UPDATE OF THE CAROTENOID DATABASE FOR FOODS

D.B. Haytowitz[1], J.M. Holden[1], G.R. Beecher[1], I.M. Buzzard[2], S. Gebhardt[1], C.S. Davis[1], S. Schakel[3], A. L. Eldridge[3] S. Bhagwat[1], and D. Trainer[1]

[1] USDA-ARS-Beltsville Human Nutrition Research Center, Beltsville, Maryland 20705

[2] Medical College of Virginia, Richmond, Virginia 23298

[3] Nutrition Coordinating Center, University of Minnesota, Minneapolis, Minnesota 55454-1015

Abstract

Traditionally only total vitamin A has been reported in food composition tables, either as International Units or Retinol Equivalents. However, during the last decade, there has been a growing interest in various food carotenoids and their possible link to chronic diseases. In 1993 the USDA-NCI Carotenoid Database containing values for five individual carotenoids was released. A collaborative effort between the USDA, Nutrition Coordinating Center and Medical College of Virginia has resulted in an updated version of the database. Data on the carotenoid content were evaluated using an expert system developed by USDA scientists. The procedures used in the 1993 database were slightly modified to accommodate recent developments in analytical methodology as well as changes in criteria for sampling plans and numbers of samples. Values for " - and $-carotene, lutein+zeaxanthin, lycopene and $-cryptoxanthin from approximately 190 new references were evaluated. Samples of more than 50 foods, including various multicomponent entrees, were obtained from three cities nationwide and the foods analyzed for the above carotenoids. The result was a new database that incorporated previous data, new acceptable literature values, and the analytical data, to yield a database of approximately 200 foods, including different forms of these foods. Mean values, ranges, standard errors, numbers of studies, and confidence codes are reported in the database for each food for the carotenoids listed above. In addition zeaxanthin values are presented for 23 foods. USDA NDB numbers were assigned to facilitate the use of carotenoid data with other USDA food composition data. Supported in part by NCI grant RO1-CXA59791.

Introduction

At one time, individual carotenoids were looked at only as precursors to vitamin A, not having any biological importance of their own. Today they are revealed as antioxidants which may protect against the development of selected diseases. Their role is hypothesized as preventing or minimizing free radical damage associated with cancer (Ziegler, 1991), coronary heart disease (Gerster, 1991), cataracts, and age-related macular degeneration (Snodderly, 1995). The National Academy of Sciences has convened a panel to look at developing Dietary Reference Intakes for carotenoids. They first met this past February and their final report is due in the fall of 1999.

Background

Fruits and vegetables are major contributors of carotenoids in human diets. Carotenoids are one category or class of compounds found in fruits and vegetables which have stimulated a great deal of interest among health researchers . The USDA/DDHS Dietary Guidelines for Americans (1995) recommends increased consumption of fruits and vegetables. Programs such as the National Cancer Institute's Five-A-Day program also recommend consuming more fruits and vegetables. Reliable databases for carotenoids are needed to conduct epidemiological studies to study an association between dietary intake of particular carotenoids and the risk of certain diseases. The first USDA database for carotenoids in foods was published by Mangels *et al* (1993) as a result of the evaluation of the published analytic data. An artificial intelligence system was used to generate a database of 120 fruits and vegetables. At that time more than 180 articles published from 1971 to 1991 were reviewed. West and Poortvliet (1993) have also generated a database for carotenoid contents of foods with special reference to developing countries.

In view of continuing interest in individual carotenoids, further development of these databases was needed to improve the reliability of the carotenoid values and to expand the database to include values for high fat foods. The improvements in analytical methods, particularly the use of HPLC for separation and quantification, and also sample handling and extraction procedures have added to the amount of data on individual carotenoids.

A grant application was submitted to the National Cancer Institute to collect and evaluate new reports of carotenoids since the 1993 release of the USDA-NCI carotenoid database. The principal investigators and research team for this project are listed in Table 1.

The grant proposal called for the development of an updated carotenoid database, but also the improvement of analytical methods for high-fat foods, such as butter, margarine, and cheeses, which will be reported in a future article; and the inclusion of more mixed dishes. The carotenoids covered are " -carotene, $-carotene, lutein+zeaxanthin, lycopene, and $-cryptoxanthin. A two pronged approach was used to develop the new database: 1) analyses at USDA's Food Composition Laboratory based on nationwide sampling; and 2) a review of literature published since the 1993 table.

Table 1 - Research Team

Principal Investigators:

Gary Beecher

I. Marilyn Buzzard

Joanne Holden

Team Members:

Beltsville Human Nutrition Research Center

Seema Bhagwat

Carole Davis

Susan Gebhardt

David Haytowitz

Chris Spangler

Denise Trainer

Nutrition Coordinating Ctr., University of Minnesota

Alison L. Eldridge (now at Procter & Gamble)

Sally Schakel

Analytical Work

Ten fruits, 23 vegetables, 14 mixed dishes, 3 dairy products, selected margarines, eggs, and corn meal were selected based on their contribution of individual carotenoids to the diet. A sampling plan was developed for each item. Samples were collected from different sources in three major metropolitan areas of the U.S. For the fruits, vegetables, dairy products, eggs, and corn meal, growing location and seasonal variation, were considered in the development of the sampling plan. For the processed products (mixed dishes and margarine) brand predominance and distribution patterns were considered. For example, if one brand item was manufactured in only one plant, the product was collected from several sources and composited. In most cases, analyses were done by brand, which were composited by city. For some products, nationwide composites were prepared and analyzed. Results from the analytical portion of this project were then entered into the database using the expert system described below.

Literature Search and Data Evaluation

Research published in national and international journals since 1992 was reviewed using the expert system developed by USDA. This system evaluates analytical values for method of analysis, analytical quality control, number of samples, sample handling,

and sampling plan. Data for each food and nutrient are rated on a scale of 0 to 3 with 3 representing the optimum score for each evaluation category. The criteria needed to get the highest score for each category are as follows: methods must be documented, validated for the foods analyzed and reference materials used with results within an acceptable range; analytical quality controls must be documented and optimum accuracy and precision of methods must be obtained; number of samples must be 10 or higher with standard deviation, standard error or individual values reported; complete documentation of the sample handling procedures, including validation of homogenization, detailed description of food preparation procedures, and monitoring of storage and moisture changes must be reported; and multiple geographic sampling, representative of brands/varieties consumed with complete descriptions, is also required. Results from analytical contracts sponsored by USDA to add values to the USDA Nutrient Database for Standard Reference were also included in this review.

Analytical methods consist of several steps including sample processing, and carotenoid separation, identification and quantification. Validation of the method by using a reference material, or good recoveries with an internal standard, or good agreement with another valid method or laboratory is also very important. The studies which used only the AOAC method for the separation were not included in the evaluation since the AOAC method alone does not separate individual carotenoids; however used in conjunction with other separation methods it can he utilized effectively. Some of the studies which used the AOAC method with modified separation procedures and also extensive identification procedures were included for the data evaluation.

Developing the Tables

In the 1993 release, different forms of a single food (e.g., raw, cooked, canned, etc.) with similar values were aggregated, and median values were presented. In the new version, food forms are disaggregated to be consistent with the USDA Nutrient Database codes for food names/descriptions. Data for U.S. and non-U.S. foods were separated. The U.S. foods were defined as those consumed in the United States. Acceptable data for U.S. foods were combined to generate mean values. Data for non-U.S. foods will be finalized and released at a later date.

A Quality Index (QI), the mean of the five ratings for the evaluation categories, was calculated to indicate the overall data quality for the particular carotenoid in a specific food and source. If the rating for the analytical method was zero or if three of the five ratings were zero, the Quality Index for that value became zero. QIs for foods with similar descriptions were summed and a confidence code (CC) of a, b or c assigned to each value (Table 2). The Confidence Code is an indicator of relative quality of the data and the confidence a user can have in each mean.

Table 2. Assignment and Meaning of Confidence Codes

Sum of Quality Indices	Confidence Code	Meaning of Confidence Codes
> 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, problems exist regarding the data on which the value is based
1.0 to < 3.4	c	The user can have less confidence in this value due to limited quantity and/or quality of the data

Carotenoid values were expressed as means instead of medians as reported in the earlier database as a result of the consensus reached during a USDA Statistical Workshop organized by the principal investigators in April 1996. During aggregations, carotenoid values from each reference/study were weighted by their respective sampling plan ratings, which had been assigned during the data evaluation process. Sampling plan reflects the representativeness of the sample regarding the brand or cultivar, method of preparation and the geographic origin. The higher rating for sampling plan indicates the national representativeness for that particular food. Lower ratings were assigned to data for foods which were sampled in a more limited way or which were grown in experimental conditions or small regional production facilities. Therefore mean values derived more weight from those values which were more representative of the food supply.

The total number of means/individual values (indicated by #S) used to compute the data in the Carotenoid Database was included rather than the total number of samples analyzed. In the scientific literature each value can be a mean of many values (depending on the number of samples used in the study) or an individual value. Furthermore there may be more than one value for a single food in one reference. As a result, the total number of references may not equal #S. Since the data have been compiled from various sources, #S does not necessarily equal "n" in statistical terms.

The definition of number of samples was clarified to differentiate between the number of sample units purchased and the number of samples analyzed. The replicate values for the same laboratory sample were counted as part of the same sample.

The completed database contains 3 files:

1. Car_tble (carotenoid_table) is the table of analytical carotenoid values.
2. Car_ref (carotenoid_references) is a list of references/studies from which carotenoid values were obtained.
3. Zea_tble (zeaxanthin_table) contains a table of zeaxanthin values and references for 23 selected foods.

Car_tble - Carotenoid Table

This table contains the actual values generated as part of this project. The attributes are given in Table 3:

Table 3. Attributes of the Carotenoid Table

Attribute	Description	
NDB	USDA Nutrient Data Bank Number	
Desc	Food Description	
Carot	Name of the carotenoid	
	a_car	" -Carotene
	b_car	$-Carotene
	b_cryp	$-Cryptoxanthin
	lut+zea	Lutein+Zeaxanthin
	lyc	Lycopene
Mean	Mean value (mcg/100g, edible portion)	
SEM	Standard error of the mean	
#S	Number of means/individual values	
Min	Minimum Value (mcg/100g, edible portion)	
Max	Maximum Value (mcg/100g, edible portion)	
CC	Confidence Codes	
Ref. No.	Reference(s) from which carotenoid values were obtained	

The NDB number is a five digit numerical code used in the USDA Nutrient Database for Standard Reference, the electronic version of Agriculture Handbook No. 8. This number also corresponds to one of the codes used to designate foods as ingredients in the Recipe File for the USDA Nutrient Database for Individual Food Intake Surveys and can be used to update calculated carotenoid values for those multi-component foods

containing fruits and vegetables. Items in this table, which do not have corresponding entries in the USDA Nutrient Database for Standard Reference, are indicated by 'xxxxx' in the NDB No. Column. The USDA Database for Standard Reference can be downloaded from the USDA Nutrient Data Laboratory's (NDL) Home Page.

The Confidence Code (CC) designated as a, b, or c is a general indicator of the quality of the data (a=most confidence). It was determined using the expert system described above.

The references used to generate each value in the table are given in the "Ref. No." fields. This number links directly to the Carotenoid References list.

Car ref- Carotenoid References

A complete list of the 49 references used to create the USDA-NCC Carotenoid Database is provided. In addition to the usual information (authors, title, and journal citation), a brief description of the analytical method used and carotenoids analyzed is included along with the list of references.

Zea_tble - Zeaxanthin values

A separate table is included for zeaxanthin values for 23 U.S. foods. As there are very limited data for the zeaxanthin content of foods, a single value from a reference constitutes the 'mean', the SEM (standard error of the mean) could not be calculated, and a confidence code was not assigned. The references for this table are also included in the "Car_ref" file.

The result is a database with 215 food items, containing up to 5 carotenoids. The database will be available on the NDL Home Page: http://www.nal.usda.gov/fnic/foodcomp. It will be accessible online and you will be able to either view it on your monitor or download a compressed file, containing the database files which can be used with your database program.

Future

In the future the carotenoid database will become part of the USDA Nutrient Database for Standard Reference. As this new carotenoid database replaces the database released in 1993, it in turn will be replaced by another, newer database in the future. The Nutrient Data Laboratory in cooperation with the National Heart Lung and Blood Institute has begun the National Food and Nutrient Analysis Program which is described elsewhere in the proceedings by Joanne Holden. This new program gives us the resources to analyze foods identified by this project as needing additional data on carotenoids. For example, carrots have long been know to have large amounts of

$-carotene and we have identified a number of sources of data for this food. However, carrots in their various forms (raw, cooked, canned, frozen) contribute approximately 1/3 of vitamin A to the diet as identified by our Key Foods approach. Clearly, we need to develop a nationwide representative sample for carrots, so that intake can be accurately assessed.

The carotenoid content of foods is highly variable due to a number of factors, such as growing areas, cultivars, processing techniques, lengths and conditions of storage, and possibly different methods of analysis. The data were obtained from many sources and may represent different growing years. All of these factors contribute to the variability in carotenoid content of foods. Analysis of nationwide samples of the key contributors of carotenoids to the diet will allow us to better understand the sources of this variability.

The Nutrition Coordinating Center (NCC) at the University of Minnesota also develops and maintains a nutrient database used for clinical diets and epidemiological studies that is derived from the USDA Nutrient Database for Standard Reference. The data developed in this project will also be added to the NCC database. In creating the 1993 carotenoid database, values were calculated for carotenoid containing items in the Survey Nutrient Database. NCC and NDL will work together to impute carotenoid values for items in the primary nutrient database (PDS) so that carotenoid values can be calculated for many multi-component foods. These foods make a significant contribution of carotenoids to dietary intakes. Ultimately, using new analytical values and imputed values, carotenoids will be added to future releases of the USDA Nutrient Database for Standard Reference. In time these data and others will be used to add carotenoids to the PDS so that carotenoid data can be used with food consumption survey data collected by USDA's Continuing Survey of Food Intakes by Individuals (CSFII) and DHHS' National Health and Nutrition Examination Survey (NHANES).

References

Gerster, G. 1991. Potential Role of $-carotene in the Prevention of Cardiovascular Disease. Internat. J. Nutr. Res. 61:277-291.

Mangels, A.R., Holden, J.M., Beecher, G.R., Forman, M.R., and Lanza, E. 1993. Carotenoid Content of Fruits and Vegetables: An evaluation of Analytic Data. J. Am. Dietet. Assoc. 93(3):284-296.

Snodderly, A.M. 1995. Evidence for protection against age-related macular degeneration by carotenoids and anti-oxidant vitamins. Am. J. Clin. Nutr. 62:1448S-1461S.

U.S. Department of Agriculture/Department of Health and Human Services. 1995. Dietary Guidelines for Americans, 4th ed. U.S. Government Printing Office. Washington, D.C.

West, C.E., and Poortvliet, E.J. 1993. The Carotenoid Content of Foods with Special References to Developing Countries. VITAL, International Science and Technology Institute, Arlington, Virginia.

Ziegler, R.G. 1991. Vegetables, Fruits and Carotenoids and the Risk of Cancer. Am. J. Clin. Nutr. 53:231s-259s.