Development of a Database for Flavonoids in Foods

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Abstract

Production of flavonoids in plants is enhanced in response to stresses such as fungal or bacterial infection or exposure to UV radiation. Recent interest of the scientific community in flavonoids in foods centers on the varied biological properties of certain flavonoid compounds; these include antioxidative, antimicrobial, and possibly anticarcinogenic, and/or cardioprotective effects. Therefore a food composition database for flavonoids in foods is essential to evaluate associations between flavonoid intakes and risk factors for various chronic degenerative diseases. We conducted an exhaustive literature review which yielded approximately 475 articles on flavonoids since 1970, of which ~125 articles contained quantitative analytical data on flavonoids. We reviewed all of the analytical data and have estimated values on approximately 220 foods for key flavonoid compounds. Data will be presented for selected compounds in the five subclasses of flavonoids of interest (Flavonols, Flavones, Flavanones, Flavans, and Anthocyanidins). We observed that most of the available or existing data came from studies conducted in countries other than the United States. For many foods there were only single values available and analysts frequently concentrated on quantifying one or two particular subclasses because a suitable analytical method was lacking to separate and quantify compounds from all five subclasses simultaneously. The full database will be released in late 2002 on the NDL's web site: http//www.nal.usda.gov/fnic/foodcomp.

Introduction

Flavonoids belong to plant phenolics. The varied biological properties of flavonoids have stimulated interest in these compounds. Hertog, et al (1996) observed reduced risk of Coronary Heart Disease (CHD) 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 glycoside residues and when converted to aglycone forms it was ~170 mg/day. 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, it is the aglycone form that is utilized by the body. 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.

Structure of the Database:

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

Data from analytical studies which used acceptable procedures to separate the flavonoids were used. Separation by thin layer or paper chromatography was not acceptable. Similarly values for just the total flavonoids or just the total by subclass of flavonoids, except for the subclass anthocyanidins, were not acceptable. That is, values were used only if reported for individual flavonoids. The values for glucosides were converted into aglycone forms. The catechins and epicatechins which were present as gallic acid esters were reported as such. The values in the database were reported as mg/100g of fresh weight except for teas which were reported on a dry weight basis. Therefore the 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 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 based on the criteria described earlier by Holden, et al 1987, and Mangels, et al 1993 with some modifications. We have attempted to make the criteria for each category of evaluation (sampling plan, sample handling, no. of samples, analytical method and analytical quality control) as objective as possible. The critical analytical steps to aid in the evaluation for the five subclasses have been developed. We have also changed the discrete rating scale of 0 - 3 to continuous rating scale of 0 - 20. Finally we have revised the algorithm for combining ratings from the five categories at the data aggregation to avoid the possibility that the aggregation of several mediocre data points would together, merit the higher Confidence Code (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 for each food along with data quality rating will be included in the final database.

Results

Literature Review

•.Approximately 475 articles since 1970 collected and reviewed

•.Approximately 125 articles contained acceptable analytical data

•.Approximately 350 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:

•.Separate table for each subclass of flavonoids

•.Analytical values for selected compounds on ~ 220 foods

•.Foods include fruits, vegetables, herbs, teas, wines

•.Database will be released in late 2002

Preliminary flavonoid data for selected foods

ANTHOCYANIDINS

FOOD	Cyanidin	Delphinidin	Malvidin	Pelargonidin	Petunidin	Peonidin
	mg/100g	mg/100g	mg/100g	mg/100g	mg/100g	mg/100g
Blueberries, raw	15.0	29.5	49.2		11.7	7.1
Cherries, sweet, raw	111.4			0.8		5.2
Table wine, red	0.3	0.5	4.2		0.9	0.7

FLAVANS

FOOD	Catechin	Epicatechin
	mg/100g	mg/100g
Apples, raw with skin	0.9	7.7
Apples, raw without skin	0.9	6.3
Apricots, raw	5.0	6.1
Broad beans, cooked	8.2	12.2
Cherries, sweet, raw	2.2	9.5
Chocolate bar, dark	12.0	41.2
Chocolate bar, milk	2.9	10.5
Grapes, black, raw	8.9	10.5
Table wine, red	8.9	5.0
Tea, black, brewed	0.6	2.4
Tea leaves, black, dry	157.0	293.3

FLAVANONES

FOOD	Eriodictyol	Hesperetin	Naringenin
	mg/100g	mg/100g	mg/100g
Grapefruit, raw		3.2	78.1
Lemon, raw	21.4	26.3	0.8
Lime, raw		43.0	3.4
Orange juice, raw	0.3	13.9	2.4
Orange, raw		39.0	12.8

FLAVONES

FOOD	Apigenin	Luteolin
	mg/100g	mg/100g
Broccoli, raw	0.0	0.0
Cabbage, raw	0.1	0.2
Carrots, raw	0.0	0.0
Celery, raw	6.1	1.7
Lettuce, iceberg, raw	0.9	0.1

FLAVONOLS

FOOD	Quercetin	Myricetin	Kaempferol
	mg/100g	mg/100g	mg/100g
Broccoli, raw	2.8	0.0	6.3
Carrots, raw	0.4	0.0	0.0
Celery, raw	3.5		
Cocoa powder, unsweetened	20.1		
Cranberries, raw	14.0	4.3	0.1
Kale, raw	5.1	0.0	14.6
Lettuce, looseleaf,raw	2.0	0.0	0.0
Lingonberries, raw	11.3	0.0	0.0
Onions, raw	22.6	0.0	0.3
Tomatoes, red ripe, raw	0.5	0.0	0.1

Summary

This literature review has shown there 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.
• Values analyzed for "Anthocyanidins" using only one standard and by spectrophotometry alone, are not reliable
•There is a lack of analytical method 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 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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