Development of USDA's Flavonoid Database for Foods

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Abstract

Recent interest in flavonoids and their possible role as contributors in the reduction of risk of several chronic diseases has led to the development of a database on the flavonoid content of selected foods. The objective of this project was to collect, evaluate and compile a table of published flavonoid values for foods, to identify gaps in data and to set priorities for new research, including the development of new analytical methods. A search of the scientific literature identified 105 articles which contained quantitative data generated by valid and accurate methods. The data from these articles were evaluated according to USDA's data quality evaluation system and a quality score was assigned to each value and food. These values were aggregated by food and component to generate a database with approximately 225 foods. Selected compounds from five subclasses of flavonoids included in the database are: flavonols; flavones; flavans; and anthocyanidins. The distribution of flavonoids varies from plant to plant. Not every flavonoid subclass is present in every plant food. Foods with significant amounts of specific flavonoids are citrus, red wine, berries, onions and teas. This new database on the flavonoid content of foods will enable researchers to assess dietary intakes of flavonoids and to identify relationships between flavonoid intakes and various chronic disease risk factors. The database will be available on the Nutrient Data Laboratory Web site: http://www.nal.usda.gov/fnic/foodcomp.

Introduction

Flavonoids are plant polyphenols. The varied biological properties of flavonoids have stimulated interest in these compounds. Hertog, et al (1996) observed reduced risk of coronary heart disease in the seven countries study and the Zutphen study with high intakes of flavonoids, but did not observe any effect on cancer risk. However, Le Marchand, et al (2000) observed inverse association between quercetin (flavonol) intake and risk of lung cancer. Onions and apples were the major contributors of flavonoids in this study. Hertog, et al (1993) estimated average intake of quercetin, kaempferol, myricetin, apigenin and luteolin of 23 mg/day in aglycone forms in the Dutch population. Justesen, et al (1997) estimated a very similar intake of 26 mg/day for the same flavonoids in the Danish population. Their estimates were considerably lower than the average intake of 1g/day for total flavonoids estimated by Kühnau (1976). The 1g/day estimate included 170 mg of flavonol, flavone and flavanone glycosides and were equivalent to 115 mg of quercetin aglycones. The discrepancies could be explained due to methodologies used to estimate the intakes and analytical techniques used for food analysis (Hertog, et al 1993). Dietary flavonoids consist mainly of five subclasses - flavonols, flavones, flavanones, flavans and anthocyanidins and most of them exist in nature as glycosides except for catechins which are present in free forms and as esters of gallic acid (Robards and Antolovich, 1997). The glycosidic linkages are important for absorption (Hollman *et al* 1999). However, research findings suggests that the aglycone form is one of the intermediates in the metabolism of these compounds. Food sources of flavonoids are vegetables, fruits, nuts, seeds, roots, and beverages like tea, and wine.

Methods

Literature searches were done using key words for flavonoids and by taxonomic names, genus, species for tea and citrus fruits using the Food Science and Technology Abstracts (FSTA) database for articles. The relevant articles were reviewed and articles containing analytical data were retrieved. These articles were further examined to separate articles containing data on the selected compounds in the five subclasses of the dietary flavonoids.

Flavonoids Includes in the Database (based on abundance in the food supply)

- FLAVONOLS: Quercetin, Kaempferol, Myricetin, Isorhamnetin
- FLAVONES: Apigenin, Luteolin
- FLAVANONES: Hesperetin, Naringenin, Eriodictyol
- FLAVANS: Catechins, Epicatechins, Theaflavins, Thearubigins
- ANTHOCYANIDINS: Cyanidin, Delphinidin, Malvidin, Pelargonidin, Peonidin, Petunidin

The following steps were then applied to compile the final database:

- Only values obtained by high performance liquid chromatography (HPLC) were used. Thin layer and paper chromatograpy have been used primarily as qualitative techniques, therefore data were not included. Data generated by spectrophotometric or pH differential methods for total flavonoids or total by subclass were not used because of the lack of specificity of such procedures. However, data for total anthocyanidins generated by HPLC techniques were included in the database.
- The values for glucosides were converted into aglycone forms.
- Values for beverages were adjusted for specific gravities.
- Trace values were quantified as 0.71x LOQ (Limit Of Quantitation) (Mangels, et al 1993) if the LOQ was available.
- A zero value reported in the database is a true zero (below the limit of detection). Therefore, the lack of a value for a particular flavonoid in a food (e.g., a missing value) does not imply a zero value, but an unavailable value.

Data Evaluation and Compilation

The NDL has developed new software for evaluating data quality (Holden, et al 2002) based on the criteria described earlier (Mangels, et al 1993). Each value for each compound is evaluated for the following criteria:

- Sampling plan
- Sample handling
- Number of samples
- Analytical method
- Analytical quality control

Critical analytical steps to aid in the evaluation for each of the five categories have been developed. Data values are rated on a scale of 0-20 for each of the five criteria. Ratings are combined over all sources for a single compound to yield a Confidence Code (CC). The algorithm for combining ratings from the five categories at the data aggregation has been revised to avoid the possibility that the aggregation of several mediocre data points would together, merit the higher CC rating which is the indicator of data quality.

The data were aggregated according to the Nutrient Data Bank number (NDB) for each food and the mean value (mg/100g) determined. The standard error of the mean (SEM), minimum (Min.) and maximum (Max.) values for each flavonoid compound for each food along with data quality rating are also included in the database. Values are reported on the fresh weight basis.

14096 Alcoholic beverage, wine, table, red

Flavonoid	Class	Value (mg/100 g)	SE	N	Min	Max	CC
Quercetin	Flavonols	0.99	0.73	91	0.00	3.36	B
Kaempferol	"	0.06	0.10	55	0.00	0.36	B
Myricetin	"	0.62	0.47	91	0.00	1.79	B
Isorhamnetin	"	0.03	0.04	25	0.00	0.16	B
Apigenin	Flavones	0.00	0.00	4	0.00	0.00	B
Luteolin	"	0.00	0.00	4	0.00	0.00	B
Catechin	Flavans	8.92	8.60	63	0.00	39.00	B
Catechins, Total	"	14.28	11.93	54	1.77	45.00	B
Epicatechin	"	5.03	4.38	64	0.23	16.50	B
Cyanidin	Anthocyanidins	0.27	0.32	15	0.00	0.95	B
Delphinidin	"	0.46	0.40	10	0.17	0.74	B
Malvidin	"	4.18	5.86	29	0.00	25.67	B
Peonidin	"	0.69	0.84	10	0.10	1.29	B

09050 Blueberries, raw

Flavonoid	Class	Value (mg/100 g)	SE	N	Min	Max	CC
Quercetin	Flavonols	3.11	1.88	7	1.70	7.30	B
Kaempferol	"	0.00	0.00	6	0.00	0.00	B
Myricetin	"	0.82	1.27	6	0.00	2.60	B
Catechin	Flavans	0.00		4	0.00	0.00	B
Catechins, Total	"	1.11		4	1.11	1.11	B
Epicatechin	"	1.11		4	1.11	1.11	B
Cyanidin	Anthocyanidins	15.02	6.93	12	4.79	28.72	B
Delphinidin	"	29.54	7.51	12	20.82	47.37	B
Malvidin	"	49.21	11.88	12	32.95	69.44	B
Peonidin	"	7.05	5.27	12	1.01	19.37	B

09206 Orange juice, raw

Flavonoid	Class	Value (mg/100 g)	SE	N	Min	Max	CC
Quercetin	Flavonols	0.19	0.40	23	0.00	1.34	B
Kaempferol	"	0.00	0.00	2	0.00	0.00	B
Myricetin	"	0.05	0.00	2	0.05	0.05	B
Apigenin	Flavones	0.00	0.00	20	0.00	0.00	B
Luteolin	"	0.00	0.00	2	0.00	0.00	B
Eriodictyol	Flavonones	0.33	0.48	127	0.00	1.88	B
Hesperetin	"	13.16	7.90	257	2.56	39.20	B
Naringenin	"	2.27	1.45	227	0.00	6.37	B

11282 Onions, raw

Flavonoid	Class	Value (mg/100 g)	SE	N	Min	Max	CC
Quercetin	Flavonols	22.55	26.14	303	1.50	118.70	B
Kaempferol	"	0.27	0.38	9	0.00	0.96	B
Myricetin	"	0.00		1	0.00	0.00	C
Isorhamnetin	"	1.91	0.58	7	1.26	2.51	C
Apigenin	Flavones	0.00		1	0.00	0.00	C
Luteolin	"	0.00		1	0.00	0.00	C

14355 Tea, black, brewed, prepared with tap water

Flavonoid	Class	Value (mg/100 g)	SE	N	Min	Max	CC
Quercetin	Flavonols	2.72	1.38	31	1.00	4.75	A
Kaempferol	"	1.51	0.48	31	0.63	2.40	A
Myricetin	"	0.45	0.21	31	0.17	0.90	A
Apigenin	Flavones	0.00	0.00	11	0.00	0.00	B
Luteolin	"	0.00	0.00	11	0.00	0.00	B
Catechin	Flavans	0.59	0.19	17	0.35	0.88	A
Catechins, Total	"	15.95	9.27	28	6.50	41.84	A
Epicatechin	"	2.27	1.47	56	0.70	6.24	A
Epicatechin gallate	"	5.31	2.17	28	2.00	10.00	A
Epigallocatechin	"	2.14	2.52	28	0.29	9.27	A
Epigallocatechin gallate	"	5.46	2.84	28	2.72	12.84	A
Gallocatechin	"	1.26	0.90	16	0.56	2.78	A
Theaflavin	"	1.53	0.69	11	0.65	2.61	A
Theaflavin-3,3'-digallate	"	2.09	1.08	11	0.45	3.60	A
Theaflavin-3'-gallate	"	1.00	0.39	11	0.47	1.88	A
Theaflavin-3-gallate	"	1.84	0.84	11	0.79	3.19	A
Theaflavins, total	"	6.46	2.90	11	2.89	10.95	A
Thearubigins	"	73.44	25.23	11	48.28	139.50	A

Results

Literature Review

- Approximately 475 articles since 1970 collected and reviewed
- Approximately 105 articles contained acceptable analytical data
- Approximately 370 articles contained either unacceptable data (values for totals for a subclass or for compounds other than compounds of interest) or methods for separation and identification of compounds, but no quantitative data

Flavonoids Database:

- Table sorted by food and flavonoid class
- Individual analytical values (~5800) for selected aggregated compounds (~1128) on ~225 foods (fruits, vegetables, herbs, teas, wines)
- Confidence code and number of each aggregated flavonoid for each code.

Confidence code	Number
A	51
B	570
C	437
D	70

- Database will be released in late 2002

Summary

This literature review has shown there are a number of gaps in the knowledge of Flavonoids Composition:

- There is only limited analytical data for U.S. foods.
- For many foods there are only single values.
- There is a lack of analytical methods to separate and quantify all the major flavonoids from all the classes simultaneously. As a result many researchers only analyze one class of flavonoids in a particular food and therefore comprehensive data on all the classes is often missing.

A new database for flavonoids in foods will be released on NDL's Web site in late 2002. The database will be based on values obtained from the search of the scientific literature and will include information on the quality of the data. A future update will add analytical data being analyzed by the Food Composition Lab (FCL) using samples of 59 fruits, nuts, and vegetables collected as part of NDL's National Food and Nutrient Analysis Program. These samples will be analyzed using a new analytical method developed by FCL for the simultaneous separation and quantitation of all five flavonoid classes.

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