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Database values do not reflect selenium contents of grain, cereals, and other foods grown or purchased in the upper Midwest of the United States

Anna-Sigrid Keck[a], John W. Finley[b,*]

[a]Department of Food Science and Human Nutrition, University of Illinois, Champaign-Urbana, IL, USA

[b]United States Department of Agriculture[1,2], Agricultural Research Service, Grand Forks Human Nutrition Research Center, Grand Forks, ND, USA

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Abstract

In an effort to establish reliable selenium (Se) values for foods, we have previously reported the variability of Se concentrations in foods commonly available in the upper Midwest. The present report extends this investigation to other foods as well as agricultural commodities, and has compared analyzed values to values predicted by the US Department of Agriculture National Nutrient Database for Standard Reference 16. Total variation in Se content was 72-fold (11-774 μg Se per 100 g) for wheat flakes, 57-fold (14-803 μg Se per 100 g) for wheat, and 11-fold (19-217 μg Se per 100 g) for beef. The variability between analyzed values and values found in the US Department of Agriculture National Nutrient Database for Standard Reference 16 were sufficiently large to make database values of little use for diet planning or assessment. These results emphasize that Se concentrations in foods vary, and professionals should be aware of this complication when designing diets with predicted amounts of Se.

Keywords: Selenium; Grains; Cereals; Foods; Nutrient database; Variation

1. Introduction

Selenium (Se) is an essential nutrient, and Se deficiency results in disease conditions in humans and animals [1]. Human consumption of greater amounts of Se than the recommended dietary allowance (RDA, 55 μg/d for adult men and women) [2] have been demonstrated to significantly reduce the risk for several cancers [3]. Individuals seeking to optimize their Se intake have been urged to do so through the consumption of whole foods and not dietary supplements [4].

Nutrient databases contain the average nutritional content of many foods. Health professionals often use databases such as the National Nutrient Database for Standard Reference maintained by the US Department of Agriculture (USDA) [5,6] for making dietary recommendations. Such systems work well if the nutrient of interest is present at consistent concentrations in a particular food. Selenium is not considered essential for plant growth, and plants do not control Se uptake [7]. Consequently, Se concentrations in plants generally reflect the concentration of Se in soils [8,9]. Soil Se concentrations in the United States vary greatly depending on the presence of underlying Se-containing geologic formations [10]. The upper Midwest and some regions of the west may have areas with high to very high soil Se concentrations, whereas the Northeast, Ohio Valley, and Pacific Northwest tend to have soils with low soil Se concentrations [11]. As a result, similar foods may have

* Corresponding author. A.M. Todd, Inc., Montgomeryville, PA 18936, USA. Tel.: +1 215 469 1972; fax: +1 215 628 8651.

E-mail address: finleyj2@amtodd.com (J.W. Finley).

[1] The US Department of Agriculture (USDA), Agricultural Research Service, Northern Plains Area, is an equal opportunity/affirmative action employer, and all agency services are available without discrimination.

[2] Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of others that may also be suitable.

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Table 1
Comparison of analyzed Se content in foods with database values present in the USDA National Nutrient Database for Standard Reference 16 [6]

Food item	Sample size (n)	μg Se per 100 g	Standard serving (g)	μg Se per standard serving
Breakfast cereals, ready-to-eat				
Analyzed				
Corn Flakes country (General Mills, Minneapolis, MN)	15	4.6 ± 0.1	30	1.4 ± 0.0
Wheat flakes (General Mills)	20	10.7 ± 0.8	30	3.2 ± 0.2
Wheat flakes, experimentally made from northwest ND wheat	10	43.3 ± 1.6	30	13.0 ± 0.5
Wheat flakes, experimentally made from southwest SD wheat	10	774.7 ± 29.8	30	232.4 ± 8.9
USDA database				
Corn Flakes, country (General Mills)	1	5.1	30	1.5
Wheat Bran Flakes (Kellogg's, Battle Creek, MI)	10	10.5 ± 0.6	30	3.2 ± 0.2
Wheaties (General Mills)	10	4.7 ± 0.9	30	1.4 ± 0.3
Cereals and grains, whole grain				
Buckwheat				
Analyzed				
Buckwheat grain, southwest ND	2	53.8 ± 0.3	100[a]	53.8 ± 0.3
Buckwheat grain, southwest ND	2	17.7 ± 1.4	100[a]	17.7 ± 1.4
Buckwheat grain, northeast ND	2	29.7 ± 0.5	100[a]	29.7 ± 0.5
USDA database				
Buckwheat	1	8.3	30	2.5
Buckwheat, groats, roasted, dry	1	8.4	30	2.5
Buckwheat flour, whole grout	1	5.7	30	1.7
Flax				
Analyzed				
Flaxseed (Neche), northwest ND	2	111.7 ± 1.2	12	13.4 ± 0.1
Flaxseed (Neche), northwest ND	2	102.8 ± 0.8	12	12.3 ± 0.1
Flaxseed (Neche), northwest ND	2	82.8 ± 7.7	12	9.9 ± 0.9
Flaxseed (Neche), northwest ND	2	62.7 ± 0.1	12	7.5 ± 0.0
Flaxseed (Neche), northwest ND	2	48.0 ± 0.3	12	5.8 ± 0.0
Flaxseed (Neche), northwest ND	2	34.2 ± 0.2	12	4.1 ± 0.0
Flaxseed (Omega), northwest ND	2	32.7 ± 0.1	12	3.9 ± 0.1
Flaxseed (Omega), northwest ND	2	82.8 ± 1.3	12	9.9 ± 0.2
Flaxseed (Omega), northwest ND	2	94.9 ± 1.0	12	11.4 ± 0.1
Flaxseed (Omega), northwest ND	2	37.5 ± 0.2	12	4.5 ± 0.0
Flaxseed (Flanders), northwest ND	2	182.4 ± 0.8	12	21.9 ± 0.1
Flaxseed (Pembina), northwest ND	2	195.5 ± 1.2	12	23.5 ± 0.1
Flax oil (Barleans)	2	3.9 ± 0.6	12	05 ± 0.1
USDA database				
Flaxseed	1	5.5	12	0.7
Oat				
Analyzed				
Oats, 1999, northeast Mont	3	25.4 ± 0.9	27	6.9 ± 0.2
USDA database				
Oats, instant, fortified, plain, dry	12	34.0 ± 4.5	27	9.2 ± 1.2
Oats, Quick Oats, dry (Quaker, Chicago, IL)	1	34.0	27	9.2
Wheat				
Analyzed				
Wheat, spring, 2000, southwest SD	3	802.9 ± 10.1	48	385.4 ± 4.9
Wheat, winter, 2000, northwest ND	3	69.9 ± 0.3	48	33.5 ± 0.1
Wheat, winter, 1999, northwest ND	8	66.8 ± 3.3	48	32.1 ± 1.6
Wheat, spring, 1999, northeast ND	2	29.0 ± 0.2	48	13.9 ± 0.1
Wheat, red spring, 2001, southeast ND	3	22.3 ± 2.1	48	10.7 ± 1.0
Wheat, red spring, 2000, southeast ND	3	18.9 ± 3.3	48	9.1 ± 1.6
Wheat, durum, dryland, 1999, northeast Mont	3	69.1 ± 1.0	48	33.2 ± 0.5
Wheat, durum, valley, 1999, northeast Mont	3	13.9 ± 0.3	48	6.6 ± 0.2
Wheat, winter, 2001, northwest Minn	3	20.4 ± 0.4	48	9.8 ± 0.2
USDA database				
Wheat flour, whole grain	3	70.7 ± 8.2	48	33.9 ± 3.9
Wheat flour bread, unenriched	15	39.7 ± 4.3	48	19.1 ± 2.1
Wheat, durum	1	89.4	48	42.9
Wheat, hard red, spring	1	70.7	48	33.9
Bread, whole wheat, commercially prepared	65	36.6 ± 0.4	28	10.2 ± 0.1
Bread, white, commercially prepared	3	17.3 ± 0.7	28	4.8 ± 0.2
Bread, whole wheat, prepared from recipe	1	38.6	28	10.8

Table 1 (*continued*)

Food item	Sample size (n)	μg Se per 100 g	Standard serving (g)	μg Se per standard serving
Meats				
Analyzed				
Beef, ground, raw, 2001, southwest SD	5	217.6 ± 8.9	113	246.8 ± 10.1
Beef, ground, cooked, dried, 2001, southwest SD	3	830.0 ± 12.3	28	232.4 ± 3.5
Beef, ground, cooked, dried, northeast ND (2)[a]	5	66.4 ± 2.8	28	18.6 ± 0.8
Beef, eye of round, raw, northeast ND (4)	3	18.7 ± 0.6	113	21.2 ± 0.7
Beef, sirloin tip, raw, northeast ND (2)	3	21.9 ± 0.7	113	24.9 ± 0.8
Pork, raw, southeast ND	5	62.3 ± 11.4	113	70.7 ± 12.9
Pork, rump roast, raw, northeast ND (1)	3	18.5 ± 0.2	113	20.9 ± 0.2
Pork, rump roast, raw, northeast ND (3)	3	17.7 ± 0.2	113	20.0 ± 0.2
USDA database				
Beef, ground, 95% lean, raw	72	17.4 ± 1.0	113	19.7 ± 1.1
Beef, round, eye of round, 1/2″ fat, raw	1	20.8	113	23.5
Beef, chuck, top blade, 1/4″ fat, USDA choice, raw	1	30.0	113	33.9
Beef, chuck, clod roast, 1/4″ fat, USDA select, raw	3	10.0 ± 0.0	113	11.3 ± 0.0
Pork, ground, raw	5	24.6 ± 4.5	113	27.8 ± 5.1
Pork, loin, tenderloin, raw	5	28.9 ± 4.7	113	32.7 ± 5.3
Pork, center rib, boneless, raw	5	35.4 ± 3.6	113	40.0 ± 4.0
Pork, cured, salt pork, raw	1	5.8	113	6.6
Miscellaneous				
Analyzed				
Milk 2% (Land 'O Lakes, Franklin Park, IL)	5	4.7 ± 0.1	240	11.4 ± 0.2
Milk 2% (Cass Clay, Fargo, ND)	5	4.6 ± 0.2	240	10.9 ± 0.5
Diet 7-up (Dr Pepper/Seven up, Inc, Norlake, IL)	2	0.0 ± 0.0	355	0.1 ± 0.0
Diet Mountain Dew (Pepsi-cola Co, Watertown, WI)	2	0.0 ± 0.0	355	0.1 ± 0.0
Diet Coke (Coca-cola Co, Atlanta, GA)	2	0.0 ± 0.0	355	0.1 ± 0.0
Nestea, iced, lemon, sugar sweetened, powder (Nestle, Glendale, CA)	2	0.1 ± 0.0	23	0.0 ± 0.0
Water, sparkling, black cherry (Klarbrunn; Pepsi-cola Co)	2	0.0 ± 0.0	355	0.1 ± 0.0
Coffee, regular, instant (Taster's Choice; Nestle)	2	2.8 ± 0.0	1.5	0.0 ± 0.0
Black pepper (Schillings, McCormick & Co, Hunt Valley, MD)	2	14.8 ± 0.4	0.5	0.1 ± 0.0
Pasta				
Analyzed				
Italian made (dry)				
Angel hair (Venecia, Wessanen, St Augustine, FL)	2	6.7 ± 0.1	57	3.8 ± 0.1
Conchigle shells (Venecia)	5	8.3 ± 2.5	57	4.7 ± 1.4
Fetuccini (Venecia)	3	6.5 ± 0.7	57	3.7 ± 0.4
Linguini (Venecia)	7	5.7 ± 1.0	57	3.3 ± 0.6
Penne rigate (Venecia)	3	11.6 ± 5.1	57	6.6 ± 2.9
Penne ditali (Venecia)	4	7.2 ± 1.1	57	4.1 ± 0.7
Rotini springs (Venecia)	2	24.9 ± 3.0	57	14.2 ± 1.7
Tricolor penne (Venecia)	2	7.6 ± 0.4	57	4.3 ± 0.2
Bowties (Davinci, World Finer Foods, Bloomfield, NJ)	3	15.4 ± 2.9	57	8.8 ± 1.6
Fusilli (Davinci)	2	12.5 ± 0.0	57	7.1 ± 0.0
Fusilli (Davinci)	2	7.1 ± 0.2	57	4.0 ± 0.1
Rotini (Davinci)	2	16.1 ± 3.3	57	9.2 ± 1.9
Seashells (Davinci)	2	12.9 ± 4.1	57	7.3 ± 2.4
American made (dry)				
Fettucine (Creamette, New World Pasta Co, Harrisburg, PA)	2	74.1 ± 6.7	57	42.2 ± 3.8
Penne (Creamette)	1	88.0 ± 0.0	57	50.2 ± 0.0
Shells (Creamette)	2	102.6 ± 11.1	57	58.5 ± 6.3
Shells (Leonardo, Cando, ND), made in ND	1	100.0 ± 0.0	57	57.0 ± 0.0
Spagetti (Market Pantry, Target, Minneapolis, MN)	2	139.0 ± 7.0	57	79.2 ± 4.0
USDA database				
Macaroni, enriched, dry	1	35.5	57	20.2
Spaghetti, enriched, dry	1	35.5	57	20.2
Whole-wheat spaghetti, dry	1	41.6	57	23.7
Snacks				
Analyzed				
Corn chips, original (Old Dutch, St Paul, MN)	5	8.8 ± 0.2	28	2.5 ± 0.1
Corn chips, fritos original (Frito Lay, Plano, TX)	5	8.5 ± 0.4	28	2.4 ± 0.1

(*continued on next page*)

Table 1 (*continued*)

Food item	Sample size (n)	μg Se per 100 g	Standard serving (g)	μg Se per standard serving
Corn tostadas, 100% corn white (Frito Lay)	5	6.5 ± 0.2	28	1.8 ± 0.1
Corn tortilla chips, rest style (Old Dutch)	5	23.4 ± 0.3	28	6.6 ± 0.1
Crackers, Townhouse (Keebler, Battle Creek, MI)	5	2.2 ± 0.2	16	0.4 ± 0.0
Crackers, Ritz (Nabisco, Kraft Foods, East Hanover, NJ)	5	7.0 ± 0.3	16	1.1 ± 0.0
Crackers, snack (Our Family, Nash Finch Co, Minneapolis, MN)	5	9.9 ± 0.3	16	1.6 ± 0.0
Pretzels, tiny twist (Old Dutch)	5	6.9 ± 0.1	28	2.0 ± 0.0
Pretzels, fat free, tiny twists (Rold Gold, Frito Lay)	5	6.6 ± 0.1	28	1.9 ± 0.0
Wafers, vanilla (Our Family)	5	2.1 ± 0.1	30	0.6 ± 0.0
Wafers, Nilla (Nabisco)	5	5.3 ± 0.2	30	1.6 ± 0.1
USDA database				
Crackers, wheat, regular	8	6.3 ± 1.0	16	1.0 ± 0.2
Crackers, whole wheat	5	14.7 ± 7.7	16	2.4 ± 1.2
Crackers, saltines	51	11.7 ± 0.1	16	1.9 ± 0.0
Cookies, vanilla wafers, higher fat	3	11.3 ± 1.3	30	3.5 ± 0.4
Cookies, sugar wafers with cream filling, regular	1	2.4	30	0.7
Snacks, corn based, extruded, chips, plain	39	6.7 ± 0.8	28	1.9 ± 0.2
Snacks, pretzels, hard, plain, salted	3	5.8 ± 1.3	28	1.6 ± 0.4
Vegetables				
Analyzed				
Broccoli florets 1999, fresh produce purchased in ND (1)	5	2.8 ± 0.2	71	2.0 ± 0.2
Broccoli florets 2002, fresh produce purchased in ND (1)	20	1.2 ± 0.1	71	0.9 ± 0.1
Broccoli florets 2003, central Calif	3	1.3 ± 0.2	71	0.9 ± 0.1
Broccoli florets 2000, west side of central valley of Calif	5	20.4 ± 0.4	71	14.5 ± 0.3
Mushrooms, shitake, dried, Ohio	3	4.9 ± 0.6	15	0.7 ± 0.1
USDA database				
Broccoli, raw	8	2.5 ± 0.1	71	1.8 ± 0.1
Broccoli, frozen, spears, unprepared	9	1.9 ± 0.3	71	1.3 ± 0.2
Broccoli, frozen, chopped, unprepared	1	2.8	71	2.0
Broccoli, flower cluster, raw	1	3.0	71	2.1

Selenium content (microgram Se per 100 g)[b], standard serving, and amount of Se (microgram) per serving[b] of grain, cereals, and other foods grown or purchased in the upper Midwest[c] compared with database values. All values are on a fresh weight basis.

[a] This number is a daily intake value and not a standard serving value.

[b] Values shown are mean ± SD (n = 1-20), if SE was available in the database.

[c] Numbers within parenthesis indicated that the same food item was obtained from different local stores in the Grand Forks area of North Dakota: (1), Hugo's; (2), Super One; (3), L & M Meats; and (4), Levers.

very different concentrations of Se depending on the origin of the raw agricultural product. Thus, because similar foods may be grown in several locations, use of single database Se concentrations may lead to erroneous conclusions.

We have previously reported variability of Se concentrations in common foods purchased from grocery stores or obtained from local sources in eastern North Dakota [12]; the present report extends this to different foods as well as some agricultural commodities. Moreover, when analyzed values were compared with values in the USDA National Nutrient Database for Standard Reference 16, the variability was sufficiently large to make database values of little use for diet planning or assessment.

2. Methods and materials

Foods and products purchased from local grocery stores in eastern North Dakota or collected directly from agricultural producers were analyzed in duplicate by Hydride Generation Atomic Absorption Spectrometry after wet and dry digestion as previously reported [12]. Quality control was maintained with matrix-matched certified standards (certified reference materials from the National Institute for Standards and Technology: NIST 1577B Bovine Liver, 765.5 ± 45 ng Se per gram; NIST 15167A Wheat Flour, 1323.8 ± 51.9 ng Se per gram; NIST 1515 Apple Leaves, 52.2 ± 8.6 ng Se per gram). Analyzed values were only accepted if the values were within the range of values for the certified standards. Standard serving sizes were obtained from the USDA National Nutrient Database for Standard Reference 16 [6], except for flax and buckwheat, for which serving sizes were obtained from the scientific literature [13,14].

3. Results

The Se concentration and amount of Se in a standard serving of analyzed foods is shown in Table 1 and compared with values present in the USDA National Nutrient Database for Standard Reference 16.

The Se content of pasta products showed a 24-fold variation, ranging from 5.7 to 139.0 μg/100 g. Most American-made pastas had Se concentrations more than

10-fold greater than comparable Italian brands. Wheat collected from producers across the northern plains showed even more variability, ranging from 14 to 803 μg Se per 100 g wheat (>57-fold variability).

Buckwheat and flax also are grown primarily in the upper Midwest. The Se content of whole flaxseeds varied from 34 to 182 μg Se per 100 g (multiple varieties were analyzed). Only one variety of buckwheat is grown in North Dakota, and the Se concentrations of whole buckwheat groats ranged from 18 to 54 μg Se per 100 g.

Fresh broccoli florets purchased in eastern North Dakota had a 2.3-fold range in Se concentrations (1.2-2.8 μg Se per 100 g) and were similar to broccoli purchased in central California (1.3 μg Se per 100 g). However, broccoli from central California but irrigated with water from a seleniferous aquifer contained almost 10-fold more Se (20.4 μg/100 g).

The Se content of meat varied more than 12-fold (18 to 217 μg/100 g fresh weight). The range of Se concentrations in pork was 17.7 to 62.3 and, in beef, was 18.7 to 217.6 μg/100 g. A single site in South Dakota provided the beef with an exceptionally high Se level, whereas the Se content of other beef samples was much less variable (18.7-66.4 μg/100 g).

4. Discussion

The present data demonstrate great variability in Se concentrations in similar foods and agricultural products (Fig. 1). Comparison with the USDA National Nutrient Database for Standard Reference 16 (Table 1) suggests that such variation may make it very difficult to use the database for assessment of specific diets. Our sampling occurred only in one small geographic region; thus, these values are not intended to be representative of all values used to derive the database value. Our sampling shows that specific values are often quite different from the database average. The USDA National Nutrient Database was created primarily to provide estimates of average intake for large populations and not specific intakes by specific brands, and for that task, the database values may be more accurate.

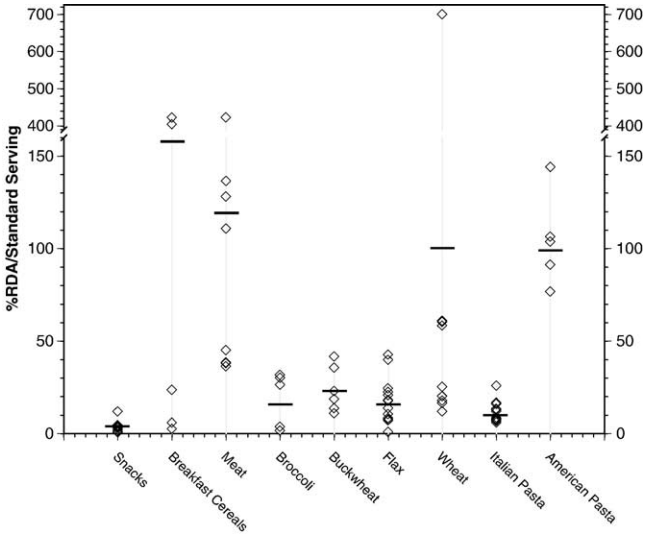

Fig. 1. Percentage of recommended daily allowance of Se (55 μg/d) in one standard serving in different types of foods. Each data point (◇) is mean samples analyzed in at least duplicate samples. Mean of the data points in each food category is displayed by a bold horizontal line.

Grain and grain products are often cited as primary sources of Se [15]. According to the USDA Nutrient Database, a single serving of spaghetti will provide 20.2 μg of Se, whole-wheat spaghetti will provide 23.7 μg of Se, and macaroni will provide 20.2 μg of Se (Table 1). When pasta brands were analyzed individually, American-made spaghetti provided 79.2 μg per serving, whereas Italian angle hair pasta provided only 3.8 μg per serving. The average Se content of all Italian pasta brands was 6.2 μg per serving, whereas the average of all American pasta was 57.4 μg. Consequently, if an individual ate a variety of all of the imported and domestic pastas analyzed, their average Se intake would be approximately 20.5 μg per serving or almost identical to the amount predicted by the USDA National Nutrient Database for Standard Reference 16; but individuals develop brand loyalties [16] and different areas of the country carry different predominate products, meaning that it is unlikely that an individual would eat an "average" pasta. If they consumed primarily American brands, they would receive the Se RDA [2] from pasta alone, but imported Italian brands would contribute a negligible amount of Se to the diet.

An analysis of multiple wheat samples collected across the northern plains demonstrates that the variation of Se in pasta is reflective of the variation of Se in wheat. The intention of the present data is to show the potential variation of Se in wheat and not to define the sources and causes of the variations. Consequently, analyzed samples are not representative of all types and locations of wheat production in the area. If individual batches of wheat were used to make bread, they would supply from 3.9 to 224.8 μg of Se per 28 g serving (~1 slice of bread). The USDA National Nutrient Database for Standard Reference 16 estimates that wheat bread would supply 4.8 to 10.8 μg Se per standard serving (28 g, Table 1). It should be noted that spring wheat containing 18.9 μg Se per 100 g was produced in an area similar geographically and approximately 100 miles away from the wheat that contained 802.9 μg Se per 100 g.

Beef is the single greatest source of Se in the North American diet [15], and the USDA National Nutrient Database for Standard Reference 16 lists a Se content of 10 to 30 μg per serving (Table 1). In the United States, beef cattle are transferred in feedlots before slaughter; and while there, most animals are fed defined diets supplemented with Se. Consequently, most beef from retail outlets probably contain similar amounts of Se. However, specialty beef such as organically raised beef is increasing in popularity [17], and we have shown that the Se content of beef can vary

between 19 and 247 μg Se per serving. The Se content of beef previously has been reported to vary according to geographic origin of the animal and feeds supplied to the animal [8].

Buckwheat and flaxseed are not standard items in the diet of most North Americans, but inclusion of both foods may provide health benefits. Flaxseed is a plant source of ω-3 fatty acids, and some dietary guidelines suggest adding approximately 12 g of whole flaxseed to the daily diet [13,18]. The USDA National Nutrient Database for Standard Reference 16 lists flaxseed as a poor source of Se (5.5 μg/100 g); a single serving would supply only 1% to 2% of the RDA [2]. However, much US flaxseed is grown in seleniferous areas, and the present analyses indicate that a single serving of most of the sampled flaxseed would supply at least 20% of the Se RDA [2] and some samples would supply almost 50%. A daily intake of 100 g of buckwheat may be beneficial for lowering blood pressure [14] and controlling blood glucose [19]. Buckwheat Se concentrations in the USDA National Nutrient Database for Standard Reference 16 range from 5.7 to 8.4 μg/100 g and a daily intake of 100 g of buckwheat is predicted to supply 10% to 15% of Se RDA [2], whereas buckwheat analyzed in the present study would supply 18 to 54 μg Se per 100 g or 33% to 98% of Se RDA [2]. Consequently, although flaxseed and buckwheat are minor dietary components, sources from the northern plains of the United States could supply a substantial part of the daily requirement for Se.

In conclusion, use of databases for estimating individual Se intakes or development of specific diets may be problematic because of the large variation in Se content of similar foods. Analysis of specialty and infrequently consumed foods may be especially prone to error. However, databases are probably more suitable for estimation of Se intake of large heterogeneous populations consuming multiple brands and products.

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