Dietary Fiber[1]

Dietary fiber is primarily derived from plant material and is composed of complex, nonstarch carbohydrates and lignin that are not digestible within the small intestine because mammals do not produce enzymes capable of hydrolyzing them into their constituent monomers. As a result, these compounds make it to the colon intact, where they are available for fermentation by the resident bacteria. Dietary fiber is considered to contribute no calories to our diet, yet the metabolites released by the bacteria in the colon are used by humans and other mammals to meet their energy requirements. However, variability among individuals in their ability to acquire and utilize this source of energy precludes assigning a caloric value to dietary fiber. In contrast, ruminants (e.g. cattle) acquire much of their energy requirements from plant fibers because they have bacteria in their rumen, a forestomach, that are capable of hydrolyzing these compounds into molecules that are absorbed and metabolized by the host.

In 2001, the Institute of Medicine (IOM) of the National Academies issued a report that provided a proposed definition for dietary fiber for use in the US and Canada (1). The proposed definition differentiated between fiber that was endogenous to a food (called dietary fiber) and fiber that was extracted and/or synthesized (called functional fiber). These 2 added together represent the total fiber content of the food. The rationale for distinguishing between the dietary fiber and functional fiber categories was the long history of studies showing beneficial effects of a high-fiber diet but less data on potential health benefits of items found in the functional fiber category. The motivation for the separate categories was that the phrase "dietary fiber" would be considered by most to be positive for human health and that phrase should not be used to provide the perception of health benefits to a fiber that had not been tested to determine its potential health benefits. This proposed definition of dietary and functional fiber was then used to develop the recommended levels of total fiber intake in 2005 (2). In 2009, the Codex Alimentarius Commission adopted a definition of dietary fiber that was similar to the IOM definition in that it divided dietary fiber into 3 categories: "naturally occurring in the food as consumed"; "obtained from food raw material by physical, enzymatic or chemical means…"; and "synthetic carbohydrate polymers" (3). Items within the latter 2 categories (obtained from food raw material and synthetic carbohydrate polymers) have to provide a physiological effect that confers a health benefit as contrasted with the fiber naturally occurring in the food as consumed, which does not have to be proven to demonstrate such a benefit. The major difference between the Codex definition and the IOM definition is that with the Codex definition, once the extracted or synthesized fiber is shown to have physiological effects that confer a health benefit, it is then referred to as "dietary fiber." In contrast, the IOM definition kept the term "functional fiber" for material that was not endogenous to the plant. Another important part of the Codex definition is footnote 2, which states that whether or not carbohydrates with a degree of polymerization from 3 to 9 are considered dietary fiber is left to national authorities. At this time, the FDA has not adopted a definition for dietary fiber and has not stated whether it will include degree of polymerization 3–9 carbohydrates.

Deficiencies: The most notable response to diets providing very low levels of fiber intake is an increase in constipation. However, several negative physiological responses occur in individuals who consume low levels of dietary fiber over time, particularly an increased risk for coronary heart disease.

Diet recommendations: The current DRI value is an adequate intake level and is based on the decreased risk of coronary heart disease with dietary fiber consumption (2). The recommendation is to consume 14 g/1000 kcal, and those quantities are then converted to g of fiber/d based on energy intake recommendations for both genders at all age groups (**Table 1**). This means that the higher the recommended energy intake level, the higher the fiber recommendation. Thus, girls and women in each age group have a lower recommended value than do boys or men, except for infants. There are no dietary intake recommendations for infants $<$ 1 y of age, because it is assumed that most of the nutrients will be provided by milk for the first 6 mo of life, and there are no data on fiber intake for infants until after 1 y of age.

Table 1. Recommended intake levels for fiber (adequate intake)[1]

Age, *y*	Male	Female
	g/d	
1–3	19	19
4–8	25	25
9–13	31	26
14–18	38	26
19–50[2]	38	25
>51	30	21

[1]Adapted from (2).
[2]Intakes for females are increased to 28 g/d during pregnancy and to 29 g/d for lactation.

Food sources: Compounds that are classified as fiber are primarily obtained from plant-based foods. Good sources of dietary fiber include whole grains, legumes, vegetables, nuts and seeds, and fruits. Fiber supplements are also available to increase the intake of dietary fiber; however, most experts recommend that fiber should be obtained through the consumption of foods, because this form allows consumption of many micronutrients and bioactive compounds contained in high-fiber foods, which provide their own nutritional benefits.

Clinical uses: Clinical recommendations for dietary fiber are routinely provided to improve laxation and reduce diverticular disease (4). In addition, physicians recommend an increase in the consumption of foods containing fiber to reduce obesity, cardiovascular disease, type 2 diabetes, and some cancers.

Toxicity: No tolerable upper intake level has been set for dietary fiber (2). However, the IOM suggested that there may be a need for a tolerable upper intake level in the future if supplements or foods with added functional fiber were to become ubiquitous. Very high levels of consumption could lead to reductions in the absorption of some minerals. Yet, it is not thought that this could create mineral deficiencies in areas where diets are not limiting in minerals.

Recent research: We have known for a long time that dietary fiber plays important roles in the health of humans and in meeting the nutritional needs of animals. Much of the recent literature has revolved around the ability of certain dietary fiber types to affect different physiological systems. Part of that research aims to understand how dietary fiber influences the characteristics and fermentation patterns of the intestinal microbiome in humans (5,6) and in production agriculture species (7). It is now possible to understand the prebiotic function of fibers using new DNA sequencing procedures that permit complete characterization of the bacterial populations (microbiome). One of the products of fermentation, butyrate, is able to regulate gene transcription through its actions as a histone deacetylase inhibitor, which affects cell proliferation, differentiation, and apoptosis of colon cells (8,9). The overall goals of these studies are to determine why some individuals are more at risk to develop diseases and some animals are more efficiently using their food for production purposes, as well as to identify dietary modifications that improve animal production efficiency and human health.

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Literature Cited

1. Institute of Medicine, National Academy of Sciences. Dietary reference intakes: proposed definition of dietary fiber. Washington, DC: National Academy Press; 2001.
2. Institute of Medicine, National Academy of Sciences. Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein and amino acids. Washington, DC: National Academies Press; 2005.
3. ALINORM. Report of the 30th session of the CODEX committee on nutrition and foods for special dietary uses [cited 2010 Nov 18]. Available from: http://www.codexalimentarius.net/download/report/710/al32_26e.pdf.
4. Hall J, Hammerich K, Roberts P. New paradigms in the management of diverticular disease. Curr Probl Surg. 2010;47:680–735.
5. Meyer D, Stasse-Wolthuis M. The bifidogenic effect of inulin and oligofructose and its consequences for gut health. Eur J Clin Nutr. 2009;63:1277–89.
6. Roberfroid M, Gibson GR, Hoyles L, McCartney AL, Rastall R, Rowland I, Wolvers D, Watzi B, Szajewska H, Stahl B, et al. Prebiotic effects: metabolic and health benefits. Br J Nutr. 2010;104 Suppl 2:S1–63.
7. Brulc JM, Antonopoulos DA, Berg Miller ME, Wilson MK Yannarell AC, Dinsdale EA, Edwards RE, Frank ED, Emerson JB, et al. Gene-centric metagenomics of the fiber-adherent bovine rumen microbiome reveals forage specific glycoside hydrolases. Proc Natl Acad Sci USA. 2009;106:1948–53.
8. Wilson AJ, Chueh AC, Togel L, Corner GA, Ahmed N, Goel S, Byun DS, Nasser S, Houston MA, et al. Apoptotic sensitivity of colon cancer cells to histone deacetylase inhibitors is mediated by an Sp1/Sp3-activated transcriptional program involving immediate-early gene induction. Cancer Res. 2010;70:609–20.
9. Crim KC, Sanders LM, Hong MY, Taddeo SS, Turner ND, Chapkin RS, Lupton JR. Upregulation of $p21^{Waf1/Cip1}$ expression in vivo by butyrate administration can be chemoprotective or chemopromotive depending on the lipid component of the diet. Carcinogenesis. 2008;29:1415–20.