

Perspectives in Practice

Low-Digestible Carbohydrates in Practice

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ABSTRACT

Low-digestible carbohydrates are carbohydrates that are incompletely or not absorbed in the small intestine but are at least partly fermented by bacteria in the large intestine. Fiber, resistant starch, and sugar alcohols are types of low-digestible carbohydrates. Given potential health benefits (including a reduced caloric content, reduced or no effect on blood glucose levels, non-cariogenic effect), the prevalence of low-digestible carbohydrates in processed foods is increasing. Low-digestible carbohydrate fermentation in the gut causes gastrointestinal effects, especially at higher intakes. We review the wide range of low-digestible carbohydrates in food products, offer advice on identifying low-digestible carbohydrates in foods and beverages, and make suggestions for intakes of low-digestible carbohydrates.

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Nutrition advice in the mass media uses terms such as *good*, *bad*, *simple*, *complex*, and *net carbs* to describe carbohydrates, and often promotes counting or cutting carbohydrates. How do registered dietitians (RDs) address carbohydrates? They can begin by recommending that carbohydrates comprise 45% to 65% of total energy intake (1). However, not all carbohydrates are equal with respect to nutrition and health effects. Therefore, recommendations have been made for specific types of carbohydrates: The Adequate Intake (AI) for fiber is 25 g/day for women and 38 g/day for men; added sugars should be limited to 25% of the total energy intake (1).

Considering that most Americans do not meet the AI for fiber (1), RDs often counsel clients to increase their intake of fiber as well as decrease their consumption of foods with added sugars, especially if clients need to lose weight or have other health conditions like diabetes. RDs promote fruits, vegetables, and whole grains as sources of fiber and suggest patients limit their consumption of convenience foods and other processed or refined foods,

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which are often high in added sugar and low in fiber. Consumers, however, want the benefits of a high-fiber, low-sugar diet without having to change their eating habits. The food industry has responded by adding low-digestible carbohydrates to various products to increase the fiber content and/or decrease the sugar content of these foods.

WHAT ARE LOW-DIGESTIBLE CARBOHYDRATES?

Low-digestible carbohydrates are carbohydrates that are incompletely digested and absorbed in the small intestine and are at least partially fermented in the large intestine (2). Products of fermentation include short-chain fatty acids and gases. As a result, they have lower energy contents than fully digestible carbohydrates like sucrose (approximately 1 to 3 kcal/g for low-digestible carbohydrates compared with 4 kcal/g for fully digestible carbohydrates). Some low-digestible carbohydrates occur naturally in foods; others are extracted from natural sources or synthesized and added to processed foods. Fiber and sugar alcohols are the two most prevalent types of low-digestible carbohydrate in the American food supply.

Fiber

Fiber is not digested in the small intestine but is fermented in the colon and/or excreted in feces. As defined by the Institute of Medicine, the term *fiber* includes non-digestible carbohydrates from plant and animal sources, carbohydrates that are not recovered by alcohol precipitation but are resistant to human enzymes (such as inulin and polydextrose), lignin, and resistant starch (3). Fiber that occurs naturally and is intact in foods is *dietary fiber*; nondigestible carbohydrates that have beneficial physiological effects and are added to foods after being isolated or extracted from natural sources or even synthesized are classified as *functional fiber* (3). Food manufacturers use fibers as bulking, stabilizing, and thickening agents (1,4). Inulin and fructo-oligosaccharide may be used as a fat-replacer and sugar-replacer, respectively (4), as well as for their prebiotic capabilities to stimulate the growth of beneficial intestinal bacteria such as bifidobacteria (5). Other fermentable carbohydrates also are known to alter the gut microflora (5). Generally, fibers do not add sweetness to foods.

Sugar Alcohols

Sugar alcohols (also called polyols) are used as sugar replacers for sugars like sucrose or high-fructose corn syrup and have a wide variety of food applications, from candy and gum to bakery and ice cream products (6). They are different from high-intensity sweeteners such

as aspartame or sucralose, which are used in very small amounts so that their contribution to the energy content of foods is negligible. The sweetness of sugar alcohols varies from 40% to 100% that of sucrose (6); sugar alcohols are used volume-for-volume like sugar. Although sugar alcohols are sweet, they are not true sugars. Chemically, they are hydrogenated sugars, so they have an additional hydroxyl group compared to a sugar. The hydrogenated monosaccharides (erythritol, mannitol, sorbitol, and xylitol) are absorbed more slowly than glucose; the linkages of the hydrogenated disaccharides (isomalt, lactitol, and maltitol) and hydrogenated polysaccharide (polyglycitol) are more resistant to human digestive enzymes than those in sucrose and lactose, and, thus, are digested and absorbed more slowly. Sugar alcohols that are not digested or absorbed in the small intestine enter the large intestine, where they are fermented or excreted in the stool.

WHAT SHOULD RDs KNOW ABOUT LOW-DIGESTIBLE CARBOHYDRATES?

As the prevalence of added low-digestible carbohydrates in the food supply increases, RDs must be knowledgeable about low-digestible carbohydrates.

Health Benefits

Consuming low-digestible carbohydrates may have beneficial health effects, including reducing the risk of chronic diseases or treating other health conditions. These benefits are related to their incomplete digestion, absorption, fermentation, and/or excretion. The AI for fiber is based on evidence that high intake of dietary fiber (especially cereal fibers) is associated with a reduced risk for coronary heart disease (1); other research has shown that fiber is associated with a reduced risk of diabetes (1). Certain fibers may improve laxation (cellulose, polydextrose, and psyllium), blood lipids (guar gum, pectin, psyllium, and resistant starch), and blood glucose responses (guar gum, inulin, beta glucans, pectin, psyllium, resistant dextrins, and resistant starch) (1). Fiber also delays gastric emptying and, thus, may decrease digestion and absorption as well as increase satiety, which may assist in weight maintenance, although more research is needed in this area (1).

Sugar alcohols provide approximately half of the energy per gram of fully digestible carbohydrates, so substituting foods made with sugar alcohols for high-sugar versions may help consumers reduce their energy intake and lose weight or maintain weight loss over time. Erythritol differs from other polyols in that it is absorbed, but yields only 0.2 kcal/g. In addition, sugar alcohols are noncariogenic and low-glycemic, so foods with these low-digestible carbohydrates may be appropriate choices for consumers, including those with diabetes (7). Like fiber, sugar alcohols can help normalize bowel function (7).

Gastrointestinal Effects

Because they are only partially (if at all) digested and absorbed in the small intestine, low-digestible carbohydrates can have a laxative effect and increase the ease and/or frequency of laxation. Any low-digestible carbohydrate

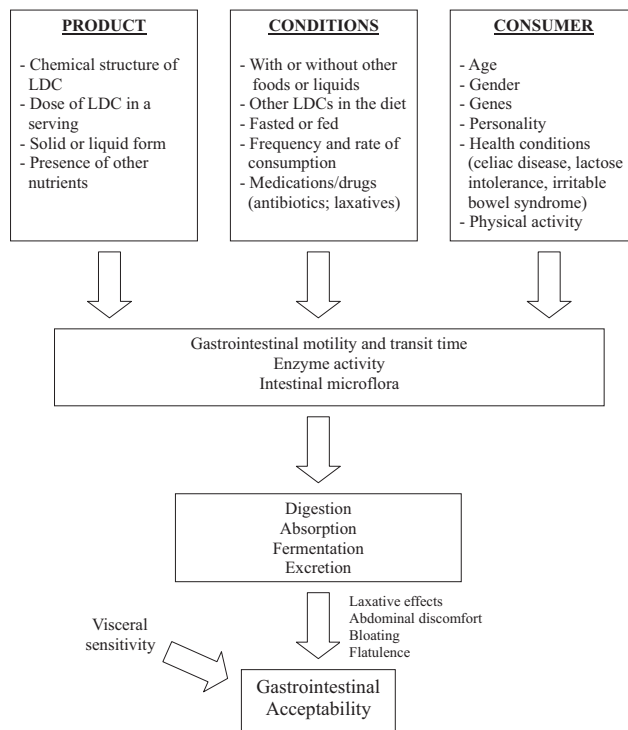


Figure 1. Factors that affect gastrointestinal acceptability of foods containing low-digestible carbohydrates (LDCs). Characteristics of the product containing low-digestible carbohydrates, conditions of consumption, and the consumer affect gastrointestinal motility and transit time, enzyme activity, and intestinal microflora, which affect digestion, absorption, fermentation and excretion. Changes in these processes may result in a laxative effect and other gastrointestinal symptoms, which determine the gastrointestinal acceptability of foods containing low-digestible carbohydrates.

that is not fermented is excreted and increases the bulk and water content of stools. Although the laxative effect of low-digestible carbohydrates may be desirable, excess intakes of fiber or sugar alcohols may cause diarrhea and other gastrointestinal symptoms such as flatulence, bloating, and abdominal discomfort (8). A large intake of sugar alcohols can cause osmotic diarrhea because water follows the undigested and unabsorbed carbohydrates into the large intestine; if time is inadequate for the intestinal cells to absorb the excess water, it will be eliminated in the feces. The dose of low-digestible carbohydrate that will have a laxative effect or contribute to other gastrointestinal symptoms depends on several factors related to the food and consumer (Figure 1). Such symptoms, though transient, may affect consumers' perception of well-being and their acceptance of foods containing low-digestible carbohydrates.

FACTORS THAT AFFECT THE ACCEPTABILITY OF LOW-DIGESTIBLE CARBOHYDRATES

The effects of low-digestible carbohydrates on gastrointestinal function and symptoms vary widely between individuals, and many factors affect the gastrointestinal

acceptability of foods containing low-digestible carbohydrates (Figure 1). These include characteristics of the low-digestible carbohydrate and food as well conditions of consumption and characteristics of the consumer. Modifying one or more of these factors could decrease or increase the potential for gastrointestinal side effects by affecting gastrointestinal motility and transit time, enzyme activity, and intestinal microflora, and these directly affect the degree to which low-digestible carbohydrates are digested, absorbed, fermented, or excreted. In general, low-digestible carbohydrates are best tolerated when they are consumed in solid foods with a meal by increasing the transit time of the low-digestible carbohydrates through the gastrointestinal tract; liquids may decrease acceptability by decreasing transit time (7,8). Consumers may find relatively large doses acceptable if they gradually increase the amount over time and divide daily intake into smaller portions throughout the day (8).

Clinical research studies have identified dose-dependent relationships between consumption of low-digestible carbohydrates and gastrointestinal effects. A review of studies reporting laxative and other gastrointestinal effects of various low-digestible carbohydrates concluded that nonstarch polysaccharides like guar gum, inulin, and fructo-oligosaccharides are generally well-tolerated at intake levels of 15 g/day (9). Polydextrose, a synthetic low-digestible carbohydrate that is used as a bulking agent, is tolerated at much higher doses of 50 g/day or more (10). Resistant starch is well-tolerated at doses of 45 g/day (11), although different resistant starches vary greatly in fermentability and may not all be this well-tolerated. The estimated acceptable intake of sugar alcohols ranges from 20 g/day for mannitol to 40 g/day for isomalt, maltitol, and polyglycitol (12). More research is needed to determine the gastrointestinal effects of combining various low-digestible carbohydrates and if such combinations have an additive or interactive effect.

SOURCES OF LOW-DIGESTIBLE CARBOHYDRATES

Dietary fiber occurs naturally in foods such as fruits, vegetables, whole grains, and legumes, but functional fiber and sugar alcohols are found in various other foods, from baked goods, dairy products, and snack bars to candy, ice cream, and gum. The fiber content in the US Department of Agriculture food composition database does not include inulin and oligofructose; the average intake of these low-digestible carbohydrates is approximately 5 g/day (1). Identifying foods that are sources of functional fiber and sugar alcohols requires careful reading of the ingredient list and Nutrition Facts panel on processed foods (Figure 2). The total amount of low-digestible carbohydrates per serving is found by adding the amounts of fiber and sugar alcohols, which are listed under *carbohydrates* on the nutrition facts panel.

RDs should go to the grocery store to familiarize themselves with the types and amounts of low-digestible carbohydrates available in various types of foods and specific brands, because these vary. This exercise will help RDs estimate the low-digestible carbohydrate content of clients' diets and recommend foods to include or limit, depending on a client's specific needs and health concerns.

Fiber ^a	Sugar Alcohols
Cellulose	Erythritol
Chitin and chitosan	Isomalt
Beta-glucans	Lactitol
- barley	Maltitol or maltitol syrup
- oats	Mannitol
Gums	Polyglycitol
- guar gum or partially hydrolyzed guar gum	Sorbitol
Hemicellulose	Xylitol
Polydextrose	
Inulin, oligofructose, and fructo-oligosaccharides	
- chicory root extract	
- fructan	
- Jerusalem artichoke	
Lignin	
Pectin	
Psyllium	
- ispaghula husk	
Resistant dextrins or maltodextrins	
Resistant starch	

Figure 2. Examples of low-digestible carbohydrates and terms used in lists of ingredients on food labels. ^aFor a description of these fibers, see reference 1.

HOW SHOULD RDs ADDRESS LOW-DIGESTIBLE CARBOHYDRATES IN PRACTICE?

Because RDs counsel clients to increase their fruit and vegetable, whole grain, or legume intake, they should keep in mind other sources of low-digestible carbohydrates in their clients' diets. RDs should ask clients about foods and beverages that might contain low-digestible carbohydrates as well as sugar-free gum, hard candy, and other very low calorie items clients may neglect to report, especially if they complain about gastrointestinal effects such as flatulence, bloating, and watery stools or diarrhea. Clients consuming multiple servings or several types of foods with fiber and/or sugar alcohols could easily have an excessive intake of low-digestible carbohydrates and experience gastrointestinal effects.

RDs should discuss with clients the potential health benefits of consuming foods with dietary fiber as well as added fiber and sugar alcohols; however, they should also make clients aware of the potential for gastrointestinal side effects with a sudden increase in the consumption of low-digestible carbohydrates or excessive intake of these carbohydrates. RDs should also: (a) inform clients about which foods (including sugar-free gum and hard candy) contain dietary and added low-digestible carbohydrates and provide a list of low-digestible carbohydrates and ingredients that contain them (Figure 2); (b) provide clients with a handout showing where the ingredient list and amount of fiber and sugar alcohols per serving is

Table. Total low-digestible carbohydrate in processed foods^a

Product type	Brand	Type of low-digestible carbohydrate	Amount of low-digestible carbohydrate
Crackers	Kellogg's All-Bran ^b	Whole-wheat flour, oat fiber, wheat germ, wheat bran, steel-cut oats	5 g fiber
High-fiber cereals	Post Grape Nuts ^c		7 g fiber
	Kellogg's All-Bran ^b		10 g fiber
	Kellogg's Bran Buds ^b		13 g fiber
Instant oatmeal	General Mills Fiber One ^d		14 g fiber
	Kashi, cinnamon ^e	Chicory root	5 g fiber
	Kashi, vanilla ^e	Chicory root	7 g
	Quaker ^f	Guar gum	3-4 g fiber
Quick oats	Quaker weight control ^f	Guar gum	6 g fiber
Wheat germ			4 g fiber
Breakfast/cereal bars			2 g fiber
	Kellogg's Nutri-Grain ^b		<1 g fiber
Granola bars	Cub fruit and grain ^g	Sodium alginate, modified cellulose, xanthan gum	2 g fiber
	Kellogg's Special K ^b		<1 g fiber
	Quaker oatmeal ^f	Sodium alginate	5 g fiber
	General Mills, Curves ^d	Chicory root extract (first ingredient)	5 g fiber
	Kashi TLC ^e	Chicory root fiber	4 g fiber
	Nature Valley Healthy Heart ^h		3 g fiber
	Quaker ^f	Oligofructose, polydextrose	2-3 g fiber
Other bars	South Beach ⁱ	Maltitol syrup, oligofructose (<2%) inulin	3 g fiber
	Kellogg's Nutri-Grain (fruit and nut) ^b	Sorbitol (<2%)	3 g fiber
	Quaker (muffin bars and breakfast cookies) ^f		4 g fiber
Muffins	Kellogg's Rice Krispies ^b		0 g fiber
	General Mills FiberOne Oats and Chocolate ^{di}	Chicory root extract	9 g fiber
	Weight Watchers, blueberry ^k	Inulin (natural extract of chicory root), sodium alginate	3 g fiber
Cake	Weight Watchers, chocolate ^k	Inulin (natural extract of chicory root)	5 g fiber
	Weight Watchers ^k	Inulin, cellulose gum	2 g fiber
Sugar-free cookies	Fifty 50 wafers ^l	Sorbitol	9 g sugar alcohol
	Cream wafers	Sorbitol	5 g sugar alcohol
Cake mix	Sweet'N Low ^m	Sorbitol, cellulose fiber, guar gum, xanthan gum	1 g fiber
			14 g sugar alcohol
Fruit spread	Fifty 50 ^l	Sorbitol, gellan gum	2-3 g sugar alcohol
Chocolate-flavored syrup	Sweet'N Low ^m	Sorbitol, xanthan and gellan gum	<1 g fiber
Strawberry-flavored syrup	Sweet'N Low ^m	Maltitol	3 g sugar alcohol
Sugar-free gum	All brands	Sorbitol, maltitol, mannitol	1.5 g sugar alcohol
Sugar-free hard candy	LifeSavers, Wint-o-green, Pep-o-mint ⁿ	Sorbitol	2 g sugar alcohol
	LifeSavers, 5 Flavors ⁿ	Isomalt	14 g sugar alcohol
	LifeSavers, CreamSavers ⁿ	Isomalt, maltitol syrup	13 g sugar alcohol
	Werther's ^o	Isomalt	13 g sugar alcohol
	Dove ^p	Maltitol; PGPR ^{q?}	3 g fiber
	Hershey's ^r	Maltitol; polydextrose	17 g sugar alcohol
	Reese's Peanut Butter Cups ^f		2 g fiber
Frozen dairy desserts			21 g sugar alcohol
	Blue Bunny Sugar-free ^s	Maltitol, lactitol; cellulose gel, polydextrose	5 g fiber
			18 g sugar alcohol
	Breyers Light ^t	Sorbitol, polydextrose, guar gum	2 g fiber
	Healthy Choice fudge bars ^u	Polydextrose, guar gum	7 g sugar alcohol
Kemps Sugar-free ^v	Polydextrose, sorbitol, guar gum	3 g fiber	
	Guar gum	0 g fiber	

(continued)

Table. Total low-digestible carbohydrate in processed foods^a (continued)

Product type	Brand	Type of low-digestible carbohydrate	Amount of low-digestible carbohydrate
Ice cream	Skinny Cow cookie sandwiches ^k	Fructan, cellulose gum	3 g fiber
	Weight Watchers, cone sundae ^k	Polydextrose, liquid sorbitol, lactitol, cellulose gel	4 g fiber
	Blue Bunny, no sugar added/ reduced fat ^s	Polydextrose, sorbitol, guar gum	3 g fiber
	Breyers Carb Smart ^t	Polydextrose, sorbitol, guar gum	3 g sugar alcohol
	Kemps Light ^v	Guar gum	3 g fiber

^aFoods purchased on June 6, 2007, at Cub Foods, Roseville, MN.

^bKellogg's, Battle Creek, MI.

^cRalcorp Holdings, St Louis, MO.

^dGeneral Mills, Minneapolis, MN.

^eKashi, La Jolla, CA.

^fQuaker, Chicago, IL.

^gCub Foods, Minneapolis, MN.

^hNature Valley, GMI, Minneapolis, MN.

ⁱSouth Beach, Glenview, IL.

^jInformation for this item collected in July 2008.

^kWeight Watchers International, New York, NY.

^lFifty 50 Foods, Mendham, NJ.

^mSweet'N Low, Brooklyn, NY.

ⁿLifesavers, Chicago, IL.

^oWerther's, Chicago, IL.

^pMars, Inc, Mount Olive, NJ.

^qPGPR=polyglycerol polyricinoleate.

^rHershey's, Hershey, PA.

^sBlue Bunny, Le Mars, IA.

^tBreyers, Green Bay, WI.

^uHealthy Choice, Omaha, NE.

^vKemps, St Paul, MN.

located on food labels (Table); (c) remind clients to look at the serving size and advise them to consume only one serving of a given food at a time, especially if the food is new to their diet and they typically consume a diet low in fiber; and (d) discuss with clients ways to increase the gastrointestinal acceptability of low-digestible carbohydrates, as discussed earlier.

Although an AI has been established for fiber, experts have not recommended a maximum level of intake for fiber or sugar alcohols. Gastrointestinal acceptability is likely the limiting factor for consuming high doses of these low-digestible carbohydrates. Because both fiber and sugar alcohols have the potential to provide health benefits as well as affect gastrointestinal function, RDs must be aware of current clinical research involving low-digestible carbohydrates so that they can counsel their clients appropriately with regard to their consumption.

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