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The Biological Justification of Manganese Requirements in Fat-Tailed Ewes in Arid Zone Conditions

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Abstract

The article presents the results of physiological research carried out in a large sheep farm in the arid zone of southern Russia to study the manganese metabolism of single ewes of the Kalmyk breed and to establish their needs for this element by a factorial method of research. A scientific justification is given for optimizing the ration of manganese in single mutton ewes. The dynamics of the manganese content in the organs and tissues of the sheep and the organism of single mutton ewes for the first time have been revealed. Considering the physiological state of the ewes, the real daily requirement of the ewes in the studied microelement and the degree of its assimilation from the diets have been determined. It has been established that the intensity of manganese metabolism in the organism of fat-tailed ewes has been considerably increased during the non-dairy period and the distribution of manganese in their bodies has not been even. It has been higher in udder, uterus, chyme, omasum, and liver, and lower – in the fat of sheep's tail, blood, and internal fat.
The factorial method about endogenous losses in feces and urine has been used to determine the daily requirement of manganese in the dry weight of single fat-tailed sheep. The daily requirement is 82 mg per head per day, or 50.3 mg/kg of dry substance of a diet and 1.44 mg/kg of live weight of an ewe.

Keywords: Single ewes, Standard, Manganese, Element, Concentration, Kalmyk breed

Introduction

The main condition for increasing animal productivity is to provide them with the right amount of feed to meet their nutrient and mineral requirements (Gull & Kausar, 2019; Pham *et al.*, 2020). However, most feeds are deficient in some nutrients, particularly manganese, and excessive in others. Due to insufficient content of minerals in feed and disturbance of their proportions, their digestibility and assimilation of nutrients in feed is often reduced. This, in turn, leads to a decrease in productivity and reproductive ability of animals and the occurrence of various diseases associated with mineral deficiency (Lapshin, 1979; Kwiatkowski & Sldonskl, 1987; Mungin, 2009; Mohammed & Razzaque, 2016; Uslu *et al.*, 2017; Mandzhiev & Gayirbegov, 2019).

Despite the detailed study of manganese metabolism in the organism of ewes, the issues of rationing this element in diets of fat-tailed ewes depending on their physiological condition and zonal features of their breeding remain insufficiently studied.

The manganese norms recommended in 2003 by the Russian Academy of Agricultural Sciences for fat-tailed ewes do not consider the peculiarities of this direction of production and are the same as those for wool and wool-meat sheep (Kalashnikov *et al.*, 2003). In this regard, the objective of the study was to scientifically justify the optimization of manganese in diets of single fat-tailed ewes in dry climatic conditions of their breeding. To achieve this goal, using the factorial method of research, the following tasks were solved:

- To determine the content of manganese in organs, tissues, and gastrointestinal tract of ewes during the non-dairy period and the degree of manganese assimilation from diets
- To calculate the daily requirement and rate of manganese for single ewes

Materials and Methods

Physiological studies were conducted in the production conditions of the farm "Budda" of the Republic of Kalmykia on Kalmyk fat-tailed ewes after weaning and before mating, 3 animals of each period with an average live weight of 55-57 kg. During the experiment, the animals were kept in individual cages and fed according to the recommended RAAS norms (Kalashnikov *et al.*, 2003), about the chemical composition of the local feed.

The diets of the ewes during the period of failed impregnation included: grass from mixed grass pasture — 3.5 kg, alfalfa hay — 0.3 kg, barley sod — 0.1 kg, table salt — 11 g, and sulphuric manganese — 58 mg. It contained manganese according to the norm of the Russian Academy of Agricultural Sciences (2003), in the amount of 65 mg.

To study the level of absorption of manganese from diets, to find out the real daily requirement of ewes in this element, and to establish its rates in diets, physiological (balance) experiments were conducted on single ewes after weaning and on single ewes before they were mated. On the day of the end of each balance experiment, to study

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the manganese content in organs, tissues, and the whole organism, three ewes of similar weight in every single period were slaughtered. The weight of the organs, tissues, and contents of the digestive tract of each ewe was determined. Three samples of each organ and tissue of sheep were taken to determine the concentration of manganese using an atomic absorption spectrophotometer (Getachew *et al.*, 2017; Abdoli *et al.*, 2018; Mirzaei-Alamouti *et al.*, 2018; Mandzhiev *et al.*, 2019).

To calculate the manganese requirement of ewes, we used the factorial method of research, which, according to data (Georgievskii *et al.*, 1979; Kalnitskii *et al.*, 1988; Gromova & Kuznetsov, 2003; Chalmeh *et al.*, 2020), is the most reliable and accurate.

As this method provides, we determined the total content of manganese in the body of ewes, then determined the amount of this element that is deposited in the body during the non-dairy period and per day. Endogenous losses of manganese with urine were determined by the direct method, and with feces by calculation, using data (Georgievskii *et al.*, 1979) obtained based on the generalization of literature data and results of own experiments carried out by radioisotope studies.

Received daily accumulation of manganese in ewes and endogenous losses of this element with feces and urine were summarized and, thus, the true daily requirement of the studied element was established.

Based on the results of balance experiments, considering endogenous losses in feces, the true digestibility of manganese from diets was calculated using the following formula:

$$R = \frac{I-(Ex-E)}{I} \times 100 \quad (1)$$

where: R — actual digestibility, %;
I — intake of the element in the diet, g;
Ex — excretion of the element in feces, g;
E — endogenous losses in feces, g.

The determined total actual requirement was divided by the percentage of actual digestion and the result was the amount of the element that should be contained in the diet.

The digital material obtained from all the studies was processed on a computer using the program "Statistics". The results were studied and compared by the group method. The difference in the average indices between the groups was considered reliable at the level of probability (p=0.05), determined using Student's t-test according to E.K. Merkureva (Merkureva, 1970).

Results and Discussion

A study showed that, as a biologically active element, manganese is present in all tissues of ewes but distributed unevenly among them **(Table 1)**. For example, in single ewes, the highest concentration of manganese was concentrated in the brain. In ewes after weaning their lambs, the concentration was 258.44 mg/kg, but in ewes before mating, it increased by 1.4 times to 362.14 mg/kg.

A relatively high concentration of manganese is observed in the tongue, which is also subject to large variations depending on the period of failed impregnation of the ewes and the content of their ration. During the non-dairy period of ewes, the concentration of the element in the tongue increased from 189.61 to 293.07 mg/kg, and its total amount from 18.0 to 27.0 mg, or 1.5 times.

From the fatty tissues, the internal fat and tail fat are slightly inferior to the circumrenal fat in terms of the concentration of this element. Due to the increase in the concentration of the element, the total amount of the element in the inner fat increased from 8.0 to 13 mg or 1.6 times, in the fatty fat from 23.0 to 26.0 mg or 1.13 times, and in the circumrenal fat from 5.0 to 9.0 mg or 1.8 times.

Among all tissues, blood had the lowest concentration of manganese. In single ewes, it contained 12.17-17.28 mg/kg of the element. A high concentration of manganese was also found in bone tissue, which contained 55.90 to 95.36 mg/kg in the case of single ewes. As for muscle tissue, manganese concentration in it was 2.5-2.6 times lower in non-dairy ewes than in bone tissue. As the concentration of the element increases, so does the total amount in bone tissue, from 362 to 657.0 mg.

The main organ depositing manganese is the liver, which has the highest concentration of this element (355.92-651.43 mg/kg), then, with decreasing concentration of this element, the internal organs of single fat-tailed ewes are in the following order: spleen (120.09-247.39 mg/kg), kidneys (83.0-107.2 mg/kg), heart (76.66-87.96 mg/kg), lungs (20.42-24.48 mg/kg). The total amount of manganese in the heart and lungs increased by 1.3 times, in the liver — by 1.8 times, in kidneys — by 1.4 times, in the spleen — by 2.4 times **(Table 1)**.

Since the places of absorption and excretion and the intensity of absorption of minerals in different parts of the gastrointestinal tract of ruminants are not the same, it was interesting to study the accumulation of this element in them.

The conducted analyses of gastrointestinal tract samples of single ewes showed that the highest concentration of manganese was observed in the walls of the omasum (260.78-547.898 mg/kg) and small intestine (62.49-243.25 mg/kg). The remaining parts, in descending order of this element, were as follows: large intestine — rumen — reticulum — rennet. It should be noted that the concentration of manganese increased in all parts of the digestive tract of single ewes by the end of the period under study: in the rumen by 3.3% (p>0.05), in the reticulum and omasum by 2.1 times (p<0.05), in the rennet by 1.3 times (p<0.05), in the small intestine by 3.9 times (p<0.001), and in the large intestine by 1.2 times (p<0.001. All these testify that the metabolism of manganese in digestive organs of single ewes of meat production type becomes more intensive to the mating period. The total content of manganese in an alimentary tract wall of single ewes by the end of the period of observation gradually increases and reaches its maximum in the small intestine (304 mg), followed by the large intestine (178 mg), omasum (104 mg), rumen (84 mg), rennet (17.2 mg), and reticulum (12 mg).

During the absorption and redistribution of manganese in the body of single ewes, the chymus of the gastrointestinal tract departments are also of particular importance. Studies showed an uneven distribution of this element in the contents of the digestive tract.

In single fat-tailed ewes, the chymus of the omasum and the small and large intestine are more saturated with this element.

The absolute content of this element in the rumen and reticulum contents increased by 1.9 times ($p < 0.001$), in the scut 2.9 times ($p < 0.001$), in the omasum by 7.6% ($p > 0.05$), in the small intestine by 1.8 times, and in the large intestine by 3.1 times ($p < 0.001$) during the studied period.

In general, the total amount of this element in single ewes increased from 2,273.2 mg to 4,657.3 mg.

Table 1. The Manganese Content in the Tissues and Organs of Single Ewes

Indicators	Concentration, mg/kg Total amount, mg		Concentration, mg/kg Total amount, mg	
	Ewes after weaning	Ewes before mating	Ewes after weaning	Ewes before mating
Blood	12.17±0.39	17.28±1.26	42.60±0.30	67.00±2.51
Muscle tissue	22.25±0.63	36.24±0.53	369.35±4.5	670.00±3.78
Bone tissue	55.90±2.30	95.36±2.40	363.35±2.3	657.00±3.60
Skin with coat	39.76±1.58	76.43±2.01	246.51±4.0	496.0±3.05
Internal fat	15.53±2.56	19.27±2.75	7.92 ±1.52	13.00±1.52
Perirenal fat	61.79±10.89	43.64±4.28	4.94 ±1.15	9.00±1.15
Tail fat	4.86±0.55	4.90±0.15	23.33 ±1.52	26.00±1.52
Brain	258.44±13.66	362.14±13.49	34.89 ±2.88	50.00±2.30
Tongue	189.61±15.87	293.07±9.72	18.00±1.52	27.00±1.52
Heart	76.66±15.18	87.96±2.45	17.63 ±2.08	22.00±1.15
Lungs	20.42±0.72	24.48±2.69	10.62 ±0.20	14.00±1.73
Liver	355.92±14.71	651.43±9.02	284.73 ±1.77	508.0±3.08
Kidneys	83.00±7.87	107.20±7.98	7.97 ±1.00	11.00±1.52
Spleen	120.09±23.17	247.39±18.29	10.21±1.52	24.00±1.52
Uterus	173.69±10.71	1,073.50±34.05	19.97 ±1.52	134.00±1.15
Udder	79.98±6.65	1,435.53±100.17	17.60 ±0.40	128.00±1.52
Rumen	66.89±3.41	69.13±1.26	68.22 ±1.52	84.0±1.73
Reticulum	39.12±10.69	84.31±6.95	6.06 ±1.52	12.00±1.15
Omasum	260.78±22.48	547.89±27.26	44.33 ±2.08	104.10±1.46
Rennet	27.80±0.54	36.18±2.34	13.62±0.34	17.20±1.20
Small intestine	62.49±3.78	243.25±3.12	81.24 ±2.08	304.00±2.08
Large intestine	40.53±1.49	169.55±1.34	47.00±1.73	178.00±2.08
Content: Rumen	27.95±0.45	52.17±6.05	162.11±2.64	305.00±2.51
Reticulum	98.97±4.77	211.42±3.04	35.63±0.76	69.70±1.45
Omasum	184.41±2.18	876.96±9.50	63.72 ±1.07	190.30±12.3
Rennet	141.50±1.54	111.11±15.32	32.51 ±0.65	35.00±1.37
Small Intestine	218.69±4.98	364.68±1.98	177.14±1.73	310.00±4.04
Large Intestine	116.97±1.74	384.79±30.31	62.00±2.08	192.00±2.30
Total:			**2,273.2**	**4,657.3**

The calculations revealed that for normal functioning of the body of the Kalmyk single ewes and to increase their productivity, their actual requirement of manganese is 32.47 mg per head per day. Considering the biological availability of manganese from diets of single fat-tailed ewes during the period under study, the daily requirement of this element for them is 82 mg or 50.3 mg per 1 kg of dry matter of the diet and 1 kg of live weight — 1.44 mg **(Table 2)**.

Table 2. Daily Requirement of Single Ewes for Manganese and Its Norm in Rations, mg

Indicators	Ewes after weaning	Ewes before mating
Total manganese content in the body:	2,273.2	4,657.3
Total manganese deposition in the body over a single period	-	2,384.1
Daily deposition of manganese	-	26.49
Endogenous losses:	4.8	4.8
In the feces	1.18	1.18
In the urine	5.98	5.98
Total	-	32.47
The true daily requirement of manganese, mg	-	39.60
True digestibility from diet, %	-	82
The actual daily requirement in the ration:	-	50.3
Per 1 head, mg	-	1.44

Conclusion

The approbation of the developed norms showed that feeding of single ewes with diets is containing the established norm of manganese increases the intensity of their growth and has a positive effect on meat and wool productivity.

Thus, the average daily gains of live weight of the ewes that received manganese in their diet according to the norm that we established were 17.8 g or 27.6% higher than those of the control group that received manganese according to the RAAS (2003). It should also be noted that ewes that received manganese according to the norm set by us had better expressed sexual dominance. Among all the flock, 92% of ewes showed readiness whereas in the control group it was 84%. Out of the mature flock, 93.1% of ewes in the experimental group were inseminated at first mating while in the control group it was 4.4% less.

Thus, the results of product testing confirmed that optimizing the amount of manganese in the diets of single ewes was more consistent with their need for this element. Our developed norms of manganese for single fat-tailed ewes are higher than recommendation]. In our opinion, they are more accurate and may well be applied in other regions with arid climatic conditions of feeding and keeping sheep.

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