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Growth rate, indicators of slaughter and quality of pork with the additional introduction of a chelated copper complex into the diet of pigs

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Abstract. The efficiency of conducting industrial competitive pig breeding in Ukraine depends on the level of feeding and provision of animals with the necessary biologically active substances. Lack of mineral substances leads to a decrease in growth rates, an increase in the duration of the fattening period, excessive feed consumption, and, accordingly, an increase in the cost of pork, which determines the relevance of the chosen subject. The purpose of the study was to identify the effect of the mineral additive of the copper chelate complex on the meat productivity of hybrid pigs and

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the quality of pork. the following methods are used to fulfil the purpose of the study: zootechnical (live weight dynamics, determination of average daily and relative gains), biochemical (analysis of chemical composition and microelement content in muscles, indicators of pork quality: moisture content, tenderness, marbling, colour intensity), morphological (slaughter yield parameters determination), and statistical (identification of substantial differences between values). The effectiveness of the chelated copper complex with glycine on the growth intensity of pigs, slaughter parameters, chemical and microelement composition of muscles, and pork quality indicators after cold storage is investigated. It is established that the additional introduction of a chelated copper complex into the diet increased the intensity of average daily weight gain of pigs by 9.1% and relative live weight gain by 4.5 percentage points. From pigs of this group, heavier carcasses were obtained by 4.5 percentage points with a smaller fat thickness over the 6-7 thoracic vertebra by 10.6% and an internal fat mass of 7.5%, and 9.7% more internal organs. Pork was obtained from animals of the experimental group with a lower fat content by 10.0 percentage points, a higher protein content – by 3.9 percentage points, and ash – by 12.1 percentage points. The diet with a chelated copper complex increased the moisture capacity and tenderness of pork after cold ageing, and helped reduce the caloric content of meat. The concentration of minerals in muscle tissue in the experimental group was higher in terms of copper, manganese, cobalt, iron, and zinc. Based on the obtained data, the possibility of effective feeding of the copper chelate complex with glycine to fattening pigs was established

Keywords: young pigs; live weight; microelement additive; chelated copper; slaughter yield; internal organ yield; meat quality

INTRODUCTION

It is necessary to provide proper feeding for the young animals, ensuring that they receive all the necessary nutrients to achieve the full genetic potential of meat breed pigs. This problem can be solved by using feed additives of various origins and therefore the diets of animals are determined depending on their physiological state and level of productivity, which proves the relevance of the chosen subject. The studies conducted by Ukrainian and foreign researchers A. Hutsol *et al.* (2018) and O. Skoromna *et al.* (2019) show that the use of feed with a sufficient amount of all the necessary nutrients contributes to the achievement of high rates in the reproduction, growth, development, and fattening of pigs. A variety of feed additives are used to improve feed consumption and increase the efficiency of its use, achieve maximum productivity, and obtain better quality products. Among feed additives, enzyme preparations, protein, amino acid, mineral and vitamin supplements, probiotics, prebiotics, and acidifiers are often used. Feed additives with antibacterial and immunostimulating properties, such as acidifiers, copper, and zinc, are added to the diets of pigs to maintain a balanced microbiota in the gastrointestinal tract and to control pathogens. Betaine and the trace element chromium, have a positive effect on energy and lipid metabolism in the pig body, which is described in the study by R. Fu *et al.* (2021). Animals are fed supplements containing enzymes to improve the absorption of nutrients and have a positive effect on the state of the gastrointestinal tract. However, the data obtained on the use of these additives and their impact on pig growth productivity vary from one researcher to another. They explain such discrepancies in the results obtained by the physiological state of development of animals, the period of their rearing and fattening.

O. Skoromna *et al.* (2019) noted that the importance of micronutrient supplements to the animal diet lies in the fact that they are involved in the formation of cells, tissues, organs, physiological, catalytic and regulatory functions in animals, and accordingly their inclusion in the animal diet is necessary. Mineral supplements are added to the pig's diet to improve health, digestion, and productivity (Myronenko & Usachova, 2022). Depending on the phase of pork production, a different amount of each mineral element is required in the animals' diet. The results of the study by N. Grushanska *et al.* (2018) and S. Villagómez-Estrada *et al.* (2020) confirm the positive effect of mineral supplements to improve the mineral status of piglets in rearing. They also established that in the case of excessive accumulation of these elements in the tissues, they are removed from the body. Maintaining 50% of the need for copper, iron, manganese, and zinc in a diet based on corn and soy meal is justified. A decrease in the content of certain trace elements (zinc, copper, manganese and iron) in the diets of pigs does not negatively affect the productivity of animals, but it causes a substantial decrease in the release of these minerals from the faeces. The main factor affecting the elimination of mineral elements is their concentration in feed and does not depend on the source of origin. J. Faccin *et al.* (2023) confirmed an increase in the use of alternative sources of chelated minerals, such as copper, manganese, selenium, and zinc. Feeding diets with organic trace elements included leads to an improvement in meat quality indicators. X. Bo *et al.* (2022) explain this by greater enzyme activity and protein biosynthesis. Under such conditions, pork is more resistant to protein oxidation, pork belly has a greater moisture-retaining ability. The concentration of complex minerals (calcium, zinc, copper, magnesium,

manganese, iron) in the diet of pigs improves the efficiency of feed use and meat quality, while not affecting the percentage of lean meat.

Copper is a component of metalloenzyme systems, and it can activate enzymes to better function in various biochemical processes. C. Espinosa & H. Stein (2021) argue that the growth-stimulating effect of copper occurs in pigs of different ages due to a decrease in the frequency of diarrhea and an increase in the efficiency of feed use by the body. They attribute this improvement to the effect of copper on enzymes involved in digestion and lipid metabolism. A number of authors, such as X. Li *et al*. (2022) state that the quality of meat is not affected by the dose of copper in the diet of animals.

After analysing the above studies, it was determined that the problem of proper feeding of young pigs has not been sufficiently examined, so the purpose of the study is to investigate the effect of copper chelate on the growth rate of pigs, slaughter indicators, and pork quality.

MATERIALS AND METHODS

The scientific-economic study was conducted at the "Plebanivskyi Sad" farm in Vinnytsia region, Ukraine, during 2022-2023, focusing on the hybrid piglets F1 (Velyka Bila×Landras). For this purpose, 24 pig heads with an average initial live weight of at least 32 kg were selected, which were divided into various feeding rations and raised to a final live weight of approximately 110-120 kg. The selected hybrid piglets were divided into 2 groups of 12 heads each. Groups of experimental animals were formed by the method of analogue groups, considering such factors as origin, age, gender, and live weight. The piglets involved in the study were obtained from sows of the Velyka Bila × Landras breed. In the course of studies related to feeding fattening pigs, a complete mixed feed was used that met the nutritional requirements for pigs and provided them with all the nutrients.

Piglets aged 75 days were selected for testing. At the beginning of the experiment, the pigs were given mixed feed "Grower", in the second period of fattening – mixed feed "Finisher". The period of feeding mixed feed "Grower" lasted 35 days, "Finisher" – 55 days. In the first period of fattening, piglets were fed mixed feed "Grower" until they reached a live weight of 65 kg. The composition of mixed feed "Grower" included: corn – 25%, wheat – 25%, barley – 23%, sunflower meal – 12%, wheat bran – 7%, soy cake – 3%, protein mineral vitamin supplements (PMVS) – 5%. The nutritional value of such a diet was 2173 Kcal in terms of metabolic energy, 157 g of digested protein. During the second fattening period, the pigs were fed mixed feed "Finisher" until they reached a live weight of 110 kg. The composition of this mixed feed included: barley – 38%, wheat – 24%, wheat bran – 12%, corn – 9%, sunflower meal – 9%, PMVS – 4%. In terms of nutritional value, mixed feed provided the body of pigs with 2051 kcal of metabolic energy, and 148 g of digestible protein. Pigs of the control and experimental groups were fed the main diet. Additionally, a mineral supplement was added to the diet of experimental pigs of the second group chelate complex copper, which contains 5% copper, 20% glycine. The test additive was given to pigs together with water, at the rate of 0.3 kg/ton of water. During the entire fattening period, pigs had arbitrary access to feed and water.

Pig growth was monitored by individual weighing at the beginning and end of each fattening period. Based on the results of weighing, the live weight of animals, average daily, absolute and relative weight gains during the experiment were determined. In the experiments, the consumed feed was recorded and the consumption of mixed feed per 1 kg of pork growth was calculated. Growth efficiency was evaluated by the average daily and relative live weight gain.

At the end of the experiment (day 110), 4 pigs were selected from each group that were not fed for 12 hours, and then slaughtered by electric shock (250 V, 0.5 A, for 5-6 seconds) to assess the effect of the copper chelate complex on slaughtering and pork quality. The long back muscle and internal organs (liver, spleen, kidneys, heart) were removed and weighed on an electric scale. In the muscle tissue of pigs, the physico-chemical parameters of the longest back muscle were determined: the level of initial moisture – by drying samples at a temperature of 60-65°C; hygroscopic moisture – by drying the suspension in a drying cabinet at a temperature of 103±2°C; protein content – by Kjeldahl's method; moisture retention capacity and tenderness-by pressing; caloric content-by mathematical calculation method based on chemical composition; acidity (ph) – by potentiometric method using a pH meter; colour intensity – using a photoelectrocolourimeter. Qualitative indicators of pork in terms of mineral content were determined by atomic absorption spectrometry on PRK-1M.

Data analysis was performed using variance analysis (ANOVA) using Excel 2010 software. The data is expressed as the average value of x±SD. Differences between the groups were considered statistically substantial at $P<0.05$ (adjusted for Bonferroni), comparisons were classified as substantial ($P<0.05$) or insubstantial ($p>0.10$). All experimental studies were conducted in accordance with modern methodological approaches and in compliance with the relevant requirements and standards, in particular, they meet the requirements of DSTU ISO/IEC 17025:2005 (2006). The keep of animals and all manipulations were conducted in accordance with the Order by the HCM of Ukraine No. 416/20729 on the "Approval of the Procedure of Animal Tests in Research Institutes" (Law of Ukraine No. 249, 2012), the European Convention for the Protection of Vertebrate Animals used for Experimental and other Scientific Purposes (European convention…, 1986).

RESULTS AND DISCUSSION

Studies conducted with additional administration of copper chelate complex show a positive effect on the

growth dynamics of pigs, slaughter indicators, and the quality of the resulting pork. The use of a chelated copper complex in the diet of fattening pigs (the second group) increased their live weight by 5.6% ($p<0.05$) in 110 days and by 6.5% ($p<0.05$) at 165 days in comparison with the indicators of animals of the control group (Table 1).

Table 1. *Growth rate of fattening pigs and feed payment for the introduction of a chelated copper complex into the diet, x±SD, n=12*

Indicator	Group	
	control (MD)	experimental (CC)
Live weight of pigs at the beginning of the feeding period of mixed feed "Grower" (75 days), kg	32.5±0.9	32.6±0.7
Live weight of pigs at the end of the feeding period of mixed feed "Grower" (110 days), kg	62.6±2.2	66.1±1.5
Absolute increase	30.1±1.1	33.5±0.96*
Average daily increase in live weight of pigs during the period of feeding mixed feed "Grower", g	860±24	957±22**
Relative increase in live weight of pigs during the period of feeding mixed feed "Grower", %	63.3±1.2	67.9±1.3*
Live weight of pigs at the end of the Finisher's mixed feed period (165 days), kg	112.5±8.4	119.8±7.9
Absolute increase	49.9±1.0	53.7±1.1*
Average daily increase in live weight of pigs during the period of feeding mixed feed to the Finisher, g	908±17	976±23
Relative increase in live weight of Pigs during the period of feeding mixed feed to the Finisher, %	57.0±2.1	57.8±1.9*
Average daily live weight gain for the study fattening period	888±19	969±25**

Note: ** – P<0.05; ** – P<0.01; *** – P<0.001 differences between the control and experimental groups; MD – the main diet, CC – copper chelate*
Source: *compiled by the authors*

Additional feeding of the copper chelate complex with mixed feed "Grower" increased the average daily growth in pigs by 11.3% ($p<0.01$), and during the period of feeding mixed feed "Finisher" – by 7.5% ($p<0.05$). For the entire study period of fattening animals, the average daily weight gain was higher in the second group by 9.1% ($p<0.01$). This accordingly had a positive effect on the relative increase in live weight of pigs. The supplement contributed to an increase in this indicator during the fattening period by 4.5 percentage points. Slaughter rates in pigs of both groups differed depending on the feeding diet. The use of a copper chelate complex in feeding fattening pigs increased the slaughter yield by 4.5 percentage points ($p<0.05$) compared to the animals of the control group. Pigs of the experimental group had a smaller fat thickness over the 6-7 thoracic vertebra by 10.6% ($p<0.001$). According to the indicator of the area of the "muscle eye", the best results were obtained in pigs for feeding the copper chelate complex, in which the advantage was 6.3% ($p<0.05$). Under the influence of a mineral supplement in the second group, the weight of internal fat decreased by 7.5% ($p<0.05$), the weight of the front legs increased by 4.2% (Table 2).

Table 2. *Indicators of pig slaughter with additional introduction of a chelated copper complex into their diet, x±SD, n=4*

Indicator	Group	
	control (MD)	experimental (CC)
Pre-slaughter weight, kg	111.2±3.8	115.6±3.2
Slaughter weight, kg	81.3±2.4	88.4±2.9
Slaughter yield, %	73.1±1.2	76.4±1.1*
Lard thickness over 6-7 thoracic vertebra, mm	32.1±0.9	28.7±0.8***
Internal fat, kg	1.74±0.06	1.61±0.04*
Area of the "muscle eye", cm^2	44.3±0.8	47.1±0.9*
Head weight, kg	4.2±0.07	4.7±0.03
Leg weight, g:		
front	763±24	795±28
rear	804±23	803.5±1.97

Note: ** – P<0.05; ** – P<0.01; *** – P<0.001 differences between the control and experimental groups; MD – the main diet, CC – copper chelate*
Source: *compiled by the authors*

The effect of a mineral supplement on the mass of internal organs was determined from the conducted studies. Under the influence of the test drug, liver weight increases by 12.7% ($p<0.001$), hearts – by 10.0% ($p<0.01$), lungs – by 10.0% ($p<0.001$). There was also a slight increase in kidney mass by 4.4% and a decrease in spleen mass by 4.3% compared to the control data (Table 3).

Table 3. *Weight (g) and slaughter yield (%) of internal organs of pigs with additional introduction of a chelated copper complex into their diet, g, x ± SD, n=4*

Indicator	Group	
	control (MD)	experimental (CC)
Liver, g	1832±46	2064±48***
%	1.65±0.08	1.78±0.05
Heart, g	378±17	416±19**
%	0.34±0.02	0.36±0.03
Lungs	485±12	542±18***
%	0.44±0.07	0.47±0.06
Kidneys	339±37	354±23
%	0.30±0.02	0.31±0.03
Spleen	188±34	161±27
%	0.17±0.01	0.14±0.02
Mass of internal organs, g	3226±47	3539±93**

Note: ** – P<0.05; ** – P<0.01; *** – P<0.001 differences between the control and experimental groups; MD – the main diet, CC – copper chelate*
Source: *compiled by the authors*

In general, 9.7% more internal organs were received from pigs of the experimental group ($p<0.01$). Feeding pigs a chelated copper complex in the diet increases not only the total slaughter yield but also the slaughter yield of internal organs. Correction of diets with trace elements increases the yield of the liver and heart by 7.8 percentage points and 5.9 percentage points, lungs – by 6.8 percentage points. There was a slight increase in renal yield by 3.3 percentage points and a decrease in spleen yield by 17.6 percentage points compared to the control data. Important indicators for fattening pigs are meat qualities, in particular, chemical composition, caloric content, marbling, and tenderness of meat. The nutritional value of meat depends on the quantitative ratio of moisture, protein, fat, mineral elements, and indicators of pork. The use of a copper chelate complex in pig feeding slightly increases the level of dry matter in meat of the second group. In meat samples of this group, the protein content and ash residue increased by 3.9 percentage points and 12.1 percentage points, respectively ($p<0.001$). Therewith, there is a decrease in the fat content in the meat of pigs that were fed the examined mineral preparation by 10.0 percentage points ($p<0.01$) (Table 4).

Table 4. *Chemical composition of pig meat with additional introduction of a chelated copper complex into their diet, % (x±SD, n=4)*

Indicator	Group	
	control (MD)	experimental (CC)
dry matter, %	91.6±2.4	92.3±2.7
Protein, %	64.8±2.6	67.3±2.4
Fat, %	22.8±0.7	20.5±0.9
Ash	3.3 ±0.1	3.7±0.1***

Note: ** – P<0.05; ** – P<0.01; *** – P<0.001 differences between the control and experimental groups; MD – the main diet, CC – copper chelate*
Source: *compiled by the authors*

The moisture-retaining properties of meat affect its technological characteristics, namely, juiciness and tenderness. When storing pork, these indicators vary depending on the shelf life and feeding factor of pigs. Moisture capacity is a substantial characteristic of meat and is determined by the amount of bound moisture in it. The more bound water contained in meat, the higher its technological properties will be. The action of the copper chelate complex leads to an increase in bound moisture in the muscles of pigs, which indicates an

increase in the juiciness of muscle fibres. When using the copper chelate complex, no changes were identified in the acidity, colour intensity, and tenderness of pig meat compared to the control sample. Marbling indicates the ratio of muscle to adipose tissue and is an important indicator that affects the taste and level of intramuscular fat in pork. It was established that feeding a mineral additive of the copper chelate complex led to a slight increase in the content of total and bound moisture in pig meat after daily exposure. The mineral supplement examined did not affect the active acidity value of the pH of meat (Table 5).

Table 5. *Indicators of pork quality after ageing with the additional introduction of a chelated copper complex into their diet, x±SD, n=4*

Indicator	Daily exposure time		30-day exposure time	
	Group			
	control (MD)	experimental (CC)	control (MD)	experimental (CC)
Total humidity, %	74.8±2.1	75.1±2.4	74.3±1.8	74.9±1.7
incl. bound, %	42.5±0.9	43.4±0.9	42.1±0.8	43.3±0.6
ph	5.6±0.2	5.6±0.2	5.4±0.2	5.4±0.2
colour intensity, E^{-100}	14.6±0.18	15.1±0.13	11.7±0.4	11.3±0.5
Tenderness, cm^2/g	287±12	328±13*	238±14	282±11*
Marbling	11.8±0.2	10.1±0.4***	9.6±0.2	8.2±0.3***
Caloric content, KJ	4818±43	4727±39*	4442±32	4193±64***

Note: ** – P<0.05; ** – P<0.01; *** – P<0.001 differences between the control and experimental groups; MD – the main diet, CC – copper chelate*
Source: *compiled by the authors*

The presence of adipose tissue gives pork tenderness and increased caloric content. However, a large amount of fat in meat leads to a decrease in protein levels, which in turn reduces its nutritional value. Due to the action of the copper chelate complex, there is an increase in the tenderness of meat by 14.3% (p<0.05) and a decrease in the level of marbling – by 14.4% (p<0.001) compared to the corresponding indicators in the control. According to the results of the calculation, it was identified that a decrease in the fat content in the meat of pigs of the experimental group affected a decrease in its caloric content by 1.9%.

Long-term storage of pork in a frozen state for 30 days has made some changes in its quality indicators. It has reduced the level of total and bound moisture. In addition, during the 30-day ageing of frozen pork, there was a decrease in its colour intensity in the control group by 19.8%, in the experimental group – by 25.1%, marbling – by 18.6% and 18.8%, respectively. In addition, long-term storage of pork made changes in the caloric content of meat, this indicator decreased in the control by 7.8%, in the experimental group – by 11.3%. Slightly better indicators were obtained in the experimental group, where a chelated copper complex was introduced into the diet of pigs. In terms of colour intensity in the samples of this group, compared with pork of animals that were fed the main diet, the decrease was by 21.2 percentage points, marbling – almost at the same level. The copper chelation complex also made changes in the caloric content of pork. Higher-calorie pork was obtained in the control group of animals.

Analysis of the chemical composition of pork identified changes in the selected samples depending on the diet of pigs. The additional introduction of a chelated copper complex into the diet of animals led to an increase in the content of zinc in the muscles of pigs by 7.7% (p<0.001), manganese – by 13.2% (p<0.001), copper – by 18.6% (p<0.001), cobalt – by 22.8% (p<0.01), and iron – by 8.4% (p<0.001) (Table 6).

Table 6. *Microelement composition of pig muscles with additional introduction of a chelated copper complex into the diet of animals (x±SD, n=4)*

Indicator	Group	
	control (MD)	experimental (CC)
Zinc, mg/kg	138.7±2.3	149.4±2.6***
Manganese, mg/kg	0.83±0.01	0.94±0.02***
Sulfur, mg/kg	7.78±0.11	9.23±0.12***
Cobalt, mg/kg	2.02±0.11	2.48±0.14**
Iron, mg/kg	72.5±1.4	78.6±1.5**

Note: ** – P<0.05; ** – P<0.01; *** – P<0.001 differences between the control and experimental groups; MD – the main diet, CC – copper chelate*
Source: *compiled by the authors*

Thus, high-quality pork in terms of the content of trace elements (zinc, copper, manganese, and cobalt) was established in the group of pigs that were additionally injected with a chelated copper complex in the diet. Pig breeding in Ukraine has been expanding in the area of industrial production in recent years and is becoming competitive on the world market. For this purpose, substantial efforts are being made to increase production volumes and improve the quality of pork. These data are consistent with other researchers who believe that chelated forms of trace elements are effective in feeding animals. According to the results of the study, it was established that the chelated complex of copper with glycine affects the growth rate of pigs, slaughter indicators, and pork quality. Indicators of animal growth intensity are influenced by a number of factors, among which the breed and feeding factors (Garmatyuk *et al.,* 2020). Interbreeding substantially increases the average daily live weight gain of pigs (Karpenko, 2020). In the conducted studies on examining the effect of additional administration of a copper chelate complex, hybrid young animals of Velyka Bila×Landras were used. Copper is used in pig feeding as an additive to stimulate animal productivity.Various sources of copper can alter the composition of the gut microbiota and improve gut health (Xiong *et al.,* 2023). The use of unconventional natural mineral additives in diets for fattening young pigs led to more efficient use of minerals in diets, which contributed to more intensive growth of animals and reduced feed costs per unit of production (Bomko & Baranyuk, 2017; Verbelchuk *et al.,* 2021). Given the limited amount of copper supplements in pigs' diets, the use of chelated copper may be an alternative to maintain the effect of stimulating growth and reducing exposure to the environment.

Mineral supplement based on chelated trace elements (copper, zinc, iron, manganese), examined by M. Chorny *et al.* (2018) on young pigs, allowed for higher average daily gains with lower feed costs, which contributed to additional profits. The use of biomicroelement complexes in feeding enhances the metabolic processes and stimulates the growth rate of young pigs. Complexes containing copper and cobalt in combination with tryptophan have a more noticeable stimulating effect on the clinical and physiological state of animals (Espinosa *et al.,* 2019). The use of organic copper and zinc in pig feeding does not have a lasting effect on growth productivity. These trace elements can maintain their serum concentrations and substantially reduce the faecal excretion of these elements. The wide spectrum of action of chelated compounds of trace elements causes an increase in multiple pregnancies, nest weight, improved pig viability, increased pig weight, improved slaughter yield and physical and chemical properties of meat. Accordig to M. Chorny *et al.* (2018), additional levels of microminerals (copper, iron, and manganese) do not affect the activity of liver enzymes, but severe intoxication with copper and zinc compounds leads to metabolic disorders and irreversible pathological processes in the liver. The use of a chelated form of copper with glycine in our studies is confirmed by other data from researchers on the stimulating effect of micromineral supplementation on the growth rate of fattening pigs. J. Zhao *et al.* (2014) investigated the feasibility of replacing $CuSO_4$ on chelated copper as a growth stimulator in pigs. They established that pigs fed chelated copper were 6.0% heavier at the end of the experiment, they used feed more efficiently and obtained heavier carcasses from them. The authors' study confirms the data of previous researchers on the positive effect of the copper chelate complex on the increased yield of carcasses and internal organs.

The use of mineral supplements containing various forms of trace elements increases the growth and development of young animals, which further increases the profitability of pork production (Korobka *et al.,* 2018). Therewith, the introduction of carbon dioxide and chelated forms of salts into the diet of pigs has substantially better indicators. The introduction of copper, even in low doses, into the diet of pigs contributes to healthy changes in the composition of intestinal bacteria and increases growth productivity (Li *et al.,* 2021). Enriching the diets of pigs with mineral additives of natural origin contributes to better preservation of livestock, increases the mineral content in slaughter products, ensuring high-quality pork. The use of mineral supplements in feeding improves the quality and biological value of meat (Razanova *et al.,* 2022). With the introduction of the protein-vitamin-mineral supplement "Minactivit", the slaughter yield of pigs increased, and the physico-chemical parameters of muscle tissue (water retention capacity, protein content) improved, the yield of fat in the carcass decreased (Suprovych *et al.,* 2019). Similar results were obtained for feeding LG-MAX and Sal-Plex additives in feeding pigs during rearing and fattening, but in this study, the fat content of pork (Tkachik & Tkachuk, 2019). The results of this study also showed that a chelated copper complex can improve the chemical and mineral composition of pork, and its quality indicators after cold ageing. Studies of the feeding factor of introducing a chelated copper complex into the diet of fattening pigs contributed to more intensive growth of animals, obtaining a higher slaughter yield of carcasses and high-quality pork.

CONCLUSIONS

In the course of the study, the intensity of pig growth was determined and indicators of slaughter and quality of pork with the additional introduction of a chelated copper complex into the diet were measured and determined. The results fully fulfil the set goal of the study. Additional feeding of the copper chelate complex increased the live weight of pigs in 110 days by 5.6%, 165 days – by 6.5% compared to the control, increased the average daily weight gain for the study fattening period

by 9.1%, and the relative increase in live weight – by 4.5 percentage points.

Under the influence of the examined drug in the experimental group, the slaughter yield is higher by 4.5 percentile points and the area of the "muscle eye" – by 6.3%, the thickness of lard over the 6-7 thoracic vertebra is smaller by 10.6%, the mass of internal fat is increased by 7.5%, the mass of internal organs (liver, heart, lungs, and kidneys) increases by 9.7%. In the meat samples of the second group, the protein and ash residue content was increased by 3.9 percentage points and 12.1 percentage points, respectively, and the fat content was reduced by 10.0 percentage points. Under the action of the copper chelate complex, there is an increase in meat tenderness by 14.3%, a decrease in marbling – by 14.4%, and caloric content – by 1.9%. Long-term storage of pork made some changes in its quality indicators and the best indicators were obtained in the experimental group, where a chelated copper complex was introduced into the diet of pigs. The additional introduction of a chelated copper complex into the diet of animals led to an increase in the content of zinc in pig muscles by 7.7%, manganese – by 13.2%, copper – by 18.6%, cobalt – by 22.8%, and iron – by 8.4%.

Future research in this area should be aimed to further improve understanding of the effects of the copper chelate complex on pork growth rate, slaughter rates, and quality. It is important to conduct a more detailed study of the molecular and biochemical mechanisms underlying improved feed growth and conversion using this complex. The research may also include an analysis of the effects of the copper chelate complex on pig metabolism and hormone levels to better understand the underlying mechanisms.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Інтенсивність росту, показники забою та якості свинини за додаткового введення до раціону свиней хелатного комплексу міді

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Анотація. Ефективність ведення промислового конкурентоспроможного свинарства в Україні залежить від рівня годівлі і забезпеченості тварин необхідними біологічно активними речовинами. Недостатність мінеральних речовин спричиняє зниження темпів росту, збільшення тривалості періоду відгодівлі, надмірне споживання кормів і, відповідно, підвищення вартості свинини, що зумовлює актуальність обраної теми. Метою дослідження було виявити вплив мінеральної добавки хелатного комплексу міді на м'ясну продуктивність гібридних свиней та якість свинини. Для виконання мети досліджень використані наступні методи: зоотехнічні (динаміка живої маси, визначення середньодобових і відносних приростів), біохімічні (аналіз хімічного складу та вмісту мікроелементів у м'язах, показників якості свинини: вміст вологи, ніжність, мармуровість, інтенсивність забарвлення), морфологічні (визначення показників забою), статистичні (визначення достовірної різниці між значеннями). Досліджено ефективність хелатного комплексу міді з гліцином на інтенсивність росту свиней, показники забою, хімічний та мікроелементний склад м'язів, показники якості свинини після холодної витримки. Встановлено, що додаткове введення до раціону хелатного комплексу міді підвищувало інтенсивність середньодобових приростів свиней на 9,1 % та відносного приросту живої маси на 4,5 п.п. Від свиней даної групи отримано важчі туші на 4,5 п.п. з меншою товщиною шпику над 6-7 грудним хребцем на 10,6 % та масою внутрішнього жиру на 7,5 %, а також на 9,7 % більше внутрішніх органів. Від тварин дослідної групи отримано свинину з меншим на 10,0 п.п. вмістом жиру, більшим вмістом білку – на 3,9 п.п та золи – на 12,1 п.п. Раціон з хелатним комплексом міді підвищував після холодної витримки вологоємність та ніжність свинини, сприяв зниженню калорійності м'яса. Концентрація мінеральних речовин у м'язовій тканині у дослідній групі була вищою за вмістом міді, марганцю, кобальту, заліза, цинку. На підставі отриманих даних досліджень встановлено можливість ефективного згодовування хелатного комплексу міді з гліцином свиням на відгодівлі

Ключові слова: молодняк свиней; жива маса; мікроелементна добавка; хелатна мідь; забійний вихід; вихід внутрішніх органів; якість м'яса