ORIGINAL ARTICLE

Scandinavian Journal of Nutrition/Näringsforskning Vol 44:158-160, 2000

Estimation of daily intake distribution of flavonols and flavanones in Denmark

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Received: August 28; Revised: November 9; Accepted: November 28, 2000

ABSTRACT

Flavonoids are a part of the large group of polyphenols, and they are found in tea, fruit, vegetables, and red wine. The daily flavonoid (flavonols and flavanones) intake in Denmark was calculated based on consumption and analysis of flavonoid contents of foods on the Danish market. Orange, tea, onions, and orange juice were found to provide the greatest contributions to the total flavonoid intake, whereas green vegetables made minor contributions to the intake. Gender differences in flavonoid intake were observed, a lower mean flavonol and flavanone consumption was calculated for men (20 mg/day) than for women (26 mg/day). The gender difference could be almost solely explained by the differences in consumption of tea and oranges. It will, however, be relevant to consider a total estimate of flavonoids (flavones, flavonols, flavanones, procyanidins, and anthocyanidins), as well as other natural antioxidants, to evaluate the health effects of foods.

Key words: Flavonoids, fruit and vegetables, gender differences, intake, tea

Introduction

There is much interest in plant polyphenols, as it has been shown that high intakes of fruit and vegetables have protective effect against stroke and heart diseases (1-3) as well as cancer (2,4). Rich sources of polyphenols are tea, wine, fruits and vegetables (5-7). Tea consumption has been shown protective to digestive and urinary tract cancers (8) in addition to beneficial effects on atherosclerosis (9). Epidemiological studies have been performed to investigate the relationship between dietary intakes of individual polyphenolic compounds, and the risk of heart diseases and cancers. Dietary intakes of flavonoids have been negatively associated with the incidence of heart diseases (9-12) and dementia (13). It has not been possible, until recently, in epidemiological studies, to verify any significant negative association of a single nutrient group as flavonoids and cancer risks (2,14) even though flavonoids have been proved to be strong *in vitro* and *in vivo* antioxidants (15). However, a recent study found intake of one flavonol, kaempferol, to be protective to gastric cancer in Spain (16).

The most common flavonoids in foods are the flavonols, flavones, flavanones (figure 1), catechins, and anthocyanidins. They are widely distributed and exist mainly as O-glycosides where one or more of the hydroxyl groups are bound to sugar units (17). It is not firmly established in which form (glycosides or aglycones) the flavonoids are absorbed in the gut system. It has been shown that absorption can occur in the ileum (18), and a recent paper from the same research group suggests that the bioavailability is in part dependent on the glycosyl conjugate (19). The major part of the flavonoids is still expected to reach the colon, where it is subject to bacterial degradation (2,20,21). In feeding studies, only a minor fraction of the ingested quercetin has been detected as urinary excretion product (19,22,23), whereas a much higher proportion of ingested isorhamnetin (22) and flavanones in citrus products (24) have been recovered in urine. The bioavailability may thus be dependent on the aglycone nature as well as the glycosyl conjugate.

Based on the potential beneficial effects of flavonoids in the diet, it is of great interest to estimate the dietary intake of flavonoids. A number of reports on dietary intake of flavonoids, based on compositional data of foods, have been published so far (11,13,16,25-28), most studies reporting the intake of flavones and flavonols. Total flavonol and flavone intake ranged from 3 to 65 mg/day, lowest in Finland (3 mg/day) and highest in Japan (65 mg/day), quercetin accounting for the majority of the intake.

The present study estimates the intake of flavonoids (flavonols and flavanones) in Denmark, based on analytical data of foods available on the Danish market (6) and consumption of the individual foods (29). We found that flavones contributed virtually nothing to the mean flavonoid consumption; instead, we included flavanones as they provide a major contribution.

We have previously presented preliminary data on flavonoid intake in Denmark (30), covering only a part of the food composition data in the present study (e.g. not including red wine) and estimating food consumption from household consumption data from 1987. The use of dietary records in the present study allows a more accurate measurement of food consumption and also determination of gender differences in flavonoid intake.

Methods

Food consumption

Calculation of consumption of the individual foods was based on the Dietary Habits in Denmark 1995 (29). The nation-

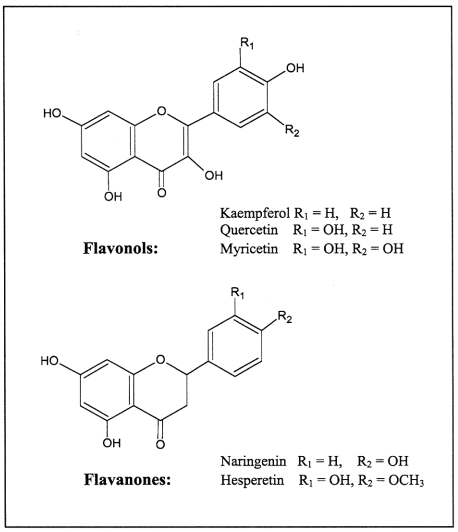

Figure 1. Structures of flavonols and flavanones.

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wide survey included 3098 participants aged 1-80 years. The dietary records of 933 female and 904 male participants aged 15–80 years were used for calculating intakes of flavonoids. Dietary data were self-recorded for seven consecutive days in booklets with pre-printed fixed answering categories supplemented with open categories covering 210 individual food items. The quantity of food eaten was estimated from household measures and four different series of pictures. The survey population was a random sample drawn from the Central Population Register, stratified by sex and age. The total response rate was 58% for adults. Data were collected in three periods of 1995: January-February, April-May and August-September, to account for seasonal variations of the diet.

Determination of flavonoids

Determination of flavonoids in foods was performed as described in (6). Briefly, a wide range of food samples were purchased at local grocery stores, rinsed, divided in edible and non-edible parts, freeze-dried and kept at -18°C. Different varieties were purchased of each sample type over a 2-year period. The red wines were produced throughout the world, and from different years (1989–1995). Black and green bulk and bagged teas were used, and brewed as indicated by the manufacturer. The freeze-dried food samples and the liquid samples were acid-hydrolysed prior to HPLC separation and the flavonoids determined as aglycones by diode-array detection. The peak areas were used for calculation of the contents in the samples. The data reported for onion are for yellow onion as the intake of other varieties (red and spring onion) is limited. Quantifiable levels (>0.1 mg/100g fresh weight sample) of quercetin, kaempferol, hesperetin, naringenin, myricetin, apigenin, and luteolin were found in 38 food subjects. Flavonoid intake was calculated by multiplying the individual consumption of each food by the mean flavonoid content in the food samples and the products were summarized for each individual participant. The five flavonols and flavanones presented in Figure 1 were found to be significant contributors to the flavonoid intake. Mean and percentiles of the intake distributions were calculated. In the nation-wide survey questionnaire, apple and pear were not distinguished, so the value of apple consumption in Table 1 includes the pear consumption as well. This is not likely to introduce a significant error in flavonoid intake, since the apple consumption is considerably higher than the pear consumption and the flavonoid contents of whole apple and pear are at comparable levels. Likewise, tangerines (with flavanone contents similar to those found in oranges) were included in the orange consumption value in Table 1.

Results

A number of fruit, vegetables, and beverages were found to contain flavones, flavonols, and flavanones (6). Table 1 lists the mean consumption (g/day) of the foods with major contributions to flavonoid intake. The mean daily intake of flavonols and flavanones was estimated to 23 mg/day (median 16 mg/d), as shown in Table 2. The main food contributors were oranges, tea, onions, orange juice, red wine, apples and tomatoes (Table 1). Vegetables other than onions were found to provide 1% or less of the total flavonoid intake. Quercetin was found to be most widely distributed, and to comprise, as single component, the major part (37%) of the mean flavonoid intake (Table 2). Citrus fruit contain high levels of the flavanones naringenin and hesperetin, and due to the high consumption of oranges and other citrus fruit, the contribution of flavanones was therefore found to be considerable (40%). The intakes of apigenin, luteolin, isorhamnetin, and eriodictyol are negligible (<0.1 mg/d) and therefore not included in the results of the present study.

Table 3 illustrates the gender differences in mean and median values for flavonoid intake. The mean intake for all participants was 23 mg/day, mean values of 26 mg/day for women and 20 mg/day for men. Data from the Dietary Habits in Denmark 1995 (29) showed a gender difference in tea and fruit consumption, which explains the differences in flavonoid intake for men and women. Since tea is a major source of flavonoids, the gender differences in tea consumption influence the total flavonoid intake, as well as the intake of other polyphenols that were not included in this study. The mean flavonol (quercetin, kaempferol and myricetin) intake from tea consumption was calculated to 5.2 mg/day and 8.3 mg/day for men and women, respectively, based on a mean tea consumption of 153 g/day for men and 245 g/day for women.

Oranges contain high amounts of the flavanones naringin and hesperidin. The mean flavanone intakes for men and women were 5.5 and 8.0 mg/day, respectively, based on a mean orange consumption of 13 g/day for men and 19 g/day for women. The gender differences in tea and orange consumption almost explain the difference in mean flavonoid intake of 6 mg/day.

Discussion

We found the mean Danish flavonol (13.5 mg/day) and flavanone (9.3 mg/day)

Table 1. Mean consumption of the main food items that contribute to the flavonoid intake among men n=904 and women n=933 (total n=1837). Contributions of the individual foods to the flavonol and flavanone intake are presented as % of the total mean intake (=23 mg/d).

Food	Consumption g/day	Contribution %
Apple	48	4
Onion	10	16
Orange	16 [1]	30
Orange juice	23	10
Red Wine	67	5
Tea	200 [2]	29
Tomatoes	16	2
Other	-	4

For men and women: [1](13;19); [2](153;245)

Table 2. Mean and median values, 10th and 90th percentiles of intake for the most important individual flavonols and flavanones. n=1837; men n= 904 and women n=933.

	Quercetin mg/day	Hesperidin mg/day	Kaempferol mg/day	Naringenin mg/day	Myricetin mg/day	All mg/day
Mean	8.6	7.1	3.4	2.2	1.5	23
Standard dev.	6.3	12.2	5.3	4.1	1.7	22
Median	6.9	1.9	1.0	0.5	0.9	16
10th	2.4	0	0	0	0	4
90th	16.9	21.6	10.8	6.8	3.8	51

Table 3. Gender distribution of flavonoid intake; mean, median and percentiles.

	Female (n=933) mg/day	Male (n=904) mg/day	p[1]
Mean	26	20	<0.001
Standard dev.	22	20	
Median	19	14	
10th	5	3	
90th	55	44	

[1]t-test

intake to be 23 mg/d. This corresponds well with the mean intakes determined in other populations, although the results are not directly comparable since different flavonoid subgroups have been determined in the individual studies. *Hertog et al.* (25) reported the intake of flavones and flavonols in The Netherlands to be 23 mg/d, not including the determination of flavanones in their study. They found a higher tea consumption contributing 48% to the mean flavonoid intake, which partly explains the similar mean intake at 23 mg/day in the two countries.

The Danish intakes of flavonols and flavanones are more directly comparable with the results reported for a Bavarian subgroup (63 women, 56 men) of a German national food consumption survey (28). Their total average intake was 25 mg/day obtained from flavonols 12.0 mg/day and flavanones 13.2 mg/day. The Japanese flavonol intake of 13.8 mg/day reported by *Kimira* et al. (27) was also in agreement with the present data. No flavanone data were reported in the Japanese study.

We observed gender variations in Danish flavonoid intake, largely due to differences in the consumption of the two major contributors, tea and oranges. Due to a more frequent fruit and tea consumption, women have a higher intake of flavonoids even though they have a lower energy intake (29). Some foods contain high amounts of flavones and flavonols (celery leaves, parsley, cranberries). However, the contributions of these foods to the intake were not calculated in the present study, because the consumption data were not sufficiently specific. Besides, the mean intake of these foods in Denmark is expected to be negligible. Other foods such as potatoes and carrots that are consumed in relatively large amounts in Denmark, do not contain significant levels of the flavonoids included in this study, but contain other natural antioxidants as ascorbic acid, carotenoids, and simple phenols. It will be relevant to consider a total estimate of flavonoids, antioxidant vitamins, simple phenols, and other natural antioxidants to evaluate the health effects of foods.

AKNOWLEDGEMENTS

The authors warmly thank Mrs. *Jytte Børup* and Mr. *Gunner Rasmussen* for technical assistance, and Mrs. *Sisse Fagt* and Mrs. *Margit V. Groth* for valuable discussions.

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