

THE INFLUENCE OF SELENIUM SUPPLEMENTATION OF ANIMAL FEED ON HUMAN SELENIUM INTAKE IN SERBIA

Z. Pavlović¹, I. Miletić², Ž. Jokić³, J. Stevanović⁴, S. Šobajić², Z. Bulat⁵

¹Institute for Public Health Požarevac, Jovana Šerbanovića 14, 12000 Požarevac, Republic of Serbia
Corresponding author: zpavlovicpo@yahoo.com

²Department of Bromatology, Faculty of Pharmacy, University of Belgrade, Vojvode Stepe 450, 11221 Belgrade, Republic of Serbia

³Institute for Animal Science, Faculty of Agriculture, University of Belgrade, Nemanjina 6, 11080 Beograd - Zemun, Republic of Serbia

⁴Association of Agriculture, Food-processing and Tobacco and Water Industry
Serbian Chamber of Commerce, Resavska 13-15, 11000 Belgrade, Republic of Serbia

⁵Department of Toxicology, Faculty of Pharmacy, University of Belgrade, Vojvode Stepe 450, 11221 Belgrade, Republic of Serbia

Original scientific paper

Abstract: The use of selenium as animal feed supplement in Serbia was approved in 1989 for some categories of pigs, sheep and poultry. From 2000 selenium in animal feed became a requirement for all categories of farm animals. The aim of this study was to determine the consumption of selenium by Serbian livestock and in poultry production between 1990-1991 and 2000-2008 and to analyze the selenium content of meat, milk and eggs sold on Serbian markets to gain insight into human selenium intake. Data indicate a low level of selenium inclusion in animal feed during 1990-1991 compared to during 2000-2008. These results coincide with Serbian regulations. From 2001 an organic form of selenium (selenized yeast) was introduced in small quantities (less than 8% of the total consumed selenium). Analysis of meat, milk and eggs from Serbian markets shows increased selenium levels compared to 1991. However, the estimated total human daily intake in Serbia is 40.9 µg, which is under the recommended quantity. Increasing the quantity of selenium included in animal feed and the substitution of inorganic selenium with selenized yeast could be beneficial for animal health and farm productivity. As a consequence a further improvement in the human selenium status in Serbia should be possible.

Key words: selenium, feed, mineral-vitamin premixes, foods animal origin

Introduction

Modern livestock farming and poultry production have three main challenges: To increase productivity, to have better quality products and to lower production costs. All targets can be met by improving animal genetics through breeding and selection, providing adequate nutritionally-balanced diets and improving management practice. Selenium is one of a number of dietary components that can have direct and/or indirect implications on productivity and health of farmed animals. The selenium content of foodstuffs reflects its level in soil. Many regions in the world, including Serbia, have very low selenium concentrations in the soil (*Combs, 2001*). Fodder from such soils cannot provide sufficient selenium to ensure optimal animal health and productivity (*Trenkovski, 1989*). Such a situation requires selenium supplementation of animal feed through mineral-vitamin premixes. Feed supplementation with selenium apart from helping to achieve optimal conditions for livestock farming and poultry production has another important benefit for humans: By increasing the level of selenium in meat, eggs and milk prevention of selenium deficiency in the Serbian population can be achieved.

Prior to this study there was no available data regarding selenium consumption as a function of feed supplementation of livestock and poultry in Serbia from 1990 to the present. Furthermore, there are insufficient data concerning selenium in food of animal origin and its influence on the human intake of selenium.

Our study had two main objectives. Firstly, to determine the consumption of selenium (as feed supplement) by Serbian livestock and in poultry production between 1990-1991 and 2000-2008 and secondly, to determine the selenium content of meat, milk and eggs from Serbian markets (selling foodstuffs produced in Serbia) and their contribution to human selenium intake.

Material and Methods

The consumption of selenium supplements for animal farming was calculated on the basis of Serbia's import of selenium as feed additive. Data regarding import of selenium supplements, production and import and export of mineral-vitamin premixes were obtained from the Serbian Chamber of Commerce. Human food consumption assessed by household budget surveys in 2007 (*Statistical Office of the Republic of Serbia, 2009*) was used to calculate the average daily intake of selenium.

Eggs (battery farmed hens, class A), milk (containing 2.8% fat), pork (leg), beef (leg) and poultry meat (breast) were collected from Serbian market. Selenium was determined using hydride generation atomic absorption spectrometry with a Varian SpectrAA-10 containing a VGA-76 hydride unit according to a method

described previously (Pavlovic et al., 2009). Method verification involved the use of certified reference material: NIST RM 8415 (whole egg powder), IAEA 155 (whey powder) and IAEA 407 (fish tissue). Our obtained results agreed with official certified values.

Results and Discussion

Mineral-vitamin premix production and its consumption in Serbia during 1990-1991 and 2000-2008 are shown in Table 1. During 2000-2008 the average year's premix production was only about one half of the year's production during 1990-1991. From 2000 increased import of mineral-vitamin premix combined with decreased premix production changed the structure of premix consumption in Serbia. During 1990-1991 imported mineral-vitamin premix accounted for about 16% of the total consumed premix, while from 2000 the value was 34%. Export of premix was small, less than 5% of the total quantity produced and that imported. The quantity of imported inorganic selenium during 1990-1991 was small (Table 1). From 2000 Serbia's import of inorganic selenium grew significantly but suffered from year-to-year fluctuations. During 2000-2008 the average import of inorganic selenium compounds amounted to 147 kg per year (as selenium). Average yearly premix production was 11066 tones. Therefore, average selenium content was 14.3 mg/kg premix. In 2001 importation of an organic form of selenium (selenized yeast) started in small quantities (about 12 kg per year, as selenium). Data regarding the selenium content of imported premixes are not available.

Table 1. Mineral-vitamin premix production in Serbia

year	Premix production, tons	Import of premix, tons	Export of premix, tons	Premix consumed in Serbia, tons	Import of Selenium,* kg
1990	22799	4883	899	26783	11,5
1991	22460	3475	252	25424	22,5
2000	10189	2435	0	12624	99
2001	8662	2788	29	11421	22,25
2002	15467	7121	233	22355	67,5
2003	14318	7862	251	21929	124
2004	8601	6557	530	14628	465
2005	8837	4119	215	12741	33,25
2006	9231	5503	517	14217	357,5
2007	9900	7282	303	16879	152
2008	14385	8694	416	22663	212

*selenium as feed additive

Table 2. Estimated Serbian selenium consumption from animal products

Foodstuff	Se concentration Average \pm SD ¹	Range	Daily consumption	Daily Se contribution to diet, μ g
Milk (n=15)	12,1 \pm 3,61 μ g/l	<5-16	0,490 l ²	5,9
Pork (n=20)	112,7 \pm 27,64 μ g/kg*	79-189	83,1 g ³	9,4
Beef (n=19)	95,7 \pm 30,39 μ g/kg*	44-163	17,8 g ³	1,7
Poultry (n=20)	121,7 \pm 17,98 μ g/kg*	89-145	65,7 g ³	8,0
Eggs (n=20)	186,1 \pm 28,77 μ g/kg*	138-247	36 g	6,7

¹standard deviation, ²calculated as milk and dairy, ³fresh, frozen and processed item
* per kg wet weight

Animal-based food for human consumption is a good dietary source of selenium in Serbia (Table 2). The highest selenium concentration was found in eggs with an average of 186 μ g/kg. Selenium in meat sold at Serbian markets was in the range 44–163 μ g/kg for beef, 89–145 for chicken and 79–189 μ g/kg for pork. Milk produced in Serbia is not rich in selenium as the average content was only 12.1 μ g/l. Taking into consideration selenium food content and daily food consumption, pork is the richest source of human selenium intake in Serbia. Pork provides more than one sixth of the Recommended Dietary Allowance (RDA) for selenium (Food and Nutrition Board-USA Institute of Medicine, 2000). Poultry, eggs and milk and dairy produce also importantly contribute to selenium intake (14%, 12 % and 11% of RDA, respectively). Beef has a minor influence on selenium intake due to its low consumption in Serbia.

The first large-scale geochemical investigation of selenium in Serbia showed low selenium content in river sediments (*Maksimovic et al., 1985*). Four years later the low selenium content Se content of Serbian agricultural soil and selenium deficiency in animal feed were reported (*Trenkovski 1989*). Selenium supplementation of animal feed in Serbia started in 1989, by inorganic selenium compounds, for some categories of pigs, sheep and poultry but not for fattening pigs, hens, dairy cows and cattle (*Rulebook 15/89, 1989*). As a consequence of the limited use of selenium supplements insignificant quantities of selenium were imported during 1990-1991. Our results, together with the fact that at this time selenium supplements were not permitted for animals that provided the greatest contribution to human selenium intake in Serbia, are in agreement with results of *Djujic et al., (1995)* who reported poor human dietary selenium intake in Serbia in 1991 and low selenium in food animal origin for human consumption. Our findings coincided with those of *Maksimovic et al., (1992)* who reported that the mean serum selenium level in a healthy Serbian population (n=602) was below 45 μ g/L.

The new period of selenium supplementation in the Serbian animal feed industry began in 2000 with the obligatory inclusion of selenium in animal feed for all farm animals. From 2000 onwards the yearly minimal requirement of selenium content in animal feed was 0.1 mg/kg for all categories of pigs and cows and 0.15 mg/kg for poultry feed, and using an organic form of selenium was approved (*Rulebook 20/00, 2000*). Our results show that selenium import during 2000-2008 was adequate for mineral-vitamin premix production and that the calculated average content of selenium in premixes satisfied the demands of Serbian regulations but not the needs of modern livestock and poultry production.

The analysis of selenium levels in food origin from animals in our study showed some disagreement between average selenium content in premixes and selenium content of animal food origin for human consumption. Given that the selenium content in mineral-vitamin premix is about 14 mg/kg, the analysis of food of animal origin for human consumption showed that the selenium content in some groceries was not adequate therefore putting into doubt the average level of selenium in premixes. However, selenium levels in pork and eggs were elevated compared to 1991 (as a consequence of higher selenium content in premixes, as required by Serbian regulations). In contrast, the selenium content of milk and beef are similar to findings by *Djujic et al., (1995)*. We propose that suboptimal use of selenium supplements for dairy cows and other cattle was the cause. Selenium has been a supplement in broiler feed since 1989. Our results regarding the selenium content in poultry meat correspond to those of *Djujic et al., (1995)* and confirmed the use of selenium according to modern poultry production methods. A possible explanation for the discrepancies mentioned above is that imported selenium is included in premixes for some categories of farmed animals in quantities according to the demands of modern livestock and poultry production, while on the other side feed for dairy cows and other cattle is not currently supplemented with selenium.

Research in Serbia from 2000 onwards reported improvement of selenium status in healthy Serbian population. *Mihajlovic et al., (2002)* found 71.8 µg Se/l in plasma of healthy persons, while *Pesut et al. (2005)* reported slightly lower plasma selenium content in healthy adults of both sexes in the central city area of Belgrade (66.9 µg Se/l). Except changes in feed industry, during last two decade in Serbia there weren't other activities that could be to influence dietary selenium intake of general population. We suppose that increment of selenium inclusion in animal feed is the mainly reason for improvement of Se status in Serbian population. Cited researches (*Mihajlovic et al., 2002; Pesut et al., 2005*), also indicate effectiveness of the selenium supplementation in animal feed programme.

In Serbia inorganic selenium compounds, primarily sodium selenite, are most often used for inclusion in animal feed. An organic form selenium (selenized yeast) has many advantages compared with inorganic selenium: greater deposits in meat, eggs and milk, better productivity by animals and a better effect in the prevention of some diseases (*Pavlovic et al., 2009, Pavlovic et al. 2010, Krstic et*

al., 2012). However, selenized yeast accounts for less than 8% of selenium included in animal feed in Serbia. Currently, the important reason for a low degree of supplementation with selenized yeast is economically-higher price (selenized yeast compared with sodium selenite).

Food of animal origin plays a significant role in human nutrition in Serbia. The average Serbian citizen consumes 61 kg meat, 180 l milk (as milk and dairy products) and 240 eggs per year (Statistical Office of the Republic of Serbia 2009). Therefore, the selenium content in such foodstuffs is important for human selenium intake. In 1991 the estimated average daily Se intake in the Serbian population was 29.7 μg (Djujic et al., 1995). The greatest part was provided by food of animal origin (20.5 μg), while cereals were ensured 7.3 μg and vegetables, fruits and alcoholic beverages less than totally 2 μg Se/day (Djujic et al., 1995). The composition of food consumed in Serbia in 2007 (Statistical Office of the Republic of Serbia 2009) revealed increased ingestion of pork, poultry and eggs, which together with elevated levels of selenium in pork and eggs, resulted in an increased daily intake of selenium by food originating from farmed animals (31.7 μg) compared with 1991 (Djujic et al., 1995). However, the currently estimated total human daily intake in Serbia is 40.9 μg , which is still under the recommended quantity and points to the need increased.

Conclusion

Clearly selenium supplementation of animal feed affects the selenium level in food. However, there are still many points for improvement. An increased quantity of selenium in animal feed and the substitution of inorganic selenium compounds with selenized yeast could offer benefits for animal health and farming productivity, and also for human selenium status. Improving the selenium status in Serbia's citizens via consumption of better quality food is an ongoing goal for agricultural and food technology companies.

Uticaj suplementacije stočne hrane selenom na humani status selena

Z. Pavlović, I. Miletić, Ž. Jokić, J. Stevanović, S. Šobajić, Z Bulat

Rezime

Upotreba selena kao suplementa za stočnu hranu odobrena je u Srbiji 1989. godine za neke kategorija svinja, ovaca i živine. Od 2000. propisan je obavezan

sadržaj selena u hrani za sve domaće životinje. Cilj rada bio je istraživanje upotrebe selena za suplementaciju stočne hrane selenom u periodima 1990-1991 i 2000-2008 i analiza sadržaja selena u namirnicama životinjskog porekla. Rezultati ukazuju na povećanu upotrebu selena kao aditiva za stočnu hranu od 2000. i povećan sadržaj selena u svinjskom mesu i jajima u poređenju sa podacima iz 1991. Procenjeni dnevni unos selena stanovnika Srbije je 40.9 μg što je značajno manje od preporučenog dnevnog unosa selena. Povećana upotreba selena u ishrani domaćih životinja, i zamena neorganskih jedinjenja selena seleniziranim kvascem, pored povoljnih efekata na zdravlje i produktivnost životinja, dovela bi do daljeg poboljšanja statusa selena stanovnika Srbije.

References

- COMBS G.F.Jr. (2001) Selenium in global food systems. *Br. J. Nutr.* 85, 517-547.
- DJUJIC I., DJUJIC B., TRAJKOVIC Lj. (1995) Dietary intake of selenium in Serbia: results for 1991. Serbian Academy of science and arts (Department of natural and mathematical sciences). Scientific meetings 6, 81-87.
- FOOD AND NUTRITION BOARD – USA Institute of Medicine (2000). Dietary References Intakes for Vitamin C, Vitamin E, Selenium and Carotenoids. Washington: National Academy Press, pp 284-324.
- KRSTIC B., JOKIC Z., PAVLOVIC Z., ZIVKOVIC D. (2012) Options for the production of selenized chicken meat. *Biol. Trace Elem. Res.* 146:68-72.
- MAKSIMOVIC Z., DUJIC I., JOVIC V., RSUMOVIC M. (1992) Selenium deficiency in Serbia and possible effects on health. *Bull. Acad. Serbe. Sci. Arts*, 33, 65-83.
- MAKSIMOVIC Z., RSUMOVIC M., RADOSEVIC P. (1985) Selenium in certain river sediments in Serbia (Yugoslavia). *Bull. Acad. Serbe. Sci. Arts*, 26, 101-109.
- MIHAJLOVIC M.B., VASILJEVIC Z., SOBAJIC S., JOVANOVIC I.B., PESUT O., MATIC G. (2002) Antioxidant status of patients with acute myocardial infarction. *Trace Elem. Electrolytes*, 19(4), 171-173.
- PAVLOVIC Z., MILETIC I., JOKIC Ž., PAVLOVSKI Z., ŠKRBIC Z., SOBAJIC S. (2010) The Effect of Level and Source of Dietary Selenium Supplementation on Eggshell Quality, *Biol Trace Elem Res*, 133(2):197-202
- PAVLOVIC Z., MILETIC I., JOKIC Z., SOBAJIC S. (2009) The Effect of Dietary Selenium Source and Level on Hen Production and Egg Selenium Concentration. *Biol. Trace Elem. Res.* 131(3), 263-270.
- PESUT O., BACKOVIC D., SOBAJIC S. (2005) Dietary selenium supplementation of pigs and broilers as a way of producing selenium enriched meat. *Acta Vet (Beograd)* 55, 483-492.
- PRAVILNIK O KVALITETU I DRUGIM ZAHTEVIMA ZA HRANU ZA ŽIVOTINJE. (2000) Službeni list SRJ 20/00, 3-31.

PRAVILNIK O KVALITETU STOČNE HRANE (1989) Službeni list SFRJ 15/89, 381-402.

STATISTICAL OFFICE OF THE REPUBLIC OF SERBIA (2009) Household Budget Survey 2007. Bulletin 493, pp 71.

TRENKOVSKI V. (1989) Selenium content of soils and feeds from different regions of Serbia, "in Serbian, with English abstract". Stočarstvo 43, 331-336.

Received 7 March 2013; accepted for publication 12 June 2013