams product, as supplied*	
Total calories	320
Total fat, g	0
Cholesterol, mg	0
Sodium, mg	860
Potassium, mg	2800
Total Carbohydrate, g	80
Dietary Fiber, g	80
Soluble fiber, g	80
Sugars, g	0
Other Carbohydrate, g	0
Protein, g	0
Vitamins:	0
Calcium, mg	140
Phosphorus, mg	160
Magnesium, mg	72
Moisture, g	12
Ash, g	8

*This product is not a significant source of any nutrients that are not shown above.

Table 10
Selected Xanthan Gum Products for Food Applications

	(All xanthan gum products meet FCC, NF and EU requirements)
Product	Description
KELTROL	Standard (80-mesh) xanthan gum with low dust and rapid hydration
KELTROL 521	Low-dust version of KELTROL
KELTROL F	Fine (200-mesh) xanthan gum. Suitable for systems such as dry mixes where rapid hydration is needed (but transparency is unnecessary) and the other ingredients aid dispersion.
KELTROL® T	Standard (80-mesh) transparent xanthan gum with low dust and rapid hydration
KELTROL T 622	Low-dust version of KELTROL T
KELTROL TF	Fine (200-mesh) transparent xanthan gum. Suitable for systems such as dry mixes where rapid hydration is needed and the other ingredients aid dispersion.
KELTROL BT	Brine tolerant xanthan gum for high salt systems of as much as 20% sodium chloride
KELTROL GM	Granular mesh xanthan gum to reduce dusting in pre-mix preparation and provide a slower hydration rate where a holding time in processing is desired
KELTROL RD	Readily dispersible xanthan gum for applications where ease of dispersion is required
KELTROL RD 576	Non-transparent version of KELTROL RD
KELTROL SF	Xanthan gum with modified rheology to provide "smooth flow" characteristics.
KELTROL 630*	High viscosity xanthan gum with improved acid stability. Hydrates well in the presence of salts and dilute acids.

* Not approved for sale in Europe

Note: **KELTROL** products (except **KELTROL 630**) comply with EC Directives 1829/2003 and 1830/2003. Some customers have set internal standards concerning the use of traceable non-GMO ingredients that exceed the requirements of these EC Directives. Our **KELTROL [E]** product line is designed to meet these special needs.

Following is a summary of the many food applications for xanthan gum or blends of xanthan gum and galactomannans and their related functions and benefits.

Batters – In wet prepared batters, xanthan gum reduces flour sedimentation, improves gas retention, imparts enzyme, shear and freeze-thaw stability, and provides uniform coating and good cling. In predusts, xanthan gum improves adhesion and controls moisture migration during frying. In pancake batters, xanthan gum improves spread control, volume, and air retention.

Baked goods – Xanthan gum contributes smoothness, air incorporation and retention, and recipe tolerance to batters for cakes, muffins, biscuits and bread mixes.

Baked goods have increased volume and moisture, higher crumb strength, less crumbling and greater resistance to shipping damage. Xanthan gum improves volume, texture and moisture retention in refrigerated doughs, reduced-calorie baked goods and gluten-free breads.

Bakery and pie fillings – Adding xanthan gum to either cold- or hot-processed bakery and fruit pie fillings improves texture and flavor release. The

added benefits in cream and fruit fillings include extended shelf stability, freeze-thaw stability and syneresis control.

Beverages – Xanthan gum in dry-mix beverage bases provides enhanced body and quality to the reconstituted drink, along with rapid viscosity development. In addition, it uniformly suspends fruit pulp in prepared drinks to improve product appearance and texture.

Confectionery – Marshmallow toppings containing xanthan gum retain uniform air-cell structure throughout the products' shelf life. Xanthan gum/locust bean gum blends improve manufacturing efficiency of starch jelly candies by accelerating setting time.

Dairy products – Blends of xanthan gum, carrageenan, and galactomannans are excellent stabilizers for a range of frozen and chilled dairy products: ice cream, sherbet, sour cream, sterile whipping cream and recombined milk. These economical blends provide

optimal viscosity, long-term stability, improved heat transfer during processing, enhanced flavor release, heat-shock protection and ice-crystal control.

Desserts – Xanthan gum improves structure, provides greater stability during storage, and controls syneresis in desserts like puddings, mousses and flans.

Dietetic foods – Xanthan gum, as a partial replacement for starch, is an excellent bodying and texturing agent for reduced- and low-calorie foods. Low use levels ensure that the desired textural properties can be obtained without excessive gumminess or impaired flavor release. Blends of xanthan gum and galactomannans provide a greater range of textural variations.

Dressings – Xanthan gum's stability to acid and salt, effectiveness at low concentrations, and highly pseudoplastic rheology make it the ideal stabilizer for pourable no-oil, low-oil, and regular salad dressings. Dressings with xanthan gum have excellent long-term emulsion stability and a relatively constant viscosity over a wide temperature range; they pour easily but cling well to the salad. As a partial replacement for starch in regular and reduced-calorie spoonable dressings, xanthan gum imparts desirable body, texture, and freeze-thaw stability, as well as improved flavor release and eating sensation.

Dry mixes – Fine mesh xanthan gum provides rapid, high-viscosity buildup in cold or hot systems and yields excellent texture and flavor release. Fine-mesh xanthan gum permits easy preparation of desserts, salad dressings, dips, soups, milk shakes, sauces, gravies and beverages.

Flavor emulsions – Emulsions prepared with xanthan gum have excellent long-term stability, a smooth, pourable consistency and mix easily into products.

Frozen foods – Stability, syneresis control and consistent viscosity during freeze-thaw cycles and heating are achieved by adding xanthan gum to a variety of frozen products such as whipped toppings, sauces, gravies, batters, entrees, and soufflés.

Icings and frostings – Xanthan gum in icings and frostings imparts improved sheen and cling, better spreading characteristics, resistance to cracking, and protection from moisture migration and sugar crystallization.

Relish – The addition of xanthan gum to relish improves the drained weight and virtually eliminates the loss of liquor during handling. In portion-pack relish, xanthan gum keeps the relish and liquor uniformly distributed during fillings and prevents spattering.

Retorted products – Although xanthan gum provides stable high viscosity over a range of temperatures, this viscosity is temporarily reduced at retort temperatures, ensuring good thermal penetration in retorted foods. At the same time, xanthan gum's excellent viscosity recovery upon cooling provides a uniform, high-quality product. In retort pouch products, xanthan gum also improves filling and reduces splashing and fouling of the critical heat-seal area of the pouch.

Sauces and gravies – Low levels of xanthan gum provide high viscosity in sauces and gravies at both acid and neutral pH. Viscosity is also extremely stable to temperature changes and is maintained under a variety of long-term storage conditions. These sauces and gravies cling to hot foods and have excellent flavor release and appearance.

Syrups and toppings – Xanthan gum promotes ease of pouring and excellent cling to ice cream, fruits, and pancakes. Under refrigerated storage, syrups and toppings retain uniform consistency. Cocoa powder in chocolate syrups remains uniformly suspended. Frozen, nondairy whipped toppings and frozen whipped topping concentrates have firm texture, high overrun and excellent freeze-thaw stability.

VI. Personal Care Applications

The high viscosity of xanthan gum solutions at low shear rates effectively stabilizes the dispersed-oil phase and suspends insolubles such as pigments and zinc pyrithione (in medicated shampoos). Its shear thinning properties provide good lubricity and products containing it feel pleasant on the skin.

KELTROL[®] CG line of xanthan gum is tested to meet the purity criteria of the NF monograph. Xanthan gum improves the flow properties of shampoos and liquid soaps and promotes a stable, rich and creamy lather.

VII. Pharmaceutical Applications

XANTURAL[®] line of xanthan gum stabilizes suspensions of a variety of insoluble materials, such as: barium sulfate (for x-ray diagnoses), complexed dextromethorphan (for cough preparations), and thiabendazole. Other benefits are cling to vertical surfaces (for dentifrice products) and ease of swallowing (for syrups). Xanthan gum is playing an increasingly important role in pharmaceutical controlled release applications, where erosion of the tablet is the primary mechanism of release.

VIII. Oral Care Applications

KELDENT[®] xanthan gum is an excellent binder for all toothpastes, including gel and pumpable types. Its ease of hydration, excellent enzyme stability, and consistent viscosity help produce a uniform, stable product. Ribbon quality and ease of extrusion also are improved. This grade of xanthan gum is compatible with cellulosic binders. The salt tolerance of xanthan gum makes it the binder of choice for all dentifrice systems, particularly high-salt formulations such as anti-tartar and sensitive teeth toothpastes.

Table 11
Selected Products for Personal Care,
Oral Care and Pharmaceutical Applications

Product	Description
KELTROL[®] CG	Basic cosmetic grade.
KELTROL CG-T	Cosmetic grade. Solutions have similar rheology to those of KELTROL CG , and offer the additional benefit of being transparent.
KELTROL CG-SFT	Cosmetic grade. Solutions are less pseudoplastic (smoother flowing) than those of other KELTROL CG products. Solutions are transparent.
KELDENT[®]	For toothpaste applications.
XANTURAL[®] 180	Basic pharmaceutical grade.
XANTURAL 75	Fine particle size pharmaceutical grade. Recommended for sustained release tablets and reconstitutable suspensions.
XANTURAL 11K	Large particle size pharmaceutical grade. Virtually dust-free; excellent powder flow properties. Concentrated stock solutions (up to 5%) can be prepared by adding quickly to well stirred water.

Examples of personal care, oral care and pharmaceutical applications:

Hair Colors – Xanthan gum suspends pigments.

Lotions and Creams – Xanthan gum enhances oil-in-water emulsion stability and provides a light, silky skin-feel. Its properties are unaffected by salts and pH changes. The fact that the viscosity is little affected by temperature is particularly beneficial in sun care products.

Make-up – Xanthan gum suspends pigments and makes the product easy to apply to the face and eyes.

Shampoos – Xanthan gum prevents separation on storage of anti-dandruff agents (e.g., zinc pyrithione, selenium sulfide) and silicone conditioning agents.

Shower Gels – Xanthan gum makes the gel easy to apply from the package onto the hands and to rub on the skin. It enhances the quality of the foam. Xanthan is compatible with the surfactants used.

Toothpaste – Xanthan gum produces a glossy, relatively soft paste, which can be packaged in pump dispensers and laminated tubes. Xanthan is compatible with all normal ingredients, including baking soda and the salts used in pastes for sensitive teeth.

Sustained-Release Tablets – Xanthan gum is highly effective as a hydrophilic matrix polymer. This enables high dosage drugs to be formulated in tablets of a reasonably small size. When the tablet comes into contact with the stomach liquid, xanthan particles at the surface become hydrated. This creates a viscous layer through which the drug (if soluble) diffuses and is released. The viscous layer is relatively resistant to erosion and the penetration of liquid. This results in the drug being released over an extended period. A further beneficial feature of xanthan is that its properties are similar in gastric and intestinal fluids.

Oral Suspensions – Xanthan gum is used in ready-to-use and reconstitutable suspensions to reduce the sedimentation rate of the active ingredient.

Regulatory Status

After extensive investigation of xanthan gum's safety, efficacy, and composition, CP Kelco applied to the appropriate authorities in a number of areas of the world for food-use authorization.

The safety studies indicated no adverse effects from high-dosage ingestion of xanthan gum⁴. The Joint FAO/WHO Expert Committee on Food Additives has established an acceptable daily intake (ADI) of "not specified" (no quantitative limit) for xanthan gum⁵.

Below is a partial list of approvals for the use of xanthan gum. Space restrictions preclude a complete listing.

- U.S Food & Drug Administration food additive order for xanthan gum, 21 CFR 172.695⁶, It may be used in paper and paperboard in contact with aqueous and fatty foods (21 CFR 176.170)
- Canadian FDA Section 16, Table IV X.1
- The European Union list of food additives xanthan gum E-415⁷
- Japanese Specifications and Standards for Food Additives (JSSFA)
- **KELTROL**[®] is acceptable for use in Kosher and Halal foods, as labeled.
- **KELTROL** food-grade xanthan gum meets the purity criteria specified in the above approvals. In addition, it meets the requirements set forth in the Food Chemicals Codex, current edition.

XANTURAL[®] xanthan gum is manufactured to meet the requirements of the USP/NF for pharmaceutical excipients, the European Pharmacopoeia, and the Japanese Pharmaceutical Excipients.(JPE).

Most of the approvals for xanthan gum are quite broad; however, it is recommended that users review the specific applicable regulations before incorporating xanthan gum in any new formulations.

⁴ Woodard, Woodard, McNeely, Kovacs, and Cronin, Tox. and Appl. Pharm., 1973, pp. 30-36. Studies included chronic studies in rats and dogs, and a 3-generation reproduction study in rats.

⁵ Thirtieth Report of JECFA; WHO Technical Report Series #751 (1986).

⁶ Federal Register, 34, 3376 (March 19, 1969).

⁷ Annex I to directive 78/663/EEC.

IX. Industrial Applications

CP Kelco manufactures industrial xanthan gum products to meet formulation criteria such as long-term suspension and emulsion stability in alkaline, acid and salt solutions; temperature resistance and pseudoplasticity. See **Table 12**, which lists the typical physical properties of **KELZAN[®]** xanthan gum. In addition, a range of differentiated xanthan gum products designed to meet specific applications requirements has been developed.

These include a transparent grade to improve clarity of solutions, and a dispersible grade for low shear mixing conditions. **Table 13** is a partial list of the differentiated products currently available.

Enhanced Acid Stability

To compensate for an expected decrease in viscosity during storage of acid-based cleaners, manufacturers traditionally use higher concentrations of xanthan gum. **KELZAN ASX** was developed specifically for use in acid-based cleaners.

Unlike conventional xanthan gum products that lose effectiveness at low pH levels when used at lower concentrations, **KELZAN ASX** maintains viscosity on storage. With **KELZAN ASX** in the formulation, product shelf life is extended and use level is up to 30% lower than that of traditional xanthan gum.

Table 12
Typical Physical Properties of
KELZAN[®] Xanthan Gum

Physical state	Cream-colored powder
Mesh Size	40 mesh (381 µm)
Moisture content	12%
Ash	10%
Color	70
Specific gravity	1.6
Bulk density ^b	52.4 lb./cu. ft. (842 kg/m ³)
Browning temperature	320°F (160°C)
Charring temperature	520°F (270°C)
Ignition temperature	†
Viscosity ^a	1400 cP
1% solution in 1% KCl	
As a 1% solution (distilled water)	950 cP
pH	7.0
Surface tension	75 (dynes/cm ²)
Freezing point	32°F (0.0°C)
† Spontaneous combustion did not occur in air.	
^a 60 rpm, 25°C (77°F) Brookfield LVF viscometer, spindle 3.	
^b 42 mesh product.	

Table 13
Selected Xanthan Gum Products for Industrial and Animal Feed Applications

Product	Description
KELZAN [®]	Standard viscosity grade. (Use KELZAN T if transparent solutions are required.)
KELZAN AR	Less pseudoplastic (smoother flowing) solutions than other KELZAN products. Better compatibility with alkali than other KELZAN products.
KELZAN ASX	Better acid stability than other KELZAN products. (Use KELZAN ASX T if transparent solutions are required.)
KELZAN CC	Low cellulase activity. Recommended for products, which contain a cellulose ether.
KELZAN HP	Higher suspending power than other KELZAN products.
KELZAN RD	Virtually dust-free; excellent powder flow properties. Concentrated stock solutions (up to 5%) prepared by adding quickly to well stirred water.
KELZAN S	Disperses in water without lumping, even when the stirring is slow. (Use KELZAN ST if transparent solutions are required.)
KELFLO [®]	Food-grade for animal feed applications.

Xanthan gum products are used in a wide range of industrial applications. Some examples follow.

Agrochemicals – In pesticide suspension concentrates (flowables) xanthan gum prevents sedimentation on storage, thus ensuring an even distribution of active ingredient throughout the container. When added to water in the spray tank, the SC pours freely and mixes in well.

Animal Feed – In liquid feed supplements, **KELFLO**[®] food-grade xanthan suspends insoluble ingredients (e.g., minerals, vitamins, medications, fats), ensuring they are delivered uniformly. The supplements are easily mixed, pumped and poured. By varying the xanthan concentration, the viscosity can be adjusted to suit different feeding methods. The viscosity is little affected by changes in ambient temperature.

Carpet Printing – In jet printing processes for carpet coloration, xanthan gum can be used to thicken the print paste. It controls print definition and the penetration of paste into the pile. It is not degraded by repeated passes through the machine.

Ceramic Glaze – Xanthan gum prevents sedimentation on storage and controls flow during the application of glazes to tableware and sanitaryware.

Cleaners – Xanthan gum is used in many household, institutional and industrial cleaners, including toilet bowl cleaners (acidic), all-purpose cleaners (neutral) and oven cleaners (alkaline). The pseudoplastic rheology it imparts ensures that vertical and inclined surfaces are covered with an effective amount of cleaner. Xanthan enhances the shelf-life of cream cleansers by preventing the sedimentation of abrasive particles.

Fire-Fighting Foam – Xanthan gum is used in alcohol-resistant fire-fighting foam concentrates. It enhances foam stability and produces a film on the alcohol surface that prevents re-ignition. The compatibility of xanthan with high concentrations of surfactants is a key feature in this application.

Pigments and Minerals – Xanthan gum prevents sedimentation during shipment and storage of calcium carbonate, kaolin, talc and iron oxide suspensions. It is compatible with the dispersants used in these high solids systems. The suspensions are easy to mix and pump.

Process Chemicals – Xanthan gum prevents separation during storage of various emulsions and suspensions supplied to the process industries. The products include anti-foams, defoamers and biocides.

Surface Coatings – Xanthan gum is used in high-build and textured wall coatings to enhance shelf-life, facilitate application and prevent slumping, sagging and loss of texture definition. **KELZAN**[®] **AR** xanthan gum is used to thicken silicate paints.

Waxes and Polishes – Xanthan gum enhances the shelf-life and ease of application of metal polish, car polish and shoe cream.

Regulatory Status

In the United States, xanthan gum appears on the EPA's TSCA US: (TSCA) Toxic Substance Control Act inventory (CAS #11138-66-2)
EU: (EINECS) European Inventory of Existing Chemical Substances
JP: (ENCS) Japanese Inventory of Existing and New Chemical Substances
Australia: (AICS) Australian Inventory of Chemical Substances
Canada: (DSL) Canadian Domestic Substances List DSL
Korea: (ECL) Korean Existing Chemicals List
Philippines (PICCS) Philippine Inventory of Chemicals and Chemical Substances

Xanthan gum is exempt from the requirement of a tolerance when used in pesticide formulations (40 CFR 180.1001 [c] and [e]). **KELZAN**[®] xanthan gum meets purity requirements specified in the above regulations.

For specific applications and regulatory status please contact CP Kelco Regulatory Affairs.

X. Oil Field Applications

Fluids perform a variety of functions in drilling, work-over, and completion operations. Success of the fluid can be directly attributed to its viscosity at the shear rate of interest. While circulating, fluids are exposed to a wide range of shear rates, varying from less than one reciprocal second (1 1/sec) to greater than one hundred thousand reciprocal seconds (100,000 1/sec). Optimum fluid performance is achieved when viscosity is minimized at high flow rates (such as at the drilling bit) and when viscosity is increased at low flow rates (as in the annular region), and under static conditions.

In addition to providing optimal viscosity characteristics, xanthan gum regains structure when circulation ceases. This property prevents settling of particles and is unique among hydrocolloid polymers commonly used in oil field applications. Shear thinning viscosity profiles for several concentrations of xanthan are illustrated in **Figure 22**. These shear-thinning characteristics with extended power law behavior closely approximate the ideal viscosity profile for fluids used in the following applications.

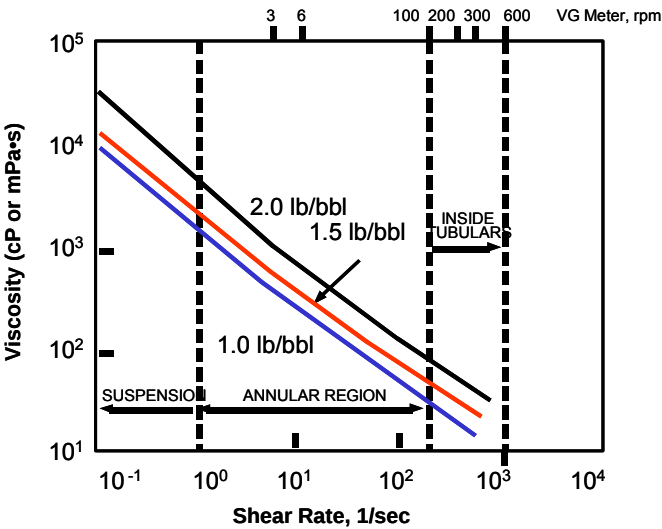


Figure 22. Xanthan gum viscosity profiles

Table 14
Selected Xanthan Gum Products for Oil Field Applications

Product	Description
KELZAN [®] XCD polymer	Premium dispersible form of xanthan gum for improved mixing in drilling fluids.
KELZAN [®] XC polymer	Xanthan gum for use as a viscosifier in drilling muds.
XANVIS [®]	Premium grade xanthan gum ideally suited for applications where preservation of payzone formation permeability is required, such as in workovers, completions, underreaming, and horizontal drilling fluids.
XANVIS [®] L	A premium-grade xanthan gum slurry designed to eliminate waste and improve polymer performance where good dry powder mixing equipment is not available, such as coiled tubing operations.
XANCO-FRAC [®]	Xanthan gum for use as a viscosifier and suspending agent in oil and gas well-fracturing applications.
ZANFLO [®]	Technical grade xanthan gum.
ZANFLO D	Technical grade xanthan gum, dispersible.

Xanthan gum products are used in a range of oil field drilling applications

Workover and completion fluids – The pseudo-plastic properties of fluids formulated with xanthan gum make it a highly useful additive for workover and completion operations. Other key features include its compatibility with most field-formulated brines, its temperature and pH stability, and its lack of shear degradation. It provides superior solids suspension, friction reduction and minimal formation damage.

Gravel packing – Carrier fluids formulated with xanthan gum improve the stability and durability of gravel packs. In addition, these fluids allow efficient gravel placement in deviated wells, improved slurry transport at high gravel concentrations, and superior suspension at low polymer concentrations. At the same time, xanthan gum-based fluids protect formation permeability.

Coiled tubing operations – Xanthan gum allows higher pumping rates by reducing friction-pressure losses in coiled tubing units. The increased flow rates allow solids to be removed more efficiently from the well. Field experience has indicated that xanthan gum can double the flow rates obtained with water and can often provide a 25-60% improvement over other polymers.

Hydraulic fracturing – Xanthan gum provides excellent visco-elastic properties for water- or acid-based hydraulic fracturing fluids. Its unique properties offer improved proppant suspension and maximum viscosity within the fracture without damaging fracture conductivity.

Enhanced oil recovery – Xanthan gum forms viscous, pseudoplastic fluids with superior mobility control for efficient fluid displacement in secondary and tertiary oil recovery processes.

Drilling fluids – The unique low shear rate viscosity of xanthan gum enhances the suspension properties of low colloid and bentonite-free fluid formulations. In addition, the pseudoplastic behavior of xanthan formulated systems provides optimum hydraulic efficiency of drilling fluids. It reduces pressure losses within the drill string, allowing maximum hydraulic power to be delivered to the bit. As a result, penetration rates can be increased. Other benefits from fluids formulated with xanthan gum include improved bottom-hole cleaning, increased cutting-carrying capacity under annular shear-rate conditions, and better separation efficiency in mechanical solids-control equipment. Because xanthan gum is compatible with most drilling fluid additives, it can be used in a wide variety of fluid formulations. These fluids include those with high pH, fresh water, and seawater, as well as electrolyte-inhibited systems containing dissolved electrolytes like calcium, potassium, and sodium. For special drilling applications, xanthan gum is also used to formulate stiff foams to improve stability and carrying capacity for drilled cuttings.

XI. Preparing Xanthan Gum Solutions

For optimal results, xanthan gum must be properly hydrated before use. Hydration depends on six factors:

- dispersion of the particles,
- agitation rate of the hydration medium,
- composition of the hydration medium,
- temperature,
- size of the particles,
- desired concentration.

To hydrate properly, the gum particles must be well dispersed. Otherwise, they tend to stick together during the mixing process and form swollen lumps (sometimes called "fisheyes"). Severe lumping prevents complete hydration and effective use of xanthan gum. Uniform dispersion of the gum in water is the key to rapid preparation of solutions. As shown in **Figure 23** a solution can be achieved in a few minutes when the dry powder particles are dispersed correctly.

CP Kelco offers certain products in low dust versions for applications where environmental dusting is a problem. One of these is **KELTROL® 521** xanthan gum, which also has improved dispersion characteristics. Please contact your CP Kelco representative if your needs require reduced dusting.

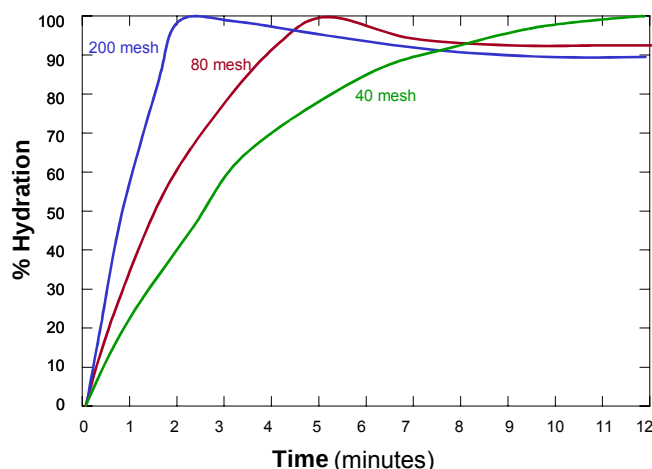


Figure 23. Hydration of xanthan gum solutions of various mesh sizes. Data taken on CP Kelco hydration rate tester with 1% gum dispersed in PEG, mixed at 600 rpm in 1%NaCl

Equipment Related Options for Hydrating Xanthan Gum

Eductor Funnel

Eductor funnels are highly effective at hydrating xanthan gum when operated properly. A certain amount of care is required to ensure that the funnel and powder tube remain dry so the powder does not become pre-wetted and plug the powder tube. Care must be taken to ensure that all of the gum is added before the available water has passed through the eductor. This can be problematic when dealing with formulations that are low in water content. This approach is attractive in that capital requirements are minimal. Labor requirements, however, can be high. This approach also tends to be less practical when the eductor has to be used with a large number of different formulations covering a broad range of gum concentrations. These units are not effective with hot water. Eductor funnels produce xanthan gum solutions at concentrations as high as 8%, but concentrations closer to 4% are more common.

Powder Funnels

There are a variety of hydration systems available that use essentially a pump impeller to draw powder into a chamber where it is mixed with water. These systems can be designed to effectively hydrate xanthan gum at concentrations up to 8%, although concentrations closer to 4% are more common. As with the eductor funnel, a certain amount of care must be taken to ensure that the powder funnel and feed tube remain dry. This approach is relatively inexpensive. The main drawback is that a fair amount of water is generally required. These units also tend to incorporate air into the product, and are also ineffective with hot water.

Bulk Mixers

It is possible to hydrate xanthan gum using a high-speed mixer, as long as the mixer is capable of creating a vortex. Care must be taken to slowly sift the gum into the vortex to prevent lumping. A vibratory feeder can be used to control addition rates. This approach is moderately capital intensive. The primary problem is that such systems are fairly unforgiving. If lumps do form, for one reason or another, they can be extremely difficult to break-up and hydrate.

High Shear Mixers

Perhaps the best method of mixing to assure complete hydration of xanthan gum is the use of a high shear mixer. Manufacturers of these devices include:

- Silverson
- Ross
- Scott Turbon Mixer, Inc.
- Arde-Barinco
- IKA
- Ystral
- Lightnin
- Premier Mill

High shear mixers are extremely effective at hydrating xanthan gum. Because of xanthan gum's excellent stability in response to mechanical forces, such mixers can normally be used without the risk of degradation or reduction of the solution's viscosity. These high shear mixers break down any lumps formed when the product was added. High shear mixers are highly recommended when hydrating xanthan gum into solutions containing salts or acids. In these ionic environments, a higher level of mix energy is often required to complete the hydration process. High shear mixers provide this additional mix energy and will assure full hydration in the shortest possible time.

Filterability of gum solutions can also be improved by using high shear mixing. High shear mixers are also useful where bulk mixing is inadequate. In this case the xanthan solution can be passed through an in-line re-circulation pump, preferably equipped with a rotor-stator device or static mixer to provide the additional mix energy required. One must ensure that the other components of the formulation won't be adversely impacted by the high shear. The main drawback to this approach is that it can be rather capital intensive, especially for larger mix tanks (>1,000 gallons).

Non-Equipment Related Options for Hydrating Xanthan Gum

Dry-Mix Dispersion

Quite often a formulation that includes xanthan gum will also contain ingredients like sugar or starch, which can be blended with the gum to facilitate dispersion. The gum particles can be separated by pre-blending the gum with these other ingredients. The blend of gum and the other dry ingredients is then slowly added to the vortex created by an agitator. Solution is completed in a matter of minutes. Salts can also be used, although these compounds will inhibit hydration rates.

Liquid-Mix Dispersion

Another way to improve dispersion is separating xanthan gum granules with non-solvents such as miscible, nonaqueous liquids (alcohols or glycols), or non-miscible liquids (vegetable oil or mineral oil). Compounds such as corn syrup can also be used in some instances.

Xanthan gum is slurried in the non-aqueous liquid and poured into water that is being agitated. Glycerin and propylene glycol dispersions should be used within a few minutes, because xanthan gum tends to solvate and swell in these liquids.

Dispersible Xanthan Gum Products

CP Kelco manufactures several products that are specially processed for ease of dispersion. An example is **KELZAN[®] S** industrial grade xanthan gum, which can be mixed with relatively low-shear equipment. **KELZAN S** does not hydrate rapidly unless triggered by the addition of alkali. Another example of readily dispersible xanthan gum is **KELTROL[®] RD** for food applications.

Improved Hydration Product

When hydration into high salt or low pH is required, high shear mixing is highly recommended to assure complete hydration of the gum. If high shear mixing is not available, **KELTROL BT** is recommended. This grade of xanthan gum is specially processed to hydrate directly into salt or low pH environments with much lower mix energy than is required with typical xanthan.

Preservation

Although xanthan gum is stable to most enzymes, microorganisms in the environment can degrade it. This degradation can easily be prevented with a suitable biocide or preservative, which should be added to solutions of xanthan gum held longer than 24 hours before use. The choice of preservative depends on factors such as formulation, type of microorganisms present, pH, and temperature. Contact your CP Kelco technical/sales representative for specific preservative recommendations.

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