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Biogenic Concentration of Microelements in the Body of Cattle based on Reserves in Pasture Samples (Case Study: The Astrakhan Region)

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Modern animal farming is currently becoming important in the socio-economic development of the Astrakhan region. Physiological characterizes of farm animals especially economic-cattle breeds or population is highly-important for using in breeding program. Concentration of microelements is one of first key point in this identification. Our work presents data from biogeochemical studies of pasture ecosystems (dominant plants of ranges) in the Astrakhan region and its effect on microelement reserves in body (meat, muscles and other tissue). The studies were carried out in 2021 on Simmental cattle. Trace elements in the selected samples of the pasture ecosystem, as well as in the organs and tissues of Simmental cattle were determined by the atomic absorption method. A low rate of trace elements was found in the soil, plants and feed of the ecosystem of the Astrakhan region. In conclusion, the greatest amount in the soil and plants contains manganese and zinc, in the least - selenium. In pasture-samples, the highest content of microelements was found in astragalus (*Astragalus mongholicus*) as a sample. In addition, a low level of trace elements was found in the organs and tissues of Simmental cattle.
Keywords: Cattle, Ecosystem, Hypomicroelementoses, Pasture, Zinc.

INTRODUCTION

For the normal course of physiological processes in the body of animals, in addition to nutrients, a regular intake of vitamins, micro- and macroelements is necessary. The quantitative content of chemical elements that make up organisms varies widely depending on the habitat, species, age, and a number of other reasons (Panichev *et al.*, 2017; Gelain *et al.*, 2021). Most minerals are part of protein complexes, enzymes, respiratory pigments, hormones, and a number of vitamins in economical animals (Soetan *et al.*, 2010; Alagawany *et al.*, 2021). In this regard, copper is part of many oxidative enzymes, iodine is an integral part of thyroid hormones (thyroxine), and cobalt is vitamin B_{12}. Vital mineral elements (iodine, cobalt, iron, zinc, selenium, fluorine, etc.) are involved in metabolism, affect the basic functions of the body development, growth, reproduction (Saha *et al.*, 2021).

The important role of trace elements is manifested when they are supplied in biotic quantities that do not exceed the maximum physiological concentration in the animal body (Shukla *et al.*, 2018). In such cases, when they enter the animal body as nutritional components, they do not cause a reaction of resistance from protective barriers, but enter into integrations with the corresponding systems (Stepanova *et al.*, 2023).

The lack of single or complex minerals in soils, water, and feed is considered the main cause of low productivity and diseases of the reproductive system of pasture animals (McDowell, 1996; Martin *et al.*, 2020).

An obligatory parameter for the introduction of animal husbandry in modern, intensive conditions is the analysis of the microelement profile of a certain biogeochemical territory in order to comparatively assess the microelement status of various pasture animals (Ahmed *et al.*, 2021).

The availability of mineral elements is directly dependent on their concentration in the soil, as well as the nature of the soil. For example, the taiga-forest non-chernozem soil is characterized by high soil acidity, lack of calcium, phosphorus, potassium, copper, boron, iodine, and sufficient or excessive content of manganese, zinc, and strontium. In the soils of the floodplain areas, there is a lack of iodine, copper, and selenium (Adetunji *et al.*, 2021; Fadlalla, 2022). The soils of the dry steppe, desert and semi-desert zones are

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characterized by a neutral or alkaline reaction and an increased content of sodium, calcium, boron and sulfate salts, and a lack of copper, molybdenum, and zinc (Lukin *et al.*, 2019). Animal nutrition primarily depends on the soil-plant-animal complex and the season, which can also affect the requirement for micronutrients. To assess the mineral and immunological status of animals, it is necessary to regularly analyze the mineral composition of the feed. However, feed cannot fully meet the needs of the animal organism in minerals. As a result, their deficiency develops, which causes significant economic damage, consisting of a decrease in live weight gain, fertility, which are accompanied by impaired functioning of the whole organism. Due to a decrease in the resistance and reactivity of the animal organism, morbidity and mortality increase (Ahmed *et al.*, 2021).

In practice, deficiency of iron, copper, selenium, cobalt, zinc is often detected simultaneously, which leads to more severe processes of metabolic disorders and insufficient severity of the clinical picture. For veterinary medicine, a very urgent task is the development of complex, highly effective drugs for the simultaneous prevention of mineral deficiency conditions and the treatment of animals with micro-elementoses (Balakirev *et al.*, 2020). Previous studies have shown that the content of mineral elements in the soils of the Astrakhan region is low, which affects the lack of them in the plants of the region, which, in turn, leads to a violation of metabolic processes in animals, a decrease in productivity (Khismetov and Vorobyov, 2015). The purpose of the work is to study the biogeochemical situation with microelements in the Astrakhan region and the level of microelements in the organs and tissues of cattle.

MATERIALS AND METHODS

The studies were carried out in 2021 on Simmental cattle. Experimental analysis was performed at the Department of Veterinary Medicine of the Astrakhan State University and the Joint Research Laboratory of Fundamental and Applied Problems of Biogeochemistry and Veterinary Medicine of the Volga-Caspian Region of the Astrakhan State University and the Institute of Geochemistry and Analytical Chemistry. V. I. Vernadsky

Determination of the levels of trace elements in the ecosystem was carried out in the Astrakhan region at the latitude 46°20’58" (46° 20'98) north latitude and longitude 48°2'26" (48° 2'44) east longitude. The Astrakhan region is located in the Caspian lowland, where the Volga flows into the Caspian Sea. The flat surface lies mostly below sea level with elevations ranging from -2.7 m in the north to -27.5 m in the south. The relief is flat, with saline uplifts of the Caspian lowland. The Astrakhan Region is located in a semi-desert zone. The climate is sharply continental, arid. The coldest month is January (average temperature is -10 °C), the warmest is July (average temperature is +26 °C). The Astrakhan region is characterized by sand dunes and ridges, clay deserts (takyrs), and in some places solonchaks (shors) and solonchaks 30–40 cm thick, devoid of vegetation.

Ecosystem samples (soil, plants, water and feed) were collected from pastures in the Astrakhan region. In addition, in 6 cattle animals, during planned slaughter, various tissues and organs were taken for analysis in order to determine the level of trace elements. Average samples of soil, water, plants, feed and various organs were taken for microelement analysis in accordance with generally accepted methods. Soil samples from pastures were taken from different depths using a sampling auger. Six samples were collected from each of the selected pastures and a representative sample was taken. All soil samples were sifted through a 0.15 mm nylon sieve. Samples were stored separately in two zippered plastic bags. One was used to determine the content of trace elements in the soil, the other was used to measure physical indicators. Forage plant species were collected from pastures in triplicate. Plant samples were collected after careful observation of the cattle grazing regime. Feed leaves were washed with 1% HCl solution, followed by washing with distilled water. The air-dried samples were again dried in an oven at a temperature of 65±5°C. The dried leaves were ground to a powder in a homogenizer and subjected to wet digestion. Trace elements in the selected samples were determined by atomic absorption spectrophotometry on a CHITAHI 180-50 spectrophotometer (Japan). After combustion in a flame, the samples were aerolyzed and mixed with gases (acetylene and air). The individual atoms, which had gone into an excited state by passing UV light, were released. When absorbing UV light, the measurable region of the spectrum. The detector and output signal were amplified and sent to a computer data processing system. The received data was processed using software. The resulting digital material was subjected to statistical processing on a personal computer using the standard program of variational statistics Microsoft Excel. To assess the significance of differences, the student’s coefficient was used, at a critical significance level of 0.05.

RESULTS AND DISCUSSION

It was revealed that different types of soils in the Astrakhan region contain the following concentrations of such trace elements as cobalt, selenium, iodine, manganese, zinc and copper (Table 1).

It has been established that the content of mineral elements in environmental objects fluctuates. It was found that the average content of cobalt in soil and plants was 7.78 ± 0.12 and 3.13 ± 0.65 mg/kg, respectively. The distribution of cobalt in nature is insignificant. However, the role of cobalt in nature is great. Cobalt is also a biogenic element, the role of which in the life of living organisms is extremely high. In plants, cobalt has a positive effect on photosynthesis, activates the enzymes of protein metabolism. In animals, cobalt is part of vitamin B_{12}, forming an intracomplex compound, where cobalt is 4.5%. Vitamin B_{12} is absent in plants, but the supply of this vitamin to animals and humans depends on the presence of cobalt in plant feed (Eliseeva *et al.*, 2013; Gille and Schmid, 2015).

Table 1. Average content of trace elements (Co, Se, I, Mn, Zn) in soils and plants of the Astrakhan region, mg/kg.

Microelement	Soil (n = 40)	Plant (n = 20)
Cobalt	7.78 ± 0.12	3.13 ± 0.65
Selenium	0.11 ± 0.08	0.06 ± 0.01
Iodine	0.63 ± 0.13	0.56 ± 0.03
Manganese	157.74 ± 5.98	41.76 ± 6.03
Zinc	48.73 ± 4.03	37.11 ± 0.65

The content of selenium in the soil was at the level of 0.11 ± 0.08 mg/kg. The average selenium content in plants was 0.06 ± 0.013 µg/g. Selenium (Se) is an essential micronutrient for humans and animals, but when taken in excessive amounts leads to toxicity. Plants are the main source of selenium for animals, but its importance to plants is still controversial. However, Se at low doses protects plants from various abiotic stresses such as cold, drought, desiccation, and metal stress. In animals, Se acts as an antioxidant and aids in reproduction, immune responses, and thyroid hormone metabolism. Selenium is chemically similar to sulfur; therefore, it is absorbed by plants through sulfur carriers present inside the root plasma membrane, metabolized by sulfur assimilation, and volatilizes into the atmosphere (Vorobyov and Vorobyov, 2014). The content of iodine in soil and plants was 0.63 ± 0.13 and 0.56 ± 0.03 mg/kg, respectively. The distribution of iodine between various components of terrestrial ecosystems occurs with a significant participation of microbiological processes. From a physiological point of view, the flow of iodine between different organisms is believed to be a valuable source of antioxidant potential, as well as the metabolic value of the compounds resulting from the reaction between the amino acids tyrosine and iodine. From an ecological point of view, the flow of iodine between different soil layers, ecological compartments and organisms can be considered as part of a global energy dissipation system.

The content of manganese in plants was 3.8 times lower than in the soil. Manganese (Mn) has been found to be an essential element in virtually all living organisms, where it can serve two different functions: acting as an enzyme cofactor or as a metal with catalytic activity in biological systems. In mammals, Mn acts as a cofactor for various enzymes, including arginase, glutamine synthetase, pyruvate carboxylase, and Mn superoxide dismutase (MnSOD). However, in dry, well-aerated and calcareous soils, as well as in soils containing a large amount of organic matter, where the bioavailability of Mn for plants decreases below the level required for normal plant growth (Alejandro *et al.*, 2020). The average concentration of zinc in the components of the terrestrial ecosystem (soil and plants) was at the level of 37.11 - 48.73 mg/kg. It is known that zinc is a microelement necessary for all living organisms, playing a key role in growth, development and protection. In our study, it was found that the level of zinc is within the normal range for the soils of the Astrakhan region.

Minerals are directly involved in the protection of plants and animals as structural components and regulators of metabolism. Essential trace elements affect the physiological functions of plants and animals both directly, by activating enzymes that produce protective metabolites, and indirectly. The next stage of our research was the study of the content of certain trace elements in feed prepared in the Astrakhan region. As a result of the research, a rather low level of mineral elements in natural feeds was established. The content of trace elements in feed can be affected by their content in the soil, the physicochemical properties of the soil and the types of plants growing in the area. Trace element ions are mainly absorbed on the hydroxyl surfaces of oxides or clay minerals. An increased content of soil organic matter contributes to a decrease in the concentration of microelements in the soil due to complex formation and adsorption (Table 2). As a result of the research, a rather low level of mineral elements in natural feeds was established. The content of trace elements in feed can be affected by their content in the soil, the physicochemical properties of the soil and the types of plants growing in the area.

Table 2. Concentration of trace elements (Mn, Co and Se) in cattle feed in the Astrakhan region, mg/kg (n = 10; M±m).

Forage species	Microelement		
	Mn	Co	Se
Lucerne hay	38.13±1.13	0.49±0.007	0.10±0.006
Hay meadow	47.32±1.33	0.23±0.009	0.16±0.011
Bread crumbs	50.03±2.00	0.47±0.011	0.09±0.006
Delphinium consolida	73.94±3.55	0.10±0.007	0.12±0.023
Sudanese grass	82.09±3.33	0.15±0.009	0.11±0.002
Birch leaf	55.06±2.03	0.43±0.013	0.08±0.001
Chenopodium quinoa	10.00±0.33	0.86±0.130	0.13±0.021
Sandy oats	13.65±1.66	0.23±0.008	0.11±0.032
Prickly thorn	98.03±4.93	1.33±0.210	1.13±0.100

Trace element ions are mainly absorbed on the hydroxyl surfaces of oxides or clay minerals. The increased content of soil organic matter contributes to a decrease in the concentration of trace elements in the soil due to complex formation and adsorption. Animal feed ingredients, which constitute complete feed products, are obtained from a variety of raw materials of plant and animal origin, as well as the addition of pharmaceutical compounds. Many metal compounds, calcium, copper, manganese, magnesium and

Table 3. Levels of some microelements in organs and tissues of Simmental cattle under biogeochemical conditions of the Astrakhan region, mg/kg (n = 10; M±m).

Organ	Se	Co	Mn	Zn	I
Muscles	0.09±0.006	0.08±0.003	48.63±2.00	101.45±3.96	0.09±0.002
Liver	0.72±0.113	3.66±0.090	53.17±3.73	140.50±7.34	0.39±0.012
Spleen	0.41±0.016	2.03±0.186	43.56±1.18	48.98±2.16	0.16±0.037
Blood	0.53±0.025	1.73±0.009	60.63±1.57	48.84±2.00	0.58±0.008
Lung	0.10±0.066	1.14±0.053	32.98±1.18	137.85±4.03	0.47±0.009
Kidney	0.74±0.018	1.98±0.013	67.46±1.33	100.95±11.9	0.49±0.020
Abomasm	0.53±0.028	1.99±0.031	56.78±2.67	165.50±9.99	0.53±0.012
Small intestine	0.37±0.012	1.47±0.054	54.80±2.00	81.98±6.33	0.54±0.019

zinc compounds, as well as metal amino acid complexes, are incorporated into animal feed to meet the nutritional needs of farm animals and pets. Various by-products of the industrial production of metals are also widely used (Khismetov, and Vorobyov, 2015).

It has been observed that the highest concentration of selenium was determined in the tissues of the kidneys and liver (0.74 ± 0.018 and 0.72 ± 0.113 mg/kg, respectively), and the lowest - in the muscles and lungs. In other studied tissues, the trace element concentration was at the level of 0.37 ± 0.012 mg/kg to 0.53 ± 0.028 mg/kg. It has been established that the largest amount of selenium in cattle is in the kidneys, while in the muscles it is present in the largest total amounts. The kidneys are the organs that store the most selenium, followed by the liver. During the absorption and distribution of selenium in the body, most of it is sent to the liver, which is considered the depot of the microelement, and in case of its excess, it is excreted in the bile.

According to the content of cobalt, all the studied tissues can be arranged in the following sequence (in ascending order): muscles > lungs > wall of the small intestine > blood > kidneys > abomasum wall > spleen > liver. Cobalt in the body of ruminants is necessary for the microbial metabolism of the rumen, for the synthesis of methane, acetate and methionine. It is also a structural component of vitamin B12, which acts as a coenzyme in energy metabolism. In our studies, it was found that the highest content of cobalt is found in the hematopoietic organs (spleen and liver). The concentration of manganese in the body of cattle ranged from 32.98 ± 1.18 to 67.46 ± 1.33 mg/kg. The highest concentration of the microelement was found in the kidneys, and the lowest - in the lung tissue. An animal weighing 70 kg is estimated to contain 10 to 20 mg of manganese. The amount of Mn in the body is widely distributed in tissues and fluids and may vary depending on age, type of organs and interaction with other trace elements. Some authors report that approximately 1 to 4% of dietary manganese is absorbed into the body. Zinc is found in the largest amount in the body. All studied organs and tissues can be arranged in the following sequence according to the content of zinc (in increasing order): blood > spleen > wall of the small intestine > kidneys > muscles > lungs > liver > abomasum wall. It has been established that there are many zinc-deficient soils in the world, as a result of which pastures and crops have a low zinc content. In animals, zinc deficiency is expressed in reduced growth, damage to the skin, hair, wool and feathers, as well as in violations of reproductive processes (Hill and Shannon, 2019; Stepanova *et al.*, 2023).

The highest concentration of iodine was recorded in the blood -0.58 ± 0.008 mg/kg, and the lowest - in muscle tissue (0.09 ± 0.002 mg/kg). In other studied organs, the iodine content ranged from 0.16 ± 0.037 to 0.54 ± 0.012 mg/kg. Iodine is an important dietary mineral that is essential for the synthesis of thyroid hormones. It is known that from 70 to 90% of the iodine supplied with feed is absorbed directly from the rumen of cattle (Vorobyov *et al.*, 2018; Silva *et al.*, 2022). In rennet, the rate of iodide secretion is about 18 times that of absorption. Circulating thyroxin enters the small intestine with bile. Most of the iodide excreted by abomasum is reabsorbed in the small and large intestines.

***Conclusions*:** The results of the study indicate a low level of some trace elements in the ecosystem of the Astrakhan region. The greatest amount in the soil and plants contains manganese and zinc, in the least - selenium. In feed, the highest content of microelements was found in Astragalus forage. In addition, a low level of trace elements was found in the organs and tissues of Simmental cattle. Present study strongly shows the relation of environmental microelements with their reserve in animal body (grazing animals). It's suggested that micro-element supplementation should be more considered for grazing animals, based on local and environmental conditions.

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***Availability of data and material*:** We declare that the submitted manuscript is our work and data will be available when journal request it.

***Code Availability*:** Not applicable

***Consent to participate*:** All authors are participating in this research study including laboratory works, sampling from pastures, and writing of manuscript.

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