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Consumption of quercetin and kaempferol in free-living subjects eating a variety of diets

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Abstract

Quercetin and related flavonoids are anticarcinogenic in rats, but little is known about human intakes. The intake of five major flavonols and flavones was calculated using 1-day dietary records of 17 volunteers from 14 countries, and using both 3-day records and a food frequency questionnaire of eight Dutch adults. Total consumption (±SD) was 27.6 ± 19.5 mg/day in the international subjects, 34.1 ± 31.2 mg/day in the Dutch adults according to 3-day records, and 41.9 ± 23.7 mg/day according to questionnaires. Quercetin contributed 68–73%, and kaempferol 22–29%, the major sources being tea and onions. A brief food frequency questionnaire may be a suitable method for ranking individuals by flavonol intake. © 1997 Elsevier Science Ireland Ltd.

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1. Introduction

Flavonoids, a group of polyphenolic compounds with antioxidant properties, are widely distributed in foods of plant origin such as vegetables, fruit, tea and wine [1,2]. It has been suggested that the consumption of flavonols and flavones, a subgroup of the flavonoids, would protect from cancer [3]. Furthermore, beneficial associations with the occurrence of coronary heart disease have been reported [4].

Within the subgroup of flavonols and flavones the flavonol quercetin is the major compound in foods, with smaller contributions from kaempferol, myricetin, and the flavones apigenin, and luteolin [5]. The main sources of flavonols and flavones are tea and onions [5]. The most important flavonol in onions is quercetin [1], while tea contains considerable amounts of both quercetin and kaempferol [2].

In order to study the relation of flavonoids in the diet with chronic diseases a method for ranking of individuals by flavonoid consumption is needed. For evaluation of dietary assessment methods information is needed about the main dietary sources and the within- and between-subject variations. For these purposes, we calculated the intake of the five flavonols and flavones from three existing datasets, obtained

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with 1-day records, 3-day records, and a food frequency questionnaire.

2. Methods

2.1. Subjects and design

Thirteen non-resident aliens and four Dutch subjects consuming non-traditional diets enrolled in the 'international' part of the study. These participants, six men and 11 women from 14 countries and four continents, ate a wide variety of diets (Table 1). Their mean age was 29 ± 7 years (±SD), and their body mass index 21 ± 3 kg/m^2. Four female and four male Dutch subjects, aged 25 ± 9 years (mean ± SD), with a body mass index of 23 ± 5 kg/m^2 consumed a normal Dutch diet (Table 2).

All subjects were healthy and gave their written informed consent for participation in the study. The protocol was approved by the Medical Ethics Committee of the Department of Human Nutrition.

2.2. Dietary assessment

The 17 'international' subjects weighed and recorded all foods and beverages, including herbs and spices, in a diary for 1 day. The eight Dutch subjects recorded their foods and beverages in household measures for 2 weekdays and 1 weekend day, and filled out a 74-item food frequency questionnaire which specifically asked about the habitual consumption of flavonoid-rich foods such as vegetables, fruit, beverages, ready-to-eat meals containing onions, herbs, and spices. Trained dieticians checked the food records and the questionnaires.

The intake of five flavonols and flavones (quercetin, kaempferol, myricetin, luteolin, and apigenin) was calculated using published values for contents in vegetables, fruit and beverages [1,2], supplemented with values for other Dutch foods including herbs and spices, and some American and Italian foods, also determined at the RIKILT–DLO laboratory (Hollman P.C.H, unpublished data), using an identical method [6]. We calculated energy and dietary fibre intakes using the computerised version of the Netherlands Nutrient Data Bank NEVO [7]. We assessed the between- and within-person variations by analysis of variance using SAS procedure ANOVA [8].

3. Results

In the 17 international subjects, intake of energy was 9.0 ± 3.1 MJ (means ± SD), and mean intake of dietary fibre was 1.7 g per MJ of energy. The lowest consumption of the five flavonols and flavones was 3.6 mg/day for the subject with a South-American diet, whose single source was a small amount of onions (Table 1). The highest value was 77 mg/day for the subject with a Scandinavian diet, who drank almost 2 litres of tea on the day records were kept. The between-person coefficient of variation was 70%. The mean contribution of quercetin to the total flavonol plus flavone consumption was on average 73%, of kaempferol 22%, and of myricetin 4%. The intakes of luteolin and apigenin were almost at zero. Tea was

Table 1
Flavonol and flavone intake in subjects

Subject	Country of origin	Type of diet	Intake of flavonols plus flavones (mg/day)
1	USA	Macrobiotic	15.7
2	China	Chinese	5.1
3	Czechoslovakia	East-European	24.2
4	Ethiopia	African	52.9
4	Finland	Scandinavian	77.0
6	India	Asian	15.6
7	Indonesia	Asian	28.3
8	Italy	Mediterranean	15.3
9	Lithuania	East-European	13.2
10	Malaysia	Asian	12.7
11	Mexico	South American	3.6
12	The Netherlands	Lacto-ovo vegetarian	50.3
13	The Netherlands	Vegetarian	26.3
14	The Netherlands	'Prehistoric'[a]	26.8
15	The Netherlands	Western	47.7
16	Surinam	Surinam	35.4
17	Turkey	Middle-eastern	19.8
Mean ± SD			27.6 ± 19.5

Subjects ate a variety of diets according to a 1-day weighed food record, including herbs and spices.
[a]Uncooked and unprocessed products, vegetables and fruit were typical of this diet.

Table 2
Habitual flavonol and flavone consumption

Subject	Age	Sex	Flavonoids (3-day records, mg/day)	Flavonoids (questionnaire mg/day)
1	21	Male	11	9
2	24	Male	1	37
3	22	Female	24	27
4	47	Male	2	33
5	21	Female	28	25
6	25	Female	81	72
7	22	Female	71	75
8	20	Male	55	57
Mean ± SD			34.1 ± 31.2	41.9 ± 23.7

Flavonol and flavone consumption of four Dutch men and four Dutch women according to 3-day records and a food frequency questionnaire for assessment of flavonoid intake are shown.

the major source contributing 37% of flavonols and flavones, followed by onions 26%, vegetables 14%, fruits 22%, and red wine 1%.

In the eight Dutch adults the daily energy intake was 10.6 ± 1.5 MJ, and the mean dietary fibre intake 2.2 g per MJ of energy according to the 3-day records. Flavonol plus flavone intake calculated from the food records ranged from 1 to 81 mg/day, and from the food frequency questionnaires from 9 to 75 mg/day (Table 2). The mean contribution of quercetin to the total flavone and flavonol consumption according to 3-day records and food frequency questionnaires was 68% for both, of kaempferol 28% and 29%, and of myricetin 4% and 2%, respectively. The contributions of luteolin and apigenin were again negligible. The within- and between-person coefficients of variation calculated from the 3-day records were 63% and 84%, respectively. The ratio of the within-person and between-person components of variance was 0.57. The between-person coefficient of variation calculated from the food frequency questionnaires was 56.5%. Tea contributed 47% to the total amount of the five flavonols and flavones according to 3-day records, and 28% according to the food frequency questionnaires, onions 26% and 34%, vegetables 20% and 27%, fruits 6% and 11%, and red wine 1% and 0%, respectively. The correlation coefficient between the 3-day records and the food frequency questionnaires in the full Dutch group was 0.85 ($n = 8$).

4. Discussion

We found marked differences of up to 80 mg/day in flavonol and flavone intake between free-living subjects. Tea and onions were the most important sources for flavonoid consumption in both groups. The between-subject coefficient of variation was higher in the 'international' than in the Dutch group. The variation within subjects in the Dutch subjects according to the 3-day records was large, and comparable with, for example, vitamin C in US women [9]. However, in contrast with many nutrients the ratio of within- and between-person variance was lower than 1 [9]. The relatively large between-person variation gives a fine opportunity to study the relationship between flavonoids and health.

The results of one or 3-day records were possibly not sufficient to represent the long-term average daily individual intake. The within-subject coefficient of variation of 63% suggests that the number of days needed to estimate the individual intake within 20% of the actual intake 95% of the time is 38 days [10]. The results of the food frequency questionnaire probably provided the best data as this method inquired after food intake over 30 days. The high correlation coefficient of this method with the 3-day records suggests that these methods are similar for ranking of individuals.

We did not have flavonol values for all plant foods consumed by the subjects. However, we have lacked only the data of a few foods, for example, citrus fruits, which we do not expect to contribute significant amounts of flavonols and flavones [2]. Therefore, we probably made only a small underestimation of actual flavonoid intake. The contribution of herbs and spices to flavonol and flavone intake was at most 3 mg/day.

The flavonol and flavone intake of all subjects was within the distribution of flavonoid intake in the Netherlands [5], although some subjects were at the highest intake range. Hertog [4,5] also found tea and onions to be the major sources of flavonol and flavone consumption. However, the contribution of tea that he found in elderly men (61%), and in Dutch adults (48%) was higher than in our study.

We conclude that there was a large variation in flavonol and flavone consumption in this study, but the within-person variation was less than the between-

person variation. For ranking of subjects for flavonoid intake, a short food frequency questionnaire appears to be suitable. However, it needs to be tested in a larger study.

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