Dietary Fiber

Dietary fiber is derived from plant material and is composed of complex, nonstarch carbohydrates and lignin. Dietary fiber is not digestible within the small intestine because mammals do not produce enzymes capable of hydrolyzing the polymers into their constituent monomers. As a result, these compounds make it to the colon intact, where they are available for fermentation by the resident microbiota. 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. Variability among the microbiota present in the intestines influences the host's ability to acquire and utilize this source of energy, which precludes assigning a caloric value to dietary fiber. In contrast, ruminants (e.g., cattle) acquire much of their energy requirements from indigestible plant fibers because they have microbiota in their rumen (a forestomach) that can hydrolyze 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 to be used in the United States 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 two added together represent the total fiber content of a food. The rationale for distinguishing between 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 intake levels of total fiber 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) must 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. In 2016, the FDA adopted a definition for dietary fiber that includes nondigestible carbohydrates containing $\geq$3 monomeric units, along with lignin, that are intrinsic and intact in plants, and also isolated or synthetic carbohydrates containing $\geq$3 monomeric units and determined by the FDA to have beneficial physiological effects (4).

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, such as 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, 5). The recommendation is to consume 14 g/1000 kcal, and those quantities are then converted to grams of fiber per day 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 and pregnant or nursing women. There are no dietary intake recommendations for infants aged <1 y 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 age 1 y.

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 (7).

Clinical uses: Clinical recommendations for dietary fiber are routinely provided to improve laxation and reduce diverticular disease. 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, 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

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

Age, y	Male, g/d	Female,[2] g/d
1–2	19.0	19.0
2–3	14.0	14.0
4–8	20.0	17.0
9–13	25.0	22.0
14–18	31.0	25.0
19–30	34.0	28.0
31–50	31.0	25.0
≥51	28.0	22.0

[1] Adapted from reference 6.
[2] Intakes for females during pregnancy and lactation depend on age and trimester. For the first, second, and third trimesters, respectively, the recommendation is 25, 31, and 34 g/d for those aged 14–18 y; 28, 34, and 36 g/d for those aged 19–30 y; and 25, 31, and 34 g/d for those aged 31–50 y.

become ubiquitous. Very high levels of consumption could lead to reductions in the absorption of some minerals. Yet, it is not thought that this would create mineral deficiencies in areas where diets are not limiting in minerals.

Recent research: Much of the recent literature has described the ability of certain dietary fiber types to affect different physiological systems. Newer sequencing procedures not only have allowed the identification of microbiota present in the intestinal tract but also have led us to better appreciate the role of fiber on intestinal health through its effect on the microbiota present and their metabolites (7, 8), which are thought to play a major role in the health benefits derived from fiber intake (9). Improvements in type 2 diabetes have been observed in parallel with changes in microbiota and SCFA production from a high-fiber diet (10). Although consumption of whole foods to increase fiber intake is most desirable, a systematic review of intervention studies led Armet et al. (11) to conclude there was an improvement in cholesterol concentrations and insulin resistance with supplement use. The role of dietary fiber in health maintenance of adolescents (ages 14–18 y) has not been the subject of much work, but 1 study demonstrated that lower soluble and insoluble fiber intakes are associated with higher fasting insulin levels and HOMA-IR and that lower soluble fiber intake is associated with elevated blood pressure (12). One of the SCFAs, butyrate, is able to regulate gene transcription through its actions as a histone deacetylase inhibitor, which affects cell proliferation, differentiation, and apoptosis in colon cells (13, 14). Another epigenetic effect may include maintenance of telomere length with increasing dietary fiber intake (15), suggesting an increase in fiber intake contributes to a reduction in biological aging and cell senescence. The overall goals of these studies are to determine why some individuals are more at risk to develop diseases (9) and some animals are more efficiently using their food for production purposes (16), as well as to identify dietary modifications that improve animal production efficiency and human health.

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