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Effect of balanced mineral supplements on milk productivity of cows

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Abstract. The implementation of the genetic potential of cows is primarily related to the usefulness of providing cows with nutrients, including trace elements, during lactation. Therefore, the purpose of the study was to determine the optimal doses of mineral supplements of zinc (Zn), manganese (Mn), and cobalt (Co) in the diet of dairy cattle by lactation phases and evaluate the economic efficiency of their use. To achieve this goal, a scientific and economic experiment was conducted, for the organisation of which 5 subgroups of cows were formed, 10 individuals each – group 1, which was the control, and 4 experimental groups. According to the experiment design, animals of different groups were fed different amounts of mixed ligand complexes of Zn, Mn, and Co. During the experiment, productivity, dry matter consumption, metabolism, and economic efficiency were evaluated. Based on experimental studies of the use of mineral supplement complexes of Zn, Mn, and Co, in comparison with their sulphate salts, it was found that during the first 100 days of lactation, optimal for highly productive individuals were doses in one kg of dry matter of the feed mixture: Zn – 60.8 mg; Mn – 60.8 mg; Co – 0.78 mg, which were provided by their mixed ligand complexes and which were lower by 20% of the recommended ones and led to an increase in milk productivity of cows by 15%, and profit – by 47%. In the second 100 days of lactation, the best productivity indicators were found in cows that consumed a feed mixture in which the concentration in one kg of dry matter was: Zn – 35 mg, Mn – 35 mg, and Co – 0.4 mg due to the introduction of mixed ligand complexes of trace elements. The advantage of animals in this group over the control group in terms of milk productivity was 18%, in terms of profit – 29%. In the last 100 days of lactation, the best performance indicators were in cows with a dry matter content of Zn – 35 mg, Mn – 35 mg, Co – 0.4 mg per kg of feed mixture. They exceeded the control in terms of milk yield by 9%, and profit – by 42%. Thus, it is proved that highly productive cows require different concentrations of trace elements during lactation. It is proved that due to the introduction of balanced mineral supplements in the diet, the optimal amount of trace elements is less than the use of inorganic compounds, which has a positive effect on the environment by reducing the content of these minerals in manure

Keywords: milk productivity, organic forms of trace elements, profit, lactation phase

Introduction

Feed and feed additives provide highly productive cows with basic nutrients (proteins, lipids, structural and non-structural carbohydrates, and minerals) and biologically active substances (trace elements and vitamins) [1; 2]. Industrial dairy farming in Ukraine over the past three decades increasingly shows a lack of trace elements in the soil-feed-diet and a higher need for them while increasing the milk yield of highly productive cows. Under such circumstances, it is difficult to provide the animal body with the necessary amount of essential trace elements,

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and therefore, for the normal functioning of the body of highly productive cows, an appropriate amount of mineral supplements is required, the ratio of which depends on a number of physiological, economic, and other factors.

The creation of high-performance herds of dairy cattle and the continuation of breeding work in this line encourages a systematic revision of the recommendations for animal nutrition, because ensuring high productivity, reproductive capacity, and preserving the health of cows is impossible only at the expense of natural feed [1-3].

Over the past decade, a number of studies have been conducted in Ukraine and around the world on the feasibility of using organic compounds of trace elements in animal feeding, in particular Zn, Mn, Co, and Cu. Thus, in the available literature, there are reports of an increase in milk productivity [4-6] and milk quality [4; 6; 7] in cows, and an improvement in reproductive function in bulls [8]. In addition to milk productivity, there is also an improvement in the growth of calves [9], pigs [10-12], broiler chickens [13; 14] and rabbits [15] due to the use of chelated forms of trace elements in their feed. The reason for the growing interest of the scientific community in organic compounds is the high degree of their assimilation by the body, which provides animals with the necessary amount of trace elements and reduces the negative impact of their faeces and urine on the environment [3].

Zn is a common element in the body's cells because it is involved in many physiological processes. It is an important component of several metalloenzymes and many transcription factors that control gene expression, so it plays a fundamental role in cell division, development, and differentiation. Zn also plays an important role in stabilising RNA, DNA, and ribosomes as a component of biological membranes; is involved in the production of insulin; has an antioxidant effect; is crucial for maintaining the integrity and barrier function of the skin, and is involved in the immune system. The inability of the body to store Zn necessitates its constant supply with feed [16; 17].

The bioavailability of Zn depends on the source of its entry into the body, the ability to be absorbed and available for storage and use for further processes of digestion, absorption, and metabolism.

Zn from organic sources is usually more readily available to animals than from inorganic compounds. This is conditioned by the mechanism of transition of trace elements from the intestines to the blood of the animal. Thus, microelements from inorganic sources are mainly released from the body through antagonism and the formation of hard-to-reach compounds, while organic microelement compounds (ligands, chelates) are absorbed as amino acids [8; 11; 16]. Microbial fermentation of fibre in the rumen has an additional effect on the bioavailability of trace elements [16].

When Mn is deficient in the feed mixture of dairy cows, the process of fatty acid synthesis is disrupted, skeletal deformity occurs, which is accompanied by animal sterility and abortions, and paralysis occurs in newborn calves. Mn deficiency in the reproductive phase, especially in the dry period, negatively affects the offspring. In cows with insufficient consumption of Mn, due to its lack in the diet, the reproductive capacity of animals may decrease, which may manifest itself in a hidden oestrous cycle, low fertilisation, spontaneous miscarriages in the first months of pregnancy, or possible foetal resorption and frequent gynaecological diseases. At the same time, milk productivity, and often the fat content of milk, decrease [17; 18].

The synthesis of B vitamins depends on the presence of Co in the feed mixture [19; 20]. Excess Co causes the synthesis of a number of vitamin B_{12} analogues, which are physiologically inactive [21]. According to [22], if there is a lack of Co in the feed mixture for the synthesis of cyanocobalamin, which activates the biosynthesis of methionine, Co is consumed by 10% more and accounts for about 13% of its total level, while with its optimal amount – up to 3%. The demand for cobalt is on average 0.10 mg/kg of dry matter of the feed mixture [23].

The purpose of the study is to establish optimal doses of balanced mineral supplements in the feed mixture of highly productive cows by lactation periods and on this basis to substantiate the economic efficiency of using these compounds.

Materials and Methods

In the course of scientific and economic experiments, the effect of balanced mineral additives of Zn, Mn, Co with the addition of Suplex Se against the background of cuprum sulphates and potash iodides with the same type of feeding of dairy cows on the economic efficiency of milk production. To determine the optimal doses of mixed ligand complexes of Zn, Mn, and Co, a scientific and economic experiment was conducted on the premises of the dairy complex of the additional liability company "Terezyne" in the Kyiv Oblast in 2015. The study was carried out in the following sequence: 1) selection was carried out, 20 cows of the Holstein breed; 2) 15 cows of the Ukrainian black and spotted breed were selected; 3) 15 individuals of the Ukrainian red-spotted breed were selected; 4) 5 subgroups of cows of 10 individuals each were formed – 1 control group and 4 experimental groups ((2, 3, 4, and 5).

The experiment was performed on highly productive cows with a milk yield of 7,000-9,000 kg of milk for the previous lactation.

The experiment was conducted by the method of groups of analogues according to the recommendations for experiments in animal husbandry [24]. The actual content of trace elements in the feeds used during the scientific and economic experiment was preliminarily determined; the replacement of Zn, Mn, Co sulphates in the recommended for cows premix P 60-5M (developed by VIT) with their organic forms with the additional introduction of Suplex Se (manufacturer ViloFoss, Denmark) was experimentally substantiated.) Microelements were introduced by step weight mixing with one of the grain components of mixed feed, which was then introduced into the compound feed. Cows of control group 1 were given the recommended cow premix P 60-5M (developed by VIT). In the experimental cows, the sulphate salts of the trace elements Zn, Mn, and Co were replaced with their mixed ligand complexes of different concentrations and additional administration of Suplex Se for all groups. Each group was kept separately, in separate reconstructed premises for loose housing. The animals had free access to fresh clean water around the clock.

During the first 100 days of lactation, advanced feeding was carried out to milk cows and during this period they had the highest productivity. With the onset of new pregnancy, the productivity of cows gradually decreased. In this regard, different levels of mixed ligand complexes were studied, considering lactation periods, and economic efficiency was determined after each experiment.

Each experiment was divided into two periods – preparatory and accounting. During the preparatory period, the animals consumed a complete feed mixture of the same composition, and during the accounting period, cows were fed in accordance with the research scheme (Table 1). The duration of the preparatory period was 10 days and the accounting period was 100 days. Milk yield for each group was determined by weighing, and for each cow – by control yields every 10 days. In one of the control milk yields, samples were taken once a month to determine fat and protein content (Table 1).

Table 1. *Scheme of scientific and economic experiments*

Group	Number of animals, units	Factor under study
1	2	3
Experiment No. 1. First 100 days of lactation		
Control 1	10	Feed mixture (FM) + $CuSO_4$ + KI. 1 kg of dry matter (DM) contains, mg: Zn – 32.4; Mn – 27.8; Co – 0.27; Se – 0.3; Cu – 12; I – 1.1
Experimental 2	10	FM + $ZnSO_4$, $MnSO_4$, $CoSO_4$, $CuSO_4$ + Suplex Se + KI. 1 kg of DM contains, mg: Zn – 76; Mn – 76; Co – 0.97 mg, Cu – 12, Se – 0.3; I – 1.1
Experimental 3	10	FM + mixed ligand complexes Zn, Mn, Co + Suplex Se + $CuSO_4$ + KI. 1 kg of DM contains, mg: Zn – 76; Mn – 76; Co – 0.97; Se – 0.3; Cu – 12; I – 1.1
Experimental 4	10	FM + mixed ligand complexes Zn, Mn, Co + Suplex Se + $CuSO_4$ + KI. 1 kg of DM contains, mg: Zn – 60.8; Mn – 60.8; Co – 0.78; Se – 0.3; Cu – 12; I – 1.1
Experimental 5	10	FM + mixed ligand complexes Zn, Mn, Co + Suplex Se + $CuSO_4$ + KI. 1 kg of DM contains, mg: Zn – 49; Mn – 49; Co – 0.63; Se – 0.3; Cu – 12; I – 1.1
Experiment No. 2. Second 100 days of lactation		
Control 1	9	FM + mixed ligand complexes Zn, Mn, Co + Suplex Se + $CuSO_4$ + KI. 1 kg of DM contains, mg: Zn – 65; Mn – 65; Co – 0.8; Se – 0.3; Cu – 10; I – 0.9
Experimental 2	9	FM + mixed ligand complexes Zn, Mn, Co + Suplex Se + $CuSO_4$ and KI. 1 kg of DM contains, mg: Zn – 50; Mn – 50; Co – 0.7; Se – 0.3; Cu – 10; I – 0.9
Experimental 3	9	FM + mixed ligand complexes Zn, Mn, Co + Suplex Se + $CuSO_4$ and KI. 1 kg of DM contains, mg: Zn – 45; Mn – 45; Co – 0.6; Se – 0.3; Cu – 10; I – 0.9
Experimental 4	9	FM + mixed ligand complexes Zn, Mn, Co + Suplex Se + $CuSO_4$ and KI. 1 kg of DM contains, mg: Zn – 40; Mn – 40; Co – 0.5; Se – 0.3; Cu – 10; I – 0.9
Experimental 5	9	FM + mixed ligand complexes Zn, Mn, Co + Suplex Se + $CuSO_4$ and KI. 1 kg of DM contains, mg: Zn – 35; Mn – 35; Co – 0.4; Se – 0.3; Cu – 10; I – 0.9
Experiement No. 3. Last 100 days of lactation		
Control 1	9	FM + mixed ligand complexes Zn, Mn, Co + Suplex Se + $CuSO_4$ and KI. 1 kg of DM contains, mg: Zn – 50; n – 50; Co – 0.7; Se – 0.3; Cu – 9; I – 0.8
Experimental 2	9	FM + mixed ligand complexes Zn, Mn, Co + Suplex Se + $CuSO_4$ and KI. 1 kg of DM contains, mg: Zn – 45; Mn – 45; Co – 0.6; Se – 0.3; Cu – 9; I – 0.8
Experimental 3	9	FM + mixed ligand complexes Zn, Mn, Co + Suplex Se + $CuSO_4$ and KI. 1 kg of DM contains, mg: Zn – 40; Mn – 40; Co – 0.5; Se – 0.3; Cu – 9; I – 0.8
Experimental 4	9	FM + mixed ligand complexes Zn, Mn, Co + Suplex Se + $CuSO_4$ and KI. 1 kg of DM contains, mg: Zn – 35; Mn – 35; Co – 0.4; Se – 0.3; Cu – 9; I – 0.8
Experimental 5	9	FM + mixed ligand complexes Zn, Mn, Co + Suplex Se and $CuSO_4$ and KI. 1 kg of DM contains, mg: Zn – 32; Mn – 32; Co – 0.3; Se – 0.3; Cu – 9; I – 0.8

In the course of a scientific and economic experiment, the milk productivity of cows was determined:

– gross milk yield per 1 animal unit – by summing up the daily milk produced from each cow of the group over a certain period of time;

– gross milk yield of basic fat content – by multiplying the amount of milk (in kilograms) by the percentage of fat in it, followed by dividing by the basic fat content of milk (3.4%).

To determine the cost and profitability of milk production, the cost of feed consumed was calculated, which was determined at farm prices, wages and other expenses, considering the actual selling price of 1 metric centner of milk. Since the sale of milk in farms is carried out according to the basic fat content, the actual milk yield was converted to the basic fat content – 3.4%.

Results and Discussion

The economic effect of feeding mixed ligand complexes of Zn, Mn, and Co to dairy cows during the first 100 days of lactation is shown in Table 2.

Table 2. Economic efficiency of feeding high-performance cows mixed ligand complexes of Zn, Mn, and Co as part of diets during the first 100 days of lactation

Indicators	Group				
	Control 1	Experimental			
		2	3	4	5
Gross milk yield, kg/cow	3,096	3,400	3,456	3,560	3,416
Gross milk yield of basic fat content, kg/cow	3,369.2	3,710	3,791.4	3,968.4	3,767.7
Total production costs, UAH.	8,423.6	8,776.5	8,780.7	8,845.8	8,658.8
including: sulphates		99.6	–	–	–
mixed ligand complexes	–	–	74.4	56.8	32.4
Profit, UAH	3,705.4	4,579.5	4,868.3	5,440.2	4,905.2

The intake of various sources of Zn, Mn, and Co and the levels of their mixed ligand complexes in the body of experimental cows during the first 100 days of lactation affected the consumption of feed mixture by experimental cows and the intake of more nutrients into their bodies, which was discussed in detail in previous studies. As a result of higher feed consumption by experimental cows, their milk productivity also increased, namely: in the 2nd experimental group – by 304.0 kg; in the 3rd – by 360.0; in the 4th – by 464.0; in the 5th – by 320.0 kg or, respectively, by 9.82%; 11.63%; 14.99%; 10.34%, compared to the control group. This allowed for additional profit in the experimental groups. Thus, the replacement of Zn, Mn, and Co sulphates with their mixed ligand complexes in the 2nd experimental group, which provided the norm in Zn, Mn, and Co, and Zn, Mn, and Co sulphates in the control group by 100%, the additional profit amounted to UAH 874.1 for 80 days of the main experiment period. Meeting the demand for Zn, Mn, and Co by 75% due to their mixed ligand complexes gave an additional profit of UAH 11,621.9, or 31.4%; by 50% – UAH 1,734.8, or 46.8%; and by 25% – UAH 1,199.8, or 32.4%.

Therefore, providing a 50% shortage of Zn, Mn, and Co by their mixed ligand complexes ensures a stable economic effect and is more cost-effective than covering the deficit in Zn, Mn, and Co by 100% due to Zn, Mn, and Co sulphates. The probable reason for this is the orientation of the feeding standards of dairy cows to the results of studies in which inorganic compounds were used as sources of trace elements, the bioavailability of mineral elements of which is 10-15%. The introduction of supplements of organic trace elements into the diet of cows, the bioavailability of trace elements of which is 80-95%, demonstrated that the need of these animals is lower than previously stated.

It is well known that the period of milk production in cows has certain patterns, according to which the cow's lactation is divided into conditional three phases. At the same time, not only the nutritional value of the diet changes, but also its structure [18]. Therefore, it is important to analyse the effectiveness of using feed additives at each stage of changes in productivity, feeding, etc.

The economic efficiency of using Zn, Mn, and Co mixed ligand complexes in feeding dairy cows during the second 100 days of lactation is shown in Table 3.

Table 3. Economic efficiency of including balanced mineral supplements in the diets of dairy cows during 101-200 days of lactation

Indicator	Group				
	Control 1	Experimental			
		2	3	4	5
Gross milk yield, kg/cow	3,120	3,302	3,395	3,556	3,685
Gross milk yield of basic fat content, kg/cow	3,413.7	3,632.2	3,701.5	3,922.1	4,064.3
Total production costs, UAH.	8,200.5	8,879.3	8,607.8	8,753.7	8,843.3
including sulphates		–	–	–	–
mixed ligand complexes	135.2	127.5	95.9	63.9	31.8
Profit, UAH	4,771.6	4,923.1	5,457.9	6,150.2	6,601.0

Replacement of Zn, Mn, and Co sulphates with their mixed ligand complexes in the first 100 days of lactation maintains the trend of better productivity in experimental cows in subsequent lactation periods. However, the lowest dose of mixed ligand complex, which was used in the diets of the 5th experimental group, during this period contributed to an increase in milk productivity of natural fat content by 18.1% against the 1st control group; by 11.6% more against the 2nd experimental group, in whose diets due to mixed ligand complexes, the norms of Zn, Mn, and Co were supplemented by 100%; by 9.8% more against the 3rd experimental group, in whose diets the deficiency of Zn, Mn, and Co was replenished by 75%; and by 3.6% more than the 4th experimental group, where the deficit was replenished by

50%. Obviously, this result is associated with a change in the origin of trace element additives, namely, the replacement of inorganic compounds with organic complexes. Better bioavailability of minerals from mixed ligand complexes has led to a decrease in the need of cows for these trace elements, compared to the recommended standards.

As a result, the cost of manufactured products (milk for 100 days) per 1 animal unit in the control group was equal to UAH 12,972.1, in the 2nd – UAH 13,802.4, 3rd – UAH 14,065.7, 4th – UAH 14,903.9, and 5th – UAH 15,444.3. Thus, in the experimental groups it was higher than the control, respectively, by UAH 830.3; 1,093.6; 1,931.8; 2,472.2.

Comparing the profit of the experimental groups fed mixed ligand complexes of Zn, Mn, and Co, the highest profit was in the 5th experimental group – by UAH 1,829.4, or 38.34% more than in the control group; by UAH 1,677.9, or 35.16% compared to the 2nd experimental group; by UAH 1,143.1, or 23.96% compared to the indicators of animals of the 3rd experimental group; by UAH 450.8, or 9.45% – compared to the analogues of the 4th experimental group.

Thus, the use of mixed ligand complexes of trace elements such as Zn, Mn, and Co in feeding highly productive cows during the milk production period, in an amount that eliminates their deficiency by 25%, is the most cost-effective.

During the last 100 days of lactation, feed consumption in experimental cows was better and milk productivity of cows of experimental groups in terms of basic fat content was higher compared to the control group: in the 2nd experimental group – by 58.3 kg, or 2.33 %; in the 3rd – by 57.2 kg, or 2.29 %; in the 4th – by 150.8 kg, or 6.05%; in the 5th – by 224.3 kg, or 8.99 %, which, in turn, increased the economic efficiency of milk production (Table 4).

Table 4. *Economic efficiency of using balanced mineral supplements in feeding dairy cows during 201-300 days of lactation*

Indicator	Group				
	control 1	Experimental			
		2	3	4	5
Gross milk yield, kg/cow	2,320	2,360	2,430	2,540	2,440
Gross milk yield of basic fat content, kg/cow	2,606.6	2,665.4	2,780.2	2,921.0	2,834.7
Cost of milk produced, UAH/animal	9,905.1	10,128.5	10,564.8	11,099.8	10,771.8
Total production costs, UAH	6,763.4	6,861.8	6,812.8	6,624.9	6,492.6
including: sulphates	–	–	–	–	–
mixed ligand complexes	112.3	102.0	76.5	45.6	24.3
Profit, UAH	3,141.7	3,266.7	3,752.0	4,474.9	4,279.2

The difference in gross milk yield and its total sale value between the experimental groups of cows and the control resulted in the highest profit in the experimental cows of the 4th and 5th experimental groups where the required level of Zn, Mn, and Co was provided by their mixed ligand complexes by 50% and 25%, despite slightly increased costs of wages, feed, direct and overhead costs in these groups. In cows of the 2nd and 3rd experimental groups, where the deficiency of Zn, Mn, and Co was covered by their mixed ligand complexes by 100% and 75%, due to its higher cost compared to Zn, Mn, and Co sulphates, despite higher milk yields, the profit was slightly higher than in the control group.

If in the control group the total profit was UAH 3,141.7, then in the 2nd and 3rd experimental groups it was higher by UAH 125.0 and 610.3, or 3.98% and 19.43%, while in the 4th and 5th experimental groups it was higher by UAH 1,333.2 and 1,137.5, or by 42.44% and 36.21%, respectively.

Economic calculations show that during the launch period, it is better not to use trace element preparations in feeding highly productive cows, or to use them in small doses that cover the deficit by 25-50%.

Summarising the results obtained experimentally, it can be argued that the conducted studies are consistent with the data of numerous literature sources that have shown a high level of bioavailability of biometals for the body of dairy cows in general and high-performance cows in particular. Their ability to significantly affect the productivity and physiological state of animals of this group is also proven. Thus, an increase in the average daily milk yield by lactation phases under the condition of using mixed ligand complexes of trace elements was also noted in the studies by other Ukrainian [4] and foreign [5-7] researchers. In particular, the replacement of inorganic salts of trace elements (control group) in feeding dairy cows with their metal-chelate complexes, described in the study by A. Gorchanok *et al.* [4], contributed to an increase in the average daily milk yield of cows compared to the control by 11%. An increase in productivity by 6% with the introduction of chelated compounds of trace elements and a decrease by 4% with an excessive amount of chelates in the diet was recorded by Kholif *et al.* [7]. At the same time, some of these studies [3; 4] contain reports on the economic and environmental feasibility of using organic sources of trace elements in feeding animals, in particular cows. Increasing the productivity of cows with optimal mineral nutrition (dose and source) contributes to greater profit and reduced emissions of heavy metals into the environment with manure, which is used as an organic fertiliser.

Conclusions

To ensure high milk productivity and increase the profitability of milk production, it is recommended to use Zn, Mn, and Co mixed ligand complexes in feeding dairy cows to eliminate the deficiency of these trace elements, considering the lactation phase.

During the first 100 days of lactation, the highest economic effect was achieved by providing dairy cows with only 50% of the needs for Zn, Mn, and Co, but due to their mixed ligand complexes. It was at this dose that the milk productivity of animals was maximum, and despite the highest indicator of production costs, the profit from the sale of produced milk significantly exceeded both the control indicator and the indicators of analogues of other groups.

A similar trend occurred during the next 100 days of lactation, but the optimal dose of Zn, Mn, and Co mixed ligand complexes was 25% of the recommended requirement.

In the last 100 days of lactation (201-300 days), cows showed the highest level of productivity for the consumption of diets, the amount of Zn, Mn, and Co in which was provided by 50% due to mixed ligand complexes. However, it is possible to reduce the recommended dose to 25%, since the profit indicator is very close to the maximum.

Thus, the findings indicate a positive reaction of the body of dairy cows to the replacement of Zn, Mn, and Co sulphates in their diet with mixed ligand complexes. At the same time, the need for the amount of trace elements is reduced to 50-25%, depending on the lactation phase. Thus, this issue requires further thorough investigation to review the existing feeding standards for dairy cows, which are developed using inorganic compounds of trace elements with low availability.

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Вплив збалансованих мінеральних добавок на молочну продуктивність корів

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Анотація. Реалізація генетичного потенціалу корів насамперед пов'язана з повноцінністю забезпечення корів поживними речовинами, в тому числі і мікроелементами, за періодами лактації. Тому метою дослідження було встановлення оптимальних доз мінеральних добавок Цинку (Zn), Мангану (Mn) і Кобальту (Co) у раціоні молочного стада за фазами лактації та оцінка економічної ефективностіZn їх застосування. Для досягнення встановленої мети провели науково-господарський дослід, для організації якого сформували 5 підгруп корів по 10 особин в окремій групі – 1 групу, яка була контрольною і 4 дослідні групи. Згідно зі схемою досліду тваринам різних груп згодовували різну кількість змішанолігандних комлексів Zn, Mn і Co. У ході експерименту досліджували продуктивність, споживання сухої речовини, обмін речовин та економічну ефективність. На основі експериментальних досліджень застосування комплексів мінеральних добавок Zn, Mn і Co, в порівнянні із їх сульфатними солями, було встановлено, що упродовж перших 100 днів лактації оптимальними для високопродуктивних особин – дози в одному кг сухої речовини кормової суміші: Zn – 60,8 мг; Mn – 60,8 мг; Co – 0,78 мг, які забезпечувались за рахунок їх змішанолігадних комплексів і які були нижчими на 20 % від рекомендованих і зумовили підвищення молочної продуктивності корів на 15 %, а прибутку – на 47 %. У другі 100 днів лактації найкращі показники продуктивності були в корів, які споживали кормосуміш, в якій концентрація у одному кг сухої речовини була: Zn – 35 мг, Mn – 35 мг і Co – 0,4 мг за рахунок уведення змішанолігандних комплексів мікроелементів. Перевага тварин цієї групи над контрольною за молочною продуктивність становила 18 %, за прибутком – 29 %. В останні 100 днів лактації найкращі результати продуктивності були у корів у одному кг сухої речовини кормової суміші, вміст яких склав Zn – 35 мг; Mn – 35 мг; Co – 0,4 мг. Вони переважали контроль за надоєм молока на 9 %, за прибутком – на 42 %. Таким чином, доведено, що високопродуктивні корови за періодами лактації потребують різної концентрації мікроелементів. Доведено, що за рахунок введення в раціон збалансованих мінеральних добавок оптимальна кількість мікроелементів менша, порівняно з використанням неорганічних сполук, що позитивно впливає на навколишнє середовище шляхом зменшення вмісту цих мінеральних речовин у гною

Ключові слова: молочна продуктивність, органічні форми мікроелементів, прибуток, фаза лактації