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Carbohydrates and Related Food Components: INFOODS Tagnames, Meanings, and Uses

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INFOODS international food component identifiers, also known as tagnames, are used in retrospectively evaluating and updating existing food composition systems and in the prospective design and implementation of new systems. In this paper the relationships between 88 food components that are predominantly carbohydrate in nature, their preparations, and methods of analysis and presentation are examined. Some examples of the ambiguity and/or opportunity for misinterpretation of carbohydrate and dietary fiber data are quantified, and guidelines for selecting and using INFOODS tagnames are discussed. © 1996 Academic Press, Inc.

INTRODUCTION

Making sense of food components that can be classified as carbohydrates, dietary fiber, or constituents of these, can be difficult. The large number of methods for expressing and/or analyzing carbohydrates and dietary fiber (Southgate, 1991; Monro, 1995) and the continuing debate about the meanings of these terms creates problems for those who generate, compile, and use food composition data.

These uncertainties are reflected in the numeric values presented in food composition tables and data files. To the user of these data, the information is often ambiguous at best and can lead to serious misinterpretation at worst. The problem is easily illustrated with the commonly used proximate compositional term ''carbohydrate,'' which can represent any of five accepted conventions for analyzing/expressing this nutritional entity, each of which represents a different mixture of constituents.

Other terms such as ''dietary fiber'' and ''pectin'' refer not to specific chemical species, but to overlapping mixtures of polymers, defined as much by their solubility under certain sets of conditions as by their chemical identity. ''Nonstarch polysaccharides'' (NSP) is a more precise term, but also denotes a mixture. Furthermore, the components in such mixtures are often described more precisely elsewhere within a food component list, so there is considerable scope for redundancy.

An INFOODS expert committee was convened with the goal of establishing a system of international food component identifiers, to eliminate ambiguity and misinterpretation of nutritional information. This committee developed and published international food component identifiers, also know as tagnames, in 1989 (Klensin *et al.*,

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1989). Since that time an electronic system for registering new tagnames and distributing them has been established (INFOODS, 1995b). Tagnames incorporate the food component entity, the method of analysis (or method of calculation) when different methods are known to produce different values, and the units of expression. Each tagname reflects a unique representation of a food component. Tagnames are used in the retrospective evaluation and updating of existing food composition systems (Burlingame, 1991, 1993; Lewis, 1995; Haytowitz, personal communication; Murphy, personal communication) and in the prospective design and implementation of new systems (Matenga-Smith, 1995; Alexander, 1995).

Tagname use for all food components is a requirement for the INFOODS data interchange scheme (Klensin, 1992), as well as for proper interpretation of the food data. Experience in New Zealand with electronic interchange of data files with and without tagnames has been a beneficial exercise in demonstrating the value of tagnames for this purpose, and it is particularly striking for food components that are carbohydrate in nature (Burlingame, 1991; Burlingame *et al.,* 1994a).

METHODS

Categorizing Tagnames That Are Predominantly Carbohydrate in Nature

Tagnames that refer to food components that are predominantly carbohydrate in nature were identified and divided into five main categories on the basis of their use in food composition tables/datafiles and their chemistry: (1) aggregations of constituents commonly referred to as the proximate entity ''carbohydrate''; (2) the individual components of (1); (3) dietary fiber preparations that can be subdivided by method of analysis; (4) monosaccharide components of (3); and (5) other food components such as polysaccharides and cell wall fractions that would also contribute to category 3 in fiber analysis.

Illustrating the Magnitude of Numeric Differences Possible among the Proximate Carbohydrate Aggregations

Terms representing the proximate carbohydrate entity from food composition tables from several different countries were examined (ASEAN Food Habits Project, 1988; Burlingame *et al.,* 1994b; USDA, 1993; English *et al.,* 1990; Holland *et al.,* 1991). The theoretically true composition of standardized wheat bran and maize flour was conjectured and calculated on a dry matter basis. A ''correct'' value for each term was then calculated to illustrate the magnitude of numeric differences possible with the different expressions of the proximate entity carbohydrate. Other reasons for variability were not addressed or considered.

Illustrating the Components of Different Dietary Fiber Preparations

The relationship between food polymer fractions that typically comprise dietary fiber, commonly used synonyms for dietary fiber, and tagnamed fiber preparations as well as the approximate contribution of various food constituents to the fiber preparations were diagrammed to illustrate two points: (i) cell wall polymers are not fully recovered in some fiber preparations even though plant cell walls are central to the concept of dietary fiber in human nutrition, and (ii) non-cell-wall materials including

TABLE 1

AGGREGATIONS OF CONSTITUENTS COMMONLY REFERRED TO AS THE PROXIMATE ENTITY CARBOHYDRATE

Tagname	Description
CHOAVL	Carbohydrate, available (by summation of analytical values); includes free sugars plus dextrins, starch and glycogen
CHOAVLDF	Carbohydrate, available (by difference); calculated as 100g minus the sum of grams of water, protein, fat, fibre and ash
CHOAVLM	Carbohydrate, available, expressed as the monosaccharide equivalent; includes free sugars plus dextrins, starch and glycogen
CHOCDF	Carbohydrate, total (by difference); calculated as 100g minus the sum of grams of water, protein, fat and ash
CHO-	Carbohydrate, method unknown

polysaccharides, amylase-resistant starch, and any other materials that resist digestion by enzymes of the human digestive tract may be contained in the preparation, depending on method and definition.

Identifying Fiber Components and Mixtures as Soluble and Insoluble

Most methods for soluble fiber analysis are simply modifications of total-fiber methodology, with a step inserted after starch digestion to separate soluble fiber from insoluble material by filtering or centrifuging the digestate. The soluble fiber is then recovered from the liquid phase, most often by precipitating with ethanol. Dietary fiber solubility and therefore the distribution of nonstarch polysaccharide between insoluble and soluble fractions is very method-dependent, but even so, conditions for extracting starch/soluble fiber have not been standardized. Methods differ in pH and buffer species, both of which can have a powerful effect on solubility of pectic substances that are a major component of soluble fiber (Monro, 1991), so ''soluble fiber'' food components may not be equivalent for a given sample. The usual approximate distribution of several food components between soluble and insoluble fiber fractions has been summarized.

RESULTS AND DISCUSSION

Tables 1–5 show the placement of tagnames for food components that are predominantly carbohydrate in nature in five main categories: (1) aggregations of constituents commonly referred to as the proximate entity carbohydrate; (2) the individual components of (1); (3) dietary fiber preparations that can be subdivided by method of analysis; (4) monosaccharide components of (3); and (5) other food components such as polysaccharides and cell wall fractions that would also contribute to category 3 in

TABLE 2

THE INDIVIDUAL COMPONENTS AND SUBAGGREGATES OF THE AGGREGATE CARBOHYDRATE

Tagnames	Components
Monosaccharides determined by direct analysis	
FRUS	Fructose
GALS	Galactose
GLUS	Glucose
ARAS	Arabinose
XYLS	Xylose
Disaccharides determined by direct analysis	
LACS	Lactose
LACSM	Lactose, expressed as the monosaccharide equivalent
MALS	Maltose
MALSM	Maltose, expressed as the monosaccharide equivalent
SUCS	Sucrose
SUCSM	Sucrose, expressed as the monosaccharide equivalent
Aggregations of mono- and/or disaccharides	
DISAC	Disaccharides
DISACM	Disaccharides, expressed as the monosaccharide equivalent
SUGAR	Total available sugars
SUGARM	Total available sugars, expressed as the monosaccharide equivalent
SUGNRD	Non-reducing sugars
SUGRD	Reducing sugars
Other "available" carbohydrate polymers determined by direct analysis	
STARCH	Starch
STARCHM	Starch, expressed as the monosaccharide equivalent
GLYC	Glycogen
GLYCM	Glycogen, expressed as the monosaccharide equivalent
INULN	Inulin
ALGNT	Alginates
AMYP	Amylopectin
AMYPM	Amylopectin, expressed as the monosaccharide equivalent
AMYS	Amylose
AMYSM	Amylose, expressed as the monosaccharide equivalent
DEXTN	Dextrins
DEXTNM	Dextrins, expressed as the monosaccharide equivalent
MALTRS	Maltotriose
MALTRSM	Maltotriose, expressed as the monosaccharide equivalent
OLSAC	Oligosaccharides
OLSACM	Oligosaccharides, expressed as the monosaccharide equivalent
RAFS	Raffinose
RAFSM	Raffinose, expressed as the monosaccharide equivalent
RIBS	Ribose
SORTL	Sorbitol

TABLE 3

TAGNAMES FOR FOOD DIETARY FIBER PREPARATIONS

Fiber by gravimetric methods for forage research	
FIBAD	Fiber; determined by acid detergent method
FIBADC	" (Clancy modification)
FIBC	Fiber, crude
FIBND	Fiber; determined by neutral detergent method
FIBNDH	" (Holloway)
Food fiber by gravimetry	
FIBINS	Fiber, water-insoluble
FIBSOL	Fiber, water-soluble
FIBTG	Fiber, total dietary; determined gravimetrically by the AOAC total dietary fiber method
Food fiber by sugar-specific quantitation plus gravimetry	
FIBTS	Fiber, total dietary; sum of non-starch polysaccharide components and lignin
FIBTSW	" (Wenlock)
Food "fiber" (as NSP) by sugar-specific quantitation; non-gravimetric	
PSACNC	Polysaccharides, non-cellulosic
PSACNCI	Polysaccharides, non-cellulosic, water-insoluble
PSACNCS	Polysaccharides, non-cellulosic, water-soluble
PSACNS	Polysaccharides, non-starch
PSACNSI	Polysaccharides, non-starch, water-insoluble
PSACNSS	Polysaccharides, non-starch, water-soluble
PSNSGII	Polysaccharides, non-starch, insoluble under GI conditions
PSNSGIS	Polysaccharides, non-starch, soluble under GI conditions
Fiber; method not specified	
FIB-	Fiber; method of determination unknown

fiber analysis. Placement within a category is based on their usage in food composition tables/data files and their chemistry. Tables 6–9 illustrate the rationale for the creation and use of INFOODS tagnames, as opposed to, or in addition to, common and simple terms in popular use.

Aggregations of Constituents Commonly Referred to as the Proximate Entity Carbohydrates

(1) CHOAVL, (2) CHOAVLM, (3) CHOCDF, (4) CHOAVLDF, (5) CHO-

In analysis and/or expression of a nutrient entity called carbohydrate, the aggregation can include or exclude a number of components.

TABLE 4

MONOSACCHARIDE COMPONENTS OF FIBER PREPARATIONS

Tagname	Component
ARAFB	Arabinose in dietary fiber
GALFB	Galactose in dietary fiber
GLUFB	Glucose in dietary fiber
MANFB	Mannose in dietary fiber
RHAFB	Rhamnose in dietary fiber
XYLFB	Xylose in dietary fiber
FIBHEX	Hexoses in dietary fiber
FIBPENT	Pentoses in dietary fiber

Table 1 shows tagnames for five commonly used, and very different, methods of expressing the proximate compositional entity, often simply referred to as carbohydrate.

CHOAVL and CHOAVLM are aggregations of analytical values (i.e., the sum of individual mono- and disaccharides + starch), while CHOCDF and CHOAVLDF are calculated by difference (i.e., 100 g minus the sum of the gram amounts of the other proximate entities). CHO-, representing carbohydrate with an unknown method of determination, is a useful tagname when retrospectively evaluating food composition data that have insufficient documentation. The terminal M in a carbohydrate or fiber tagname represents expression of this component as its monosaccharide equivalent (ME). Conversion of disaccharides, trisaccharides, tetrasaccharides, pentasaccharides, and starch to ME requires multiplying by 1.05, 1.07, 1.08, 1.09, and 1.1, respectively (Southgate, 1991). The most important distinction made by these proximate representation of carbohydrates, in terms of proper interpretation of values, is available vs total (i.e., unavailable). CHOAVL, CHOAVLM, and CHOAVLDF represent the so-called available carbohydrates, that is those that exclude fiber in their representation.

It can be guessed by the above discussion that the different representations of ''carbohydrate'' would necessitate differences in the correct numeric values for this proximate entity. Since virtually all food composition tables in the world (INFOODS, 1995a) present carbohydrate values, this component is particularly useful in demonstrating the importance of tagnames as they relate to eliminating ambiguity and misinterpretation of the numeric data.

To illustrate, the theoretically true compositions of standardized wheat bran and maize flour on a dry matter basis, according to the constituents represented by the term ''carbohydrate'' as used in food composition tables/data files of different countries/regions, are presented in Table 6 (ASEAN Food Habits Project, 1988; Burlingame *et al.*, 1994b; USDA, 1993; English *et al.*, 1990; Holland *et al.*, 1991). These examples were chosen to represent the most extreme situation, and the differences in carbohydrate values for most foods will not be as great.

TABLE 5

OTHER FOOD COMPONENTS THAT MAY BE CLASSIFIED AS "DIETARY FIBER" IN FOODS

Tagname	Component
Cell wall polymer fractions	
PECT	Pectin
HEMCEL	Hemicellulose
CELLU	Cellulose
LIGN	Lignin
PENSN	Pentosan
HEXSN	Hexosan
PURAC	Polyuronic acid
Specified polysaccharides	
ARAN	Arabinan
GALTN	Galactan
GLUCNB	Betaglucan
XYLN	Xylan
MANN	Mannan
STARES	Starch, resistant
Complex nonstructural heteropolysaccharides	
AGAR	Agar
ALGNT	Alginate
CARGN	Carageenan
GUMS	Gums
MUCIL	Mucilages
PSACALG	Polysaccharides, algal

Columns one and two of Table 6 show examples of the simple, common terms used for carbohydrate as a proximate constituent in food composition tables from seven different countries/regions. An expanded description of what the terms mean follows in the third column. Typically, the expanded description, related to the method of determination and/or the fractions included within the entity carbohydrate, is found somewhere in the introductory pages of tables of food composition.

As can be seen in Table 6, the same term is often used to describe different entities of carbohydrate. For example, both the U.S.A. and Australia use the term "Total carbohydrate." The expanded description shows that two very different aggregations are represented, with the major difference being that the USDA's includes fiber and Australia's excludes fiber. Therefore, the true and correct values for high fiber foods will be expected to be very different in these two countries. The column headed "Standardized value for wheat bran" shows 75 vs 40 g/100 g dry matter for the USDA and Australia, respectively. The values presented are the theoretically correct values, without consideration of other factors which could contribute to differences.

TABLE 6

TERMS, MEANINGS, AND TAGNAMES ASSOCIATED WITH CARBOHYDRATE VALUES* IN FOOD COMPOSITION TABLES

Country	Term used	Expanded description	Tagname	Standardized value for wheat bran (dry matter basis)	Standardized value for maize flour (dry matter basis)
USA (USDA, 1975-94)	Carbohydrate, Total	Total carbohydrate by difference	<CHOCDF>	75g/100g	85g/100g
UK (Holland et al., 1991)	Carbohydrate	Available carbohydrate (summation) in monosaccharide equivalents	<CHOAVLM>	42g/100g	93g/100g
East Asia (US Dept HEW/FAO, 1972)	Carbohydrate	Total carbohydrate by difference	<CHOCDF>	75g/100g	85g/100g
Australia (English et al., 1990)	Carbohydrate, Total	Available carbohydrate (summation) (not in monosaccharide equivalents)	<CHOAVL>	40g/100g	85g/100g
New Zealand (Burlingame et al., 1994b)	Available carbohydrate	Available carbohydrate (summation) in monosaccharide equivalents	<CHOAVLM>	42g/100g	93g/100g
Malaysia (ASEAN, 1988)	Carbohydrate	Available carbohydrate by difference	<CHOAVLDF>	40g/100g	85g/100g

* The values presented are the standardized, theoretically correct values. Other sources of discrepancies or error are not considered.

Another reason for differences in values in some tables is the expression of ''available carbohydrates'' in monosaccharide equivalents. For foods high in starch, oligosaccharides, and disaccharides, the differences are marked. Tables in the United Kingdom and New Zealand express available carbohydrate as the monosaccharide equivalent, while the others listed do not. The difference is usually calculated as 10% for starch and 5% for disaccharides. The last column in Table 6 shows carbohydrate values of 85 vs 93 g/100 g dry matter for carbohydrate in maize flour, a high starch food, with the sole difference being the expression of the carbohydrate as the monosaccharide equivalent for the higher value (again these values have been standardized to eliminate other potential differences such as different extraction rates for flours in different countries and normal biological variability).

Comparing tagnames for the term carbohydrate in Table 6 makes clear an important reason for the significant differences in values for the same food in different tables. The simple term used in the tables does not suffice. The use of tagnames is important in printed materials, but even more so in electronic data files where expanded descriptions, methods of analyses, and other important information are in separate files, often without direct links to the food records (USDA, 1993; NZICFR, 1995).

The Individual Components That Make Up the Proximate Aggregation of Carbohydrate

Table 2 shows the ''available'' constituents that make up the proximate carbohydrate aggregation.

TABLE 7

RELATIONSHIP BETWEEN TAGNAMES, DIETARY FIBER DEFINITIONS, AND ANALYTICAL METHODS

Tagname	Fiber definition	Analytical objective
FIBC	The residue of plant food left after extraction with solvent, dilute acid, and dilute alkali[1].	To obtain an empirical measure of the non-nutritive fraction of animal feeds.
FIBAD, FIBADC, FIBND, FIBNDH	Insoluble organic matter indigestible by animal enzymes[2].	As above: To obtain an empirical measure of the feed cell wall fraction resistant to fermentation in the rumen.
FIBINS, FIBSOL, FIBTG	Remnants of plant cells resistant to hydrolysis by the alimentary enzymes of man[3].	To measure non-digestible food constituents (mainly polysaccharides and lignin) resistant to activities of the type shown by human digestive enzymes.
FIBTS, FIBTSW	Sum of lignin and the plant polysaccharides not digested by the endogenous secretions of the human digestive tract[4].	To measure non-digestible polysaccharides and lignin, resistant to activities of the type shown by human digestive enzymes.
PSACNC, PSACNCI, PSACNCS, PSACNS, PSACNSI, PSACNSS, PSNSGII, PSNSGIS	Non-starch polysaccharides[5].	To measure non-starch polysaccharides (NSP) as an index of plant cell walls in food.

(6) FRUS, (7) GALS, (8) GLUS, (9) ARAS, (10) XYLS

These tagnames represent monosaccharides determined by direct analysis, representing the free sugars in the foods, rather than sugars measured after hydrolysis. The conventional methods, GC, HPLC, and enzymatic assays, are not expected to yield different results.

(11) LACS, (12) LACSM, (13) MALS, (14) MALSM, (15) SUCS, (16) SUCSM, (17) DISAC, (18) DISACM

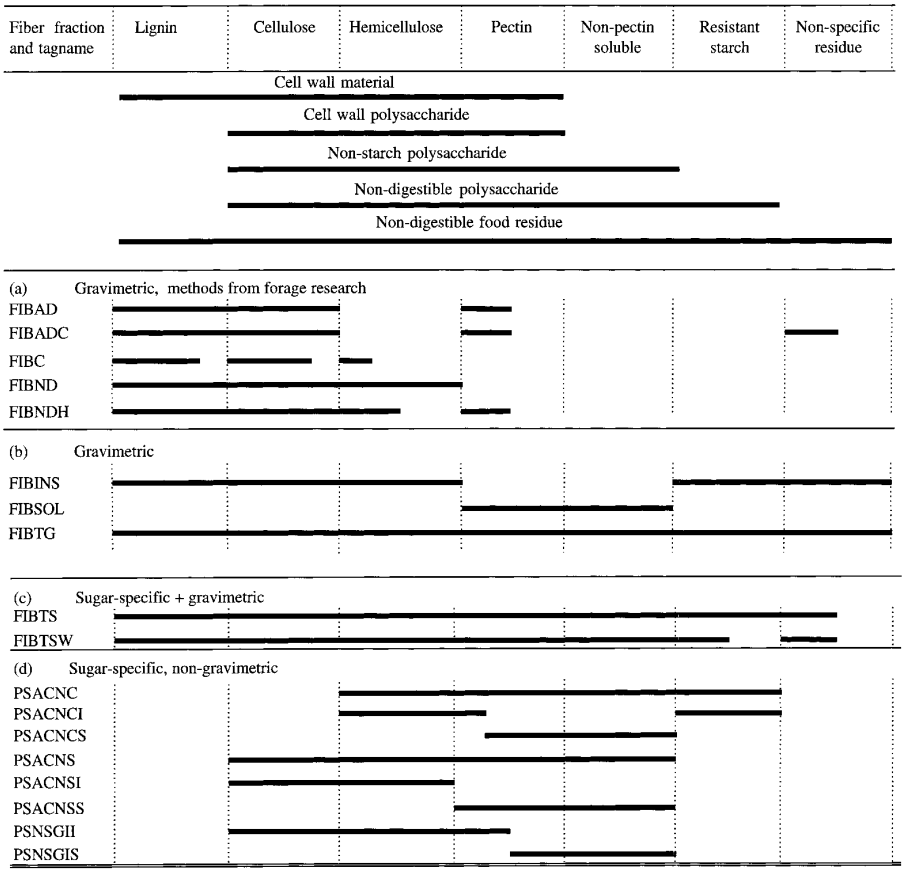
These tagnames represent disaccharides determined by direct analysis. They are expressed as the weight of the sugar in LACS, MALS, SUCS, as its monosaccharide equivalent in LACSM, MALSM, SUCSM, or as the sum of the individual disaccharides in DISAC and DISACM. As with the monosaccharides, the conventional methods of analysis are not expected to yield different results.

(19) SUGAR, (20) SUGARM, (21) SUGNRD, (22) SUGRD

These tagnames represent aggregations of various combinations of mono- and disaccharides. SUGNRD and SUGRD are chemical aggregations. SUGRD represents sugars

TABLE 8

TAGNAMES, DEFINITIONS OF DIETARY FIBER FRACTIONS, METHODS FOR FIBER ANALYSIS: APPROXIMATE RELATIONSHIPS



measured colorimetrically by methods depending on the reactive aldehyde or ketone group of the common pentose and hexose monosaccharides that often occur in foods. SUGNRD is nonreducing sugar, into which category the disaccharide sucrose falls. It is often measured by the increase in reducing sugar on hydrolyzing the disaccharide to its reducing monosaccharide units. It cannot, however, be used as a tagname for di- or oligosaccharides, because it depends, not on the number of sugar units involved, but on their reactivity. Some disaccharides, such as maltose and lactose, are reducing.

SUGAR and SUGARM represent the summation of the individually measured mono- and disaccharides.

(23) STARCH, (24) STARCHM, (25) GLYC, (26) GLYCM, (27) INULN, (28) ALGNT, (29) AMYP, (30) AMYPM, (31) AMYS, (32) AMYSM, (33) DEXTN, (34) DEXTNM, (35) MALTRS, (36) MALTRSM, (37) OLSAC, (38) OLSACM, (39) RAFS, (40) RAFSM, (41) RIBS, (42) SORTL

These tagnames represent other ‘‘available’’ carbohydrate polymers determined

TABLE 9

DISTRIBUTION ON FOOD COMPONENTS BETWEEN SOLUBLE AND INSOLUBLE FIBER FRACTIONS

Food Polysaccharides		Insoluble	Soluble
Tagname	Component	FIBINS PSACNSI PSNSGII	FIBSOL PSACNSS PSNSGIS
PECT	Pectin	±	+
HEMCEL	Hemicellulose	+	–
CELLU	Cellulose	+	–
LIGN	Lignin	+	–
PENSN	Pentosan	±	±
HEXSN	Hexosan	±	±
PURAC	Polyuronic acid	–	+
ARAN	Arabinan	–	+
GALTN	Galactan	–	+
GLUCNB	Betaglucan	–	+
XYLN	Xylan	+	–
MANN	Mannan	+	–
STARES	Starch, resistant	+	–
AGAR	Agar	–	+
ALGNT	Alginate	–	+
CARGN	Carageenan	–	+
GUMS	Gums	–	+
MUCIL	Mucilages	–	+
PSACALG	Polysaccharides, algal	–	+

by direct analysis. Different expressions of the same chemical entity relate only to monosaccharide equivalents, as in STARCH/STARCHM and GLYC/GLYCM, with a conversion factor of 1.10; AMYP/AMYPM, AMYS/AMYSM, DEXTN/DEXTNM, MALTRS/MALTRSM, OLSAC/OLSACM, with conversion factors in the range of 1.05–1.09; and RAFS/RAFSM with a conversion factor of 1.07. STARCH is the most common of the analytes in this group, while the others are only rarely found in food composition data sets.

Although typically characterized as ''available carbohydrate,'' starch can exist in an amylase-resistant form that analyzes as dietary fiber in some methods (discussed below).

Dietary Fiber Preparations That Can Be Subdivided by Method of Analysis

The nature of the dietary fiber entity is determined by the method used for fiber analysis. This, in turn, is dictated by fiber definition (Table 7). For instance, defining fiber as NSP requires that steps be taken to remove all indigestible starch and to measure NSP by methods that measure polysaccharide specifically. Thus, differential extraction and recovery selects components that may be measured as dietary fiber, and which of these components is selectively measured determines the apparent composition of the ''dietary fiber'' preparation (43–61 in Table 3) finally obtained (Fig. 1).

In Table 8 the relationship between food polymer fractions that typically comprise dietary fiber, commonly used terms for dietary fiber, and tagnames of fiber preparations is shown, as well as the approximate contribution of various food constituents to the fiber preparations. One can see that although plant cell walls are central to the concept of dietary fiber in human nutrition, cell wall polymers are not fully recovered in some fiber preparations. On the other hand, non-cell-wall materials including polysaccharides, amylase-resistant starch, and any other materials that resist digestion by enzymes of the human digestive tract may be contained in the preparation, depending on method and definition.

As a result of interest in the role of soluble nonstarch polysaccharides in health, it has now become standard practice to measure soluble and insoluble dietary fiber in a sample, and figures for the two fractions are permissible on food labels (Ellefson, 1993). The usual approximate distribution of other food components classified as dietary fiber (tagnames numbered 70–88, below) between soluble and insoluble fiber fractions (tagnames numbered 48, 49, 57–60, below) is summarized in Table 9. The distribution is represented by pluses (+) and minuses (−). A ''+'' represents complete partitioning of a food polysaccharide component in one fraction; a ''−'' represents a near absence of that component in one fraction and a ''±'' represents appreciable distribution of that component between both fractions.

Most methods for soluble fiber analysis are simply modifications of total-fiber methodology, with a step inserted after starch digestion (Fig. 1), to separate soluble fiber from insoluble material by filtering or centrifuging the digestate. The soluble fiber is then recovered from the liquid phase, most often by precipitating with ethanol.

Dietary fiber solubility and, therefore, the distribution of NSP between insoluble and soluble fractions is very method-dependent, but, even so, conditions for extracting starch/soluble fiber have not been standardized. Methods differ in both pH and buffer species, both of which can have a powerful effect on solubility of pectic substances that are a major component of soluble fiber (Monro, 1991), so ''soluble fiber'' food components may not be equivalent for a given sample.

However, none of these analytical conditions generates components with necessarily any physiological significance. An attempt to achieve greater accord between chemical methods of fiber analysis and human nutrition is the measurement of soluble fiber under simulated gut conditions (Monro, 1993). In previous soluble fiber methods, true differences in solubility of fiber in a food before and after cooking, or as a result of maturity or storage, will have been largely obliterated because the food was, in effect, ''cooked'' during analysis, under conditions that cause extensive depolymerization of pectic polysaccharides.

Methods using hot phosphate buffer at pH 7 extract more than those using hot acetate buffer at pH 5 (Monro, 1991), which in turn extracts more than physiological conditions (Monro, 1993). Based on extraction conditions the expected order would be PSACNSS $\approx$ FIBSOL (phosphate, pH 7, 100°C) $>$ PSACNCS (acetate, pH 5, 100°C) $>$ PSNSGIS (HCl/NaCl, pH 2, intestinal buffer, pH 7, 37°C).

The solubility of fiber is likely to be affected by other food components associated with it, and by various properties of the food that may be expressed differently under different conditions. Therefore, the only way to be sure that soluble fiber measured during analysis *in vitro* represents that soluble *in vivo*, is to extract under conditions

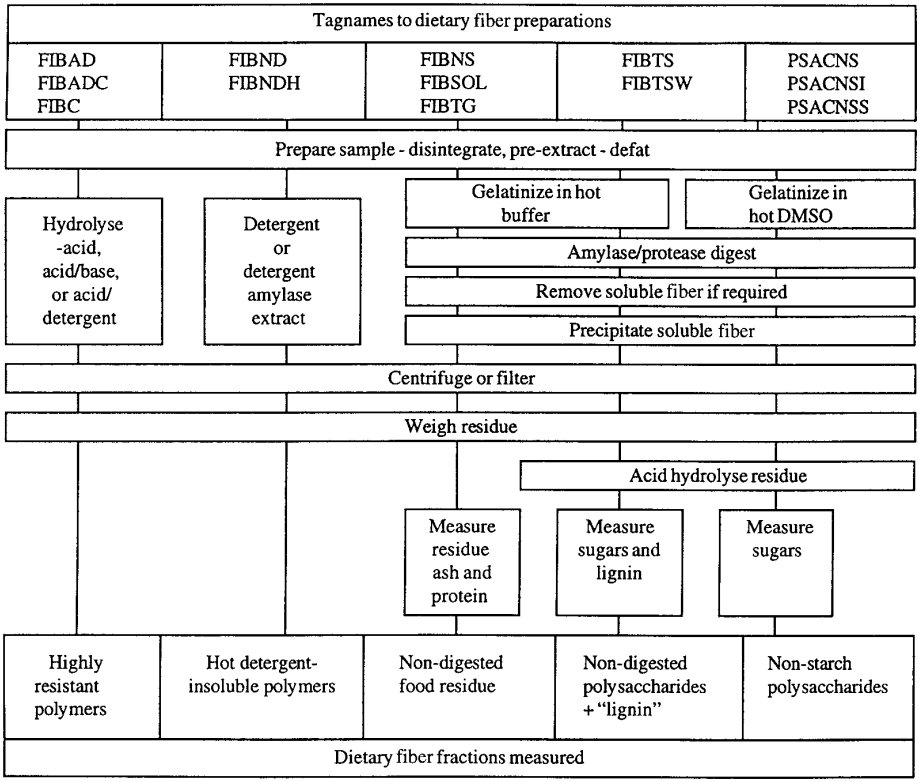


FIG. 1. Relationship between fiber tagnames (Table 3), analytical procedures, and dietary fiber preparations measured (definitions; Table 7).

dictated by the gut rather than by analysts. Then the idiosyncratic response of a food to analytical conditions will not give rise to problems of nutritional validity.

Some polysaccharides may escape precipitation by 80% ethanol used in recovering soluble fiber, so would be lost during analysis. They normally represent only a small percentage of most foods, but can be important in samples containing high levels of storage fructans, such as artichokes and onions.

(43) FIBAD, (44) FIBADC

Acid detergent (van Soest, 1963b) leaves a low-nitrogen residue of mainly lignin plus cellulose, used for predicting forage digestibility. It is used as a pretreatment before lignin (ADF lignin; AOAC method 973.18D) and cellulose analysis, although there is some loss of lignin, and extraction of hemicellulose and pectin may be incomplete. Because it is hydrolytic and measures only the filtered residue, there is usually considerable loss of dietary fiber.

(45) FIBC

The crude fiber method (Henneberg and Stohmann, 1859) (AOAC method 962.09, AACC method 32-10) is empirical and technically difficult. Most pectin and hemicellulose, and some cellulose and lignin, are destroyed. The fiber residue may be high in nitrogen.

In short, the method is unsuitable for food analysis. It was developed to predict forage digestibility (with only partial success), but is not suitable for human foods, in which the typically nonfibrous ''dietary-fiber'' is extensively destroyed, to the extent that FIBC is not consistently related to the amount of NSP in a food. Table 8 illustrates the incomplete recovery of the lignin, cellulose, and hemicellulose in the crude fiber method.

(46) FIBND, (47) FIBNDH

The neutral detergent method (Robertson and van Soest, 1981) gives low-nitrogen residue. It was designed to measure ''cell walls'' in forages, but is less suitable for foods, as most soluble fiber (e.g., pectin) is extracted by the heat plus EDTA present in the detergent. FIBND-FIBAD has been used to measure hemicellulose.

Starch may contaminate the fiber residue in starchy samples, slowing filtration and inflating fiber values. Several modifications (Schaller, 1977; Robertson and van Soest, 1977; Mongeau and Brassard, 1986) incorporate an amylase treatment to overcome the problem (AACC insoluble dietary fiber method 32-200, AOAC method 992.6, AACC method 32-06, respectively).

(48) FIBINS, (49) FIBSOL, (50) FIBTG

FIBINS, FIBSOL, and FIBTG are measured by the AOAC gravimetric method (Prosky *et al.,* 1988). The aim of measuring soluble, insoluble, and total dietary fiber rapidly by such a method, with full recovery of dietary fiber, has been pursued for a number of years, resulting in a string of methods (Monro, 1996) representing progressive modifications, each with an associated set of results. The gravimetric methods involve correction (with associated error) for ash and protein in the residue. They tend to give higher total fiber values than the sugar-specific methods that measure fiber as polysaccharide, because a range of resistant components are present in the residue.

FIBTG is determined by AOAC method 985.29, or as FIBINS plus FIBSOL measured by AOAC method 991.42. Most recent modifications (AOAC method 991.43, AACC method 32-07) for FIBTG, FIBINS, and FIBSOL involve changing the buffer from phosphate to Mes/Tris, to eliminate a pH adjustment, reducing the number of steps, averting phosphate precipitation (which had given inflated fiber values), and improving precision (Lee *et al.,* 1993).

(51) FIBTS, (52) FIBTSW

These are determined by summation of cell wall polysaccharide fractions (water-soluble NSP, hemicellulose, cellulose) measured specifically in a sample after starch digestion, plus lignin. The Southgate procedure (Southgate, 1969) involves measuring hexoses, pentoses, and uronic acids colorimetrically in the fractions. More recent methods involve measuring soluble and insoluble nondigestible polysaccharides as the sum of monosaccharides by more reliable means such as GLC and HPLC. ''Lignin'' is determined gravimetrically. FIBTS and FIBTSW contain resistant starch, but FIBTSW contains less than FIBTS by the Southgate method because a more effective starch digestion was used (Wenlock *et al.,* 1985).

Results are similar to but often lower than with the (AOAC) gravimetric methods for total dietary fiber.

(53) PSACNC, (54) PSACNCI, (55) PSACNCS

These polysaccharide fractions are isolated essentially as in the Southgate procedure above, and measured specifically. PSACNCI corresponds to conventional hemicellu-

lose (HEMCEL) plus some pectin (PECT), because acetate buffer is used to extract soluble polysaccharides rather than the conventional pectin extractants such as EDTA or ammonium oxalate. Englyst's modification (Englyst *et al.*, 1982) of Southgate's method uses GLC, and colorimetry only for uronic acids. It does not exclude resistant starch. The fractionation is complex for routine analysis but provides detailed information. It has been modified to the more rapid Englyst procedure for NSPs.

(56) PSACNS, (57) PSACNSI, (58) PSACNSS

These are the NSP fractions produced by methods such as Englyst's. Usually total NSP (PSACNS) and insoluble NSP (PSACNSI) are measured, either chromatographically (Englyst *et al.*, 1992) or colorimetrically (Englyst and Hudson, 1987), with soluble NSP obtained by difference. However, measuring soluble fiber by difference between two separate fiber analyses leads to accumulation of errors.

Hot, pH 7, phosphate buffer is used in the Englyst procedure to extract soluble fiber. As it removes pectic substances more effectively than pH 5 acetate buffer used in extracting PSACNCS (55 above), PSACNSS values are likely to be higher than PSACNCS values and PSACNSI lower than PSACNC + PSACNCI (53 + 54 above).

DMSO used to gelatinize starch for digestion in the Englyst method may also increase the solubility of NSPs during analysis, inflating PSACNSS at the expense of PSACNSI. The absence of resistant starch may also give PSACNS and PSACNSI fiber values that are lower than for corresponding total fiber and insoluble fiber components 48–55 above.

(59) PSNSGII, (60) PSNSGIS

PSNSGII and PSNSGIS are nonstarch polysaccharides soluble and insoluble, respectively, under simulated human gastrointestinal conditions (Monro, 1993). Soluble nonstarch polysaccharides (PSNSGIS) are extracted under physiological conditions, before digesting starch. PSNSGII remaining in the residue is then measured as NSP and by the Englyst method, and PSNSGIS calculated by the difference between PSNSGII and PSACNS measured in a duplicate of the sample. The procedure can be put at the front end of any total fiber method to give a ''nutritionally valid'' measure of soluble fiber.

This modification to the Englyst procedure circumvents effects of nonphysiological conditions (e.g., heat, DMSO, phosphate buffer) during starch removal on polysaccharide distribution between soluble and insoluble fractions and allows effects of food processing/cooking and maturity on fiber solubility to be measured.

PSNSGIS values may be lower than the soluble fiber values from other methods, particularly for uncooked pectin-rich materials.

(61) FIB-

This does not refer to any particular method or fiber preparation. FIB- identifies values representing unknown fiber components, or those from unknown methods. Use of FIB- is particularly relevant when tagging undocumented data sets. FIB- is also used when a single fiber value is needed from a larger data set; it can represent any of several known methods which are also represented by their specific tags. Choice of value is based on such considerations as nutritional validity, soundness of method related to the food matrix, and recovery of proximates.

Monosaccharide Components of Dietary Fiber Preparations

(62) ARAFB, (63) GALFB, (64) GLUFB, (65) MANFB, (66) RHAFB, (67) XYLFB

These are the monosaccharide components of the dietary fiber polysaccharides. The

conventional methods of analysis, GC and HPLC, are not expected to yield different results.

(68) FIBHEX, (69) FIBPENT

Derived from the use of colorimetric assays ''specific'' for hexoses (e.g., anthrone method) or pentoses (e.g., orcinol/$FeCl^3$ method) measured in hydrolysates of the polysaccharide fractions from fiber. They do not therefore denote discrete polysaccharides.

Other Polysaccharides and Cell Wall Fractions That Would Also Contribute to Category Dietary Fiber Preparations

(70) PECT, (71) CELLU, (72) HEMCEL

These are classical cell wall polysaccharide fractions. Their measurement is based on solubility in various solvents rather than chemical composition, although they usually have some distinctive compositional features: PECT is soluble in hot aqueous chelating agents and is generally high in polyuronic acids; CELLU is relatively resistant to acid and alkali and is almost totally $\beta(1-4)$ linked glucose; HEMCEL is a mixture of polysaccharides extracted by ''dilute'' acid (e.g., 1 *M* H_2SO_4) or alkali (e.g., 10% KOH) subsequent to pectin extraction.

PECT corresponds approximately to soluble fiber, but the amount of pectin that enters the soluble fiber fraction during analysis of fiber is very dependent on extraction conditions, as discussed above (soluble fiber).

(73) LIGN

LIGN seldom refers to true lignin, the accurate measurement of which is difficult, and therefore not attempted in most fiber methods. Instead, the weight of residue remaining after 12 *M* H_2SO_4 hydrolysis of the insoluble fiber residue (''Klason lignin'') is used as an approximation to true lignin. Klason lignin may contain nonspecific residual substances that can inflate total and insoluble fiber values from gravimetric methods.

Most foods contain little true lignin, and the Klason lignin obtained from them may contain a high proportion of nonlignin residuals. If lignin is suspected of being a significant component it can, like resistant starch, be measured separately from cell wall polysaccharides measured as NSP.

(74) PENSN, (75) HEXSN, (76) PURAC

Strictly speaking, these tags refer to pentose, hexose, and uronic acid that is present in some form of food polysaccharide, rather than to polymers consisting solely of pentose or hexose or uronic acid.

(77) ARAN, (78) GALTN, (79) GLUCNB, (80) XYLN, (81) MANN

Similarly, although these names refer to homopolymers, most food polysaccharides are heteropolymers of more than one type of monosaccharide.

(82) STARES

Resistant starch (STARES) plus NSP adds up to nondigestible polysaccharide. Therefore, STARES should never be added to values for fiber preparations containing nondigestible polysaccharide, such as FIBTG and FIBTS. Conversely, where starch is measured as available carbohydrate, and fiber as NSP, the resistant starch component will be missed.

Resistant starch is a minor component in most foods, but it may contribute signifi-

cantly to nondigestible polysaccharides in starchy foods that contain little cell wall material, particularly when the physical structure of the food or starch, or retrogradation of starch as a result of food processing, renders it indigestible.

Resistant starch has been a contentious issue. Gravimetric methods have been criticized (Englyst and Cummings, 1990) for not measuring cell wall NSPs free from resistant starch, as the concept of dietary fiber was originally intended to equate to plant cell walls in food, and inclusion of resistant starch may make fiber values vulnerable to food processing. Others (Prosky and DeVries, 1992) argue that when starch behaves as dietary fiber (nondigestible polysaccharide) it should be classed as a fiber component, particularly as it has the physiological properties of fiber.

Starch resistant to gelatinization and enzymatic hydrolysis during fiber analysis is not, however, the same as that resistant to digestion in the human intestine. Therefore, the presence of resistant starch in fiber preparations does not necessarily enhance their nutritional validity.

Englyst (Englyst and Cummings, 1990) prefers measuring resistant starch as an important food constituent in its own right, with fiber measured independently as nonstarch polysaccharide, so that it can act as a valid index of plant cell walls in a food. Methods are available for measuring resistant starch separately.

(83) AGAR, (84) ALGNT, (85) CARGN, (86) GUMS, (87) MUCIL, (88) PSACALG

These are all soluble, often complex polysaccharides that would contribute to total and soluble fiber (and NSP) fractions.

CONCLUSION

The above results and discussion have stressed the point that what is often loosely referred to as ''carbohydrate'' and ''dietary fiber'' covers a quite diverse range of food components. Because food composition data are fundamental to clinical, epidemiological, and agricultural research; nutrition, public health, and agricultural policy development; and many other endeavours, nutrient data must be generated, compiled, and presented without ambiguity. Carbohydrates have a particularly extreme potential for creating ambiguity when INFOODS tagnames are not used.

Tagnames are not prescriptive in nature, in that only in a few rare cases is one tagname plus method described as ''obsolete'' or ''not recommended.'' Judgments about the suitability of one measurement over another are not made. Therefore, issues related to the limitations of analytical measurements and the relevance of data to human health must be addressed separately.

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