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Research Article

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Biogeochemical Ecology and Physiological Substantiation of the Application of Mineral Additives in Different Formulations for Feeding Animals

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ABSTRACT:
This paper presents data on the relationship of the mineral composition of soils, plants and living organisms. Mineral supplements in various forms are introduced into the animal diets that are deficient in a number of trace elements, and the physiological parameters of the organism that determine its homeostasis are studied. The effect of mineral supplements in diets on changes in productivity is also being studied. All studies were carried out in the farms of Tver region, which soil is poor in many trace elements.

Keywords: mineral elements, homeostasis, nanopowder, nanosilicon, blood, red blood cells, leukocytes, hemoglobin, enzymes.

INTRODUCTION:

The ecological link of organisms with the geochemical environment occurs through the migration of chemical elements in the biosphere and depends largely on the geochemical environment, climate, physico-chemical composition of soil-forming rocks, which are the storehouse of trace elements, as well as the agrophysical and agrochemical properties of the soil cover. The basis of geochemical ecology is the study of the adaptation of plants and animals to the geochemical environment. This environment is heterogeneous and is characterized by a significant variety of the chemical composition of soils and soil-forming rocks. Some soils of Russia are poor in some microelements, and some soils are rich in them. Plants growing on these soils reflect their content of chemical elements. In the central and northwestern Non-chernozem zone, the content of all the leading trace elements is below the background [5].

Soil is the beginning and end of the biotic circulation of macro- and microelements. The biotic circulation of chemical elements begins and ends in the soil. From the point of view of geochemical ecology, soil is a link in the biogeochemical trophic chain, a reservoir of macro- and microelements used by plants and animals.

Soil geochemistry is one of the leading factors determining the livelihoods of farm animals, their productivity, reproductive ability and natural resistance. With negative changes in soil biogeochemistry, there is a decrease in

productivity, reproductive ability of farm animals, their resistance to macro- and microelementoses.

The chemical composition of parent rocks and soils largely determines the concentration of macro-and microelements in waters. The waters of different water sources used for watering animals differ in the content of copper, fluorine and other chemical elements. By the concentration of boron, water differs from each other by 30 times, copper - by 40, strontium - by 100, zinc - by 200, cobalt - by 300 times and more. Some waters contain an insignificant amount of fluorine, while others contain much. With a lack of fluorine in drinking water, animals develop dental caries, while with an excess - fluorosis. In some waters, iodine is absent, which contributes to the disease of animals with an enzootic goiter [8].

A practically accessible technique for diagnosing the deficiency of microelements is the use of a map of biogeochemical zones and provinces developed by V.V. Kowalskii. The map shows the main zones of insufficient copper, cobalt, iodine, and excess boron, nickel, molybdenum, fluorine, lead and a number of other elements. These data help prevent micronutrient deficiencies. To do this, all animal farms located in such zones are recommended to introduce the trace elements missing in the feed in prophylactic doses. For the most extensive Central-Non-chernozem zone the following indicative norms of additives are recommended [5].

Mineral substances play an important and diverse role in the organism of animals. They affect the energy, nitrogenous, carbohydrate and lipid metabolism; they are structural material in the formation of tissues and organs; part of organic substances; involved in maintaining the normal colloidal state of protein, osmotic pressure and acid-base balance, in the processes of respiration, blood formation, digestion, absorption, synthesis, decomposition and excretion of metabolic products from the body; have a great influence on the activity of enzymes and hormones, thereby affecting the metabolism, support the protective functions of the body, participating in the processes of neutralization of toxic substances and antibody synthesis; and affect the symbiotic microflora of the gastrointestinal tract [9].

It is known that the body has a high-degree regulation of homeostasis of minerals. Despite the wide variations in the content of mineral elements in the feed, the mineral status of the organism remains fairly constant. However, these regulatory mechanisms are not infinite. Lack or excess of individual mineral elements, distortion of their optimal ratio in diets lead to disruption of metabolic processes, reduced digestibility, feed efficiency and animal productivity, and even to specific diseases in case of prolonged or acute deficiency or excess. These include: anemia, endemic goiter, hypomicroelementoses, etc. [3,6].

Many researchers use the introduction of mineral substances in the diet of animals in the form of complexions (chelates), which are a complex of microelements (iron, copper, zinc, cobalt, iodine) with an organic ligand — ethylene diamine disuccinic acid (EDDSA) [1].

In recent years, studies have been conducted to clarify the role of insufficiently studied mineral substances in a living organism. These include silicon. The emergence of new natural, chemical and microbiological compounds of silicon marked the beginning of their research in medicine and veterinary medicine [2].

Trace elements such as iron, copper, iodine, cobalt, zinc, manganese, molybdenum, selenium, fluorine, play an important role in the vital processes. They are found in all tissues of the body, but in large quantities, in the so-called, depot of trace elements - the liver, spleen, bones, kidneys, skin, pancreas, etc. Biogenic trace elements are part of the enzymes, vitamins, hormones, respiratory pigments, cell structures, cytoplasm, blood, lymph, tissue fluid and are essential components of the intracellular environment [1].

An important role in maintaining the hemostasis of the body belongs to the blood and its homeostatic mechanisms. There is reason to believe that the degree of success of the corrective action of bioelements on a living organism depends on their state when entering the body.

To study the effect of complex compounds of microelements (Hemovit-meian) on the physiological state of Trakehner horses, a scientific experiment was conducted on the basis of the stud farm "Pallada" of Tver region. Hemovit-meian is a complex of microelements (Se, Zn, Cu + organic ligand - methionine succinic acid). The supplement was administered into the diet of lactating mares at the 3rd month of lactation and fed for 60 days in an amount of 30 g per 1 head according to the manufacturer's recommendation mixed with concentrated feed 1 time per day. Then blood was sampled in the animals that received the supplement and the animals of the control group and the complete blood count and biochemistry tests were performed and the content of trace elements was studied in the object of research.

Table 1 - Hematological indices of lactating Trakehner mares at the end of the research

Groups of animals	Red blood cells, 10^{12}/l	Hemoglobin, g/l
Control	7.07±0.29	128.25±0.51
Experimental	7.56±0.38	150.9±0.56***

Table 2 - Indicators of protein metabolism of lactating mares

Indicators	Beginning		End	
	Control	Experimental	Control	Experimental
Total protein, g/l	68.41±0.99	69.28±1.04	62.46-1.29	69.31±2.01**
Albumin, g/l	32.84±0.61	32.89±0.26	33.63-1.26	33.12±0.99
Globulin, g/l	35.57±0.24	36.39±0.36	28.84-0.34	35.72±0.38
Urea mmol/l	4.89±0.17	4.98±0.22	5.13-0.29	5.89±0.31
Creatinine μmol/l	89.33±1.04	105.09±0.89	80.79-0.87	87.30±0.89**

Table 3 - The content of selenium, copper and zinc in the mane hair of lactating mares at the beginning of research

Groups of animals	Se, mg/kg	Cu, mg/kg	Zn, mg/kg
Control	0.20±0.01	5.70±0.69	112.56-0.86
Experimental	0.20±0.02	6.20±0.04	117.50-0.64

Table 4 - The content of selenium, copper and zinc in the mane hair of lactating mares at the end of research

Groups of animals	Se, mg/kg	Cu, mg/kg	Zn, mg/kg
Control	0.23±0.02	5.94±0.12	113.27-0.35
Experimental	0.29±0.04	6.96±2.29	123.74-2.62

According to the results of the research, we found that the introduction of compounds of microelements affected the metabolic processes in the horses, and, namely, there was a tendency to an increase in the content of red blood cells and hemoglobin in the blood of experimental mares by 6% and 18%, respectively, which indicates intensity of metabolic processes in the body and blood circulation in the mammary glands and the process of lactogenesis during lactation.

Mares treated with the above supplement had a significant increase in the amount of selenium in their hair, which exceeds the control group by 31%, as well as copper and zinc, on average, by 7%.

The content of microelements in the hair is an informative value, since the hair stores integral information about the mineral metabolism of the whole organism over the period of its growth.

Thus, we can conclude that the mineral supplement used promotes an increase in the general metabolism in the body of lactating mares, as well as mineral metabolism, and this, in turn, has affected the quality of milk and its amount.

Of particular interest are ultrafine metal powders, which act as biological preparations of a new generation. They have exceptional features: in small doses, they activate biochemical and physiological processes in the organism of animals, are environmentally safe, have low toxicity and a prolonged effect, which is economically beneficial in comparison with the use of salts of microelements. UFMPs are particles of metal in reduced form and have an effect on the synthesis, regulation of carbohydrate metabolism and mineral nutrition.

Nanopowders are presented as some version of nanomaterials. Nanomaterials themselves are structured at the level of molecular dimensions, with random or regular structure. When using plasma etching or when processing with particle beams, the surface of a random nanostructure is obtained. The active elements of nanopowders are copper, cobalt, molybdenum, and iron, which are in the ultradisperse state. Such substances have differences from particulates, in their structure, and also take on new chemical and physical properties. There is evidence that ultrafine powders of metals in their pure form do not show biological activity. High adsorption of nanopowder particles is manifested due to their high surface energy [10, 11].

There is a known method of obtaining ultrafine metal powders using low-temperature hydrogen reduction with further ultrasound treatment in water.

Kashin Lug LLC of the Kashinsky district of Tver region conducted an experiment with the introduction of a nanopowder of copper and its salt into the diet of small Hereford bulls.

The objective of the research was to determine the effect of these supplements on the growth rate of animals and changes in homeostasis in their body.

The object of research was the small Hereford bulls. Animals were selected at the age of five months, according to the generally accepted methodology of the experiment by the method of analogue pairs. The number of animals in each group was 5 heads (total 3 groups of animals). The age of the animals was 5 months.

Animals of the control group were on a diet deficient in many elements, including copper. The diet of bulls of the first experimental group was supplemented with copper nanopowder (at a dose of 0.02 mg per 1 kg of live weight), and the second experimental group was supplemented with copper sulfate (at a dose of 8 mg per 1 kg of dry matter of the diet). Supplements were mixed with the feed mixture (wheat + oat).

For laboratory studies, blood samples were taken from both the experimental and control animals to determine the morphological parameters of blood.

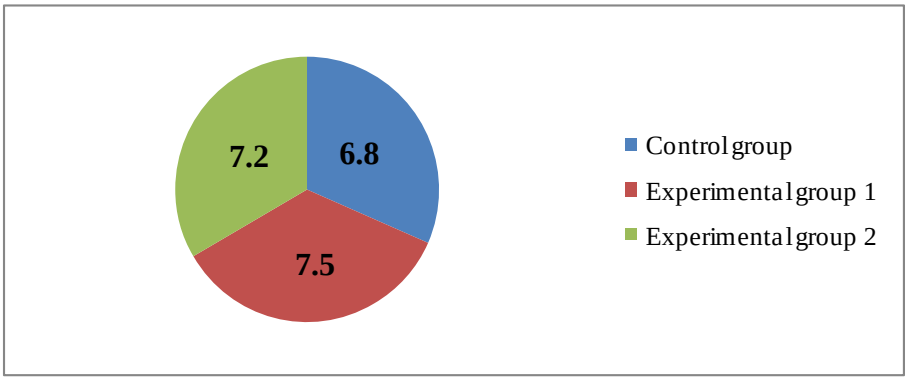

Figure 1 – Red blood cells, 10^{12} g/l

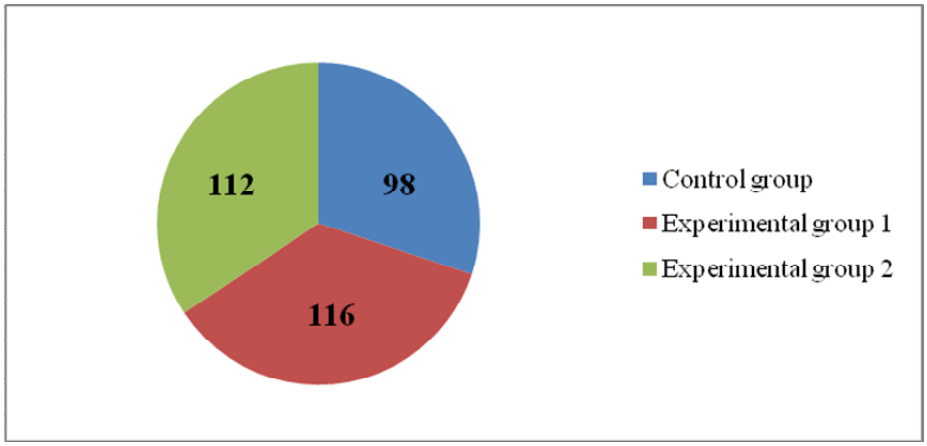

Figure 2 – Hemoglobin, g/l

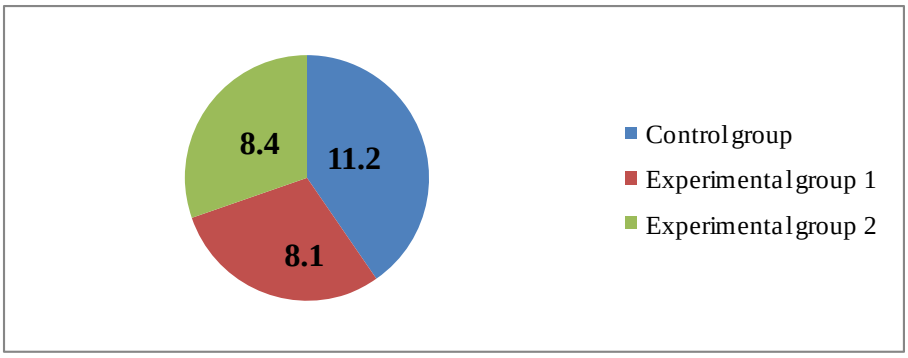

Figure 3 – Leukocytes, 10^9 g/l

The figures presented reflect the data 60 days after the start of the experiment. In our studies, an increase in the number of red blood cells in the blood of animals of the first experimental group treated with copper nanopowder was found, by 10.3% compared with the control group and in the blood of animals of the second experimental group who received salt of copper sulfate, by 6% compared with the control. These indicators stay within the physiological norm. The amount of hemoglobin in the blood of animals of the first experimental group increased by 18.4% compared with the control group, and by 14.3% in the blood of animals of the second experimental group, which implies an increase in the intensity of hematopoietic processes, as well as an increase in the rate of redox processes in the body of bulls under the action of the above additives. It is known that oxygen combines with copper and forms a fragile compound that has a short bond with hemoglobin. Copper promotes the maturation of erythrocytes in the initial stages, promotes the incorporation of iron into the heme structure, therefore, with its deficiency, the number of erythrocytes decreases, but the concentration of hemoglobin does not change, which is confirmed by the results of our research.

The blood of animals of the first experimental group had a decreased number of leukocytes within the physiological norm by 28% and 25% compared with the control group, which indicates the maintenance of the genetic homeostasis of the organism of animals and, accordingly, the improvement of cellular immunity.

The data obtained prove that the additives used in feeding the bulls do not have a toxic effect.

At the very beginning of the experiment, animals were weighed in order to determine the change in their live weight and average daily gains.

After 60 days, the average live weight of the bulls of the experimental groups exceeded the live weight of the animals of the control group: the first experimental group exceeded by 5%, and the second - by 3%. The average increase in live weight in animals of the first experimental group was higher than in the control by 53%, in animals of the second experimental group — by 36% [7].

The nanosilicon supplement is a mixture of mineral components (copper, zinc, iron) based on silicon containing materials. The product has an expert opinion on the results of laboratory tests and in accordance with the hazard classification according to GOST 12.1.007-76 "Harmful substances", this drug belongs to low-hazard substances [4].

An experiment with nanosilicon supplement in the diet of dairy cows was conducted in Kalininskoe CJSC of Tver region. The objective of our research was to determine the effective and environmentally friendly forms of microsupplements (a new supplement - nanosilicon) introduced into the diet of dairy Holsteinized cows. The supplement was administered in the amount of 100 mg per 1 head per day, dissolving in water and pouring mixed feed (as recommended by the manufacturer).

Blood was sampled for the study from the jugular vein of the animals. Then morphological and biochemical parameters were determined, as well as indicators of the enzymatic activity of the blood. The cost-effectiveness of the supplement was determined. According to the results of our experiment, the number of red blood cells 30 days after the start of the experiment in the body of cows from the

experimental group increased by 4.95% compared with the beginning of the experiment and by 6% compared with the control group (Figure 5).

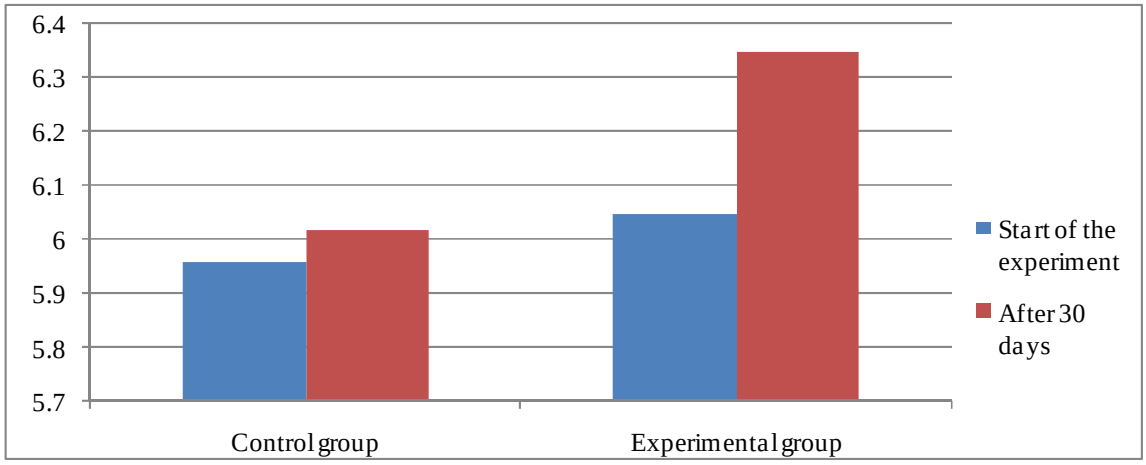

Figure 5 - The number of red blood cells (10^{12} g/l)

The amount of hemoglobin in the blood of cows in the experimental group, who received the nanosilicon supplement at a dose of 100 mg per head per day, increased after 30 days of the experiment by 5.6%, and in the blood of cows in the control group - by 1.7% (Figure 6).

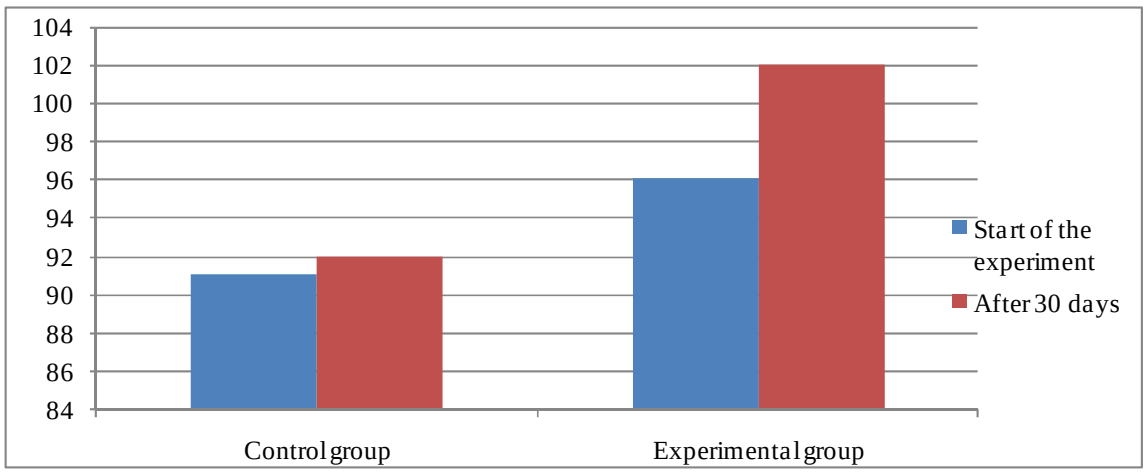

Figure 6 – Hemoglobin (g/l)

The average hemoglobin content in red blood cells in the blood of experimental cows exceeded the control group by 5.6 x 10^{12} g/l after 30 days of the experiment (Figure 7).

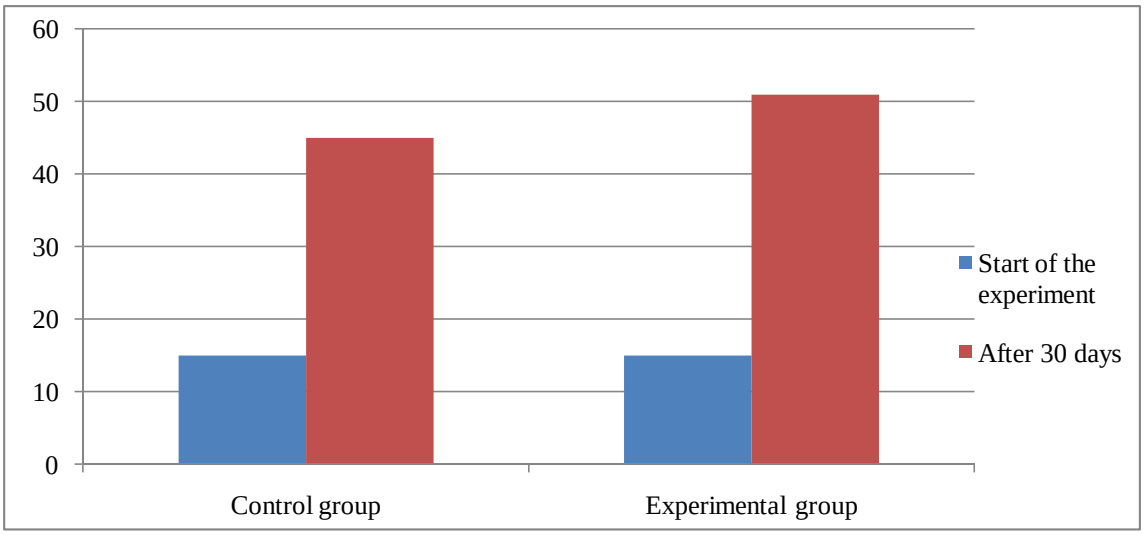

Figure 7 - The average hemoglobin content in red blood cells (10^{12} g/l)

Thus, the above changes indicate an increase in the hematopoietic functions of the body of experimental animals, i.e. the nanosilicon supplement introduced into the body of lactating cows contributes to an increase in the amount of hemoglobin and red blood cells in the blood of animals, and the result is an increase in metabolic rate and an increase in cow productivity by an average of 30%.

The number of platelets in the blood of cows in the experimental and control groups was normal and amounted to 279-300 x 10^9 g/l. Platelet hemostasis is provided by platelets. Their formation occurs continuously in the red bone marrow by ligation from megakaryocytes. Platelet cytoplasm contains a large number of specific organelles, including α-granules, lysosomes and dense granules. Also the blood plates contain the Golgi apparatus, vacuoles, mitochondria and peroxisomes. It can be assumed that the introduction of the nanosilicon supplement into the diet of dairy cows stabilized the number of platelets in the blood of cows, normalized their activity in the thrombovascular mechanisms of homeostasis, i.e. in blood coagulation processes [4].

According to the results of the blood test, the number of leukocytes was normal in animals of all experimental groups (7.54-9.44 · 10^9 g/l) (Figure 8).

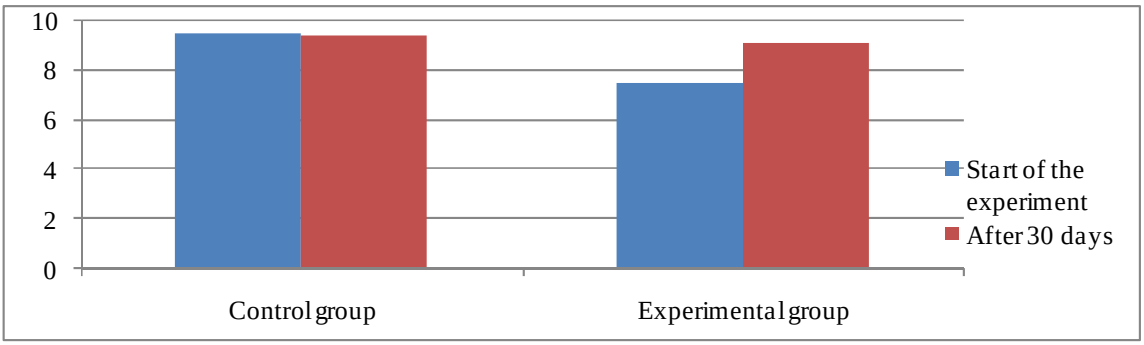

Figure 8 – The number of leukocytes (10^9 g/l)

Therefore, the introduction of the nanosilicon supplement (which consists of the above microelements, activating their functions in the body under the action of silicon) increases the number of blood cells, which in turn increases the intensity of redox processes in the body and maintains its homeostasis. The AST content in the blood of cows of the experimental group, who received the addition of nanocrystals increased after 30 days of the experiment by 1.3%, the ALT content in the blood of the animals of the experimental group increased 12.2%. ALT (alanine aminotransferase) and AST (aspartate aminotransferase) are special enzyme proteins that are contained within the cells of the body and are involved in the exchange of amino acids. According to the results of our research, the content of these enzymes in the blood of experimental animals was within the normal range and increased slightly during the 30 days of the experiment, which proves the positive effect of the drug on the physiological state of the cows during active lactation processes.

Analysis of the data shows that an increase in the average daily productivity of cows and milk fat content in the experimental group (by 10.0 and 3.6% compared with the control group) when nanosilicon was introduced into the diet resulted in a decrease in the cost of 1 kg of milk by 9%, and increase in the level of profitability by 14.7%, respectively.

The performed calculations fully confirm the increase in the efficiency of the production of raw milk with the introduction of the nanosilicon supplement into the animal diet, which allowed increasing the productivity of animals and the fat content of milk, and filling the lack of trace elements in the body of dairy cows.

Thus, the used microelement supplement (nanosilicon) in the diet of dairy cows adjusts the homeostatic processes in the body of animals, this affects their productivity and level of profitability.

Tver region belongs to the Non-chernozem zone poor in mineral elements (for example, Cu, I, Co, Cr, etc.). Therefore, diets consisting of

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plants growing on these soils require adjustment by introducing mineral supplements in various forms. The results of research on this issue are given in the presented paper. Studies have shown a chain of relationships between the mineral compositions of the soil plant living organism. Since the lack of mineral elements in the main fodder plants can be filled with the various mineral supplements, this stabilizes the homeostasis of a living organism and leads to high-quality products.

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