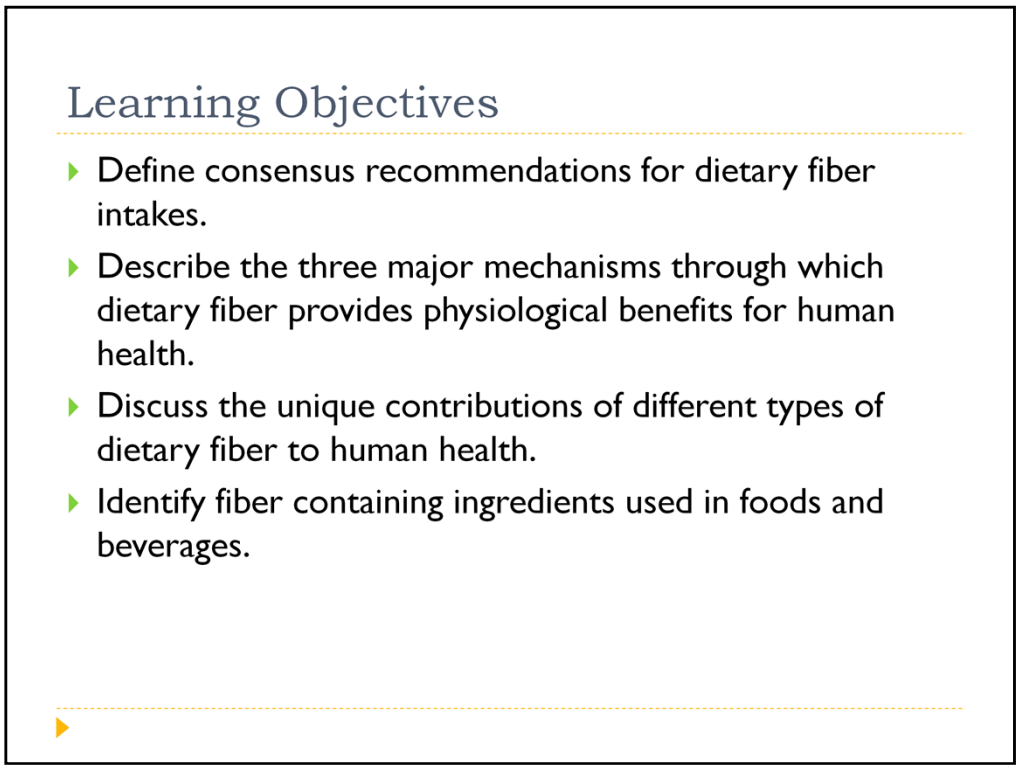
"Dietary Fiber Ingredients: Expanding options for meeting dietary fiber recommendations" is a self-study module produced by the Calorie Control Council, an accredited provider of continuing professional education (CPE) for dietetic professionals by the Commission on Dietetic Registration. The module provides one hour of level 1 CPE credit for dietetic professionals. The full text of the module is in the notes section of each page, and is accompanied by summary points and/or visuals in the box at the top of the page. Directions for obtaining CPE are provided at the end of the module.



After completing the module, learners will be able to:

- Define consensus recommendations for dietary fiber intakes.
- Describe the three major mechanisms through which dietary fiber provides physiological benefits for human health.
- Discuss the unique contributions of different types of dietary fiber to human health.
- Identify fiber containing ingredients used in foods and beverages.

An Evolving Definition of Dietary Fiber

What is fiber?

- Partially or completely indigestible and not absorbed
  - Not hydrolyzed by small intestine enzymes
- Varied chemical and physical properties
- Varied physiological effects
  - Most fibers exert more than one physiological effect, but none exert all
  - Some effects shared by many fibers, while some are fiber specific

The key characteristic of dietary fibers is that they are not hydrolyzed by the enzymes in the small intestine and therefore escape digestion and absorption (NRC, 2005; Lupton et al 2009; Howlett et al 2010). Beyond this commonality among all dietary fibers, they otherwise differ greatly in chemical and physical properties and physiological effects. Although most fibers will produce more than one physiological effect, no one fiber produces all of them. Some effects are well recognized for a large number of different fiber types, while others can be very fiber specific. Thus, consuming a variety of fibers provides a broader range of health benefits.

Physiological versus Chemical Classification

- IOM Macronutrient DRI Report, 2005
  - Dietary Fiber: nondigestible carbohydrates and lignin, intrinsic and intact in plants
  - Functional Fiber: isolated, nondigestible carbohydrates with beneficial physiological effects in humans
  - Recommended against use of terms "soluble" and "insoluble"
- Classification according to Physiological Effect
  - Mechanisms of action
  - Health effects

The 2005 IOM Macronutrient DRI report distinguished fibers as either dietary or functional (NRC 2005). Dietary fiber was defined as nondigestible carbohydrates and lignins that are intrinsic to and intact in plants. Functional fibers were defined as isolated, nondigestible carbohydrates with beneficial physiological effects in humans. They recommended against using the terms "soluble" and "insoluble," as this classification was inadequate to capture the health effects attributed to various fibers. Also the methods used to determine solubility have proven to be inconsistent.

Classification according to physiological effect may be more appropriate in that it takes into account expanding knowledge regarding mechanisms of action, and gives some indication of the health effects to be expected from a fiber.

However, "soluble" and "insoluble" are still commonly used to describe dietary fibers, including on the food label.

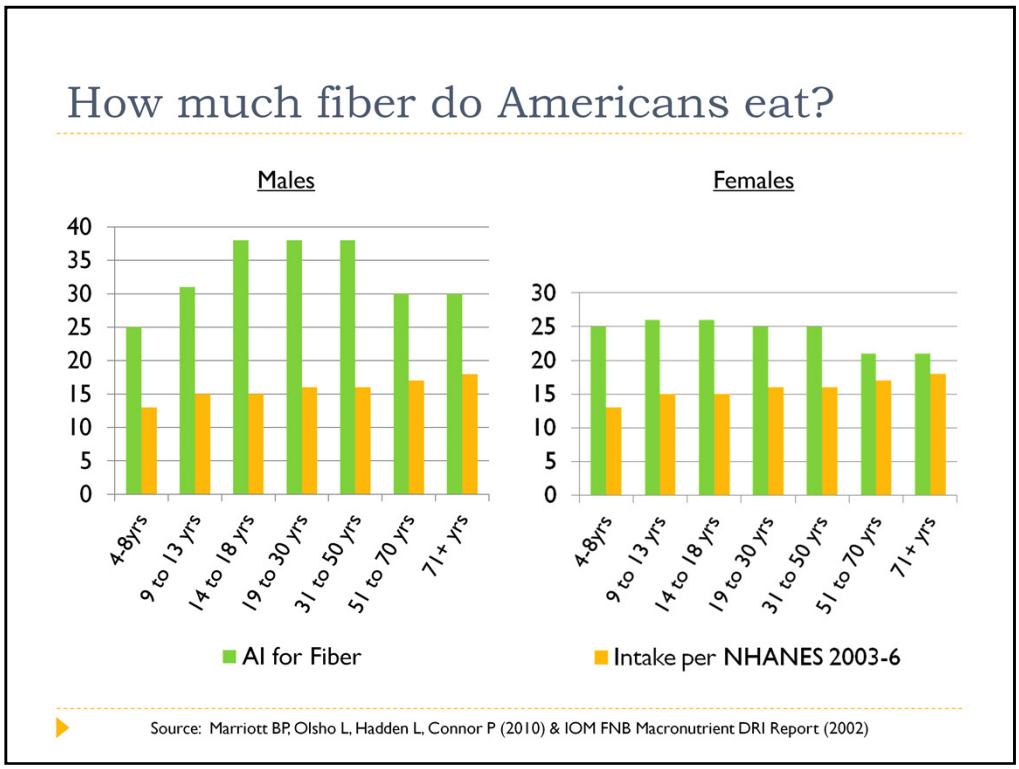
The Gap Between Fiber Recommendations and Intakes

Consensus Recommendations

- 25 g for women and 38 g for men of total fiber per day
  - Adequate Intake (AI), IOM Food and Nutrition Board, 2002
  - 14g total fiber per 1,000 calories per day associated with lower CHD risk
- Dietary recommendations are developed to meet individual nutrient needs
  - Dietary Guidelines for Americans, 2010
  - American Diabetes Association, 2008, 2011
  - American Heart Association, 2006, 2011

In 2002, the Food and Nutrition Board of the Institute of Medicine published the Dietary Recommended Intakes (DRI) for Macronutrients (NRC, 2002). The committee for the report based its recommendations for fiber on usual intakes that have been associated with lower risk of coronary heart disease, specifically 14 g total fiber per 1,000 calories consumed per day.

The DRI values are the foundation of dietary recommendations from a number of sources, including the 2010 Dietary Guidelines for Americans (USDA and HHS, 2010), and those from the American Heart Association (2006, 2011) and the American Diabetes Association (2008, 2011). These guidelines are intended to translate nutrient-specific nutrient targets into foods. Although a particular intake level of fiber or other nutrients is not quantified, with some exceptions, fiber needs would be met through foods if an individual were to adhere to the dietary recommendations.



However, Americans do not consume enough fiber, in part because of poor intakes of vegetables, fruits, whole grains, and legumes. According to the 2005 IOM Macronutrient DRI report, Americans consume an average of 15 g of fiber per day. An analysis of NHANES data from 2003 to 2006 found that estimated usual intakes meet approximately 40 to 85 percent of the AI for fiber (Marriott et al 2010). The same analysis found that no more than 4 percent of individuals in any age group up to 50 years of age met the AI for fiber (Marriott et al 2010). It was met by 5 percent of the males 71 and older, 13 percent of females 51 to 70, and 15 percent of females 70 and older (Marriott et al 2010). There were no males 14 to 50 years who met the AI (Marriott et al 2010).

Fiber-Containing Ingredients & Foods

- Agar
- Alginates
- Gum arabic (acacia)
- Carrageenan
- Carboxymethylcellulose
- Cellulose
- Gellan gum
- Hydroxypropyl Methylcellulose
- Inulin
- Karaya gum
- Konjac flour
- Larch gum (arabinogalactan)
- Locust bean gum
- Methylcellulose
- Maltodextrin
- Modified resistant starch
- Oligofructose
- Pectin
- Polydextrose
- Psyllium
- Resistant corn starch
- Rice bran
- Soluble corn fiber
- Soy fiber
- Gum tragacanth
- Xanthan gum

Because of the clear need to help Americans increase fiber intake, the food industry has developed fiber ingredients that can be added to foods and beverages. A comprehensive list of these fibers are seen on this page (http://fiberfacts.org/dietary-food-labels.asp). A growing number of products, such as cereals, breads, fruit juices, yogurts, and milk, now contain added fiber.

There are now over 50 different types of fiber ingredients. The availability of these additional sources of fiber makes it possible to increase the amount of fiber in foods and beverages containing inherent fiber (such as whole grain baked goods, breads, and cereals) as well as products that traditionally do not contain fiber (such as fruit juices and yogurt).

Dietary Fiber Facts on Food Label

- Nutrition Facts Panel
  - Total fiber in grams (g) (voluntary if <1g and no claims made)
  - Percent Daily Value (%DV) based on 25 g
  - Insoluble fiber (voluntary)
  - Soluble fiber (voluntary)
- Ingredients
  - Individual fibers (see page 5)
  - Ingredients that provide fiber (eg, whole wheat flour)

In the U.S., information about the amount of dietary fiber per serving appears in the Nutrition Facts Panel on the food label unless the product contains less than 1 g of fiber and no fiber claims are made (CFR 21 § 101.9). If total fiber is declared, the percent Daily Value (%DV), based on 25 g of fiber, must also be included.

A declaration of the number of grams of soluble or insoluble dietary fiber in a serving is voluntary, except when a claim is made about the type of fiber in the product.

Each ingredient in a food or beverage is listed on the package label. Fibers may be listed as a type of flour (e.g., wheat, rye, and oat) or as individual fibers. As the NFP still displays fibers as soluble or insoluble, knowledge of the physiological properties of specific fiber ingredients allows for a clearer understanding of the potential health effects of a product.

Dietary Fiber Claims on Food Label

- Content Claims
  - "Good" source of fiber contains ≥ 10% DV or 2.5 g
  - "High" fiber contains ≥ 20% DV or 5 g
  - Disclosure statement if defined levels of fat, saturated fat, cholesterol, and/or sodium exceeded
- Health Claims
  - Only for fruit, vegetable, or whole grain foods
  - Only if a "good" source of fiber without or before fortification
  - Limits on total fat, saturated fat, cholesterol
  - For reduced risk of cancer and CHD

A nutrient content claim is allowed on a food or beverage product that provides a defined level of the nutrient (CFR 21 § 101.9). To qualify for a **good source of fiber** claim, the product must contain at least 10 percent of the daily value (DV) or 2.5 grams of fiber per serving. For a **high fiber** claim, the product must contain at least 20 percent of the daily value of fiber or 5 g or more of fiber per serving. (See http://www.fda.gov/Food/LabelingNutrition/LabelClaims/NutrientContentClaims/default.htm)

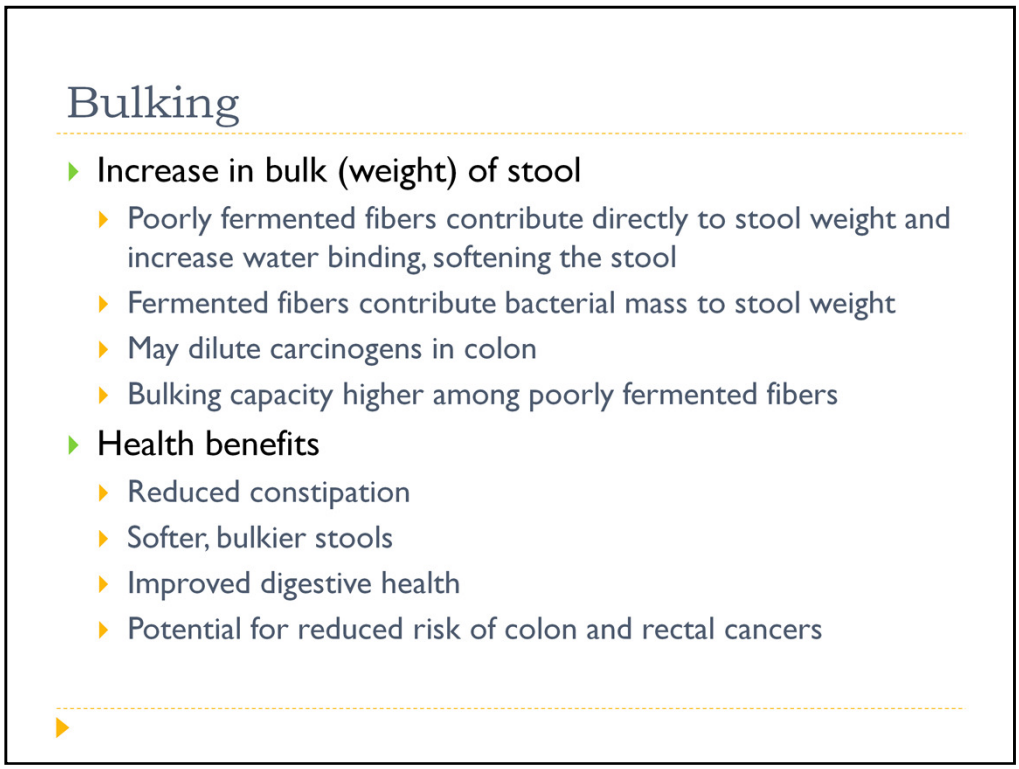
If a food or beverage qualifies to display a nutrient content claim, but contains high levels of certain nutrients that increase health risk, a disclosure statement is required (CFR 21 § 101.9). Specifically, a disclosure statement serves to inform consumers that the product contains in excess of 13 g total fat, 4 g saturated fat, 60 mg cholesterol, or 480 mg sodium per labeled serving or reference amount customarily consumed (RACC).

Health claims are allowed for fiber, communicating significant scientific agreement regarding positive associations between intake of the nutrient and reduced risk of coronary heart disease (CHD) and some cancers (CFR 21 § 101.9):

- **Fiber-containing Grain Products, Fruits and Vegetables and Cancer**
- **Fruits, Vegetables and Grain Products that contain Fiber, particularly Soluble fiber, and Risk of CHD**
- **Soluble Fiber from Certain Grain Foods and Risk of CHD**

For these health claims, the food must provide the indicated level of fiber from the defined sources, without or before fortification, as well as defined limits on fat, saturated fat, and/or cholesterol. (See http://www.fda.gov/Food/LabelingNutrition/LabelClaims/HealthClaimsMeetingSignificantScientificAgreementSSA/default.htm)

Three major mechanisms are responsible for the physiological benefits of dietary fiber: (1) bulking, (2) viscosity, and (3) fermentation (Lattimer and Haub 2010).



Bulking is the process by which certain fibers increase the bulk or weight of feces. The bulking effect of dietary fiber that is poorly fermented in the colon is associated with the mass of fiber itself and enhanced in some cases by water binding, which is maintained throughout the whole gastrointestinal (GI) tract. Fermentable dietary fibers provide a bulking effect mainly due to increased bacterial mass (fermentation will be discussed in greater detail in page 16). Bulky feces moves through the gut faster, resulting in an increased stool weight and improved regularity, the most widely known beneficial effects of dietary fibers. Stool consistency, stool weight, and frequency of defecation are indicators of colonic function. Bulky feces may also dilute carcinogens in the colon.

Different kinds of dietary fiber can have different bulking capacities, depending on whether they contribute directly to fecal mass and promote water binding, or do so indirectly through fermentation. Wheat bran (cellulose) and psyllium contribute 4-5 g of bulking effects per gram of dietary fiber in the food.

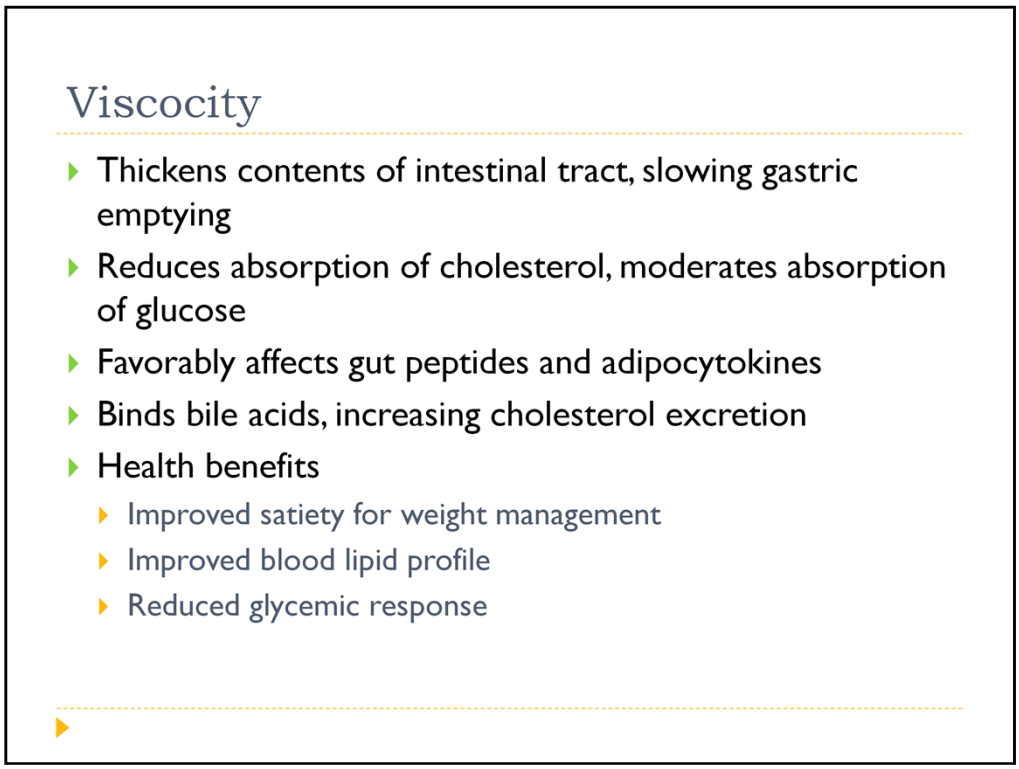
Most of the studies on fiber and colon cancer have been observational and have yielded inconsistent results. One theory is that the contents of the colon move at a more optimal rate, there is thought to be less of a toxic exposure to the interior of the colon thereby reducing risk of developing colon cancer. Another theory is that the increase in fecal bulk dilutes the effect of toxic substances in the colon. A meta-analysis of 25 studies published in the British Medical Journal in November 2011 found an association between fiber and decreased risk of colon cancer (Aune et al 2011).

Bulking Fibers

- Carboxymethylcellulose
- Hydroxypropyl methylcellulose
- Methylcellulose
- Wheat bran (cellulose)

Examples of bulking dietary fiber ingredients include:

- Carboxymethylcellulose
- Hydroxypropyl methylcellulose
- Methylcellulose
- Wheat bran (cellulose)



Viscous fibers (i.e., beta-glucan and psyllium) thicken the contents of the intestinal tract, which slows gastric emptying and impedes the migration of nutrients to the intestinal walls. Viscocity has also been shown to affect gut peptides and adipocytokines that are involved in both satiety signaling and gastric emptying. These effects explain how viscous fiber may improve satiety and assist in weight management.

The body uses cholesterol in the production of bile acids, some of which is excreted daily. Viscous fiber binds to bile acids, increasing the amount of cholesterol that is excreted, which ultimately leads to lower cholesterol levels. Studies have linked a high fiber diet with improvements in serum lipids, total cholesterol, low-density lipoprotein cholesterol (LDL-C), high density lipoprotein cholesterol (HDL-C), and triglycerides.

Similar to lowering cholesterol levels, viscous fiber also slows down the absorption of glucose and can lower the glycemic impact of foods (causing a lower rise in blood glucose levels). Foods containing viscous fibers are associated with a much slower rise in serum glucose that does not peak at as high of a level. Further, the decline in serum glucose levels after reaching the peak is less rapid.

Viscous Fibers

- Agar
- Alginates
- Arabinogalactan (larch gum)
- Arabinoxylan
- Carrageenan
- Gellan gum
- Guar gum
- Gum arabic (acacia)
- Gum tragacanth
- Karaya gum
- Konjac flour
- Locust bean gum
- Pectin
- Psyllium
- ß-glucan

Examples of viscous dietary fiber ingredients include:

- Agar
- Alginates
- Arabinogalactan (larch gum)
- Arabinoxylan
- Carrageenan
- Gellan gum
- Guar gum
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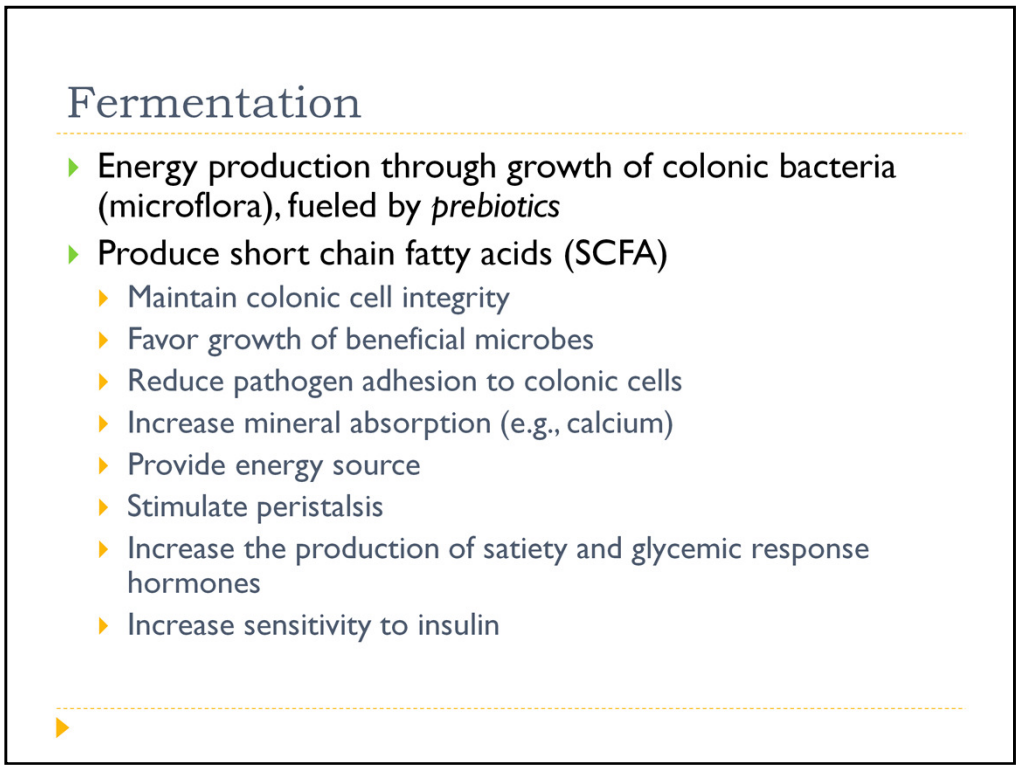
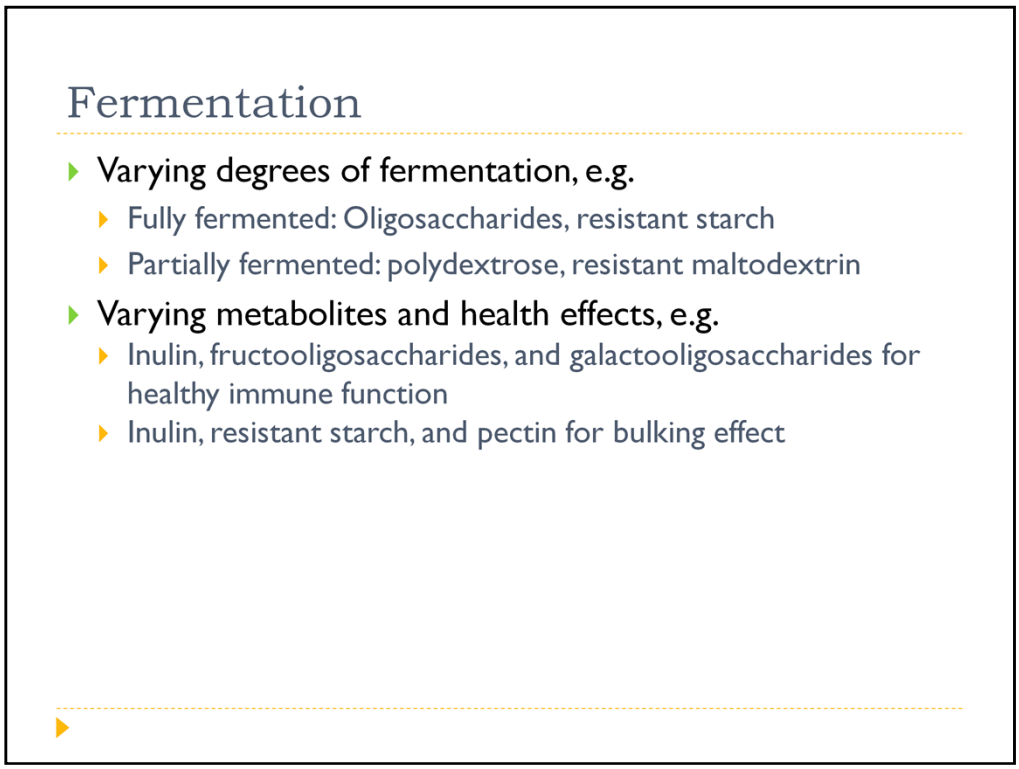


Prebiotics are dietary fibers that play an important role as a food source for microflora in colonic fermentation. The colonic bacteria produce, among other things, short chain fatty acids (SCFA), primarily acetate, propionate, and butyrate. SCFA in the colon support health in many ways, such as:

- Maintaining the integrity of colonic cells;
- Favoring the growth of beneficial microbes (which has moderate bulking effects);
- Reducing the ability of pathogenic microbes to adhere to colonic cells;
- Lowering the pH of the intestinal tract, which improves absorption of calcium and magnesium;
- Providing an energy source to colonic cells and to the body (for the SCFAs that are absorbed into circulation);
- Stimulating peristalsis to promote regularity;
- Increasing the production of satiety and insulin sensitivity hormones (GLP-1, PYY, adiponectin, etc) (Sanchez et al 2012; Vitaglione et al 2009; Barone et al 2012).



Different dietary fibers can be fermented to different degrees. For instance, oligosaccharides and resistant starch are fully fermented, while polydextrose and resistant maltodextrin are partially fermented.

Fermentation variability leads to the production of different ratios of metabolites, therefore different health effects. For example, specific fermentable fibers (inulin, fructooligosaccharides, and galactooligosaccharides) have been shown to provide support for healthy immune function through increased levels of beneficial bacteria (i.e., Bifidobacteria, Lactobacillus) and reduced adhesion of pathogens to colonic cell walls. Another example is the bulking effect of fully fermentable fibers. Inulin, resistant starch, and pectin each contribute 1-2 g of bulking per gram of dietary fiber consumed.

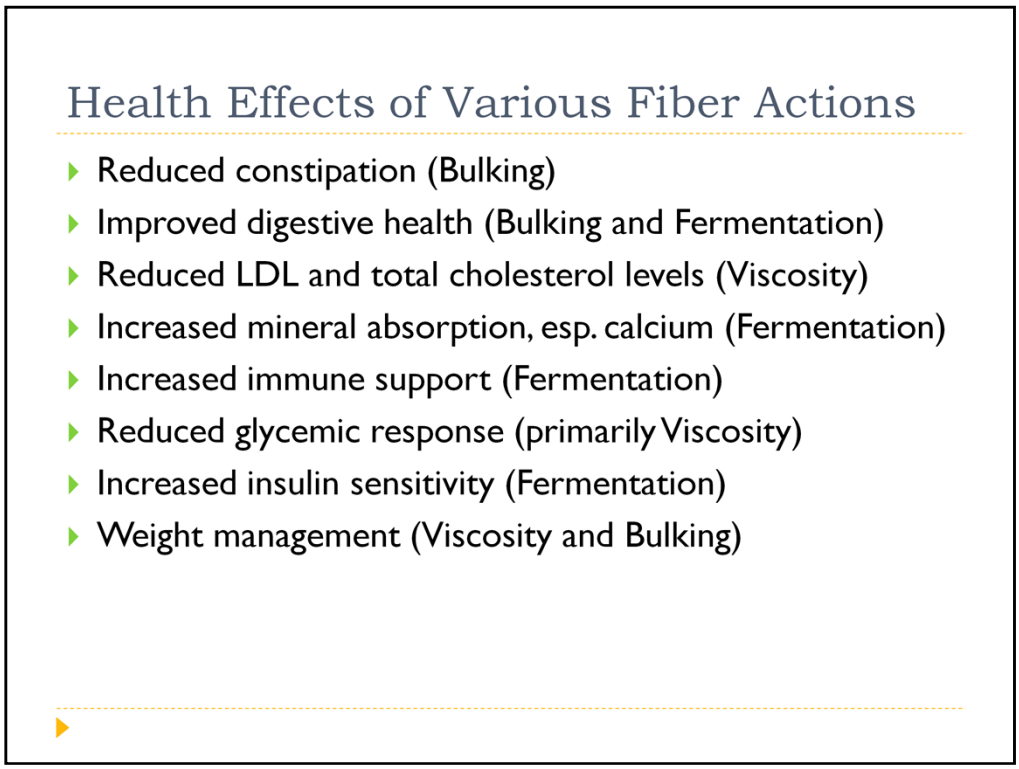
Fermentable Fibers

- Fructo-oligosaccharides
- Polyfructans
- Oligofructose
- Galacto-oligosaccharides
- Inulin
- Psyllium
- Resistant maltodextrins
- Resistant dextrins
- Resistant starches

Most dietary fiber ingredients are fermentable, although a few are almost exclusively fermented, including:

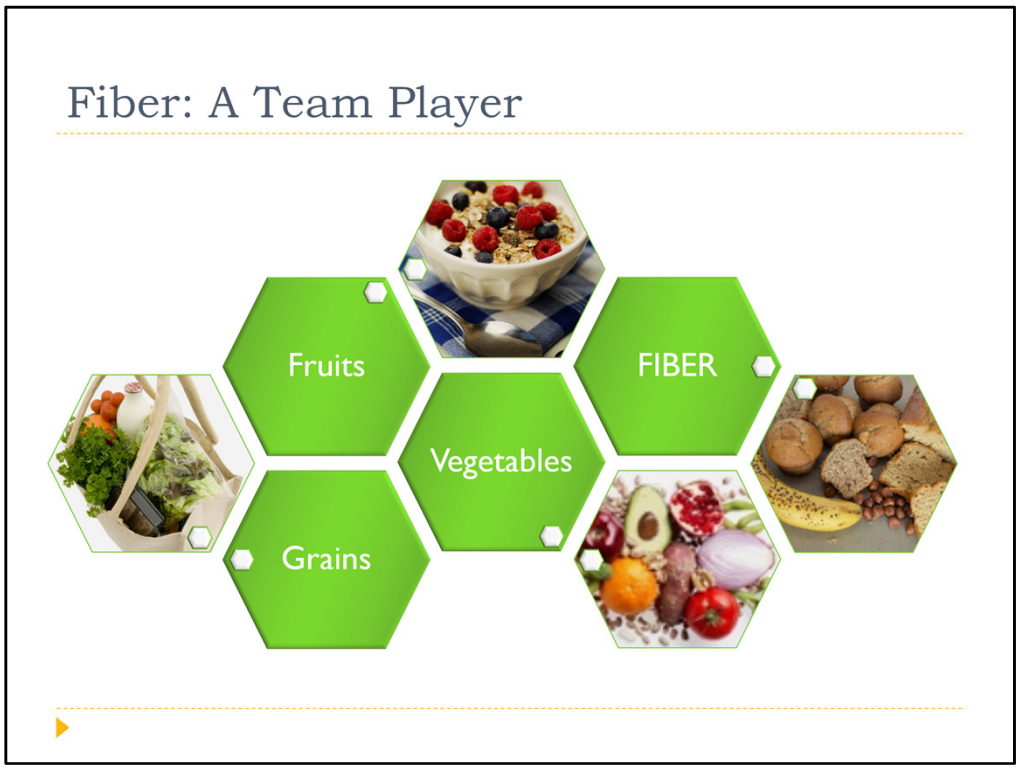
- Fructo-oligosaccharides
- Polyfructans
- Oligofructose
- Galacto-oligosaccharides
- Inulin
- Psyllium
- Resistant maltodextrins
- Resistant dextrins
- Resistant starches

The bulking fibers listed on page 13 are poorly fermented, while most other dietary fiber ingredients are fermentable, and may also contribute to viscocity (see page 14).



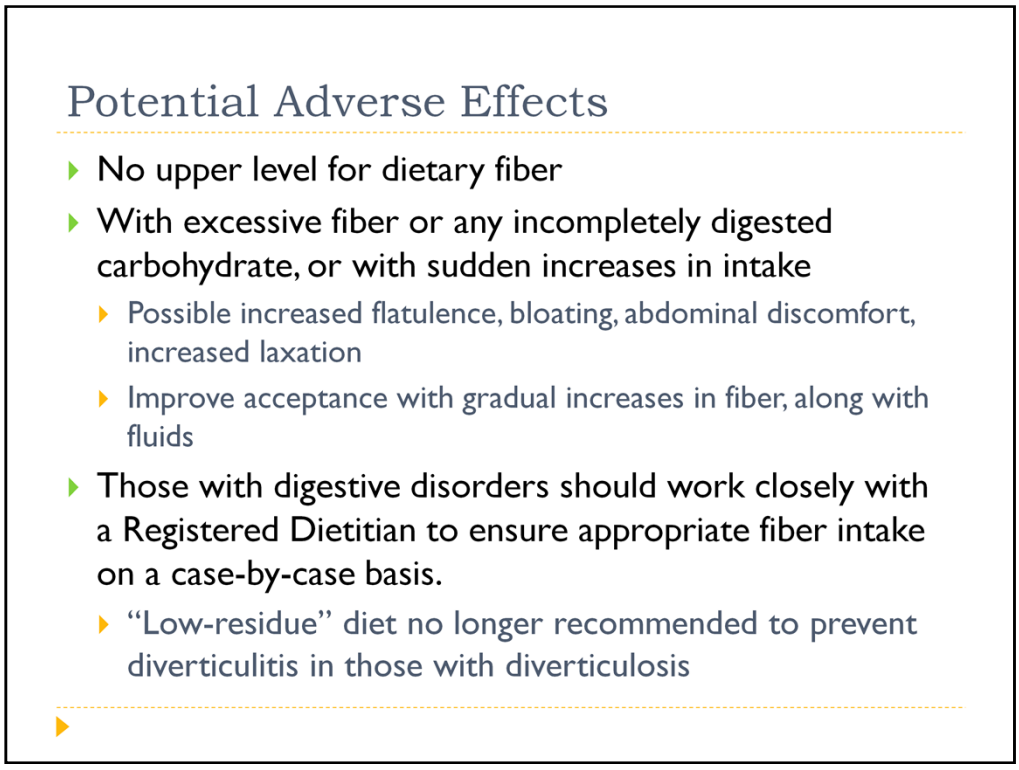
The potential health benefits of dietary fiber are widely recognized by experts in the health and science communities as well as government authorities. The list here represents those for which there is degree of understanding regarding mechanisms of action:

- Reduced constipation (Bulking)
- Improved digestive health (Bulking and Fermentation)
- Reduced LDL and total cholesterol levels (Viscosity)
- Increased mineral absorption, esp. calcium (Fermentation)
- Increased immune support (Fermentation)
- Reduced glycemic response (primarily Viscosity)
- Increased insulin sensitivity (Fermentation)
- Weight management (Viscosity and Bulking)



With the data on the health benefits of fiber mounting, and the unique roles for specific fibers being elucidated, fiber is clearly a star player in human health. The importance of the total diet and overall lifestyle cannot be overstated, however, as one nutrient is always but one piece in a large, complex puzzle.

Application to Nutrition Education & Medical Nutrition Therapy



As the vast majority of Americans are not getting enough fiber, most stand to benefit from increased intakes. In fact, the Institute of Medicine did not set an Upper Level (UL) for fiber.

It is essential for normal gut function, as discussed with respect to mechanisms of action. Some people may experience increased flatulence, bloating, abdominal discomfort, or laxation if fiber is increased rapidly, or if intake is excessive.

"Low-residue" diets are no longer recommended to prevent diverticulitis in those with diverticulosis. Still, those with digestive disorders should work closely with a Registered Dietitian to ensure appropriate fiber intake on a case-by-case basis.

Ensuring Tolerance

- Inform of the potential for increased flatulence, bloating, abdominal discomfort, laxation
  - Most common with highly fermentable fibers
  - Temporary: the body will adapt
  - Benefits outweigh potential side effects
- Increase gradually, by no more than 5 g per day
- Increase fluid intake as fiber increases

In order to help ensure tolerance to increased fiber intakes, it is helpful to inform individuals of the potential for increased flatulence, bloating, abdominal discomfort, or laxation so they are prepared. Although these symptoms are most common with highly fermentable fibers, they may be noticed by anyone who is not used to a high-fiber intake. It is important to equip them with tools to avoid or minimize these conditions. They can do so by increasing intake gradually, by up to 5 g every few days, and concurrently increasing fluid intake.

Expanding Fiber-Rich Food Choices

- Vegetables and Fruits
  - Broccoli, those with edible skins (eg, apples, corn) or seeds (eg, berries)
- Whole Grains
  - Whole wheat pasta, barley, quinoa, oatmeal
- Legumes and Beans
- Nuts and Seeds
- Foods with added Fiber
  - Cereals, granola bars, yogurts, fruit juices, vegetarian patties, prepared dishes, snacks, baked goods, and pasta

Four out of five (79 percent) of Americans are aware that fiber has health benefits beyond basic nutrition (IFIC 2011). Still, with so few getting the needed amount of fiber from day to day, most will need guidance regarding what foods and beverages are good sources of fiber, including those that naturally contain fiber and those that are fortified. For the latter, label reading guidance will be particularly useful.

For Individuals with Diabetes

- American Diabetes Association recommends total fiber consistent with Dietary Guidelines for Americans, 2010
- Adjust carbohydrate count for high-fiber foods
- Fiber and fat decrease glycemic index (GI) of foods
  - Nutrient density independent of GI
  - Many other factors to consider

In general, the total fiber recommendations for diabetes prevention and for individuals with diabetes are consistent with the 2010 Dietary Guidelines for Americans (ADA 2008).

For those who are counting carbohydrates in meal planning, total carbohydrates should be adjusted for foods with 5 g or more of fiber per serving. Specifically, half of the fiber grams should be subtracted from the total carbohydrate grams.

Another consideration is that the glycemic index (GI) of a food is decreased by fiber, as well as fat. Knowledge of the GI values of foods can be useful for fine tuning meal plans for diabetes. It is important to convey, however, that high GI foods are not to be avoided. First, nutrient density is independent of GI. Second, the actual glycemic effect of a food varies with the quantity of the food that is eaten, and with respect to other foods that are eaten at same time.

For Individuals with High LDL or CVD Risk

- Aim for 25-30 g total fiber
- Seek viscous fibers
  - Especially oats (oat bran, oatmeal)
  - Also beans, peas, rice bran, barley, citrus fruits, strawberries, apples
  - Foods like yogurt or snack bars that have added fiber (see page 15)
- Check the Nutrition Facts for 10% DV fiber, as well as saturated fat and sodium

As for the general population, those at risk for CVD and those with high cholesterol should aim for 14 g of fiber per 1,000 calories (Lichtenstein et al 2006). For this group, special attention to increasing viscous fibers may help to lower LDL cholesterol. Oats, oat bran, and oatmeal are particularly good sources of viscous fibers, as well as beans, peas, rice bran, barley, citrus fruits, strawberries, and apples. Check the Nutrition Facts for 10 percent DV of total fiber, and look for added viscous fibers in the ingredient list (see page 16). Also, it is still important to be mindful of the saturated fat and sodium content of foods.

For Weight Management

- Key role- increasing satiety
  - All fibers
  - Particularly viscous fibers (eg, β-glucan)
- Pre-meal fiber and fluids reduce intake during meal
  - Broth-based soups, with vegetables and legumes
  - Salad with legumes
- Fiber and fluids at each meal and snack to improve satiety without excess calories
  - Consider foods like baked chips or crackers that have added fiber (see page 15 for viscous fibers)

The key role for fibers in weight management relates to their effects on satiety. All fibers, especially with sufficient fluids, will improve satiety throughout the day. Some viscous fibers should be included, however, due to the unique effect of viscosity on satiety signaling. Reduced intake at meals following a pre-meal snack high in fluids and fibers has been observed. A broth-based soup rich in vegetables and legumes would include both for a healthy start to any meal.

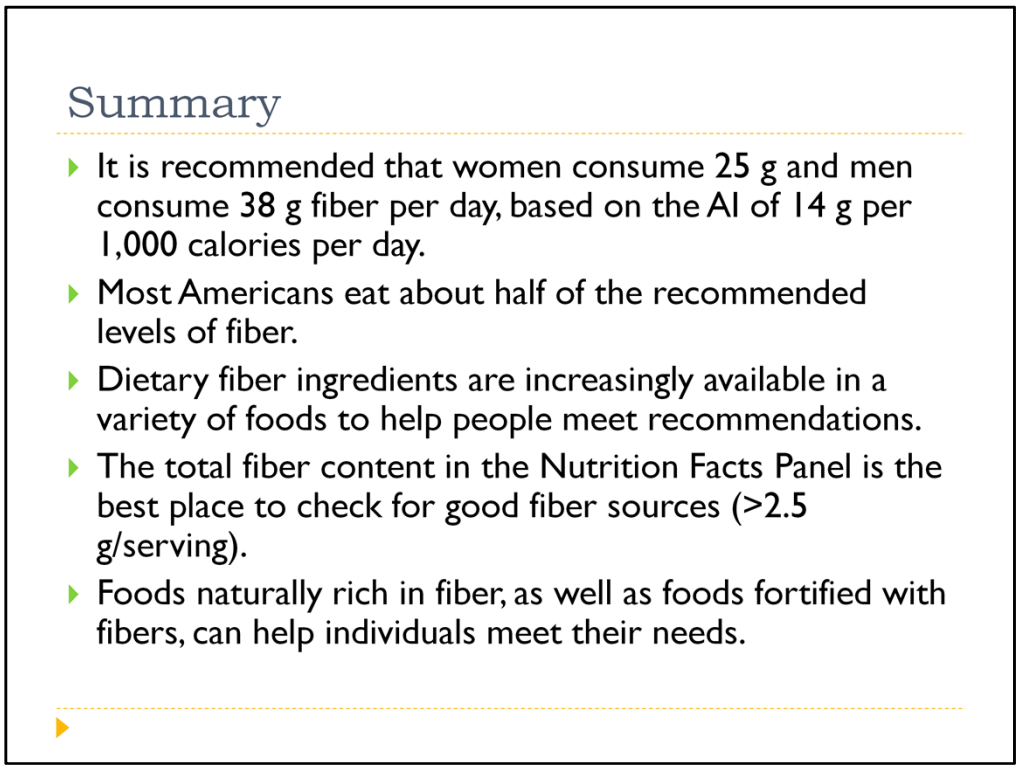
For Individuals with Digestive Disorders

- Case-by-case approach is needed, as evidence is limited and/or mixed for digestive disorders
  - IBS
  - Crohn's Disease
  - Diverticulosis
    - Potential increase in stool weight and decrease in transit time to prevent or slow progression
  - Ulcerative Colitis
    - High fiber diet may worsen symptoms or increase relapse risk
    - Fermentable fibers may reduce symptoms

Surprisingly, evidence regarding the effects of dietary fiber on gastrointestinal health and disease is limited, particularly for irritable bowel syndrome (IBS) and Crohn's Disease. Although not proven, the dominant theory is that a low-fiber diet causes diverticular disease. Diverticular disease is common in developed or industrialized countries—particularly the United States, England, and Australia—where low-fiber diets are consumed. The disease is rare in Asia and Africa, where most people eat high-fiber diets. Increasing the amount of fiber in the diet may reduce symptoms of diverticulosis and prevent complications such as diverticulitis. Fiber keeps stool soft and lowers pressure inside the colon so that bowel contents can move through easily.

And although a high fiber diet is noted to increase symptoms for those with ulcerative colitis, fermentable fibers may reduce symptoms.

Significant advances are being made in understanding not only bulking and viscocity effects of fibers, but especially fermentation effects. The Human Microbiome Project at the National Institutes of Health (http://commonfund.nih.gov/hmp/) and related research on the relationship between a healthy gut microbiome and its human host may provide considerable insight into the roles of fermentable fibers in digestive, as well as metabolic, disorders.



In summary:

- It is recommended that women consume 25 g and men consume 38 g fiber per day, based on the AI of 14 g per 1,000 calories per day.
- Most Americans eat about half of the recommended levels of fiber.
- Dietary fiber ingredients are increasingly available in a variety of foods to help people meet recommendations.
- The total fiber content in the Nutrition Facts Panel is the best place to check for good fiber sources (>2.5 g/serving).
- Foods naturally rich in fiber, as well as foods fortified with fibers, can help individuals meet their needs.

Summary (continued)

- Bulking, viscocity, and fermentation are the three major mechanisms of fiber function for health.
- Although most fibers will produce more than one beneficial effect, no one fiber produces all. Therefore, a variety of fibers is needed to ensure comprehensive health benefits.
- Gastrointestinal effects of a high-fiber diet can be reduced or avoided by increasing intake gradually and increasing fluids.

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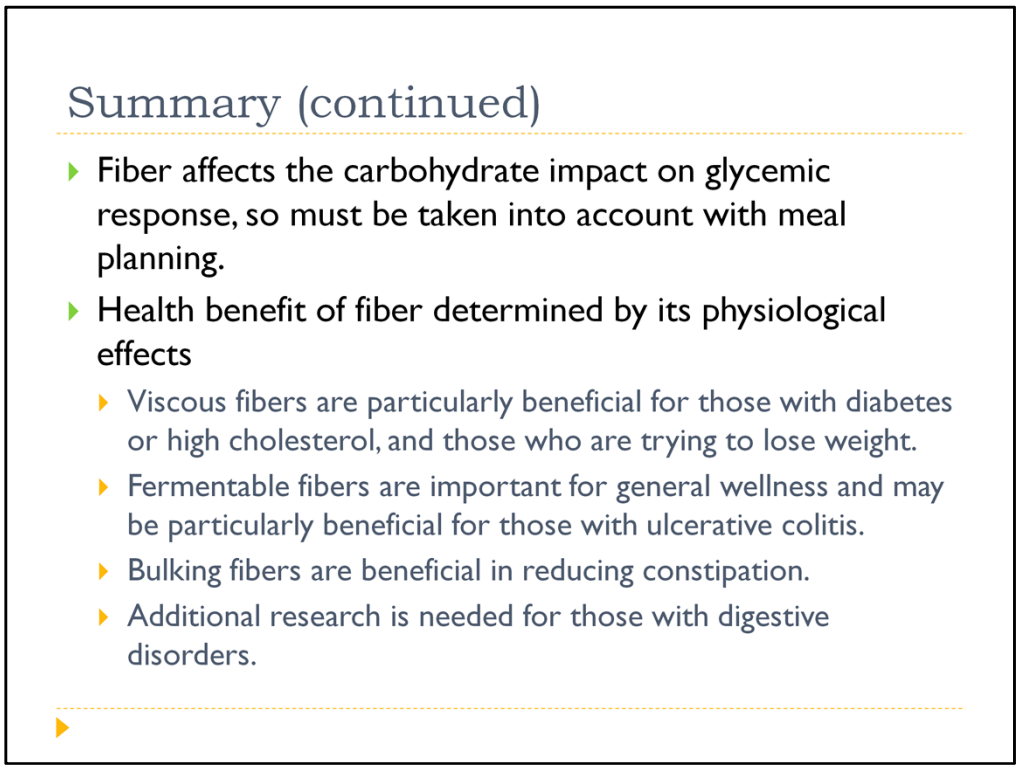

- Fiber affects the carbohydrate impact on glycemic response, so must be taken into account with meal planning.
- Health benefit of fiber determined by its physiological effects
    - Viscous fibers are particularly beneficial for those with diabetes or high cholesterol, and those who are trying to lose weight.
    - Fermentable fibers are important for general wellness and may be particularly beneficial for those with ulcerative colitis.
    - Bulking fibers are beneficial in reducing constipation.
    - Additional research is needed for those with digestive disorders.

For More Information on Fiber Ingredients…

- Fiber Facts: fiberfacts.org
- Calorie Control Council: www.caloriecontrol.org

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