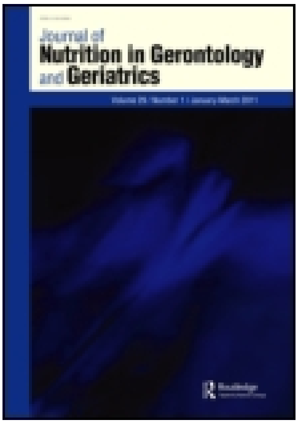

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Estimated Flavonoid Intake of the Elderly in the United States and Around the World

Ock K. Chun PhD, MPH [a] , Sang Gil Lee MS [a] , Ying Wang MS [a] , Terrence Vance MS, RD [a] & Won O. Song PhD, MPH, RD [b]
[a] Department of Nutritional Sciences , University of Connecticut , Storrs , Connecticut , USA
[b] Department of Food Science and Human Nutrition , Michigan State University , East Lansing , Michigan , USA
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OCK K. CHUN, PhD, MPH, SANG GIL LEE, MS, YING WANG, MS, and TERRENCE VANCE, MS, RD
Department of Nutritional Sciences, University of Connecticut, Storrs, Connecticut, USA

WON O. SONG, PhD, MPH, RD
Department of Food Science and Human Nutrition, Michigan State University, East Lansing, Michigan, USA

The aging population has been growing fast in the United States and worldwide. The morbidity of age-related chronic degenerative diseases has also been increasing in parallel. Numerous studies have reported that consumption of flavonoid-rich fruits and vegetables is inversely associated with such chronic diseases as Alzheimer's disease, age-related macular degeneration, cardiovascular disease, and osteoporosis. In establishing flavonoids as one of the contributors to the protective effects, the very first step is to estimate flavonoid intake from various dietary sources. Estimation of flavonoid intake from dietary sources has been feasible since 2003 when the U.S. Department of Agriculture (USDA) released the database for the flavonoid content of selected foods. Since then, several articles have been published in which flavonoid intake in various subpopulation groups was estimated from relatively large, current databases of flavonoid concentration data. However, information is still limited on the intake by seniors in the United States and worldwide. This review summarizes the most current estimates of flavonoid intake by seniors in the United States and elsewhere.

KEYWORDS *aging, antioxidant, diet, elderly, flavonoids*

Address correspondence to Won O. Song, PhD, MPH, RD, Department of Food Science and Human Nutrition, Michigan State University, East Lansing, MI 48824, USA. E-mail: song@msu.edu

INTRODUCTION

The growth rate of the aging population, both in number and in proportion of the total population, has been high in the United States and worldwide. By 2030, the number of people 65 years of age or older in the United States is expected to increase to 71 million, accounting for 20% of the U.S. population, compared with 12% in 2000 (1). The worldwide senior population is expected to increase from 550 million to 973 million, from 6.9% to 12% of the population between 2000 and 2030. By 2030, European countries are expected to have the highest proportions of seniors, followed by North America, Asia, Latin America, and the Caribbean (2).

Aging is a multifactorial process. Although the underlying mechanisms are not fully understood, the free-radical–induced oxidative stress theory has long been proposed and tested (3). Oxidative stress is also a potential mechanism in the pathogenesis of age-related degenerative diseases, such as Alzheimer disease, age-related macular degeneration (AMD), cardiovascular disease (CVD), and osteoporosis (4–7).

Numerous epidemiological studies have reported that consumption of fruits and vegetables is inversely associated with the risks of various age-related chronic diseases (8, 9). Although it still is not clear which components or nutrients in fruits and vegetables exert protective effects against age-related chronic diseases, antioxidants have been drawing increasing attention due to their inhibitory effects on free radicals and anti-inflammatory effects in both in vitro and animal studies (10, 11).

Among the antioxidants abundant in food, flavonoids are a large group of phenolic compounds comprising 15 carbons arranged in three rings, and exhibiting high antioxidant capacity in vitro (12). Flavonoids are divided into various subgroups depending on the degree of hydroxylation, substitutions, and conjugation, such as flavanols (e.g., catechin, and epicatechin), flavonols (e.g., quercetin, myricetin, and kaempferol), anthocyanidins (e.g., cyanidin, and delphinidin), flavones (e.g., apigenin, diosmin), flavanones (e.g., naringenin, and hesperetin), isoflavones (e.g., daidzein, genistein, and glycitein), and chalcones (e.g., phloretin). The main roles of flavonoid compounds in plants are to defend and provide protection against infections and such external stimuli as ultraviolet radiation, pathogens, and physical damage (12). Flavonoids have been shown to exert a variety of beneficial effects for several chronic diseases, such as coronary heart disease (13), CVD (14), osteoporosis (15), and certain types of cancers (13).

In establishing flavonoids as one of the contributors to the protective effects, the very first step is to estimate flavonoid intake from various dietary sources. Since diverse methods of measurement are one of the key factors contributing to the variation, an accurate method is an essential requirement. Estimation of flavonoid intake from dietary sources has been feasible since

2003 when the U.S. Department of Agriculture (USDA) released the database for the flavonoid content of selected foods. Since then, several papers have been published with relatively accurate estimates of flavonoid intake in various subpopulation groups in the United States, but limited information is available on the intake by seniors in the United States and worldwide. This review focuses on the most current original research papers in estimating flavonoid intake among seniors, to provide a better understanding of the association between flavonoid intake status and disease risk.

DATABASES OF FLAVONOID CONTENTS IN FOODS

Various epidemiological studies have used several different methodologies and databases resulting in large variations in estimated flavonoid intake (16–18). We attribute the large variations mainly to the differences among flavonoid databases that each study used. Flavonoid contents measured by diverse methods led to the variation in daily flavonoid intake. In addition, differences in target population (e.g., area, number, gender, and age), dietary data collection methods (e.g., dietary recall, food frequency questionnaire [FFQ]), and the duration for dietary data collection are also factors that influence estimation of flavonoid intake.

Before the release of the 2003 USDA database of the flavonoid content in selected foods, flavonoid intake was estimated only based on four of the six major classes of flavonoids: flavonols, flavones, flavan-3-ols, and isoflavones. Analytical data on the sources of flavonoids were generated originally in the Netherlands (19), and later supplemented with additional food items (20). The addition of anthocyanidin content in foods to the database in 2003 furthered the completion of the flavonoid database.

The 2003 USDA database of flavonoids included a total of 26 flavonoids in 5 subclasses: flavonols (quercetin, kaempferol, myricetin, isorhamnetin), flavones (luteolin, apigenin), flavanones (eriodictyol, hesperetin, naringenin), flavan-3-ols ((+)-catechin, (+)-gallocatechin, (−)-epicatechin, (−)-epigallocatechin, (−)-epicatechin 3-gallate, (−)-epigallocatechin 3-gallate, theaflavin, theaflavin 3-gallate, theaflavin 3′-gallate, theaflavin-3,3′-digallate, thearubigins), and anthocyanidins (cyanidin, delphinidin, malvidin, pelargonidin, peonidin, petunidin) (21). Since the first database was released in 2003 it has been updated twice and the most recent version (release 3) was released in 2011 (22). Subsequently proanthocyanidin content of selected foods was released in 2004 (23). The content of isoflavones (daidzein, genistein, glycitein, biochanin A, and formononetin) in 128 foods has been available since 1999 and a 2.0 version was released in 2008 (24). These most recently released databases on flavonoid content of foods report the amounts as aglycones and additional data generated by the USDA Agricultural Research Service. Although these databases include limited numbers of processed and mixed foods that vary in bioavailability of polyphenols (25), the combined flavonoid and isoflavone databases provide a more comprehensive estimation of flavonoid intake than did previously available databases.

MAJOR FOOD SOURCES OF FLAVONOIDS IN THE U.S. DIET AND ESTIMATED FLAVONOID INTAKE OF THE U.S. ELDERLY

Flavonoid Composition of Most Consumed Foods by U.S. Adults

Flavonoids are widely distributed in fruits and vegetables. Tables 1–3 show the flavonoid content of the 29 most consumed fruits, vegetables, and beverages in the United States that were estimated with the 2003 USDA flavonoid database. The primary dietary sources of flavonoids in the United States are beverage products, such as tea, wine, and juices. Fresh fruits and vegetables are also important dietary sources of flavonoids. Table 4 shows the major contributors to the flavonoid subgroups. With regard to individual flavonoid subgroup, fruits and fruit juices are the major sources of flavanones and anthocyanidins. Of the fruit group, citrus fruits are the only source of flavanones (hesperetin, naringenin, and eriodictyol). Vegetables and vegetable products are the major sources of flavonols and flavone. Wine is rich in flavonols and anthocyanidins, whereas tea contributes most to flavonols and flavan-3-ols (26).

Kimmons and colleagues 2009 reported the top 10 fruits and vegetables consumed by the U.S. population using two 24-hour recall data from the 2003–2004 National Health and Nutrition Examination Survey (NHANES) (27). The most consumed fruit sources were in the order of 100% orange juice, bananas, apples, oranges, watermelons, grapes, cantaloupe, apple juice, cranberry juice cocktail, and strawberries. With regard to vegetable consumption, white potato was consumed most, followed by lettuce, spinach, various beans, tomatoes, string beans, broccoli (for women), and raw and pickled cucumbers (for women). In addition, pizza, pasta sauce, salsa, and French fries significantly contributed to vegetable consumption (27).

Estimated Flavonoid Intake of the U.S. Elderly

Previously we reported the estimated intake of dietary flavonoids and their major food sources in U.S. adults, utilizing 24-hour dietary recall from the NHANES 1999–2002 and the USDA flavonoid database (26). Flavonoid intake in the United States has been reported in several epidemiological studies with large variations in total and subgroups of flavonoids (18, 26). The estimated total flavonoid and subgroup intakes reported in different countries are summarized in Table 5. Using the combined USDA databases on flavonoids and isoflavones, Chun and colleagues (26) reported that of adults in various age and gender groups, men and women at aged 51–70 years had the highest

TABLE 1 Flavonoid Composition of Top Consumed Fruits in the U.S. Diet*

Subclass (Unit) Flavonoids (mg/100 g or 100 mL)	Orange, 100% juice	Banana, raw	Apple, raw	Orange, raw	Grape (red), raw	Grape (white), raw	Watermelon, raw	Cantaloupe	Apple, 100% juice	Cranberry, juice drink, cocktail	Strawberry, raw
Anthocyanidins											
Cyanidin	0		1.27		0.95		0	0	0.01	0.37	1.63
Delphinidin		7.39	0		2.1		0	0	0	0.01	0.31
Malvidin			0		36.2		0	0	0	0	0.01
Pelargonidin			0		0.02		0	0	0	0.03	25.69
Peonidin			0.01		2.9		0	0	0	0	0.05
Petunidin			0		1.8		0	0	0	0	0.07
Flavan-3-ols											
(−)-EC		0.02	7.53		0.96	1.7	0	0	4.71	0	0.42
(−)-ECG			0.01		0.17	0.25	0	0	0	0	0.15
(−)-EGC			0.26		0.08	0.02	0	0	0	0	0.78
(−)-EGCG			0.19		0	0	0	0	0	0	0.11
(+)-Catechin		6.1	1.3		0.82	3.73	0	0	1.25	0.19	3.11
(+)-GC			0		0	0.01	0	0	0	0	0.03
Flavanones											
Eriodictyol	0.17										
Hesperetin	20.39		0	27.25			0	0	0	0	
Naringenin	3.27		0	15.32			0	0	0	0	0.26
Flavones											
Apigenin	0		0	0	0	0	0	0	0	0	0
Luteolin	0		0.12	0.19	1.3	0	0.46	0.64	0	0	0
Flavonols											
Kaempferol		0.11	0.14	0.13	0	0.04	0.45	0.07	0	0.01	0.54
Myricetin	0.05	0.01	0								
Quercetin	0.25	0.06	4.01								
Isoflavones											
Total isoflavones	0.01	0	0	0	0	0	0	0	0	0	0

*Flavonoids compositions of top consumed fruits in the U.S. diet were estimated based on USDA Database for the Flavonoid Content of Selected Foods Release 3.0 (22) and USDA Database for the Flavonoid Content of Selected Foods Release 2.0 (24).

TABLE 2 Flavonoid Composition of Top Consumed Vegetables in the U.S. Diet*

Subclass (Unit) Flavonoids (mg/100 g or 100 mL)	Potato, baked	Lettuce, raw	Green beans, raw, cooked	Tomatoes, raw, cooked, and juice	Broccoli, raw, cooked	Corn, raw, cooked	Squash, raw, cooked	Peas	Carrot, raw, cooked	Onion, raw, cooked	Sweet potatoes, raw, cooked
Anthocyanidins											
Cyanidin	0	0–2.75	0.02				0	0	0	0–2.56	1.6
Delphinidin	0	0	0.02				0	0	0	0–2.28	0.9
Malvidin	0	0					0	0	0	0–0.02	0
Pelargonidin	0	0	0.02				0	0	0	0–1.22	0.02
Peonidin	0	0					0	0	0	0	0
Petunidin	0	0					0	0	0	0	0
Flavan-3-ols											
(−)-EC	0	0				0	0	0.01	0	0	0
(−)-ECG	0	0				0	0	0	0	0	0
(−)-EGC	0	0				0	0	0	0	0	0
(−)-EGCG	0	0				0	0	0	0	0	0
(+)-Catechin	0	0				0	0	0	0	0	0
(+)-GC	0	0				0	0	0	0	0	0
Flavanones											
Hesperetin	0	0					0	0	0	0	0
Naringenin	0	0		0.68–3.19			0	0	0	0	0
Flavones											
Apigenin	0	0–0.13		0.01			0	0	0	0–0.26	0.01
Luteolin	0	0–2.5	0.13	0.02			0	0	0–0.11	0.1–0.19	0.02
Isoflavones											
Total isoflavones	0	0	0.02–0.03	0	0	0	0	0	0	0	0.01

*Flavonoid compositions of most consumed beverages in the U.S. diet were estimated based on USDA Database for the Flavonoid Content of Selected Foods Release 3 (22) and Database for the Flavonoid Content of Selected Foods Release 2.0 (24).

TABLE 3 Flavonoid Composition of Most Consumed Beverages in the U.S. Diet*

Subclass (Unit) Flavonoids (mg/100 g or 100 mL)	Black tea, brewed and ready to drink	Green tea, brewed and ready to drink	Coffee, brewed	Wine, white	Wine, red	Milk, fluid and commercial	Beer
Anthocyanidins							
Cyanidin	0	0	0	0	0.45		
Delphinidin	0	0	0		2.75		
Malvidin	0	0	0	0.06	15.29		
Pelargonidin	0	0	0				
Peonidin	0	0	0		2.02		
Petunidin	0	0	0		2.67		
Flavan-3-ols							
(−)-EC	0.37–2.13	1.98–7.36	0.04	0.55	3.76	0.26	0.33
(−)-ECG	0.08–5.84	0.93–16.39	0		0.01		
(−)-EGC	0.09–8.07	4.99–22.27	0.04		0.06		
(−)-EGCG	0.12–9.36	3.96–64.15	0		0		
(+)-Catechin	1.51	0–3.28		0.77	7.12	0.82	2.07
(+)-GC	1.25	0–1.54			0.1		0.08
Theaflavin	0.01–1.58	0.02–0.05					
Theaflavin-3, 3′-digallate	0.00–1.75	0–0.11					
Theaflavin-3′-gallate	0.00–1.51	0–0.04	0				
Theaflavin-3-gallate	0.01–1.2	0.01–0.11					
Thearubigins	15.82–81.30	0–8.78	0				
Flavanones							
Hesperetin				0.4	0.63		
Naringenin				0.38	1.77		
Flavones							
Apigenin	0.02	0.17	0–0.13		1.33		
Luteolin	0.06	0.13	0–2.5		0.04		
Flavonols							
Kaempferol	1.31	0.32–1.31	0.11	0.01	0.2		0.81
Myricetin	0.05–0.45	1.00–1.03	0.01	0.03	0.83	0.05	0.03
Quercetin	0.05–1.99	0.21–2.77	0.06	0.09	1.76	0.12	0.02
Isoflavones							
Total isoflavones	0	0	0.04	0	0	0	0

*Flavonoids compositions of top consumed fruits in the U.S. diet were estimated based on USDA Database for the Flavonoid Content of Selected Foods Release 3.0 (22) and USDA Database for the Flavonoid Content of Selected Foods Release 2.0 (24).

TABLE 4 Major Food Contributors to the Intake of Flavonoid Subclasses in the U.S. Diet*

Flavonoid subclass	Description	Contribution to total intake (%)
Flavan-3-ols	Tea, black, brewed	88.3
	Tea, black, brewed, decaffeinated	6.0
Flavanones	Oranges, raw	52.8
	Grapefruit juice, white, canned	15.7
	Orange juice, reconstituted and raw	14.1
Flavones	Parsley, dried	50.9
	Parsley, raw	12.6
	Peppers, sweet, green, raw	7.5
	Celery, raw	6.1
Flavonols	Tea, black, brewed	32.1
	Onions, raw	21.5
	Apples, raw, with skin	7.0
	Beer, regular	6.2
Anthocyanidins	Blueberries, raw	31.3
	Bananas, raw	21.1
	Strawberries, raw	13.5
	Cherries, sweet, raw	7.6
Isoflavones	Soy milk	22.3
	Tofu	12.3
	Chicken	12.3
	Meatless products including vegetarian products	12.1

*Major contributors of the intake of flavonoid subclass in the U.S. diet were estimated based on Sources of Flavonoids in the U.S. Diet Using USDA's Updated Database on the Flavonoid Content of Selected Foods (49) and Assessment of Sources and Dietary Intake of Isoflavones in the U.S. Diet (50).

flavonoid intake (215 mg/day), and participants older than 71 years have the lowest flavonoid intake (150 mg/day) in 1999–2002. Flavan-3-ols accounted for 82.5% of total flavonoid intake followed by flavanones, flavonols, anthocyanidins, flavones, and isoflavones among 19 + year adults during 1999–2002. The major food sources of flavonoids were tea, citrus fruit juice, wine, and citrus fruits (26). Similarly, McCullough and colleagues (31) reported that the estimated mean of total flavonoid intake was 268 mg/day for 38,180 men and 60,289 women, with average ages of 70 and 69 years, respectively, in 1999 by using the combined USDA databases on flavonoids, proanthocyanidins, and isoflavones. In contrast, studies that were conducted prior to the release of a complete flavonoid database reported much lower estimates of total flavonoid intake (14, 28). Sesso and associates (14) reported in 2003 a mean total flavonoid (flavonols and flavones) intake of 24.6 mg/day among 38,445 postmenopausal women using food tables developed by the Department of Nutrition, Harvard School of Public Health, Boston. Similarly, Lin and colleagues (28) documented that the mean total flavonoid (flavonols and flavones) intake was 21.2 mg/day among 66,360 middle-aged and older women.

TABLE 5 Flavonoid Intake Status in the United States and Worldwide*

Country	Population* (n), age	Year	Database	Dietary method*	Anthocyanidins (mg/day)	Flavan-3-ols (mg/day)	Flavanones (mg/day)	Flavones (mg/day)	Flavonols (mg/day)	Isoflavones (mg/day)	Total (mg/day)
Hong Kong, China (37)	W (141), 45–55 y	2001–2002	The CU Soy Isoflavone Database	FFQ, 23 day 24-hour DR						7.8	
Finland (7)	M (2,682), 42, 48, 54, or 60 years	1984, 1989	The USDA database	4 day FR	6.2	119.7	3.1	0.3	10.0		139.3
Japan (48)	W (115), 29–78 years	1997–1998	Analysis of 27 food samples	3 day FR				0.3	16.4	47.2	63.9
Zutphen, Netherlands (45)	M (804), 65–84 years	1985	Analysis of 49 food samples	Dietary history				1.4	24.5		25.9
Netherlands (47)	W (17,357), 50–69 years	1993–1997	Previous publications	FFQ (227 items)						0.5	
Netherlands (46)	W M (707), ≥65 years	1997–1998	Analysis of food samples	The Dutch National Food Consumption Survey 1998					75.1		
United States (14)	W (38,445), ≥45 years postmeno-pausal	1992	Food tables	FFQ (131 items)				0.7	23.9		24.6
United States (28)	W (66,360), 44–69 years	1990–1998	Food tables	FFQ				0.03	21.1		21.2
United States (26)	WM (4,101), ≥51 years	1999–2002	The USDA database	2 day 24-hour DR	3.6	156.8	15.3	1.4	12.9	1.1	191.2
United States (51)	W (964), postmeno-pausal	1991–1994	Previous publications	FFQ (130 items)						0.2 (median)	

*W, women; M, men; FFQ, food frequency questionnaire; DR, dietary recall; FR, food record.

**Individual compounds used to calculate the intake of flavonoid subgroups in each study may vary.

FLAVAN-3-OL INTAKE AND MAJOR FOOD SOURCES

In 2008, Song and Chun (29) reported that the daily average intake of flavan-3-ols of participants older than 51 years from NHANES 1999–2002 was 156.8 mg, accounting for 82% of the total flavonoid intake. Tea was the major source of flavan-3-ols in the U.S. diet followed by wine, apples, other fruits and fruit mixtures, and milk. However, tea intake varies greatly among different age and gender groups. The major tea consumers were older White women. Tea consumers had a more than 100 times greater amount of flavan-3-ols intake than nonconsumers. Storey and colleagues (30) also reported that tea consumption increased with age, with the highest intake by adults aged 40–59 years, and then decreased among women older than 60 years. This trend is similar with total flavonoid intake by different age groups in our previous study (26). With respect to ethnicity, white women aged 40–59 years consumed the highest amount of tea. African Americans and Mexican Americans drank relatively low amounts of tea (30).

FLAVONOL INTAKE AND MAJOR FOOD SOURCES

Flavonols include quercetin, kaempferol, myricetin, and isorhamnetin (19, 20). The major sources of flavonols in the U.S. diet are tea and vegetables (29). Daily dietary flavonol intake of 51–70 year-old and 70+ year-old U.S. populations are 14.2 mg and 10.8 mg, respectively. Sesso and colleagues (14) and Lin and associates (28), who used food tables of flavonoid contents, reported 23.9 mg/day and 21.1 mg/day for middle-aged and older women.

FLAVANONE INTAKE AND MAJOR FOOD SOURCES

Flavanones are exclusively concentrated in citrus fruit and fruit juices (Table 4). Hesperidin, a monomethoxylated flavanone abundant in orange juice, has been shown to have bone-sparing effects in ovariectomized rats (15). Most of hesperidin and naringin intakes are attributed to orange juice consumption. Daily dietary flavanone intake of 51–70 year-old and 70+ year-old subgroups of the U.S. populations were 15.5 mg and 15.0 mg, respectively. Men had higher intakes of flavanones than women (26).

FLAVONE INTAKE AND MAJOR FOOD SOURCES

Celery, garlic, green peppers, and herbal tea are rich sources of flavones (31). Compared with flavonols and flavanones, the intake of flavones is much lower. Several studies reported that the mean daily intake for middle-aged and older women was around 1 mg (14, 26, 28).

ANTHOCYANIDIN INTAKE AND MAJOR FOOD SOURCES

Anthocyanins are representative plant pigments that are responsible for the blue, purple, and red colors in many plant tissues. Six major anthocyanins in various fruit and vegetable sources are cyanidin (Cy), delphinidin (Dp), petunidin (Pt), peonidin (Pn), pelargonidin (Pg), and malvidin (Mv). Anthocyanins have high antioxidant capacity and have been reported to prevent colon cancer (32), inflammation (33), and CVD (34).

The major sources of anthocyanins in the U.S. diet are blueberries, grapes, and raspberries as fruits; red cabbage and onions as vegetables; and wine and grape juice as beverages. Daily intake of anthocyanins in the United States based on the NHANES 2001–2002 was 12.5 mg/day (35). However, our previous data of anthocyanin consumption in U.S. adults based on the NHANES 1999–2002 was 3.1 mg/day (26). Anthocyanin consumption of U.S. elderly of 51–70 years and 70 + years averaged to 4.1 mg/day and 3.0 mg/day, respectively (26). While anthocyanins show high antioxidant capacity compared with other flavonoids, their low bioavailability allows only a limited amount of ingested anthocyanins to reach the peripheral circulation (25).

ISOFLAVONE INTAKE AND MAJOR FOOD SOURCES

While some estrogen-like side effects have been reported, such as infertility observed from sheep that ate large amounts of clover in Australia (36, 37), isoflavones have also been reported to have several health benefits such as prevention of breast cancer (38), osteoporosis (39), and CVD (40). The richest sources of isoflavones are soy and soy products. The USDA–Iowa State University released Isoflavone Content of Foods, edition 1.0 in April, 1999 and subsequent editions 1.2, 1.3, 1.4 to the latest edition 2.0 released in September 2008, focusing on the differently processed soy foods and soy products (24). By utilizing NHANES 1999–2002 and the database of Isoflavone Content of Foods (1.3), the isoflavone intake of the elderly population (>60 years) in the United States was estimated to be 0.6–7 mg/1000 kcal/day (41). This amount was lower than that of younger adult groups (19–49 years). Genistein contributed about half of total daily isoflavone intakes of the elderly (41). Asian Americans had greater isoflavone intake than Caucasian Americans, African Americans, and Hispanic Americans (41). Old Japanese American women have been reported to ingest 10.2 mg/day soy isoflavones (42), which is approximately 700 times of the amount of isoflavones consumed by Caucasian Americans (38). In a study that examined the relationship between isoflavone intake and breast cancer risk in Japan, Japanese women aged 40–59 years consumed higher amounts of isoflavones (5.74 to 15.95 mg/1000 kcal/day) than U.S. elderly women (38). The research demonstrated that isoflavone intake was inversely associated with breast cancer risk with a stronger association seen in postmenopausal women than in premenopausal women (38).

PROANTHOCYANIDIN INTAKE AND MAJOR FOOD SOURCES

Proanthocyanidins, also called condensed tannins, are the polymers of flavan-3-ols. Proanthocyanidins are subclassified on the basis of the degree of polymerization, such as monomers, dimers, oligomers, and polymers. Theoretically only monomers of proanthocyanidins belong to flavonoids. Proanthocyanidins have recently received attention due to their functional health benefits such as anti-inflammatory and anticarcinogenic effects, and cardiovascular protection attributed to their antioxidant capacity (43). Major sources of proanthocyanidins in the U.S. diet were tea (monomers and dimers), legumes (oligomers and polymers), and wines (43). We have recently reported that the estimated intakes of total proanthocyanidins of Americans based on the NHANES 1999–2002 food consumption data were 100 mg/day and 80.7 mg/day by adults aged 50–70 years and 70+ years, respectively (43). In 2004, Gu and colleagues (44) reported that the mean proanthocyanidin intake of men and women older than 60 years was 70.8 and 54.6 mg/day, respectively. The low estimation of total proanthocyanidin intake in the report of Gu and colleagues may be due to the absence of tea.

ESTIMATED FLAVONOID INTAKE BY THE ELDERLY IN OTHER COUNTRIES AND MAJOR FOOD SOURCES

Several studies conducted in the Netherlands reported flavonoid intake of free-living people. Hertog and colleagues (45) measured three flavonols (quercetin, kaempferol, and myricetin) and two flavanones (apigenin and luteolin) in foods and the estimated intake in 805 men aged 65–84 years was 25.9 mg/day. In terms of flavonoid sources, tea consumption contributed 61% and vegetables and fruits (mainly onions, kale, endive, and apples) contributed 38% to total flavonoid intake. Later, Arts and associates (46) reported that the average daily catechin intake was 75.1 mg in Dutch men and women aged 65 years and older, which is 50% higher than the average intake in a 1–97 year population. The main catechin source was tea in all age groups; chocolate was second in children, and apples and pears were second in adults and the elderly. The isoflavone intake was also low in the Netherlands, as reported by Boker and colleagues (47), with a mean daily intake of 0.5 mg in women aged 50–59 years. In contrast, a Japanese study documented the mean isoflavone intake in women aged 29–78 years to be 47.2 mg/day, which is 50–100 times higher than that in Western women (48). A Chinese study conducted in Hong Kong reported a high isoflavone intake of 7.8 mg/day in middle-aged women (37).

CONCLUSION

Estimation of flavonoid intake was limited by the completeness and availability of food content databases until the USDA flavonoid database was published and updated. The mean intake of flavonoids in the elderly is higher than other age groups in the United States and other countries. Tea is the major contributor to total flavonoid and proanthocyanidin intakes in the United States as well as in several other countries, even though the prevalence of tea consumption is not high in western countries. Future studies that investigate the beneficial effects of flavonoid intake on chronic diseases should pay attention to the methodologies in estimating accurate total flavonoid intake.

TAKE AWAY POINTS

- The major contributor to total flavonoid and proanthocyanidin intakes is tea, even though tea consumption is not as prevalent in western countries as in other parts of the world.
- Future studies on the health benefits of flavonoid intake should pay attention to the methodologies in accurately estimating total flavonoid intake.

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