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Development of an updated phytoestrogen database for use with the SWAN Food Frequency Questionnaire: intakes and food sources in a community-based, multiethnic cohort study

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Abstract

Phytoestrogens, heterocyclic phenols found in plants, may benefit several health outcomes. However, epidemiologic studies of the health effects of dietary phytoestrogens have yielded mixed results, in part due to challenges inherent in estimating dietary intakes. The goal of this study was to improve the estimates of dietary phytoestrogen consumption using a modified Block Food Frequency Questionnaire (FFQ), a 137-item FFQ created for the Study of Women's Health Across the Nation (SWAN) in 1994. To expand the database of sources from which phytonutrient intakes were computed, we conducted a comprehensive PubMed/Medline search covering January, 1994 through September, 2008. The expanded database included 4 isoflavones, coumestrol and 4 lignans. The new database estimated isoflavone content of 105 food items (76.6%) versus 14 (10.2%) in the 1994 version and computed coumestrol content of 52 food items (38.0%), compared to 1 (0.7%) in the original version. Newly added were lignans; values for 104 FFQ food items (75.9%) were calculated. In addition, we report here the phytonutrient intakes for each racial and language group in the SWAN sample and present major food sources from which the phytonutrients came. This enhanced ascertainment of phytoestrogens will permit improved studies of their health effects.

INTRODUCTION

Phytoestrogens are of growing interest to both the scientific community and health care consumers, who strive to identify “natural” methods to maintain wellness. Phytoestrogens are heterocyclic phenols found in many plant foods. There are 3 major categories of phytoestrogens: isoflavones (e.g. daidzein and genistein), coumestans (e.g., coumestrol), and lignans (e.g. secoisolariciresinol and matairesinol). (1–6)

As of this writing, phytoestrogens have been implicated in the prevention of at least 12 diseases and conditions, making them worthy subjects of scientific investigation (7–15). The hypothesis that phytoestrogens may prevent chronic diseases stemmed from ecological epidemiological studies which found that the rates of some cancers, cardiovascular disease, and osteoporotic hip fracture were low in Asian countries, in which a high isoflavone diet is consumed (3,6,7,16–22) Population-level associations between diet and disease, which must be interpreted cautiously as many other factors differ among cultures, have been buttressed by numerous studies showing that phytoestrogens and their metabolites have biological activity *in vitro*. Phytoestrogens bind to both α and β estrogen receptors and are

predominantly agonists based on transcriptional activation studies; but they can also have relative antagonist properties depending on circulating estradiol levels and conformational effects on receptors (7,16,18,23–27). Non-estrogen-receptor-based mechanisms may also account for some of the proposed health benefits of phytoestrogens and their metabolites: for example, they have anti-oxidant properties and inhibit enzymes such as aromatase (23, 28–33)

The amounts and types of phytoestrogens in the diet vary among cultures, based on our admittedly incomplete knowledge base. Isoflavones are the best-documented example of dissimilar intakes of phytoestrogens across cultures: they are strongly represented in soy products, mainstays of Asian diets, but until recently have been rare in Western diets (34–52). Secular increases in the availability of soy products such as soy milk, soy meat and soy energy bars may diminish this disparity (53). Less is known about dietary intakes of lignans and coumestans. Both Eastern & Western diets contain substantial amounts of cereals, grains, vegetables and fruits, common sources of lignans. Thus consumption of this class of phytoestrogen should be common in both diets, although estimated intakes are few and exact food sources are likely to differ (43, 47, 48, 54). Assessments of coumestan in the diet are similarly rare; because tofu is one source, one might expect higher relative intakes in Asian compared to non-Asian samples (46, 55–57).

Longitudinal studies of the health effects of usual dietary consumption of phytoestrogens are rare due to challenges inherent in measuring dietary intakes of phytoestrogens and also owing to limited representation in cohort studies of persons with diets rich in phytonutrients. Without a comprehensive database, epidemiologic studies are limited to examining the health effects of phytoestrogens based on a limited number of foods; thus the observed phytoestrogen-disease relationships are likely confounded by unmeasured sources of exposure and misclassification of exposure. The Study of Women's Health Across the Nation (SWAN) is a multisite, multiethnic, longitudinal study of African American, Caucasian, Chinese, Japanese and Hispanic midlife women (58). SWAN provides an excellent opportunity to explore the ethnic variation in usual dietary intake of phytoestrogen in the United States. SWAN collected information on numerous factors that may affect women's health, including conducting detailed dietary assessments using a 137-item food frequency questionnaire (FFQ) specifically modified to account for phytoestrogen intake (59). The database used to quantify phytoestrogen exposures was state-of-the-art in 1994 when it was created; however, since that time the phytonutrient contents of many additional foods have been reported. We therefore undertook a revision of the original SWAN-FFQ phytoestrogen database with the aim of improving SWAN's ascertainment of isoflavones and coumestrol and newly adding lignans.

METHODS

Updating and Expansion of the SWAN Phytoestrogen Database

To create the original SWAN phytoestrogen database Reinli and Block compiled information about two types of isoflavones (daidzein and genistein) and coumestrol extant through 1994 (59). To expand upon the original SWAN phytoestrogen database we conducted an extensive PubMed/Medline search to identify published phytoestrogen data on phytoestrogen content of foods from 1994 through September, 2008. An addition to updating information about isoflavones and coumestrol, we incorporated a third class of phytoestrogen, lignans. We searched for reports of primary laboratory analyses as well as compilations of published results using the following key words: phytoestrogens, plant estrogens, soy, soybean, isoflavones, genistein (Gen), daidzein (Dai), formononetin (For), glycitein (Gly), lignans, enterolactone, enterodiol, lariciresinol (Lar), pinoresinol (Pin), secoisolariciresinol (Sec), matairesinol (Mat) and coumestrol (Cou). We also contacted

experts to inquire about any unpublished data but we did not acquire any additional information from them. We identified 20 articles that reported food content values for at least one of the 3 classes of phytoestrogens and updated the SWAN phytonutrient database to include 9 phytoestrogens: 4 isoflavones (daidzein, genistein, formononetin, glycitein), coumestrol, and 4 lignans (lariciresinol, pinoresinol, secoisolariciresinol and matairesinol). All phytonutrient values were computed as aglycone equivalents and are reported per $\mu\text{g}/100\text{g}$ of fresh weight of food.

Assigning Phytoestrogen Values to Foods Listed in the SWAN FFQ

We assigned the updated phytoestrogen values to foods contained in the SWAN Food Frequency Questionnaire (FFQ) (60–62). The SWAN FFQ has been previously described (63) and is summarized later in the Methods. We first determined whether a food source found in the literature exactly matched an item listed in the FFQ or was similar to a food item contained in the FFQ. Examples of exact matches included bananas and cantaloupe, which are listed as unique items in the FFQ and for which specific phytoestrogen values were reported. Examples of similar, but not exact, food matches that were used to compute phytoestrogen values included: evaporated milk values were based on those for cow's milk (recognizing that in this would result in an underestimate, due to evaporation of water) and values for raw plums were used for pickled plums. If multiple published values were identified for a single food item, the average of all reported values was used. In 70 instances two or more foods were grouped on the same line of the FFQ (i.e., the consumption of more than one food was asked in a single question). These 70 instances of grouped foods fall into 6 categories. In the first category, only one food on the line had an exact match; therefore, we used the phytonutrient content of the single matched food item for all items in that line. Examples include: values of apples were used for “apples or apple sauce” and values of cauliflower were used for “cauliflower or brussel sprouts”. Of the 70 grouped items, there were 19 lines in which we used this approach.

In the second category of grouped foods, we were able to find a similar (but not exact) match to only one of the items in the line. An example of this was “fish eaten whole (such as canned sardines, canned mackerel.....)” in which the values for tuna (light and dark) were used for this line.

In the third category of grouped items, which consisted of 8 lines on the FFQ, we used a simple average of the phytonutrient content of each of the items in the line, because the nutrient contents and portion sizes of all items were similar. Examples of lines that were simply averaged were “spinach, raw or cooked” and “wine or wine coolers”. In the fourth category, comprising 9 FFQ lines, the phytonutrient content of the foods differed and the usual portion size or consumption patterns of the foods also differed. In this case, we used a weighted average to estimate the phytonutrient value for that group based on both its nutrient value and its relative consumption. The weights for each of the foods were based on U.S. population intake estimates derived from two sources: 4-yr National Health and Nutrition Examination Survey (NHANES) 24-h recall data conducted by NutritionQuest (64); and food group intake analyses using USDA data matched to food reported as consumed in NHANES 2001 – 2004 (65). Exact methods for deriving weights have been published (60, 66, 67). One example of this category in which we used a weighted average was “oranges and grapefruit”. Because the NHANES 24-h recall data showed that U.S. adults consumed oranges in an amount that was about 5 times greater than that of grapefruit, the phytonutrient values for oranges and grapefruit were weighted by a factor of 5 to 1. A second example is “peanuts and peanut butter”, for which NHANES data show that more U.S. adults eat peanut butter than peanuts, but typical intake amounts are higher for peanuts, resulting in roughly equal total population intake (NHANES). An average of the literature-based phytoestrogen values for peanuts and peanut butter were used to assign values to this

item. The fifth category consisted of grouped foods those that may have different phytonutrient values (but detailed data were lacking) and/or for which portion size or consumption patterns may vary, but for which we did not have adequate data to determine a weighting factor. In this case, a simple average was used. There were 5 such lines. Examples include “doughnuts and pastry” (no good data for pastry, average value of doughnuts used) and “cookies or cake regular or low fat” (used values for cookies only). The last category consisted of 14 lines of grouped items, such as “beef, including roasts, steaks,” and “salad dressing and mayonnaise” that had trace or not detectable phytoestrogen content and were assigned as zero.

For mixed dishes or food items made from ingredients, we averaged their phytoestrogen levels using a recipe if one was available. Some recipes were obtained from internet recipe sites (such as foodnetwork.com, allrecipes.com) and some were selected based on knowledge of typical dishes, for example the steamed dumpling recipe. For others, such as “pies other than pumpkin”, proportions of major ingredients were derived by NutritionQuest using NHANES 24-hour recall data and USDA food group data (64, 65). Recipes were used to determine the proportions of key ingredients in 100 grams of a commonly consumed version of the food item. For example, pork and cabbage dumplings were selected as a typical version of “Steamed or boiled Chinese dumplings with meat... including wonton”, consisting of 14% pork (by weight), 56% cabbage, 8% green onion and 22% dumpling wrappers; only the cabbage contributed to phytoestrogen content.

Specific phytoestrogen components reported as ‘a trace’ or ‘not detectable’ were counted as zero. Finally, if no data were available for a food item, we assumed the phytoestrogen values were zero.

Of the 137 food items in the SWAN dietary assessment, the original SWAN phytonutrient database provided isoflavone values for 14 food items and coumestrol values for 1 food items. The revised database assigns isoflavone estimates for 105 items, coumestrol estimates for 52 items, and lignan estimates for 104 items.

Summary estimates of the lignans and isoflavones were calculated. Total lignans were the sum of values for secoisolariciresinol, matairesinol, pinorensinol, and lariciresinol. Total isoflavones were the sum of values for daidzein, genistein, formononetin and glycitein. Total phytoestrogens were the sum values for isoflavones, lignans and coumestrol. The phytoestrogen content of the SWAN FFQ is contained in Appendix 1.

Estimation of Dietary Phytoestrogen Intakes

An interviewer-administered dietary assessment, which has been previously described, was used to assess participants’ usual food consumption over the past year. In brief, the SWAN dietary assessment instrument was made up of 3 components: 1) a full FFQ; 2) an “Ethnic Foods Page”, and 3) an open-ended question (of which there were 4 versions, described below) (49, 68).

The SWAN FFQs were modifications of the 1995 version of the Block food frequency questionnaire (60). Because SWAN is multilingual and multiethnic, it was necessary to create four versions of the FFQ, tailored to language/ethnicity. The English language FFQ version contained a 103-item core food list. The core food list was based on the responses of African American and Caucasian participants in the Second National Health and Nutrition Examination Survey (NHANES II) (66, 67). The Chinese and Japanese ethnic group versions included the same 103-item core food list plus between 12 and 16 additional foods appropriate for the particular ethnic group (the “Ethnic Foods Page”). The Ethnic Foods Pages were created because the NHANES surveys did not include a sufficient number of

Chinese or Japanese respondents to identify all potentially important additional ethnic foods. Therefore, Chinese and Japanese nutrition researchers and dietitians were asked to enumerate items that they considered important in the Chinese and Japanese diets that were not contained on the 103-item core FFQ. To ensure the appropriateness of the proposed ethnic food supplements list, information from focus groups (Chinese) or food records (Japanese) were examined. For the Chinese and Japanese SWAN FFQs, 12 and 16 foods were added to the core food list, respectively.

Finally, an open-ended question about any other foods eaten at least once per week was asked of all respondents. Responses were manually coded into food groups and assigned typical nutrients from these foods and were included in the nutrient estimates for those respondents.

SWAN administered the dietary assessment three times: at baseline and annual follow-up visits 5 and 9. The two ethnic foods pages were administered two ways. At baseline, the corresponding ethnic foods page was administered to Caucasian participants only at the sites that included Chinese or Japanese participants. For example, the Japanese ethnic foods page was administered to Caucasian participants at the Los Angeles site. This was done to ensure that Caucasian and non-Caucasian ascertainment was comparable at the same geographic site. At follow-up visits 5 and 9, both Japanese and Chinese ethnic foods pages were administered to all participants at all SWAN sites. This administration change was made to avoid under-reporting of ethnic foods.

We report here the phytoestrogen intakes for SWAN participants based on our updated phytoestrogen database. Each phytoestrogen intake was estimated as the amount contained in each food item multiplied by the frequency of consumption of that food and then summed over all foods.

Identification of Major Food Sources of Phytoestrogens

We also analyzed the food sources that contributed to phytoestrogen intakes. We chose visit 5 FFQ data for this analysis because the administration of the Japanese and Chinese ethnic foods pages to all participants began at visit 5. The contribution of each food was calculated as the ratio of phytoestrogen provided by that food to the phytoestrogen intake from all foods consumed in the entire study sample (66, 67).

Study sample

SWAN is a community-based, multisite, multiethnic, longitudinal study of the menopausal transition (58). At baseline, eligible participants were women aged 42 to 52 years; with an intact uterus and at least one ovary; with no current use of estrogens or other medications known to affect ovarian function; who had at least one menstrual period in the 3 months prior to screening; and self-identified as Caucasian, African American, Hispanic, Chinese, or Japanese. Participants from 6 of the 7 SWAN sites (Boston, Chicago, Detroit, Pittsburgh, Oakland, and Los Angeles) were eligible for the present project. Participants from the Newark site were not included because retention was 18% for Caucasian women and 45% for Hispanic women at visit 5; that site did not conduct a visit 9 dietary assessment. Other exclusions were: absence of baseline dietary assessment ($N = 17$); a reported intake of less than 4 or greater than 17 solid foods per day ($N = 130$); skipped more than 10 food items when responding to the FFQ ($N = 1$); and a calculated energy intake of less than 500 kcal or more than 5,000 kcal daily ($N = 24$). Final sample sizes for each visit were: 2721 at baseline, 1905 at follow-up visit 5, and 1677 at follow-up visit 9.

Data Analysis

Distributions of phytoestrogens were substantially skewed; therefore, medians and interquartile ranges are reported, to provide appropriate estimates of the central tendency and distributions. The percentage of intake of isoflavones, coumestrol and lignans from different food sources are presented by ethnicity and site. The Signed Rank test was used to evaluate the differences of phytoestrogen intakes between study visits. In the two Asian groups (Chinese and Japanese), comparisons of phytoestrogen intake between English-speaking and non-English women were assessed using Wilcoxon Score test. All analyses were conducted using SAS 9.1 (SAS Institute Inc., Cary, NC, USA).

RESULTS

Overview of food sources of phytoestrogens

Isoflavone content of foods ranged from zero to ~87,000 µg/100g. The food sources that were richest in phytoestrogens were soy and soy products, with roasted soybeans having the highest levels of isoflavones (87,400 µg/100g), followed by fermented soybeans/natto (74,900 µg/100g) and fresh soybeans/edamame (65,800 µg/100g). Food content of genistein was usually equal to or higher than daidzein with the exception of soy milk, spiced tofu and soy sauce, which had substantially higher levels of daidzein than genistein. Alfalfa sprouts were the richest source of formononetin (1,500 µg/100g). Two unexpected non-soy products contained relatively high amounts of total isoflavones: doughnuts (4,400 µg/100g) and pancakes/waffles (1,300 µg/100g). The use of soy flour in these products likely accounts for their high isoflavone contents. Foods of animal origin, such as meat and dairy products, were generally low in isoflavones.

While levels of isoflavones in foods ranged widely, the amounts of lignans and coumestrol in foods were less variable, spanning from zero to ~400 µg/100g and zero to 1,600 µg/100g, respectively. In our database, avocados had the highest levels of total lignans, 400 µg/100g. Fruits, vegetables, coffee and tea were also common sources of lignans. Of the lignan subtypes, secoisolariciresinol and lariciresinol were generally present in higher amounts than matairesinol and pinoresinol. Foods that contained the highest levels of secoisolariciresinol and lariciresinol were Chinese herbs in soup or tea (300 µg/100g) and chili pepper (200 µg/100g). The highest coumestrol amounts were predominantly found in sprouts, such as alfalfa (1,600 µg/100g), regular bean (800 µg/100g) and soybean (500 µg/100g). Similar to isoflavones, lignans and coumestrol are found in low levels, or not at all, in animal food sources.

Estimation of dietary phytoestrogen intakes

While median intakes of the 3 classes of phytoestrogens varied widely in the four racial/ethnic groups, the greatest difference was between the Asian groups vs. the non-Asian groups (Table 1). Compared to Caucasian and African American participants, Chinese and Japanese women had significantly higher estimated daily intakes of phytoestrogens at each of the 3 study visits. Median intakes of isoflavones for the non-Asian groups averaged < 500 µg/day, whereas the daily isoflavone intakes in Chinese and Japanese women were 6,500 µg or more. Between baseline and visit 5, intakes of all phytonutrients increased in all racial/ethnic groups (Signed Rank test, all $p < 0.05$) with the exception of coumestrol, which declined during this time interval. Between visits 5 and 9, estimated total phytoestrogen, isoflavone and lignan intakes remained stable in the two Asian groups; during this time interval, coumestrol intake declined in Chinese women, but did not change in Japanese participants. In contrast, between visits 5 and 9, intakes of these compounds declined among Caucasian and African American women. Between visits 5 and 9, total phytoestrogen intake increased in Caucasian participants and did not change in African American women.

For all racial/ethnic groups across the three visits, genistein was the major contributor (50 to 60%) to total isoflavone intake, followed by daidzein (36 to 45%). Formononetin only accounted for 0.1 to 0.2 % of total isoflavone intake in the two Asian groups and 2 to 4% in the two non-Asian groups. For lignans, in most cases, secoisolariciresinol was the top contributor and lariciresinol was the second most frequent.

Among Asian women, at baseline non-English speakers reported 20 to 86% higher daily phytonutrient intakes than did English speaking Asian women. At visits 5 and 9, the differences in phytonutrient intakes by interview language in the Japanese women remained evident, but not among Chinese women.

Major food sources of phytoestrogen

Results regarding food sources of isoflavones, lignans, coumestrol and total phytoestrogens among Japanese and Chinese participants were based on visit 5 data, because the ethnic foods pages were uniformly administered at this visit (please see Methods). In English-speaking Japanese women, 35% of the total phytoestrogen and isoflavone intakes were contributed by fresh green soybeans (edamame) (Table 2). For non-English speaking Japanese women, about 30% of the total phytoestrogen and isoflavone intakes were from fermented soybeans. Regardless of interview language, fermented soybeans, fresh soybeans, tofu, soy milk, roasted soybeans, dry spiced tofu and aburage/atsuage constituted 90% of the total phytoestrogen and isoflavone intakes in the Japanese diet.

Language was not related to food sources of total phytoestrogens and isoflavones in Chinese women (Table 3). Soy milk was the top food source and contributed about 50% to total phytoestrogen and isoflavone intakes. The food sources that supplied 90% of total phytoestrogen and isoflavone intakes were similar in English and non-English speaking Japanese and Chinese women, although the rankings of specific foods varied in the four race-ethnicity/language subsets.

Food sources of lignans were more ubiquitous, thus the top 7–10 food sources comprised less than 75% of total intakes (Table 3). Coffee and green tea contributed 15% and 20%, respectively, to total lignan intake of English-speaking and non-English speaking Japanese groups. In addition, coumestrol was found mainly in regular bean sprouts (contributed ~49% to 65% of the coumestrol intake) in both Asian groups. Major food sources of lignans and coumestrol did not differ by interview language in Japanese and Chinese women.

Major food sources of intakes of the phytoestrogen classes or of total phytoestrogen did not differ much across study sites (Table 4). In African American women, soy milk was the foremost food source of total phytoestrogens and isoflavones and contributed between 72% and 86% to total phytoestrogen and isoflavone intakes at the four study sites that included African American women. At the Detroit, Boston and Pittsburgh sites, tofu or doughnuts were the second highest contributors to African American participants' intakes (about 8–9%), whereas in Chicago meat substitute/soy protein/soy burger was the second highest in African American women and accounted for about 6% of the intakes. Coffee, tea, green salad and Chinese herbs in soup or tea were the main sources of lignans, but these foods contributed only 10 to 15% of total lignan intake. Therefore, the 6 highest lignan food contributors for each site represented 44% to 49% of total intake among African American participants. The main sources of coumestrol among African American women at all four sites were doughnuts, bean sprouts, and alfalfa sprouts. These foods combined contributed 78% to 96 % to total coumestrol.

Although soy milk was also the most important contributor to total phytoestrogen and isoflavone intakes in Caucasian women, its relative importance varied greatly by study site:

the highest was 83% in Detroit and the lowest was 52% in Los Angeles (Table 5). Tofu/meat substitute was the second most prominent source of the total phytoestrogen and isoflavone intakes. At the California sites, fresh green and roasted soybeans were also major phytoestrogen and isoflavone sources in Caucasians. Coffee and black tea contributed about equally to lignan intake (13% to 19%), except at the Detroit site; among Caucasian women in Detroit, coffee contributed 23%, followed by green salad (10%). The top 5 lignan food sources contributed only about 50% to 57% to the total daily intake. Bean sprouts were the main source of coumestrol intake in Caucasian women at the Detroit, Boston, Los Angeles, and Oakland sites, ranging from 29% to 40%. In Chicago and Pittsburgh, doughnuts were the leading contributors, making up 38% and 58% of coumestrol intake. Bean sprouts, doughnuts, alfalfa sprouts and Tofu contribute 84% to 94% of total coumestrol intake in Caucasian women.

DISCUSSION

The overarching goal of this project was to update the original SWAN phytoestrogen database to improve ascertainment of phytoestrogen intakes estimated from the 137-item SWAN FFQ (49, 59). We incorporated information from 20 new references, representing all identified English-language publications from 1994 through September, 2008. The expanded data base allowed us to compute isoflavone contents of 105 FFQ food items (76.6%) and coumestrol contents of 52 FFQ food items (38.0%). Newly added were lignans, for which estimated values for 104 FFQ food items (75.9%). In addition to describing the development of the new phytonutrient data base, we report the phytonutrient intakes for each racial and language group in our study sample and identify the major food sources from which the phytonutrients came.

Intakes of all 3 classes of phytonutrients, calculated using the updated database, were uniformly higher than those computed using the original version (68). For example, the original database estimated median intakes of genistein and daidzein at less than 10 $\mu\text{g/day}$ and intakes of coumestrol of mostly zero for the SWAN African American and Caucasian women. Using the new database, daidzein and genistein intakes of the same women ranged from ~100 to 200 $\mu\text{g/day}$ and coumestrol intake was between 5 to 10 $\mu\text{g/day}$. Because we are applying a new data base to already-collected data, currently estimated higher intakes are a result of crediting more food items with phytoestrogen content. In the old data base, 1 food contributed to coumestrol calculations and 14 foods contributed to isoflavone calculations; the new data base used 52 and 105 foods to estimate coumestrol and isoflavone intakes. There were also apparent increases in phytoestrogen intake with time; however, the analysis presented here is cross-sectional at each of the 3 visits and therefore inferences about within-woman change in consumption cannot be made.

There were substantial differences in phytoestrogen intakes, predominantly driven by the isoflavone component, among the ethnic/racial groups in SWAN. As expected, Asian women's phytoestrogen intakes were 13 to 20 times higher than those of non-Asian women (68–70). The heavy influence of soy-based foods in Japanese and Chinese diets accounts for the vastly higher phytoestrogen exposures in these women compared to the non-Asian groups. (48, 59, 71). Phytoestrogen consumption differences within the Asian groups were also striking: Japanese women took in about 100% to 200% more than did Chinese women. Higher phytoestrogen intakes of Japanese vs. Chinese participants may be explained by the relatively greater concentrations of phytonutrients in foods commonly consumed by Japanese women (48, 71–73). In a sample that included both Japanese and Chinese women, Maskarinec *et. al*, similarly reported higher mean phytoestrogen intake in the former (19 mg/day) than the latter (12 mg/day) (69). Comparing across-studies, Japanese women's intakes of isoflavones specifically also appear to be higher than those of Chinese women, but cross-

study results must be interpreted with caution due to differences in dietary measurement methods (74, 75).

Japanese or Chinese language use was a marker of higher phytoestrogen (mainly isoflavone) intake, consistent with less dietary acculturation in those who retained their native language (76–78). Similarly, at baseline, phytoestrogen consumption was about 70% higher in Chinese-speaking compared to English-speaking Chinese participants. Unexpectedly, the phytoestrogen differential by language disappeared at subsequent visits, as the intakes of phytonutrients among the English speaking Chinese women increased over time. This counterintuitive observation may be related to the increasing availability of the 2 major phytoestrogen food sources for Chinese, soy milk and tofu, which account for over 70% of total phytoestrogens and isoflavones in Chinese participants. It is plausible that the English-speaking Chinese women increased their consumption when tofu and soy milk became pervasive in U.S. grocery chains (53).

The average daily coumestrol intakes in our 2 Asian groups were comparable with the single previous report of coumestrol intake among Chinese women in Hong Kong, which cited an average consumption of $63.9 \pm 34.3 \mu\text{g/day}$ (46). Diverse estimates of coumestrol intake emanate from 3 studies of Caucasian women, highlighting the differences that can arise based on study samples and nutrient databases (43, 47, 48). Current SWAN results for Caucasian women are similar to those obtained in Framingham, Massachusetts and in the Netherlands, in which coumestrol intakes were low (mean $11 \mu\text{g/d}$ and $< 1 \mu\text{g/day}$) (43, 47). However, in San Francisco, California, the average daily coumestrol consumption, primarily from orange juice and coffee, was calculated at $210 \mu\text{g/day}$ (47, 48).

The revised version of the SWAN-FFQ phytonutrient database newly includes lignans. Until recently, estimates of “total lignan intake” were based on 2 compounds, secoisolariciresinol and matairesinol (43,47,48,54). SWAN’s lignan values were based on 4 compounds (secoisolariciresinol, matairesinol, lariciresinol and pinoresinol). Our lignan estimates for Caucasian women were much lower than those of French women ($1,112 \mu\text{g/day}$) and Finnish men ($1,224 \mu\text{g/day}$), based on the same 4 lignans (79, 80). Higher lignan intake in the European compared to the US sample is likely due to greater consumption of seeds, cereals, whole grains and berries, rich sources of lignans. There are no comparative studies using a 4-lignan assessment for the other ethnic groups in SWAN.

We conducted in-depth analyses to enumerate foods that were the leading sources of each major class of phytoestrogen in each ethnic/racial and language group, for 2 reasons: 1) bioavailability of some phytonutrients may vary by food source and 2) knowing the food sources may allow development of shorter, phytonutrient-specific food questionnaires. Fermented soy foods accounted for a greater proportion of isoflavone intake in Japanese vs. Chinese women; fermented soy contains more readily absorbed forms of isoflavones which may result in a more potent biological effect than non-fermented soy (81–83). SWAN previously reported that despite similar isoflavone intakes, Japanese participants had higher bone mineral density values than Chinese participants, supporting the hypothesis that not only the amount, but the source, of isoflavones matters (84).

Although FFQs have several attributes that recommend their use in studies of diet and health outcomes, limitations include respondent burden and cultural and ethnic specificity (85–87). An alternative approach is development of nutrient-specific FFQs, intended to capture the intake of a single nutrient (e.g., isoflavones only). Nutrient-specific questionnaires, such as those for vitamin C or fatty acids (88, 89), are shorter but risk omission of important food sources. The inclusion of foods that make up 90% of the total intake of a given nutrient is a widely-used criterion for nutrient-specific food lists (66, 67, 89–91). In our study, 7 to 10

soy foods in the Asian groups and 2 to 5 soy foods or foods made with soy flour in the non-Asian groups contributed 90% of total phytoestrogen and isoflavone intakes. Thus, few dietary items were needed to capture total phytoestrogen/isoflavone intakes. Similarly, in all ethnic/racial groups, 91% to 97% of coumestrol intake was accounted for by sprouts, tofu and doughnuts. Capturing 90% of lignan intake, however, required a much more expansive list: 24 to 31 foods for Asian groups and 28 to 33 foods for non-Asian groups. Thus, nutrient-specific FFQs might be feasible for isoflavones and coumestrol, but appear less attractive for lignans.

Strengths of this work include: the ability to examine, in the same cohort, nutrient intakes of women who consume Eastern and Western diets and who have varied ethnic and acculturation backgrounds; an FFQ that can handle analysis of mixed dishes; and having 3 waves of FFQ data collection. Limitations must also be recognized. Several factors, such as variation in growing seasons, geographic origin of foods and food preparation, threaten the accuracy of phytonutrient estimates (59, 92). Although phytonutrient values contained in this database were as current as possible in 2009, a new online flavanoid database (93) was released in 2010; however, most of the novel information contained on this site is about flavanoids that are not among 3 classes of phytoestrogen compounds considered here. While our project represents a carefully done, exhaustive compilation of reported isoflavone, coumestrol and lignan values, the resulting estimates have not been validated using biomarkers, which has been done for other phytonutrient data bases (94). Nonetheless, the FFQ's ability to rank individuals according to their position in the measurable distribution of intake should provide information on relative intake (49, 95, 96). This work also has limitations common to FFQ creation and analysis: some foods are not a perfect match with existing databases of nutrient values; commercial and home-made products are not distinguishable; and appropriate weighting factors for grouped food items cannot always be estimated (60, 97). We also used the same phytonutrient estimates for the FFQ food items at all 3 visits, 1996, 2001 and 2005; this will be inaccurate if phytonutrient contents of foods changed over time.

In conclusion, we updated the phytonutrient data base for use with the SWAN-Block FFQ (68) and used this data base to re-compute phytonutrient intakes in SWAN. We acknowledge the limitations inherent in nutritional observational studies, but we believe the challenges well balanced by the benefits. Intervention studies can administer controlled amounts of specific phytoestrogens but at the price of smaller sample sizes and short term-exposures. Large, longitudinal, observational studies, such as SWAN, can capture longer-term phytonutrient eating patterns and use this information to address important translational research questions about the health effects of phytoestrogens in free-living persons.

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Table 1

Daily phytoestrogen nutrient intakes ($\mu\text{g/day}$), by visit and ethnicity

Baseline	African American			Caucasian			Chinese			Japanese								
	N = 860			N = 1361			English ^I (N=148)			Chinese ^I (N=96)			English ^I (N=156)			Japanese ^I (N=100)		
	Median	Quartile Range		Median	Quartile Range		Median	Quartile Range		Median	Quartile Range		Median	Quartile Range		Median	Quartile Range	
Isoflavones	284.6	544.6		317.5	699.2		5487.3	13545.0		9714.3	15214.8		6743.4	9333.9		24585.0	21704.3	
Formononetin	10.1	13		12.1	14.1		10.2	8.4		10.7	9.1		11.8	13.0		17.6	15.4	
Daidzein	114.8	211.5		126.6	260.6		2401.4	4864.3		3877.5	6369.2		2689.0	3845.9		9848.7	8859.9	
Genistein	152.5	317.6		171.1	424.2		3050.7	7242.1		5213.0	8581.3		3708.2	5140.0		13472.5	11447.5	
Glycitein	2.6	5.1		3.2	12.5		163.6	515.5		460.0	766.0		262.9	496.1		1828.1	2135.6	
Lignans	190.6	145.8		250.2	169.9		291.1	248.0		353.7	232.1		232.9	180.4		370.7	292.3	
Matairesinol	14.1	15.1		12.0	11.7		9.2	9.2		6.1	5.8		12.0	9.5		13.0	8.9	
Lariciresinol	59.9	48.4		74.3	56.5		91.1	76.2		110.6	74.7		70.8	51.9		120.1	96.7	
Pinoresinol	27.6	32.0		36.7	40.8		75.0	91.2		125.0	91.9		33.2	27.6		74.1	62.1	
Secoisolariciresinol	79.7	67.3		105.5	83.4		105.2	98.4		96.9	71.8		104.2	84.4		162.4	96.0	
Coumestrol	8.0	21.7		9.2	24.9		38.3	59.3		61.5	83.3		32.9	41.7		62.3	80.1	
Phytoestrogens	557.2	661.1		633.8	798.4		5947.4	13618.6		10042.7	15367.6		7095.2	9362.0		25015.8	21840.4	
Year 5	African American			Caucasian			Chinese			Japanese								
	N = 487			N = 1000			English (N=137)			Chinese (N=68)			English (N=140)			Japanese (N=73)		
	Median	Quartile Range		Median	Quartile Range		Median	Quartile Range		Median	Quartile Range		Median	Quartile Range		Median	Quartile Range	
Isoflavones	313.9	956.1		567.7	3399.1		15265.5	35161.5		14327.2	19598.6		10379.7	19522.9		33008.1	25346.7	
Formononetin	10.8	13.3		13.4	14.1		10.2	9.5		9.7	8.5		12.6	10.1		18.9	12.5	
Daidzein	128.9	349.5		203.9	1386.7		5643.0	16511.4		6068.3	9456.5		4438.5	8657.9		13455.5	10411.9	
Genistein	169.0	606.8		336.0	1689.8		8655.4	15392.2		7454.8	9407.6		5548.4	9825.8		16921.6	11878.8	
Glycitein	3.0	13.5		6.5	121.5		654.1	2430.3		710.6	1397.7		472.7	1062.8		2620.1	2235.5	
Lignans	216.6	154.1		270.8	184.2		341.1	286.2		355.1	252.9		294.4	195.2		408.9	266.4	
Matairesinol	13.6	13.0		12.1	11.0		10.0	10.3		6.6	5.6		12.2	11.2		11.0	7.9	
Lariciresinol	65.6	51		80.1	65		102.4	74.0		97.0	70.2		90.2	69.4		123.0	81.8	

Baseline	African American		Caucasian		Chinese		Japanese					
	N = 860		N = 1361		English ^I (N=148)		Chinese ^I (N=96)		English ^I (N=156)		Japanese ^I (N=100)	
	Median	Quartile Range	Median	Quartile Range	Median	Quartile Range	Median	Quartile Range	Median	Quartile Range	Median	Quartile Range
Pinoresinol	32.9	35.1	42	48.3	104.6	95.6	127.9	79.4	54.7	42.9	85.4	74.6
Secoisolaricresinol	90.9	74.1	118.5	81.1	109.1	101.5	106.0	127.1	133.2	76.3	165.9	103.4
Coumestrol	5.2	20.6	7.8	21.3	38.3	54.5	52.0	68.4	34.4	46.5	67.0	72.2
Phytoestrogens	623.3	1112.5	874.3	3443.9	15729.3	35647.0	14669.6	19656.5	10786.5	19642.3	33397.1	25078.7
Year 9	African American		Caucasian		Chinese		Japanese					
	N = 434		N = 867		English (N=103)		Chinese (N=72)		English (N=136)		Japanese (N=65)	
	Median	Quartile Range	Median	Quartile Range	Median	Quartile Range	Median	Quartile Range	Median	Quartile Range	Median	Quartile Range
Isoflavones	285.9	684.5	390.8	2548.6	13799.2	42925.0	12445.0	24568.3	10334.2	13573.2	39251.1	49651.4
Formononetin	11.9	15.1	14.7	15.0	11.7	11.2	11.4	6.6	12.5	11.9	15	11.2
Daidzein	112.9	262.9	148.6	892.8	5410.7	20459.2	5276.4	10456.5	4343.8	5970.6	17561.6	21404.2
Genistein	152.5	420.5	209.4	1287.7	6923.9	21691.3	6338.0	10299.2	5430.8	7187.1	21079.2	22185.4
Glycitein	2.8	10.1	4.9	70.0	699.1	2754.4	656.9	1600.6	443.2	1077.5	3428	4139.3
Lignans	216.9	167.5	275.3	181.7	338.3	243.8	402.8	338.7	279.5	189.3	424.8	234.1
Matairesinol	12.8	14.5	11.9	10.9	11.0	9.5	9.8	10.0	11.8	9.6	11.7	8.1
Lariciresinol	66.3	58.0	86.7	67.3	106.9	74.5	109.4	95.7	88.8	68.9	134.8	81.6
Pinoresinol	32.8	31.6	48.2	53.5	97.8	85.6	135.2	106.4	51.4	43.0	93.8	70.3
Secoisolaricresinol	95.9	76.8	117.0	77.3	111.4	94.2	110.8	107.3	126.4	79.5	166.9	106
Coumestrol	4.7	14.3	4.7	14.8	30.2	42.5	33.7	46.2	34.3	48.1	83.0	118.9
Phytoestrogens	561.9	873.8	763.5	2624.7	14334.6	43083.8	12936.7	24588.6	10773.7	13550.0	39617.6	49901.3

Table 2

Major food contributors to phytoestrogen intakes in Japanese women by language, Study of Women's Health Across the Nation (SWAN) follow-up visit 5, 2001–2003, United States

English-speaking (N = 140)		Japanese speaking (N = 73)	
Total Phytoestrogen /	%	Total Phytoestrogen	%
	Cumulative %		Cumulative %
Fresh green soybeans/edamame	35.2%	Fermented soybeans/natto	29.6%
Tofu, bean curd	20.3%	Fresh green soybeans/edamame	25.2%
Soy milk	15.0%	Tofu, bean curd	20.6%
Roasted soybeans	13.0%	Soy milk	7.4%
Fermented soybeans/natto	4.1%	Roasted soybeans	6.0%
Dry spiced tofu	2.6%	Aburage/atsuage	3.3%
Isoflavone ²	%	Isoflavone	%
	Cumulative %		Cumulative %
Fresh green soybeans/edamame	35.8%	Fermented soybeans/natto	30.0%
Tofu, bean curd	20.6%	Fresh green soybeans/edamame	25.5%
Soy milk	15.3%	Tofu, bean curd	20.8%
Roasted soybeans	13.2%	Soy milk	7.5%
Fermented soybeans/natto	4.2%	Roasted soybeans	6.1%
Dry spiced tofu	2.7%	Aburage/atsuage	3.3%
Lignan ³	%	Lignan	%
	Cumulative %		Cumulative %
Coffee, not de-caf	14.6%	Green tea (black tea nutrients)	19.8%
Green tea (black tea nutrients)	11.9%	Chinese herbs in soup or tea	12.5%
Green salad	9.8%	Tea-Black/English	10.6%
Tea-Black/English	9.2%	Coffee, not de-caf	8.9%
Fresh green soybeans/edamame	7.0%	Fresh green soybeans/edamame	7.3%
Broccoli	4.9%	Green salad	4.3%
Salty snacks (chips, popcorn)	3.2%	Daikon radish/burdock/kabu	3.7%
Chocolate candy	2.9%		
Olive oil, canola oil	2.1%		
Green leafy vegetables	1.9%		
Coumestrol	%	Coumestrol	%
	Cumulative %		Cumulative %
Bean sprouts, regular	48.6%	Bean sprouts, regular	56.1%

	English-speaking (N = 140)		Japanese speaking (N = 73)	
Doughnuts, pastry	17.5%	66.1%	Tofu, bean curd	16.9%
Tofu, bean curd	15.5%	81.6%	Soybean sprouts	13.2%
Soybean sprouts	11.3%	92.9%	Doughnuts, pastry	9.0%
Alfalfa sprouts	3.6%	96.5%	Alfalfa sprouts	2.0%

¹Total phytoestrogen includes daidzein, genistein, formononetin, glycitein, coumestrol, lariciresinol, pinoreesinol, secoisolariciresinol and matairesinol. The contribution of each food was calculated as the ratio of phytoestrogen provided by that food to the phytoestrogen intake from all foods consumed

²Isoflavone includes daidzein, genistein, formononetin, and glycitein matairesinol. The contribution of each food was calculated as the ratio of isoflavone by that food to the phytoestrogen intake from all foods consumed.

³Lignan includes lariciresinol, pinoreesinol, secoisolariciresinol and matairesinol. The contribution of each food was calculated as the ratio of lignan provided by that food to the phytoestrogen intake from all foods consumed.

⁴Only top major food contributors are presented in the table.

Major food contributors in Chinese women by language, Study of Women's Health Across the Nation (SWAN) follow-up visit 5, 2001–2003, United States

Table 3

Total Phytoestrogen ¹	English-speaking (N = 137)		Chinese speaking (N = 68)	
	%	Cumulative %	%	Cumulative %
Soy milk	49.9%		Soy milk	50.6%
Tofu, bean curd	20.7%	70.6%	Tofu, bean curd	25.9%
Fresh green soybeans/edamame	9.5%	80.1%	Dry spiced tofu	5.3%
Dry spiced tofu	8.5%	88.6%	Fermented soybeans/natto	3.2%
Fermented soybeans/natto	2.4%	91.1%	Soybean sprouts	2.9%
Meat subst, soy ptn, soy burger	2.1%	93.1%	Fresh green soybeans/edamame	2.7%
Isoflavone ²				
	%	Cumulative %		%
Soy milk	50.7%		Soy milk	51.7%
Tofu, bean curd	20.9%	71.6%	Tofu, bean curd	26.5%
Fresh green soybeans/edamame	9.6%	81.3%	Dry spiced tofu	5.4%
Dry spiced tofu	8.7%	89.9%	Fermented soybeans/natto	3.2%
Fermented soybeans/natto	2.4%	92.4%	Soybean sprouts	2.9%
Meat substitute, soy protein, soy burger	2.1%	94.5%	Fresh green soybeans/edamame	2.8%
Lignans ³				
	%	Cumulative %		%
Chinese herbs in soup or tea	24.7%		Chinese herbs in soup or tea	23.2%
Tea-Black/English	12.8%	37.5%	Tea-Black/English	15.8%
Green tea (black tea nutrients)	7.7%	45.2%	Green leafy vegetables	10.8%
Green leafy vegetables	6.2%	51.4%	Green tea (black tea nutrients)	9.2%
Coffee, not de-caf	5.4%	56.8%	Coffee, not de-caf	4.5%
Broccoli	4.5%	61.4%	Soy milk	3.0%
Soy milk	4.1%	65.4%	Broccoli	2.7%
Green salad	3.3%	68.8%		
Fresh green soybeans/edamame	2.2%	71.0%		
Olive oil, canola oil	2.0%	73.0%		
Coumestrol			Coumestrol	
	%	Cumulative %		%
Bean sprouts, regular	53.5%		Bean sprouts, regular	64.8%

Total Phytoestrogen ¹	English-speaking (N = 137)	Chinese speaking (N = 68)
Tofu, bean curd	20.2%	13.7%
Soybean sprouts	10.5%	12.8%
Doughnuts, pastry	10.2%	5.2%
Alfalfa sprouts	2.9%	1.4%
		98.0%

¹Total phytoestrogen includes daidzein, genistein, formononetin, glycitein, coumestrol, lariciresinol, pinoresinol, secoisolariciresinol and matairesinol. The contribution of each food was calculated as the ratio of phytoestrogen provided by that food to the phytoestrogen intake from all foods consumed

²Isoflavone includes daidzein, genistein, formononetin, and glycitein. The contribution of each food was calculated as the ratio of isoflavone by that food to the phytoestrogen intake from all foods consumed.

³Lignan includes lariciresinol, pinoresinol, secoisolariciresinol and matairesinol. The contribution of each food was calculated as the ratio of lignan provided by that food to the phytoestrogen intake from all foods consumed.

⁴Only top major food contributors are presented in the table.

Major food contributors in African American by site, Study of Women’s Health Across the Nation (SWAN) follow-up visit 5, 2001–2003, United States

Table 4

Detroit		Cumulative%		Boston		Cumulative %		Chicago		Cumulative %		Pittsburgh		Cumulative %	
Phytoestrogen ¹				Phytoestrogen ¹				Phytoestrogen ¹				Phytoestrogen ¹			
Soy milk		72.3%		Soy milk		83.6%		Soy milk		83.3%		Soy milk		72.2%	
Tofu, bean curd		7.5%		Tofu, bean curd		9.0%		Meat substitute, soy protein, soy burger		5.7%		Doughnuts, pastry		8.5%	
Doughnuts, pastry		6.8%		Doughnuts, pastry		1.9%		Tofu, bean curd		4.1%		Tofu, bean curd		4.6%	
												Pancakes, waffles		3.8%	
												Meat substitute, soy protein, soy burger		1.7%	
														89.1%	
														90.8%	
Isoflavone ²				Isoflavone ²				Isoflavone ²				Isoflavone ²			
Soy milk		76.4%		Soy milk		85.7%		Soy milk		86.0%		Soy milk		78.2%	
Tofu, bean curd		7.9%		Tofu, bean curd		9.2%		Meat substitute, soy protein, soy burger		5.9%		Doughnuts, pastry		8.9%	
Doughnuts, pastry		6.9%		Doughnuts, pastry		1.9%		Tofu, bean curd		4.3%		Tofu, bean curd		5.0%	
Lignan ³				Lignan ³				Lignan ³				Lignan ³			
Coffee, not de-caf		12.8%		Tea-Black/English		15.6%		Coffee, not de-caf		11.4%		Coffee, not de-caf		11.0%	
Chinese herbs in soup or tea		12.4%		Coffee, not de-caf		11.8%		Green salad		10.5%		Green salad		9.7%	
Green salad		8.6%		Green salad		9.8%		Tea-Black/English		7.7%		Broccoli		6.9%	
Tea-Black/English		7.8%		Broccoli		6.3%		Green tea (black tea nutrients)		7.1%		Tea-Black/English		6.6%	
Broccoli		5.0%		Chinese herbs in soup or tea		5.4%		Broccoli		5.4%		Chocolate candy		5.3%	
								Chinese herbs in soup or tea		5.4%		Chinese herbs in soup or tea		4.8%	
												Salty snacks (chips, popcorn)		4.5%	
														48.8%	
														Cumulative%	
														53.3%	
Coumestrol				Coumestrol				Coumestrol				Coumestrol			
Doughnuts, pastry		54.9%		Doughnuts, pastry		40.8%		Bean sprouts, regular		45.5%		Doughnuts, pastry		59.8%	
Bean sprouts, regular		27.7%		Bean sprouts, regular		28.3%		Doughnuts, pastry		27.4%		Bean sprouts, regular		24.0%	
Alfalfa sprouts		8.1%		Tofu, bean curd		12.1%		Alfalfa sprouts		18.0%		Alfalfa sprouts		7.6%	
Tofu, bean curd		3.9%		Alfalfa sprouts		12.0%				93.2%		Tofu, bean curd		2.1%	
														93.5%	

¹Total phytoestrogen includes daidzein, genistein, formononetin, glycitein, coumestrol, laticresinol, pinoresinol, secoisolaricresinol and matairesinol. The contribution of each food was calculated as the ratio of phytoestrogen provided by that food to the phytoestrogen intake from all foods consumed

² Isoflavone includes daidzein, genistein, formononetin, and glycitein. The contribution of each food was calculated as the ratio of isoflavone by that food to the phytoestrogen intake from all foods consumed.

³ Lignan includes lariciresinol, pinoresinol, secoisolariciresinol and matairesinol. The contribution of each food was calculated as the ratio of lignan provided by that food to the phytoestrogen intake from all foods consumed.

⁴ Only top major food contributors are presented in the table.

Major food contributors in Caucasian by site, Study of Women’s Health Across the Nation (SWAN) follow-up visit 5, 2001–2003, United States

Table 5

	Detroit			Boston		Chicago		Los Angeles		Oakland		Pittsburgh	
Phytoestrogen	Soy milk	82.7%		Soy milk	69.2%	Soy milk	62.9%	Soy milk	52.2%	Soy milk	54.0%	Soy milk	57.6%
	Tofu, bean curd	4.8%	87.5%	Tofu, bean curd	17.6%	Tofu, bean curd	12.3%	J Soybeans-fresh green-edamame	73.1%	J Soybeans-fresh green-edamame	17.3%	Tofu, bean curd	10.0%
	soy ptn, soy burger	4.8%	92.2%	soy ptn, soy burger	7.0%	soy ptn, soy burger	6.6%	Tofu, bean curd	82.5%	Tofu, bean curd	12.9%	Doughnuts, pastry	8.3%
						Doughnuts, pastry	5.7%	J Soybeans-roasted	88.4%	J Soybeans-roasted	5.0%	Meat subst, soy ptn, soy burger	82.7%
						Pancakes, waffles	2.3%	Meat subst, soy ptn, soy burger	91.9%				
Isoflavone	Soy milk	86.1%		Soy milk	71.5%	Soy milk	68.8%	Soy milk	53.7%	Soy milk	55.2%	Soy milk	65.7%
	Tofu, bean curd	5.0%	91.1%	Tofu, bean curd	18.1%	Tofu, bean curd	13.4%	J Soybeans-fresh green-edamame	75.1%	J Soybeans-fresh green-edamame	17.6%	Tofu, bean curd	11.4%
	Meat subst, soy ptn, soy burger	5.0%	96.1%	Meat subst, soy ptn, soy burger	7.2%	Meat subst, soy ptn, soy burger	7.2%	Tofu, bean curd	84.7%	Tofu, bean curd	13.1%	Doughnuts, pastry	9.2%
						Doughnuts, pastry	6.0%	J Soybeans-roasted	90.8%	J Soybeans-roasted	5.1%	Meat subst, soy ptn, soy burger	93.9%
Lignan	Coffee, not de-caf	22.8%		Coffee, not de-caf	17.9%	Tea-Black/English	19.5%	Tea-Black/English	13.6%	Coffee, not de-caf	14.4%	Coffee, not de-caf	19.4%
	Green salad	9.8%	32.6%	Tea-Black/English	17.5%	Coffee, not de-caf	19.3%	Coffee, not de-caf	26.2%	Tea-Black/English	12.9%	Tea-Black/Englis	15.3%
	Broccoli	7.9%	40.6%	Green salad	9.7%	Green salad	9.8%	Green salad	38.2%	Green salad	11.8%	Green salad	11.0%
	Chinese herbs in soup or tea	6.8%	47.4%	Broccoli	7.0%	Broccoli	5.6%	Chinese herbs in soup or tea	44.9%	Broccoli	8.2%	Broccoli	6.0%
	Tea-Black/English	5.8%	53.1%	Wine or wine coolers	4.4%			Broccoli	50.9%	Chocolate candy	4.0%	Chocolate candy	5.6%
Coumestrol	Bean sprouts, regular	38.7%		Bean sprouts, regular	39.8%	Doughnuts, pastry	38.1%	Bean sprouts, regular	40.1%	Bean sprouts, regular	29.3%	Doughnuts, pastry	57.5%
	Doughnuts, pastry	31.6%	70.3%	Doughnuts, pastry	21.4%	Bean sprouts, regular	33.0%	Doughnuts, pastry	19.9%	Doughnuts, pastry	20.8%	Bean sprouts, regular	17.8%
	Alfalfa sprouts	18.3%	88.6%	Alfalfa sprouts	17.1%	Alfalfa sprouts	17.2%	Alfalfa sprouts	16.0%	Alfalfa sprouts	20.7%	Alfalfa sprouts	11.6%
	Tofu, bean curd	5.0%	93.6%	Tofu, bean curd	15.9%	Tofu, bean curd	5.2%	Tofu, bean curd	9.7%	Tofu, bean curd	13.2%	Tofu, bean curd	4.4%
						C Soybean sprouts (rice bowl)	8.7%	C Soybean sprouts (rice bowl)	94.4%	C Soybean sprouts (rice bowl)	11.5%		

¹Total phytoestrogen includes daidzein, genistein, formononetin, glycitein, coumestrol, laricresinol, pinoresinol, secoisolariciresinol and matairesinol. The contribution of each food was calculated as the ratio of phytoestrogen provided by that food to the phytoestrogen intake from all foods consumed

²Isoflavone includes daidzein, genistein, formononetin, and glycitein. The contribution of each food was calculated as the ratio of isoflavone by that food to the phytoestrogen intake from all foods consumed.

³Lignan includes laricresinol, pinoresinol, secoisolariciresinol and matairesinol. The contribution of each food was calculated as the ratio of lignan provided by that food to the phytoestrogen intake from all foods consumed.

⁴Only top major food contributors are presented in the table.