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Phyto-oestrogen database of foods and average intake in Finland

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Information on phyto-oestrogen intake in various populations has been scanty until now, primarily because data on the content of these compounds in foods were lacking. We report here on expansion of the Finnish National Food Composition Database (Fineli®) with values for the plant lignans matairesinol and secoisolariciresinol and the isoflavones daidzein and genistein. The values, expressed as aglycones, were based on food analyses (mainly GC–MS) or imputed from analytical data for 180 foods for lignans and 160 foods for isoflavones; additionally, over 1000 values were derived from the recipe database of Fineli. Average intake of these phyto-oestrogens was calculated using food consumption data of the National Dietary Survey FINDIET 1997, which was carried out in a random sample of the adult population in five areas in Finland. The dietary data were collected by 24 h recall (n=2862). The mean lignan intake was 434 (standard deviation (SD) 1575) μg/d and the mean isoflavone intake was 788 (SD 673) μg/d. Women had a higher lignan density (μg lignans/MJ) in their diet than men ($P<0.05$). Men had a higher mean daily isoflavone intake, 902 (SD 368) μg, than women, 668 (SD 963) μg ($P<0.05$). The sources of lignans were many: seeds, cereals, fruit, berries and vegetables. The main sources of isoflavones appeared to be processed meat products/sausages containing soya as an ingredient, and legumes as such. The average intake of lignans and isoflavones in Finland seems to be low, but intake varies throughout the population.

Oestrogen-like compounds: Lignans and isoflavones: Food composition: Diet in Finland

Introduction

Since the early 1980s, interest in oestrogen-like compounds of plant origin, such as isoflavonoids and lignans, and in their occurrence in the diet and their possible effects on health, has increased steadily and led to many reviews (e.g. Adlercreutz & Mazur, 1997; Adlercreutz, 1998; Bingham *et al.* 1998; Cassidy & Faughnan 2000; Mazur & Adlercreutz, 2000). The importance of isoflavonoids such as phyto-oestrogens has long been recognised in the veterinary field (Price & Fenwick, 1985). After the initial discovery of mammalian lignans (Setchell & Adlercreutz, 1979; Setchell *et al.* 1980), the possible role of these diphenols in human health and disease was postulated (Adlercreutz & Mazur, 1997). The mammalian lignans enterolactone and enterodiol are formed from their plant precursors by the action of intestinal microflora (Borriello *et al.* 1985).

While our knowledge of biological effects in experimental settings has increased for a fair variety of these compounds, studies of the relationship between actual intake in various populations and the maintenance of good health and risk of disease have focused mainly on isoflavone intake and phyto-oestrogen-rich diets (Anderson *et al.* 1995; Strauss *et al.* 1998; Wu *et al.* 1998), providing few data on lignans. The main epidemiological evidence for possible disease prevention by lignans has been obtained from case–control studies, where mammalian lignan

Abbreviations: SD, standard deviation; VENUS, Vegetal Estrogens in Nutrition and the Skeleton.
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metabolites (mainly enterolactone) were mostly measured in biological fluids (Ingram *et al.* 1997; Strom *et al.* 1999; Vanharanta *et al.* 1999; den Tonkelaar *et al.* 2001; Pietinen *et al.* 2001). The causal relationship and mechanism of phyto-oestrogen action in man still remain to be demonstrated and possible adverse effects of phyto-oestrogens to be evaluated (Strauss *et al.* 1998).

The food analysis of phyto-oestrogens is complicated by the conjugation of these molecules to a variety of carbohydrate moieties (Mazur & Adlercreutz, 1998; Liggins *et al.* 2000). However, reliable methods for the determination of food phyto-oestrogen composition are available now. Not least important for the estimation of phyto-oestrogen intake through everyday diets is information on foods whose phyto-oestrogen content may be low but not zero and which may be consumed commonly by the population.

In the late 1990s a couple of studies were carried out in epidemiological settings that allowed compilation of a phyto-oestrogen database for food frequency questionnaires and calculated phyto-oestrogen intakes in the USA (Pillow *et al.* 1999; Horn-Ross *et al.* 2000; de Kleijn *et al.* 2001). However, it is well known that food supply may differ greatly geographically and, therefore, sound food composition databases should preferably be compiled using laboratory analysis data of locally representative foods (Greenfield & Southgate, 1992).

Within the last decade, an exceptionally comprehensive analytical study has been carried out on the lignan and isoflavone contents of foods consumed in Finland (Dwyer *et al.* 1994; Mazur *et al.* 1996; Adlercreutz & Mazur, 1997; Mazur, 1998; Mazur *et al.* 1998*a,b*). The purpose of the present study was to evaluate the quality of the previously generated analytical data on phyto-oestrogens in foods and to expand the Finnish National Food Composition Database (Fineli®; Ovaskainen, 2001) to include values for the lignans matairesinol and secoisolariciresinol and the isoflavones daidzein and genistein, to meet the needs of future epidemiological studies. In a first application of the National Food Composition Database, the average intake of these phyto-oestrogens was calculated, using the National Dietary Survey FINDIET 1997 study as the source of food consumption data (FINDIET Study Group, 1998).

Materials and methods

Compilation of the phyto-oestrogen database was based mainly on recently published analytical values for two lignans, matairesinol and secoisolariciresinol, and two isoflavones, daidzein and genistein, drawing on domestic as well as imported foods (Dwyer *et al.* 1994; Mazur *et al.* 1996; Adlercreutz & Mazur, 1997; Mazur, 1998; Mazur *et al.* 1998*a,b*). These values were produced after a three-step hydrolysis converting the diphenolic glucosides into their respective aglycones; most of the analyses were carried out by GC–MS using synthesised deuterated internal standards for the correction of losses during the procedure as described earlier (Mazur *et al.* 1996; Mazur & Adlercreutz, 1998). A small fraction of the isoflavone analyses was carried out by HPLC (Nurmi & Adlercreutz, 1999) for samples pretreated by applying the procedure published previously (Mazur *et al.* 1996). Part of the laboratory analysis data used for compiling the database are previously unpublished (Table 1). Original data expressed as dry weights of foods were converted to values on a wet weight basis (μg/100 g wet weight of a food or μg/dl of a beverage).

When a new data set for nutritional values is used, it is important to evaluate the quality of the analytical information (Greenfield & Southgate, 1992). In our data quality assessment, quality criteria published previously (Greenfield & Southgate, 1992) and modified for special purposes (Mangels *et al.* 1993) were used, as shown in Table 2. Of the items in the Fineli database (Ovaskainen, 2001), 110 and ninety foods were assigned lignan and isoflavone values, respectively, directly from the original data, and seventy foods were assigned lignan and isoflavone values based on analysis of comparable food products (in total, about 10 % of the food items in the database). In some cases lignan values were estimated by assuming a constant ratio of lignan to fibre, e.g. for whole-grain rye flour *v.* refined rye flour. Similarly, the isoflavone composition of some foods was estimated by comparing the relative soya content in comparable foods. For processed meats, i.e. sausages and commercial minced meat products, commonly eaten in Finland, isoflavone values were estimated using information obtained from major meat-processing companies concerning the use of soya or soya protein isolates in different products. The bread and bakery product supply was also evaluated for the use of isoflavone-containing ingredients (e.g. soya flour, soya protein); partial variation in recipes was considered relevant here and resulted in database adjustments. Values for brewed tea were derived by taking into account the average amount of tealeaves needed for a standard volume of beverage, as well as the shorter brewing time in household preparation compared with the methods used in laboratory analyses (Mazur *et al.* 1998*b*).

In addition to the foods that obtained values directly from the original laboratory analysis data or values based on analysis of comparable food products (about 10%), for about 60 % of the approximately 2000 foods in the whole Fineli database (Ovaskainen, 2001), phyto-oestrogen values were derived based on the Fineli recipe database. For the rest (about 30 %) of the food items (mainly of animal origin) the intake calculation program was allowed to use a zero value.

The cross-sectional average intake of these phyto-oestrogens was calculated using food consumption data obtained from the FINDIET 1997 Study (FINDIET Study Group, 1998) carried out in a random sample of the population aged 25 to 64 years in five areas of Finland. Dietary intake data were collected by computerised 24 h recall (n=2862), with 72 % of those invited attending the study (FINDIET Study Group, 1998). Phyto-oestrogen intake was calculated from the FINDIET 1997 food consumption data set by the nutrient intake calculation software, applying our new phyto-oestrogen data from the Fineli food composition database (FINDIET Study Group, 1998; Ovaskainen, 2001). The food consumption data included 1374 entries from the Fineli database. In that database about 10 % of the lignan values and 9 % of the isoflavone values were analytical data or derived

Table 1. Phyto-oestrogen content of selected foods (μg/100 g fresh weight*; W Mazur and T Nurmi, unpublished results)

Food	Matairesinol	Secoisolariciresinol	Daidzein	Genistein
Vegetables				
Asparagus, green (*Asparagus officinalis*)	3·4	78·3	–	–
Asparagus, white (*Asparagus officinalis*)	0·5	28·7	–	–
Brussels sprouts (*Brassica oleracea*)	0·4	21	–	–
Celeriac (*Apiceae rapaceum*)	0	9·9	–	–
Horseradish (*Armoracia rusticana*)	0	14	–	–
Leek (*Allium porrum*)	0	11·8	–	–
Rutabaga (*Brassica napus*)	0·3	3·7	–	–
Salad green, rucola (*Cichoriaceae crispa*)	0·2	105·6	–	–
Swiss chard (*Beta vulgaris*)	0	8·2	–	–
Turnip (*Brassica rapa*)	0	6·3	–	–
Wheat sprout juice	0	1·6	–	–
Herbs and spices				
Basil (*Ocimum basilicum*), dried	1·9	546·8	–	–
Capers (*Capparis spinosa*)	15·1	44·5	–	–
Ginger (*Zingiber officinalis*)	0	21·3	–	–
Oregano (*Oreganum vulgare*), dried	1	44·4	–	–
Mushrooms				
Black chanterelle (*Craterellus cornucopioides*)	0·1	1·3	–	–
Edible boletus (*Boletus edulis*)	0·3	0·6	–	–
Edible boletus (*Boletus testaceoscaber/aurantiacus*)†	0·3	0·9	–	–
Funnel-shaped chantarelle (*Craterellus tubaeformis*)	7·3	3·9	–	–
Shiitake (*Shiitake tricholomopsis edodes*)	0	0·2	–	–
Fruit				
Grape, green (*Vitis vinifera*)	1·3	2	–	–
Grapefruit (*Citrus paradisi*)	0	26·3	–	–
Kiwi (*Atinidia chinensis*)	1·2	174·6	–	–
Olive (*Olea europaea*)	2·7	55·9	–	–
Pear (*Pyrus communis*)	0·7	9·9	–	–
Rosehip (*Rosa canina*)	2·2	78·8	–	–
Miscellaneous				
Cocoa powder	0	34·8	–	–
Soya milk‡	1·9	16·1	6038·7	8485·4
Soya protein isolate‡	–	–	23 040	38 400

* Or μg/dl of food in liquid form.
† 'Punikkitatti', not defined further.
‡ HPLC was used for isoflavone analyses; in all other analyses GC–MS was used.

from the analytical value of a similar product. More than half of the values (62 % for lignans, 54 % for isoflavones) were derived from recipe calculations. The proportion of zero values in the recipe-derived data was 32 % for matairesinol and 4 % for secoisolariciresinol, 47 % for daidzein and 50 % for genistein. The proportions of non-relevant or missing values for lignans and isoflavones were 27 % and 37 %, respectively.

A mixed model for measurement error was used in testing the differences in nutrient intakes on the basis of 24 h recall. The model uses auxiliary information on 48 h dietary recall and 3 d food record data, collected in random sub-populations (n=223 and n=334, respectively) of the same study, to minimise the effect of daily variation. The same model was used in calculating the corrected means and standard deviations (SD) of lignan and isoflavone intakes of men and women. P-values$<$0·05 were considered significant.

Results

The quality assessment of the analytical data revealed high quality indices (2–3) on three out of the four criteria evaluated: analytical method used, analytical sample handling and documentation, and quality control. The quality index for the fourth criterion, sample plan and number of samples analysed, was scored lower (0–2). Summing of quality indices for all published values resulted in confidence codes A for those data. The sum of quality indices for unpublished values resulted in confidence codes B for those data (Table 2).

The lignan and isoflavone contents of foods vary greatly. The upper limits of the ranges of values for different food groups in the newly compiled phyto-oestrogen database are presented in Table 3. The lower limits of the ranges of lignan and isoflavone values for different food groups were zero or close to zero (not shown) in the vast majority of food groups, which elucidates the large differences in lignan and isoflavane values between foods.

The average intakes of the lignans matairesinol and secoisolariciresinol and the isoflavones daidzein and genistein are presented in Table 4. Mean intakes of these two groups of compounds were found to be below 1 mg/d among men and women in Finland: mean lignan intake was 434 (SD 1575) μg/d and mean isoflavone intake was 788 (SD 673) μg/d. The corrected mean lignan intake was 285 (SD 9347) and 601 (SD 1670) μg/d for men and women, respectively. The average lignan density of the diet was higher among women (56 μg/MJ) than among men (29 μg/MJ, $P<$0·05). The corrected mean isoflavone

Table 2. Confidence codes and criteria* to evaluate analytical data, and results on the quality assessment on the analytical data used in the construction of the Finnish database

Quality index	Documentation of analytical method	Analytical sample handling and documentation	Quality control	Number of samples and sample plan
0	none	totally incorrect handling	no duplicate, no estimate of data quality and recoveries	not reported
1	unpublished, but method described	no documentation	duplicates, no estimates of quality control parameters	1–2, limited description of procedures
2	modified from a published method	reasonable, documented, common technique	duplicates or internal controls, restrictions of analysis estimated, recovery estimate	3–9, procedures documented
3	complete documentation published	extensively documented and appropriate method	standards, reference materials, spikes, recoveries or blind duplicates	≥10, complete documentation of sample handling

Sum of quality indices	Confidence code	Explanation	Proportion (% of analytical data): Lignans	Proportion (% of analytical data): Isoflavones
≥9 points	A	the user can have confidence in the mean value	63	81
4–8 points	B	the user can have some confidence in the mean value; however, some questions have been raised about the value or the way it is obtained	27	19
0–3 points	C	serious questions have been raised about this value; it should be considered only as a best estimate of the level of the nutrient in this food	0	0

*Modified from Greenfield & Southgate (1992) and Mangels *et al.* (1993).

Table 3. Maximum values of phyto-oestrogens (μg/100 g fresh weight*) in different food groups (Dwyer *et al.* 1994; Mazur *et al.* 1996; Adlercreutz & Mazur 1997; Mazur, 1998; Mazur *et al.* 1998*a,b*)

Food group	Example foods of the food group	Matairesinol	Secoisolariciresinol	Daidzein	Genistein
Cereals					
Rye bread	whole-grain rye bread	44	32	0	0
Rye products	whole-grain rye flour	56	49	6	9
Wheat bread	white bread, wheat bread	14	20	<1	<1
Wheat products	wheat flour, bran, pasta	4	95	3	6
Savoury pastries and pizzas	pizzas of all sorts, Karelian rice pasty	8	18	<1	3
Coffee bread	sweet wheat buns, cakes and pastries	1	70	<1	0
Cookies	cookies of all kinds	0	5	0	0
Bread of other cereals	oat and barley bread, flat bread	1	16	0	0
Other cereal products	oat flakes and bran, barley flakes, rice	136	109	11	1
Porridges and gruels	rye, oat, rice, wheat porridges (plain or including fruit or berries)	10	61	<1	<1
Cereal dishes	muesli, pancakes	88	25	20	2
Vegetables					
Potatoes	cooked potato	8	13	0	0
Potato dishes	mashed potatoes with spinach, French fries	1	6	<1	0
Roots	carrot, red beets, parsnips, mixed root vegetables	<1	31	0	0
Root dishes	carrot casserole, rutabaga casserole, red beet sauce	<1	32	<1	<1
Other vegetables	sprouts, pumpkin, cabbages, mushrooms, fresh herbs, lettuce	8	576	27	63
Vegetable salads	mixed vegetable salads	2	187	<1	<1
Other vegetable dishes	cooked vegetables, mashed pumpkin, mushrooms in sauce	1	325	<1	4
Legumes, seeds and nuts	linseed, soyabean, low-fat soya flour	1021	347 336	85 350	117 170
Legume dishes	bean pot, cooked soyabeans, lentil soup, pea soup	2	64	13 690	19 720
Fruit and berries					
Fruit	kiwi, apple, pear, apricot, dried apricot	9	175	8	0
Fruit dishes and juices	baked apple, fruit salad, rosehip pudding	9	26	2	0
Berries	lingonberry, strawberry, gooseberry, cranberry	5	365	0	0
Berry dishes and juices	mashed lingonberries, blueberry soup, berry pudding	4	170	0	0
Fats					
Oils	soya oil	<1	1	<1	<1
Salad dressings	French salad dressing	<1	1	<1	0
Milk products					
Milk dishes	quark dishes, milk shake with berries or fruit, chocolate pudding	<1	36	<1	0
Yoghurt/cultured milk	yoghurts or cultured milk products with fruit and berries	1	10	NR	NR
Ice cream	ice cream with berry products	<1	10	0	0
Meat and fish					
Sausages	frankfurters, link sausage, cold cut sausages	10	9	912	1520
Sausage dishes	cooked frankfurters, baked link sausage, sausage soup	<1	8	512	853
Other meat dishes	chilli con carne, meat soup, chicken & vegetable stew	22	16	3	19
Fish dishes	fish baked in rye dough shell, fish & vegetable soup, salmon lasagne	20	15	<1	2
Beverages					
Coffee	brewed coffee	NR	NR	NR	NR
Tea	brewed tea, lemon tea, green tea	<1	4	NR	NR
Alcoholic beverages	red wine, white wine	9	98	NR	NR
Non-alcoholic beverages	soft drinks	<1	3	NR	NR
Sweets					
Sweets, chocolate, etc.	candy bars (including seeds/nuts), chocolate, marzipan	403	60	1245	2074
Miscellaneous					
Sauces	pesto sauce, guacamole	3	52	<1	<1
Dishes with soya	minced meat balls, vegetarian hamburger	<1	14	2300	3840
Desserts with soya	tofu ice cream	0	0	115	192
Special dietary products	glutein-free bread	1	16	6570	9010

NR, not relevant or missing values.
* Or μg/dl if in liquid form, e.g. tea.

Table 4. Average lignan (matairesinol and secoisolariciresinol) and isoflavone (daidzein and genistein) intakes (μg/d) in Finland according to food consumption data of the FINDIET 1997 Study (subjects aged 25–64 years)

(Values are corrected mean and standard deviation*)

	Men (n=1361)		Women (n=1501)		All (n=2862)	
Compound	Mean	SD	Mean	SD	Mean	SD
Lignans, total†	285	9347	601	1670	434	1575
Matairesinol	45	20	31	13	38	18
Secoisolariciresinol	240	9387	570	1665	396	1571
Isoflavones, total‡	902	368	668	963	788	673
Daidzein	346	149	264	470	306	291
Genistein	556	220	404	512	482	381

* A mixed model for measurement error was used in calculating the corrected means and standard deviations.
† Matairesinol plus secoisolariciresinol.
‡ Daidzein plus genistein.

intake was 902 (SD 368) μg/d and 668 (SD 963) μg/d for men and women, respectively ($P<0.05$). There was no difference in the isoflavone density of the diet between men and women (78 μg/MJ *v.* 100 μg/MJ, $P>0.05$).

Discussion

Based on the analytical data of domestic foods and imported foods consumed in Finland, the National Food Composition Database Fineli® (Ovaskainen, 2001) was supplemented with lignan and isoflavone values and intake of these compounds was calculated. Quality assessment of the analytical data showed that there were no concerns about the analytical methods used. The issue that was less optimal for database compiling purposes in this set of data was the food sampling underlying the analytical data, because the documentation of this sampling was scanty and the number of samples in some cases was less than three. The resulting analytical data can, however, be considered relevant for database compilation and intake calculation in Finland, because the samples drew mainly on the domestic food supply. Lignan and isoflavone values were obtained for about 70 % of the food items, most of them through the recipe database. It has to be pointed out that in the case of isoflavones about 50 % of the recipe-derived values in the database are zero values, whereas in the case of lignans, only 32 % of the recipe-derived values for matairesinol and 4 % of values for secoisolariciresinol are zero. This is in accordance with the fact that isoflavones are present in only a few plant families (Dewick, 1993). The list of lignan sources is much longer. Most of the foods also obtained a value for secoisolariciresinol through the recipe database, which is comprised of typical recipes used in Finland.

For this study the composition of processed meat products and bakery products was evaluated using information obtained from the largest manufacturers of these products in the country. Some minor modifications to the recipes were made. Evaluation of the meat and bakery products made it clear that the use of isoflavone-containing soya ingredients is fairly common in processed meat products, but not very common in breads and other bakery goods. This shows the importance of knowing the origin of the domestic food supply and the compositional differences between imported foods from different countries when food databases are compiled. The observation in the EU Concerted Action VENUS (van Erp-Baart *et al.* 2003) that, in four EU countries, bread and cereals are the main sources of isoflavones does not seem to apply in Finland today. However, information on soya in food products in general is not very reliable. The commercial food supply changes rapidly, and soya is one of the ingredients that has a fluctuating popularity among consumers.

The average intake of both lignans and isoflavones was found to be below 1 mg/d in men and women. This is in agreement with other findings in the USA and Europe (de Kleijn *et al.* 2001; van Erp-Baart *et al.* 2003). The average isoflavone intake is low in Finland because soyabeans and soya products are not a common part of the diet (FINDIET Study Group, 1998). Intake of isoflavones is mainly due to soya-containing components used as ingredients in commercially processed meat products and a few bakery products. Because our food consumption data were collected by 24 h recall, these data do not allow us to identify a subgroup of high consumers of soya products or other isoflavone-containing foods.

The average lignan intake was not more than 500 μg/d among Finns and the median intake less than that (not reported here). This is lower than the lignan intake reported by de Kleijn *et al.* (2001) in women in the USA. Caution must be taken, however, when comparing these results, because food consumption and database compiling processes were not comparable. First and foremost, diets differed in the main sources of lignans. In Finland these sources were the following: seeds, cereals (especially rye), berries, fruits and vegetables. In the USA the main source of lignans was fruits (de Kleijn *et al.* 2001).

Our phyto-oestrogen database included two lignans for which a fairly large set of analytical data was available. Recently it has been shown (Heinonen *et al.* 2001) that other precursors of mammalian lignans, namely pinoresinol, lariciresinol and syringaresinol, are also present in foods.

The average intake of lignans and isoflavones in Finland seems to be low, and far below those intake levels commonly used in phyto-oestrogen experiments or suggested to have any biological effects. In the future more laboratory analysis data need to be added to the food database on mammalian lignan precursors in foods generally, and on isoflavones especially in processed foods, in order to obtain more reliable estimates of the dietary phyto-oestrogen intake for epidemiological studies.

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