Impact of gums on the growth of probiotics

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INTRODUCTION
Gums are complex polysaccharides extracted from sources such as endosperm of plant seeds, plant exudates, sea weeds, bacteria, and animal sources (1, 2). Gums are polymers with hydrophilic ability due to the presence of a hydroxyl bond. The composition and structure of gums enable gums to imbibe large amount of water forming a gel, which makes gums useful in the food industry. Gums are used as stabilizers improving viscosity and texture by preventing “wheying off” (3). Gums have also found usefulness in other industries, namely pharmaceutical, cosmetic, paint, ink, paper, color, and adhesive industries (4).

A number of polysaccharides are used as prebiotics to promote growth and viability of lactic acid bacteria (LAB) in dairy products (5) already exist with inulin and fructooligosaccharide (FOS) being the most recognized (6-9). A prebiotic is defined as a “non-digestible food ingredient that beneficially affects the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon, and thus improves host health” (6). These health benefits include reinforcement of gut mucosal immunity, decreased risk associated with mutagenicity and carcinogenicity, alleviation of lactose intolerance, acceleration of intestinal mobility, hypocholesterolemic effect, reduced duration of diarrhea, prevention of inflammatory bowel disease, prevention of colon cancer, inhibition of Helicobacter pylori and intestinal pathogens, and treatment and prevention of allergy (10). Though gums are known to improve texture of food, limited studies have been conducted using gums to enhance growth and viability of probiotics. Thus, the aim of this review was to provide general information about common gums used in different food applications and to introduce a new application of gums as possible functional ingredients to promote the viability of probiotics in food products.

TABLE 1. Main chemical composition of algal, plant, and exudates gums.

<table>
<thead>
<tr>
<th>Gum</th>
<th>Composition</th>
<th>Main Chain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Furcelluran</td>
<td>Galactose, D-galactose, 2, 4, or 6 sulfated, 3, 6-anhydro-D-galactose</td>
<td>Galactan</td>
</tr>
<tr>
<td>Carrageenan</td>
<td>(kappa) D-galactose-4-sulfate</td>
<td>Galactomannan</td>
</tr>
<tr>
<td>Alginate</td>
<td>Gluconic, mannuronic acid</td>
<td></td>
</tr>
<tr>
<td>Agar</td>
<td>D-Galactose, 3, 6-anhydro-D-galactose</td>
<td></td>
</tr>
<tr>
<td>Locust bean gum</td>
<td>Mannonse, galactose</td>
<td>Mannonse</td>
</tr>
<tr>
<td>Fenugreek gum</td>
<td>Mannonse, galactose</td>
<td>Mannonse</td>
</tr>
<tr>
<td>Flaxseed gum</td>
<td>Glucose, xylose, galactose, rhamnose</td>
<td>Xylan</td>
</tr>
<tr>
<td>Tara gum</td>
<td>Mannonse, galactose</td>
<td>Mannonse</td>
</tr>
<tr>
<td>Psyllium</td>
<td>Xylose, arabinose, rhamnose</td>
<td>Galacturonic</td>
</tr>
<tr>
<td>Guar gum</td>
<td>Mannonse, galactose</td>
<td>Mannonse</td>
</tr>
<tr>
<td>Pectin</td>
<td>Galacturonic acid, rhamnose</td>
<td>Galacturonan</td>
</tr>
<tr>
<td>Tamarind gum</td>
<td>Glucose, xylose, galactose</td>
<td>Glucan</td>
</tr>
<tr>
<td>Quince seed gum</td>
<td>Galactose, arabinose, xylose</td>
<td>Galactose</td>
</tr>
<tr>
<td>Cassia gum</td>
<td>Mannonse, galactose</td>
<td>Mannonse</td>
</tr>
<tr>
<td>Plant Exudates gum</td>
<td>Galactose, fructose, xylose, arabinose</td>
<td>Galactan</td>
</tr>
<tr>
<td>Gum tragacanth</td>
<td>Galactose, rhamnose</td>
<td>Galacturonic</td>
</tr>
<tr>
<td>Kamy gum</td>
<td>Galactose, rhamnose</td>
<td>Galacturonan</td>
</tr>
<tr>
<td>Gum arabic</td>
<td>Xylose, arabinose, rhamnose, glucuronic acid</td>
<td></td>
</tr>
<tr>
<td>Gum ghatti</td>
<td>Arabinose, galactose</td>
<td>Galactan</td>
</tr>
</tbody>
</table>

*Williams and Phillips, 2000, Piotr Tomasik, 2004
Plant gums

Guar gum
Guar gum is obtained from the seed of Cyamopsis tetragonolobus. It is a straight chain galactomannan with a manno:galactose ratio of 1.6:1. Its flour is used in the production of noodles, jellies, and as a texture modifier and thickener (16). It has a molecular weight of 200,000 to 2,000,000 Da. Konjac swells at room temperature but shear and heat increase the hydration rate. It is considered a pseudoplastic viscous fluid, and yields thermally irreversible gels that are stable at pH 3 to 9 when set with alkali or heat (15).

Locust bean gum
Locust bean gum, also a galactomannan, is extracted from carob seed, Ceratonia silqua. It has a molecular weight of 400,000 to 1,000,000 and is comprised of long chains of galactose and mannose. It consists of a D-mannopyranosyl backbone with attached D-galactopyranosyl units in a 4:1 ratio giving rise to synergistic activities with carrageenan. Locust bean gum is similar to guar gum in structure but the uneven side chain distribution makes it less soluble and less viscous, thus forming a weaker gel. Though locust bean gum swells at room temperature, its solubility is enhanced with higher temperature (60 to 90°C). Locust bean gum contributes water binding property, smoothness, body and chewiness to frozen desserts, speeds up curd formation in cheeses, and acts as a binder in sausages, salami, and bologna (13).

Cassia
Cassia is produced from the seeds of leguminous plants (Cassia tora and Cassia obtusifolia). It consists mainly of high molecular weight (~ 200,000-300,000) polysaccharides composed of galactomannans. The mannose:galactose ratio is about 5:1. Cassia gum is insoluble in ethanol but disperses well in cold water and forms colloidal solutions. Cassia forms a firm viscoelastic gel with xanthan at 40°C and with sodium borate at the pH of 9 and above (fao.org). It is used as a thickening agent in dry soups and seasonings, water retention agent in baked products, and texture improvement in meat and poultry products. Cassia is also used as an emulsifier, foam stabilizer, and texturizing agent.

Tara gum
Tara gum is obtained by grinding the endospem of seeds of Caesalpinia spinosa. Tara gum is structurally characterized as a galactomannan, and is similar to guar and locust bean gums, two other galactomannans. It consists of a linear chain of (1→4)-β-D-mannopyranose units with α-D-galactopyranose units attached by (1→6) linkages with a ratio of mannose to galactose being 3:1 (14). Tara gum possesses some unique properties, making it ideal for use in stabilizer blends for dairy foods such as frozen desserts, cream cheese, and cultured products (15).

Konjac
Konjac is extracted from the tubers of Amorphophallus konjac. Konjac has been cultivated for centuries in Japan. It is a β-(1→4) linked polysaccharide composed of a D-lyxose and D-mannosyl backbone lightly branched, possibly through β-(1→6) glucosyl units (3). The mannans:galactose ratio is 1.6:1. Its flour is used in the production of noodles, jellies, and as a texture modifier and thickener (16). It has a molecular weight of 200,000 to 2,000,000 Da. Konjac swells at room temperature but shear and heat increase the hydration rate. It is considered a pseudoplastic viscous fluid, and yields thermally irreversible gels that are stable at pH 3 to 9 when set with alkali or heat (15).

Probiotics
Pectin
Pectin is obtained from the cell walls of plants. Pectin consists of chains of 300 to 1,000 galacturonic acid units joined linearly with α-1→4 linkages. The degree of esterification affects the gelling properties of pectin. The neutral side-chains in the pectin molecule form weak non-covalent bonds and hinder gel formation. The structure of pectin has three methyl ester join to every two carboxyl groups; hence it has a 60% degree of esterification called a DE-60 pectin. Pectin gel formations are complex and are mostly influenced by factors such as pH, Ca2+, and soluble solids, which vary in their in their effect on gelling process of different pectin types. Pectin is used in fruit preservation and in jellies, and jams preparations.

Inulin
Inulin is a natural plant-derived polysaccharide obtained mostly from the Compositae family including chicory, dahia, and Jerusalem artichoke (17). Inulin is also produced by microorganisms such as Streptococcus mutants, and fungi belonging to the Aspergillus family. Chemically described as a-D-glucopyranosyl-[β-D-fructofuranosyl](n-1)-D-fructofuranoside, inulin is a polymer of fructans consisting of linear carbon chains. Generally, inulin has chain length with 2-200 glucose attached subject to the species. It has much larger degree of polymerization ranging from 10,000 to 100,000 (17). Biochemically, inulin is inert, non-toxic, and soluble in water. Inulin and fructooligosaccharides are the best studied prebiotics for their bifidogenic activity in the intestine (6). Inulin has β-(2-1) glycosidic bonds that make it indigestible by humans but digestible by certain microorganisms living in the gut that have inulinase activity including lactobacilli. The non-digestible nature of inulin in the digestive system makes it a prebiotic which enhances growth of a healthy gut flora that in turn produces bioproducts which suppress colon cancer development. Inulin also has several food and pharmaceutical applications (17).

Algal and microbial gums
Carrageenan
Carrageenan is a group of polysaccharides extracted from seaweeds (Rhodophyta). Carrageenan is made of polysaccharides which are linear sulfated galactose polymers with a size of 400-600 kilodaltons. Like other gums, varieties of carrageenan are grouped according to their composition and functionality. There are three commonly known types of carrageenan, namely; kappa (κ), which is made up of about 25% sulfate ester groups and about 34% anhydro-galactose; iota (ι) constitutes about 32% sulfate ester groups and about 30% anhydro-galactose; and lambda (λ) which comprises 35% sulphate ester groups and no anhydro-galactose (18). According to Bixler (19), these chemical differences confer varying functionality as well. K-carrageenan is soluble and forms a hard brittle gel that is converted by heat at low temperature. ι-Carrageenan, on the other hand, is soluble at lower temperature and forms soft, elastic gels. λ-carrageenan is non-gelling and soluble in cold water (19). These three types of carrageenan are extracted traditionally from Irish moss, Chondrus crispus. Of major importance to food are κ and λ-carrageenan (19).
**Alginate**

Alginate is a polysaccharide extracted from different seaweeds (Macrocytis pyrifera, L. digitata, or L. saccharinana). They are composed of chains of β-D-mannuronic and α-L-guluronic acids attached with 1→4 linkages (20). Though insoluble in water, alginates are able to readily absorb water. Alginate is used as a gelling and thickening agent. The sodium salt of alginic acid, sodium alginate, is used in the food industry to increase viscosity and as an emulsifier. Alginate is used in combination with carrageenan, locust bean, or xanthan and gellan gum in microencapsulation to enhance the viability of probiotics. Alginites are used in food products such as ice cream, mousse, and in slimming aids where they serve as appetite suppressants. Alginites have a wide range of applications in food, drug delivery, tissue engineering, cell encapsulation, and transplantation (20).

**Xanthan**

Xanthan is produced through fermentation by microorganisms, Xanthomonas campestris (21), found on cruciferous vegetables such as cabbage and cauliflower. Xanthan is made up of a β-D-glucose backbone with every second glucose unit attached to a trisaccharide consisting of mannose, glucuronide acid, and mannose. The mannose closest to the backbone has an acetic acid ester on carbon 6, and the mannose at the end of the trisaccharide is linked through carbon 6 and 4 to the second. Xanthan gum is used extensively in the food industry because it is soluble in cold and hot water, highly viscous at low concentrations, and stable, and provides good freeze-thaw stability (21). The negatively charged carboxyl groups on the side chains cause the molecules to form very viscous fluids when mixed with water. Xanthan gum is used as an emulsifier, a thickener for sauces, prevents ice crystal formation in ice cream, and a fat replacer in food (22).

**Agar**

Agar is a water-soluble, gel-forming polysaccharide extract from agarophyte members of the Rhodophyta, composed of repeating agarobiose units alternating between 3-linked β-D-galactopyranosyl and 4-linked 3,6-anhydro-α-L-galactopyranosyl units (23). This disaccharide may be marked or modified in a number of ways by substitution of hydroxyl groups with sulfate hemiesters and methyl ethers in various combination, and more rarely with a cyclic pyruvate ketal as 4,6-O-[(R)-1-carboxethylidene] acetal and sometimes by additional monosaccharides (23).

**Gellan**

Gellan gum is a polysaccharide with a high molecular weight produced as a fermentation product by a pure culture of the microbe Sphingomonas elodea which is then recovered with isopropyl alcohol (USDA.gov). Its structure consists of four linked monosaccharides, including one molecule of rhamnose, one molecule of glucuronic acid, and two molecules of glucose (USDA.gov). The molecular formula of gellan gum varies depending on different factors. Gellan gum is a water soluble, off-white powder with molecular weight greater than 70,000 Da. It forms gels when positively charged ions are added. Gellan gum is highly temperature resistant. Its thickening property can be manipulated to give impact on texture by adding potassium, magnesium, calcium, and/or sodium salts. Gellan gum has numerous uses in dairy products, bakery fillings, confections, dessert gels, frostings, icings and glazes, jams and jellies, low-fat spreads, microwavable foods, puddings, sauces, structured foods, and toppings (24).

**Curdlan**

Curdlan is produced by pure culture fermentation from a nonpathogenic and nontoxicogenic strain of Agrobacterium biobar (identified as Alcaligenes faecalis var. myxogenes) or Agrobacterium radiobacter. It is a high molecular weight polymer of glucose, β-(1→3)-glucan. This water-insoluble polysaccharide has an unusual property of forming an elastic gel when its aqueous suspension is exposed to heat (25). The linear structure of curdlan makes it resistant to heat and pH between 2 and 10. Curdlan forms a retortable, freezeable gel at both relatively high and low temperatures. At temperatures above 80°C, this gel is irreversible; however, at temperatures below 60°C, the gel is reversible. Curdlan powder can be stored for a long period, and, nutritionally, it is an inert dietary fiber (25).

**Plan exudate gums**

**Gum arabic**

Gum arabic, the oldest and best known of all natural gums, originates from exudate of trees of Acacia senegal. Gum arabic is made up of arabinose and galactose in a 1:1 ratio. It is a branched, neutral or slightly acidic, complex polysaccharide obtained as a mixed calcium, magnesium, and potassium salt (26). The backbone consists of 1,3-linked β-D-galactopyranosyl units. The side chains are composed of two to five 1,3-linked β-D-galactopyranosyl units, joined to the main chain by 1,6-linkages. Both the main and the side chains contain units of α-l-arabinofuranosyl, α-l-rhamnopyranosyl, β-D-glucuronopyranosyl, and 4-O-methyl-b-D-glucuronopyranosyl, the latter two mostly as end-units. It also contains glycoprotein as a minor component (26). Gum arabic is used as a stabilizer, thickener, and binder in the making of confectionaries, soft drinks, food flavorings, food sweeteners, and drugs (26).

**Gum tragacanth**

Gum tragacanth is an exudate extracted from leguminous shrubs of the genus Astragalus. The main chain is formed by 1,4-linked d-galactose residues with side chains of d-xylane units attached to the main chain by 1,3 linkages. The water-soluble tragacanthin is a neutral, highly branched arabinogalactan with a spherical molecular shape. Its structure probably consists of a core composed of 1,6- and 1,3-linked d-galactose with attached chains of 1,2-1,3- and 1,5-linked l-arabinose in a molar ratio of 3:52:29:6:5:5 (27). Gum tragacanth is less brittle and has a binding strength 8 to 10 times greater than that of gum arabic. It is slightly acidic and composed of tragacanthin, bassorin, starch, and cellulose (28). Gum tragacanth has a large molecular weight of 840,000 and forms strong gel at a lower concentration than gum arabic (29). Gum tragacanth solutions become thin at high temperatures but regain viscosity upon cooling. This characteristic indicates the non-degradable nature of the gum. Solutions of gum tragacanth have longer shelf lives than other gums (28).

**HEALTH BENEFITS OF GUMS**

The application of gums in the food industry as stabilizing and thickening agents is well known. Some gums also serve...
as prebiotics (inulin and fructooligosaccharides), which impact numerous health benefits for consumers. Guar and pectin have been found by many studies to lower blood cholesterol in individuals with mild to moderate hypercholesterolemia when their diet was supplemented with these gums (30). The high fiber level (80–85%) of guar gum has also made it an important ingredient in the development of functional foods capable of reducing plasma cholesterol and glucose levels and subsequently lowering the risk of cardiovascular disease and diabetics, respectively (31). Diets supplemented with gum arabic also showed elevated fecal nitrogen excretion and decreased urea nitrogen concentration in patients with chronic renal failure (31). A study conducted among rats with acute renal failure fed on diet supplement with gum arabic has shown an improvement in renal function (31). Inulin also induces production of a glucagon-like peptide (GLP)-1 hormone, stimulates insulin secretion, and suppresses appetite. Dietary inulin inhibits development of colon cancers in animal models. Dietary inulin has also been shown to have an immunomodulatory effect on the gut, increasing secretory immunoglobulin (Ig) A and interleukin-10 production, and decreasing the oxidative burst activity of blood neutrophils (32).

IMPACT OF GUMS ON PROBIOTICS

To create the required microbial balance that promotes health, there is a need to ingest and maintain a minimum amount of 10⁶ CFU/ml of probiotic cultures in food daily (33). Gums, like other polysaccharides, contain the necessary food ingredients that could support the survival of probiotics in food and subsequently in the gut creating gastrointestinal balance, and impacting intestinal and other health benefits (33-35). Several studies use other polysaccharides to enhance viability of probiotics. However, to our knowledge, there has not been a study to determine the impact of gums on viability of probiotics in dairy foods. A study conducted by Ghasempour et al. showed that zedo gum did not improve viability although minimum therapeutic level of 10⁶–10⁷ cfu/g was maintained. Inulin being a recognized prebiotic was reported in several studies to enhance growth and viability of probiotic bacteria (5, 7).

PRELIMINARY RESULTS

The impact of different gums on the growth of Lactobacillus reuteri was recently studied in our laboratory. In this study, batches of modified M17 broth were prepared with 0.5% (w/v) of one of the following gums: carrageenan, guar, carrageenan-maltodextrin, locust bean, pectin-dextrose, alginate, pectin, pectin-carrageenan, and inulin, sterilized at 121°C for 15 minutes and

Figure 1. Growth of Lactobacillus reuteri in the presence of different gums during incubation at 37°C for 16 hours.
allowed to cool to 42°C. Sterilized samples were inoculated with Lactobacillus reuteri strains at a final inoculum level of 3 log CFU/ml, incubated at 37°C for 16 h, serially diluted, and plated on MRS agar to obtain final bacterial counts. Our results showed higher bacterial counts in samples with gums compared to control (without gum). Bacterial population in the control sample increased from initial counts of 2.78 log CFU/ml to 7.16 log CFU/ml whereas samples with pectin increased from 3.3 log CFU/ml to 9.0 log CFU/ml (Figure 1). The bacterial population in samples with carrageenan-maltodextrin also increased from 3.1 log CFU/ml to 8.9 log CFU/ml. This study therefore indicates that pectin and carrageenan-maltodextrin could enhance the growth of Lactobacillus reuteri and subsequently improve the quality of functional food.

CONCLUSION

Gums have been used in diverse ways in the food industry as stabilizing and texture enhancing agents while improving the organoleptic quality of food. These properties of gums have been the main focus of research over the years. Gums have also been found to comprise cellulose, starches, sugars, oxidation products of these materials, salts, minerals, and sometimes protein. In addition, gums can bind with water forming a gel, a structure that supports the stability and activities of probiotic microorganisms. These properties could make gums a good candidate as growth enhancer for probiotics. We studied the impact of different gums on the growth of probiotics and found that pectin and carrageenan-maltodextrin could be added to different food application to enhance the growth of Lactobacillus reuteri. However, with further research, gums could be used as prebiotics to promote the quality of functional food through maintenance of viability and functionality of probiotics in food products.

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REFERENCES AND NOTES