Carbohydrate Data - Present and Future Needs

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Introduction

The Nutrient Data Research Branch (NDRB) of the Human Nutrition Information Service (HNIS), USDA, collects, compiles, and publishes information about the nutrient content of foods in Agriculture Handbook No. 8 (AH-8) (1). New labeling regulations have focused attention on the carbohydrate fractions of foods and the methods available to analyze them.

Carbohydrate data are obtained from contracted research, trade associations, the scientific literature, industry, and other government agencies. Most of the total dietary fiber (TDF) data in NDRB's current computer files have been obtained through contracts. Most of the sugar data are from the literature.

Dietary Fiber Methodology and Publications

Understanding the methodology for any nutrient analysis is the key to proper data evaluation and use. This is especially true with fiber. Dr. Li, in another paper in this session, presented an overview of carbohydrate methodology. This paper will begin with a brief review of the progression of dietary fiber data that have been compiled by this agency for food consumption surveys and for AH-8.

The development of a carbohydrate data base at HNIS began in the early 1980's. Dietary fiber was added to the food consumption survey data tape (2) starting with the 1985 Continuing Survey of the Food Intakes by Individuals (3) and updated with all subsequent survey data tapes. (The latest available data tape is Release 6 (4).

The Breakfast Cereal section of AH-8 (section 8, 1982) lists insoluble fiber in addition to crude fiber for many foods. The insoluble fiber values were generally determined using the neutral detergent fiber (NDF) dietary fiber method, which is approved by the American Association of Cereal Chemists (5).

For the Fruits and Fruit Juices section of AH-8 (section 9, 1982), the Vegetables and Vegetable Products section (section 11, 1984), and the Legumes and Legume Products section (section 16,

1986) footnotes on the data pages give NDF and pectin values for many foods. The pectin value was considered a measure of soluble fiber, especially in fruits (6).

HNIS began publishing total dietary fiber (TDF) values in 1988. The "Provisional Table on the Total Dietary Fiber Content of Selected Foods" (7) lists analytical TDF values for over 200 foods determined using the Prosky method (8). At that time, the Prosky method was the only method approved by the Association of Official Analytical Chemists (AOAC) for estimating the combined soluble and insoluble components of dietary fiber. This enzymatic-gravimetric method was initially approved in 1984, received final approval in 1986, and was modified in 1988 (9).

Appendix tables included in the 1989 Supplement to AH-8 present TDF values for selected fruits and fruit juices, vegetables, legumes, nuts and seeds, and snacks and sweets. The Baked Products section (AH 8-18, 1992), also contains an appendix table with TDF values.

In the 1993 release of the Standard Reference data base (10), the electronic version of AH-8, TDF replaced crude fiber. The TDF values are coded to indicate whether the value is analytical or calculated. In the 1992 Supplement to AH-8, TDF also replaced crude fiber.

Total Dietary Fiber Data

Tables 1 and 2 list the eight most consumed raw fruits and vegetables in the United States. Consumption order was determined using data from the 1990 Continuing Survey of Food Intakes by Individuals (4). The TDF values listed are the current values in Release 10 of the Standard Reference data base. They are all aggregates of values determined using AOAC methods.

Raw fruits generally are 1 to 3 percent dietary fiber on a wet weight basis (as eaten). A notable exception in table 1 is watermelon. Some fruits that contain small seeds have higher TDF values. Standard deviations and number of analyses are listed. Citrus fruits (oranges and grapefruit), can show a large variation in fiber content because of differences in the amount of albedo (the spongy white material beneath the outer peel) remaining during analysis.

TDF values in vegetables also usually range from 1 to 3 percent on a wet weight basis. Broccoli has a higher standard deviation than other vegetables, probably because different ratios of stem to floret in individual samples affect fiber content. The cucumber value includes analyses both with and without skin.

Sugar Methodology

The Food and Drug Administration, for nutrition labeling purposes, has defined total sugars as the sum of free monosaccharides and disaccharides. The individual sugar content of many foods, especially fruits and vegetables, varies considerably among cultivars and among samples with different moisture levels, growing times, maturity, storage times, and growing locations.

A few commodity-level foods contain single sugars, for which almost any method of analysis would be appropriate(11). However, most sugar-containing foods in a mixed diet contain combinations of sugars. For analysis of these foods, chromatographic methods are most accurate. Gas liquid chromatography(GLC) for separation and quantification of sugars is useful once the sugars have been derivatized. However, high-performance liquid chromatography(HPLC), which does not require derivatization, has become the preferred method for analysis of sugars in foods(11).

Table 1. TOTAL DIETARY FIBER IN RAW FRUITS

FOOD ITEM	MEAN*	STD	n
Apple with skin	2.7	0.56	10
Banana	2.4	0.54	10
Orange	2.4	0.33	6
Watermelon	0.5	0.10	9
Grapes	1.0	0.31	8
Grapefruit	1.1	---	2
Peach	2.0	---	2
Pear	2.4	---	2

*grams per 100 grams, edible portion (10)

TABLE 2. TOTAL DIETARY FIBER IN RAW VEGETABLES

FOOD ITEM	MEAN*	STD	n
Tomato	1.1	0.36	5
Lettuce, iceberg	1.4	0.17	4
Cucumber	0.8	0.31	9
Carrot	3.0	0.28	6
Onion, mature	1.8	0.27	4
Pepper, sweet	1.8	0.21	9
Broccoli	3.0	0.65	5
Cauliflower	2.5	0.22	5

*grams per 100 grams, edible portion (10)

Sugar Publications

Information on individual sugars was first published by HNIS in an appendix table to the Breakfast Cereals section (AH-8-8) in 1982.

In 1986, a "Provisional Table on the Sugar Content of Selected Foods" (12), the first comprehensive publication on individual and total sugars for many foods across food groups, was published. This was expanded in 1987 to "Home Economics Research Report No. 48" (13), a listing of the individual monosaccharides and disaccharides and total sugars content of approximately 500 foods, both per 100 grams and by serving size. Data on stachyose, raffinose, mannitol, and sorbitol were also presented. The total sugars data from this publication were linked to the Nutrient Data Base for Standard Reference and disseminated through our bulletin board beginning in 1989.

The Snacks and Sweets section (AH 8-19) was updated with an appendix table listing individual and total sugars in 1991.

Sugars Data

Tables 3 and 4 list individual sugar data for high-consumption fruits and vegetables. In table 3, the individual sugar patterns vary from one fruit to another. They all contain fructose, the largest component for three of the eight fruits. In the fruits reported here, total sugars ranges from 6.4 grams per 100 grams for grapefruit to almost 17 grams per 100 grams for grapes.

In table 4, the raw vegetables also show differences in sugar patterns as well as total sugar amounts. The values per 100 grams for three of the most highly consumed vegetables are 0.1 grams for spinach, 0.9 grams for broccoli, and 4.2 grams for carrots.

Both tables present values for glucose, fructose, and sucrose. This should not suggest the absence of other sugars but represents those found in the largest amounts and for which data were available.

Contract Data

USDA/HNIS contracts with laboratories to obtain carbohydrate data. The laboratories are evaluated on a regular basis as part of an on-going quality assurance program. This program includes an initial technical evaluation of each proposal. All technically acceptable offerors are sent samples to analyze. Based on the analytical performance and on the proposals, the contract is awarded. Any problem nutrients are double-checked using demonstration samples that require the laboratory to demonstrate the ability to analyze for that nutrient. Check samples are sent twice each year to monitor the accuracy of analysis. Written into each contract is also a provision for repeating the analyses that yield inconsistent or questionable data.

Table 3. SUGARS IN RAW FRUITS

FOOD ITEM	INDIVIDUAL SUGARS*				TOTAL SUGARS		
	glucose	fructose	sucrose		Mean*	STD	n
Apple w/skin	2.6	6.4	2.5		11.5	2.1	9
Grapes	7.0	7.3	1.1		16.8	1.7	6
Grapefruit	2.0	1.9	2.5		6.4	0.3	3
Peaches	2.5	1.0	5.3		8.7	1.7	6
Pears	3.3	6.7	0.9		11.4	2.3	3
Plums	3.1	2.6	2.7		8.4	1.9	3
Watermelon	1.6	3.3	3.5		8.7	1.7	3

*grams per 100 grams, edible portion (10)

Table 4. SUGARS IN RAW VEGETABLES

FOOD ITEM	INDIVIDUAL SUGARS[*]				TOTAL SUGARS		
	glucose	fructose	sucrose		Mean[*]	STD	n
Broccoli	0.4	0.4	0.1		0.9	0.4	3
Carrots	0.6	0.5	3.1		4.2	0.4	3
Spinach	0.1	tr[**]	tr[**]		0.1	0.0	3

[*] grams per 100 grams, edible portion (10)
[**] trace amounts (<0.05) detected

Table 5 lists the contracts that have collected TDF data for HNIS over the last 10 years. A wide variety of foods have been analyzed. Most of the contracts were planned to provide complete nutritional profiles of the foods. Some contracts were specifically for carbohydrate or dietary fiber analysis. Our most recent contracts focus on ethnic foods, new foods, and reduced-calorie foods.

The 1988 dietary fiber contract provided soluble dietary fiber (SDF) and insoluble dietary fiber (IDF) data in addition to TDF data. At the time, the recommended method for SDF was a two-step process conducted on separate samples of the same food: SDF was calculated as the difference between TDF determination and a direct IDF analysis.

TABLE 5. CONTRACT DATA FOR TOTAL DIETARY FIBER

YEAR	CONTRACT	NUMBER OF FOODS
1983-1985	Carbohydrate Fractions of Foods	56
1984-1987	Cereal and Cereal-based Products	115
1986-1987	Selected Foods	31
1988	Dietary Fiber Contract	303
1987-1988	Nutrients in Specialty Fruit	31
1987-1988	Collaborative Study-TDF Methods	25
1989-1992	Selected Foods	38
1991-1992	Key Foods[*]	115
1991,1992	TDF Purchase Orders	154
1991	New, Reduced-fat and Fat-free Foods	35
1992	Ethnic Foods	31
	TOTAL	934[**]

[*] Key foods are those foods identified by nationwide survey data as, in sum, contributing 80 percent of a particular nutrient to the U.S. diet.
[**] This value may represent some duplication of foods.

As discussed earlier, most of the sugars data compiled by HNIS came from the scientific literature. Data were obtained from three contracts (table 6), one of them specifically devoted to sugars analysis. This contract studied the variability of individual sugars for the same food but after different storage times.

Earlier contract data (1985 contracts) are available on individual sugars. With new labeling regulations, total sugars has been defined as the sum of monosaccharides and disaccharides; many of the earlier values for total sugars are no longer acceptable. This certainly applies to much of the total sugars values derived from the scientific literature. A 1991 report indicates that galactose is present in many fruits and vegetables (14). Assumptions on the presence or absence of certain sugars in a food need to be re-evaluated. Not all individual monosaccharides present in foods are reported (e.g., mannose and pentoses such as arabinose).

Table 6. CONTRACT DATA FOR SUGARS

YEAR	CONTRACT	NUMBER OF FOODS
1985	Determination of the Nutrient Content of Selected Candies, Nuts, Condiments, Beverages and Vegetables	66
1985	Investigation of the Carbohydrate Fraction of Foods	62
1989	Variability of Sugar Content of Foods	100
	TOTAL	228*

*This value may represent some duplication of foods.

Soluble Dietary Fiber

In an effort to establish which analytical methods were acceptable for dietary fiber compilation, HNIS sponsored an international collaborative study in 1989. Each laboratory analyzed 25 foods in duplicate using several different methods of analysis. Food samples were freeze-dried. The same samples of food and enzymes were provided to the laboratories to minimize variables. Table 7 illustrates the results for the fruits and vegetables analyzed using only the AOAC method. The TDF values were consistent from laboratory to laboratory. The range of soluble fiber values, however, was quite broad. The results clearly indicate a lack of consistency in the soluble fiber data determined using the 1988 AOAC procedure. This lack of precision, which was also evident in the 1988 AOAC interlaboratory study (15), is the main reason why SDF calculated by difference was recommended for a time. The 1988 HNIS contract, which calculated SDF by difference, however, produced soluble fiber data which was not consistent or reliable for some types of foods.

In table 7, the TDF mean is composed of values determined directly as well as those calculated by summing soluble fiber plus insoluble fiber. Because the soluble and insoluble values were determined by filtering the same sample, the insoluble values adjusted with the soluble to produce a TDF value that is quite acceptable—in line with TDF determined directly.

TABLE 7. 1989 INTERNATIONAL COLLABORATIVE STUDY - AOAC Method Results

FOOD ITEM	SOLUBLE FIBER* (Range)	TDF* (direct & s+i)	STD	CV	n
Apple, raw	0.44-0.75	2.01	0.101	5.35%	7
Carrot, raw	0.91-1.36	3.02	0.148	4.90%	7
Cabbage, raw	0.71-1.25	4.00	0.166	4.16%	6
Potato, cooked	0.44-0.67	1.69	0.112	6.64%	6

*grams per 100 grams, edible portion

Future of Carbohydrate Data

For nutrition labeling and for many data bases, dietary fiber data determined using the soluble and insoluble breakdowns by enzymatic-gravimetric methods are adequate. Foods can be compared to each other and fiber intake estimated.

An AOAC-approved method for the direct determination of soluble fiber and insoluble fiber is now available (16). The organic buffer used in this method produces more consistent soluble fiber data. TDF can be determined accurately by direct analysis or by totaling direct soluble and insoluble data. These calculated analytical values for TDF can also be aggregated with direct analytical TDF values from other approved enzymatic-gravimetric methods (17).

For sugar analysis, methods using high-performance liquid chromatography (HPLC) are proposed for compliance with U.S. food labeling regulations. HPLC is precise, accurate, practical, and widely used. It is appropriate for broad range sugars analysis and the method of choice for publishable data in the Nutrient Data Bank. The AOAC Task Force on Nutrient Labeling Analyses, Carbohydrate Subgroup, has recommended a specific HPLC method (using an amino-bonded column) for sugar analysis. Samples should be defatted prior to extraction and free from sodium chloride interference (11).

The new labeling regulations should make available from industry TDF, soluble fiber, insoluble fiber, and total sugars data. In the future, HNIS will be planning new contracts for the determination of SDF, IDF, TDF (by calculation), and individual monosaccharides and disaccharides in high-consumption foods. Other contracts will continue to generate TDF data. The upcoming redesign of the National Nutrient Data Bank will facilitate incorporation of new carbohydrate fractions into the Standard Reference data base.

Much research is still needed on the chemical components of total dietary fiber. For example, pectin and hemicellulose are found in both the soluble and insoluble fractions of many foods (18). Reliable methods are needed for analysis of other carbohydrate fractions such as starch, sugar alcohols, oligosaccharides, and resistant starch. For all analyses, quality assurance programs in laboratories and the use of standard reference materials will help to assure consistency and accuracy of data.

As approved methods become available for the different carbohydrate fractions (especially starch), total carbohydrate will be determined by summing the individual fractions, instead of being calculated by difference.

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