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EFFECT OF DIFFERENT FORMS OF SELENIUM ON TRACE ELEMENTS IN THE BLOOD SERUM AND LIVER TISSUE OF LAMBS

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Abstract

The objective of the present research was to evaluate the dynamics of changes in the mineral content in blood serum and liver of lambs under dietary selenium supplementation. The study was conducted on 48 lambs assigned to three equal groups. The experiment started when the lambs were 5 weeks old, proceeded for 8 weeks and consisted of two stages. During the first, 4-week stage, the lambs were divided into three groups: group I – clinical control group, II – which received 0.2 mg Se/day in the form of enriched yeast, and III – which was fed 0.2 mg Se/day in the form of sodium selenite (POCH, Poland). During the second, 4-week stage, the lambs did not receive any supplements. Blood samples were taken after 1, 2, 3 and 4 weeks of the experiment. Liver samples were collected from slaughtered animals after 2, 4, 6 and 8 weeks since the onset of the experiment. Selenium supplementation significantly increased the Se concentration in the blood serum and liver of lambs. Selenium compounds significantly contributed to changes in the analyzed minerals, i.e. manganese, zinc, copper and iron. The results of this experiment suggest that selenium supplementation might lead to a decrease in levels other health-promoting elements such as Zn, Cu and Fe, and an increase in the Mn levels in the liver. Differences in the influence of organic and mineral forms of selenium on the Mn, Zn, and Cu content in the blood serum and liver were noticed. A significant decrease in the copper and iron content may induce symptoms of the deficiency of these trace elements in animals.

Keywords: manganese, zinc, copper, iron, selenium, lambs.

WPŁYW RÓŻNYCH FORM SELENU NA ZAWARTOŚĆ METALI ŚLADOWYCH W SUROWICY KRWI I WĄTROBIE JAGNIĄT

Abstrakt

Celem badań była ocena dynamiki zmian zawartości składników mineralnych w surowicy i w wątrobie jagniąt po suplementacji diety selenem. Badanie przeprowadzono na 48 jagnię-

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tach w wieku 5 tygodni. Doświadczenie trwało 8 tygodni i zostało podzielone na dwie części. W pierwszych 4 tygodniach jagnięta podzielono na trzy równe grupy: Grupę I stanowiły jagnięta kontrolne, grupę II – jagnięta otrzymujące drożdże wzbogacone w selen w dawce 0,2 mg/dzień/zwierzę, grupę III – jagnięta, którym podawano selen w tej samej dawce co w grupie II w formie seleninu sodu. W drugiej części doświadczenia jagnięta nie otrzymywały suplementacji. Próbki krwi pobierane były po 1, 2, 3, 4 tygodniach eksperymentu, zaś wątroby po uboju po 2, 4, 6, 8 tygodniach od rozpoczęcia doświadczenia.

Zastosowanie doustnej suplementacji selenem w sposób istotny przyczyniło się do wzrostu koncentracji tego pierwiastka w surowicy krwi i wątrobie jagniąt, ale jednocześnie spowodowało znaczne zmiany w koncentracji innych składników mineralnych, tj. manganu, cynku, miedzi i żelaza. Wyniki tego doświadczenia wskazują, że podawanie selenu może prowadzić do obniżenia poziomu ważnych dla zdrowia pierwiastków Cu, Zn i Fe oraz wzrostu koncentracji Mn w wątrobie. Stwierdzono różnice w oddziaływaniu organicznych i mineralnych form selenu na zawartość Mn, Zn, Cu w surowicy krwi i wątrobie jagniąt.

Znaczny spadek zawartości miedzi i żelaza stwierdzony po zastosowaniu suplementacji selenem może sugerować ryzyko wystąpienia u jagniąt objawów związanych z niedoborem tych pierwiastków.

Słowa kluczowe: mangan, cynk, miedź, żelazo, selen, jagnięta.

INTRODUCTION

Maintenance of good health of animals, their adequate growth and performance depend on appropriate concentrations of trace elements and their correct balance in tissues and organs. The required animal supply with micro- and macro-elements is governed by the animal species, physiological status, age and production type (Hylland et al. 2009).

One of the mineral elements critical for the optimal functioning of organisms is selenium (Se), an essential trace element known to demonstrate complex biological activities, for example participating in the reproductive process (Van Niekerk et al. 1996, Hemingway 2003, Makhoul et al. 2004, Lekatz et al. 2010 *a*, *b*,) or being present in enzymatic proteins (Bik 2003). Analysis of an animal's demand for should account for the fact that Se biological availability depends not only on sources of feedstuffs or the form of Se, but also on interactions with other dietary elements. Some dietary ingredients compete in the absorption process or form compounds insoluble in the rumen or intestines, which leads to excretion of elements unavailable to an animal organism (Grela, Sembratowicz 1997). Moreover, selenium bioavailability and retention in ruminants is also influenced by diet composition, for example absorption of Se is better in sheep fed a concentrate-based diet than in ones receiving forages (Koenig et al. 1997). This and other experiments have revealed that the selenium form is of key importance in its retention in an animal organism. Nutrition of ruminants, especially sheep and goats, is based on homegrown forages, therefore a local soil selenium deficit results in a low selenium content in plant feeds, and consequently a low level of this trace element in farm animals (Hartikainen 2005). There are

a number of methods to prevent selenium deficiency in both humans and animals (SZAREK et al. 1997), of which oral supplementation is the preferred one. Most commonly, functional food products are enriched with selenium, analogously to adding this element to pharmaceutical preparations for humans and for breeding animals. Another solution is dietary supplementation of feeds. However, it is vital for selenium supplementation of animals to be preceded by reliable recognition of the deficiency status and to be accompanied by monitoring the availability to supplemented animals with elements antagonistic to selenium (manganese, copper, iron, zinc).

The objective of the present research was to assess the dynamics of changes in mineral content in the blood serum and liver of lambs under the dietary supplementation with selenium.

MATERIAL AND METHODS

The study included 48 lambs, young rams of the synthetic meat-prolific line BCP, with the mean body mass of 4-5 kg and aged 5 weeks. During the investigations, the lambs were raised and kept with mothers. They received extra feed such as meadow hay and crushed oats. The experimental animals were assigned into 3 equal groups; two groups were supplied with oral selenium supplement from 5 weeks of age. Group I comprised the experimental lambs without any dietary additives. The animals from group II received 0.2 mg Se/day/animal – Se enriched yeasts (Sel-plex, Alltech, Serbia and Montenegro). Group III consisted of the lambs given the same dose of selenium but in the form of sodium selenite (POCH, Poland). The preparations were administered daily for 4 weeks during the morning feeding. Throughout the mineral supplementation period, the lambs had blood samples collected every seven days to monitor the trace element concentration in their organisms. Blood was drawn from the external jugular vein to separator tubes and centrifuged at 3000/rpm to obtain serum.

After 2 and 4 weeks of mineral supplementation and 2 and 4 weeks after the supplementation had been stopped, some of the animals were slaughtered to obtain liver samples. The level of elements in blood serum and in the liver was determined with atomic absorption spectrometry using atomic absorption spectrometers: with electrothermal induction and deuter Zeeman-effect background correction, SpektrAA 220Z (Varian, Australia) and with the flame atomization system Avanta PM (GBC Scientific Equipment, Australia). Samples of liver were immediately deep-frozen, freeze-dried (lyophilized) and homogenized before analysis. For particular determinations, three parallel samples of the liver, about 0.5 g each, were taken for analysis. Samples were digested under a higher-pressure level in a microwave stove Multiwave 3000 (Anton Paar, Austria), using concentrated nitric

acid and hydrochloric acid (3:1 v/v) for each sample. Afterwards, the samples were quantitatively transferred into 50 ml plastic flasks and measured with the AAS method. All results have been recalculated to wet mass. The water content was the basic difference between the weight of samples before and after lyophilization. Simultaneously, the reagent blank and certified reference material NIST 1570a (bovine muscle powder) were mineralized. The blood serum selenium content was established after GFAAS atomic absorption spectrometry modified by NEVE and MOLLE (1986). Each blood serum sample was diluted in a 1:3 ratio with matrix modifier: 0.5 g dm^{-3} Cu acetate (II); 1.0 g dm^{-3} nitrate Mg (II); 0,15% TritonX-100 in 2% HNO_3. At the same time, determinations of the reagent blank and reference material Seronorm (Nycomed and Co., Norway) were performed.

The results were analyzed statistically with two-factor analysis of variance, which included the following experimental factors in the mathematical model: the feeding group, sample collection time. The statistical computations were made using a Statistica statistical software package. Significance of differences between the groups was estimated by the Duncan's test.

RESULTS AND DISSCUSION

The research results obtained during the first stage of the experiment displayed marginal, low values of the blood serum selenium concentrations in the lambs. The four-week administration of selenium in either form manifested itself as changes in levels of this element in both blood serum and the liver of the animals. The peak serum response indicating the highest Se concentration increase was recorded in the group of lambs with a dietary supplement of selenium yeasts in the form of Sel-plex preparation. After the mineral supplementation was discontinued, the blood serum selenium content remained on a similar level, but decreased significantly in the liver. However, it continued to be significantly higher than in the control group (CHAŁABIS-MAZUREK, WAŁKUSKA 2008*a b*). The above research results served as the basis for discussing the determinations made during the second research stage.

The results on the manganese concentration in the blood serum during the supplementation period are summarized in Table 1. The manganese content in blood of the control group lambs remained fairly constant throughout the experiment and ranged between 0.052 up to 0.063 mg dm^{-3}. A statistically significant difference in the elemental concentration was noted only between the first and the last week of the research. After the first week of selenium supplementation, the Mn content in the experimental groups was about twice as high as in the control. Importantly, the same week was distinguished by the highest selenium increase in the examined lambs. In

Table 1

Blood serum manganese content (mg dm^{-3}) in lambs fed different forms of supplementary selenium (n =16; x ± s)

Group	Week				Differences between weeks
	1	2	3	4	
Control	0.052 0.009	0.054 0.011	0.053 0.014	0.063^{a} 0.014	$^{x}1 - 4$
Sel-plex	0.027 0.007	0.038 0.007	0.045 0.016	0.048^{b} 0.016	
Sodium selenite	0.021 0.004	0.024 0.004	0.027 0.004	0.026c 0.010	$^{x}1 - 4$

Key: statistically significant differences between groups marked with different letters: a, b, c – $p \leq 0.05$; A, B, C – p ≤ 0.01
^{x} $p \leq 0.05$; ^{xx} – $p \leq 0.01$ – statistically significant differences between weeks

Table 2

Blood serum zinc content (mg dm^{-3}) in lambs fed different forms of supplementary selenium (n =16; x ± s)

Group	Week				Differences between weeks
	1	2	3	4	
Control	2.220^{A} 0.461	2.963 0.366	2.015 0.302	2.103 0.182	
Sel-plex	1.457^{B} 0.264	1.630 0.107	2.003 0.174	2.545 0.502	$^{xx}4 – 1,2$ $^{x}1 – 2$ $^{x}3 – 1,4$
Sodium selenite	2.087^{A} 0.441	1.985 0.287	2.105 0.176	2.370 0.412	

Key: cf. Table 1.

the subsequent weeks, a substantial growth of the blood serum manganese concentration was observed in the group of lambs administered Sel-plex preparation against the first week. On the other hand, in the group of lambs fed an additional inorganic selenium form, the manganese level remained unchanged.

After four weeks of dietary mineral supplementation, statistically significant differences in the manganese concentration between the groups were observed. In the control group, this trace element level reached 0.063 mg dm^{-3} and in the lamb group supplemented with selenium yeasts it averaged 0.048 mg dm^{-3}, while in the group with dietary sodium selenite, the manganese concentration was approximately 2.5-fold lower than in the control.

The results on the zinc level in the blood serum of lambs are presented in Table 2. After one-week selenium supplementation, a significantly lower content of the element (1.457 mg dm^{-3}) was found in the group of lambs given the organic form of selenium, compared to the control group and the group administered sodium selenite (2.220 and 2.087 mg dm^{-3}, respectively).

The second week was marked with a significant rise in the zinc concentration in the Sel-plex supplied group against the values obtained in the first week. The tendency continued during the subsequent weeks, unlike in the group with the mineral form of selenium, where no significant changes in the zinc content were reported.

Oral selenium supplementation contributed to a significant decline in the copper concentration in the blood serum of lambs with the dietary supplements (Table 3). The mean content of this trace mineral in blood serum of lambs from the control was found within 0.665 mg dm^{-3} and 0.751 mg dm^{-3} and did show any significant changes in any week. In the first experimental week, group II given the organic form of selenium had a copper level lower by 44% than the control, while in group III, it was lower by 22%. Similar relationships were found in the following weeks.

The data in Table 4 show the influence of selenium supplementation on the iron concentration in the blood serum. A significant decrease in this element versus the control was observed in both groups fed additional selenium. The blood serum iron content in the animals from the control group ranged from 5.183 mg dm^{-3} up to 6.265 mg dm^{-3}, while in the groups with dietary Se supplementation they were between 3.478 mg dm^{-3} and 3.935 mg dm^{-3} (group II) and from 2.970 mg dm^{-3} up to 4.555 mg dm^{-3} (group III).

Table 3

Blood serum copper content (mg dm^{-3}) in lambs fed different forms of supplementary selenium (n =16; x ± s)

Group	Week				Differences between weeks
	1	2	3	4	
Control	0.751^{A} 0.183	0.665^{A} 0.045	0.711^{A} 0.200	0.698^{a} 0.039	
Sel-plex	0.424^{B} 0.052	0.499^{B} 0.102	0.526^{B} 0.102	0.546^{b} 0.028	
Sodium selenite	0.583^{A} 0.121	0.565^{B} 0.166	0.560^{B} 0.043	0.559^{b} 0.308	

Key: cf. Table 1.

Table 4

Blood serum iron content (mg dm^{-3}) in lambs fed different forms of supplementary selenium (n =16; x ± s)

Group	Week				Differences between weeks
	1	2	3	4	
Control	6.093^{A} 0.592	5.183^{A} 0.539	5.763^{A} 0.138	6.265^{A} 0.530	$^{x}1 - 2,3$ $^{x}4 - 2,3$
Sel-plex	3.478^{B} 0.403	3.547^{B} 0.416	3.935^{B} 0.797	3.660^{B} 0.848	
Sodium selenite	4.490^{C} 0.542	3.163^{B} 0.403	2.970^{B} 0.437	4.555^{B} 0.891	$^{xx}1 - 2,3$ $^{xx}3 - 4$

Key: cf. Table 1.

Many authors claim that changes in the mineral content of the liver are the most reliable indicator of the trace mineral status of an animal (GEHRKE, LACHOWSKI 1999). Table 5 presents the Mn, Zn, Cu and Fe content in the

Table 5

Mineral content (mg kg^{-1} wet mass) in lamb liver during and after dietary supplementation with different selenium forms, (n =16; x ± s)

Trace element	Research week	Group			Differences between groups
		control (1)	sel-plex (2)	sodium selenite (3)	
Mn	2	2.063 0.029	3.432^{A} 0.183	2.470^{A} 0.156	^{xx}1 - 2,3 ^{xx}2 - 3
	4	2.123 0.035	3.318^{AC} 0.120	3.396^{B} 0.166	^{xx}1 - 2,3
	6	2.134 0.098	2.274^{B} 0.130	3.285^{B} 0.096	^{xx}1 - 3 ^{xx}2 - 3
	8	2.239 0.086	3.233^{BC} 0.114	2.368^{A} 0.093	^{xx}1 - 2 ^{xx}2 - 3
Zn	2	27.25 0.731	22.34^{A} 1.448	21.59^{A} 0.847	^{xx}1 - 2,3
	4	26.71 1.637	20.93^{A} 0.941	22.72^{A} 0.487	^{xx}1 - 2,3
	6	27.88 1.046	25.63^{B} 2.479	28.57^{B} 0.591	^{xx}1 - 2
	8	25.25 1.539	24.45^{B} 1.312	27.79^{B} 0.574	^{xx}3 - 1,2
Cu	2	49.37 4.789	26.28^{a} 1.366	31.78^{a} 2.265	^{xx}3 - 1,2
	4	48.52 3.111	19.73^{b} 1.004	27.68^{b} 1.491	^{xx}3 - 1,2
	6	48.42 3.215	15.49^{c} 1.041	18.77^{c} 0.501	^{xx}3 - 1,2
	8	46.82 0.459	9.212^{d} 0.699	12.31^{d} 0.440	^{xx}3 - 1,2
Fe	2	73.54 7.657	46.99^{A} 2.960	45.88^{A} 1.600	^{xx}1 - 2,3
	4	63.91 6.393	36.48^{B} 2.376	37.19^{B} 2.322	^{xx}1 - 2,3
	6	65.82 2.731	29.79^{C} 0.994	33.26^{B} 1.419	^{xx}1 - 2,3
	8	66.14 2.826	29.83^{C} 1.127	33.06^{B} 1.738	^{xx}1 - 2,3

Key: cf. Table 1.

lamb liver during and after supplementation with the mineral and organic form of selenium. Application of a dietary selenium supplement produced a significant rise of the hepatic manganese content in lambs receiving selenium preparations as compared to the control. The tendency held true in both 2 and 4 week of trace mineral supplementation. After the selenium supplementation was discontinued, in 6 research week, a significant decrease appeared in the manganese concentration in the liver of lambs from group II against the values recorded during the trace mineral supplementation and the Mn content in group III. However, the determined value proved to be significantly higher than the control.

The zinc content in the control group of lambs in the successive weeks remained on a similar level: from 27.25 in 2 week up to 25.25 mg kg^{-1} of wet mass in the final week. During the trace element supplementation, significantly less zinc was determined in the groups receiving selenium preparations compared to the control. No significant differences were reported in the Zn level in the experimental groups. In 6 and 8 experimental week, a significant rise was observed in the zinc content in the treatment groups compared to the selenium supplementation period.

In both periods i.e., of additional trace mineral supply and after its termination, the copper and iron concentrations declined significantly in both groups of lambs fed supplementary selenium preparations. This tendency was observed throughout all the research. After two supplementation weeks, the Cu and Fe levels were 47% and 36% lower, respectively, in group II and 36% and 38% in group III than in the control. Afterwards, despite the discontinuation selenium supplementation, the content of both minerals persistently declined, down to the following values in the last experimental week: Cu 9.212 and Fe 29.830 mg kg^{-1} in group II, Cu 12.308 and Fe 33.056 mg kg^{-1} in group III. The biggest decrease in the copper concentration was reported in the lambs whose diet was enriched with selenium yeasts. In the case of iron, no effect of a selenium form on the liver mineral content in lambs was determined.

The above results imply potential interaction between selenium and the analyzed trace minerals. However, consideration should be given to the fact that a number of other factors may have additionally affected the course of each mineral element concentration in both the blood serum and liver (Spears 2003). The antagonistic effect between selenium and other elements such as cadmium (Cd), lead (Pb) or mercury (Hg) has been described by El-Sharaky et al. (2007), Abdollahi (2001) and Su et al. (2008). The investigations of other authors have confirmed the zinc-selenium and copper-selenium antagonism (Jensen 1975, Hause, Welch 1989). Iron (Fe) and manganese (Mn) have also been shown to be selenium antagonists (Martin et al. 1989).

The present research shows that dietary supplementation with different selenium forms affected the content of Mn, Zn, Cu and Fe in the blood serum and liver of lambs. Manganese is found in virtually all tissues and

organs of animal organism, with its highest concentration recorded in the pancreas, liver, bone tissue and hair and hair cover. Most animal organisms show high tolerance to this mineral element. Manganese deficiency is more often associated with its disturbed availability than a low Mn level in feedstuffs (Gehrke 1997b). In animals, the Mn shortage causes animal growth inhibition, disordered urea synthesis and mineral metabolism in bones as well as inferior reproduction performance. The present research has shown a lower Mn content in the blood serum throughout the supplementation period in both experimental groups against the control. A contrary tendency was observed in the liver. Selenium supplementation has elevated the Mn concentration in both lamb groups with administered dietary selenium compounds. Selenium supplementation of lambs seems to be beneficial with respect to the Mn function as an oxidant contained in superoxide dismutase, whose activity is conditioned by the presence of selenium and manganese. Beside copper and iron, magnesium proves to be an essential trace element for hemoglobin synthesis.

Zinc belongs to the minerals whose shortage is more strongly related to its reduced assimilation in the digestive track than to its low content in a diet (Klebaniuk, Grela 2008). The effects of zinc deficiency may strike many bodily functions, including delayed and inhibited growth, impaired reproduction, immune system suppression and biochemical changes in blood. Cases of dermatitis and abnormal glossy-white hair appearance are also reported (White et al. 1994, Danek 2002). Throughout the experiment, the blood serum zinc content fluctuated, showing a rising tendency after the 4-week supplementation treatment. However, statistically significant differences were noted in the lamb group given organic selenium supplementation. A probable explanation could be the differentiated effeminacy of inorganic and organic selenium compounds included in ruminant diet (Taylor 2005). The zinc concentration in the liver appeared different. The initial decline during the supplementation period was followed by a significant growth in the successive weeks, as compared to the control, especially in the group of lambs whose diet included the inorganic form of selenium. Similar results were obtained by Chmielnicka et al. (1988). This behavior of zinc in the liver may be governed, inter alia, by the influence of metallothionein MT, a low molecular mass protein likely to participate in the uptake, transport and regulation of zinc in biological systems; it is formed through the synthesis stimulated in mucous cells by competitive zinc and copper atoms (Eck, Pallauf 1999, Oh et al. 1981). Metallothionein also acts as a zinc and copper store in the cell and has been documented to be a potent scavenger of free radicals (Park et al. 1985).

Copper proves to be an essential component of different proteins and metalloenzymes. This trace element contributes to iron metabolism, hemoglobin synthesis and erythrocyte production. The most pronounced changes were noted in the Cu and Fe concentration in liver. The observed behavior of the mineral elements indicates a strong antagonistic interaction in their

deposit and metabolism in the liver. The current results agree with those reported by other authors (Bik, Bednarek 1997), who noted a significant decrease in the copper level in sheep's blood serum after a subcutaneous injection of sodium selenite aqueous solution.

A low concentration of copper (the liver being its main storage organ) is likely to induce in future some clinical signs associated with this mineral deficit. Ruminants, sheep and goats predominantly, prove to be very susceptible to copper deficiency; also, wooly breeds and dairy animals are more sensitive than meat ones. Common symptoms of copper shortage include anemia or anemization, depending on the severity and duration of the deficit. Hypochromic anemia reported in animals and associated with copper shortage constitutes a major challenge in a differential diagnosis, to distinguish from an iron deficit-induced disease (Suttle et al. 1987). Prolonged copper shortage leads to lesions and deformations in bone tissue as well changes in the appearance and structure of animal hairs and wool (Gehrke 1997a). The vital role in copper regulation is attributed to the plasma ceruloplasmin concentration (Ransom-Stern et al. 2007). The present research did not include an assessment of the activity of this enzyme, although the blood serum copper content appeared to be significantly lower compared to the control.

The experiment performed by South et al. (2000) on mice showed that selenium deficiency played a role in iron accumulation in the liver and in cholesterol plasma; it affected the triglyceride level as well. Iron is essential to virtually all living organisms, it is a key component of cytochromes, an important electron carrier and plays a critical role in cellular respiration. This trace element is found deficient mainly in juvenile animals fed monotonous diets or milk alone, with no iron supplementation for long periods. As a consequence, an insufficient iron supply to animals causes the depletion of the body iron reserves in the liver, kidneys, spleen and bone marrow, leading to anemia. Besides, a reduced iron concentration in plasma is observed, alongside an enhanced iron-binding capacity by serum proteins (Underwood, Suttle 1999).

The influence of Se supplementation on reproductive efficiency can be varied (Hemingway 2003). Apart from the main source of Se, such as organic and inorganic supplements, we should also consider a period of supplementation before mating and check the vitamin E status of animals.

Se supplementation between 15 and 35 days after mating and during the first month of pregnancy is not recommended because it reduces the embryonic survival rate. On the other hand, Se supplementation from 21 days before gestation until near term in ewes (days 135 of gestation) is suggested (Lekatz 2010b).

Ample evidence shows that Se supplemented in the maternal diet may be of vital importance for the development of ruminant offspring; also in humans, a diet supplemented with Se can contribute to decreasing mortality and morbidity of preterm infants (Makhoul et al. 2004).

CONCLUSIONS

Selenium supplementation significantly increased the Se concentration in the blood serum and liver of lambs. Selenium compounds significantly contributed to changes of the minerals: manganese, zinc, copper and iron, in the blood serum and liver. Selenium supplementation distinctly depressed the Cu and Fe content in the blood serum and liver in both selenium-supplemented lamb groups. The highest copper concentration decrease was reported in the lambs whose diet was enriched with selenium yeasts. In the case of iron, no effect of the selenium form on the hepatic mineral content in lambs was determined. At the same time, selenium compounds had a synergistic effect on the Mn content in liver, especially in the group of lambs whose diet included inorganic selenium. The Zn concentration in the liver responded differently. The initial decline during the supplementation period was followed by a significant growth of the Zn content in the liver of lambs whose diet contained sodium selenite.

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