Influence of consumption of pork enriched by organic selenium on selenium level in blood serum and selected blood lipid parameters in consumers

PETER JUHÁS – JANA MRÁZOVÁ – ONDŘEJ BUČKO – ANDREA LEHOTAYOVÁ – PETRA LENÁRTOVÁ – PETER CHLEBO

Summary

The aim of this study was to evaluate the effect of selenium-enriched pork consumption on selenium concentration in blood and on the lipid profile in consumers. The experimental group of consumers ($n = 10$) was served selenized pork in a dose of 3 × 200 g per week during 28 days. The control group of consumers ($n = 10$) consumed a diet with the same amount of normal pork. The concentration of selenium in blood was analysed before the start of consumption (1st sample), after 14 days (2nd sample) and after 28 days (3rd sample) of the pork consumption. Selenium concentration in experimental group significantly increased in all three samples (1st sample/2nd sample – $p = 0.005$; 1st sample/3rd sample – $p = 0.005$, 2nd sample/3rd sample – $p = 0.022$). Total level of cholesterol in experimental group decreased, difference between the 1st and 3rd sample was significant at $p < 0.05$. Levels of triglycerides and low-density lipoprotein cholesterol showed a decreasing tendency, levels of high-density lipoproteins cholesterol increased in experimental group, but the differences were not significant.

Keywords

selenium; pork; human; blood serum; lipid

Selenium is an essential trace element in human nutrition as well as in animal nutrition. Currently, people are interested about the effect of nutrition on health, in connection with the intake antioxidants to prevent the formation of harmful oxidation products in the organism. These include vitamins and essential trace elements zinc, copper and selenium, which are the components of antioxidant enzymes. One of the main nutritional antioxidants is the trace element selenium. Nutritional selenium deficiency in people plays a role in the expansion of the heart muscle, it causes degenerative bone and joint diseases and disorders of the thyroid gland. Some epidemiological studies revealed an indirect relationship between selenium intake and incidence of oncological and cardiovascular diseases. Selenium is also essential for the human immune defensive system. Studies confirmed the fact that low levels of selenium increase the risk of coronary heart disease in humans and also to various cardiovascular diseases in livestock [1–5].

The content of selenium in the whole food chain is determined by the content of selenium in the soil, which differs in different geographical areas. An adequate supplementation of the body by selenium, in terms of physiological needs, is dependent mainly on the consumption of food of animal origin. In some areas of Central and Northern Europe, the intake of selenium through food is very low, which is caused by its very low content in the soil [6, 7]. Some of the most important contributors to the daily selenium intake in Central Europe are represented by eggs and pork because of the significant part they constitute in the diet of the population [7]. Pork is the

Peter Juhás, Ondřej Bučko, Department of Animal Husbandry, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia.
Jana Mrázová, Petra Lenártová, Peter Chlebo, Department of Human Nutrition, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia.
Andrea Lehotayová, Agroinstitute Nitra, Akademická 4, 949 01 Nitra, Slovakia.

Correspondence author:
Peter Juhas, e-mail: Peter.Juhas@uniag.sk, tel.:+421904921714, fax: +421 37 6415494

most consumed meat in the 27 countries of European Union (52 % of all the consumed meat is pork) [8]. There is some non-animal source of selenium, such as Brazil nuts, cereal grains, grassland legumes, soybeans, garlic, yeast and broccoli, but selenium level in plants ultimately depends on the selenium content in soil. The distribution of Se in various parts of the plant depends on species, phase of development and physiological conditions [9]. The most "natural" way of providing enough of the essential trace element in a usable form through the food chain is a higher consumption of dedicated functional foods [10]. Higher concentration of selenium in pork produced by selenium supplementation through animal feed mixture was confirmed [9, 11]. Pork is occasionally affected by quality change, mainly after stressors as transport or group mingling. Main quality change results in a pale, soft and exudative pork [12, 13]. Pigs fed higher selenium doses had a higher quality pork, which contained more oxidative fibres that impact on slower pH decrease, less lactate and was less pale, soft and exudative [14]. Selenium status depends not only on food consumption but also on various factors related to its bioavailability, such as absorption and excretion [15]. The bioavailability of selenium for the animal as well as human organism depends on its chemical form. Selenium bound to organic molecules is more bioavailable than inorganic selenium [16–20].

The aim of this research was to evaluate the effect of selenium-enriched pork consumption on selenium concentration in blood and on the lipid profile of the consumers.

MATERIALS AND METHODS

Twenty persons volunteering in the experiment were represented by 10 men and 10 women of the age from 30 to 61 years. All volunteers come from the same area of Western Slovakia (Nitra district) and presented no pathological changes in the basic hematological and biochemical blood parameters. Volunteers were randomized into the experimental group and the control group. Each group consisted of 5 men and 5 women. The average age of volunteers in experimental group was 43.70 ± 8.26 year, average body weight 83.88 ± 16.48 kg, body mass index (*BMI*) 28.01 ± 3.41 kg·m^{-2}. The average age of volunteers in control group was 49.40 ± 9.24 year, average body weight 81.24 ± 18.10 kg, *BMI* 27.09 ± 4.78 kg·m^{-2}. Nutrition and selenium intake of all probands was evaluated by food record protocols. Each participant recorded all meals and nutrition additives or drugs per 24 h by type of meal, amount or weight and all courses. Nutrition protocol was recorded in 3 days per week (2 working days and 1 weekend day) during the experimental period. Volunteers were in good physical state, without any metabolic diseases. They did not change in any way the diet and lifestyle habits during the experimental period. All procedures involving human subjects were approved by the Slovak University of Agriculture Ethics Committee and a written informed consent was acquired from each subject.

The pork from two pig feed treatments was served to the volunteers. Both groups of pigs were fed the same feed mixture, with one group of pigs having their mixture enriched by a mineral-protein premix to 300 μg·organic selenium in 1 kg of mixture. The pork was conserved by heat sterilization in a thermostatic pot at 100 °C for 3 h in hermetically sealed containers (cans) in 1% saline solution. The pork enriched by selenium had average level of 0.153 ± 0.010 mg selenium per kilogram. The pork with a natural level of selenium contained 0.088 ± 0.008 mg selenium per kilogram. Selenium content was measured in fresh matter post-cooking. The selenium level in pork was analysed from thigh (*musculus semimembranosus*). Details on the pork quality and composition from both groups of fattened pigs were published [21]. Experimental group had 200 g of the selenized pork in 3 days (non-consecutive) per week during a 28-day period. Control group had the same amount of pork with natural level of selenium in the same design as experimental group. The nutrition record was recorded on the days without a dose of conserved pork.

Three blood samples were taken from each volunteer. The first sample was taken before the period of pork consumption, the second sample was taken after 14 days of pork consumption and third sample after 28 days of pork consumption. Blood was sampled from the veins of the volunteers, in the morning between 8.00 and 9.00 at an empty stomach. The blood serum was separated and the samples were stored in the freezer (–80 °C). The biochemical parameters of blood serum in the volunteers were determined after thawing of the blood samples.

The daily intake of selenium in volunteers was estimated by the nutritional protocol analysis of Alimenta software, version 4.3 (Food Research Institute of National Agricultural and Food Centre, Bratislava, Slovakia).

Determination of the concentration of selenium in blood serum was carried out and evaluated by the spectrofluorometric method [22] at the Institute of Animal Physiology, (Slovak Academy of

Sciences, Košice, Slovakia). Spectrofluorometer RF–540 (Shimadzu, Kyoto, Japan) was used. The analysis of biochemical parameters was done by the automatic biochemical analyser LISA 200 (Biocode Hycel, Massy, France). The reference levels by the company Spinreact (Girona, Spain) were used for analysis. The following parameters were determined: total cholesterol, triglycerides, high-density lipoproteins (HDL) cholesterol and low-density lipoprotein (LDL) cholesterol. All parameters were expressed as millimoles per litre.

The effect of the selenized pork on the selenium status, total cholesterol, triglycerides, HDL and LDL cholesterol levels were evaluated by comparison of Se levels among three samples in each group separately. Changes in levels of particular traits were tested by the Wilcoxon Signed Ranks Test. All statistical analyses were performed using SPSS v. 20 software (IBM, Armonk, New York, USA).

RESULTS AND DISCUSSION

Despite of randomization of volunteer groups, initial selenium level in blood was higher in the experimental group. The initial selenium status (1st sample) in the experimental group was 86.39 ± 1.68 $\mu g \cdot l^{-1}$ and 76.82 ± 4.85 $\mu g \cdot l^{-1}$ in the control group. Selenium level in the experimental group increased to 91.69 ± 3.61 $\mu g \cdot l^{-1}$ after 14 days (2nd sample) of the selenized pork consumption, and to 105.76 ± 20.58 $\mu g \cdot l^{-1}$ after 28 days (3rd sample) of the selenized pork consumption. Differences among all samples in the experimental group were statistically significant (1st/2nd and 1st/3rd – $p = 0.005$; 2nd/3rd – $p = 0.022$). The increase of variability, from standard deviation $SD = 1.68$ in 1st sample to $SD = 20.58$ in 3rd sample, is an interesting fact. The cause of such a variability is unknown. Genetic variation in the selenoprotein genes influencing the selenoprotein activity and response to dietary selenium were reported [23, 24]. Intra-individual variation in selenium level has been reported, too [25]. Selenium levels in the control group also showed small variations (78.71 ± 4.35 $\mu g \cdot l^{-1}$ in 2nd sample and 79.65 ± 3.56 $\mu g \cdot l^{-1}$ in 3rd sample) without significant differences among the three samples neither in mean, median or *SD*. Selenium level and its change in the experimental and the control groups are given in Fig. 1, outliers in the 3rd sample from the experimental group being omitted. Comparable results were presented in previous studies with Se supplementation by shrimp, fish, yeast, wheat, bread and meat [26–29]. On contrary, Bügel [30] reported plasma selenium level being unaffected either by natural pork or by pork with rapeseed oil-based Se enrichment in 12 volunteers.

The recommended concentration of selenium in blood serum for protection against the effect of free radicals is 100–122 $\mu g \cdot l^{-1}$ [31]. A satisfactory level of plasma selenium is greater than 80 $\mu g \cdot l^{-1}$ [32]. Although initial levels of serum selenium were above this threshold in the experimental group and very close in the control group, recent research in Slovakia as well as in Central Europe showed selenium deficiency in population. Maďarič and Kadrabova [33] presented concentration of serum selenium levels in the range from 46 $\mu g \cdot l^{-1}$ to 77 $\mu g \cdot l^{-1}$ in 1 056 examined people from various regions of Slovakia.

Combs [6] in a review reported the serum or plasma levels in the range 48–79 $\mu g \cdot l^{-1}$ in Slovakia. Population in 69 countries showed concentrations of selenium in blood serum or plasma lower than 60 $\mu g \cdot l^{-1}$ in 22% of the population [6]. Low average selenium concentrations in blood serum, 75.9 ± 12.8 $\mu g \cdot l^{-1}$ in men and 69.5 ± 14.7 $\mu g \cdot l^{-1}$ in women, were determined in a sample of 136 Polish people from Gdańsk region [34]. Concentration of selenium in the blood serum ranged from 52.9 $\mu g \cdot l^{-1}$ to 73.43 $\mu g \cdot l^{-1}$ in a group of 386 healthy people in Czech Republic [35].

The total cholesterol level in the experimental group in the 1st sample was 5.93 ± 1.08 $mmol \cdot l^{-1}$ and decreased to 5.52 ± 1.06 $mmol \cdot l^{-1}$ and 5.40 ± 1.12 $mmol \cdot l^{-1}$ in 2nd and 3rd sample, respectively. The difference between the 1st and 3rd sample was statistically significant at $p < 0.05$.

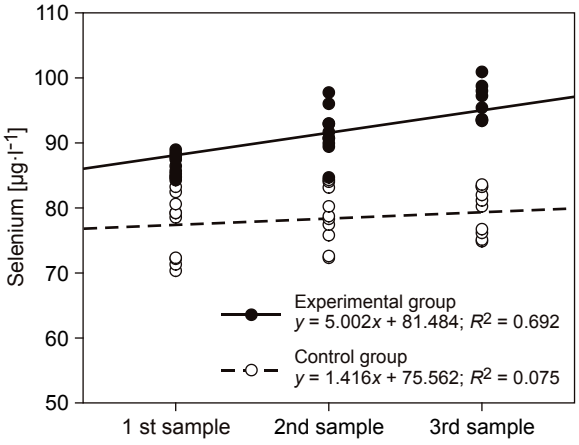

Fig. 1. Changes of selenium levels in serum in the experimental and control groups.

1st sample – sample taken before the start of pork consumption, 2nd sample – sample taken after 14 days of the pork consumption, 3rd sample – sample taken after 28 days of the pork consumption.

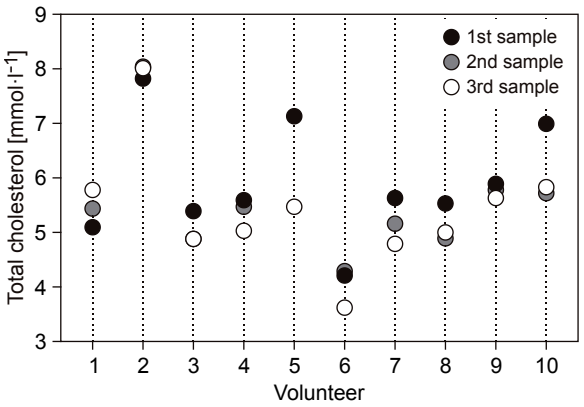

Fig. 2. Serum cholesterol levels in three samples of volunteers from experimental group.

1st sample – sample taken before the start of pork consumption, 2nd sample – sample taken after 14 days of the pork consumption, 3rd sample – sample taken after 28 days of the pork consumption.

Total cholesterol level decreased in 8 volunteers after 28 days of the selenized pork consumption, in 5 volunteers the total cholesterol level reached reference range (4.2–5.2 mmol·l^{-1}, Fig. 2).

The total cholesterol level in the control group was recorded at levels of 5.10 ± 1.08 mmol·l^{-1}, 4.96 ± 1.13 mmol·l^{-1} and 4.94 ± 1.52 mmol·l^{-1} in 1st, 2nd and 3rd sample, respectively. The differences being insignificant.

Total concentration of HDL cholesterol increased, LDL cholesterol and triglycerides decreased in the experimental group. Although a positive trend was recorded regarding the selenium impact on HDL cholesterol, LDL cholesterol and triglycerides, differences among the three samples were not significant. Lipid profile traits in the control group showed small variability in all analysed traits but without a significant difference (Tab. 1).

The effect of selenium on the lipid profile was studied thoroughly in experimental animals in which selenium supplementation decreased the total cholesterol and LDL cholesterol and increased HDL cholesterol levels, whereas selenium deficiency had the opposite effect. The mechanisms by which selenium influences plasma lipids are not known but there are several ways by which selenoproteins affect lipids and lipoproteins. It was found that inactivation of the synthesis of selenoproteins in mice resulted in increased plasma cholesterol concentration and increased concen-

Tab. 1. Lipid profiles of volunteers in the experimental and control groups.

Sample		Total cholesterol	Triglycerides	HDL cholesterol	LDL cholesterol
Experimental group					
1st sample	*n*	10	10	10	10
	Mean ± *SD* [mmol·l^{-1}]	5.93 ± 1.08 *	1.89 ± 0.75	1.70 ± 0.52	3.37 ± 1.06
	Median [mmol·l^{-1}]	5.61	1.83	1.57	3.32
2nd sample	*n*	9	9	9	9
	Mean ± *SD* [mmol·l^{-1}]	5.52 ± 1.06	1.35 ± 0.57	1.74 ± 0.53	3.18 ± 1.11
	Median [mmol·l^{-1}]	5.41	1.07	1.62	2.95
3rd sample	*n*	10	10	10	10
	Mean ± *SD* [mmol·l^{-1}]	5.40 ± 1.12 *	1.28 ± 0.46	1.73 ± 0.49	3.08 ± 1.02
	Median [mmol·l^{-1}]	5.25	1.07	1.69	3.01
Control group					
1st sample	*n*	10	10	10	10
	Mean ± *SD* [mmol·l^{-1}]	5,10 ± 1.08	1.54 ± 0.68	1.43 ± 0.74	2,98 ± 0.61
	Median [mmol·l^{-1}]	5,41	1,50	1,55	3,01
2nd sample	*n*	10	10	10	10
	Mean ± *SD* [mmol·l^{-1}]	4.96 ± 1.13	1.27 ± 4.45	1.41 ± 0.74	2.97 ± 0.84
	Median [mmol·l^{-1}]	5.01	1.28	1.40	2.91
3rd sample	*n*	10	10	10	10
	Mean ± *SD* [mmol·l^{-1}]	4.94 ± 1.52	1.49 ± 0.55	1.31 ± 0.76	2.96 ± 0.92
	Median [mmol·l^{-1}]	5.12	1.39	1.49	2.93

1st sample – sample taken before the start of pork consumption, 2nd sample – sample taken after 14 days of the pork consumption, 3rd sample – sample taken after 28 days of the pork consumption.

HDL – high-density lipoprotein, LDL – low-density lipoprotein, *SD* – standard deviation, * – values are significantly different ($P < 0.05$).

tration of apolipoprotein E, which was caused by the increased expression of genes for the biosynthesis of cholesterol and decreased expression of genes responsible for metabolism and transport of cholesterol. However, relevance of these studies for humans is questionable. It is supposed that the association between the selenium status and cardiovascular risk depends on the selenium status of the monitored population [36]. On the other hand, mechanisms of adaptation to low intakes of selenium, such as reduced excretion or higher body retention, were reported [30, 37].

CONCLUSION

Serum selenium level was positively changed in effect of the selenized pork diet in the presented study. The results suggest that selenium addition to the feed mixtures for pig fattening can influence the selenium content in human blood. Our results are in contradiction with the results of BÜGEL [30] stating that pork is not a good source of selenium in human diet and recommending combination with other nutritional sources. Positive impact on the lipid profile was not confirmed, except for total cholesterol level. The relation among various selenium sources in human diet, selenium status and health status remains a topic for next research.

Acknowledgements

This work was supported by projects VEGA 1/0364/15 and KEGA 035SPU-4/2015

REFERENCES

1. Duntas, L. H. – Benvenga S.: Selenium: an element for life. Endocrine, *48*, 2015, pp. 756–775. DOI: 10.1007/s12020-014-0477-6.
2. Kieliszek, M – Błażejak, S.: Selenium: Significance, and outlook for supplementation. Nutrition, *29*, 2013, pp. 713–718. DOI: 10.1016/j.nut.2012.11.012.
3. Mao, J. – Pop, V. J. – Bath, S. C. – Vader, H. L. – Rerman, C. W. G. – Rayman, M. P.: Effect of low-dose selenium on thyroid autoimmunity and thyroid function in UK pregnant women with mild-to-moderate iodine deficiency. European Journal of Nutrition, *55*, 2016, pp. 55–61. DOI: 10.1007/s00394-014-0822-9.
4. Rayman, M. P.: Selenium and human health. The Lancet, *379*, 2012, pp. 1256–1268. DOI: 10.1016/s0140-6736(11)61452-9.
5. Šustala, M. – Třináctý, J. – Illek, J. – Kudrna, V. – Šustková, K.: Effect of short-term supplementation of dairy cow diets with surplus selenium and rapeseed meal on milk and blood selenium levels. Czech Journal of Animal Science, *48*, 2003, pp. 223–231. ISSN: 1212–1819.
6. Combs, G. F.: Selenium in global food systems. British Journal of Nutrition, *85*, 2001, pp. 517–547. DOI: 10.1079/bjn2000280.
7. Navarro-Alarcon, M. – Cabrera-Vique, C.: Selenium in food and the human body: A review. Science of the Total Environment, *400*, 2008, pp. 115–141. DOI: 10.1016/j.scitotenv.2008.06.024.
8. Stancu, A.: The relationship among population number, food domestic consumption and food consumer expenditure for most populous countries. Procedia Economics and Finance, *22*, 2015, pp. 333–342. DOI: 10.1016/s2212-5671(15)00298-1.
9. Lyons, M. P. – Tapazyan, T. T. – Surai, P. F.: Selenium in food chain and animal nutrition: lessons from nature : Review. Asian-Australasian Journal of Animal Sciences, *20*, 2007, pp. 1135–1155. DOI: 10.5713/ajas.2007.1135.
10. Olmedilla-Alonso, B. – Jiménez-Colmenero, F. – Sánchez-Muniz, F. J.: Development and assessment of healthy properties of meat and meat products designed as functional foods. Meat Science, *95*, 2013, pp. 919–930. DOI: 10.1016/j.meatsci.2013.03.030.
11. Mahan, D. C. – Clinet, T. R. – Richert, B.: Effects of dietary levels of selenium-enriched yeast and sodium selenite as selenium sources fed to growing-finishing pigs on performance, tissue selenium, serum glutathione peroxidase activity, carcass characteristics, and loin quality. Journal of Animal Science, *77*, 1999, pp. 2172–2179. DOI: 10.2527/1999.7782172x.
12. Barbut, S. – Sosnicki, A. A. – Lonergan, S. M. – Knapp, T. – Ciobanu, D. C. – Gatcliffe, L. J. – Huff-Lonergan, E. – Wilson, E. W.: Progress in reducing the pale, soft and exudative (PSE) problem in pork and poultry meat. Meat Science, *79*, 2008, pp. 46–63. DOI: 10.1016/j.meatsci.2007.07.031.
13. Vermeulen, L. – Van de Perre, V. – Permentier, L. – De Bie, S. – Verbeke, G. – Geers, R.: Pre-slaughter handling and pork quality. Meat Science, *100*, 2015, pp. 118–123. DOI: 10.1016/j.meatsci.2014.09.148.
14. Šperanda, T.: Utjecaj dodatka selena u hranu svinja na proizvodna svojstva, antioksidativni status i kvalitetu mesa. (Effect of selenium suplementation on pig production properties, antioxidant status and meat quality.) Agriculture, *19*, 2013, pp. 70–71. <http://hrcak.srce.hr/112555>. In Croatian.
15. Ermidou-Pollet, S. – Szilágyi, M. – Pollet, S.: Problems associated with the determination of trace element status and trace element requirements – a mini review. Trace Elements and Electrolytes, *22*, 2005, pp. 105–113. DOI: 10.5414/TEP22105.
16. Mahan, D. C. – Moxon, A. L.: Effects of adding inorganic or organic selenium sources to the diets of young swine. Journal of Animal Science, *47*, 1978, pp. 456–466. DOI: 10.2527/jas1978.472456x.
17. Mahan, D. C.: Effect of organic and inorganic selenium sources and levels on sow colostrum and milk selenium content. Journal of Animal Science, *78*, 2000, pp. 100–105. DOI: 10.2527/2000.781100x.
18. Bobček, B. – Mrázová, J. – Mlynek, J. – Bučko, O. – Imrich, I.: The pork meat enriched with organic selenium and its effect on selenium

concentration and total antioxidant status in healthy volunteers. Biotechnology in Animal Husbandry, *27*, 2011, pp. 791–798. DOI: 10.2298/BAH1103791B.
19. Fairweather-Tait, S. J. – Collings, R. – Hurst, R.: Selenium bioavailability: current knowledge and future research requirements. American Journal of Clinical Nutrition, *91*, 2010, pp. 1484S–1491S. DOI: 10.3945/ajcn.2010.28674J.
20. Fordyce, F. M.: Selenium deficiency and toxicity in the environment. In: Selinus, O. (Ed.): Essentials of medical geology. Revised edition. Dordrecht : Springer, 2013, pp. 375–416. ISBN: 9789400743748 (print), 9789400743755 (online). DOI: 10.1007/978-94-007-4375-5_16.
21. Bučko, O. – Křížová, Z. – Lehotayová, A. – Vavrišínová, K. – Juhás, P.: The effect of added organic selenium on nutritional value, chemical and technological quality characteristics of pork. Journal of Central European Agriculture, *17*, 2016, pp. 585–597. DOI: 10.5513/JCEA01/17.3.1747.
22. Rodriguez, E. M. – Sanz, M. T. – Romero, C. D.: Critical study of fluorimetric determination of selenium in urine. Talanta, *41*, 1994, pp. 2025–2031. DOI: 10.1016/0039-9140(94)e0060-5.
23. Méplan, C. – Pagmantidis, V. – Hesketh, J. E.: Advances in selenoprotein expression: patterns and individual variations. In: Brigelius-Flohé, R. – Joost, H. J. (Eds.): Nutritional genomics: Impact on health and disease. Weinheim : Wiley, 2006, pp. 132–158. ISBN: 9783527608102. DOI: 10.1002/3527608109.ch8.
24. Reszka, E. – Wieczorek, E. – Jablonska, E. – Janasik, B. – Fendler, W. – Wasowicz, W.: Association between plasma selenium level and NRF2 target genes expression in humans. Journal of Trace Elements in Medicine and Biology, *30*, 2015, pp. 102–106. DOI: 10.1016/j.jtemb.2014.11.008.
25. Elsom, R. – Sanderson, P. – Hesketh, J. E. – Jackson, M. J. – Fairweather-Tait, S. J. – Åkesson, B. – Handy, J. – Artur, J. R.: Functional markers of selenium status: UK Food Standards Agency workshop report. British Journal of Nutrition, *96*, 2006, pp. 980–984. DOI: 10.1017/BJN20061893.
26. Levander, O. A. – Alfthan. G. – Arvilommi, H. – Gref, C. G. – Huttunen, J. K. – Kataja, M. – Koivistoinen, P. – Pikkarainen, J.: Bioavailability of selenium to Finnish men as assessed by platelet glutathione peroxidase activity and other blood parameters. American Journal of Clinical Nutrition, *37*, 1983, pp. 887–897. ISSN: 0095-9871. <http://ajcn.nutrition.org/content/37/6/887.full.pdf+html>
27. Van Der Torre, H. W. – Dokkum, W. V. – Schaafsma, G. – Wedel, M. – Ockhuizen, T.: Effect of various levels of selenium in wheat and meat on blood Se status indices and on Se balance in Dutch men. British Journal of Nutrition, *65*, 1991, pp. 69–80. DOI: 10.1079/bjn19910067.
28. Meltzer, H. M. – Bibow, K. – Paulsen, I. T. – Mundal, H. H. – Norheim, G. – Holm, H.: Different bioavailability in humans of wheat and fish selenium as measured by blood platelet response to increased dietary Se. Biological Trace Element Research, *36*, 1993, pp. 229–241. DOI: 10.1007/bf02783957.
29. Bügel, S. H. – Sandström, B. – Larsen, E. H.: Absorption and retention of selenium from shrimps in man. Journal of Trace Elements in Medicine and Biology, *14*, 2001, pp. 198–204. DOI: 10.1016/s0946-672x(01)80002-x.
30. Bügel, S. H. – Sandström, B. – Skibsted, L. H.: Pork meat: a good source of selenium? Journal of Trace Elements in Medicine and Biology, *17*, 2004, pp. 307–311. DOI: 10.1016/S0946-672X(04)80033-6.
31. Thomson, C. D.: Assessment of requirements for selenium and adequacy of selenium status: a review. European Journal of Clinical Nutrition, *58*, 2004, pp. 391–402. DOI: 10.1038/sj.ejcn.1601800.
32. Human mineral and vitamin requirements. Report of a joint FAO/WHO expert consultation Bangkok, Thailand. Rome : Food and Agriculture Organization, 2001. <ftp://ftp.fao.org/docrep/fao/004/y2809e/y2809e00.pdf>
33. Maďarič, A. – Kadrabová, J.: Selén v potravinách a možnosť jeho suplementácie u slovenskej populácie. (Selenium in food and possibility its supplementation in Slovak population.) Bulletin potravinárskeho výskumu, *37*, 1998, pp. 11–17. <http://www.vup.sk/download.php?bulID=398> In Slovak.
34. Hać, E. – Krechniak, M. – Szyszko, M.: Selenium in plasma of inhabitants of the Gdansk region. Polish Journal of Environmental Studies, *10*, 2001, pp. 275–278. ISSN: 1230-1485. <http://www.pjoes.com/pdf/10.4/275-278.pdf>
35. Střítecká, H. – Hlúbik, P. – Nováková, J.: Serum selenium in a group of 386 volunteers from the Czech Republic rescue fire brigades. Mediterranean Journal of Nutrition and Metabolism, *2*, 2009, pp. 133–138. DOI: 10.1007/s12349-009-0049-0.
36. Rayman, M., P. – Stranges, S. – Griffin, B. A. – Pastor-Barriuso, R. – Guallar, E.: Effect of supplementation with high-selenium yeast on plasma lipids: a randomized trial. Annals of Internal Medicine, *154*, 2011, pp. 656–665. DOI: 10.7326/0003-4819-154-10-201105170-00005.
37. Hawkes, W. C. – Alkan, F. Z. – Oehler, L.: Absorption, distribution and excretion of selenium from beef and rice in healthy North American men. Journal of Nutrition, *133*, 2003, pp. 3434–3442. ISSN: 1541-6100. <http://jn.nutrition.org/content/133/11/3434.full.pdf+html>

Received 19 July 2017; 1st revised 22 August 2017; accepted 11 September 2017; published online 20 November 2017.