CFW PERSPECTIVE

A Historical Perspective on Defining Dietary Fiber

J. W. DeVRIES, L. PROSKY, B. LI, AND S. CHO

It is generally believed that Hipsley in 1953 was the first to use "dietary fiber" as a shorthand term for the nondigestible constituents that make up the plant cell wall (1). These constituents were known to include cellulose, hemicellulose, and lignin. The term "dietary fiber" was clearly an attempt to distinguish some property or constituent of the food above and beyond what was then being measured by the crude fiber method.

Between 1972 and 1976, Trowell, Burkitt, Walker, Painter, and co-workers (2–6) adopted Hipsley's term in conjunction with a number of health-related hypotheses they were developing, referred to as their "dietary fiber hypotheses." The term was used to describe the remnants of plant components that are resistant to hydrolysis by human alimentary enzymes. Thus it was a physiological-botanical description, characterizing dietary fiber's indigestibility in the human small intestine, with plant cell walls being the major source of digestion-resistant material. The components included cellulose, hemicellulose, lignin, and associated minor substances, such as waxes, cutin, and suberin. Its edibility was implied. The inclusion of certain other obvious fiber properties was probably implied as well, such as those associated with the stringy fiber of celery and other vegetables and the character of edible peels on fruits, as well as the resistance of cereal bran to grinding. The "dietary fiber hypotheses" postulated an inverse relationship between dietary fiber consumption and the incidence of colon cancer and heart diseases. Publication of the hypotheses led to numerous dietary fiber research projects in nutrition, analysis, and food technology, among other areas.

By 1976, the dietary fiber definition had been broadened to include all indigestible polysaccharides (mostly plant storage saccharides), such as gums, modified celluloses, mucilages, oligosaccharides, and pectins (7). It remained primarily a physiological definition, identifying dietary fiber on the basis of edibility and resistance to digestion, but was broadened to reflect chemical research findings obtained in the interim years. Some of the nondigestible polysaccharides were included because they were found to have the physiological actions attributed to dietary fiber but could not necessarily be chemically identified as having their origins in the cell wall. This broadened definition (6) quickly gained widespread acceptance.

Driven by growing knowledge of the benefits of dietary fiber, numerous researchers began developing analytical methods in an attempt to quantify the portion of foods that provides the physiological functionality of dietary fiber. Among others, Asp of Sweden (8,9), Schweizer of Switzerland (10), Theander of Sweden (11,12,13), Southgate of the United Kingdom (14,15,16), and Furda, Baker, Van Soest, Heckman, and co-workers in the United States (17–23) developed procedures aimed at achieving this goal. The focus was primarily on removing the digestible portions of the food from the digestion-resistant portions, using enzymes as the primary tool. Various degrees of success were achieved, but success was limited in part by digestive activity present in commercially available enzymes that was not present in human enzymes.

In the late 1970s, Prosky began to seek consensus on a dietary fiber definition in the scientific community (24). To assist in the effort to quantify dietary fiber in foods for nutrition improvement and labeling purposes, he also sought consensus on analytical methodology that would be commensurate with the definition and gathered the opinions of over 100 scientists worldwide. By the 1981 spring workshop of the Association of Official Analytical Chemists (AOAC) in Ottawa, Canada, general consensus had been achieved (25) on pursuing methodology that would quantify dietary fiber, as defined by Trowell and co-workers in 1976. The methodological research work of Asp, Furda, and Schweizer and co-workers was deemed to be the best approach. In a cooperative effort led by Prosky, these researchers (along with DeVries and Harland) arrived at a single method deemed suitable for a multinational collaborative study. Interest in and support for this approach was so high that 43 laboratories in 29 countries agreed to participate in the study.

After researcher's initial disappointment with enzymatic-gravimetric methodology during a first collaborative study, minor modifications in the method protocol were made, a rugged accurate method was obtained, and a successful collaborative study was completed (26,27). The method was adopted by AOAC as the first Official Method of Analysis for total dietary fiber, AOAC Official Method 985.29, Total Dietary Fiber in Foods—Enzymatic-Gravimetric Method (28). Based on the same successful collaborative study (27) and in the same year, the AACC adopted the method as AACC Approved Method 32-05 (29).

Among the keys to success in achieving adequate methodology were specifications on enzyme purity and on precise handling of the digestion steps of the method. It was determined that strict attention had to be paid to ensure that the enzymes used are digesting the food components normally digested in the human system and not the digestion-resistant components of the sample. This is to ensure both adequate performance of the method and accuracy in terms of consistency with the dietary fiber definition.

Routine use of the method spread rapidly worldwide as the analytical and nutrition research communities responded to the interest in the positive effects of increased dietary fiber in the diet. Because it was designed to effectively quantify those food components commensurate with dietary fiber, as agreed upon at the Ottawa workshop (25) and because of its widespread acceptance and use, AOAC 985.29/AACC 32-05 became the de facto operating definition of dietary fiber. As the important nutritional distinctions between insoluble and soluble dietary fiber emerged, AOAC 985.29 was modified to allow the isolation and quantification of the insoluble and soluble dietary fiber fractions. The distinction between the two fiber fractions is somewhat arbitrary, based on the solubility of the soluble fraction in a pH-controlled enzyme solution, as is the case in the human alimentary system; however, the solution in the laboratory is much more dilute.

The de facto defining method depends on the soluble fiber being precipitated in a mixture of 1 volume aqueous enzyme solution with 4 volumes of 95% ethanol, a solution long used by analytical chemists to separate complex from simple molecules. While this is the case in the method, the dietary fiber definition per se does not imply insolubility or precipitation in aqueous ethanol as a

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requirement. The modified methodology was validated by collaborative study and adopted by AOAC as Official Method 991.42, Insoluble Dietary Fiber in Food and Food Products—Enzymatic-Gravimetric Method, Phosphate Buffer (30). Later, in 1993, Official Method 993.16, Soluble Dietary Fiber in Food and Food Products—Enzymatic-Gravimetric Method (Phosphate Buffer) was also adopted by AOAC.

With a generally accepted "gold standard" definition and a benchmark method in place, research scientists added improvements to the method or developed alternative approaches to arrive at the same objective. Lee, Mongeau, Li, Theander, and co-workers developed, validated through collaborative study, and gained official approval of other methods. Prominent among these was AOAC 991.43 for total, insoluble and soluble dietary fiber in one procedure similar to the AOAC 985.29/991.42/993.16 group except using MES-TRIS buffer. It was approved as a joint AOAC/AACC method, with the AACC Approved Method number being 32-07 (31,32).

Also adopted as official methods were: AOAC 992.16, Total Dietary Fiber, Enzymatic-Gravimetric Method; AOAC 993.21, Total Dietary Fiber in Foods and Food Products with ≤2% Starch, Nonenzymatic-Gravimetric Method; and AOAC 994.13, Total Dietary Fiber (Determined as Neutral Sugar Residues, Uronic Acid Residues, and Klason Lignin)—Gas Chromatographic-Colorimetric-Gravimetric Method (Uppsala Method). These methods utilized different approaches to quantifying the digestion-resistant portion of the food sample, but the benchmark for total dietary fiber was still the de facto defining method, AOAC 985.29/AACC 32-05.

In 1992, to reaffirm that the scientific community was pursuing the appropriate path with regard to dietary fiber methodology, Lee and Prosky conducted an international survey of 147 professionals involved in the research (33). Sixty-five percent of the scientists supported the current physiological definition, while an additional 5% favored using it in combination with a chemical definition. Fifty-nine percent supported the inclusion of digestion-resistant oligosaccharides. In a follow-up survey in 1993, 65% of the respondents favored inclusion of nondigestible oligosaccharides, and 80% supported the inclusion of resistant starch (34). At an international workshop on definition and analysis of complex carbohydrates and dietary fiber held by AOAC International in Memphis, TN, in 1995, there was general agreement on the physiological definition of fiber and the inclusion of digestion-resistant oligosaccharides in that definition. However, workshop participants acknowledged that AOAC 985.29/AACC 32-05 did not quantify certain unique components of dietary fiber as defined. Since methodology that would include these components is still lacking, it behooves researchers to develop, validate, and adopt appropriate methodology that would do so. In the meantime, at the request of its Technical Committee on Dietary Fiber, AACC has made available an analytical reference standard with analytical values for total, insoluble, and soluble dietary fiber, based on collaborative method study of the two principal method groups (35).

Summary

There has been consensus since the late 1970s that *"dietary fiber consists of the remnants of edible plant cells, polysaccharides, lignin and associated substances resistant to (hydrolysis) digestion by the alimentary enzymes of humans."* This definition identifies a macroconstituent of foods that includes cellulose, hemicellulose, lignin, gums, modified celluloses, mucilages, oligosaccharides, and pectins and associated minor substances, such as waxes, cutin, and suberin. The physiological definition was reaffirmed among scientists internationally in surveys in 1992 and 1993 and as the outcome of a consensus workshop in 1995. Methodology commensurate with most aspects of the definition (AOAC 985.29 /AACC 32-05) was adopted and became the de facto defining method. Minor gaps between the definition and current methods will require further method development, validation, and adoption to ensure inclusion of all components that make up dietary fiber.

Defining Dietary Fiber

Year	Event
1953	Hipsley coins term "dietary fiber."
1972–1976	Trowell and co-workers define constituent makeup as part of their "dietary fiber hypotheses." This definition is used to describe the remnants of plant cell wall components that are resistant to hydrolysis by human alimentary enzymes.
1976	Trowell and co-workers. broaden definition to include all digestion-resistant polysaccharides (mostly plant storage saccharides), such as gums, modified celluloses, mucilages, oligosaccharides, and pectins. The broadened definition includes cellulose, hemicellulose, lignin, gums, modified celluloses, mucilages, oligosaccharides, and pectins, and associated minor substances, such as waxes, cutin, and suberin.
1976–1981	Researchers Asp, Schweizer, Furda, Theander, Baker, and Southgate, among others, develop methods aimed at quantifying food components included in the definition.
1979	Prosky begins process of developing an international consensus on definition of and methodology for dietary fiber.
1981	Consensus on dietary fiber definition and analytical approach at AOAC Spring Workshop in Ottawa, Ontario, Canada
1981–1985	Prosky, Asp, Furda, Schweizer, DeVries, and Harland validate consensus methodology in multinational collaborative studies.
1985	AOAC Official Method of Analysis 985.29, Total Dietary Fiber in Foods—Enzymatic-Gravimetric Method Adopted. Method and the equivalent AACC Approved Method 32-05 become de facto working definition for dietary fiber.
1985–1988	Methodology developed and collaboratively studied for insoluble and soluble dietary fiber.
1991	AOAC Official Method of Analysis 991.42, Insoluble Dietary Fiber in Foods and Food Products, Enzymatic-Gravimetric Method, Phosphate Buffer and the equivalent AACC Approved Method 32-07 first adopted.
1988–1994	Taking a variety of approaches, Lee, Mongeau, Li, Theander and co-workers develop, validate, and bring to official or approved method status other methods fitting the definition of dietary fiber.
1992	International survey reaffirms consensus on physiological dietary fiber definition.
1993	Second international survey reaffirms consensus on physiological dietary fiber definition and reaffirms inclusive components.
1995	AOAC International Workshop on Definition of Complex Carbohydrates and Dietary Fiber reaffirms consensus on physiological dietary fiber definition and inclusive components.
1999	Definition of dietary fiber remains as "dietary fiber consists of the remnants of edible plant cells, polysaccharides, lignin and associated substances resistant to (hydrolysis) digestion by the alimentary enzymes of humans." This definition identifies a macroconstituent of foods that includes cellulose, hemicellulose, lignin, gums, modified celluloses, mucilages, oligosaccharides, and pectins and associated minor substances, such as waxes, cutin, and suberin. AOAC 985.29/AACC 3205, AOAC 991.43/AACC32-07, and equivalent methods are being used as de facto defining methods for total dietary fiber.

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