ELSEVIER

Food Chemistry 85 (2004) 445–452

Food Chemistry

www.elsevier.com/locate/foodchem

Selenium in selected foods grown or purchased in eastern Croatia

T. Klapec[a,*], M.L. Mandić[a], J. Grgić[b], Lj. Primorac[a], A. Perl[a], V. Krstanović[a]

[a] *University J. J. Strossmayer, Faculty of Food Technology, Kuhačeva 18, HR-31107 Osijek, Croatia*
[b] *Institute of Public Health, Krežmina bb, HR-31000 Osijek, Croatia*

Received 5 December 2002; received in revised form 31 July 2003; accepted 31 July 2003

Abstract

The total selenium content of various foods produced and/or consumed in two rural regions of eastern Croatia was determined using the AAS hydride generation technique. The samples were previously digested in a mixture of perchloric, sulfuric, and nitric acids (1:1:5). As expected, rich sources of protein like fish, meat, eggs, etc., were also rich in selenium. The lowest selenium levels were found in fruits and vegetables. Significant differences were noted for some foods grown on two separate locations around Rivers Drava and Sava in eastern Croatia with higher concentrations in samples from the Sava basin. The mean content of selenium in foods (on the wet weight) was compared with the levels reported from other countries. On the basis of this, the dietary Se intake in both areas is likely to be between suboptimal or adequate supply of this element.

Keywords: Selenium; Food; HG–AAS; Croatia

1. Introduction

The essential element selenium (Se) is primarily known by its antioxidant role through enzymes like glutathione peroxidase (Cohen & Avissar, 1994; Sunde, 1994) and thioredoxin reductase (Becker, Gromer, Schirmer, & Muller, 2000), but it is also a component of numerous other selenoproteins with functions ranging from thyroid metabolism to selenoprotein synthesis (Arthur & Beckett, 1994; Kohrle, Brigelius-Flohe, Bock, Gartner, Meyer, & Flohe, 2000; Moschos, 2000; Ursini et al., 1999; Whanger, 2000). Additionally, either not dependent on the known or any selenoenzymes, are the effects of the element on the immune system (Rayman, 2000), reproductive function (Hansen & Deguchi, 1996), protection from heavy metal toxicity (Johnston & Savage, 1991), risk and/or prognosis of certain diseases (Navarro-Alarcón & López-Martínez, 2000), etc. For example, it has been proved that Keshan disease is a result of deficient Se dietary intake (Yang, Chen, Wen, Ge, Zhu, & Chen, 1984). There have also been reports that Se status may be linked to the etiology of diseases like cancer (Clark et al., 1996), cardiovascular diseases (Kardinaal et al., 1997), viral diseases (Beck & Levander, 1998; Taylor, Nadimpalli, & Ramanathan, 1997), etc.

A great range of Se concentrations can be found in a food from different geographical regions, which is mainly due to variations in total Se content in soil, but also because of its variable availability to plants controlled by soil composition and pH (Fordyce, Zhang, Green, & Liu, 2000). Therefore, methods of Se dietary intake assessment other than duplicated portions, must be based on Se content data obtained on samples of foods actually consumed by the investigated population.

Previous research on Se in eastern Croatia revealed the occurrence of selenium deficit disorders in domestic animals and deficient concentrations of the element in soil and grains in central part of the area (Gavrilović & Matešić, 1987; Matešić, Kos, & Strašek, 1981). A suboptimal provision with Se was also determined in a sample of urban subjects (Klapec et al., 1998), as well as the corresponding levels in human milk (Mandić, Mandić, Grgić, Hasenay, & Grgić, 1995).

The objective of this work was to determine the total Se concentration in foods consumed in two distinct rural areas of eastern Croatia. This is essential for the assessment of the daily dietary intake of Se by respective populations.

* Corresponding author. Tel.: +385-31-224-364; fax: +385-31-207-115.
E-mail address: tomi@ptfos.hr (T. Klapec).

0308-8146/$ - see front matter © 2003 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodchem.2003.07.031

2. Materials and methods

Samples of foods produced by farmers were taken from two areas of eastern Croatia. Two villages (Ivanovci and Zelčin) from the northern part of eastern Croatia (Drava basin), and two villages (Bebrina, Slavonski Kobaš) from the southern part of the region (Sava basin), were sampled. The purchased foods were obtained from local food stores and markets. The criteria for selection of foods to be analyzed were either their high consumption or expected indispensable Se content.

Wet weights of samples (0.2–3.5 g) were chosen taking into account anticipated Se content and sample composition (Analytical Methods Committee, 1979). Mineralization of food samples was performed following homogenization and overnight predigestion using a mixture of nitric, sulfuric, and perchloric acids (5:1:1) (Kadrabova, Madarič, & Ginter, 1997). Wet digestion was performed in a digestion block with air cooling and reflux. The temperature was gradually raised until solutions cleared. The temperature of 195–205 °C was kept until no more white fumes of perchloric acid were observed (Néve, Hanocq, Molle, & Lefebvre, 1982). Total Se in digestates was determined using hydride generation atomic absorption spectrometry (Perkin-Elmer 2380, MHS Type 10) following the reduction of Se (VI) to Se (IV) in digestates. To this effect, 1 cm^3 concentrated hydrochloric acid was added at 90 °C and the temperature was held for 15 min (Kadrabova et al., 1997). Before measurement, sample solutions were prepared in a manner to achieve the final HCl concentration of 1.7 M, except for samples like offal meats where HCl concentration was 6 M to prevent signal depression on account of high copper content (Julshamn, Ringdal, Slinning, & Braekkan, 1982). In the HG–AAS system, total Se was transformed into H_2Se using 3% $NaBH_4$ in 1% NaOH. The hydride was measured with standard apparatus settings: atomization temperature 900 °C, slit width 2 nm, and absorption wavelength of 196 nm. Calibration was performed by the method of standard additions (10, 20, and 50 ng Se). The detection limit for Se was 0.02 $\mu g/dm^3$. The adequacy of applied methodology was checked by usual measures of accuracy, reproducibility, and recovery, which were found to be satisfactory. The determined mean concentration of Se in wheat gluten (RM 8418, NIST) was 2.55 ± 0.09 ppm, compared to the certified value of 2.58 ± 0.19 ppm. Similarly, analysis of bovine liver (RM 1577b, NIST) gave a value of 0.74 ± 0.03 ppm, with the certified value of 0.73 ± 0.06 ppm. The mean CV of 3.7% was obtained by measuring Se content of several food samples ten times. Recovery of added inorganic (SeO_2) or organic (seleno-l-methionine) Se to different food matrices (garlic, pork, wheat flour) ranged from 93.7 to 100.8%.

Significance of differences between Se concentration in foods from two areas was examined using a *t*-test (Statistica 6.1, StatSoft Inc.).

3. Results and discussion

The results of the analyses for total Se in selected food samples are shown in Tables 1–4.

Selenium level in most fresh fruits is rather low (Tables 1 and 2). Such values were anticipated because of the high water fraction and low protein fraction in these products. Namely, food Se is mainly present in the form of selenoamino acids (Navarro-Alarcón & López-Martínez, 2000). This association between protein and Se is confirmed in present paper by the determined concentrations of this element in protein-rich walnut and peanut (Tables 1 and 2). The mean level of Se in purchased peanut samples is at the upper margin of values reported in the literature (Table 2). Peanut can accumulate high concentrations of the element dependent on Se concentration and availability in soil.

Similarly to fruits, most vegetables are poor sources of Se, which is in agreement with findings by other workers (Tables 1 and 2). Again, products richer in protein (e.g. beans) have higher Se levels (Table 1). Cruciferous vegetables, as well as onion and garlic, also tend to have somewhat higher Se concentrations. These plants have a greater fraction of sulfur-containing amino acids and their derivatives, but also some other sulfur-containing compounds like glucosinolates or sulfoxides. Adequate analogs of these can be formed by substitution of sulfur with Se, resulting in higher Se levels (Ip and Ganther, 1994). Comparing Se levels of vegetable samples grown in the two areas of eastern Croatia, a tendency of higher levels in samples from the Sava basin can be seen (Table 1). Although no firm conclusions can be drawn due to the small number of samples, a statistically significant difference was determined for some vegetables. In addition to the apparent explanation of higher total Se content and/or availability in soils from the Sava basin, part of the difference can be ascribed to different plant varieties (e.g. cabbage), which differ in the fraction of protein and/or sulfur-containing compounds (Kaić-Rak and Antonić, 1990). The Se concentration in purchased mushrooms is well above the average Se content for other vegetables, and this is consistent with other reports (Table 2). However, mushrooms mainly accumulate inorganic forms of Se.

The concentrations of Se in wheat flour and homemade wheat bread are equal in samples from both areas (Table 3). Contrary to samples from the Sava basin, sampled white breads from the villages in the Drava basin were made from purchased wheat flour. The Se content in purchased wheat flour does not reflect its

Table 1
Selenium content in fruits and vegetables produced in eastern Croatia

	Average Se concentration (ng/g as received)±SD		
	Sava basin	Drava basin	Other authors
Apple	8.8±1.6 ($n=2$)	7.8±0.2 ($n=2$)	8±1[a], 1.4±0.6[b], 4[c], 6[d], 4.5[g], 5[o]
Plum	8.7±0.9 ($n=2$)	8.9±2.0 ($n=2$)	7±2[a], 5[n]
Grape	12.9±3.6 ($n=2$)	8.9±0.0 ($n=2$)	17±6[a], 12±4[e], 6.7[g], 2[n]
Peach	11.0±3.5 ($n=2$)		13±2[a], 5.8[f], 2[l]
Walnut	46.1±15.5 ($n=2$)		55±8[a], 406[h], 31[k], 46[n]
Beans	48.5±14.9 ($n=4$)	33.7±1.9 ($n=2$)	125±19 / 143±37[a], 37.5±24.5[b], 65 / 129[d], 31±10[e], 210.4[h], 18[i], 1–450[k], 7[l], 160±40[m], 6[n]
Green peas	13.4±2.2 ($n=2$)	10.1±0.6 ($n=2$)	9±2[a], 13.5±8.4[b], 4[c], 10[d], 9±3[e], 2[k], 18[n]
String beans	9.6±0.3 ($n=2$)*	7.1±0.0 ($n=2$)	15±4[a], 6[n]
Cauliflower	24.4±5.6 ($n=2$)	24.9±7.2 ($n=2$)	9±3[a], 2.2±1.2[b], 3[c], 6[n]
Cabbage, fresh	66.1±5.6 ($n=2$)*	8.3±0.5 ($n=2$)	13±4 / 20±3[a], 7.5±7.9[b], 0.75[c], 16.0[g], 9[n], 8[o]
Sauerkraut	29.6±6.3 ($n=2$)	10.2±0.5 ($n=2$)	6[n]
Pepper, fresh	9.1±1.3 ($n=2$)	11.4±2.1 ($n=2$)	11±2[a], 0.7±0.1[b], 4±2[f], 12.1[g], 3[n]
Pepper, pickled	8.5±1.7 ($n=2$)	6.5±0.9 ($n=2$)	3[n]
Cucumber, fresh	11.5±2.7 ($n=2$)	6.3±1.3 ($n=2$)	8±3[a], 2±1[f]
Cucumber, pickled	9.4±0.7 ($n=2$)	6.3±1.0 ($n=2$)	
Carrot	19.6±0.2 ($n=2$)*	8.1±1.2 ($n=2$)	15±3[a], 1.3±0.7[b], 10[d], 13±6[e], 8±6[f]
Onion	15.3±1.8 ($n=2$)	12.4±0.7 ($n=2$)	15±2[a], 5.8±8.0[b], 11.5±13.4[c], 7±4[f]
Garlic	34.2±5.1 ($n=2$)	57.6 ($n=1$)	44±8[a], 57.9±47.5[b], 82±11[e], 142[n]
Parsley	17.6±1.2 ($n=2$)*	9.0±0.4 ($n=2$)	14±3[a], 2.0±1.1[b], 1[n]
Potato	9.5±1.3 ($n=3$)	7.2±0.8 ($n=2$)	10±3[a], 3.5±2.2[b], 3[c], 7.5±5.0[d], 7±1[f], 25±4[j], 16[k], 5[o]
Tomato	7.9±3.2 ($n=2$)	10.2±0.1 ($n=2$)	10±2[a], 0.5±0.2[b], 0.6±0.6[c], 0.5[g], 1[l], 4[n]
Red beet	11.1±1.2 ($n=2$)	8.6±1.7 ($n=2$)	6±2[a]
Celery	14.7±0.7 ($n=2$)		12±2[a], 40±7[e], 11.8[g], 9[n]

[a] Greece (Bratakos et al., 1987).
[b] Slovakia (Kadrabova et al., 1997).
[c] New Zealand (Thomson & Robinson, 1980).
[d] Ohio, USA (Moxon & Palmquist, 1980).
[e] France (Simonoff, M., Hamon, Moretto, Llabador & Simonoff, G., 1988).
[f] Ohio, USA (Snook, Kinsey, Palmquist, DeLany, Vivian & Moxon, 1987).
[g] Australia (McNaughton & Marks, 2002).
[h] Spain (Díaz-Alarcón, Navarro-Alarcón, López-García de la Serrana, López-Martínez, 1996a).
[i] Ireland (Murphy & Cashman, 2001).
[j] North Dakota, USA (Finley, Matthys, Shuler & Korynta, 1996).
[k] UK (Barclay et al., 1995).
[l] Egypt (Hussein & Bruggeman, 1999).
[m] Mexico (Wyatt, Meléndez, Acuña & Rascon, 1996).
[n] USA (USDA, 2002).
[o] Germany (Oster & Prellwitz, 1989).
* Significantly higher than product from Drava basin ($P<0.05$).

content and availability in local soil on account of the production practice of mixing imported wheat flour with domestic one. The established values are two times higher than the values found in several European countries (Table 3), but at the same time significantly lower than the Se wheat concentration in the USA. Previous investigations of Se content in wheat (whole grain) in the area, specifically the central part of the region where animal selenodeficiency occurred, revealed the highest level of 18 ng/g (Gavrilović & Matešić, 1987). Wheat mostly contains Se in the form of selenomethionine incorporated into proteins (Olson, Novacek, Whitehead, & Palmer, 1970). Therefore, in addition to the content and availability of soil Se, the fraction of protein in wheat is another important factor determining final Se level in wheat and products. This explains the difference between the soft and hard wheat varieties reported for Greece (Table 3). Accordingly, of the four analyzed samples of purchased egg noodles, the highest levels were determined in imported products made exclusively from hard wheat.

The samples of corn meal were produced from locally grown corn. The mean concentration of Se is three times higher in samples grown in the Sava basin (Table 3). Nevertheless, the mean value is a consequence of two of the samples from the area having several times more Se than the other two (183 vs. 45 ng/g). A wide range of values of Se in corn could be the result of variations in soil composition within the same village which affect the element's availability to plants, as has been observed

Table 2
Selenium content in foods purchased in eastern Croatia

	Average Se concentration (ng/g as received)±SD	Other authors
Fruits and vegetables		
Tangerine	9.6±0.1 (n=2)	8±2[a], 1.8±0.3[b], 5[o]
Orange	7.6±1.5 (n=2)	10±3[a], 1.1±0.4[b], 6.0[f], 13±3[h], 1[n], 5[o]
Banana	20.3±0.6 (n=2)	10±2[a], 6.5±1.2[b], 10±20[e], 8.9[f]
Kiwi	11.4±0.1 (n=2)	6[o]
Peanut	610.7±118.5 (n=2)	78[d], 10±20[e], 140[f], 162-538[i], 13[n], 75[o]
Champignon	151.6±6.8 (n=2)	110±13[a], 66.7±24.7[b], 165±54[g], 51.3±7[h], 33[k]
Lettuce	14.5±1.2 (n=2)	9±4[a], 0.9±0.4[b], 17.9[f], 15±7[g], 1[n], 2[o]
Kale	25.6±0.6 (n=2)	9[o]
Milk and dairy products		
Milk, 1.0% m.f.	16.9±1.1 (n=2)	28±3 (skim)[a], 20-30 (skim)[f], 8±4 (2% m.f.)[g], 6±2 (skim)[h], 18 (low fat) / 14 (skim)[k], 51±2 (2% m.f.)[l], 10 (skim)[m], 21 (skim) / 22 (1 & 2% m.f.)[o]
Milk, 2.8% m.f.	28.7±1.0 (n=2)	
Cheese, edam	72.6±7.8 (n=2)	40.5±1.3[b], 61[k], 64[m], 145[o]
Cheese, cream	35.7±6.7 (n=2)	27.6±3.7[b], 24[g], 51±3[l], 35[m], 24[o]
Yogurt, 3.2% m.f.	29.9±10.4 (n=2)	17±3[a], 20[f], 3.2±2[h], 14[m], 22[o]
Cereal products		
Noodles	43.8±11.1 (n=4)	247±15[a], 56.8±3.3[b], 571[d], 156±11[h], 29.5[i], 49±3[p]
Crackers	34.2±14.7 (n=2)	73±9[a], 56±12[g], 70±50[e], 36 / 54[l]
Rice	40.5±9.6 (n=2)	57±11[a], 28.8±7.4[b], 73[c], 387[d], 147±80[g], 29±3[h], 18.0[i], 130[m], 3[n]
Meat, fish and products		
Ham, pressed	106.5±0.1 (n=2)	174[o]
Salami	118.4±8.8 (n=2)	61±7[a], 32.0±6.7[b], 130±30[e], 71[j]
Pate	94.4±16.9 (n=3)	416[o]
Luncheon meat	85.5±23.8 (n=2)	71±13[a], 171±38[g], 100[n], 286[o]
Hot dog	68.7±17.0 (n=2)	138[o]
Sardine, canned	571.0±22.0 (n=2)	565±29[a], 570[f], 132±44[h], 223[m]
Tuna, canned	859.2±101.6 (n=2)	599±24[a], 780±180[e], 116±24[h], 701[k]
Sweets		
Chocolate, milk	45.1±7.5 (n=2)	37±7[a], 20±4[e], 10[f]
Soup concentrates		
Chicken, noodle & vegetables	49.2 (n=1)	632 (chicken & noodle)[o]
Beef, noodle & mushroom	126.3 (n=1)	360 (beef & noodle)[o]
Asparagus, cream	27.7 (n=1)	207 (cream of vegetable)[o]

[a] Greece (Bratakos et al., 1987).
[b] Slovakia (Kadrabova et al., 1997).
[c] New Zealand (Thomson & Robinson, 1980).
[d] Ohio, USA (Moxon & Palmquist, 1980).
[e] USA (Pennington, Young, Wilson, Johnson, & Vanderveen, 1986).
[f] Australia (McNaughton & Marks, 2002).
[g] Ohio, USA (Snook et al., 1987).
[h] France (Simonoff et al., 1988).
[i] Spain (Díaz-Alarcón et al., 1996a).
[j] Spain (Díaz-Alarcón et al., 1996b).
[k] Ireland (Murphy & Cashman, 2001).
[l] North Dakota, USA (Finley et al., 1996).
[m] UK (Barclay et al., 1995).
[n] Egypt (Hussein & Bruggeman, 1999).
[o] USA (USDA, 2002).
[p] Germany (Oster & Prellwitz, 1989).

before (Fordyce et al., 2000). The corn meal samples from the Drava basin and the samples from the Sava basin with lower Se levels are within the range of concentrations determined in previous research in eastern Croatia (Table 3), but also higher than the levels established in Slovakia, Ohio, USA, or Spain (Table 3). The higher Se concentration in corn meal from the Sava basin is similar to the levels determined in Greece, and

Table 3
Selenium content in milk and dairy products, eggs and cereals produced in eastern Croatia

	Average Se concentration (ng/g as received)±SD		
	Sava basin	Drava basin	Other authors
Milk, whole	40.9±22.9 ($n=3$)	18.9±6.3 ($n=2$)	17±5[a], 7.1±2.3[b], 12±1[c], 20-40[f], 6-18[g], 12-64 (Japan) / 32-138 (South Dakota, USA)[h], 13±3[i], 18[l], 15[n], 140±50[p], 20[r], 7.2±2.8[s]
Cheese, cottage	53.4±2.5 ($n=3$)*	39.9±3.8 ($n=2$)	34[c], 40±4[e], 40±40[j], 37[n], 80±30[p], 90[r], 38±2[s]
Egg, whole	177.3±101.3 ($n=3$)	52.5±9.7 ($n=2$)	87±23[a], 215.2±20.7[b], 240[c], 63-284[e], 190[f], 150±17[i], 470±54[m], 168[o], 50[p], 308[r]
Wheat flour, white	58.8±5.1 ($n=4$)	56.3±4.4 ($n=3$)	38±6 (soft) / 193±22 (hard)[a], 25.1±7.4[b], 14[c], 340±28[d], 68±9[i], 69[l], 159-399[m], 17-37[n], 24[s]
Bread, white	47.7±3.7 ($n=3$)	45.7±5.3 ($n=3$)	194±11[a], 17.6±2.6[b], 11[c], 298±18[e], 92.6[f], 78±9[i], 66[l], 195 / 267[m], 44[n], 19±4[s]
Corn meal	114.2±80.0 ($n=4$)	38.1±1.0 ($n=2$)	158±38[a], 18.0±3.3[b], 67[d], 26±12[e], 4.6[k], 75±6[m], 140±60[p], 8-50[t]

[a] Greece (Bratakos et al., 1987).
[b] Slovakia (Kadrabova et al., 1997).
[c] New Zealand (Thomson & Robinson, 1980).
[d] Ohio, USA (Moxon & Palmquist, 1980).
[e] Ohio, USA (Snook et al., 1987).
[f] Australia (McNaughton & Marks, 2002).
[g] Russia (Golubkina & Sokolov, 1997).
[h] A review (Alaejos & Romero, 1995).
[i] France (Simonoff et al., 1988).
[j] USA (Pennington et al., 1986).
[k] Spain (Díaz-Alarcón et al., 1996a).
[l] Ireland (Murphy & Cashman, 2001).
[m] North Dakota, USA (Finley et al., 1996).
[n] UK (Barclay et al., 1995).
[o] Egypt (Hussein & Bruggeman, 1999).
[p] Mexico (Wyatt et al., 1996).
[r] USA (USDA, 2002).
[s] Germany (Oster & Prellwitz, 1989).
[t] Croatia (Matešić et al., 1981).
[x] Significantly higher than product from Drava basin ($P<0.05$).

northern Mexico (Table 3). The established Se levels in purchased crackers and noodles seem to reflect the Se content of raw materials, while rice Se content is within the wide range of values reported for other countries (Table 2).

Whole milk is another product with considerable variations in Se level (Table 3). The mean concentration is again almost twice as high in the samples from the Sava basin. The established levels in whole cow's milk from the Drava basin are among the highest reported for European countries (Table 3). The levels found in samples from the Sava basin are similar to the milk Se content in Australia, Japan, and seleniferous regions of USA (South Dakota) (Table 3). Since the diet of milking cows is mainly based on grazing and silage, such levels in milk could also be explained by the level of available Se in soil. Possible feeding of Se-supplemented feeds to cows would not increase Se levels in milk significantly because ruminal microorganisms convert the inorganic Se to its elemental form, which is biologically unavailable (Wright & Bell, 1966). Purchased low fat milk samples have mean Se levels which are within the ranges reported in the literature (Table 2). In the same way, the concentrations of the element in dairy products correspond to the content in milk from which they were produced, and the resulting increase in protein fraction (Tables 2 and 3).

The mean level of Se in whole egg samples is three times higher in samples from the Sava basin (Table 3). Eggs are potent accumulators of Se, but final concentration is hard to predict if no details on laying hens diet are available (Beale, Fasulo, & Craigmill, 1990). For example, inclusion of commercial feeds supplemented with Se can dramatically increase the concentration of this element in eggs. However, the results from both locations are within the ranges from other countries (Table 3).

Consistent with the results for foods mentioned so far, the levels of Se in meat and products are higher in the samples from the southern part of eastern Croatia (Table 4). On average, the established values for fresh pork, chicken, turkey, and beef are somewhat higher than the values determined in some European countries, but are, except fresh beef, within the range of concentrations determined in previous investigations in Croatia (Table 4). The same can be said for the determined range of Se concentrations in offal meats. Previously determined mean Se content for samples of Croatian beef of 50 ng/g is similar to the mean level for samples from the Drava basin, but almost three times

Table 4
Selenium content in meat, fish and products produced in eastern Croatia

	Average Se concentration (ng/g as received)±SD		
	Sava basin	Drava basin	Other authors
Sausage, pork	198.7±41.9 ($n=5$)	116.1±17.7 ($n=2$)	56±8[a], 50.0±7.5[b], 83-163[c], 94[f], 128[h], 55±8[i], 375±51[k]
Blood sausage, pork	154.4±0.2 ($n=2$)	158.3 ($n=1$)	118[o], 13.0±2.8[p]
Ham, pork	183.5±35.9 ($n=2$)	105.4±11.3 ($n=2$)	77±11[a], 68.7±13.1[b], 150±4[c], 32[d], 200[f], 87[h], 82±3[i]
Bacon, pork	89.5±46.0 ($n=2$)	52.9±1.2 ($n=2$)	41±6[a], 79±10[c], 182±3[k], 250[o], 77.5±4.9[p]
Cracklings, pork	121.3±64.3 ($n=2$)	129.6±4.6 ($n=2$)	
Beef	131.1±14.4 ($n=2$)*	75.9±6.1 ($n=2$)	84±7[a], 57.2±15.6[b], 66±6[c], 11[d], 50[e], 110[f], 60±43[g],99±12[i], 81[j], 60-371[k], 76[l], 53[m], 80±40[n], 58±22[p]
Chicken, raw meat	162.8±20.3 ($n=2$)	115.3±13.9 ($n=2$)	80±15[a], 35.2±3.1 (farmyard) / 140.1±36.8 (industry)[b], 73[h], 47±11 (farmyard) / 60±4 (industry)[i], 115[j], 349±5[k],90±10[n], 157[o], 195.0±29.7[p], 115-170[r]
Turkey, raw meat	218.1±10.8 ($n=2$)	150.7±18.8 ($n=2$)	88[c], 97-180[l], 265[o],
Pork	158.1±15.3 ($n=2$)	129.9±2.6 ($n=2$)	99±23[a], 66.8±3.0 (farmyard) / 105.6±3.6 (industry)[b], 57[d], 40-140[e], 163±55[g], 61-116[h], 82±9 (farmyard) / 132±15 (industry)[i], 104[j], 507±24[k], 140[l], 100±20[n], 118±20[p]
Heart, chicken	254.9±71.6 ($n=2$)	164.8±6.5 ($n=2$)	317[h], 120±30[n], 43[o]
Liver, chicken	298.1±29.8 ($n=2$)*	197.3±5.9 ($n=2$)	398.3±57.2[b], 280-1420[h], 20±10[n], 641[o], 293-460[e]
Stomach, chicken	221.2±19.2 ($n=2$)	177.3±18.2 ($n=2$)	
Liver, pork	284.9±1.9 ($n=2$)	235.0±22.6 ($n=2$)	277±56[a], 230.9±25.2[b], 160-390[e], 256-800[h], 290±60[n], 527[o]
Heart, pork		202.1 ($n=1$)	52±12[a], 115[h], 160±50[n], 104[o]
Carp	169.8±13.4 ($n=2$)	166.1±14.9 ($n=2$)	243.3±29.2[b]

Industry—animals bred in industrial units; farmyard—animals bred in private households
[a] Greece (Bratakos et al., 1987).
[b] Slovakia (Kadrabova et al., 1997).
[c] Ohio, USA (Snook et al., 1987).
[d] New Zealand (Thomson & Robinson, 1980).
[e] Croatia (Beker & Šatović, 1994).
[f] Australia (McNaughton & Marks, 2002).
[g] Austria (Gamerith, Lichtenegger, Schindler & Steindl, 1991).
[h] Spain (Díaz-Alarcón et al., 1996b).
[i] France (Simonoff et al., 1988).
[j] Ireland (Murphy & Cashman, 2001).
[k] North Dakota, USA (Finley et al., 1996).
[l] UK (Barclay et al., 1995).
[m] Egypt (Hussein & Bruggeman, 1999).
[n] Mexico (Wyatt et al., 1996).
[o] USA (USDA, 2002).
[p] Germany (Oster & Prellwitz, 1989).
[r] Croatia (Beker, Šatović & Vukelić, 1994).
* Significantly higher than product from Drava basin ($P<0.05$).

lower than the mean level for the Sava basin (Table 4). Presuming that nutrition of the cattle was mainly based on pasture and silage, and considering the above-mentioned actions of ruminant gut microflora on added inorganic Se supplements, most of the difference could be ascribed to the soil Se content and availability.

The Se content in both homemade and purchased meat products varies according to their composition, Se concentration in raw materials, processing methods, and numerous other factors. The obtained results are similar to findings reported for some other countries (Tables 2 and 4). The addition of Se to commercial feeds complicates interpretation of the results for meats because the usual supplementation levels in feeds (0.1–0.3 ppm) can significantly increase the concentrations of Se in tissues of poultry and swine (Beale et al., 1990). The effect is especially evident in offals like liver and kidney.

There is no significant difference between mean concentrations of Se in carp originating from lakes situated within the two areas (Table 4). The means are lower than the mean Se level in carp from Slovakia.

The analyzed samples of canned sardines and tuna are foods richest in Se, with levels of up to 960 ng/g in one sample of canned tuna (Table 2). However, the bioavailability of Se from fish is compromised by simultaneous high concentration of Hg and other heavy metals which bind to Se forming insoluble inorganic complexes (Johnston & Savage, 1991).

Sweets are generally dispensable sources of Se, with the exception of chocolate. The level determined in purchased samples of milk chocolate are similar to concentration reported for Greece (Table 2).

The analyzed soup concentrates have Se concentrations which correspond to their composition. The high-

est Se content was determined in the sample of beef soup concentrate which contains more meat and protein than the other two products (Table 2). The values are much lower than the ones for similar products from USA.

4. Conclusions

Fruits and vegetables are generally low in Se with the exception of mushrooms and products with high protein content. Cereals, and milk and dairy products are not rich in Se, but can significantly contribute to Se dietary intake at anticipated higher consumption levels of these products in the investigated rural areas. Eggs, as well as meat and products are best sources of Se. Sea fish were found to be the richest in the element, but its questionable bioavailability from such foods must also be considered.

The levels of selenium in the analyzed samples from both areas are within the range of levels reported for countries with adequate (Bratakos, Zafiropoulos, Siskos, & Ioannou, 1987; McNaughton & Marks, 2002) or suboptimal (Barclay, MacPherson, & Dixon, 1995; Kadrabova, Madarič, & Ginter, 1998; Oster and Prellwitz, 1989; Robberecht & Deelstra, 1984) provision of population with this element. Selenium levels are higher in samples of foods produced in the southern part of eastern Croatia (Sava basin), compared to foods from the Drava basin.

The determined wide range of Se levels for the samples of corn meal and cow's milk produced within the Sava basin could be an indication to the existence of localized lithological variations affecting Se bioavailability to plants.

References

Alaejos, M. S., & Romero, C. D. (1995). Selenium concentration in milks. *Food Chemistry*, *52*, 1–18.

Analytical Methods Committee. (1979). Determination of small amounts of selenium in organic matter. *Analyst*, *104*, 778–787.

Arthur, J. R., & Beckett, G. J. (1994). Roles of selenium in type I iodothyronine 5′-deiodinase and in thyroid hormone and iodine metabolism. In R. F. Burk (Ed.), *Selenium in biology and human health* (pp. 93–115). New York: Springer-Verlag.

Barclay, M. N. I., MacPherson, A., & Dixon, J. (1995). Selenium content of a range of UK foods. *Journal of Food Composition and Analysis*, *8*, 307–318.

Beale, A. M., Fasulo, D. A., & Craigmill, A. L. (1990). Effects of oral and parenteral selenium supplements on residues in meat, milk and eggs. *Reviews of Environmental Contamination and Toxicology*, *115*, 125–150.

Beck, M. A., & Levander, O. A. (1998). Dietary oxidative stress and the potentiation of viral infection. *Annual Review of Nutrition*, *18*, 93–116.

Becker, K., Gromer, S., Schirmer, R. H., & Muller, S. (2000). Thioredoxin reductase as a pathophysiological factor and drug target. *European Journal of Biochemistry*, *267*, 6118–6125.

Beker, D., & Šatović, V. (1994). Selenium levels in foodstuffs of animal origin. *Veterinarski Arhiv*, *64*, 69–75.

Beker, D., Šatović, V., & Vukelić, N. (1994). Selenium content of chicken meat in Croatia. *Nahrung*, *38*, 267–272.

Bratakos, M. S., Zafiropoulos, T. F., Siskos, P. A., & Ioannou, P. V. (1987). Selenium in foods produced and consumed in Greece. *Journal of Food Science*, *52*, 817–822.

Clark, L. C., Combs, G. F., Turnbull, B. W., Slate, E. H., Chalker, D. K., Chow, J., Davis, L. S., Glover, R. A., Graham, G. F., Gross, E. G., Krongrad, A., Wesher, J. L., Park, H. K., Sanders, B., Smith, C. L., & Taylor, J. R. (1996). Effects of selenium supplementation for cancer prevention in patients with carcinoma of the skin—A randomized controlled trial. *Journal of the American Medical Association*, *276*, 1957–1963.

Cohen, H. J., & Avissar, N. (1994). Extracellular glutathione peroxidase—a distinct selenoprotein. In R. F. Burk (Ed.), *Selenium in biology and human health* (pp. 79–91). New York: Springer-Verlag.

Díaz-Alarcón, J. P., Navarro-Alarcón, M., López-García de la Serrana, H., & López-Martínez, M. C. (1996). Determination of selenium in cereals, legumes and dry fruits from southeastern Spain for calculation of daily dietary intake. *The Science of the Total Environment*, *184*, 183–189.

Díaz-Alarcón, J. P., Navarro-Alarcón, M., López-García de la Serrana, H., & López-Martínez, M. C. (1996). Determination of selenium in meat products by hydride generation atomic absorption spectrometry- Selenium levels in meat, organ meats, and sausages in Spain. *Journal of Agricultural and Food Chemistry*, *44*, 1494–1497.

Finlay, J. W., Matthys, L., Shuler, T., & Korynta, E. (1996). Selenium content of foods purchased in North Dakota. *Nutrition Research*, *16*, 723–728.

Fordyce, F. M., Zhang, G. D., Green, K., & Liu, X. P. (2000). Soil, grain and water chemistry in relation to human selenium-responsive diseases in Enshi District, China. *Applied Geochemistry*, *15*, 117–132.

Gamerith, W., Lichtenegger, F., Schindler, E., & Steindl, W. (1991). Selengehalt in Fleisch und Nieren von Rindern und Schweinen in der Steiermark. *Fleischwirtschaft*, *71*, 1343–1345.

Gavrilović, B., & Matešić, D. (1987). Importance of selenium quantity in soil and fodder in regard to the occurrence of some diseases in cattle, pigs, sheep and poultry in Yugoslavia. In G. F. Combs Jr, J. E. Spallholz, O. A. Levander, & J. E. Oldfield (Eds.), *Selenium in biology and medicine* (pp. 740–749). New York: Van Nostrand Reinhold.

Golubkina, N. A., & Sokolov, Y. A. (1997). Level of selenium provision in the inhabitants of the northern economic region of Russia. *Gigiena Sanitariya, No*, *3*, 22–24.

Hansen, J. C., & Deguchi, Y. (1996). Selenium and fertility in animals and man—A review. *Acta Veterinaria Scandinavica*, *37*, 19–30.

Hussein, L., & Bruggeman, J. (1999). Selenium analysis of selected Egyptian foods and estimated daily intakes among a population group. *Food Chemistry*, *67*, 527–532.

Ip, C., & Ganther, H. E. (1994). Novel strategies in selenium cancer chemoprevention research. In R. F. Burk (Ed.), *Selenium in biology and human health* (pp. 169–180). New York: Springer-Verlag.

Johnston, J. N., & Savage, G. P. (1991). Mercury consumption and toxicity with reference to fish and fish meal. *Nutrition Abstracts and Reviews*, *61*, 73–116.

Julshamn, K., Ringdal, O., Slinning, K. E., & Braekkan, O. R. (1982). Optimization of the determination of selenium in marine samples by atomic absorption spectrometry: Comparison of a flameless graphite furnace atomic absorption system with a hydride generation atomic absorption system. *Spectrochimica Acta*, *37B*, 473–482.

Kadrabova, J., Madarič, A., & Ginter, E. (1997). The selenium content of selected food from the Slovak Republic. *Food Chemistry*, *58*, 29–32.

Kadrabova, J., Madarič, A., & Ginter, E. (1998). Determination of the daily selenium intake in Slovakia. *Biological Trace Element Research*, *61*, 277–286.

Kaić-Rak, A. & Antonić, K. (1990). *Tablice o sastavu namirnica i pića (Food composition tables)*. Zagreb: Zavod za zaštitu zdravlja SR Hrvatske.

Kardinaal, A. F. M., Kok, F. J., Kohlmeier, L., Martin-Moreno, J. M., Ringstad, J., Gomez-Aracena, J., Mazaer, V. P., Thamm, M., Martin, B. C., Aro, A., Kark, J. D., Delgado-Rodriguez, M., Riemersma, R. A., Van't Veer, P., & Huttunen, J. K. (1997). Association between toenail selenium and risk of acute myocardial infarction in European men—The EURAMIC study. *American Journal of Epidemiology*, *145*, 373–379.

Klapec, T., Mandić, M. L., Grgić, J., Primorac, Lj., Ikić, M., Lovrić, T., Grgić, Z., & Herceg, Z. (1998). Daily dietary intake of selenium in eastern Croatia. *Science of the Total Environment*, *217*, 127–136.

Kohrle, J., Brigelius-Flohe, R., Bock, A., Gartner, R., Meyer, O., & Flohe, L. (2000). Selenium in biology: Facts and medical perspectives. *Biological Chemistry*, *381*, 849–864.

Mandić, Z., Mandić, M. L., Grgić, J., Hasenay, D., & Grgić, Z. (1995). Selenium content of breast milk. *Zeitung für Lebensmittel Untersuchung und Forschung*, *201*, 209–212.

Matešić, D, Kos, K., & Strašek, A. (1981). Količina selena u nekim krmivima i smjesama za perad s podruèja SR Hrvatske. *Veterinarski Arhiv*, *51*, 79–82.

McNaughton, S. A., & Marks, G. C. (2002). Selenium content of Australian foods: A review of literature values. *Journal of Food Composition and Analysis*, *15*, 169–182.

Moschos, M. P. (2000). Selenoprotein P. *Cellular & Molecular Life Sciences*, *57*, 1836–1845.

Moxon, A. L., & Palmquist, D. L. (1980). Selenium content of foods grown or sold in Ohio. *Ohio Report*, *65*, 13–14.

Murphy, J., & Cashman, K. D. (2001). Selenium content of a range of Irish foods. *Food Chemistry*, *74*, 493–498.

Navarro-Alarcón, M., & López-Martínez, M. C. (2000). Essentiality of selenium in the human body: Relationship with different diseases. *Science of the Total Environment*, *249*, 347–371.

Néve, J., Hanocq, M., Molle, L., & Lefebvre, G. (1982). Study of some systematic errors during the determination of the total selenium and some of its ionic species in biological materials. *Analyst*, *107*, 934–941.

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

Oster, O., & Prellwitz, W. (1989). The daily dietary selenium intake of West German adults. *Biological Trace Element Research*, *20*, 1–14.

Pennington, J. A. T., Young, B. E., Wilson, D. B., Johnson, R. D., & Vanderveen, J. E. (1986). Mineral content of foods and total diets: The selected minerals in Foods Survey, 1982 to 1984. *Journal of the American Dietetic Association*, *86*, 876–891.

Rayman, M. P. (2000). The importance of selenium to human health. *Lancet*, *356*, 233–241.

Robberecht, H. J., & Deelstra, H. A. (1984). Dietary selenium intake in Belgium. *Zeitschrift für Lebensmitteluntersuchung und–Forschung*, *178*, 266–271.

Simonoff, M., Hamon, C., Moretto, P., Llabador, Y., & Simonoff, G. (1988). Selenium in foods in France. *Journal of Food Composition and Analysis*, *1*, 295–302.

Snook, J. T., Kinsey, D., Palmquist, D. L., DeLany, J. P., Vivian, V. M., & Moxon, A. L. (1987). Selenium content of foods purchased or produced in Ohio. *Journal of the American Dietetic Association*, *87*, 744–749.

Sunde, R. A. (1994). Intracellular glutathione peroxidases—Structure, regulation, and function. In R. F. Burk (Ed.), *Selenium in biology and human health* (pp. 45–77). New York: Springer-Verlag.

Taylor, E. W., Nadimpalli, R. G., & Ramanathan, C. S. (1997). Genomic structures of viral agents in relation to the biosynthesis of selenoproteins. *Biological Trace Element Research*, *56*, 63–91.

Thomson, C. D., & Robinson, M. F. (1980). Selenium in human health and disease with emphasis on those aspects peculiar to New Zealand. *American Journal of Clinical Nutrition*, *33*, 303–323.

Ursini, F., Heim, S., Kiess, M., Maiorino, M., Roveri, A., Wissing, J., & Flohe, L. (1999). Dual function of the selenoprotein PHGPx during sperm maturation. *Science*, *285*, 1393–1396.

US Department of Agriculture, Agricultural Research Service (2002). *USDA National Nutrient Database for Standard Reference, Release 15*. Nutrient Data Laboratory. Available: http://www.nal.usda.gov/fnic/foodcomp.

Whanger, P. D. (2000). Selenoprotein W: A review. *Cellular & Molecular Life Sciences*, *57*, 1846–1852.

Wright, P. L., & Bell, M. C. (1966). Comparative metabolism of selenium and tellurium in sheep and swine. *American Journal of Physiology*, *211*, 6–10.

Wyatt, C. J., Meléndez, J. M., Acuòa, N., & Rascon, A. (1996). Selenium (Se) in foods in northern Mexico, their contribution to the daily Se intake and the relationship of Se plasma levels and glutathione peroxidase activity. *Nutrition Research*, *16*, 949–960.

Yang, G. Q., Chen, J., Wen, Z., Ge, K., Zhu, L. Z., & Chen, X. (1984). The role of selenium in Keshan disease. In H. H. Draper (Ed.), *Advances in nutritional research* (pp. 203–231). New York: Plenum Publishing Corporation.