Sources of Flavonoids in the U.S. Diet Using USDA's Updated Database on the Flavonoid Content of Selected Foods.

Haytowitz, D.B., Bhagwat, S., Harnly, J., Holden, J.M., Gebhardt, S.E.
USDA, Agricultural Research Service, Beltsville Human Nutrition Research Center,
Nutrient Data Laboratory and Food Composition Laboratory, Beltsville, MD 20705

Abstract

Flavonoids are biologically active polyphenolic compounds widely distributed in plants and have been linked to various chemoprotective effects (Nichenametla et al, 2006). USDA first released a database on the flavonoid content of foods in 2003. The database was recently updated using data from USDA analysis of 20 different flavonoids from a nationwide sampling of 59 fruits, nuts and vegetables, providing high quality U.S. data not available in the earlier database. Data from 102 scientific papers were also added. The new database contains flavonoid data for 395 food items and is available on NDL's web site (www.ars.usda.gov/nutrientdata). These data were combined with data from NDL's Key Foods list derived from consumption data from the National Health and Nutrition Examination Survey to ascertain the intake of five classes of flavonoids: anthocyanidins, flavanones, flavonols, flavones, and flavan-3-ols on a population basis. Black tea provided the largest amount of flavonols to the diet (32%), followed by onions (25%). Parsley was the largest contributor of flavones. Dried parsley contains a large amount—13.53 g/100g, though rarely is 100g consumed at one time; a teaspoon weighs 0.5g. Oranges (53%) and grapefruit juice (16%) contributed significant amounts of the flavanones. Brewed tea provides the largest quantities of flavan-3-ols to the diet. Blueberries contributed the largest amount of anthocyanidins (31%), followed by bananas (21%) and strawberries (14%). Even though bananas contain considerably less anthocyanidins than any of the berries, U.S. consumption of bananas is much higher than that of individual berries. Daily per capita intake of flavonoids in the U.S. using these data was: anthocyanidins, 5 mg; flavanones, 4 mg; flavones, 1 mg; flavonols, 10 mg; and flavan-3-ols, 112 mg. This expanded database provides researchers with new values on the flavonoid content of many more foods in order to better ascertain the impact of flavonoid consumption on various chronic diseases.

Introduction

Interest of the scientific community in the types and levels of flavonoids in foods continues because of the growing evidence regarding beneficial health effects of dietary flavonoids. Flavonoids, particularly flavan-3-ols, have been associated with reduction in the risk of cardiovascular diseases, attributed to increasing the release of endothelial nitric oxide (NO) and inducing vasodilatation (Engler and Engler, 2004). Anthocyanidins may also protect LDL cholesterol oxidation through their high antioxidant activity (Proceedings of the ILSI North America workshop, 2005). Evidence supporting cancer prevention effects of flavonoids is limited and conflicting, but some organ-specific associations have been reported (Le Marchand 2002, Nichenametla, et al. 2006).

There are more than 5000 flavonoid compounds; however dietary flavonoids consist mainly of five subclasses of monomeric flavonoids (flavonols, flavones, flavanones, flavans and anthocyanidins), polymeric proanthocyanidins and isoflavones. USDA's Nutrient Data Laboratory (NDL) has prepared three separate databases for these three groups of flavonoids. Release 2 of the database for monomeric flavonoids, the USDA database for the flavonoid content of selected foods, will be available on NDL's web site (www.ars.usda.gov/nutrientdata) shortly. It contains values for 395 selected foods for 26 compounds representing the five flavonoid subclasses. Databases for proanthocyanidins, and isoflavones were released earlier and are available on NDL's web site. Using this new database we applied consumption data from the National Health and Nutrition Examination Study (NHANES) to determine the dietary intake of five flavonoid subclasses (Table 1).

Methods

Sources of food composition data:

- Data generated from samples of fruits, nuts and vegetables collected by NDL's National Food and Nutrient Analysis Program and analyzed at USDA's Food Composition Lab in Beltsville, Maryland (Harnly et al, 2006)[1] and at the Arkansas Children's Nutrition Center (Wu et al, 2006)[2] were added to the database.
- Several literature databases (CAB Abstracts, Biosis Previews, Agricola, Food Science and Technology Abstracts) were searched using key words for flavonoids. One hundred and two relevant articles containing analytical data on 26 compounds in edible foods published from 2002 to 2005 were retrieved and added to the 97 articles used in the first release of the database for a total of 199.

Calculation of consumption data:

- Food intake data from the NHANES[3] from 2001-02 were applied against the USDA Database of the Flavonoid Content of Selected Foods, Release 2.
- Recipes from the Food and Nutrient Dataset for Dietary Surveys (FNDDS)[4] were broken down to their component parts using the Key Foods process (Haytowitz et al, 2002)[5] to correspond to the NDB Numbers used in the flavonoid database.
- Grams consumed by the overall population for each item, designated by a NDB Number, were calculated and multiplied by the sum of each individual flavonoid by subclass (Table 1) to generate Tables 2 – 6.

[1] Harnly, J.M., Doherty, R.F., Beecher, G.R., Holden, J.M., Haytowitz, D.B., Bhagwat, S., Gebhardt, S. 2006. Flavonoid Content of U.S. Fruits, Vegetables, and Nuts. *J. Agric. Food Chem.* (Submitted).

[2] Wu, X., Beecher, G.R., Holden, J.M., Haytowitz, D.B., Gebhardt, S.E., and Prior, R.L. 2006. Concentration of anthocyanins in common foods in the United States and estimation of normal consumption. *J. Agric. Food Chem.* 54:4069-4075.

[3] National Center for Health Statistics (NCHS), CDC, DHHS. 2004. NHANES 2001-2002 Data Files: Data, Docs, Codebooks, SAS Code. NHANES Web site: http://www.cdc.gov/nchs/about/major/nhanes/nhanes01-02.htm (accessed 11/04).

[4] U.S. Department of Agriculture (USDA), Agricultural Research Service, 2004. USDA Food and Nutrient Database for Dietary Studies, 1.0. Food Surveys Research Group Home Page, http://www.barc.usda.gov/bhnrc/foodsurvey/home.htm.

[5] Haytowitz, D.B., Pehrsson, P.R., Holden, J.M. 2002. The Identification of Key Foods for Food Composition Research. *J. Food Comp. Anal.* 15(2):183-194.

Table 1. Flavonoids subclasses in the NDL Flavonoid Database

1.	Flavonols:	Quercetin, Kaempferol, Myricetin, Isorhamnetin
2.	Flavan-3-ols:	Catechins, Epicatechins, Epicatechin3-gallate, Epigallocatechin, Epigallocatechin 3-gallate, Gallocatechin, Theaflavin, Theaflavin 3-3′-digallate, Theaflavin 3′-gallate, Theaflavin 3-gallate, Thearubigins
3.	Flavones:	Apigenin, Luteolin
4.	Flavanones:	Hesperetin, Naringenin, Eriodictyol
5.	Anthocyanidins:	Cyanidin, Delphinidin, Malvidin, Pelargonidin, Peonidin, Petunidin

Table 2. Anthocyanidin consumption – top 10 sources

NDB No.	Description	Kg consumed	Total anthocyanidins (mg/100 g)	Total anthocyanidins consumed (mg)	% of total anthocyanidins consumed
09050	Blueberries, raw	260462	163.52	425908291	31.28
09040	Bananas, raw	3895447	7.39	287873527	21.14
09316	Strawberries, raw	546212	33.63	183691067	13.49
09070	Cherries, sweet, raw	128160	80.19	102771904	7.55
09252	Pears, raw	644593	12.18	78511435	5.77
11112	Cabbage, red, raw	71306	72.98	52038932	3.82
09078	Cranberries, raw	33739	91.88	30999673	2.28
09279	Plums, raw	249984	12.02	30048029	2.21
09302	Raspberries, raw	66709	38.68	25803177	1.90
16014	Beans, black, mature seeds, raw	84158	28	23564091	1.73

Table 3. Flavan-3-ol consumption – top 10 sources

NDB No.	Description	Kg consumed	Total flavan-3-ols (mg/100 g)	Total flavan-3-ols consumed (mg)	% of total flavan-3-ols consumed
14355	Tea, black, brewed	2393756	115.25	27588038224	88.25
14352	Tea, black, brewed, decaffeinated	3533556	53.09	1875964970	6.00
14003	Beer, regular, all	2015774	2.48	499912067	1.60
09016	Apple juice, bottled, unsweetened	5085184	5.96	303076960	0.97
09003	Apples, raw, with skin	3294546	8.11	267187700	0.85
09040	Bananas, raw	3895447	6.12	238401351	0.76
09050	Blueberries, raw	260462	51.71	134685162	0.43
09236	Peaches, raw	708517	9.19	65112727	0.21
09252	Pears, raw	644593	6.79	43767869	0.14
09316	Strawberries, raw	546212	4.64	25344233	0.08

Table 4. Flavanone consumption – top 10 sources

NDB No.	Description	Kg consumed	Total flavanones (mg/100 g)	Total flavanones consumed (mg)	% of total flavanones consumed
09200	Oranges, raw	1276152	42.57	543257895	52.82
09123	Grapefruit juice, white, canned	838092	19.22	161081205	15.66
09215	Orange juice, frozen concentrate, reconstituted	328229	29.48	96761810	9.41
09206	Orange juice, raw	355454	13.62	48412874	4.71
09150	Lemons, raw, without peel	93780	49.81	46711831	4.54
11529	Tomatoes, red, ripe, raw	3986593	0.68	27108833	2.64
09126	Grapefruit juice, white, frozen concentrate, reconstituted	83400	31.18	26003990	2.53
09153	Lemon juice, canned or bottled	103927	23.99	24932087	2.42
09218	Tangerines, raw	135645	17.96	24361862	2.37
09152	Lemon juice, raw	63123	20.73	13085433	1.27

Table 5. Flavone consumption – top 10 sources

NDB No.	Description	Kg consumed	Total flavones (mg/100 g)	Total flavones consumed (mg)	% of total flavones consumed
02029	Parsley, dried	1326	13525.9	179286612	50.87
11297	Parsley, raw	19466	227.17	44220832	12.55
11333	Peppers, sweet, green, raw	529498	4.98	26369024	7.48
11143	Celery, raw	725937	2.97	21560322	6.12
09003	Apples, raw, with skin	3294546	0.5	16472731	4.67
09200	Oranges, raw	1276152	1.14	14548132	4.13
09326	Watermelon, raw	1819309	0.61	11097784	3.15
11670	Peppers, hot chili, green, raw	149877	5.27	7898500	2.24
09181	Melons, cantaloupe, raw	1059105	0.64	6778269	1.92
11252	Lettuce, iceberg, raw	3314768	0.16	5303629	1.50

Table 6. Flavonol consumption – top 10 sources

NDB No.	Description	Kg consumed	Total flavonols (mg/100 g)	Total flavonols consumed (mg)	% of total flavonols consumed
14355	Tea, black, brewed	23937560	3.75	897658511	32.11
11282	Onions, raw	2216010	27.07	599873939	21.46
09003	Apples, raw, with skin	3294546	5.96	196354956	7.02
14003	Beer, regular	20157745	0.86	173356604	6.20
14352	Tea, black, brewed, decaffeinated	3533556	4.51	159363383	5.70
11283	Onions, boiled, drained	431127	24.7	106488361	3.81
11252	Lettuce, iceberg, raw	3314768	1.63	54030719	1.93
14209	Coffee, brewed from grounds	48726858	0.1	48726858	1.74
11547	Tomato puree, canned	966681	4.2	40600591	1.45
11529	Tomatoes, red, ripe, raw	3986593	0.82	32690064	1.17

Discussion

Blueberries are the major source of anthocyanidins in the U.S. diet, followed by bananas and strawberries (Table 2). Elderberries and European black currants, not widely consumed in the U.S., are significant sources, containing 769 and 272 mg/100 g respectively.

Black tea is the both the best source and contributes the highest amount of flavan-3-ols, contributing 88% of the dietary intake (Table 3). Green tea also contains significant amounts of flavan-3-ols (128 mg/100 g), but is not differentiated from black tea in the NHANES as there are not important differences in other nutrients. Oolong tea, which is not widely consumed in the U.S., is also a significant source of flavan-3-ols (50 mg/100 g).

Flavanones are found primarily in citrus products, and oranges and orange juice provide over 2/3 of the average flavanone intake (Table 4), followed by other citrus products, such as grapefruit and lemons. The one significant non-citrus item which contributes substantially is tomato, which, while containing a relatively small quantity of flavonones, is widely consumed.

Parsley, both fresh and dried, contains very high amounts of flavones(Table 5), and, as a result, contributes significant amounts of flavones to the diet, though they are used in relatively small quantities, e.g.,1 teaspoon of dried parsley = 0.5g.

Tea and onions together provide over ½ of the flavonol intake (Table 6). Other foods providing significant amounts of flavonols are yellow wax peppers (51 mg/100 g), ancho peppers (28 mg/100 g), and canned kale (22 mg/100 g).

Total per capita consumption of the five flavonoid subclasses is 132 mg/d (Table 7) with flavan-3-ols providing the largest proportion, followed by the flavonols. This compares to 79 mg per day for the five flavonoid subclasses reported by Kyle et al. for a smaller sampling in Scotland. As flavonoids are not currently monitored in the NHANES, a number of important sources are either not included in the survey database or are not widely consumed in the U.S. As these items are incorporated into the survey database or consumption increases, the calculated flavonoid intake is likely to increase.

Table 7. U.S.Per capita consumption of flavonoid subclasses

Flavonoid subclass	Per capita consumption (mg/d)
Anthocyanidins	5
Flavonones	4
Flavones	1
Flavonols	10
Flavon-3-ols	112
Total	132

References

Arab, L.,*et al*., Proceedings of the ILSI North America Workshop, May 31-June 1, 2005, Washington, DC., J. Nutr.(Submitted).

Engler M. B. and Engler, M. M. The vasculopreotective effects of flavonoid-rich cocoa and chocolate. Nutr. Res., 2004, 24:695-706.

Kyle, J.A.M. *et al*. Flavonoids, chemistry, biochemistry and applications. In *Flavonoids in Foods.* Anderson, O.M. et al., Ed. CRC Press, Boca Raton, Fl. 2006

Le Marchand L., Biomed Pharmacother., 2002, 56, 296-301.

Nichenametla,S.N. et al. *et al*., Crit. Rev. Food Sci. Nutr., 2006, 161-183.

This work was supported by USDA/ARS, NIH agreement # Y1-CN-5010, and the Produce for Better Health Foundation.