Selenium Content of Soybean Foods

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The selenium content of a variety of soybean-based foods was determined fluorometrically. Several soybean meat analogues averaged 0.375 μg of Se/g, whereas their meat counterparts contained an average of 0.205 μg/g, both well above the level of 0.10 μg/g believed to be nutritionally desirable. However, two meat extenders based on textured soy protein contained less than one-third the 0.199 μg/g found in ground beef. A canned soy-based chicken-style product had a nutritionally adequate concentration of selenium similar to that found in chicken breasts but several other soy-based products were below this level. A close correlation was observed between the protein content and the selenium content of a series of soybean derivatives. It is concluded that although some soybean analogues contain levels of selenium that are comparable to those in the corresponding ordinary foodstuffs, others do not; therefore all soybean-based products cannot be considered reliable sources of this essential trace element.

Previous analytical surveys carried out in this laboratory (Morris and Levander, 1970) have shown that meats and meat products in the American diet are a very important source of the nutritionally essential trace element, selenium (Schwarz and Foltz, 1957). Seafoods actually contain higher levels of selenium than meats but the biological availability of selenium in fish is low (Cantor et al., 1975), possibly due to the complexing of the element to heavy metals such as mercury (Ganther et al., 1972). Grains can contain substantial amounts of selenium, and milling grains into cereals was shown to cause only a modest decrease of the selenium concentration in the consumer product (Ferretti and Levander, 1974). However, grains and cereals are not reliable sources of selenium since the amount found in such foods is highly dependent upon its content in the soils where the plants were grown (Rosenfeld and Beath, 1964; Arthur, 1972). Fruits and vegetables are generally poor sources of selenium and those vegetables that do contain appreciable amounts may lose significant quantities as a result of certain cooking procedures (Higgs et al., 1972).

Because of the key role that meats and meat products play in human nutrition by contributing to an adequate intake of selenium and possibly other trace elements, the trend toward substituting meat protein with textured vegetable proteins to form meat analogues and meat extenders is viewed with concern by nutritionists interested in trace elements. Within the last decade, many edible products containing soybean derivatives have been developed by the food industry. Soybean concentrates containing up to 70% protein and isolates of 90–95% protein are already well established as aids in the production of meat-based products (Coppock, 1974). In 1969, annual sales of these "New Foods" were estimated at ten million dollars and are predicted to rise to two billion dollars by 1980 (Odell, 1969).

A search of the literature indicated that there were relatively few published data on the trace element composition of soybean and soy protein products. The purpose of this work was to determine whether soybean products and meat analogues of soy protein contain nutritionally adequate concentrations of selenium.

EXPERIMENTAL SECTION

Description of Samples. All of the soy food products and meats were purchased in the Beltsville, Md. area. The soy full-fat and defatted fractions, concentrates, and isolates were obtained from an industrial source. Representative samples of meats, soy–meat products, and canned products were passed through a tissue press and mixed thoroughly to obtain a homogeneous sample. Dry products, not already in a finely ground state, were ground in a Wiley Mill and mixed thoroughly. All samples were stored at −6°C until analyzed.

Selenium Analysis. The selenium content of duplicate 1-g samples of each product was determined by a modified version (Morris and Levander, 1970) of the fluorometric technique of Hoffman et al. (1968). The sample was wet-ashed with a nitric–perchloric–sulfuric acid mixture and the selenium then allowed to react with 2,3-diaminonaphthalene to form a fluorescing complex which was extracted into cyclohexane. The fluorescence of the complex was determined at an excitation wavelength of 365 nm and an emission wavelength of 525 nm. The precision of this technique was very good in our hands since the values obtained on replicate determinations seldom differed from one another by more than 5%. All results are presented on an "as received" basis except where otherwise noted, and the percent moisture values are included in the tables for computing the selenium values on a dry basis if desired. The percent moisture was determined by drying duplicate samples 16 hr at 105°C.

RESULTS AND DISCUSSION

Soy Meat Analogues. The data in Table I show that the average selenium content of each of the soy meat analogues was higher than that of its meat counterpart. The average selenium value for the soy products was 0.375 μg/g compared with 0.205 μg/g for the meat products. The data also show that with an increasing soy protein content, there was a corresponding increase in selenium. If one

Table I. Selenium Content of Soy Meat Analogues and Meats

	Soy meat analogue			Meat	
Product	Protein,[a] %	Moisture, % as received	μg of Se/g	Moisture, % as received	μg of Se/g
Beef, slices	23.0	54.1	0.517[b]	66.7	0.282
Ham, slices	21.4	56.1	0.368	66.1	0.125
Turkey, slices	18.8	51.9	0.327[c]	65.9	0.233
Chicken, slices	15.9	54.9	0.287	65.0	0.178
		Av	0.375		0.205

[a] Supplied by manufacturer. [b] Also contains wheat flour and garlic powder. [c] Also contains wheat protein.

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Table II. Soy Fractions: Protein vs. Selenium Content

Product	Protein,[a] %	Moisture, % as received	μg of Se/g
Full-fat soy meal	39.8	5.5	0.049
Hexane defatted soy meal	45.1	6.3	0.065
70% EtOH concentrate	60.8	8.8	0.091
pH 4.5 ppt. isolate	92.4	0.4	0.137

[a] Supplied by the manufacturer.

considers the human nutritional need for selenium to be similar to the 0.10 μg/g required in feed of animals to prevent deficiencies (Oldfield et al., 1971), then the concentration of selenium present in these samples would be considered nutritionally adequate.

Protein vs. Selenium Content of Soy Fractions. The data in Table II show that the concentration of selenium in the various processed forms of soy proteins increased as the percent protein content of these products increased. The range was from the nutritionally inadequate 0.049 μg/g for the full-fat soy meal to the nutritionally adequate 0.137 μg/g for the isolate.

Textured Vegetable Proteins. The amounts of selenium in the other food products analyzed are shown in Table III. The two textured vegetable proteins used as meat extenders and containing soy flour as an ingredient had an average selenium content of 0.056 μg/g which would be considered below that nutritionally required. This level of selenium was also considerably below the 0.199 μg/g reported in ground beef by Morris and Levander (1970). The other textured product, a meatless burger, had a high selenium value of 0.730 μg/g. This high value was probably due to the wheat protein and the mushrooms present in this product.

Chicken and Cheese Products. The soy meat, chicken style, had a nutritionally adequate selenium content of 0.123 μg/g which was essentially equivalent to the 0.116 μg/g found in chicken breasts by Morris and Levander (1970). The soy cheese sample had a selenium value of approximately one-third of the value found by Morris and Levander (1970) for a dairy cheese sample (0.037 vs. 0.090 μg/g). The selenium content of the soy cheese sample would be considered nutritionally inadequate.

Pancake and Waffle Mixes. The pancake and waffle mixes had adequate selenium levels. The selenium content of the soy mix was 0.529 μg/g while the average of the counterparts was 0.307 μg/g. All of these samples had wheat or other grains incorporated into them which may have contributed to the overall selenium content.

Roasted Soybeans and Peanuts. The average selenium content of 0.065 μg/g for roasted soybeans and toasted granules (snack foods) was below the 0.10 μg/g value believed to be considered nutritionally desirable. Even so, this value was double that of the roasted peanuts.

Soybeans and Baked Beans in Tomato Sauce or Molasses. The soybeans in tomato sauce and in molasses used in this study had twice the amount of selenium as baked beans prepared in a similar way (0.045 vs. 0.022 μg/g). Nonetheless, the amount of selenium present in all of these samples would be considered as nutritionally inadequate.

Soybeans and Soy Powders. The selenium values for soybeans and soy powders (other than soy protein, 96%) ranged from 0.070 to 0.093 μg/g with an average of 0.077 μg/g which would be considered only marginally adequate. The 96% protein soy sample had a higher value of 0.128 μg of Se/g which would be considered nutritionally adequate.

Table III. Selenium Content of Soybean Foods

Product	Moisture, % as received	μg of Se/g
Textured vegetable proteins		
Soy meat extender no. 1[a]	76.8	0.059
Soy meat extender no. 2[a]	75.8	0.053
Meatless burger	68.0	0.730
Chicken and cheese products		
Soya meat, chicken style	59.5	0.123
Soy cheese (soybeans, soyoil, peanuts)	71.6	0.037
Pancake and waffle mixes		
Soy wheat-based pancake and waffle mix	6.3	0.529
Wheat-based pancake and waffle mix	6.9	0.259
Buckwheat pancake and waffle mix	7.3	0.354
Roasted soybeans and peanuts		
Soybeans no. 1, roasted	1.3	0.063
Soybeans no. 2, roasted	2.4	0.071
Soybeans no. 3, roasted	1.9	0.039
Soybean granules, toasted	4.0	0.085
Peanuts, dry roasted	0.6	0.037
Peanuts, roasted	0.9	0.027
Canned soybeans and baked beans		
Soybeans, in tomato sauce	71.0	0.047
Soybeans, Boston style	66.3	0.042
Baked beans, in tomato sauce	71.6	0.018
Baked beans, in molasses	71.9	0.026
Soybeans and soy powders		
Green soybeans	5.0	0.071
Yellow soybeans	5.3	0.070
Soy powder, natural (24% oil)	5.3	0.075
Soy powder, low fat (6% oil)	2.7	0.093
Soy protein, 96%	7.2	0.128
Soy concentrates and isolates		
Concentrate no. 1	6.5	0.115
Concentrate no. 2	5.5	0.175
Isolate no. 1	4.5	0.153
Isolate no. 2	5.4	0.104
Isolate no. 3	5.3	0.140
Isolate no. 4	4.2	0.144
Isolate no. 5	4.3	0.130

[a] Water added as recommended on package.

Soy Concentrates and Soy Isolates. The selenium values for various soy concentrates and isolates are rather uniform and would be considered nutritionally adequate. A significant amount of selenium would be contributed to the final consumer product by these high protein concentrates and isolates when they are incorporated as supplemental ingredients in fabricated foods.

The results presented here show that the overall content of selenium in the fabricated soy products analyzed in this study was slightly higher than the amount found in their natural counterparts (0.196 vs. 0.145 μg/g). However, the average selenium content of the soy pancake mix and meat analogues that contained other ingredients, such as wheat and buckwheat, was 0.458 μg/g as compared to an average selenium content of 0.070 μg/g for the soybeans and soy products that did not have any of these added ingredients. It is known that the median selenium concentration of crops from wheat-producing states such as Nebraska and Kansas is much higher than that of crops from soybean-growing areas such as Illinois and Indiana (Kubota et al., 1967). Therefore, the contribution of the wheat to the overall selenium content of the soy-based product could have been appreciable.

Our results indicated that there existed a very good correlation between the protein content of a soy product and its selenium content. This tendency of selenium to follow protein in foods may possibly explain the low selenium levels found in the whole blood and plasma of Guatemalan children suffering from kwashiorkor, a protein deficiency disease (Burk et al., 1967).

The soy products that contained nutritionally adequate levels of selenium, such as the concentrates and isolates, could contribute significantly to meeting the nutritional need for the element. Cantor et al. (1975) found that the biological availability of selenium from plant materials was generally greater than that from materials of animal origin. For example, they reported that the nutritional availability of the selenium in soybean meal was about 60% whereas that of fish meal was only 23%.

The variation that was found in the selenium content of the soy products used in this study could be due to several factors: (1) differences in the selenium content of the soils on which the soybeans were grown; (2) losses of selenium due to the processing techniques used in the initial preparation of the soybeans, and (3) addition of other ingredients that may or may not contain substantial amounts of selenium.

The overall conclusion from this study is that although some soybean analogues contain levels of selenium that are comparable to those in the corresponding ordinary foodstuffs, others do not; therefore, all soybean-based products cannot be considered reliable sources of this essential trace element.

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Simple, Rapid Quantitative Determination of Lysine and Arginine by Thin-Layer Chromatography

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A simple, rapid method for the quantitative determination of lysine and arginine in wheat and tissue samples by thin-layer chromatography is described. Lysine and arginine are separated on thin layers of silica gel G; the chromatograms are sprayed with ninhydrin and developed under controlled conditions. Ethanol with copper sulfate is used as an eluting solvent and the optical density read at 510 mμ. As many as 12 chromatograms can be run and eluted in 2 days. Continuous attention is not required and the recovery is consistently above 96%.

The determination of amino acid composition of food proteins has been a subject of research for more than a century. Increased attention was given to this question in the last few years because of the recognition of the specific nutritive roles played by certain amino acids for growth, reproduction, lactation, and maintenance. The numerous and immense difficulties in developing reliable analytical procedures are actually best attested to by the vast literature on the subject. Considerable progress was made after the introduction of microbiological and chromatographic methods during the last two decades (Menden and Cremer, 1970).

Thin-layer chromatography on silica gel, developed especially for separating lipophilic substances, at first seemed less suitable in the case of hydrophilic substances. However, silica gel like cellulose contains a considerable amount of water, depending on its state of hydration. Its outstanding suitability for the chromatography of amino acids is therefore not too astonishing. Quantitative analysis of mixtures of amino acids by this technique is, however, beset with several difficulties. Lysine and arginine show very close values for most of the solvent systems reported and this is the major hurdle in the quantitative separation of these amino acids.

The present paper provides a method which is particularly appropriate for the estimation of these two amino acids in wheat and tissue samples by the technique of thin-layer chromatography.

EXPERIMENTAL SECTION

Reagents used included: (1) ethanol–water, freshly distilled ethanol was mixed with distilled water in the proportion of 70:30 (v/v); (2) phenol–water, freshly distilled phenol was mixed with distilled water in the proportion of 75:25 (v/v); (3) ninhydrin–spray reagent, 0.3 g of ninhydrin was dissolved in 100 ml of 1-butanol and mixed

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