

II. DEFINITIONS OF DIETARY FIBER

Since the early 1950s, various definitions of dietary fiber have been proposed by different countries and organizations (Table 1). In 1953, Hipsley defined dietary fiber as a term for nondigestible constituents that make up the plant cell wall, encompassing the "unavailable carbohydrate" that had been described much earlier by McCance and Lawrence (1929). This definition was expanded by Trowell (1972) based on: (1) a number of hypotheses relating dietary fiber to health ("dietary fiber hypothesis") including prevention of diverticular disease and colon cancer (Burkitt et al., 1972; Trowell, 1972); (2) a concern for the adverse effects from consuming diets high in refined carbohydrates, termed The Saccharine Disease (Cleave and Campbell, 1966); and (3) the need to replace the term "crude fiber" (Trowell, 1972). Based on the above concerns, dietary fiber was defined as "the skeletal remains of plant cells that are resistant to digestion (hydrolysis) by enzymes of man" (Trowell, 1972).

In 1976, Trowell and colleagues recognized the inadequacy of the 1972 definition because it was not known at the time of the first definition that components of the plant cell other than the cell wall, including mucilages, storage polysaccharides, and algal polysaccharides, were not hydrolyzed by the alimentary enzymes. Therefore, dietary fiber was redefined (Trowell et al., 1976) (Table 1). This definition is synonymous with the term "unavailable carbohydrate", a component of food that was measured by Southgate (1969). Publication of the 1976 definition was the result of interest in the possible health benefits of nondigestible storage polysaccharides, notably guar gum of the cluster bean. This gum was shown to reduce serum cholesterol concentration (Jenkins et al., 1975) and flatten the postprandial glycemia (Gassull et al., 1976).

The 1976 Trowell definition was the basis for the definition set by the Expert Advisory Committee on Dietary Fibre of Health and Welfare Canada (Health and Welfare Canada, 1985) (Table 1). The Health and Welfare Canada definition was initially intended to define dietary fiber with a view to future health claims for fiber. The Committee sought a definition that was broad enough to accommodate the range of dietary fiber values obtained from a number of analytical techniques. The term "endogenous" was added to the definition to emphasize that indigestible materials formed during processing, such as Maillard reaction products or charred carbon, were not considered to be dietary fiber. In addition, water soluble components found in foods, including gums, mucilages, and pectic substances, as well as non-nutritive fiber-associated substances, such as phytates, were intended to be part of dietary fiber.

In 1984, New Zealand Food Regulations defined dietary fiber as the "edible plant material not hydrolysed by the endogenous enzymes of the human digestive tract"; it was to be measured by the first method of analysis (Prosky et al., 1985) accepted by AOAC (AOAC method 985.29).

TABLE 1 Definitions of Dietary Fiber

Reference	Definition
Trowell et al., 1976	Dietary fibre consists of the plant polysaccharides and lignin which are resistant to hydrolysis by digestive enzymes of man.
Health and Welfare Canada, 1985	Dietary fibre is the endogenous components of plant material in the diet which are resistant to digestion by enzymes produced by humans. They are predominantly non-starch polysaccharides and lignin and may include, in addition, associated substances.
U.S. Food and Drug Administration (USFDA), 1987	Dietary fiber is the material isolated by AOAC method 985.29 (see Table 2).
Life Sciences Research Office (LSRO), 1987	Dietary fiber is the endogenous components of plant materials in the diet which are resistant to digestion by enzymes produced by humans.
Health Canada, 1988	A novel fibre source is a food that was manufactured to be a source of dietary fibre, and that (1) had not traditionally been used for human consumption to any significant extent, or (2) had been chemically processed (e.g., oxidized) or physically processed (e.g., finely ground) so as to modify the properties of the fibre, or (3) had been highly concentrated from its plant source.
Anonymous, 1989 (Germany)	Dietary fiber is substances of plant origin, that cannot be broken down to resorbable components by the body's own enzymes in the small intestine. Included are essentially soluble and insoluble non-starch polysaccharides (cellulose, pectin, hydrocolloids) and lignin and resistant starch. Substances like some sugar substitutes, organic acids, chitin and so on, which either are not or are incompletely absorbed in the small intestine, are not included.
Anonymous, 1992 (Belgium)	Dietary fiber is the components of the foods that are normally not broken down by the body's own enzymes of humans.
Anonymous, 1993 (Italy)	Dietary fiber is the edible substance of vegetable origin which normally is not hydrolyzed by the enzymes secreted by the human digestive system.
FAO/WHO, 1995 (Codex Alimentarius Commission)	Dietary fibre is the edible plant or animal material not hydrolysed by the endogenous enzymes of the human digestive tract as determined by the agreed upon method. (The Codex also approved AOAC methods 985.29 and 991.43 [see Table 2]).

continued

TABLE 1 Continued

Reference	Definition
Jian-xian, 1995 (China)	Dietary fiber is the sum of food components that are not digested by intestinal enzymes and absorbed into the body.
Denmark, 1995 ^a	Dietary fiber is the material isolated by AOAC methods 985.29 and 997.08 (see Table 2).
Ministry of Health and Welfare, 1996 (Japan)	Dietary fiber is the material isolated by the AOAC method 985.29. In addition, non-digestible, low molecular weight carbohydrate determined by high performance liquid chromatography is classified as dietary fiber.
Committee on Medical Aspects of Foods (COMA), 1998 (United Kingdom)	Dietary fibre is non-starch polysaccharide as measured by the Englyst method.
Finland, 1998 ^a	Dietary fiber is part of the carbohydrate obtained when using AOAC methods 985.29 and AOAC 997.08 (see Table 2).
Norway, 1998 ^a	Dietary fiber is the material isolated by AOAC method 985.29 (see Table 2) and inulin and oligofructose.
Sweden, 1999 ^a	Dietary fiber is edible material that cannot be broken down by human endogenous enzymes. Dietary fiber is determined with AOAC method 985.29. In addition, the fructan AOAC method 997.08 may be used (see Table 2).
American Association of Cereal Chemists (AACC), 2000	Dietary fiber is the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine. Dietary fiber includes polysaccharides, oligosaccharides, lignin, and associated plant substances. Dietary fibers promote beneficial physiological effects including laxation, and/or blood cholesterol attenuation, and/or blood glucose attenuation.
Hignett, 2000 (U.K. Food Standards Agency)	Dietary fiber is the material isolated by AOAC methods 985.29 and/or 991.43, combined with 997.08 (see Table 2).
Australia New Zealand Food Authority (ANZFA) (Proposed), 2000	Dietary fibre is that fraction of the edible part of plants or their extracts, or analogous carbohydrates, that are resistant to digestion and absorption in the human small intestine, usually with complete or partial fermentation in the large intestine. The term includes polysaccharides, oligosaccharides (degrees of polymerization >2), and lignins. Dietary fibre promotes one or more of these beneficial physiological effects: laxation, reduction in blood cholesterol, and/or modulation of blood glucose.

^a N-G Asp, Division of Applied Nutrition, Lund University, personal communication, February 22, 2001.

TABLE 2 Components Measured by the Various Methods of Fiber Analysis

Reference (Method) ^a	Lignin	Nonstarch Polysaccharide	Resistant Starch	Inulin
Asp et al., 1983	Yes	Yes	Some	Some
Craig et al., 2000 (AOAC 2000.11)	No	No	No	No
Englyst and Cummings, 1984 (E-GC)	No	Yes	No	No
Englyst and Hudson, 1987 (E-C)	No	Yes	No	No
Gordon and Ohkuma, in press (AOAC 2001.03)	Yes	Yes	Some	Yes
Hoebregs, 1997 (AOAC 997.08)	No	No	No	Yes
Lee et al., 1992 (AOAC 991.43)	Yes	Yes	Some	Some
Li and Cardozo, 1994 (AOAC 993.21)	Yes	Yes	Some	Some
McCleary et al., 2000 (AOAC 999.03)	No	No	No	Yes
Mongeau and Brassard, 1993 (AOAC 992.16)	Yes	Yes	No	No
Prosky et al., 1985, 1988, 1992, 1994 (AOAC 985.29, 993.19, 991.42)	Yes	Yes	Some	Some
Quigley and Englyst, 1992 (E-HPLC)	No	Yes	No	No
Schweizer and Würsch, 1979	Yes	Yes	Some	Some
Southgate, 1969	Yes	Yes	Some	No
Theander and Åman, 1979	Yes	Yes	Some	No
Theander and Westerlund, 1986	Yes	Yes	Some	No
Uppsala Method of Theander et al., 1995 (AOAC 994.13)	Yes	Yes	Some	No

^a E-GC = enzymatic-gas chromatographic, E-C = enzymatic-colorimetric, E-HPLC = enzymatic-high performance liquid chromatographic.

^b Yes, if molecular weight is 12,000 daltons or more.

Oligosaccharides	Polydextrose	Resistant Malto-dextrins	Chitin and Chitosan	Chondroitin Sulfate	Noncarbohydrate
No	No	No	Some	Some	Some
No	Yes	No	No	No	No
No	No	No	Some	Some	No
No	No	No	Some	Some	No
Yes	Yes	Yes	Some	Some	Some
No	No	No	No	No	No
No	No	No	Some	Some	Some
No	No	No	Some	Some	Some
No	No	No	No	No	No
No	No	No	Some	Some	Some
No	No	No	Some	Some	Some
No	No	No	Some	Some	No
No	No	No	Some	Some	Some
No	No	No	Some	Some	No
No	No	No	Some	Yes ^b	No
No	No	No	Some	Yes ^b	No
No	No	No	Some	Some	No

In 1987, the U.S. Food and Drug Administration (FDA) adopted AOAC method 985.29 for regulatory purposes to identify dietary fiber as a mixture of nonstarch polysaccharides, lignin, and some resistant starch (USFDA, 1987) (Table 1). Related methods that isolated the same components as AOAC method 985.29 were developed independently (AOAC methods 991.42, 991.43, 992.16, 993.19, 993.21, and 994.13; see Table 2) and accepted by AOAC in subsequent years. These methods are also accepted by FDA. The 1976 Trowell definition was the basis for FDA accepting the AOAC methods for isolating dietary fiber. These methods exclude all oligosaccharides (3 to 9 degrees of polymerization) from the definition and include all polysaccharides, lignin, and some of the resistant starch that is resistant to the enzymes (protease, amylase, and amyloglucosidase) used in the AOAC methods. However, FDA did not and still does not have a written definition of dietary fiber for the purposes of food labeling and health claims.

Similar to the United States, there is no official definition of dietary fiber in Japan. A standard method for measuring dietary fiber in Japan is based on AOAC method 985.29 plus a chromatographic method that isolates low molecular weight maltodextrins (Gordon and Ohkuma, in press) (Table 1). Dietary fibers can also be approved in Japan as effective ingredients in foods for specific health use; these include indigestible maltodextrin, hydrolyzed guar gum, chitosan, polydextrose, psyllium, wheat bran, and depolymerized sodium alginate (DeVries, 2001). For many Asian countries, dietary fiber intake tables have been based on AOAC methods 985.29 and 991.43, although the definition used by China since 1995 does not identify a specific method (Jian-xian, 1995) (Table 1).

The Expert Panel on Dietary Fiber of the Life Sciences Research Office (LSRO) proposed a definition of dietary fiber in 1987 similar to the one identified by Health and Welfare Canada in 1985. This definition included nonstarch polysaccharides and lignin and excluded fiber-associated substances found in the plant cell wall such as phytates, cutins, saponins, lectins, proteins, waxes, silicon, and other inorganic components (LSRO, 1987). Other substances not considered to be dietary fiber according to the LSRO definition include indigestible compounds formed during cooking or processing (e.g., resistant starch, Maillard reaction products), oligosaccharides and carbohydrate polymers of less than 50 to 60 degrees of polymerization that are not recovered in dietary fiber analysis, nonplant-derived compounds (e.g., chitin, chitosan), and synthetic carbohydrate polymers.

In 1988, Health Canada published guidelines for novel fiber sources and food products containing them that can be labeled as a source of fiber in addition to those included in their 1985 definition (Health Canada, 1988) (Table 1). The rationale for these guidelines was that there were safety issues unique to novel sources of fiber, and if a product was represented as containing fiber, it should have the beneficial physiological effects associated with dietary fiber that

the public expects. The guidelines indicate that both safety and efficacy of the fiber source have to be established in order for the product to be identified as a source of dietary fiber in Canada, and this has to be done through experiments using human subjects. Three measures of efficacy were identified: (1) laxation, (2) normalization of blood lipid levels, and (3) attenuation of blood glucose responses. Detailed guidelines were later produced for the clinical studies required to assess laxation effects, as this was the physiological function most often used by industry when seeking approval for a novel fiber source (Health Canada, 1997a).

In 1995, a definition for dietary fiber appeared in the Codex Alimentarius Guidelines on Nutrition Labelling (FAO/WHO, 1995) (Table 1). The Codex allows the analytical methods AOAC 985.29 and AOAC 991.43 (Table 2) for measurement of dietary fiber in special foods and infant formula. There have been recent attempts to revise the Codex definition; however, there has not been a consensus on the inclusion of animal and other chemically characterized substances (FAO/WHO, 2000).

Several countries in Europe published definitions for dietary fiber in the late 1980s and early 1990s, including Germany (Anonymous, 1989), Belgium (Anonymous, 1992), and Italy (Anonymous, 1993) (Table 1). For labeling purposes, Denmark, Finland, Norway, and Sweden have defined dietary fiber as edible material that cannot be degraded by human endogenous enzymes, as measured by AOAC method 985.29 (Table 1). The issue regarding inclusion or exclusion of inulin and fructooligosaccharides has been handled somewhat differently by these countries in the absence of European Union regulation. In Denmark and Norway, fructans have been allowed to be included as dietary fiber on the food labels since 1995 and 1998, respectively (i.e., before the approval of AOAC method 997.08). Sweden made a similar decision in 1999, specifying AOAC method 997.08. In 1998, the Food Administration of Finland recommended that inulin and oligofructose be labeled separately and not be included as dietary fiber. In 2001, however, AOAC method 997.08 was added to 985.29 for analysis of dietary fiber, implying that inulin and oligofructose can now be labeled as dietary fiber in the four Nordic countries (N-G Asp, Division of Applied Nutrition, Lund University, personal communication, February 22, 2001).

In 1998, the Committee on Medical Aspects of Food and Nutrition Policy (COMA) of the United Kingdom formally adopted the Englyst nonstarch polysaccharide method for defining dietary fiber (COMA, 1998) (Table 1). In September 2000, the U.K. Food Standards Agency recommended AOAC methods 991.43 and 997.08 (Table 2) to ensure consistent labeling of food products (Hignett, 2000) (Table 1). In November 2000, the U.K. Food Standards Agency acknowledged COMA's definition of dietary fiber as nonstarch polysaccharides yet recognized that the "European rules preclude insistence on a national definition". AOAC method 985.29 and the Englyst method (Englyst and Cummings, 1984) are cur-

rently accepted by the European Community to measure dietary fiber but there is no clearly written definition of the material that is measured by these methods.

In May 2000, the American Association of Cereal Chemists (AACC) adopted an updated definition of dietary fiber that was developed by a committee appointed to review, and if necessary, update the original AACC definition of dietary fiber (AACC, 2000) (Table 1). This definition is similar to the ANZFA definition. The AACC definition recognizes that the primary characteristics of dietary fiber are resistance to digestion and absorption in the small intestine and fermentation in the large intestine; the rationale for including these characteristics is that it recognizes the key physiological impacts of fiber demonstrated in the past 30 years of research (AACC, 2000).

In November 2000, the recently formed Australia New Zealand Food Authority (ANZFA) concluded that relying on a prescribed analytical method as the sole means of defining dietary fiber for regulatory purposes was unsatisfactory since analytical methods do not take into consideration the physiological impact of new food forms or food ingredients that are part of the diet (ANZFA, 2000). Thus, a definition has been proposed (Table 1) that includes the origin, chemistry, and physiology of dietary fiber, similar to the Codex Alimentarius Guidelines on Nutrition Labelling (FAO/WHO, 1995) and the earlier New Zealand Food Regulations definition (New Zealand, 1984). Furthermore, ANZFA has endorsed the use of AOAC method 985.29 or 991.43, and AOAC methods 997.08 or 999.03, which measure fructans (e.g., inulin) (Table 2).

In conclusion, a variety of definitions for dietary fiber have been promulgated by scientific and regulatory agencies worldwide. Some definitions specifically state a physiological definition of dietary fiber, whereas others rely on more prescribed analytical methods as the sole determinant of dietary fiber. The majority of accepted analytical methods for the measurement of dietary fiber are based on a variety of AOAC accepted methods.

Since many definitions are based on methods to analyze dietary fiber, the evolution of the methodologies to measure fiber were reviewed (see Appendix C). Nonstarch polysaccharides are recovered by all methods designed to measure all components of dietary fiber, and only those methods developed to measure a specific fiber component (e.g., resistant maltodextrins, inulin, polydextrose) do not recover nonstarch polysaccharides (Table 2). Most methods include the non-carbohydrate lignin as a component of dietary fiber. Only the methods of Englyst and the methods developed to measure a specific type of polysaccharide exclude lignin. In addition, the methods of Englyst and of Mongeau and Brasard, which were designed to measure all fiber components, do not include resistant starch as fiber.

Dependence on ethanol precipitation as a means of recovering polysaccharides excludes polydextrose, resistant maltodextrin, and oligosaccharides, and most inulin, which are soluble in ethanol. These saccharides also are lost if ethanol is used at the beginning of an analytical procedure to remove mono- and

disaccharides. Measurement of polysaccharides from animal sources (e.g., chitin, chitosan, or chondroitin sulfate) has not been systematically studied, but methods developed to measure total fiber do recover a portion of these types of polysaccharides.