ELSEVIER

PII: S0308-8146(96)00188-4

Food Chemistry, Vol. 58, No. 1-2, pp. 29-32, 1997

0308-8146/97 $17.00+0.00

The selenium content of selected food from the Slovak Republic

Jana Kadrabova,* Alexander Madaric & Emil Ginter

Institute of Preventive and Clinical Medicine, Limbova 14, 833 01 Bratislava, Slovak Republic

(Received 5 January 1996; revised version received 26 March 1996; accepted 26 March 1996)

The selenium concentrations in various food commodities such as meat, fish, milk and milk products, cereal products, fruits, vegetables and beverages have been determined by using the continuous hydride generating method. The highest selenium content was found in the foodstuffs of animal origin in chicken meat and eggs, due to selenium addition to the feeds, and fish. The lowest selenium levels were found in fruit and vegetables. The selenium levels, on the wet weight basis, found in the Bratislava area, Slovakia, are comparable to that of West Germany. Copyright © 1996 Elsevier Science Ltd

INTRODUCTION

Being an essential trace element, the nutritional selenium status in humans is of great importance. There is a well-known consequence of nutritional selenium deficiency (so-called Keshan disease) occurring in China (Chen *et al.*, 1980). Selenium deficiency may be a risk factor for cardiovascular diseases (Salonen *et al.*, 1982) and cancer (Salonen *et al.*, 1984). There is a direct relationship between selenium intake and blood selenium concentration (Levander, 1982) and it is thought to be that blood plasma Se reflects short term exposure whilst red blood cell and whole-blood Se reflect long term exposure (Environmental Health Criteria, 1987). Low selenium status in the Slovak population (Madaric *et al.*, 1994) is thought to be the result of low selenium content of the diet. Selenium status in populations belonging to different geographical areas can vary greatly due to the content of this element in the soil and consequently in the food chain. As regards Slovakia, there is a gap concerning the data of selenium intake or selenium content of the generally consumed foods. Although from a geographical point of view there is a great variation in the selenium content of foods, bioavailability of this element from foods must be considered. Bioavailability of the nutrient is the most important criterion when judging the nutritional quality of food for maintenance of normal metabolic function. The bioavailability of food Se is affected by its chemical form and other dietary factors (Combs & Combs, 1986; Smith & Picciano, 1987).

There is little information on the chemical forms of selenium in food (Environmental Health Criteria, 1987), which is one of the bioavailability-determining factors. The present paper reports the total selenium content of consumed foods in Slovakia.

*To whom correspondence should be addressed.

MATERIALS AND METHODS

Materials

Reagents

All chemicals used were of analytical reagent grade. The selenium stock solution containing 1000 mg Se/litre was purchased from Fision Standard Metal Solution, England. Standard solutions were freshly prepared by dilution of a stock solution of Se with deionized water and hydrochloric acid to the final concentration of 1.7 M HCl. 1% (w/v) sodium borohydride solution ($NaBH_4$) in 0.1% (w/v) sodium hydroxide was freshly prepared and filtered (Whatman 541 filter paper).

Samples

Three hundred and twenty food samples of animal and plant origin and beverages obtained from food shops, markets and private households in the Bratislava area were used. The samples were weighed into mineralization containers. Weights (wet weight) of the samples were in the range of 0.2–1.2 g except for vegetables and fruits where 2.5–3.0 g were taken for analysis.

Processing

Wet digestion

All glassware used was acid-washed to avoid contamination. To weighed samples, 7 ml of acid mixture of HNO_3–$HClO_4$–H_2SO_4 (5:1:1, v/v) were added. The mineralization containers, with reflux and cooling, were gradually heated until solutions became clear. The heating temperature of 195°C was maintained until no white fumes of perchloric acid were observed. This step was performed without reflux.

Analytical methods

Selenium determination

Spectrophotometric determinations of Se concentration in the samples were carried out on a Philips model PU 9200 atomic absorption spectrophotometer equipped with a PU 9360X continuous-flow vapour system (Unicam analytical systems) after reduction of Se (VI) to Se (IV) with 5 M HCl added to the cooled samples and then heated for 15 min at 90°C. Operating conditions of the instrument were the same as described previously (Madaric *et al.*, 1994).

Table 1. Selenium recovery from different food matrices (mean ± SD)

Food sample	Se added ppb	Found ppb	Recovery %
Egg white	0	85.0 ± 5.1	
	66.5	147.5 ± 7.5	97.4
	133.0	210.0 ± 9.1	96.4
Egg yolk	0	227.5 ± 11.9	
	200.0	465.0 ± 17.2	97.4
	400.0	660.0 ± 20.4	97.5
Potato	0	0.3 ± 0.04	
	8.0	7.8 ± 0.69	94.0
	16.0	15.3 ± 1.30	93.9
Garlic	0	103.2 ± 5.2	
	25.0	126.6 ± 6.3	98.8
	50.0	149.0 ± 7.2	97.4
Pork ham	0	59.9 ± 3.1	
	66.5	125.0 ± 6.3	98.9
	133.0	195.0 ± 7.9	101.1
Milk	0	6.5 ± 0.5	
	6.7	13.3 ± 1.1	100.8
	13.4	19.5 ± 1.6	98.0

RESULTS AND DISCUSSION

The continuous-flow vapour system for hydride generation was performed with AAS, which enabled the detection level for Se be measured at the ng/g level or below. The detection limit (3×SD blank) for Se was 0.24 μg/l. The accuracy of Se determination was checked by analysing the standard reference materials of Bovine Liver 12-2-01 (Institute of Metrology, Slovakia), ARC/CL wheat flour (Finland) and other food matrices by using recovery tests (Table 1). The mean results for bovine liver for eight determinations and for three wheat flour determinations were 322.0 ± 12.3 μg/kg and 55.9 ± 1.1 μg/kg, respectively. Certified values are 325.0 ± 14.0 μg/kg and 57.0 ± 5.5 μg/kg, respectively. The Se recovery from different matrices (four independent sample preparations) is between 93.9 and 101.1% and can be considered satisfactory (Table 1). Within-run precision was estimated by measuring the Se concentrations of some food samples 10 times. The corresponding CVs were in the range of 1.1–3.8%. The present results of Se content in food and beverage samples are shown in Table 2.

Selenium concentration of meat samples varies from 18 ng/g for beef (brisket) to 231 ng/g for pork liver, except pork liver imported from England with Se concentration up to 575 ng/g. The highest Se concentration was found in liver of beef, pork and chicken which was about 3–4 times higher than that of the corresponding skeletal muscles. Se content in our meat is lower than in France (Simonoff *et al.*, 1988) and West Germany (Oster & Prellwitz, 1989). Pork and chicken had the highest Se contents due to supplementation of animal feed with Se. Addition up to 220 μg Se/kg feed is allowed for chicken and pigs from the years 1990 and 1992, respectively (Lichvár *et al.*, 1992). Meat from animals grown in a private farmer's yard and fed the feed of the local origin without Se addition had much lower Se concentration.

Whole eggs contain 215 ng Se/g, the white having four times lower Se concentration than yolk. The rather high Se content of eggs is due to Se supplementation of the laying hens as was mentioned for chicken. Up to

Table 2. Selenium concentration in food products consumed in Slovakia (mean ± SD)

Food product	n	Se [ng/g wet weight]	Range
Beef			
Round	10	23.4 ± 5.0	(17.3–31.2)
Peroneus muscle	5	57.2 ± 15.6	(30.0–66.7)
Brisket	4	18.3 ± 8.0	(10.4–26.1)
Roast beef	2	20.3/35.7	
Liver	10	95.6 ± 37.0	(58.1–154.8)
Lung	4	31.9 ± 1.3	(30.0–33.4)
Heart	4	51.5 ± 3.3	(47.0–55.2)
Pork			
Shoulder[a]	4	105.6 ± 3.6	(102.1–109.6)
Shoulder[b]	2	64.7/68.9	
Leg	4	77.7 ± 15.9	(55.3–90.0)
Neck of pork	6	99.6 ± 45.6	(57.3–164.3)
Liver	3	230.9 ± 25.2	(204.8–255.0)
Liver[c]	5	575.0 ± 62.2	(507.0–636.4)
Lamb			
Leg	2	44.7/48.0	
Poultry–Chicken			
Leg[a]	7	140.1 ± 36.8	(94.3–215.1)
Leg[b]	2	33.0/37.4	
Breast	3	123.2 ± 8.1	(116.2–132.0)
Liver	5	398.3 ± 57.2	(323.4–464.8)
Poultry–Duck			
Leg[b]	2	18.0/19.1	
Liver[b]	2	73.0/78.0	
Fish			
Fillet of sea fish (frozen)	2	505.0/520.7	
Carp	4	243.3 ± 29.2	(204.0–272.5)
Trout	2	196.1/207.0	

Table 2.—*contd.*

Food product	n	Se [ng/g wet weight]	Range
Meat Products			
Pork ham	3	68.7 ± 13.1	(60.5–83.4)
Pork sausage	2	44.7/55.3	
Salami	7	32.0 ± 6.7	(23.6–41.5)
Poultry salami	2	92.0/94.0	
Eggs			
Whole	5	215.2 ± 20.7	(189.2–233.4)
Yolk	12	342.2 ± 46.6	(281.7–443.0)
White	12	87.5 ± 7.1	(81.6–108.8)
Milk Products			
Pasteurized cow milk[d]	10	7.1 ± 2.3	(4.0–11.6)
Fresh goat milk[b,d]	3	7.5/9.0/9.5	
Yoghurt with fruits	2	4/7.5	
Cream cheese	3	27.6 ± 3.7	(24.4–31.7)
Processed cheese	4	22.5 ± 3.5	(19.2–27.2)
Cheese of Edam origin	4	40.5 ± 1.3	(38.6–41.4)
Cereal Products			
Wheat flour	11	25.1 ± 7.4	(15.0–32.3)
Oat flakes	2	12.2/16.2	
White bread	6	17.6 ± 2.6	(14.3–21.5)
Rye bread	3	16.5 ± 1.7	(15.5–18.5)
Rolls	12	21.2 ± 3.3	(15.9–26.0)
Egg noodles	3	56.8 ± 3.3	(53.0–59.0)
White rice	2	23.5/34.0	
Corn	4	18.0 ± 3.3	(12.8–22.3)
Vegetables			
Onion	6	5.8 ± 8.0	(0.7–21.9)
Garlic	8	57.9 ± 47.5	(1.4–129.0)
Leek	2	1.6/2.6	
Green peas	7	13.5 ± 8.4	(3.1–27.2)
Split peas	4	43.5 ± 7.7	(32.5–50.5)
Beans (white and brown)	6	37.5 ± 24.5	(19.2–82.0)
Lentils	2	27.5/79.7	
Soybeans	2	28.4/50.6	
Lettuce	3	0.9 ± 0.4	(0.5–1.3)
Carrot	6	1.3 ± 0.7	(0.7–2.6)
Parsley	5	2.0 ± 1.1	(0.7–3.2)
Radish	2	0.7/0.7	
Tomato	3	0.5 ± 0.2	(0.3–0.7)
Green pepper	3	0.7 ± 0.1	(0.6–0.7)
Kohl-rabi	5	2.1 ± 0.9	(0.7–3.1)
Cauliflower	4	2.2 ± 1.2	(1.2–4.7)
Potato	8	3.5 ± 2.2	(0.5–5.7)
Cabbage	3	2.0/4.0/16.6	
Mushrooms			
Chanterelle	2	12.8/20.1	
Boletus	2	175.5/239.8	
Champignon (cultivated)	3	50.5/54.5/95.2	
Fruits			
Strawberry	2	3.1/3.3	
Cherry	2	1.1/1.3	
Apple	6	1.4 ± 0.6	(0.8–2.5)
Orange	2	1.3/0.8	
Tangerine	2	1.6/2.0	
Banana	3	5.8/5.8/7.9	
Beverages[d]			
Tea	2	0.7/0.8	
Coffee	2	0.6/0.8	
Fruit lemonade	3	0.6/0.7/1.0	
Cola drink	1	0.7	
Beer	3	0.7/1.3/2.0	

[a]Animals bred in industrial units.
[b]Animals bred in private households.
[c]Import from England.
[d]Expressed in ng/ml.

521 ng/g of Se was found in fish. Fresh water fish (carp and trout) have only half of this content. Milk and milk products (yoghurt, curd and cheese) contained up to 40 ng Se/g. Pasteurized cow's milk contained 7 ng/g. Se content in high protein dairy products, e.g. cream cheese and processed cheese, is 3–4 times higher than in milk and, in cheese of Edam origin, six times higher. Fresh goat's milk contains 9 ng Se/g.

Concentration of Se in wheat flour is rather low and ranges from 15 to 32 ng/g. Values for wheat flour and bread are comparable with that reported for West Germany (Oster & Prellwitz, 1989).

Fruit and vegetables had low Se concentrations with the exception of dry legumes (split peas, lentils and beans), where higher Se levels were found. Se is found in the protein fraction of foods, so plants with low protein content are poor sources of the element. Garlic accumulates more Se than other crops and is a frequently used vegetable in Slovakia. Se content in Allium family plants (garlic and onion) varies in wide ranges of 1–129 ng/g and 1–22 ng/g, respectively. Great variation in Se concentration in garlic was also reported in Serbia (Maksimovic *et al.*, 1992).

In low selenium areas, low Se levels in the food chain cause a correspondingly low Se status in man. The present data support the view of a rather low Se content of domestic foods which is comparable to the data of West Germany (Oster & Prellwitz, 1989) and which are the cause of low Se status in the Slovak population (Madaric *et al.*, 1994; Kadrabova *et al.*, 1995). In Finland, increased Se content in the food chain and Se status in humans was achieved by the addition of Se (in the form of selenate) to fertilizers (Aro *et al.*, 1995). Se in the form of selenite or selenate is taken up by plants and transformed mainly into selenomethionine which is the dominant form of Se in cereal grains (Osman & Latshaw, 1976; Sathe *et al.*, 1992). The chemical nature of the Se has been characterized in wheat (Olson *et al.*, 1970), mushroom (Piepponen *et al.*, 1984) and cabbage where as many as nine different compounds were found (Hamilton, 1975). The Se forms in food of animal origin are mostly selenocysteine and selenomethionine. Selenium in organic form consumed by humans is associated with proteins and amino acids (Levander, 1983). Due to the high content of selenomethionine in wheat, bioavailability of Se from wheat is high (Van der Torre *et al.*, 1991). In certain foods of plant origin (corn, soybean, mushroom), Se is poorly available (Chansler *et al.*, 1983; Gabrielsen & Opstvedt, 1980). Recent studies have shown that bioavailability of Se in meat is as good as is in wheat (Van der Torre *et al.*, 1991; Shi & Spallholz, 1994). Although Se content in fish is high when compared with other foods, fish are not a rich source of available Se, in part due to their rather high heavy metal content (Cappon & Smith, 1982). Bioavailability of Se in food is affected by its chemical form and also other dietary factors such as total protein, fat and heavy metal contents.

REFERENCES

Aro, A., Alfthan, G. & Varo, P. (1995). Effects of supplementation of fertilizers on human selenium status in Finland. *Analyst*, **120**, 841–843.

Cappon, C. J. & Smith, J. C. (1982). Chemical form and distribution of mercury and selenium in edible seafood. *J. Anal. Toxicol.*, **6**, 10–21.

Chansler, M. V., Morris, V. C. & Levander, O. A. (1982). Bioavailability to rats of selenium in Brazil nuts and mushrooms. *Fed. Proc.*, **42**, 3717.

Chen, X. S., Yang, C. Q., Chen, T. S., Chen, X. C., Wen, Z. M. & Ge, K. Y. (1980). Studies on the relation of selenium and Keshan disease. *Biol. Trace Elem. Res.*, **2**, 91–107.

Combs G. F. & Combs S. B. (1986). The biological availability of selenium in foods and feeds. In *The Role of Selenium in Nutrition*, eds. G. F. Combs & S. B. Combs. Academic Press, New York, pp. 127–177.

Environmental Health Criteria (1987). *Selenium*. WHO, Geneva, pp. 49–50.

Gabrielsen, B. O. & Opstvedt, J. (1980). Availability of selenium in fish meal in comparison with soybean meal, corn gluten and selenomethionine relative to selenium in sodium selenite for restoring glutathione peroxidase activity in selenium-depleted chicks. *J. Nutr.*, **110**, 1096–1100.

Hamilton, J. V. (1975). Chemical examination of seleniferous cabbage Brassica oleracea capitate. *J. Food Agric. Chem.*, **23**, 1150–1152.

Kadrabova, J., Madaric, A. & Ginter, E. (1995). Suboptimal selenium status in population from the Bratislava region. *Klin. Biochem. Metab.*, **3**, 175–177.

Levander, O. A. (1982). Clinical consequences of low selenium intake and its relationship to vitamin E.. *Ann. N.Y. Acad. Sci.*, **393**, 70–80.

Levander, O. A. (1983). Considerations in the design of selenium bioavailability studies. *Fed. Proc.*, **42**, 1721–1735.

Lichvár I., Polacek I., Janicsová K. & Guspan L. (1992). Databáza komponentov kŕmnych zmesí v SR. Záverečná výskumná správa, VUK, Ivanka pri Dunaji, Archív.

Madaric, A., Kadrabova, J. & Ginter, E. (1994). Selenium concentration in plasma and erythrocytes in a healthy Slovak population. *J. Trace Elem. Electrolytes Health Dis.*, **8**, 43–47

Maksimovic, Z. J., Djujic, I., Jovic, V. & Rsumovic, M. (1992). Selenium deficiency in Yugoslavia. *Biol Trace Elem. Res.*, **33**, 187–196.

Olson, O. E., Novacek, E. J., Whitehead, E. I. & Palmer, I. S. (1970). Investigation on selenium in wheat. *Phytochemistry*, **9**, 1181–1188.

Osman, M. & Latshaw, J. F. (1976). Biological potency of selenium from sodium selenite, selenomethionine and selenocysteine in the chick. *Poultry Sci.*, **55**, 987–994.

Oster, O. & Prellwitz, W. (1989). The daily dietary selenium intake of West Germany adults. *Biol. Trace Elem. Res.*, **20**, 1–14.

Piepponen, S., Pellinen, M. J. & Hattula, T. (1984). The selenium of mushrooms. *Trace Elem. Anal. Chem. Med. Biol.*, **3**, 159–166.

Salonen, J. T., Alfthan, G., Huttunen, J. K. & Puska, P. (1982). Association between cardiovascular death and myocardial infraction and serum selenium in matched-pair longitudinal study. *Lancet*, **2**, 175–179.

Salonen, J. T., Alfthan, G., Huttunen, J. K. & Puska, P. (1984). Association between serum selenium and the risk of cancer. *Am. J. Epidemiol.*, **120**, 342–349.

Sathe, S. K., Mason, A. C., Rodibaugh, R. & Weaver, C. M. (1992). Chemical form of selenium in soybean (Glycine max L.) lectin. *J. Agric. Food Chem.*, **40**, 2084–2091.

Shi, B. & Spallholz, J. E. (1994). Selenium from beef is highly bioavailable as assessed by liver glutathione peroxidase (EC 1.11.1.9) activity and tissue selenium. *Brit. J. Nutr.*, **72**, 873–881.

Simonoff, M., Hamon, C., Moretto, P., Llabador, Y. & Simonoff, G. (1988). Selenium in foods in France. *J. Food Comp. Anal.*, **1**, 295–302.

Smith, A. M. & Picciano, M. F. (1987). Relative bioavailability of seleno-compounds in the lactating rat. *J. Nutr.*, **111**, 725–731.

Van der Torre, H. W., Van Dokkum, W., Schaafsma, G., Wedel, M. & Ockhuizen, T. (1991). Effect of various levels of selenium in wheat and meat on blood Se status indices and on Se balance in Dutch men. *Brit. J. Nutr.*, **65**, 69–80.