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Efficiency of using different levels of mixed ligand complexes of Zinc, Manganese, and Cobalt in cow feeding

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Abstract. To increase productivity and reduce the negative impact on the environment, it is necessary to investigate the most optimal ratios of organic trace elements in the diets of cows involved in the production cycle, considering their physiological state and lactation stage. The purpose of the study was to determine the economic profitability of using mixed complexes of zinc, manganese, and cobalt in the diets of dairy cows. The experiment was carried out under production conditions on Holstein cows. 100 cows were divided into two groups. Cows of the control and experimental groups consumed feed mixtures made according to the same recipes, supplemented with mixed ligand complexes of zinc, manganese, and cobalt. It was found that with the optimal content of mixed ligand complexes of zinc, manganese, and cobalt in cows of the experimental group, body weight loss during the first hundred days of lactation was 16.4 kg or 2.88% less than in

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the control. Analysis of performance indicators of cows during the dry period and the first hundred days of lactation showed that in animals of the experimental group, whose diet contained mixed ligand complexes of trace elements at the rate of 54.7 mg of zinc and manganese and 0.7 mg of cobalt per 1 kg of dry matter, milk yields of natural fat content increased by 4.1 kg or 9.2%, the fat content in milk – by 0.02% compared to cows of the control group, whose diets provided the content of zinc and manganese at the level of 60.8 mg, cobalt – 0.78 mg/kg of dry matter due to mixed ligand complexes. There was also a decrease in the duration of the service period by 9 days and the insemination index by 0.17 semen doses. The cost of production remained unchanged, and the additional profit with a reduced concentration of these elements in the diet of cows of the experimental group amounted to EUR 27.24 or 9.7%. Thus, optimisation of mineral nutrition of cows by introducing mixed ligand complexes of zinc, manganese, and cobalt to achieve the concentration of trace elements of zinc and manganese – 54.7 mg each, and cobalt – 0.7 mg per 1 kg of dry matter of the feed mixture will improve milk production and reproductive capacity of cows and allow obtaining additional profit

Keywords: organic compounds of trace elements; dry cows; dairy cows; milk yield; milk fat content; economic efficiency

Introduction

According to researchers, in particular P.S. Erickson & K.F. Kalscheur (2020), in order to achieve full genetic potential, modern dairy cattle breeds need appropriate biologically complete feeding, which will ensure the restoration of the cow's body's production costs.

Zinc, iodine, cobalt, cuprum, manganese, and selenium play a significant role in increasing the biological usefulness of feeding cows. According to J. Batra *et al.* (2022) and R. Duffy *et al.* (2023) focus on the properties of zinc to enhance the activity of rumen microbial enzymes. I.M.T. Fadlalla *et al.* (2022) argue that a significant number of pathological changes that develop in the body of cattle are somehow associated with manganese deficiency. Attention is paid to the extremely low digestibility of this trace element from inorganic salts. The researchers note the exceptional role of cobalt in the synthesis of vitamin B_{12} by rumen microorganisms and also focus on the absorption of this trace element from organic and inorganic sources.

The important role of trace elements, and the importance of the source of their entry into the body of ruminants, was described by N.F. Suttle (2022), J. Arthington & J. Ranches. (2021) and R.A. Palomares (2022). They noted that the health and productivity of high-yielding cows depend on the availability of key micronutrients in their bodies. Animals can adapt to deficiencies in minerals, especially trace elements such as copper, cobalt, zinc, iodine, manganese, etc., but this can lead to abnormalities in protein metabolism and synthesis, reduced health, loss of reproductive ability, and reduced genetic productivity, which is determined by breed characteristics. P.K. Gupta (2021) emphasises that such changes develop both in the mother and in the offspring's body.

R.B. Corbett (2023) also notes that the absorption of trace elements in the gastrointestinal tract depends on their interaction with other nutrients and biologically active substances of feed and the synthesis of new forms of complex compounds in the body, which are significantly different from the forms of compounds in which they were contained in feed. The researcher also focuses on the physiological significance of the degree of stability and

solubility of the resulting compounds. The introduction of trace elements into the diets of cows in the form of inorganic salts due to their low digestibility in the body leads to environmental pollution with heavy metals, which is described by B. Mion *et al.* (2023). This group of researchers as well as J.W. Spears (2023) note that only 5-30% of trace elements obtained from salts in the form of sulphate or chloride compounds are absorbed by the animal body. However, the introduction of organic minerals in the diets of cows increases their absorption by the body up to 70-98%.

M.A. Abu El-Hamd *et al.* (2023) conducted a comparative assessment of the use of organic and inorganic sources of zinc, cuprum, and manganese and found a positive effect on the productivity, milk quality and reproduction qualities of cows of organic compounds of these trace elements. The optimal level of biotic trace elements contributes to the stable flow of metabolic processes in animals, supports their health, and ensures high productivity. Based on the findings of B. Mion *et al.* (2023), the best results are found when using complex metal compounds with amino acids, organic acids, etc., including metal compounds from amino acids, their derivatives, peptides, proteins, nucleic acids, nucleotides, carbohydrates, and carboxylic acids, which are complexons.

Metal ions show their activity when they enter into a complex with ligands, they are easily adsorbed into the bloodstream and penetrate through the cell membrane to the places of their localisation. Chelates move freely through the animal body, ensuring optimal metal transfer to the cell, and therefore, the need for ligands and carrier proteins disappears, which contributes to a more pronounced action of trace elements and determines their corresponding biochemical and physiological activity at significantly lower concentrations than when using trace elements in the ionic state.

Currently, it is recommended that 1 kg of dry matter in the diet of high-yielding cows should be: 60-80 mg of zinc; 60-80 mg of manganese; 10-12 mg of cuprum; 1-1.5 mg of cobalt; 0.8-1.4 mg of iodine; 0.3 mg of selenium; 0.5-1 mg (Suttle,2022). According to the recommendations of Ukrainian researchers, the concentration of zinc and manganese in 1 kg of dry matter in the diets of high-yielding cows with an average daily yield of 35 kg of milk or more should be 70 mg; cobalt – 0.9, cuprum – 11, iodine – 1, and selenium – 0.3 mg. However, the researchers found that the addition of mixed ligand complexes of zinc, manganese, and cobalt to the diets of dairy cows during the first 100 days of lactation to ensure the concentration of these trace elements in 1 kg of dry matter, respectively, 54.7 mg; 54.7, and 0.7 mg had a positive effect on their productivity per concentration (Bomko *et al.*, 2019).

The purpose of the study was to investigate the economic efficiency of using mixed ligand complexes of zinc, manganese, and cobalt in feeding dairy cows.

Materials and Methods

According to the experimental design, a production test was carried out at the "Terezyne" additional liability company in Kyiv oblast to determine the economic efficiency of using mixed ligand complexes of zinc, manganese, cobalt using 0.3 mg/kg organic selenium against the background of balancing rations for copper and iodine according to existing standards (12 mg and 1.1 mg/kg dry matter, respectively) at the expense of copper sulphate and potassium iodide. A production experiment in the feeding of German-bred Holstein cows using mixed ligand complexes of zinc, manganese, cobalt and Suplex Se was conducted during the dry period and the first 100 days of lactation. In total, the duration of the production test was 160 days.

Complete feed mixtures were used as cow feed, the nutritional value of which met the established requirements for the weight, physiological condition, and productivity of the animals. Cows of the control and experimental

groups consumed the same basic feed mixture, but the supply of zinc, manganese, and cobalt was different and corresponded to the scheme of the experimental design (Table 1).

Table 1. *Design of the production experiment*

Animal group	Number of animals	Feeding conditions
Control	50	Feed mixture + mixed ligand complexes of zinc, manganese, and cobalt. 1 kg of dry matter contains, mg: zinc – 60.8; manganese – 60.8; cobalt – 0.78.
Experimental	50	Feed mixture + mixed ligand complexes of zinc, manganese, and cobalt. 1 kg of dry matter contains, mg: zinc – 54.7; manganese – 54.7; cobalt – 0.7.

Source: developed by the authors

Cows were kept loose with free access to a complete feed mixture, which was distributed twice a day to the feed table. In addition to feed, the animals had free access to clean drinking water around the clock. The microclimate parameters met the established requirements. The animals were divided into sections: 1 group of 50 cows was kept in one section During the first 100 days of lactation, dairy cows were milked three times a day in the milking parlour. Cows of each group were milked separately, taking average milk samples to analyse the fat content of milk. Since the production test occurred during the insemination period, the cows were fitted with a sensor around their necks to determine their heat and monitor their health. This helped to determine the period of heat even in the absence of external signs, which is characteristic of animals of this breed. Insemination of cows was carried out no earlier than the 50th day (free waiting period) after calving. Stimulation or synchronisation of heat was not used.

During the production test, the live weight, productivity of cows, the duration of the service period, and the insemination index were recorded, and the economic efficiency of the proposed changes in animal feeding was calculated. For this purpose, the following methods were used:

- live weight – determined by weighing animals on a scale on the day following the start-up (beginning of the dry period), 6 weeks after start-up (end of the dry period), on the 5th day after calving (beginning of lactation), on the 100th day after calving (end of the first 100 days of lactation);
- cow productivity – determined by recording the daily milk yield from each cow separately, using software from the milking parlour;
- milk fat content – measured in an average milk sample from each group of cows using the Ecomilk device after each milking;
- milk yield of 4% fat content – calculated by multiplying the average daily milk yield of natural fat content by the fat content in milk and dividing by 4;
- milk yield of basic fat content – calculated by multiplying the average daily milk yield of natural fat content by the fat content in milk and dividing by 3.4;
- duration of the service period – measured by the time from calving to the first fertile insemination;
- insemination index – calculated the number of semen doses spent on one fertilisation. Studies on animals were conducted in compliance with the requirements of the "General ethical principles for conducting animal experiments", approved by the 1st National Congress on Bioethics (Law of Ukraine No. 3447-IV, 2006), and the provisions of the "European Convention for the Protection of Vertebrate Animals used for Experimental and other Scientific Purposes" (1986).

Results and Discussion

The dry period, both early and late, is an important stage of the cow's production cycle, as it lays the foundations for future lactation. Any technological methods used during this period will have a certain impact on its success. However, it is difficult to control the course of this period – there are no criteria for daily assessment. But during the first 100 days of lactation, both the amount of milk received and its qualitative composition can be evaluated daily. This greatly facilitates the comparative assessment of the impact of the feed factor on the cow's productivity.

In the course of the production experiment, live weight was assessed, as this is one of the few criteria for assessing the dry period of dairy cows. During the dry period, cows of the control group increased their live weight by 49.6 kg or 8.2%, and in the experimental group – by 53.3 kg or 8.9% relative to the weight at the beginning of the experiment (Fig. 1).

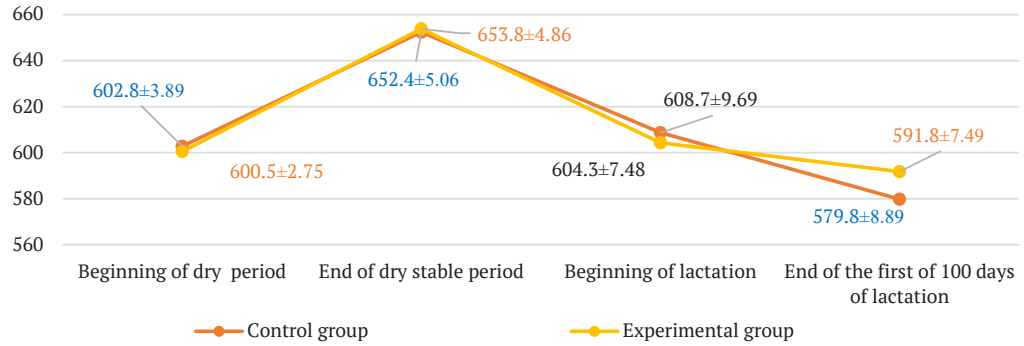

Figure 1. Dynamics of live weight, kg

Source: developed by the authors

After calving and before the start of lactation, cows of both groups lost live weight: control animals reduced their weight by 43.6 kg or 6.7%, and experimental animals – by 49.5 kg or 7.6%.

During the first 100 days of lactation, the animals of the control group lost another 28.9 kg or 4.7% of their weight, while the cows of the experimental group reduced their weight by only 12.5 kg or 2.1% (Fig. 2).

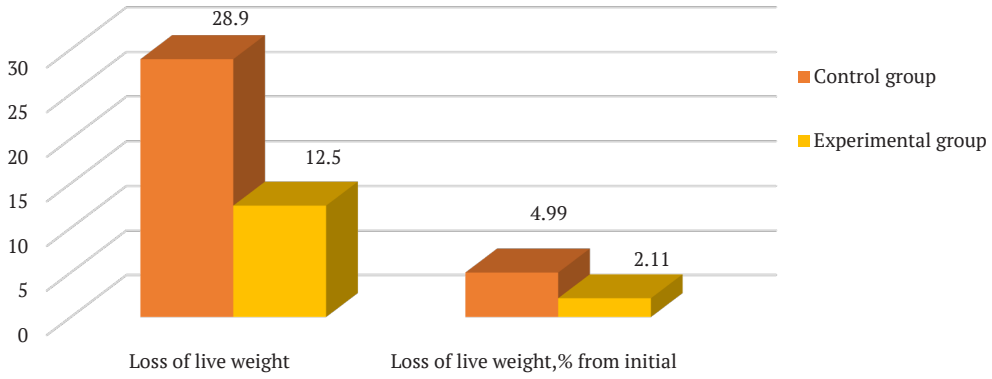

Figure 2. Dynamics of live weight loss, kg

Source: developed by the authors

Weight loss after calving is a natural process. It is typical for highly productive cows, since the animal is not able to consume enough feed during this period. In this case, the increase in productivity (divisions) is genetically determined. Thus, for a certain time, the cow gives up the reserves of its own body to ensure productivity. However, along with an increase in productivity, rumen development also occurs and animals recover quickly, including body weight.

The main production indicator in dairy cattle breeding is the average daily milk yield of natural fat content and directly the fat content of milk. From the data obtained as a result of the experiment, it can be seen that during the first 100 days of lactation, cows of the experimental group that consumed the feed mixture included mixed ligand complexes of zinc, manganese, and cobalt to ensure the content of these trace elements at the level of 54.7 mg, 54.7 mg, and 0.7 mg/kg of dry matter, on average synthesised 4.1 kg or 9.2% more natural fat milk per day compared to animals of the control group, the content of zinc, manganese, and cobalt in the dry matter of the diet which amounted to 60.8 mg, 60.8 mg, and 0.78 mg, respectively (Fig. 3).

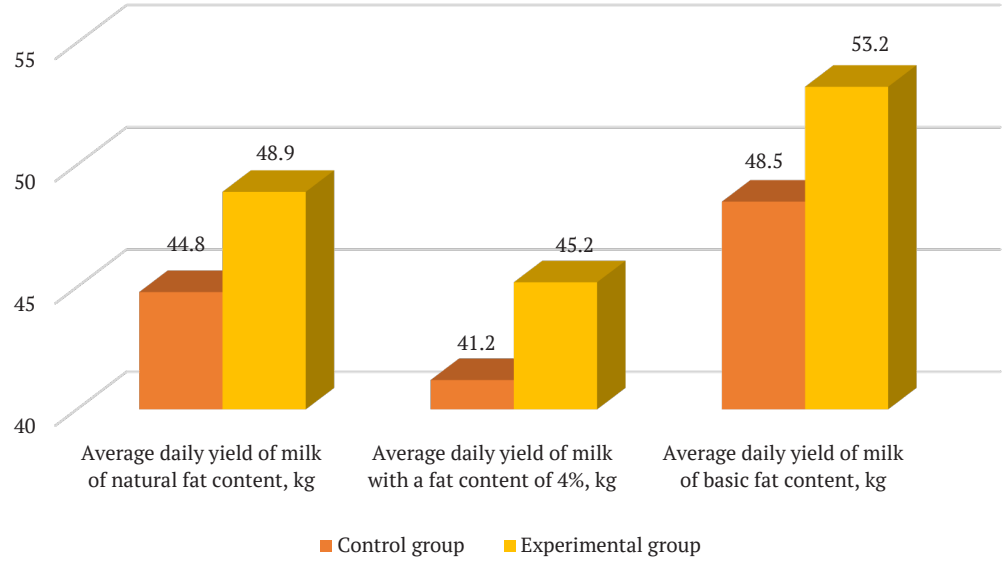

Figure 3. Milk productivity of cows

Source: developed by the authors

In addition to the increase in the average daily milk yield, an increase in the fat content in the milk of cows of the experimental group by 0.02% compared to control animals was recorded (Fig. 4). It can be assumed that the reason for this was the positive effect of the optimal content of these trace elements on the cellulolytic bacteria of the rumen. Normalisation of their vital activity directly affected the fibre digestibility, and accordingly, the fat content in milk. Since the difference in fat content in milk between the groups is quite large, converting the productivity of animals to fat content of 4% noted an increase in milk productivity of this fat content in cows of the experimental group by 4.0 kg or 9.7% relative to the control. A similar difference between the groups, namely 4.7 kg or 9.7%, occurred in terms of milk yield of basic fat content, which is a technological indicator. When selling milk, such recalculation is carried out by the milk processing enterprise and directly affects the profit.

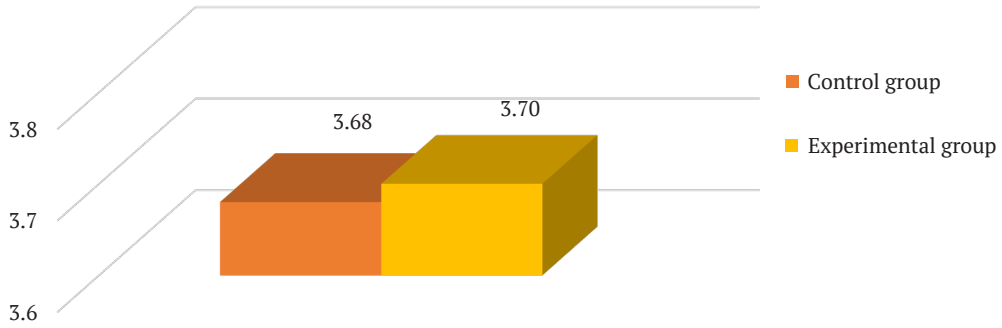

Figure 4. Fat content of cow milk, %

Source: developed by the authors

The first 100 days of lactation are the period of heat and insemination in cows. In highly productive cows, the manifestation of heat can be visually invisible, so special sensors placed on the animal's neck were used to record this physiological phenomenon. Insemination was carried out no earlier than 50 days after calving.

Studying the reproductive performance of cows of both groups, it was noted that with a lower concentration of zinc, manganese, and cobalt, the service period was reduced by 9 days, and the insemination index decreased by 0.17 (Fig. 5). The duration of the service period is a very important indicator, since the duration of lactation depends on it. The longer the service period lasts, the longer the lactation decline phase will be, which will lead to an increase in the cost of milk production. Admittedly, this indicator depends on the insemination effectiveness, since infertile insemination increases the duration of the service period, and accordingly lactation of the cow, by an average of 19-22 days.

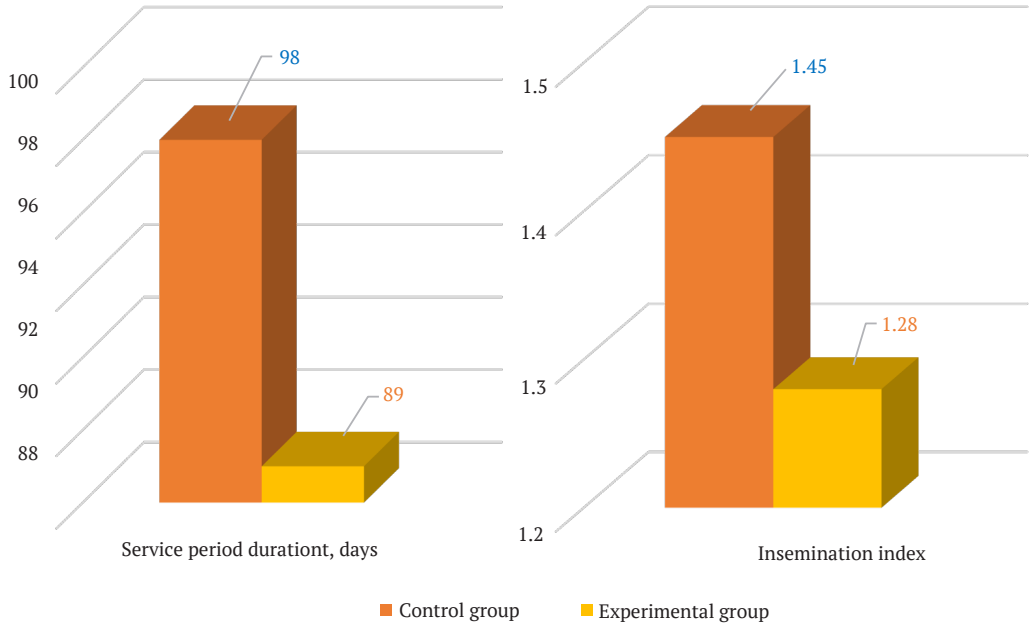

Figure 5. Reproductive indicators of cows

Source: developed by the authors

During the first 100 days of lactation, cows of the experimental group who consumed a mixture with mixed ligand complexes of zinc, manganese, and cobalt, and the content of these elements in 1 kg of dry matter was 54.7 mg, 54.7 mg, and 0.7 mg, provided 9.7% more milk of basic fat content, compared to control animals, in the mixture of which there were also mixed ligand complexes, but they supplied zinc at the level of 60.8 mg; manganese – 60.8; cobalt – 0.78 mg/kg of dry matter. At the same selling price, revenue from milk sales in the experimental group was also 9.7% higher, but production costs also exceeded the control indicator by 9.7%. Thus, the cost of production was the same in both groups. However, due to the increase in cow productivity, the additional profit per animal was EUR 31.04, which is 9.7% more than in the control (Table 2).

Table 2. *Economic efficiency*

Indicator	Group	
	control	experimental
Gross milk yield of basic fat content, hwt	2,425.0	2,660.0
Sales price of 1 metric centner of basic fat milk, EUR	23.7	23.7
Cost of gross output, thousand EUR	57.52	63.10
Total production costs, thousand EUR	41.5	45.5
including: salary	8.92	9.79
feed	25.40	27.86
other direct costs	4.63	5.05
overhead costs	2.57	2.82
Cost of 1 metric centner of basic fat milk, EUR	17.116	17.116
Profit, thousand EUR	16.02	17.57
Overall economic effect, EUR	-	1,552.09
Economic effect per 1 animal, EUR	-	31.04

Source: compiled by the authors

Thus, the results of the production test showed that the amount of pure trace elements per 1 kg of the feed mixture is important when using chelated compounds of zinc, manganese, and cobalt. With a reduced amount of them, namely 54.7 mg/kg of dry matter of zinc and manganese mixed with 0.7 mg of cobalt compared to the currently recommended dry matter concentration of 60.8 mg/kg of zinc and manganese and 0.78 mg/kg of cobalt, milk productivity, quality composition of milk, reproduction indicators, and economic efficiency in Holstein cows were the best.

The positive impact on the health and productivity of cows when feeding mixed ligand complexes of trace elements is described in numerous studies. Thus, G.M. El Ashry *et al.* (2016) noted that the replacement of inorganic salts of zinc, manganese, and copper with their methionates at the same concentration of these trace elements in the diets of dry cows had a positive effect on their milk productivity and fat content in milk during subsequent lactation. During the experiment on dairy cows, comparing the action of chelated compounds of trace elements (Co, Cr, Cu, Fe, Mn, Se, Zn) and amino acid complexes, M.D. Banadaky *et al.* (2021) found that the introduction of a combination of these trace elements produced using chelated compound technology to the diet of dairy cows helps to increase milk productivity and fat content.

According to J. Illek *et al.* (2023), feeding cows chelated complexes of trace elements

during the late dry period and the first 98 days of lactation resulted in a significant increase in milk productivity, fat and protein content in milk, and a decrease in the number of somatic cells in it. In this case, the effect of additives on udder health can be confirmed. The positive effect on the productivity of beef cows using organic sources of trace elements in diets was described in the monograph by R.A. Hill (2012). However, R. Marques *et al.* (2016) also noted an increased body weight of calves during weaning after feeding cows with diets containing chelated compounds of trace elements. A meta-analysis of 20 research papers on the amount of milk yield, composition and yield of milk components, and the reproductive function of cows with the consumption of organic sources of trace elements, conducted by A.R. Rabiee *et al.* (2010), concluded that organic micromineral supplements can improve the productivity and reproduction of dairy cows during lactation.

Ukrainian researchers, namely M. Dolgaya *et al.* (2016), according to the results of experimental studies, noted a positive effect of a 50% reduced concentration of zinc, cobalt, and manganese introduced into the diet in the form of chelated compounds in the dry matter of a complete cow feed mixture. During the experiment, an increase in milk yield during the first 100 days of lactation and an increase in the proportion of fat in it with a reduced concentration of zinc, manganese, and cobalt were recorded. A similar trend was observed in the course of this study. It is obvious that the norms of trace elements recommended for feeding animals, in particular cows, are based on the use of inorganic compounds of trace elements. Automatic recalculation of the required amount of chelated compound by the number of pure trace elements is erroneous, since with better digestibility of trace elements from organic sources, the animal needs a lower concentration of them. Therefore, when using a lower concentration of zinc, manganese, and cobalt in their chelated compounds in feed, productivity results are improved. Under such conditions, another side effect is a reduction in ecosystem pollution.

S. Kulibaba *et al.* (2017), according to the balance of cuprum, zinc, and manganese in the body of dairy cows, proposed to use microelement chelates in concentrations below the norm of their introduction in the form of sulphuric acid salts by 25% for Cu, 50% for Zn, and 65% for Mn. Thus, it can be assumed that improving the functioning of the scar microflora due to the optimal content of certain trace elements (cuprum, zinc, manganese, cobalt) contributes to positive changes in the digestion of nutrients, as mentioned by Y. Kropyvka *et al.* (2022) and milk synthesis, as discussed above.

In the course of the current experiment, the dynamics of changes in live weight of cows from start-up to the end of the first 100 days of lactation was investigated. During this period, cows lost and gained body weight, which is physiologically natural. However, in cows whose diet contained reduced amounts of zinc, manganese, and cobalt, body weight loss during lactation was significantly less than in control animals. The effect on the meat qualities of livestock was also reported by R. Raths *et al.* (2023). As for dairy cows, reducing body weight loss during the period of active increase in milk secretion in their body (energy pit) is very relevant. This will affect the further productivity of the animal, its achievement of the peak of lactation, timely heat, and successful insemination.

The researchers found a significant decrease in the duration of the service period in cows (by 9 days) and an improvement in the insemination index (by 0.17). Similar results were obtained in a study by a group of researchers led by K. Uchida *et al.* (2001), when feeding cows organic compounds of trace elements. They noted a reduction in the service period and an increase in the insemination rate of cows, but there were no changes in productivity and fat and protein content in milk. It can be assumed that improving reproductive functions in cows

is the body's response to normalising the dose of zinc, since it directly affects the reproductive function of animals – oocyte maturation and fertilisation (Spears, 2023). Thus, an increase in the fertilisation rate of cows of the experimental group leads to a decrease in the number of semen doses for successful insemination and the duration of the service period and lactation in general. This can be considered a significant production achievement as it helps to reduce the duration of the least productive phase of lactation of the cow.

The goal of most changes in animal feeding is to make a profit. The calculation of economic efficiency showed that with a reduced dose of zinc, manganese, and cobalt, total production costs increased, but productivity also increased. When these factors were combined, it was found that the cost of milk production was the same in both groups. With increased productivity, additional profit was also recorded, which is an obvious fact. For each cow that consumed a diet containing 54.7 mg of zinc and manganese, and 0.7 mg of cobalt/kg of dry matter, an additional profit of EUR 31.04 was obtained. However, it is worth noting that these calculations apply only to the first 100 days of lactation. Reducing the duration of the service period by 9 days will automatically reduce the duration of the lactation decline stage, which occurs after 200 days of lactation and is the least productive period in the cow's production cycle. This will reduce the cost of feeding an animal of relatively low productivity and provide additional profit, but the calculation of this amount was not part of the design of this study.

Thus, it was established that under the conditions of the same sales prices for products, the use of mixed feeds with zinc and manganese levels of 54.7 mg and cobalt of 0.7 mg/kg of dry matter in feeding German-bred high-yielding Holstein cows contributes to an increase in the level of profitability of milk production compared to the option with the levels of zinc, manganese 60.8 mg and cobalt 0.78 mg/kg of dry matter due to their mixed ligand complexes. Such data are consistent with the results obtained by numerous Ukrainian and foreign researchers.

Conclusions

A number of studies on the use of various types of chelated complexes of trace elements in animal feeding, in particular zinc, manganese, and cobalt, have shown that their optimal doses are slightly lower than recommended. Obviously, this is due to better absorption of trace elements from organic sources. Similar results were obtained in the course of this research. Analysing changes in the productivity of cows, the composition and quality of their milk, the preservation of reproductive ability with the introduction of mixed ligand complexes of zinc, manganese, and cobalt, it can be argued that their optimal content in feeding high-yielding Holstein cows of German selection is slightly lower than currently recommended. It was found that feeding cows during the dry period and during the first 100 days of lactation of complete feed mixtures containing 54.7 mg of zinc and manganese and 0.7 mg of cobalt per 1 kg of dry matter compared to the recommended level (zinc – 60.8 mg, manganese – 60.8, cobalt – 0.78 mg/kg of dry matter) contributes to an increase in the daily yield of natural milk by 9.2%, and its fat content by 0.02%. When calculating the average daily milk yield with a fat content of 4%, the advantage of animals of the experimental group over the control group by 4.0 kg or 9.7% was established.

Analysis of body weight dynamics showed that when 1 kg of dry matter in the diet contains 54.7 mg of zinc and manganese and 0.7 mg of cobalt instead of 60.8 mg and 0.78 mg/kg of dry matter, respectively, the weight loss after calving was 12.5 kg or 2.1%. A decrease in the concentration of zinc, manganese, and cobalt in chelated compounds also contributed to a reduction in the service period by 9 days, and a decrease in the insemination index by 0.17. This

result helps to reduce the least productive phase of lactation, which affects the cost of milk production. The economic effect of using this level of feeding was EUR 31.04 per animal during the experiment period. The results obtained complement the previously suggested assumptions that the use of organic compounds of trace elements in animal feed requires a number of studies to determine their optimal level. Therefore, it is important to continue experiments on animals of other species and groups, especially those that will participate in herd reproduction.

Acknowledgements

None.

Conflict of Interest

None.

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Ефективність використання різних рівнів змішанолігандних комплексів Цинку, Мангану та Кобальту у годівлі корів

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Анотація. Для підвищення продуктивності та зменшення негативного впливу на навколишнє середовище необхідно науково досліджувати найбільш оптимальні співвідношення органічних мікроелементів у раціонах корів, що беруть участь у виробничому циклі, враховуючи їх фізіологічний стан та стадію лактації. Мета дослідження полягала у визначенні економічної вигідності використання змішаних комплексів цинку, марганцю та кобальту у раціонах дійних корів. Дослід проводили у виробничих умовах на коровах Голштинської породи. 100 корів поділили на дві групи. Корови контрольної та дослідної груп споживали кормосуміші, виготовлені за однаковими рецептами, у яких були додані змішанолігандні комплекси Цинку, Мангану, Кобальту. Встановлено, що за оптимального вмісту змішанолігандних комплексів цинку, мангану та кобальту у корів дослідної групи втрата маси тіла за перші сто діб лактації була на 16,4 кг або 2,88 % меншою, ніж у контролі. Аналіз показників продуктивності корів упродовж сухостійного періоду та перших сто днів лактації засвідчив, що у тварин дослідної групи, раціон яких містив змішанолігандні комплекси мікроелементів з розрахунку по 54,7 мг Цинку і Мангану та 0,7 мг Кобальту на 1 кг сухої речовини надій молока натуральної жирності збільшився на 4,1 кг або 9,2 %, вміст жиру в молоці – на 0,02 % порівняно з коровами контрольної групи, в раціонах яких за рахунок змішанолігандних комплексів забезпечували вміст Цинку і Мангану на рівні 60,8 мг, Кобальту – 0,78 мг/кг сухої речовини. Також було зафіксовано зменшення тривалості сервіс-періоду на 9 діб та індексу осіменіння – на 0,17 спермодози. При цьому собівартість виробленої продукції залишалася без змін, а додатковий прибуток за зниженої концентрації вказаних елементів у раціоні корів дослідної групи становив €27,24 або 9,7 %. Таким чином, оптимізація мінерального живлення корів шляхом уведення змішанолігандних комплексів цинку, мангану та кобальту для досягнення концентрації мікроелементів у 1 кг сухої речовини кормосуміші Цинку та Мангану – по 54,7 мг, Кобальту – 0,7 мг дасть можливість покращити показники молочної продуктивності та відтворної здатності корів, а також отримати додатковий прибуток

Ключові слова: органічні сполуки мікроелементів; сухостійні корови; дійні корови; надій молока; жирність молока; економічна ефективність