A sticky business. Microbial polysaccharides: current products and future trends

Ian Sutherland

The ingredients list of many foodstuffs includes microbial polysaccharides. Ian Sutherland reveals the potential and applications of these polymers.

Many bacteria, yeasts and fungi can produce polysaccharides. Although much interest in these polymers is due to their role in infection or adhesion, some of them have proved to be useful industrial products which compete with plant and algal polysaccharides as well as synthetic products. While dextran was the first microbial polysaccharide to be commercialized and to receive approval for food use, several such polymers now have a variety of commercial uses. Surprisingly, some of the polysaccharides fetch relatively high prices. Only two, both bacterial polysaccharides, are currently employed in the food industry, except in Japan where all such polymers are regarded as natural products. If you read the labels on many manufactured foods on supermarket shelves or on the sachets of dressings you receive in planes, you will find many contain xanthan, a bacterial polysaccharide. This product is now very widely used by the food industries of Europe and North America and is produced in the US, UK and France as well as other countries.

Commercial production

Production of most microbial polysaccharides involves growth in stirred tank fermenters using media with glucose or sucrose as the carbon and energy source. Synthesis is often favoured by high C : N ratios. Because of the high viscosity of the fermentation broths, efficient mixing and aeration are required together with considerable energy input. Fed-batch fermentations may be preferable to the use of high initial sugar concentrations. After pasteurization of the broth, recovery by precipitation with iso-propanol is followed by drying and grinding to yield a fine powder. Filtration or centrifugation and other downstream processing add to the final cost.

Xanthan

Xanthan is a product from the plant pathogen *Xanthomonas campestris*. It has a cellulosic backbone on every second glucose residue of which a trisaccharide side chain is attached. This unusual structure confers physical properties to the polymer which are utilized in food and other industries. Xanthan is stable at both acid and alkaline pH and forms pseudoplastic dispersion in water. Relatively low polysaccharide concentrations produce highly viscous solutions and the viscosity does not change greatly on raising the temperature. The solutions are compatible with many other ingredients in food and give good flavour release. Xanthan is also a good suspending and stabilizing agent for oil/water emulsions such as salad dressings. Because of all these features and its inherent safety, xanthan received GRAS listing (Generally Regarded As Safe) for food use in the US after its initial discovery in the USDA laboratories in Peoria and its development by KELCO. Subsequently, the polysaccharide received approval in the EU.

Xanthan is also widely used in 'drilling muds' for lubricating the drill in oil exploration and development, playing an essential role in keeping us supplied with petrochemical products. The xanthan provides an excellent suspending agent for removing the rock cuttings released on drilling; it is also compatible with barites, used to counteract the high pressures of reservoirs. Xanthan solutions have also been proposed for enhanced oil recovery from depleted reservoirs in which fall in the initial pressure is compensated by pumping down solutions containing viscosifiers. Low oil prices preclude this usage at present.

Xanthan does, however, have a range of other industrial applications making use of its viscosifying and suspending capacity. Currently about 20,000 tonnes are produced annually for food and non-food uses in the US, UK and elsewhere in the EU and in other countries.

Two are better than one!

Xanthan does not form gels unless trivalent salts such as chromium or aluminium are added. However, if solutions are mixed with locust bean gum (another widely used food polysaccharide from seeds of the Mediterranean leguminous tree *Ceratonia siliqua*), heated to yield disordered solutes and then allowed to cool, gels can be formed with very low concentrations of total polysaccharide. Such mixtures are widely used in the preparation of manufactured foods and in the pet food industry. See how many of the products you buy contain both these polysaccharides listed on the label!

Gellan

The only other bacterial polysaccharide currently GRAS-listed is gellan, a product from *Sphingomonas paucimobilis*. It is an excellent gelling agent providing clear, brittle gels at a much lower concentration than agar. However, in its native state the polysaccharide carries various esters attached to the sugars and does not gel. These groups must be removed before it is commercially valuable and of course such a process increases the cost of production. As well as food use, gellan has been widely employed as a gelling agent in plant biotechnology under the trade name of gelrite or phytogel; it can also be used in place of agar in bacterial culture media. Other *Sphingomonas* isolates have yielded a family of polysaccharides which are closely related structurally. Although none of the others forms gels, they do yield highly viscous aqueous solutions and have been proposed for various industrial, non-food uses. Time will tell whether they prove to be commercially successful.

Costly and sticky!

Surprisingly, bacterial cellulose from *Gluconacetobacter xylinus* is a high-value product of biotechnology. Because of its purity and the orientation of its fibres, it can be formed into high quality audio membranes.

Maybe your audio system relies on bacteria for its sound quality! A Brazilian company has also found that bacterial cellulose in wound dressings promoted healing, reduced plasma loss and also appeared to maintain sterility. It suggested that such dressings, marketed under the name 'Biopol', were especially useful for burns victims and for those with extensive skin damage. Despite the apparent success of the procedure, this application does not yet appear to have been widely adopted.

The most expensive bacterial polysaccharide product is hyaluronic acid (HA). This polymer from '*Streptococcus epizooticus*' or related species is mainly employed for ethical products. It is identical to HA from the human and animal body and can substitute for animal HA previously used in eye or joint operations to replace the material lost during surgical manipulations. For this role, HA has to be of the correct mass and is much more costly to manufacture than products such as xanthan or gellan. HA is also an excellent hydrating agent which is incorporated into moisturizers for the cosmetics industry (look at the labels listing the ingredients), but whether the polysaccharide for this usage is currently of animal or bacterial origin is unclear.

Polysaccharides in health and disease

Some polysaccharides form integral components of vaccines, usually when coupled to a suitable protein. Thus, meningitis vaccines have been prepared in this way and multivalent polysaccharide vaccines have been formulated against *Streptococcus pneumoniae* and *Klebsiella* spp. However, these are expensive to prepare and only use very small amounts of material. Possibly of much greater significance is the role of certain microbial polysaccharides in tumour suppression and immune stimulation. A homopolymer named 'Scleroglucan' or schizophyllan, from several fungal species, appears to be very effective against some cancers when it is applied in the ordered, triple helical form. These β-linked glucans are therefore the subject of much current study and have already been tested clinically in Japan, proving effective against certain types of tumour. Dextran, although no longer used as a food ingredient, is the base from which the 'Sephadex' range of biochemical adsorbents is prepared.

Dextran solutions can also be used as a plasma substitute, being very poorly antigenic and having the correct physical properties.

What's new?

Although many researchers purport to have found polysaccharides 'of superior viscosity to xanthan', in reality few match the robustness of the *Xanthomonas* polysaccharide and few can maintain their physical properties in the presence of salts, at higher temperatures or extremes of pH. Most are unlikely ever to find a niche in the polysaccharide market place. Instead, several labs in the milk product sector are looking for new or improved polysaccharide production in Lactic Acid Bacteria (LAB). As these bacteria are already widely used in the production of fermented dairy products, the bacteria are already acceptable for food use. However, most only produce small amounts of polysaccharides. In Belgium, the Netherlands and Switzerland, as well as in the University of Huddersfield in the UK, researchers have recently published structures for many of these polymers, as well as determining the physiological conditions needed to enhance polysaccharide production. Currently, less is known about their physical properties and the ways in which they contribute to the texture and physical characteristics of fermented milk products. If research is successful, these products might well be used to extend or adjust the textures of many fermented milk products and would have the presumed advantage of being acceptable food ingredients. Some of these polysaccharides, as well as levans, are of interest because of their prebiotic or probiotic properties. Many of the most recent studies in the LAB area were reported at a very successful meeting held last year in Brussels.

Current interest in glycobiology and the application of new analytical methods has also stimulated academic research on microbial polysaccharides. However, there is a gap between our knowledge of the structure of polysaccharides and the ability to predict their physical properties, and thus their potential applications. Perhaps, given more time, that will come and we may see further developments in the applications field. For the moment, use of the biological properties and the potential food use of polymers from LAB appear to lead the race.

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ABOVE:
A culture of *Xanthomonas campestris* producing xanthan on a medium with a high carbon : nitrogen ratio.
PHOTO IAN SUTHERLAND

Further reading

De Vuyst, L. & Marshall, V.M. (2001). *Int Dairy J* 11(9): special issue on exopolysaccharides from lactic acid bacteria.

Sutherland, I.W. (1998). Novel and established applications of microbial polysaccharides. *Trends Biotechnol* 16, 41–46.

Sutherland, I.W. (1999). Microbial polysaccharide products. *Biotechnol Genet Eng Rev* 16, 217–229.