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Carotenoid Content of U.S. Foods: An Update of the Database

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Accurate characterization of the association between carotenoid intake and various chronic diseases requires a current and complete food composition database of individual carotenoid values. The previous database, the 1993 USDA-NCI Carotenoid Database, was updated following a comprehensive review of new carotenoid literature and extensive analysis of carotenoid-containing foods sampled from major metropolitan areas of the U.S. The 1993 procedures were modified to accommodate recent developments in analytical methodology and changes in criteria for numbers of samples. Values for α-carotene, β-carotene, lutein + zeaxanthin, lycopene and β-cryptoxanthin from approximately 200 references were evaluated for the update. In addition to values for these carotenoids, tables include zeaxanthin values for a limited number of foods. The new database was created using previous data, new acceptable literature values, and new analytical data to yield a database of 215 foods. Mean values, standard errors, number of studies, and confidence codes were tabulated for each food. USDA Nutrient Data Bank numbers were assigned to facilitate the use of the carotenoid data with other USDA data. This resulted in the disaggregation of many food item descriptions listed in the 1993 database. An electronic version of the new USDA-NCC Carotenoid Database is available at http://www.nal.usda.gov/fnic/foodcomp.

INTRODUCTION

A large number of epidemiologic studies have shown that fruit and vegetable consumption is associated with a reduced risk of many cancers and other chronic diseases (World Cancer Research Fund/American Institute for Cancer Research, 1997). Researchers have become interested in characterizing the specific components of fruits and vegetables that may be responsible for reduced risk of disease. One group of components that have biological activity are the carotenoids. Carotenoids are yellow, orange, and red pigments present in many commonly eaten fruits and vegetables (Astorg, 1997). More than 600 carotenoids have been identified, but most nutrition research has focused on the five carotenoids with the highest known blood concentrations in U.S. populations: α-carotene, β-carotene, lycopene, lutein, and β-cryptoxanthin.

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Three of these carotenoids, α-carotene, β-carotene and β-cryptoxanthin, have pro-vitamin A activity and can be converted in the body to retinol. In the past, the functional importance of carotenoids was attributed mainly to their pro-vitamin A activity, and therefore, the analytical methods of the Association of Official Analytical Chemists (AOAC) were considered adequate (Sullivan and Carpenter, 1993). However, the commonly used AOAC methods quantify total carotenes rather than individual carotenoids using β-carotene bioactivity as the basis of calculation. This tends to overestimate the vitamin A activity of foods (Beecher and Khachik, 1984). The increased use of high-performance liquid chromatography (HPLC), which is a highly capable and sensitive method for separating and quantifying carotenoids, has resulted in an increase in the data available for individual carotenoid values in foods.

The original carotenoid database for fruits and vegetables (Mangels *et al.*, 1993) was based on a review of approximately 180 articles published between 1971 and 1991. Of these, data from 38 published papers and two USDA contracts were used to create the database. This collaborative project between the United States Department of Agriculture (USDA) and the National Cancer Institute (NCI) resulted in a database for five carotenoids in 120 fruits and vegetables. In this database, lutein was combined with zeaxanthin due to the difficulty in separating these two carotenoids. The database was available electronically from USDA and contained median carotenoid values, ranges, number of samples, and a confidence code for each value.

The USDA-NCI Carotenoid Database provided a valuable resource for researchers interested in estimating carotenoid intake (Chug-Ahuja *et al.*, 1993) and investigating the association between dietary and serum carotenoids (Forman *et al.*, 1993; Seddon *et al.*, 1994; Yong *et al.*, 1994; Michaud *et al.*, 1998). However, it contained carotenoid data only for fruits and vegetables and did not contain data for other sources of carotenoids (e.g., cheddar cheese, eggs, butter, corn meal). Data for some of the major sources of carotenoids in the U.S. diet, as identified by Chug-Ahuja *et al.* (1993), were limited. The database provided no information on food mixtures containing fruits and vegetables (e.g., pizza, mixed vegetables). Furthermore, the earlier database provided median values, rather than means, for the aggregate carotenoid values which the authors felt were better estimates of central tendency considering the limited number of values for some foods and the apparent skewed nature of some of the data. Researchers at the USDA and at the Nutrition Coordinating Center (NCC), University of Minnesota, decided to update the 1993 USDA-NCI Carotenoid Database due to the large number of newly published articles on the carotenoid content of foods, new advances in analytical methods, and the issues described above. The resulting database is called the USDA-NCC Carotenoid Database for U.S. Foods.

METHODS

Sources of Data

The pool of data to be considered for the USDA-NCC Carotenoid Database for U.S. Foods included values for foods used in the 1993 USDA-NCI database, values published in national and international journals from 1992 to 1996, and new analytical data generated through contracts and at USDA laboratories. Only data from analytical studies that used chromatographic procedures for separation of carotenoids were considered. Efforts were focused on foods identified as major contributors of one or more of the carotenoids of interest (Chug-Ahuja *et al.*, 1993). In addition, a few commonly consumed food mixtures containing fruits and/or vegetables, some high-fat foods, and foods for which there were limited data were analyzed.

A review of available data in the 1993 USDA-NCI carotenoid table indicated a number of foods for which additional information on carotenoid content was needed. As a result, 10 fruits, 23 vegetables, 14 commercial food mixtures (e.g., pizza, beef stew, mixed vegetables in butter sauce, and several entrees), butter, cheese, ice cream, fluid milk, margarine, eggs and corn meal were analyzed at the USDA Food Composition Laboratory (FCL) (Beecher *et al.*, 1997). Vegetables and frozen entrees generally consumed in the cooked form were analyzed after cooking. Foods were selected to be representative of foods available in the U.S. Therefore, sales volumes, and geographic and demographic distribution patterns were taken into consideration to select brand names, cities, and grocery stores to purchase foods.

Evaluation System

All data in the pool were critically evaluated using the criteria and system adapted from Mangels *et al.* (1993). This system was used to evaluate the carotenoid data for each food in each of five categories: analytical method, analytical quality control, number of samples, sample handling, and sampling plan. Data were rated on a scale of 0 (unacceptable) to 3 (most desirable) for each category based on specific criteria developed for each rating. An overall Quality Index (QI) was calculated as the average of the five ratings for a single source, food, and carotenoid. Data for the USDA-NCC database were deemed acceptable if they received a rating of at least 1 for analytical method, and two other ratings equal to or greater than 1, to yield a minimum QI of 0.6. This is in contrast to the earlier database where a minimum QI of 1.0 was required for inclusion in the database. Experience in evaluating data coupled with the limited available data justified revision of an acceptable QI of 0.6 for this project. Acceptable data for a given food and carotenoid were combined to provide a single estimate for that food and carotenoid.

Another modification from the earlier database was a change in the rating criteria used for analytical method. In general, we relied on studies using HPLC for analysis of individual carotenoids. However, those studies which used open column methods, demonstrated adequate separation of individual carotenoids, and employed extensive identification procedures (Rodriguez-Amaya, 1999) were included in our evaluation.

The number of samples criterion was reviewed and clarified. In some cases, the number of samples reflected individual samples, and in others, the number reflected the number of composite samples (Fig. 1). The number of samples referred to the number of unique analyses, not replicates. Higher ratings were given to those studies which analyzed larger numbers of samples and provided information on variability. A rating of 3 was given to those studies which analyzed more than 10 samples and provided individual values, or mean and standard deviation. A rating of 1 was assigned to those values which represented a limited number of analyses (i.e., 1–2 samples) and provided no data for variability.

Finally, a sampling plan strategy was implemented to collect foods for analysis. While number of samples criterion addresses the number of analytical values, sampling plan indicates the scope and representativeness of individual sample units with respect to brand or cultivar and geographic origin. Higher ratings were given to those samples that represented the broadest consumption patterns or geography, or the brands or varieties with the largest sales volumes (Fig. 1). For foods analyzed at the FCL, nationwide sampling in three cities (Washington, DC, Chicago, IL, and Los Angeles, CA) was used for most foods. Samples were selected from different lots or

Number of samples Sources of food: lot, field, store, city	Sampling plan rating
Single samples	Rating = 1 for samples from 1 lot, field, store, or point-in-time
—	Rating = 2 for samples from 2 geographic areas
—	Rating = 3 for samples from more than 2 geographic areas
$n = 3$ individual analyses	
Composite samples	Rating = 1 for composites from 1 lot, field, store, or time
—	Rating = 2 for composites from 2 geographic areas
—	Rating = 3 for composites from more than 2 geographic areas
$n = 1$ individual analyses	

FIGURE 1. Relationship between source, number of samples and sampling plan rating for single samples and composite samples

TABLE 1

References evaluated for the USDA-NCC carotenoid database for U.S. foods

	Number of References
References with acceptable U.S. data from the 1993 database[1]	27
New references collected (1992–1996)	183
Reasons references were eliminated:	
Qualitative analysis only	40
Total carotenoid values only	16
Vitamin A or retinol values only	8
Carotenoids other than the 6 of interest	3
Unacceptable methods[2]	14
Experimental values[3]	5
Articles on analytical methods only	16
Review articles	8
Non-U.S. carotenoid references	51
Total eliminated	161
Carotenoid references used in the USDA-NCC database	49

[1]The number of acceptable references used in the USDA-NCC database differs from the number used in the 1993 USDA-NCI database (Mangels *et al*., 1993) due to modifications in the criteria used for evluation (see text for details).

[2]Separation and quantitation by spectrophotometric method only, values on dry weight basis without documentation of moisture content, method reference not available.

[3]Foods grown or prepared under experimental conditions which are not available in the market.

brand names, and foods were purchased at the two grocery store chains with the largest market share in each city.

Data Evaluation and Compilation

New references totaling 183 were evaluated for inclusion in the USDA-NCC Carotenoid Database (Table 1). In addition, 27 U.S. references from the 1993 USDA-NCI database were identified as acceptable using the new criteria. Initial screening eliminated 110 of these references for various reasons reported in Table 1, and an additional 51 references were eliminated because they were for foods not available in the U.S. The remaining 49 references were used to develop the USDA-NCC Carotenoid Database for U.S. Foods. Food items were categorized according to the system used in the USDA Nutrient Database for Standard Reference, and each food was assigned a USDA Nutrient Data Bank (NDB) number.

TABLE 2

Assignment and meaning of confidence codes for the USDA-NCC Carotenoid Database

Sum of quality indexes	Confidence code	Meaning of confidence code
>6.0	A	The user can have considerable confidence in this value
3.4–6.0	B	The user can have confidence in this value; however, some problems exist regarding the quantity and/or quality of the data on which the value is based
0.6 to <3.4	C	The user can have less confidence in this value due to limited quantity and/or quality of data

Several calculations were applied to selected data. Carotenoid values expressed on a dry weight basis were converted to a wet weight basis when moisture content of the food was documented. Values for carotenol fatty-acid esters were converted to individual carotenoid values using appropriate molecular weight ratios. Numerical values for "trace" amounts of carotenoids were derived using the following equation: $0.71 \times$ LOQ, where LOQ is the limit of quantification (Mangels *et al*., 1993). A zero value reported in the database represents a value that is below the detection limit for that carotenoid based on inspection of each HPLC chromatogram. A missing or unreported carotenoid value does not imply a zero value, rather analytical data are currently unavailable for this carotenoid/food combination.

In the evaluation process, the expert system provided a rating for each carotenoid value according to the criteria described above and documented elsewhere (Holden *et al*., 1987; Mangels *et al*., 1993). A QI was then calculated for every carotenoid value for each individual food. After all of the acceptable carotenoid values for all foods were entered into the system, a summary QI was calculated by adding all of the individual QIs for that carotenoid in that food, and a confidence code was assigned (Table 2). The confidence code provides the users of these data with an index for evaluating the strength of the scientific evidence for a given carotenoid value in a specific food. A confidence code of "A" indicates considerable evidence for the carotenoid value in that food, due either to a few exemplary studies or to a large number of studies. On the other hand, a confidence of "C" indicates that there is less evidence for the carotenoid value in that food, due to a smaller number of studies or poor quality of the data.

Statistics

Carotenoid values in the USDA-NCC database are expressed as means. This is in contrast to medians reported in the previous database. Mean values were chosen as the better measure of central tendency as a result of a consensus reached during a USDA statistical workshop organized by the principal investigators in April 1996. Means for individual carotenoids were weighted by their respective sampling plan ratings to give greater weight to values that were obtained from more representative samples.

Variations in the data were reported as standard errors of the mean (SEM) using equations which incorporate sampling plan rating as a weighting factor. SEMs were calculated when there were three or more data points available for a given carotenoid in a food. If all of the data points had the same sampling plan rating, no weighting was necessary and the SEM was calculated using the standard equation $SEM = S/\sqrt{N}$, where S is the standard deviation of the sample and N is the number of data points. If the values had different sampling plan ratings, weighting was necessary and SEM was calculated as follows

$$SEM = \sqrt{\sum W_k^2 S_{\bar{Y}_k}^2},$$

where W_k are relative weights for each weight class ($\sum W_k = 1$) and $S_{\bar{Y}_k}$ are the usual standard errors of the means of each weight class. That is, for each weight class,

$$S_{\bar{Y}_k} = \sqrt{\frac{\sum (Y_{ki} - \bar{Y}_k)^2}{(n-1)n}},$$

where i identifies the observation, and n was the number of observations in weight class k. Several foods had only a single observation for a given carotenoid in a weight class. In these cases, the standard error of the mean for each weight class was computed as:

$$S_{\bar{Y}_k} = \sqrt{\frac{\sum (Y_i - \bar{Y}_{ui})^2}{(n - \sum W_i)n}},$$

where $\bar{Y}_{ui}$ was the weighted mean for the data set and the $\sum W_i$ was the sum of the relative weights for that weight class. These weight class standard errors were used to compute the SEM as given above.

RESULTS

The result of these efforts was the creation of the USDA-NCC Carotenoid Database for U.S. Foods. Tables 3–5 provide information on the carotenoid content of these foods. The tables include the food description, mean carotenoid values (μg per 100 g food), *SEM*, number of values used to calculate the weighted mean (#*S*), confidence code, and the citations for the carotenoid values. Data on the α-carotene, β-carotene, β-cryptoxanthin, and lutein + zeaxanthin content of foods are presented in Table 3. Lycopene values for 79 foods are presented in Table 4. The zeaxanthin content of 22 foods is presented in Table 5.

The best sources of α-carotene are carrots, winter squash, and pumpkin. β-Carotene is present in more foods, and is found primarily in dark orange and green fruits and vegetables, such as mango, apricot, cantaloupe, carrots, red peppers, pumpkin, sweet potatoes, broccoli, and leafy greens. β-Crypoxanthin is found primarily in tropical fruits, such as mango, papaya and tangerine, and in sweet red peppers. Major sources of lutein are leafy greens, corn, and green vegetables such as broccoli, brussel sprouts, green beans, peas, and zucchini. Lycopene is found primarily in tomatoes and tomato products; other sources include watermelon, pink grapefruit, and Japanese persimmons. Major sources of zeaxanthin are egg yolks, corn, corn meal, Japanese persimmons, and leafy greens.

DISCUSSION

The data presented in Tables 3–5 provide the most current and comprehensive estimates of the individual carotenoid content of U.S. foods. This database has been

TABLE 3

α-Carotene, β-carotene, β-cryptoxanthin, and lutein + zeaxanthin content of U.S. foods (μg/100 g edible portion)

Description	α-Carotene			β-Carotene			β-Cryptoxanthin			Lutein + zeaxanthin			References
	Mean[1] (SEM)[4]	#S[2]	CC[3]	Mean (SEM)	#S	CC	Mean (SEM)	#S	CC	Mean (SEM)	#S	CC	
Apples, raw, with skin	30	1	C										10
Apricots, canned, heavy syrup, drained	0	1	C	6640 (4226)	4	B	0	1	C	0	1	C	22, 30, 33, 39
Apricots, raw	0	2	C	2554	2	C	0	1	C	0	1	C	2, 22
Arrowroot, raw	0	1	C	11	1	C	0	1	C				43
Asparagus, raw	12	2	C	493	2	C							2, 5
Avocados, raw, all commercial varieties	28	2	C	53	2	C	36	2	C				17
Babyfood, vegetables, squash, strained	308 (308)	3	B	1110 (295)	3	B	7 (4)	3	B	3527 (1850)	3	B	21
Balsam-pear (bitter gourd) pods, raw	185	2	C	190	2	C							34
Bananas, raw	5 (5)	4	B	21 (14)	4	B	0	1	C	0 (0)	3	B	8, 9, 32
Barley flour or meal	0	1	C	0	1	C	0	1	C				43
Barley malt flour	0	1	C	23	1	C	0	1	C				43
Beans, baked, canned, plain or vegetarian	147	1	C	408	1	C							10
Beans, fava, in pod, raw	0	1	C	196	1	C	9	1	C				42
Beans, pinto, mature seeds, raw				26	1	C							11
Beans, snap, green, cooked, boiled, drained, without salt	92	2	C	552	2	C	0	2	C	700	2	C	23
Beans, snap, green, canned, regular pack, drained solids	0	1	C	443	1	C	0	1	C	660	1	C	9
Beans, snap, green, frozen, all styles, unprepared				292	1	C							47

TABLE 3 (*continued*)

Description	α-Carotene			β-Carotene			β-Cryptoxanthin			Lutein + zeaxanthin			References
	Mean[1] (SEM)[4]	#S[2]	CC[3]	Mean (SEM)	#S	CC	Mean (SEM)	#S	CC	Mean (SEM)	#S	CC	
Beans, snap, green, frozen, cooked, boiled, drained, without salt	32	1	C	167	1	C							45
Beans, snap, green, raw	68 (8)	4	B	377 (40)	5	B	0	2	C	640	2	C	2, 6, 23, 47
Beef stew with vegetables (including potatoes and carrots), canned	700	1	C	1780	1	C	0	1	C	60	1	C	9
Beef, variety meats and byproducts, liver, raw				621	1	C							14
Beet greens, cooked, boiled, drained, without salt				2560	1	C							39
Beet greens, raw	5 (3)	3	C	3405 (939)	4	B							2, 5, 6, 39
Blueberries, frozen, unsweetened	2	1	C										3
Blueberries, raw	0	1	C	35	1	C							2, 32
Broccoli, chinese, cooked	29	1	C	968	1	C	0	1	C				42
Broccoli, cooked, boiled, drained, without salt	0	2	C	1042 (259)	4	B	0	2	C	2226	2	C	9, 11, 23, 39
Broccoli, frozen, chopped, cooked, boiled, drained, without salt				1000	1	C				830	1	C	1
Broccoli, frozen, chopped, unprepared				950	1	C							39
Broccoli, raw	1 (1)	4	B	779 (194)	8	A	0	2	C	2445	2	C	2, 5, 6, 11, 19, 23, 39, 47
Broccoli, stalk, frozen, unprepared				270	1	C							39
Brussels sprouts, cooked, boiled, drained, without salt	0	1	C	465	2	C	0	1	C	1290	1	C	19, 39

Brussels sprouts, frozen, unprepared				370	1	C							39
Brussels sprouts, raw	6	2	C	450 (57)	3	C	0	1	C	1590	1	C	6, 19, 39
Butter, light, stick, with salt				1164	1	C							44
Butter, with salt	0	1	C	158	1	C	0	1	C	0	1	C	9
Cabbage, napa, cooked	49	1	C	133	1	C	0	1	C				42
Cabbage, cooked, boiled, drained, without salt				90	1	C							11
Cabbage, raw	0	1	C	65	2	C	0	1	C	310	1	C	11, 19
Cake, pound, commercially prepared, fat-free				277	1	C							44
Candies, halvah, plain	0	1	C	0	1	C	0	1	C				42
Capers, canned, drained	0	1	C	83	1	C	0	1	C				42
Carrots, A-plus cultivar, cooked	15000	1	C	25650	1	C							20
Carrots, A-plus cultivar, raw	10650	1	C	18250	1	C	0	1	C	0	1	C	20
Carrots, baby, experimental coating, raw	2740	1	C	4730	1	C							18
Carrots, baby, raw	4425	2	C	7275	2	C	0	1	C	358	1	C	9, 18
Carrots, cooked, boiled, drained, without salt	4109 (708)	4	B	8015 (1047)	4	B							3, 8, 39
Carrots, canned, regular pack, drained solids	3470 (664)	3	B	5776 (852)	5	A	0	2	C	0	2	C	9, 20, 29, 33, 39
Carrot, dehydrated	38000 (4188)	3	C	68917 (9110)	3	C							49
Carrots, frozen, cooked, boiled, drained, without salt	5542 (1843)	3	B	12272 (2538)	3	B							1, 8, 39
Carrots, frozen, unprepared	5542 (1843)	3	B	12272 (2538)	3	B							1, 8, 39
Carrots, raw	4649 (832)	1 2	A	8836 (831)	1 5	A							2, 3, 5, 6, 8, 18 27, 29, 33, 36, 39, 40
Cassava, raw	0	1	C	8	1	C	0	1	C				43
Catsup	0	2	B	730 (284)	3	B	0	2	B	0	2	B	9, 11, 41
Celery, cooked, boiled, drained without salt	0	1	C	210	1	C	0	1	C	250	1	C	9

TABLE 3 (*continued*)

Description	α-Carotene			β-Carotene			β-Cryptoxanthin			Lutein + zeaxanthin			References
	Mean[1] (SEM)[4]	#S[2]	CC[3]	Mean (SEM)	#S	CC	Mean (SEM)	#S	CC	Mean (SEM)	#S	CC	
Celery, raw	0	1	C	150	1	C	0	1	C	232	1	C	9
Chard, swiss, raw	49	2	C	3954	2	C							2, 6
Chayote, fruit, raw	0	1	C	0	1	C	0	1	C				43
Cheese, cheddar	0	1	C	85	1	C	0	1	C	0	1	C	9
Cheese, low-fat, cheddar or colby				307	1	C							44
Cheese, cream, fat-free	0	1	C	0	1	C	0	1	C				43
Cherries, sweet, raw				28	1	C							32
Chicken pot pie, with carrots, potatoes, and peas, frozen	242	1	C	1048	1	C	27	1	C	105	1	C	9
Chrysanthemum, garland, raw	0	1	C	1320	1	C	24	1	C				43
Cilantro, raw	72	1	C	3440	1	C	404	1	C				42
Citronella, raw	0	1	C	3	1	C	0	1	C				42
Collards, cooked, boiled, drained, without salt	90	2	C	4418 (717)	4	B	20	2	C	8091	2	C	8, 9, 39, 42
Collards, frozen, chopped, unprepared				5510	1	C							39
Collards, raw	238	1	C	3323	2	C	80	1	C				39, 42
Cookies, oatmeal, commercially prepared, fat free				133	1	C							44
Corn, sweet, yellow, cooked, boiled, drained, without salt										1800	1	C	8
Corn, sweet, yellow, canned, whole kernel, drained solids	33	1	C	30 (15)	3	B	0	1	C	884 (219)	3	B	8, 9, 25
Corn, sweet, yellow, frozen, kernels cut off cob, unprepared				14	1	C							25

Corn, sweet, yellow, frozen, kernels cut off cob, boiled, drained, without salt	18	1	C	50	1	C	119	1	C				45
Cornmeal, degermed, enriched, yellow	63	1	C	97	1	C	0	1	C	1355	1	C	9
Cucumber, peeled raw	8	1	C	31	1	C							11
Cucumber, with peel, raw				138	1	C							11
Durian, raw or frozen	6	1	C	23	1	C	0	1	C				43
Egg, whole, raw, fresh	0	1	C	0	1	C	0	1	C	55	1	C	9
Endive, cooked				960	1	C							39
Endive, raw				960	1	C							39
Frozen desserts, ice cream, vanilla	0	1	C	19	1	C	0	1	C	0	1	C	9
Fruit cocktail, canned, heavy syrup, drained	0	1	C	138	1	C	52	1	C	112	1	C	9
Grape leaves, canned	629	1	C	2838	1	C	0	1	C				42
Grape leaves, raw	0	1	C	16194	1	C	4	1	C				42
Grapefruit, raw, pink and red, all areas	5 (4)	4	B	603 (152)	1 1	A	12 (9)	4	B	13	2	C	2, 5, 9, 22 30, 35
Grapefruit, raw, white, all areas	8	1	C	14	1	C							5
Grapes, red or green (european types, varieties, such as, Thompson seedless), raw				39	1	C							10
Gravy, chicken, canned				386	1	C							11
Green peppers stuffed with beef and rice with tomato sauce, frozen entrie, cooked	0	1	C	192	1	C	0	1	C	75	1	C	9
Greens, fiddlehead ferns, home-canned, drained	270	1	C	1640	1	C							4
Greens, fiddlehead ferns, home-frozen, unprepared	280	1	C	1870	1	C							4
Greens, fiddlehead ferns, raw	331	1	C	2040	2	C							3, 4
Horseradish, prepared	0	1	C	0	1	C	0	1	C				42
Hummus, home-prepared	0	1	C	10	1	C	15	1	C				43
Kale, cooked, boiled, drained, without salt	0	2	C	6202 (2272)	3	B	0	2	C	15798	2	C	9, 19, 39

TABLE 3 (*continued*)

Description	α-Carotene			β-Carotene			β-Cryptoxanthin			Lutein + zeaxanthin			References
	Mean[1] (SEM)[4]	#S[2]	CC[3]	Mean (SEM)	#S	CC	Mean (SEM)	#S	CC	Mean (SEM)	#S	CC	
Kale, raw	0	1	C	9226 (2885)	3	C	0	1	C	39550	1	C	19, 33, 39
Kumquats, raw				0	1	C							17
Lasagna with meat and tomato sauce, frozen entrie, cooked	0	1	C	170	1	C	0	1	C	97	1	C	9
Lentils, pink, raw	0	1	C	35	1	C	0	1	C				42
Lettuce, cos or romaine, raw	0	1	C	1272	2	C	0	1	C	2635	1	C	8, 9
Lettuce, iceberg (includes crisphead types), raw	2	2	C	192 (69)	3	B	0	1	C	352	1	C	2, 9, 11
Lotus root, cooked, boiled, drained, without salt	0	1	C	3	1	C	0	1	C				42
Mangos, canned, drained				13120	1	C	1550	1	C				30
Mangos, raw	17	1	C	445	2	C	11	1	C				17
Mangosteen, canned, syrup pack	1	1	C	16	1	C	9	1	C				42
Margarine-like spread, 0% fat	0	1	C	170	1	C	0	1	C	0	1	C	9
Margarine-like spread, stick/tub, composite, 60% fat, with salt	0	1	C	721	1	C	0	1	C	0	1	C	9
Margarine, regular, unspecified oils, with salt added	0	1	C	485 (64)	3	B	0	1	C	0	1	C	9, 24
Meatloaf with mashed potatoes and tomato-based gravy, low-fat frozen entrie, cooked	0	1	C	110	1	C	0	1	C	0	1	C	9
Melon, canary, raw				53	1	C							17
Melon, crenshaw, raw	15	1	C	450	1	C	14	1	C				17
Melon, pepino, raw	0	1	C				0	1	C				17
Melons, cantaloupe, raw	27 (12)	3	B	1595 (88)	5	A	0	1	C	40	1	C	2, 6, 9, 28, 30

Milk, human, mature, fluid	0	1	C	1	1	C				1	1	C	12
Milk, whole, fluid, 3.3% fat	0	1	C	8	1	C	0	1	C	0	1	C	9
Mushrooms, black, dried	0	1	C	0	1	C	0	1	C				43
Mushrooms, straw, canned, drained solids	0	1	C	0	1	C	0	1	C				43
Nectarines, raw	0	2	C	101	2	C	59	1	C				2, 5, 11
Okra, cooked, boiled, drained, without salt	0	1	C	170	1	C	0	1	C	390	1	C	9
Okra, raw	28	1	C	432	1	C							2
Olives, pickled, canned or bottled, green	0	1	C	207	1	C	4	1	C				43
Onions, spring (includes tops and bulb), raw	6	1	C	391	1	C							6
Orange, blood, raw	0	1	C	120	1	C	69	1	C				17
Orange juice, frozen concentrate, unsweetened, diluted with 3 volumes water	2	2	B	24 (7)	3	B	99 (71)	3	B	138	1	C	9, 30, 37
Orange juice, raw	2 (1)	3	B	4 (1)	3	B	15 (1)	3	B	36 (5)	3	B	38
Orange juice, raw, hybrid varieties	8 (1)	3	B	39 (15)	3	B	324 (150)	3	B	105 (4)	3	B	38
Oranges, raw, all commercial varieties	16	2	B	51	2	B	122	1	C	187	1	B	2, 9
Papad urad, dahl, cooked	3	1	C	7	1	C	0	1	C				42
Papayas, raw	0	1	C	276 (245)	3	B	76 (225)	3	B	75	1	C	9, 30, 31
Passion fruit, yellow, raw	35	1	C	525	1	C	46	1	C				17
Pasta in tomato sauce with cheese, canned	0	1	C	127	1	C	0	1	C	0	1	C	9
Pasta with chicken and vegetables (includes carrots, peas, onions, and mushrooms) with oriental sauce, low calorie, frozen entrie, cooked	365	1	C	620	1	C	0	1	C	312	1	C	9

TABLE 3 (*continued*)

Description	α-Carotene			β-Carotene			β-Cryptoxanthin			Lutein + zeaxanthin			References
	Mean[1] (SEM)[4]	#S[2]	CC[3]	Mean (SEM)	#S	CC	Mean (SEM)	#S	CC	Mean (SEM)	#S	CC	
Pasta with shrimp and vegetables (includes broccoli, red peppers, yellow zucchini and onions) in lemon pepper sauce, low fat frozen entrie, cooked	0	1	C	148	1	C	0	1	C	177	1	C	9
Peaches, canned, heavy syrup, drained	0	1	C	334 (123)	4	B	141 (78)	3	B	33	1	C	22, 30, 33
Peaches, raw	1 (1)	3	B	97 (13)	3	A	24	2	B	57	2	B	2, 9, 11, 22
Pears, canned, heavy syrup, drained				4	1	C							33
Pears, raw	6	1	C	27	1	C							11
Peas, green, canned, regular pack, drained solids	0	1	C	320	1	C	0	1	C	1350	1	C	9
Peas, green, frozen, unprepared	33	1	C	320	1	C							10
Peas, green, raw	19	2	C	485	2	C							2, 6
Pepper, banana, raw	39	1	C	184	1	C	0	1	C				42
Pepper, serrano, raw	18	1	C	534	1	C	40	1	C				42
Peppers, sweet, green, raw	22 (10)	3	B	198 (43)	3	B							2, 5, 6
Peppers, sweet, red, cooked boiled, drained, without salt	62	1	C	2220	1	C							39
Peppers, sweet, red, raw	59	1	C	2379 (310)	3	C	2205	1	C				13, 30, 39
Peppers, sweet, yellow, raw				120	1	C							30
Persimmons, japanese, dried	18	1	C	374	1	C	156	1	C				17
Persimmons, japanese, raw				253	2	C	1447	2	C	834	1	C	30, 31
Persimmons, japanese, raw, with skin	75	2	C	349	2	C	94	2	C				15

Pineapple, canned, juice pack, drained				30	1	C							30
Pizza, supreme with sausage and pepperoni, mushrooms, peppers, onions, cheese and sauce, thin crust, frozen	0	1	C	170	1	C	0	1	C	20	1	C	9
Pizza with pepperoni, cheese and sauce, thin crust, frozen	0	2	B	264	2	B	0	2	B	15	2	B	9
Plums, raw				98	1	C	16	1	C				11
Potatoes, raw, flesh and skin				6	1	C							3
Prickly pears, raw	0	2	C	24	2	C	3	2	C				17, 42
Pummelos, pink, raw	14	1	C	320	1	C	103	1	C				17
Pummelo, raw	0	1	C	0	1	C	10	1	C				17
Pumpkin, canned, without salt	4795	2	C	6940	2	C	0	1	C	0	1	C	20, 39
Rambutan, canned, syrup pack	0	1	C	2	1	C	0	1	C				42
Raspberries, raw	12	2	C	8	2	C	0	1	C				2, 17, 32
Sauce, hoisin, ready-to-serve	0	1	C	12	1	C	0	1	C				42
Sauce, mole, canned	0	1	C	9	1	C	0	1	C				42
Sauce, mole, prepared from recipe	199	1	C	1282	1	C	828	1	C				42
Sauce, oyster, ready-to-serve	0	1	C	13	1	C	0	1	C				42
Sauce, pasta, spaghetti/ marinara, ready-to-serve	0	1	C	440	1	C	0	1	C	160	1	C	41
Sauce, plum, ready-to-serve	0	1	C	26	1	C	0	1	C				43
Sauce, ready-to-serve, pepper or hot				558	1	C							45
Sauce, ready-to-serve, salsa				398	1	C							45
Seeds, sunflower seed kernels, oil roasted, without salt	0	1	C	0	1	C	0	1	C				43
Soup, chicken noodle, canned, condensed, commercial	151	1	C	391	1	C							10
Soup, minestrone, canned, condensed, commercial	210	1	C	920	1	C	0	1	C	150	1	C	41

TABLE 3 (*continued*)

Description	α-Carotene			β-Carotene			β-Cryptoxanthin			Lutein + zeaxanthin			References
	Mean[1] (SEM)[4]	#S[2]	CC[3]	Mean (SEM)	#S	CC	Mean (SEM)	#S	CC	Mean (SEM)	#S	CC	
Soup, tomato, canned, condensed, commercial	0	1	C	235	2	B	0	1	C	90	1	C	11, 41
Soup, vegetable beef, canned, condensed, commercial	489 (53)	3	B	1618 (68)	3	B	0	2	B	92	2	B	9, 10, 41
Soup, vegetarian vegetable, canned, condensed, commercial	410	1	C	1500	1	C	0	1	C	160	1	C	41
Spearmint, dried	0	1	C	8847	1	C	650	1	C				43
Spearmint, fresh	0	2	C	2133	2	C	0	2	C				43
Spices, thyme, fresh				2851	1	C							45
Spinach, cooked, boiled, drained, without salt	0	2	C	5242 (898)	4	A	0	2	C	7043 (1097)	3	A	8, 9, 23, 39
Spinach, canned, drained solids				4820	1	C							39
Spinach, frozen, chooped or leaf, unprepared				4940	1	C							39
Spinach, raw	0 (0)	5	A	5597 (561)	8	A	0 (0)	3	B	11938 (1462)	3	B	2, 5, 9, 19 23, 33, 39, 40
Spinach souffle, frozen, cooked	0	1	C	1300	1	C	0	1	C	2727	1	C	9
Squash, summer, crookneck and straightneck, raw	0	1	C	90	1	C	0	1	C	290	1	C	9
Squash, summer, zucchini, includes skin, raw	0	1	C	410	1	C	0	1	C	2125	1	C	9
Squash, winter, acorn, cooked, boiled, mashed, without salt	0	1	C	490	1	C	0	1	C	66	1	C	21
Squash, winter, acorn, raw	0	1	C	220	1	C	0	1	C	38	1	C	21
Squash, winter, buttercup, raw	24	1	C	710	1	C							6

Squash, winter, butternut, cooked, baked, without salt	1130	1	C	4570	1	C							39
Squash, winter, butternut, raw	834	2	C	4226 (2126)	3	C							33, 39, 40
Squash, winter, hubbard, raw				820	2	C							39, 40
Strawberries, raw	5	1	C										2
Sweetpotato, cooked, baked in skin, without salt	0	1	C	9488 (1823)	4	B	0	1	C	0	1	C	7, 20, 39, 46
Sweetpotato, canned, vacuum pack	0	1	C	8314 (2566)	4	B	0	1	C	0	1	C	7, 20, 33, 39
Sweetpotato, frozen, unprepared				6220	1	C							39
Sweetpotato, raw	0	2	C	9180 (1272)	6	A	0	1	C	0	1	C	2, 5, 7, 20, 33, 39
Tamarinds, raw	0	1	C	8	1	C	0	1	C				43
Tangerine juice, frozen concentrate, sweetened, undiluted				227 (107)	3	B	2767 (614)	3	B				30
Tangerine juice, raw	9	2	B	21	2	B	115	2	B	166	1	C	37, 38
Tangerines, (mandarin oranges), raw	14	1	C	71	2	C	485	1	C	243	1	C	9, 32
Tofu, firm, prepared with calcium sulfate and magnesium chloride (nigari)	0	1	C	0	1	C	0	1	C				42
Tomato juice, canned, without salt added	0	1	C	428	2	B	0	1	C	60	1	C	8, 41
Tomato products, canned, paste, with salt added	29 (35)	3	B	1242 (206)	3	B	0	2	B	170	2	B	8, 9, 41
Tomato products, canned, puree, with salt added	0	1	C	410	1	C	0	1	C	90	1	C	41
Tomato products, canned, sauce	0	2	B	410	2	B	0	2	B	1	2	B	9, 41
Tomatoes, red, ripe, cooked, boiled, without salt	0	1	C	300	1	C	0	1	C	150	1	C	23
Tomatoes, red, ripe, canned, whole, regular pack	0	2	B	186 (43)	3	B	0	2	B	40	2	B	9, 10, 41

TABLE 3 (*continued*)

Description	α-Carotene			β-Carotene			β-Cryptoxanthin			Lutein + zeaxanthin			References
	Mean[1] (SEM)[4]	#S[2]	CC[3]	Mean (SEM)	#S	CC	Mean (SEM)	#S	CC	Mean (SEM)	#S	CC	
Tomatoes, red, ripe, raw, year round average	112	2	C	393 (71)	7	A	0	1	C	130	1	C	6, 8, 11, 23, 30, 48
Turnip greens, cooked, boiled, drained, without salt	0	1	C	4575	1	C	0	1	C	8440	1	C	9
Vegetable combination with butter sauce (broccoli, cauliflower and baby carrot)	333	1	C	450	1	C	0	1	C	142	1	C	9
Vegetables (includes white potatoes, sweet potatoes, rutabagas, green beans, and onions) with beef and sauce, low fat frozen entrie, cooked	0	1	C	352	1	C	0	1	C	70	1	C	9
Vegetable juice cocktail, canned	210	1	C	830	1	C	0	1	C	80	1	C	41
Wasabi, root, raw	0	1	C	14	1	C	0	1	C				43
Watermelon, raw	0	1	C	295	2	C	103	2	C	17	1	C	9, 30
Yautia (tannier), raw	0	1	C	3	1	C	0	1	C				43

[1]Weighted mean.
[2]Number of samples.
[3]Confidence code.
[4]Weighted standard error of the mean.

TABLE 4

Lycopene content of U.S. foods (μg/100 g edible portion)

	Lycopene			
Description	Mean[1] (SEM)[4]	# S[2]	CC[3]	References
Apricots, canned, heavy syrup, drained	65	1	C	22
Apricots, raw	5	1	C	22
Babyfood, vegetables, squash, strained	0	2	B	21
Bananas, raw	0 (0)	3	B	8, 9
Beans, snap, green, cooked, boiled, drained, without salt	0	2	C	23
Beans, snap, green, canned, regular pack, drained solids	0	1	C	9
Beans, snap, green, raw	0	2	C	23
Beef stew with vegetables (including potatoes and carrots), canned	302	1	C	9
Broccoli, cooked, boiled, drained, without salt	0	2	C	9, 23
Broccoli, raw	0	2	C	19, 23
Brussels sprouts, cooked, boiled, drained, without salt	0	1	C	19
Brussels sprouts, raw	0	1	C	19
Butter, with salt	0	1	C	9
Cabbage, raw	0	1	C	19
Carrots, A-plus cultivar, cooked	0	1	C	20
Carrots, A-plus cultivar, raw	0	1	C	20
Carrots, baby, raw	0	1	C	9
Carrots, canned, regular pack, drained solids	0	2	C	9, 20
Catsup	17008	2	B	9, 41
Celery, cooked, boiled, drained, without salt	0	1	C	9
Celery, raw	0	1	C	9
Cheese, cheddar	0	1	C	9
Chicken pot pie, with carrots, potatoes, and peas, frozen	0	1	C	9
Collards, cooked boiled, drained, without salt	0	1	C	9
Corn, sweet, yellow, canned, whole kernel, drained solids	0	1	C	9
Cornmeal, degermed, enriched, yellow	0	1	C	9
Egg, whole, raw, fresh	0	1	C	9
Frozen dessert, ice cream, vanilla	0	1	C	9
Fruit cocktail, canned heavy syrup, drained	0	1	C	9
Grapefruit, raw, pink and red, all areas	1462 (477)	7	A	9, 22, 35
Green peppers stuffed with beef and rice with tomato sauce, frozen entrie, cooked	3092	1	C	9
Kale, cooked, boiled, drained, without salt	0	2	C	9, 19
Kale, raw	0	1	C	19
Lasagna with meat and tomato sauce, frozen entrie, cooked	7750	1	C	9
Lettuce, cos or romaine, raw	0	1	C	9
Lettuce, iceberg	0	1	C	9
Margarine-like spread, 0% fat	0	1	C	9
Margarine-like spread, stick/tub composite, 60% fat, with salt	0	1	C	9
Margarine, regular, unspecified oils, with salt added	0	1	C	9
Meatloaf with mashed potatoes and tomato-based gravy, low-fat frozen entrie, cooked	930	1	C	9
Melons, cantaloupe, raw	0	1	C	9
Milk, human, mature, fluid	3	1	C	12
Milk, whole fluid, 3.3% fat	0	1	C	9
Okra, cooked, boiled, drained, without salt	0	1	C	9
Orange juice, frozen concentrate, unsweetened, diluted with 3 volumes water	0	1	C	9
Oranges, raw, all commercial varieties	0	1	B	9
Papayas, raw	0	1	C	9

TABLE 4 (*continued*)

Description	Lycopene Mean[1] (SEM)[4]	#S[2]	CC[3]	References
Pasta incl. tomato sauce with cheese, canned	3162	1	C	9
Pasta with chicken and vegetables (includes carrots, peas, onions, and mushrooms) with oriental sauce, low calorie, frozen entrie, cooked	0	1	C	9
Pasta with shrimp and vegetables (includes broccoli, red peppers, yellow zucchini and onions) inc. lemon pepper sauce, low fat frozen entrie, cooked	0	1	C	9
Peaches, canned, heavy syrup, drained	0	1	C	22
Peaches, raw	0	2	B	9, 22
Peas, green, canned, regular pack, drained solids	0	1	C	9
Persimmons, japanese, raw	158	1	C	31
Pizza, supreme with sausage and pepperoni, mushrooms, peppers, onions, cheese and sauce, thin crust, frozen	2071	1	C	9
Pizza with pepperoni, cheese and sauce, thin crust, frozen	4449	2	B	9
Pumpkin, canned, without salt	0	1	C	20
Sauce, pasta, spaghetti/marinara, ready-to-serve	15990	1	C	41
Soup, minestrone, canned, condensed, commercial	1480	1	C	41
Soup, tomato, canned, condensed commercial	10920	1	C	41
Soup, vegetable beef, canned, condensed, commercial	364	2	B	9, 41
Soup, vegetarian vegetable, canned, condensed, commercial	1930	1	C	41
Spinach, cooked, boiled, drained, without salt	0	2	C	9, 23
Spinach, raw	0 (0)	3	B	9, 19, 23
Spinach souffle, frozen, cooked	0	1	C	9
Squash, summer, crookneck and straightneck, raw	0	1	C	9
Squash, summer, zucchini, includes skin, raw	0	1	C	9
Squash, winter, acorn, cooked, boiled, mashed, without salt	0	1	C	21
Squash, winter, acorn, raw	0	1	C	21
Sweetpotato, cooked, baked in skin, without salt	0	1	C	20
Sweetpotato, canned, vacuum pack	0	1	C	20
Sweetpotato, raw	0	1	C	20
Tangerines, (mandarin oranges), raw	0	1	C	9
Tomato juice, canned, without salt added	9318 (1269)	5	A	1, 8, 41
Tomato products, canned, paste, with salt added	29330 (10860)	5	A	8, 9, 41
Tomato products, canned, purie, with salt added	16670	1	C	41
Tomato products, canned, sauce	15916 (1829)	3	B	8, 9, 41
Tomatoes, red, ripe, cooked, boiled, without salt	4400	1	C	23
Tomatoes, red ripe, canned, whole regular pack	9708	2	B	9, 41
Tomatoes, red, ripe, raw, year round average	3025 (596)	5	A	8, 23, 48
Turnip greens, cooked, boiled, drained, without salt	0	1	C	9
Vegetable combination with butter sauce (broccoli, cauliflower and baby carrot)	0	1	C	9
Vegetables (includes white potatoes, sweet potatoes, rutabagas, green beans, and onions) with beef and sauce, low fat frozen entrie, cooked	285	1	C	9
Vegetable juice cocktail, canned	9660	1	C	41
Watermelon, raw	4868	1	C	9

[1]Weighted mean.
[2]Number of samples.
[3]Confidence code.
[4]Standard error of the mean.

TABLE 5

Zeaxanthin content of U.S. foods (μg/100 g edible portion)

	Zeaxanthin[1]		
Description	Mean	#S[2]	References
Beans, snap, green canned, regular pack, drained solids	44	1	9
Broccoli, cooked, boiled, drained, without salt	23	1	9
Carrots, baby, raw	23	1	9
Celery, cooked, boiled, drained, without salt	8	1	9
Celery, raw	3	1	9
Collards, cooked boiled, drained, without salt	266	1	9
Corn, sweet, yellow, canned, whole kernel, drained solids	528	1	9
Cornmeal, degermed, enriched, yellow	457	1	9
Egg, whole, raw, fresh	23	1	9
Kale, cooked, boiled, drained, without salt	173	1	9
Lettuce, cos or romaine, raw	187	1	9
Lettuce, iceberg (includes crisphead types), raw	70	1	9
Orange juice, frozen concentrate, unsweetened, diluted with 3 volumes water	80	1	9
Oranges, raw, all commercial varieties	74	1	9
Peaches, canned, heavy syrup, drained	19	1	22
Peaches, raw	6	1	22
Peas, green, canned, regular pack, drained solids	58	1	9
Persimmons, japanese, raw	488	1	31
Spinach, cooked, boiled, drained, without salt	179	1	9
Spinach, raw	331	1	9
Tangerines, (mandarin oranges), raw	112	1	9
Turnip greens, cooked, boiled, drained, without salt	267	1	9

[1]All confidence codes for zeaxanthin data are C.
[2]Number of samples.

expanded from the 1993 USDA-NCI carotenoid database to include 215 foods which represent a greater variety of fruits and vegetables, and a number of other sources of carotenoids in the U.S. diet, including eggs, butter, margarine, corn meal, and mixed dishes. Confidence codes associated with each carotenoid value provide users with an indication of the quality of the data.

Since β-carotene is present in a broad range of fruits and vegetables and has been the focus of much epidemiologic research, it is not surprising that nearly all of the foods in the new database have acceptable β-carotene values (98%). The other carotenoids are not as abundant and have been studied less extensively. The database contains α-carotene values for 175 foods (81%), β-cryptoxanthin values for 138 foods (64%), lutein + zeaxanthin values for 97 foods (45%), and lycopene values for 79 foods (37%). However, the other carotenoids are not present in as many foods as is β-carotene.

The new carotenoid database is greatly expanded compared to the 1993 database. This was accomplished by adding additional fruits and vegetables and adding non-fruit and vegetable sources of carotenoids including mixed dishes. In addition, different forms of a particular food item (e.g., raw, cooked, canned, frozen, etc.) were not aggregated as they were in the earlier database, and therefore, each form of a food now has its own entry. The internet version of the database contains NDB numbers to facilitate linking the carotenoid database with other USDA databases and can be found at http://www.nal.usda.gov/fnic/foodcomp.

An important difference between the two databases is that the new carotenoid values are presented as means rather than as median values. The mean carotenoid values for most foods are within the ranges previously reported (Mangels *et al.*, 1993), but the mean differs substantially from the median for some important sources of carotenoids. For example, the mean for β-carotene in carrots cooked from frozen is 12 272 μg/100 g, but the median value in the 1993 database for cooked carrots was 9800 μg/100 g. The mean β-carotene content of cooked butternut squash is nearly double the median for cooked winter squash in the 1993 database (4570 μg/100 g versus 2400 μg/100 g, respectively). Several values fell outside of the ranges reported by Mangels *et al.* (1993), including tomatoes and tomato products where the mean values for lycopene were higher in the new database. The β-carotene content of collards and cantaloupe is considerably lower in the updated database, and the lutein + zeaxanthin content of broccoli is higher in the new database. It is possible that the disaggregation of different forms and varieties of foods resulted in some of the observed differences. It is unknown at the present what effect these changes will have on population estimates of carotenoid intake in the U.S.

Another difference between the updated and 1993 databases is the use of a weighting factor in calculating the measure of central tendency. Although Mangels *et al.* (1993) decided against a weighting factor due to lack of data and because they did not want one of the categories in the evaluation program to be considered more significant than the others, they suggested that when more data were available, a weighting strategy could be devised. We decided to implement a weighting strategy based on sampling plan so that more representative samples could be counted more heavily in the calculation of the mean value.

Overall quality of the data can be assessed by evaluating the confidence code information. The confidence code summarizes the quality indices for all sources of data for that food. Each quality index represents the average of the five ratings assigned to the various categories of quality (analytical method, sampling plan, etc.) for each source for that food. One source may provide documentation of more expertise in analytical methodology while another may have used a more representative sampling plan. Frequently, sources fail to report any information on analytical quality control and, therefore, obtain a low rating for that category. Therefore, the specific ratings for individual categories can be used by USDA to assess the quality of data in a more detailed way and to determine where strengths and deficits exist in the development of analytical methodology, food sampling, and subsequent databases for specific components.

While analytically acceptable, "C" quality data do not encompass much of the variability in carotenoid content of foods, and therefore may not be very representative of foods available in the U.S. The carotenoid content of foods is highly variable due to a number of factors, including geographical area and growing conditions, cultivar or variety, processing techniques, preparation, and length and conditions of storage (Sweeney and Marsh, 1971; Khachik and Beecher, 1988; Pennington *et al.*, 1993). In addition to factors within the food itself, there are other factors which affect an investigator's ability to accurately analyze the carotenoid content of foods, such as inherent variability in selection of samples from the food supply, incomplete homogenization of samples, and analytical methods (Horwitz and Albert, 1996). Analysis of nationwide samples of key contributors of carotenoids to the diet will allow us to better understand the sources of this variability.

Although the carotenoid estimates presented in Tables 3–5 represent the best data available, there were only 12 foods out of a possible 215 (6%) for which one or more carotenoid values were assigned an "A": raw broccoli, canned carrots, raw carrots, pink grapefruit, cantaloupe, raw peaches, boiled spinach, raw spinach, sweet potatoes, tomato juice, tomato paste, and raw tomatoes. In contrast, Mangels *et al.* (1993) reported 9% of foods with a confidence code of "A". This may be attributed to the aggregation of different forms of a food into one database entry, providing more data points for each food and fewer foods in the database. Of the 706 individual carotenoid values presented in Tables 3 and 4, 17 (2%) and confidence codes of "A". 97 (14%) had confidence codes of "B", and 592 (84%) had confidence codes of "C". Confidence codes are one of the factors that will be used to prioritize future analyses of carotenoid containing foods.

The updated carotenoid database is typical of small data sets which can be developed for food components of recent scientific interest. A review of the numbers of studies which contributed acceptable data values for specific carotenoids reveals that for most foods one study contributes the values for each carotenoid. For example, β-carotene values for 139 foods were derived from single studies. It should be noted that one study may have reported values for one or more foods. Furthermore, a single study may have analyzed multiple samples for a single food. β-Carotene values for 30 foods were derived from two studies while β-carotene values for only 23 foods were based on three studies each. Estimates for other important contributors of β-carotene (e.g., carrots, raw) were derived from 6–15 studies. Data for other carotenoids are not as complete as for β-carotene.

FUTURE DIRECTIONS

The process described above to develop the USDA-NCC carotenoid database is the first step in creation of a functional database for analysis of dietary intake patterns. The USDA and NCC at the University of Minnesota will now work together to impute carotenoid values for foods in the USDA's Primary Nutrient Data Set (PDS) and NCC's Nutrient Database so that carotenoid values can be assigned to all foods and mixed dishes with ingredients that contain carotenoids. Until this database is populated, users who require certain imputed values should follow the general guidelines provided in Schakel *et al.* (1997) and the specific guidelines for imputing carotenoid values found in Mangels *et al.* (1993). In the absence of U.S. data for similar foods, the reader may consult international sources of published carotenoid values (Heinonen *et al.*, 1989; West and Poortvliet, 1993; Godoy and Rodriguez-Amaya, 1994; Hart and Scott, 1995; Hulshof *et al.*, 1997; Móller, 1997; Godoy and Rodriguez-Amaya, 1998). When the PDS and NCC databases are updated with the new carotenoid values, it will be possible for researchers to estimate carotenoid intake from food consumption surveys like the USDA's Continuing Survey of Food Intakes by Individuals (CSFII, Food Surveys Research Group, Beltsville Human Nutrition Research Center, USDA, U.S.A.), the National Health and Examination Survey (NHANES, U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics, U.S.A.) and from dietary intake records collected using the Nutrition Data System for Research (Nutrition Coordinating Center, Division of Epidemiology, University of Minnesota, Minneapolis, Minnesota, U.S.A.). These databases will be used to compare estimates of carotenoid intake using the old database with estimates obtained using the new database. One aspect of this comparison will be to evaluate the effect of using mean values versus medians on population estimates of intake and to gauge the impact of including non-fruit and vegetable sources of carotenoids in the database. These comparison studies will be initiated as soon as the imputed values for carotenoids in foods are available.

In view of the quantity of data represented here, we recognize the need for additional analyses to improve the representativeness of carotenoid estimates. Future analyses conducted by USDA's Nutrient Data Laboratory under the National Food and Nutrient Analysis Program to improve the quality of the USDA Nutrient Database for Standard Reference will include individual carotenoid values. First priority will be on analyses of highly consumed foods with "C" quality data. We would like to encourage other researchers to use the standards for data quality described here for their own carotenoid analyses (use of appropriate documentation for sample selection, sample handling, sample number, analytical methodology, and analytical quality control). Assuming that other investigators generate carotenoid data which are accurate and representative of the U.S. food supply, we request that they submit their findings to USDA for review and consideration for inclusion in the National Nutrient Databank.

As part of this research, we also collected publications on the carotenoid content of foods outside the U.S. We have identified 78 references for foods available around the world to date and are planning to collaborate with other experts to compile these data into a comprehensive database that will provide carotenoid values for foods by country. This database will be used to update the 1993 publication of international carotenoid values in foods (West and Poortvliet, 1993), and will be available on the USDA website.

A comprehensive database of the carotenoid content of foods is necessary to estimate individual intake of carotenoids in populations. The patterns and distribution of dietary intake can then be evaluated by researchers interested in characterizing associations between dietary carotenoids and various diseases.

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