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Isoflavone intake in four different European countries: the VENUS approach

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The aim of this study was to identify the level of isoflavone intake (total isoflavones, daidzein and genistein) in four European countries: Ireland, Italy, The Netherlands and the UK. For this purpose national food composition databases of isoflavone content were created in a comparable way, using the Vegetal Estrogens in Nutrition and the Skeleton (VENUS) analytical database as a common basis, and appropriate food consumption data were selected. The isoflavone intake in Ireland, Italy, The Netherlands and the UK is on average less than 1 mg/d. Small groups of consumers of soya foods could be identified in Ireland, The Netherlands and the UK. The estimated intake levels are low compared with those found in typical Asian diets (~20–100 mg/d) and also low compared with levels where physiological effects are expected (60–100 mg/d). The results (including a subgroup analysis of soya product consumers) showed that such levels are difficult to achieve with the European diets studied here.

Isoflavones in Europe: Daidzein: Genistein: Oestrogen-like compounds

Introduction

It is already established that relatively high isoflavone intakes can be found in typical Asian diets, where soya foods are consumed more commonly than in Western diets. Recent estimates indicate intakes of 20–50 mg/d (Adlercreutz *et al.* 1991; Nagata *et al.* 1997; Chen *et al.* 1999) or even higher: 102 mg/d (Ho *et al.* 2000).

It has been suggested (Cassidy & Faughnan, 2000; Mazur & Adlercreutz, 2000) that intakes of isoflavones in Western Europe are very low, but, until now, no valid quantification has been available. One major reason was that, at both European and national levels, only limited data on isoflavone contents in foods were available (Reinli & Block, 1996). The United States Department of Agriculture (USDA) and Iowa State University created a database of isoflavones, which is available on the Internet (USDA–Iowa State University Isoflavones Database; http://www.nal.usda.gov/fnic/foodcomp/Data/isoflav/isoflav.html). This database includes mainly soya-based foods and some figures on isoflavones in pulses and peanuts. At that time it was less well known that some other foods might contain isoflavones as well. Soya derivatives in many forms can serve as ingredients for diet products (e.g. replacing cow's milk), act as an alternative for meat products (vegeburgers, etc.) or are included as food ingredients for technological (bread) or cost-effective reasons (high-quality protein at low cost). Moreover, in Finland (Mazur *et al.* 1998) and in the UK (Liggins *et al.* 2000*a*,*b*, 2002), additional analytical results made clear that more foods contain isoflavones in measurable amounts.

The aim of this study was to estimate the isoflavone intake in different European countries, making use of available food consumption data and available data on isoflavones in foods (Kiely *et al.* 2003).

Methods

In order to arrive at data that would be comparable across countries, decisions had to be made on two major issues.

Abbreviations: SD, standard deviation; USDA, United States Department of Agriculture; VENUS, Vegetal Estrogens in Nutrition and the Skeleton.
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First was the establishment of an isoflavones database (the Vegetal Estrogens in Nutrition and the Skeleton (VENUS) database) that could serve as a starting point for the compilation of national isoflavones databases. Second was the selection of food consumption data that were comparable across countries. The following countries, participating in the VENUS project, were willing to make an estimate of isoflavone intake: Ireland, Italy, The Netherlands and the UK.

In Finland, Valsta *et al.* (2003) had already developed a national database. They were invited to advise on the procedures for the establishment of the VENUS database. Furthermore, in Finland as well as in The Netherlands, some preliminary calculations were carried out and this experience was used for the establishment of the VENUS guidelines.

Selection of relevant food consumption data

Comparability of food consumption data depends on aspects such as the methodology chosen, the population group, the year of collection, etc. The aim of the VENUS project was to arrive at mean intake and distribution figures of isoflavone intake.

In Ireland (Harrington *et al.* 2001) and Italy (Turrini *et al.* 1999), recent national surveys based on 7 d diary records were available. In The Netherlands, a nationwide survey, based on a 2 d record, had recently been carried out (Löwik *et al.* 1998, 1999). In the UK, a large prospective cohort study investigating the relationship between diet, cancer and chronic disease, with 7 d diary data, was identified (Day *et al.* 1999). In Italy, Ireland and The Netherlands the age group of 18–64 years was selected. Recent data on the 18–45 year age group were not available in the UK; therefore, the age group of 45–64 years was selected. Table 1 presents the food consumption surveys used to calculate isoflavone intakes. For further details the reader is referred to the individual papers.

Establishment of the VENUS isoflavones database

The establishment of the VENUS database was an important step in the estimation of isoflavone intake in the four countries. A detailed description of the procedures undertaken in its establishment is given elsewhere in this supplement (Kiely *et al.* 2003). In summary, the following steps were taken;

1. Selection and evaluation of all papers in the literature on phyto-oestrogens in foods. Only articles in which the sampling procedures as well as the analytical method were described were taken into account.
2. Conversion of reported analytical data into a form suitable for inclusion in the VENUS database: as aglycone equivalents and in μg per 100 g of 'edible' product (for example, conversion from dry weight to wet weight).

Data from 33 papers were included in the VENUS database, as well as previously unpublished UK data (Liggins *et al.* 2002). Analytical data on isoflavone levels (genistein, daidzein and total isoflavones) of 791 foods, including 300 foods commonly consumed in Europe, were included in the database, which was constructed in Microsoft® Access 2000. Analytical data on coumestrol, formononetin and biochanin A were also included. Lignan levels (secoisolariciresinol and matairesinol) in 158 foods were included in a separate table.

It was concluded that enough analytical data were available to compile a national database for the estimation of isoflavone (total, daidzein and genistein) intake in each of the four countries. Data for lignans were not considered complete enough to allow the establishment of a national database for estimation of lignan intakes within the given VENUS time frame.

Identification of relevant foods

It was obvious from available literature data and the USDA–Iowa State University database that soya products and soya-based products would contain relevant amounts of isoflavones. In addition, pulses and peanuts could be important. What was less well known was that other foods could also contain small amounts of isoflavones. These types of foods could be relevant if eaten on a regular (daily) basis and/or consumed in appreciable amounts. As mentioned previously, soya derivatives in many forms can serve as an ingredient for many different products. Due to differences expected in the consumption pattern of these foods, it was the responsibility of each partner to select the relevant ones for their country. To help the countries select the appropriate foods and to do this in a comparable way across countries, general guidelines were prepared. Twenty-three different food groups were considered for their possible isoflavone content, resulting in

Table 1. Overview of selected food consumption data

Country	Survey	Sample description	Dietary method	Reference
Ireland	North/South Ireland Food Consumption Survey, 1997–99	men and women, aged 18–64 years	7 d record	Harrington *et al.* (2001)
Italy	Nationwide Nutritional Survey – Food Behaviour, 1995	men and women, aged up to 94 years	7 d record	Turrini *et al.* (1999)
The Netherlands	Dutch National Food Consumption Survey, 1997–98	men and women, aged 1–97 years	2 d record	Löwik *et al.* (1998)
UK	EPIC–Norfolk, 1993–97	men and women, aged 40–64 years	7 d record	Day *et al.* (1999)

EPIC, European Prospective Investigation into Cancer and Nutrition.

a priority list of food groups to be included in the national isoflavones database:

1. soya products;
2. legumes and (pea)nuts;
3. bread;
4. breakfast cereals;
5. other single foods relevant for the country and where data were available.

Compilation of the four national isoflavones databases

In the VENUS database, an isoflavone figure was included for about 700 foods, of which soya foods or soya-based foods were the most common. In Western countries the use of soya foods is less common; however, other foods containing soya ingredients or soyabeans might be more important in estimating isoflavone intakes.

The compilation of national databases was necessary to ensure that all relevant foods were included. It was important not only to identify the soya foods, but also to identify foods that might contain relevant amounts of soya ingredients or foods with low amounts but very frequently consumed. For these foods an isoflavone figure had to be present in the database in order to avoid underestimation because of missing data.

The compilation of the four national databases was carried out in accordance with the following criteria;

1. Identification of all foods that have no isoflavones: i.e. foods from animal origin and foods not containing vegetable proteins. These foods get a 'zero' in the national database.
2. Selection of all foods for which an isoflavone figure can be taken directly from the VENUS database. In situations where more than one analysis is present for a food, the mean value of these results will be included when one value cannot be selected as the preferred one.
3. Selection of those foods for which a comparable food with a figure can be selected and, for this food, the isoflavone content can be borrowed.
4. Selection of those items for which a relevant figure can be calculated using conversion factors; for example, conversion from raw pulses to cooked pulses.
5. Use of recipe calculation for mixed dishes, in which isoflavone-containing foods are included.
6. For other foods that may contain relevant isoflavone levels and that are consumed regularly or in large amounts, an educated guess on the basis of ingredient specifications is made.

An overview of the type of isoflavone data for each country is given in Table 2.

Preliminary calculations based on the USDA–Iowa State University isoflavones database in The Netherlands (van Erp-Baart, 2000) already revealed that a group of consumers of soya foods could be identified. This relatively small group had a significant impact on the outcome of the mean and distribution figures of the total population. Therefore, it was decided that intakes would also be calculated excluding these soya food consumers.

Results

Total isoflavone intake in Ireland, Italy, the Netherlands and the UK is presented in Table 3. Mean intake varies across countries. On average, the lowest intake was found in Italy, 554 μg/d. The highest intake was found in the Netherlands, 913 μg/d.

Calculations excluding the consumers of soya foods showed lower mean intakes: 683 (standard deviation (SD) 372) μg/d in The Netherlands, 545 (SD 337) μg/d in Ireland and 602 (SD 350) μg/d in the UK. In Italy, no consumers of soya foods could be identified.

Daidzein and genistein intakes are presented in Tables 4 and 5. In general, daidzein intake is lower than genistein intake.

Small groups of soya food consumers could be identified in The Netherlands, Ireland and the UK. Mean isoflavone intake in the group of soya food consumers was 11 111 (SD 6728) μg/d in The Netherlands ($n = 85$), 5996 (SD 8123) μg/d in Ireland ($n = 42$) and 3176 (SD 4034) μg/d in the UK ($n = 15$).

Mean intakes of daidzein and genistein excluding consumers of soya foods were as follows: 327 (SD 187) and 356 (SD 199) μg/d, respectively, in The Netherlands; 272 (SD 176) and 282 (SD 171) μg/d, respectively, in Ireland; and 270 (SD 160) and 332 (SD 193) μg/d, respectively, in the UK.

The isoflavone intakes for men and women are presented in Tables 6 and 7. In general, the mean isoflavone intake was lower in women than in men.

Discussion

The aim of this study was to identify the level of isoflavone intake in different European countries. In total, four countries were able to provide data on isoflavone intakes:

Table 2. Overview of type of data in the four national databases
(Values are given as % of the total)

Country (number of foods)	VENUS data	Borrowed	Converted	Recipe	Missing	Not relevant
Ireland (3060)	4	2	–	7	12	75
Italy (1714)	5	6	–	23	3	62
The Netherlands (1140)	16	10	7	6	9	52
UK (1524)*	15	5	4	24	13	37

VENUS, Vegetal Estrogens in Nutrition and the Skeleton.
* A total of 2935 foods were consumed by the UK sub-sample but, due to the design of the food list and data entry program, these foods are covered by 1524 items for which nutritional data are available.

Table 3. Isoflavones intake of adult populations in four European countries

Country	n	Total isoflavones intake (μg/d)			
		Mean	SD	P5	P95
Ireland	1379	726	1770	172	1318
Italy	1513	554	1072	163	958
The Netherlands	4085	913	1898	197	1538
UK	335	718	1041	170	1486

SD, standard deviation; P5, 5th percentile; P95, 95th percentile.

Table 4. Daidzein intake of adult populations in four European countries

Country	Daidzein intake (μg/d)			
	Mean	SD	P5	P95
Ireland	366	926	81	687
Italy	252	434	76	448
The Netherlands	397	628	87	760
UK	314	405	73	648

SD, standard deviation; P5, 5th percentile; P95, 95th percentile.

Table 5. Genistein intake of adult population in four European countries

Country	Genistein intake (μg/d)			
	Mean	SD	P5	P95
Ireland	368	848	91	654
Italy	302	640	90	512
The Netherlands	516	1296	102	828
UK	389	499	92	839

SD, standard deviation; P5, 5th percentile; P95, 95th percentile.

three from Northern Europe and one from Southern Europe. The results of this study showed that the mean intake of isoflavones does not exceed the level of 1 mg/d.

In Finland, a comparable level of total isoflavone intake was found (Valsta *et al.* 2003). As previously mentioned, Finland had already compiled a national database, and the procedures for compilation of the VENUS database were similar. The only difference between Finland and VENUS was that, in Finland, the database is mostly based on analyses performed in Finnish laboratories, whereas in the VENUS database recent UK data are preferred.

De Kleijn *et al.* (2001) estimated the isoflavone (genistein and daidzein) intakes in Caucasian postmenopausal women in the USA. They also found an isoflavone intake of less than 1 mg/d. Recently, Keinan-Boker *et al.* (2002) estimated the isoflavone intake in ten European countries to be less than 2 mg/d. They used the USDA–Iowa State University database, and only soya foods were included in the calculations.

The small groups of soya food consumers had a higher intake level, namely ~11 mg/d in The Netherlands and ~6 mg/d in Ireland. However, even this intake is not as high as the intake data presented for Asian countries (Adlercreutz *et al.* 1991; Nagata *et al.* 1997; Chen *et al.* 1999; Ho *et al.* 2000), where intakes ranging from 20 to 100 mg/d can be found.

If we look to the intake distribution and particularly the figures for the 95th percentile, it is more apparent that the isoflavone intake in Western Europe is not likely to induce potential positive health effects, because at least 60–100 mg/d are probably required (Valtueña *et al.* 2003).

Underestimation of intake because important foods are missing in the isoflavones database is always possible. Therefore the completeness of the database was given serious consideration and specific guidelines were established to keep the missing data to a minimum.

In Table 2, approximately 13–50 % of all foods have an isoflavone figure. This is mainly due to the fact that not only are the typical soya foods included, but also much

Table 6. Isoflavone intakes (μg/d) in adult men from four European countries

Country	n	Total isoflavones		Daidzein		Genistein	
		Mean	SD	Mean	SD	Mean	SD
Ireland	717	857	2092	425	1084	436	1006
Italy	686	634	1125	290	465	344	661
The Netherlands	1879	1007	1708	453	573	554	1166
UK	167	773	586	341	240	424	331

SD, standard deviation.

Table 7. Isoflavone intakes (μg/d) in adult women from four European countries

Country	n	Total isoflavones		Daidzein		Genistein	
		Mean	SD	Mean	SD	Mean	SD
Ireland	662	603	1392	311	743	304	660
Italy	827	488	1022	221	404	268	621
The Netherlands	2206	834	2042	350	668	484	1396
UK	168	662	1349	287	518	355	622

SD, standard deviation.

attention is given to identify other foods that might contain isoflavones. While 4–16 % of the foods could be obtained directly from VENUS, the remaining 9–33 % were calculated using conversion and recipe procedures, a time-consuming and largely underestimated job. However, in this way we are confident that we are not missing any major contributors to isoflavones.

Under-reporting of intake figures may also depend on the method used for the collection of food consumption data. A diary method is open-ended so all foods eaten at that moment are included and as such it can be expected to be complete. Based on the consumption data, special attention was given to include all relevant foods in the VENUS database, and not only obvious isoflavone providers (soya foods and pulses). Bread and breakfast cereals especially are products that are consumed on a regular basis and it was important that isoflavone data for these foods were included in the database. Ireland estimated the contribution to isoflavone intake of bread, and it appeared to be around 95 % of the total isoflavone intake. In Italy 90 % of isoflavone intake comes from bread.

It should also be mentioned that mean as well as distribution figures can be influenced by the data collection method used. In three countries, a 7 d diary was used and the comparison is not affected by the time frame. In The Netherlands, a 2 d diary was used. This implies that the figures for the mean as well as the distribution are not completely comparable with the 7 d records of the other countries (Löwik *et al.* 1999).

When irregularly consumed foods with high levels of isoflavones are included, the upper tail of the distribution will be influenced (Lambe *et al.* 2000). Exclusion of the soya food consumers leads to lower means and more normal distributions in Ireland, The Netherlands and the UK.

Inclusion of bread in the isoflavones database did not lead to appreciable amounts of isoflavone intake in the different countries.

The intake figures derived from soya food consumers must be treated with caution, and regarded as an indication of what to expect in people consuming typical soya foods.

Looking at the 95th percentile values, it is clear that high intakes of isoflavones are rare in the four countries under study. A maximum intake of 36 000 μg/d was found in The Netherlands, whereas in the UK, the maximum was 17 000 μg/d. It is clear that a typical European diet (either a Northern or a Southern type) is not likely to meet the level assumed to have a physiological effect: 60–100 mg/d (Valtueña *et al.* 2003).

As VENUS had to rely on available food consumption data and because it was decided that relatively recent data should form the basis for these calculations, an age difference exists between the UK data set and the three other countries. In the UK, recent data could only be selected from people in the 45–65 year age group. To see whether this fact could have an impact on the comparability of the intake figures across countries, a comparable age group was selected from both Italy and The Netherlands. Total isoflavone intake for this age group was 873 μg/d in The Netherlands and 570 μg/d in Italy. Distribution figures were also of the same order of magnitude. So it can be expected that age itself will have a negligible effect on the intake of the adult groups in this study.

Conclusion

The isoflavone intake in Ireland, Italy, The Netherlands and the UK is very low in comparison with that in Asian countries, with most people eating on average less than 1 mg/d. In Ireland, The Netherlands and the UK, a small group of soya food users could be identified. In this group, the isoflavone intake is higher, at 3–11 mg/d on average. The inclusion of regularly eaten foods with relatively low isoflavone contents did not contribute to the total isoflavone intake in substantial amounts.

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