

**Special Effects With Gums**

**By: Lynn A. Kuntz  
Editor**

**Y**ou might want to think of gums as the magicians of the food-ingredient world. Certainly, they can perform functional sleight of hand by changing a product's texture and viscosity. But a wide range of special effects can be obtained from gums - the trick is in knowing how to make them work their magic.

***Structure functions***

  Gums, or hydrocolloids, are mainly long-chain, straight or branched polysaccharides that contain hydroxyl groups than can bond to water molecules. (Gelatin, a polymer of amino acids linked with peptide bonds, is also often described as a gum since it functions in a similar manner.) These chains can consist of 2,000 to over 10,000 monosaccharide units. The sugar monomers can contain linked side units, or substituent groups, such as sulfates, methyl ethers, esters and acetals. Gums can be neutral or anionic (negatively charged). It is this structure - the type and number of monosaccharides and their configuration and the type, number and location of the linked groups - that gives each gum its particular characteristics.

  "The chemical nature dictates the type of gel or texture you get," says Florian Ward, Ph.D., vice president, research and development, TIC Gums, Inc., Belcamp, MD. Different structures of the ingredient known as carrageenan can create a brittle, sliceable gel or a soft, non-gelling texture. For this particular gum, "it depends on the number of anhydrogalactose sulfate units in the polymer. What happens is if there are too many of these units, the molecules lose their ability to associate."

  The chain length, or degree of polymerization (DP), influences a gum's viscosity and hydration rate. Longer molecules tend to produce higher viscosities and take longer to hydrate than shorter ones. A highly branched molecule takes up less space than a straight one with the same molecular weight, and therefore provides less viscosity. "As a hydrocolloid molecule becomes longer, it sweeps out a much greater volume as it randomly tumbles in solution, leading to increased collisions with its neighbors, which results in an increase in viscosity," says Andrew Hoefler, manager, food gums technical services, Hercules Incorporated, Wilmington, DE. Longer molecules are slower to hydrate because they first need to untangle from the adjoining molecules.

  The number of side units per unit length of the monosaccharide chain is known as the degree of substitution (DS). The more substitution, the more the chains are held apart from each other. Because this prevents them from forming hydrogen bonds, they hydrate more quickly. The uniformity of this substitution also affects a gum's behavior, says Hoefler. "A classic example of this even vs. uneven substitution is the comparison of guar gum vs. locust bean gum," he says. "Both gums are galactomannans, but locust bean gum is highly unevenly substituted. As a result, locust bean gum is not cold-water soluble - it will swell somewhat in cold water - while guar gum is cold-water soluble." This structure also allows locust bean gum to form a synergistic gel with xanthan gum and to moderate the brittle gel produced by kappa carrageenan. Guar does not have these effects.

  When the groups attached to the chains are only negatively charged, they repulse each other and cause the chain to elongate. Because of the increased length, these also show increased viscosity.

  Hydrocolloids' main effects result from their ability to bind water and/or form networks. "Visualize a hydrocolloid molecule as looking like a three-foot long, flexible piece of string," says Hoefler. "Now visualize a cylinder of water surrounding the string, to a distance of a half inch or so. This water is organized in the sense of being associated with the long, thin gum molecule, particularly at the hydroxyl groups along the polysaccharide chain, and will travel around with the gum molecule to some extent."

  In general, gums are used to influence texture and mouthfeel, as well as water-binding and stabilization of crystallization properties of ice cream and confectionery products, says Jim Skidmore, senior project leader, Danisco-Cultor, New Century, KS. They can control the distribution of particles in solution. "We can get a variety of different textures - from just a mouthfeel texture like you'll see in a diet soft drink, to a firm, hard gel used in confectionery products. Some actually form a gel, while others act as thickeners," he says.

***Rheol-logic***

  Thickeners are individual hydrated molecules that exhibit little interaction between the molecules. When gums thicken, they provide distinctive flow properties. The science of rheology is complex, but here's the "*Reader's Digest*" version as it applies to gums. Low-viscosity ingredients can exhibit flow characteristics that are nearly Newtonian; they exhibit a direct relationship between the shear stress applied and the shear rate. (If you plot shear stress vs. shear rate, it produces a straight line with a slope equal to the viscosity.) Most gums, however, exhibit non-Newtonian flow.

  Systems that do not flow immediately upon applying force or shear, but then begin to move after an initial force (yield value) is applied, are called plastic. Plastic solutions exhibit a linear increase in rate of shear. Systems that have no yield value but that do not show a linear relationship between shear stress and shear rate are called pseudoplastic, and exhibit shear-thinning - as shear increases, they become thinner and flow increases. The more pseudoplastic a gum solution is, the shorter, less slimy its texture. If this type of shear-thinning flow does not occur until after a yield value, it is called thixotropic. "Most food systems will be a thixotropic system," says Skidmore. "You'll find differences between gums in foods and gums in solution." Temperature also can affect the viscosity, and these changes may be reversible.

  Some gums do not merely thicken, but crosslink or otherwise join molecules using various types of bonds at junction zones to form a three-dimensional network called a gel. This forms a viscoelastic structure, often after cooling down from applied heat. Some gels are thermally reversible, that is, heat dissolves the gel. Others require reactive salts, such as calcium, to form a gel. The force to break a gel, known as gel strength, can be measured by various means. Thixotropic gums are thought to form a weak gel that is broken after applied shear reaches the yield point. If the junction zones expand with time, the structure contracts and therefore squeezes out the bound water, resulting in syneresis.

  All of this rheology is related to the structure of the molecules, and more importantly for food design, the effects produced in the finished product. For example, according to Jerry Conklin, development leader, Dow Food Stabilizers, The Dow Chemical Company, Midland, MI, different forms of methylcellulose differ in substitution, so they also differ in functional properties. "Typically as you add more and more hydroxypropyl groups, you get less and less gel strength and the gelling temperature goes up."

  Hydrocolloid choice is based on the functional properties required in the finished product, and the specific rheological characteristics help determine which hydrocolloid provides the necessary viscosity, elasticity or hardness. The gum must also stand up to processing.

  Thickeners might be used in sauces, dressings, beverages, soups and other applications that require a thickened liquid, or to physically bind water and provide humectancy in a fat-reduced product. A thermally reversible gel would be used in water- or dairy-based gel desserts, canned meats and some confectionery applications. Non-thermoreversible gels might find use in jellies and jams, gelled confectionery products and restructured foods. Both thickeners and gels can stabilize products by structuring water or by slowing the separation of emulsions.

  For example, certain products, such as salad dressings and sauces require cling as a needed attribute. "Cling is a function of adhesion, or 'stickiness,' and yield point," Hoefler says. "Yield point is the amount of force required to cause the transition of a gum solution from an elastic solid - at low shear rates - to a viscous liquid, at higher shear rates. You can think of a gum solution in this case as being a very soft gel rather than a thick solution, and as having some defined network structure at zero shear. As you begin to apply force to the gel, it flexes until the network is disrupted and true flow begins. Upon removal of the shear, the system starts to rebuild the gel network again, either over time or instantaneously. This network allows a relatively thick layer of water to remain on the surface of another food, which is cling."

  The structure of the gum molecules can be disrupted by various factors, which in turn affects their performance. They can be hydrolyzed by acid or enzymes, and heat can increase this effect.

  One common mistake when formulating with gums is considering their water-binding ability a method to significantly reduce water activity. "You need lots of moles per liter to reduce water activity, which is most easily done by dissolving lots of low-molecular-weight materials such as glycerin, fructose or salt into the water," Hoefler notes. "Gums are by definition higher-molecular-weight substances, and are not efficient at lowering the water activity. I think that gums are best described as water-organizing rather than water-binding."

***Synergy energy***

  Combining two gums (and sometimes combining a gum and a starch) can often result in a synergistic effect. For example, if a product designer mixes a 1% cellulose-gum solution with a viscosity of 3,000 cps with an equivalent amount of 1% guar-gum solution of 3,000 cps, one might expect the viscosity of this 50:50 mixture to remain at 3,000 cps. Instead, the actual viscosity will be around 5,000 to 6,000 cps. "This behavior is not restricted to any particular gums," Hoefler says. "Take any two thickening-type gums and combine them in solution, and you will get more viscosity than you would have otherwise predicted." He hypothesizes that this might be due to random collisions by the hydrated long-chain polymers of a thickener. "Take a gelling gum and combine it with a thickening gum, and the net result is usually additive, not synergistic," he points out. "I believe this is because the gelling gum sets up a network, rather than tumbling randomly, and the thickening gum simply helps to fill up the spaces in the network with its additional water-organizing capacity. There is less opportunity for those random collisions due to the more 'fixed' nature of a gel network."

  Generally, these synergies provide benefits, especially in the "more bang for the buck" category. They can also help form or moderate the texture a gum will produce. Occasionally, however, they might backfire. For example, combining gelatin and an anionic gum such as pectin or cellulose gum might not be a smart move: "At certain pH ranges, the two will irreversibly bind to each other and precipitate out of solution," warns Hoefler.

  One of the more interesting synergies, according to Skidmore, is the one that develops between an alginate and a high-ester pectin. "By using a blend, you can get it to gel under conditions that neither one would ordinarily gel under," he says. "Normally with a high-ester pectin you would need low pH and high solids. With an alginate, you'll need a calcium source and a higher pH, one above 4." By mixing these together, a gel will form in a pH range lower than needed for an alginate and higher than required for a high-ester pectin (in the 3 to 4 pH range) without the high solids or the calcium ions.

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| ***New Source for Gum Arabic Substitute***  Sugar beets and sugar cane might one day provide food processors with a new, domestically available alternative to gum arabic.  Alternan, an experimental ingredient developed by scientists with USDA's Agricultural Research Service, is a carbohydrate polymer consisting of glucose units obtained from beet and cane sugars. The key to alternan's production is alternansucrase, an enzyme produced by the bacterium *Leuconostoc mesenteroides* that breaks down sucrose into glucose. The glucose units are then synthesized into compounds with properties that vary according to structure.  Current forms of alternan mimic gum arabic's bulking action; it's hoped that further research will yield a form that replicates the gum's emulsifying properties. "Presently we're trying to develop new versions of alternan that will include small amounts of proteins," says Gregory Côté, a chemist at ARS's National Center for Agricultural Utilization Research (NCAUR) in Peoria, IL. Proteins are believed to give gum arabic much of its emulsifying capacity. When perfected, alternan is expected to cost about $3 per pound. Gum arabic, most of which is imported from Sudan, is subject to global trade pressures and can sell for more than $5 per pound.  ARS scientists hold patents on three alternan-related inventions, all of which are available for licensing. The agency is currently seeking industrial research partners to further investigate alternan's potential as a cost-effective food ingredient.  - **Pam Erickson Otto** |

***Classified information***

  Gums can be classified according to their structure or function, but are most often grouped together by their sources. Most are considered natural products, depending on how they arrive at their final form. The most widely used of the plant exudates is gum arabic, but gum tragacanth, gum karaya, and gum ghatti also fall into this category. Others are considered plant extracts, such as agar-agar, alginates, carrageenan, konjac and pectin. Guar and locust bean gum are seed gums. Microbial polysaccharides produced as microbial exudates include xanthan gum, curdlan and gellan gum. Cellulosics such as microcrystalline cellulose, methylcellulose and hydroxypropyl methylcellulose are not considered "natural." In addition, some products are derived from animal sources that because of their functionality are often considered gums, such as gelatin, and chitosan.

**Gum arabic** comes commercially from the *Acacia senegal* tree. It is used as an emulsifier, thickener and flavor encapsulator. Gum arabic contains small amounts of protein surrounded by beta-1,3-linked galactose units. It is very water-soluble, compatible with high solids and provides low viscosity.

**Gum karaya**, also known as sterculia gum, comes from the tree *Sterculia urens*. This complex polysaccharide has a molecular weight as high as 9,500,000. The low concentrations typically used in foods will hydrate in cold water to produce a thick gel, but heating is needed for levels above about 4%. It is acid-tolerant, but above pH 8.5 it becomes stringy.

**Gum tragacanth** is obtained from shrubs of the *Astragalus* species. It can hydrate slowly in cold water; heating speeds the hydration rate. Tragacanth is fairly stable over a wide pH range, down to about pH 2.

**Gum ghatti** is a complex polysaccharide that hydrates in cold water, producing a translucent gel.

**Agar-agar** is a polysaccharide derived from various species of red algae such as *Sphaerococcus, Euchema* and *Gelidium*, and contains sulfated galactose monomers. Agar forms gels at approximately 35°C, but once formed, does not melt below 85°C.

**Guar gum** is derived from the seed bean plant *Cyamopsis tetragonolobus*. This long-chain, linear molecule of beta-1,4-D-galactomannans with alpha-1,6-linked D-galactose has a molecular weight of approximately 1,000,000. Guar gum is a cold-water-soluble polysaccharide, and it hydrates easily to produce solutions with a high viscosity at low concentrations. The molecules exhibit interfacial binding which makes them true emulsifiers. Guar has viscosity synergism when combined with xanthan.

**Locust bean gum**, from *Ceratonia siliqua*, is a branched beta-1,4-D-galactomannan with a high molecular weight. This non-ionic polymer is only partially soluble in cold water; to fully hydrate, it must be heated. It works synergistically with kappa-carrageenan to form a rigid gel.

**Konjac**, a beta-1,4-glucomannan, is derived from the roots of the elephant yam (*Amorphophallus konjac*). It has a molecular weight of 200,000 to 2,000,000. It swells at room temperature, but shear and heat increase the hydration rate. It is considered a pseudoplastic viscosifier, and yields thermally irreversible gels, when set with alkali or heat, that are stable at pH 3 to 9.

**Alginates** are extracted from brown seaweed or kelp. Alginate is made up of the five-carbon polymers mannuronic acid and gluronic acid. In the presence of calcium ions, it forms thermally irreversible gels. The reaction can easily be varied to control speed of set and degree of setting. Alginate gels are heat-resistant and can be prepared at very low solids.

**Carrageenans** are linear sulfated galactans obtained from red seaweeds (*Rhodophyceae*), but since the carrageenan molecule has up to 1,000 galactose residues, it has many structures. These are usually defined as one of three main types: kappa, iota or lambda. Mu, nu and xi fractions have also been identified. These types have different gelling properties and protein reactivities, although they are stable over a wide pH range. Kappa carrageenans produce strong, rigid gels, especially in the presence of potassium ions, while gels made with iota are weaker, with less tendency toward syneresis. Although lambda carrageenans do not gel in water, they interact strongly with proteins to produce a pseudoplastic thickener.

**Pectin** is commercially extracted from citrus peels and apple pomace. It consists mainly of galacturonic acid and galacturonic acid methyl ester units that form linear chains. It is normally classified according to its degree of esterification - a pectin with at least 50% DE or greater is a high-methoxy (HM) pectin, while one below a DE of 50% is a low-methoxy (LM) pectin. The two types possess different properties; for example, low-methoxy pectin requires calcium to gel.

**Tara gum**, derived from the tara bush, *Caesalpinia spinosa*, is a galactomannan that structurally resembles guar and locust bean gums. It has a similar viscosity to guar and locust bean gum and shares many of the same characteristics with these gums. It is cold-water-soluble and acts synergistically with kappa-carrageenan and xanthan gum to increase gel strength.

**Xanthan gum** is a polysaccharide produced by *Xanthomonas campestris* bacteria. Xanthan gum develops a weak structure in water, which creates high-viscosity solutions at low concentration. The viscosity remains fairly constant from 0°C to 100°C. It is pseudoplastic over broad shear rate and concentration ranges, but imparts a stringy texture. Xanthan has excellent solubility and stability under acidic and alkaline conditions and in the presence of salts, and resists common enzymes. Guar and xanthan show viscosity synergy, and when combined with tara or locust bean gum, xanthan can form thermoreversible gels above certain concentrations.

**Gellan gum** is a gel-forming polysaccharide derived from *Pseudomonas elodea*. These gels are clear, heat stable, and set quickly with minimal refrigeration.

**Pullulan** is a natural polysaccharide produced from starch by a yeast called *Aureobasidium pullulans*. It is water-soluble, and forms strong, resilient films and fibers.

**Curdlan** is a beta-1,3-glucan produced by the microorganism *Alcaligenes faecalis* var. *myxogenes*. Its linear structure makes it resistant to heat and pHs between 2 and 10. Curdlan forms a retortable, freezable gel at both relatively high and low temperatures. At temperatures above 80°C, this gel is irreversible, and at temperatures below 60°C, the gel is reversible.

**Cellulose** is the most common polysaccharide, a polymer of glucose molecules linked by beta-1,4 linkages, and is the starting material for cellulosic gums.

**Microcrystalline cellulose (MCC)** provides a high degree of thixotropy, which results from the large number of colloidal microcrystalline particles formed by hydrolyzing cellulose. The network establishes a weak gel structure with a measurable yield point that is broken down by shear. Upon removal of shear, the gel structure re-establishes. MCCs are heat- and freeze/thaw stable, and stable from pH 4 to 11.

**Carboxymethylcellulose (CMC) gum**, or cellulose gum, is a sodium salt derived from purified cellulose. The long, negatively charged molecules produce a stable thickener that can also help stabilize protein against precipitation. CMCs form viscosity synergies with guar.

**Methylcellulose (MC) and hydroxypropyl methylcellulose (HPMC)** are cellulosic gums with methyl ether and/or hydroxypropyl groups. The molecules are soluble in cold water, but also exhibit a unique reversible thermal gelation effect, forming a gel with the application of heat.

**Gelatin** is a high-molecular-weight polypeptide derived from collagen from animal connective tissues. Gelatin is not a polysaccharide, rather a mixture of peptides used as a gelling, thickening and stabilizing agent.

**Chitosan** is a linear, water-insoluble glycan derived from crustaceans and other sources. It forms a tough, protective film. Chitosan gives various types of textures - it can both impart viscosity and form gels.

  With all the different products available, it can be difficult to determine which product or combination should be used in a particular application. "The most important (factors) are the pH and the soluble solids of the system. Then I would say the thermal-processing profile that the system encounters, the handling, packaging and final texture and functionality that is desired," says Skidmore.

  With pH, for example, each gum has a range where it works best. Once a gum encounters a system outside of that range, the effect varies. "Sometimes the guidelines for a certain pH are directed to a certain functionality," explains Skidmore. "With pectin, for example, if you want a gelled texture, there are only certain pH ranges that you can work in. But if you are just looking for viscosity, you can widen the pH where you get some effectiveness. At certain pH ranges you maximize the hydrogen bonding between the water and the gum. When you get out of those pH ranges, you have less hydrogen bonding happening, as much as you get the physical entanglement of the hydrocolloid."

  The composition of the matrix can also affect the gel. Skidmore notes that alginate can continue to pull the calcium out of a system and continue to gel over a long period of time. This can cause the gel to become gradually stiffer, or harden over a period of time. "That's why sequesterants are used with alginates, to control the gelling mechanism," he says.

  Some gums require a certain solids level to gel. Carrageenan can gel with little or no solids present, but "you'll never get that with HM pectin," warns Ward. "You need at least 55% soluble solids." If solids are too high, there may be competition for water during hydration. This is why the sequence of incorporation is important. She points out that these are high-molecular-weight ingredients, and therefore do not hydrate as readily as a smaller molecule, such as sugar.

  A gum's performance also depends on other factors, including level used, as well as hydration. "You might find that there is a critical mass - if you have the optimum level, you can get a gel," says Ward. "If not, the product won't gel. The temperature of hydration is also important." For example, locust bean gum requires temperatures of at least 85°C for full hydration. Some gums require high levels of shear for complete hydration.

***It's a good thing***

  Gums can help thicken products without the associated starchy mouthful or flavor-masking that starches sometimes create. "Gum systems, particularly with gelling agents such as pectin, gellan, gelatin and carrageenan, tend to provide better flavor release, less masking of flavor, than an equally thick or gelled system based on starch," observes Hoefler. "Part of this is due to the lower use levels of gums vs. starches. Gums are generally used in the range of 0.05% to 1.00%, while starches are usually in the 0.75% to 10.0% range. The higher concentration of starches tends to encapsulate or capture flavor molecules more readily than gums."

  Modifying mouthfeel is an important facet of hydrocolloid use, but it does go beyond thickening or adding body. Xanthan gum might come across as slimy due to its long, cohesive structure, which is unpleasant in certain applications. A kappa-carrageenan or agar can promote a stiff, even cuttable texture that might be appropriate in a dessert. But these effects need to be carefully weighed in the finished product. For example, "a brittle gel does not lead to succulence," says Conklin. "Think of a cooked egg white's texture; you'd never say it was juicy."

  Gums can give a thinner process viscosity, especially at higher process temperatures. This can give better heat transfer, easier pumping and more accurate filling. A gum's temperature-dependent gel might also lead to other special effects. "Agar is a very unique product," says Ward. "It gels at 35°C, but guess when it melts - 85°C. Very few gums do this. When you want a gel that is heat-reversible, but will not melt at high-temperature conditions, agar can be used." This might be of value in applications such as icings and confectionery products.

  Another temperature-related effect from specific gums is thermal gelation. This occurs as a result of the methyl substitution in methylcellulose gums, says Conklin. "The methoxyl group helps impart surface activity and film-forming ability. In fact, it's responsible for a number of its unique applications in food." These can be tailored to the unique characteristics of a specific product. "You can take an HPMC with a weak or soft gel, put it in a retorted soup after its cook step without a significant increase in viscosity," he says. "As you heat it up during retort, the gum does not solubilize well, in fact is insoluble, but as it cools down, it starts to hydrate. So when the consumer heats it up, it does provide thickening."

  Although most people think of gums as viscosifiers, they also can be added to bakery products to extend shelf life. This is due to their ability to bind water in higher-moisture products like breads and cakes. "We see increased functionality when alginates are used in tortillas," says Skidmore. "It helps them become more pliable. Pectin can also have some interesting effects in baked products."

  High-viscosity gums often add a gummy note. This is the consequence of adding a product with a high molecular weight. But companies can modify the structure of the gum molecule so that it instead delivers a lower viscosity and less gumminess. "We can take someone from a 100,000 cps grade to a 100 cps grade (methylcellulose), get all of the other attributes that its high-viscosity cousin gave, but without the viscous component," says Conklin. This means that, for example, in a restructured product that uses this gum for binding, you can maintain structure, moisture and succulence, yet prevent the product from sticking to the forming equipment. In particular, a new line of super-gelling methylcellulose works in this capacity.

  Certain hydrocolloids act as true emulsifiers, not just thickeners that slow the movement of the oil or water droplets. They possess hydrophilic/lipophilic balance (HLB) values just like traditional emulsifying ingredients. "Xanthan is not an emulsifier, but gum arabic is," says Ward. "It has an HLB value of 10 to 11. It contains both hydrophilic and lipophilic groups."

  Product developers also shouldn't ignore the potential nutraceutical or health benefits gums can supply. Many gums contribute to soluble-fiber content, although the levels needed for functional properties might be too low for label considerations in many applications. In addition, many of these products are acceptable for an "all-natural" label statement, particularly for the plant exudates and extracts. Both agar and carrageenan can serve as plant-based gelatin substitutes for vegetarian or kosher applications.

  With all of these benefits, it's no surprise that product designers look to gums when trying to achieve a special effect in foods.

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