

Carbohydrates¹

Carbohydrates are subdivided into several categories on the basis of the number of sugar units and how the sugar units are chemically bonded to each other. Categories include sugars, starches, and fibers. Sugars are intrinsic in fruits and milk products. Sugars also are added to foods during processing and preparation or at the table. These “added sugars” (or extrinsic sugars) sweeten the flavor of foods and beverages and improve their palatability. Sugars are also used in food preservation and for functional properties such as viscosity, texture, body, and browning capacity. They provide calories but insignificant amounts of vitamins, minerals, or other essential nutrients. The Nutrition Facts label provides information on total sugars per serving but does not currently distinguish between sugars naturally present in foods and added sugars.

Starches are made up of many glucose units linked together. They are found in many foods, including vegetables, legumes, and grains. Most starches are broken down to sugars by digestive enzymes in the body, but some starches are resistant to digestive enzymes. Fibers, such as starches, are made mostly of many sugar units bonded together. Unlike most starches, however, these bonds cannot be broken down by digestive enzymes and pass relatively intact into the large intestine. There, fiber can be fermented by the colonic microflora or it can pass through the large intestine and bind water, increasing stool weight. Although fibers are not converted to glucose, some SCFAs are produced in the gut as fibers are fermented. SCFAs are absorbed and can be used for energy in the body. Fibers include both “dietary fiber,” the fiber naturally occurring in foods, and “functional fiber,” isolated fibers that have positive physiologic effects. No analytical measures exist to separate dietary fiber and functional fiber, so the Nutrition Facts label lists “dietary fiber,” which is actually total fiber.

Diet Recommendations

In its 2002 report (1), the Institute of Medicine (IOM) established an RDA for carbohydrate of 130 g/d for adults and children aged ≥ 1 y. This value is based on the amount of sugars and starches required to provide the brain with an adequate supply of glucose. The IOM set an acceptable macronutrient distribution range (AMDR) for carbohydrates of 45–65% of total calories. Thus, current dietary guidance recommends consumption of carbohydrate-containing foods, including grains, vegetables, fruits, pulses, nuts, seeds, and milk products. Carbohydrate foods are an important source of fiber and other nutrients.

Sugars and starches provide glucose, the main energy source for the brain, central nervous system, and RBCs. Glucose also can be stored as glycogen (animal starch) in liver and muscle

or, like all excess calories in the body, converted to body fat. Dietary fibers are nondigestible forms of carbohydrates. Dietary fiber is intrinsic and intact in plants, helps provide satiety, and promotes healthy laxation. Diets high in fiber reduce the risk of coronary heart disease, diabetes, obesity, and other chronic diseases.

The energy value of digestible carbohydrates is generally accepted as 4 kcal/g for both sugars and starches. Fermentation of fiber in the gut will produce SCFAs that contribute calories, generally estimated to be ~ 2 kcal/g. Few studies have linked carbohydrates to obesity. Indeed, observational data generally report that higher carbohydrate intake is linked to lower body weight.

In its 2002 report, the IOM set an Adequate Intake (AI) value for fiber of 14 g of fiber per 1000 kcal (1). This value is derived from data on the relation of fiber consumption and coronary heart disease risk, although the IOM also considered the evidence for fiber decreasing the risk of chronic disease and other health-related conditions. Consequently, the IOM fiber recommendations are highest for populations who consume the most calories, namely young men. Fiber recommendations are lower for women and the elderly. The use of this method for determining recommended fiber intake for children is problematic (e.g., intake of 19 g of fiber is recommended for 2-y-old children, an implausible number). Past recommendations for children were based on the “age plus 5” rule (e.g., a child aged 2 y should consume 7 g of fiber/d) (2).

Dietary fiber is listed on the Nutrition Facts panel, and 25 g of dietary fiber is the currently recommended amount in a 2000-kcal diet. Manufacturers are allowed to call a food a “good source of fiber” if it contains 10% of the recommended amount (2.5 g/serving) and an “excellent source of fiber” if the food contains 20% of the recommended amount (5 g/serving). Dietary fiber on food labels includes both dietary fiber and functional fiber.

Food Sources

Vegetables, fruits, whole grains, milk, and milk products are the major food sources of carbohydrates. Grains and certain vegetables including corn and potatoes are rich in starch, whereas sweet potatoes are mostly sucrose, not starch. Fruits and dark-green vegetables contain little or no starch but provide sugars and dietary fiber. Marriott et al. (3) examined the intake of added sugars and selected nutrients from 2003–2006 NHANES data. Thirteen percent of the population had an added-sugars intake of $>25\%$ of calories. Higher added-sugars intakes were associated with higher proportions of individuals with nutrient intakes below the Estimated Average Requirement (EAR), but the overall high calorie content and low quality of the U.S. diet remained the predominant issue.

Dietary fiber intake was particularly low in their analysis. With the exception of older women (≥ 51 y), only 0–5% of individuals in all other life-stage groups had fiber intakes meeting or

exceeding the AI (3). Fiber intake is closely linked to calorie intake. Thus, recommendations to reduce calorie intake will make increasing fiber intake particularly challenging.

It is advisable to select foods high in dietary fiber, including whole-grain breads and cereals, legumes, vegetables, and fruits, whenever possible. Typically, vegetables and fruits are not the most concentrated fiber sources, but these are important foods to encourage because they contribute important micronutrients. Similarly, milk and milk products, which contain lactose, generally do not contain fiber but these, too, are important because they contribute calcium, vitamin D, and protein to the diet.

Toxicity

The DRI committee concluded that evidence was insufficient to set a Tolerable Upper Intake Level (UL) for carbohydrates (1). However, a maximal intake level of $\leq 25\%$ of total calories from added sugars was suggested by the panel. This suggestion is based on dietary intake survey data showing that people with diets at or above this level of added sugars were more likely to have poorer intakes of important essential nutrients. There is also no UL for either dietary fiber or functional fiber.

Carbohydrates contribute to dental caries by providing substrate for bacterial fermentation in the mouth. A combined approach of reducing the frequency and duration of exposure to fermentable carbohydrate intake and optimal oral hygiene practices is the most effective way to reduce caries incidence.

Recent Research

Excessive amounts of fructose consumption in animals and humans have been associated with detrimental metabolic effects. In the real world, fructose is consumed with glucose (sucrose) in foods and only some fruits, pears and apples, are high in fructose. Although high-fructose corn syrup is called “high,” the usual composition is close to sucrose. Fructose, as commonly consumed in mixed-carbohydrate sources, does not exert specific metabolic effects that can account for increases in body weight seen in recent years (4). A fructose workshop concluded that health outcomes research meant to inform health policy should use large, long-term studies using combinations of sugars found in the typical American diet rather than pure fructose or glucose (5).

Studies on the amount, type, and sources of carbohydrates beyond sugar are limited. In an Asian cohort with a high carbohydrate intake, the total amount of carbohydrates consumed was not substantially associated with risk of ischemic heart disease mortality (6). In contrast, the shifting of food sources of carbohydrates toward a higher consumption of fruits, vegetables, and whole grains was associated with lower risk of ischemic heart disease death.

Low-carbohydrate diets, especially those that avoid grains, are a popular notion for weight control. Yet most studies, including a recent systematic review and meta-analysis (7), found that low-carbohydrate vs. isoenergetic balanced diets had the same effect on weight loss, especially when looking at long-

term effects on weight loss. There was little or no difference in weight loss and changes in cardiovascular risk factors up to 2 y of follow-up when overweight and obese adults, with or without type 2 diabetes, were randomly assigned to low-carbohydrate or isoenergetic balanced weight-loss diets.

Food patterns associated with health include consumption of dietary fiber, whole grains, vegetables, fruits, and dairy. The conclusions of recent research on carbohydrates and health from the 2010 Dietary Guidelines for Americans Advisory Committee report (8) are summarized below:

The primary role of carbohydrate is to provide energy to all cells in the body and dietary fiber. Adults should consume 45–65% of their total calories from carbohydrates, except for younger children who need a somewhat higher proportion of fat in their diets. A maximum intake of 25% of added sugars is suggested. Americans should choose fiber-rich foods such as whole grains, vegetables, fruits, and cooked dry beans and peas as staples in the diet. Dairy products are also a nutrient-dense source of carbohydrates. Carbohydrates are the primary energy source for active people. Sedentary people, including most Americans, should decrease consumption of caloric carbohydrates to balance energy needs and attain and maintain ideal weight.

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