Fiber, Inulin and Oligofructose: Similarities and Differences

Barbara O. Schneeman
Department of Nutrition, University of California, Davis, CA 95616

ABSTRACT  The biological, chemical and physical properties of dietary fibers are associated with physiologic actions in the small and large intestine that have important metabolic implications for health. These properties of fiber include dispersibility in water, bulk, viscosity, adsorption and binding of compounds and fermentability. Dietary fructans share some of the properties of dietary fiber and thus are likely to have similar metabolic effects. Within the small intestine, properties such as dispersibility in water, bulking and viscosity are associated with slowing the digestion and absorption of carbohydrate and lipid and promoting nutrient absorption along a greater length of the small intestine. Both of these actions are related to cholesterol reduction and blunting of alimentary glycemia. Although fructans are dispersible in water and will provide some bulk because they are nondigestible in the small intestine, they do not appear to be associated with significant increases in viscosity. Thus one would predict that any immediate effects on alimentary glycemia or on cholesterol reduction are likely to be modest compared with more viscous polysaccharides. Fermentability and bulking capacity of nondigestable carbohydrates define an essential role of fiber in maintaining gastrointestinal health. Within the large intestine, carbohydrates that are not digested in the small intestine are available for fermentation by the microflora present. Carbohydrates that are dispersible in the aqueous phase are more readily digested by microbes. A large body of evidence indicates that dietary fructans are digested in the large intestine, resulting in an increase in microbial mass and production of short-chain fatty acids.  J. Nutr. 129: 1424S–1427S, 1999.

KEY WORDS:  • dietary fibers • inulin • oligofructose

Consumption of foods rich in dietary fiber has been associated with reductions in plasma and LDL-cholesterol, blunting of the alimentary glycemic and insulin response, increases in stool bulk and improved laxation (Berger and Venhaus 1992, Cummings et al. 1992, Jenkins et al. 1978, Read and Eastwood 1992, Truswell and Beynen 1992). These physiologic responses to fiber consumption are the basis for associating high fiber diets with reduced risk of chronic diseases such as cardiovascular disease, diabetes and intestinal cancer. Dietary fiber is not digested by the enzymes in the mammalian small intestine; hence its effects on metabolism and disease risk are mediated through its chemical-physical properties as it passes through the gastrointestinal tract. These characteristics include the following: dispersibility in water or water-holding capacity, bulk due to nondigestibility, viscosity associated with certain polysaccharides, the ability to adsorb or bind bile acids and fermentability by microbes in the gut. Inulin and oligofructose are comparable to dietary fiber in that they are composed of multiple saccharide units, which are not digested by the enzymes found in the mammalian small intestine. This review will consider the similarities between dietary fiber and inulin and oligofructose on the basis of their effects on gastrointestinal function.

Small intestine

Within the small intestine, nutrients are digested and absorbed. The compounds and fluids in food are mixed with the secretions of the stomach, small intestine, pancreas and gallbladder. Although dietary fibers, as well as inulin and oligofructose, are not digested by the enzymes in the small intestine, their presence in the intestine may affect the physical characteristics of the gut contents. The water-holding capacity and nondigestibility of polysaccharides associated with fiber will directly affect the volume and bulk of small intestine contents. An increase in dry weight is directly related to the fact that, with consumption of fiber, nondigestible material is added to the small intestine, whereas the increase in volume of the small-intestinal contents is related to the water-holding capacity and viscosity of the polysaccharides in fiber (Ebihara and Schneeman 1989, Gallaher and Schneeman 1986, Schneeman 1982). Table 1 contains data from two studies and illustrates that the volume of the aqueous phase of the small-intestinal contents in rats fed guar gum or glucomannan was significantly higher than that of cellulose-fed rats. The high water-holding capacity of these two polysaccharides allowed this increase in volume. The ability to increase viscosity is a property associated with certain polysaccharides that have high water-holding capacity. These fibers are often referred to as soluble fibers, which typically refers to the fact that they are...
dispersible in water and increase viscosity. Not all polysaccha-
rides that can be dispersed in water become viscous, which is
important for understanding the variability in physiologic re-
sponses to different sources of fiber. Viscous polysaccharides
also slow the rate of gastric emptying, resulting in an overall
slower rate of digestion and absorption during the alimentary

The water-holding capacity, bulk and viscosity of fiber will
interfere with mixing of the intestinal contents and diffusion
of nutrients toward the epithelial cells or the absorptive sur-
face of the gut. These characteristics of fiber are associated
with a blunting of the insulin and/or glucose response to a
carbohydrate load and the slower disappearance of lipids from
the small intestine (Johnson and Gee 1981). These relation-
ships among the properties of fiber, small-intestinal contents
and their implications are summarized in Table 2. As confir-
mation of the importance of this relationship, Gallaher's lab-
oratory has reported the association of viscosity with chole-
terol reduction in hamsters (Carr et al. 1996, Gallaher and
Hassel 1995). Tietyen et al. (1995) demonstrated that hydro-
lysis of oat β-glucan reduces its effectiveness in lowering
hepatic cholesterol in cholesterol-fed rats. In a recent study we
demonstrated that reverse cholesterol transport can be en-
hanced in human subjects fed barley pasta enriched in β-gluc-
can (Bourdon et al. 1999). Presumably this enhancement of
reverse cholesterol transport is due to slower fat absorption in
barley-fed subjects and will contribute to the ability of barley
to lower plasma and LDL-cholesterol concentration when fed
long term.

Certain sources of fiber interact with bile acids and increase
their fecal excretion (Story and Furumoto 1990). A greater
excretion of bile acids contributes to the plasma cholesterol-
lowering ability of dietary fiber (Marlett 1997).

Inulin and oligofructose will share some but not all of the
properties of fiber in the small intestine (Table 3). They are
soluble in water and not digested by mammalian enzymes. As
a consequence, they may cause a slight increase in volume and
some increase in the dry weight of intestinal contents. Al-
though these properties may result in some effect on mixing
and diffusing within the small intestine, the overall effect is
unlikely to be very pronounced because in most cases, inulin
and oligofructose do not appear to increase viscosity signifi-
cantly. Several lines of experimental evidence illustrate the
importance of viscosity in understanding the metabolic re-
sponses to certain types of fiber. Thus for those physiologic
responses of fiber that are mediated through the small intes-
tine, the effect of inulin and oligofructose is likely to be
minimal, unless these compounds are modified in some man-
Dispersibility in water

Provides an aqueous phase for penetration of microbes

Increases microbial breakdown of polysaccharide structure

Physiologic implication

Increases microbial breakdown of polysaccharide structure

Provides substrate for microflora; aids laxation

Characteristic Effect on large intestine Physiologic implication

Dispersibility in water Provides an aqueous phase for penetration of microbes

Increases microbial breakdown of polysaccharide structure

Physiologic implication

Increases microbial breakdown of polysaccharide structure

Provides substrate for microflora; aids laxation

Bulk

Increases material entering the large intestine; affects mixing of contents

Excretion is increased; opportunity for microbial modification of bile acids

Adsorb/bind bile acids

Increases the amount of bile acids in the large bowel

Increases microbial mass and products of metabolism

Fermentability

Growth of microflora; microbial adaptation to polysaccharide substrates

Large intestine

In the large intestine, water and electrolytes are absorbed, and microbial action breaks down the macronutrients in the residual material that passes from the small bowel. The characteristics of dietary fiber that are likely to affect the large intestine and their physiologic implications are summarized in Table 4. Dietary fiber and undigested starch are the primary substrates for growth of the microflora in the large bowel (Cummings et al. 1992, Cummings and Englyst 1995). Thus the bulk associated with undigested residue contributes directly to stool bulk as undigested material or indirectly through the growth of microflora, which are a part of the stool weight. Originally it was thought that the water-holding capacity of dietary fiber was important for maintaining water content of stool and stool bulk. However, water content of stool is relatively constant at about 25%. The dispersibility of polysaccharides in water and water-holding capacity determine the ability with which microorganisms can penetrate the undigested food residue and gain access to the polysaccharides for metabolism (Stephen and Cummings 1979). Thus water-holding capacity has a relationship to stool bulk but primarily through its effects on the fermentability of polysaccharides.

Fiber sources with high water-holding capacity tend to be more readily degraded or fermented by microbes in the large bowel. For example, in the stool of rats, very little residual sugar from polysaccharide remains when animals are fed gums or pectins, but a higher level is present when they are fed wheat bran, a source of relatively insoluble polysaccharides (Nymann and Asp 1982, Nymann et al. 1986). In both cases, feeding the fiber source results in some increase in stool weight, but rats fed wheat bran have a significantly greater increase in stool weight than the ones fed more fermentable polysaccharides. Polysaccharides entering the large bowel are the primary substrates for fermentation and result in growth of the microflora or an increased microbial mass and production of products of fermentation, which include CO₂, H₂ and short-chain fatty acids (SCFA). SCFA, which include acetate, propionate and butyrate, are used as an energy source and appear to promote the health of the intestinal mucosa (Velázquez et al. 1997). Propionate has been reported to inhibit fatty acid, but not cholesterol synthesis in isolated hepatocytes (Nishina and Freedland 1990). Fatty acids synthesized in the liver are incorporated into VLDL. Further research is required to determine the role that propionate might have in triglyceride metabolism in human subjects consuming fermentable polysaccharides.

Because inulin and oligofructose are dispersible in water, they are likely to be readily degraded by microorganisms present in the large bowel. Table 5 summarizes the characteristics of inulin and oligofructose that might affect functioning of the large bowel. The fermentability of inulin and oligofructose provides a route by which they can increase stool weight because they would increase microbial mass in the colon. In addition, the fermentation can lower the pH of colon contents, and the production of SCFA is likely to affect the health of the intestinal mucosa. Further research is required to understand the effect that propionate production from fermentation of inulin and oligofructose might have on glucose and triglyceride metabolism. One of the more promising areas of investigation for inulin and oligofructose will be the effect of this fermentation relative to the distribution of microorganisms in the large intestine and the products of fermentation.

TABLE 5

Characteristics of inulin and oligofructose and their relationship to large intestine function

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Properties of inulin and oligofructose</th>
<th>Physiologic implication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dispersibility in water</td>
<td>Provide an aqueous phase for penetration of microbes</td>
<td>The solubility of inulin and oligofructose results in a high degree of fermentability and serves as an important route for these compounds to have metabolic effects. Increased microbial mass aids laxation, and production of short-chain fatty acids may affect glucose and triglyceride metabolism.</td>
</tr>
<tr>
<td>Bulk</td>
<td>Increase material entering the large intestine</td>
<td></td>
</tr>
<tr>
<td>Adsorb/bind bile acids</td>
<td>Compounds do not appear to increase bile acid excretion</td>
<td></td>
</tr>
<tr>
<td>Fermentability</td>
<td>Growth of microflora; microbial adaptation to polysaccharide substrates</td>
<td></td>
</tr>
</tbody>
</table>
**CONCLUSION**

A comparison of the properties of dietary fiber, inulin and oligofructose with respect to the characteristics that will affect gastrointestinal function is shown in Table 6. Differences in properties are based on the ability of certain polysaccharides to increase the viscosity of intestinal contents and the ability of some polysaccharides to bind compounds such as bile acids. Even within the category of compounds classified as dietary fiber, these characteristics vary among fiber sources and polysaccharide structures. For example, hydrolyzed guar gum or β-glucan are significantly less viscous than the intact molecules, and the hydrolyzed polysaccharides are less effective in reducing cholesterol levels. The characteristic that is common among dietary fiber, inulin and oligofructose is their nondigestibility by enzymes in the small intestine. In addition, most polysaccharides associated with dietary fiber, as well as inulin and oligofructose, can be fermented by microorganisms.

**LITERATURE CITED**


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**TABLE 6**

Dietary fibers, inulin, oligofructose: similarities and differences based on gastrointestinal function

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Dietary fiber</th>
<th>Inulin and oligofructose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dispersibility in water</td>
<td>Certain polysaccharides are dispersible in water</td>
<td>Soluble in water</td>
</tr>
<tr>
<td>Bulk</td>
<td>Nondigestible in the small intestine</td>
<td>Nondigestible in the small intestine</td>
</tr>
<tr>
<td>Viscosity</td>
<td>Certain polysaccharides become viscous in water</td>
<td>Typically nonviscous</td>
</tr>
<tr>
<td>Adsorb/bind bile acids</td>
<td>Some fiber sources will bind or adsorb bile acids and increase their excretion</td>
<td>Do not appear to bind bile acids</td>
</tr>
<tr>
<td>Fermentability</td>
<td>Polysaccharides with high water-holding capacity are fermentable</td>
<td>Highly fermentable</td>
</tr>
</tbody>
</table>


