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ORIGINAL ARTICLE

Influence of organic and non-organic microelements on productivity and metabolic processes in growing young pigs

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The purpose of our research was to determine the effect two different complexes of elements of copper, zinc, iron, manganese, selenium by organic and mineral origin in feeding mixture “SK-4” on growing pigs productivity, metabolic state and mineral deposition in their organs. We formed two groups of growing pigs, 40 heads each, with an average live weight of 13.6 kg at the age of 42 days. In addition to the main diet, the experimental animals were fed by two premixes of enriched mineral (in the form of sulfates) and organic (as chelates) complex of trace elements. In growing period, the pigs from control and experimental groups were kept in equal conditions. Within 56 days of experiments the productivity of animals was depended on feeding, whereas the use of organic complex increased the average daily live weight gain by 6.3% ($p<0.01$) with simultaneous decrease in exchange of energy costs by 6.4%. In the experimental group, the feeding with organic form of trace elements contributed to the increase in blood: erythrocytes - by 4.8% ($p<0.01$) and hemoglobin - by 15% ($p<0.001$) during the whole research period. We proved that the addition of chelate forms to the diet of growing pigs provided greater deposition of trace elements in their organs, which allowed reducing the excretion of trace elements, which is confirmed by the changes in histological sections. The results of our study showed that organic elements were more effective in terms of pigs production and health, and fully meet their needs in essential elements.
Key words: trace elements, chelate, pigs, blood composition, immunity.

Introduction

Iron, copper, manganese, zinc, and selenium are vital trace elements that are part of many vitamins, hormones, enzymes and are the activators of various biologically active systems, play a major role as catalysts for biochemical reactions in the body (Athanasios et al., 2018). Various premixes in the form of sulfates, carbonates, oxides, chelates have been actively used in the production of animal feed for farm animals. In search of new solutions in pig breeding, the use of chelate complexes is becoming more and more widespread (Vangroenweghe et al., 2020). At present, scientists and feed manufacturers are interested in the use of organic forms of compounds of iron, copper, manganese, zinc, selenium in feeds for farm animals in order to reduce the release of unexplored elements and increase their accumulation in the body (Mazo et al., 2007). This is a targeted effect on metabolic processes in the body to increase productivity and reduce production costs (Lee et al., 2001).

Iron is an integral part of redox enzymes, plays a major role in the process of tissue nutrition and respiration, thus contributing to the increase in live weight and conservation of young animals. Lack of iron in feed leads to the development of anemia, which is often observed in pigs (Chabaev et al., 2019). Copper is part of the enzymes of superoxide dismutase, oxidase, which stimulates hormones of the pituitary gland. In the presence of iron under the influence of copper accelerates the formation of hemoglobin and its functional ability, increases the size and number of red blood cells, leukocytes, phagocytic activity, in addition, increases oxygen - the binding ability of the blood (Kornegay et al., 1996).

V.H. Nadeev et al. (2019) found an increased accumulation of nitrogen in pigs whose diet was additionally fed with copper. If there is a lack of copper in the pigs' diet, the synthesis of body protein may be suspended. Manganese in animals is actively involved in metabolic processes, bone formation, tissue respiration, has an impact on the intensity of growth, development, hematopoiesis, functions of the reproductive organs, endocrinology and counteracts fatty liver degeneration (Cano-Sancho et al., 2014). It is necessary for oxidative phosphorylation in mitochondria, synthesis of fatty acids and cholesterol metabolism, and also participates in amino acid metabolism, promotes pig growth and normal sexual development of young animals (Brown, Zeringue, 1994).

Zinc participates in the process of breathing and has a positive effect on the activity of gonadotropic hormones of the pituitary gland, sex hormones and participate in the regulation of water, gas, nitrogen, carbohydrate, mineral and vitamin metabolism in animals (Vangroenweghe et al., 2020). Zinc deficiency in pigs leads to parakeratosis, symptoms of which are dermatitis, lack

of appetite, vomiting, diarrhea, slow and intermittent growth. Addition of mineral compounds of zinc to the diet of pigs contributed to their better growth and development, absorption of nutrients, nitrogen, calcium, phosphorus (Wedekind et al., 1990). Addition of mineral compounds of zinc to the diet of pigs contributed to their better growth.
Selenium participates in metabolic processes, is part of the enzyme glutathione peroxidase, which provides protection of animals from free radicals, maintains normal muscle tone, organs of touch and endocrine system (Chabaev et al., 2020). Consumption of selenium is necessary to maintain the cellular and humoral immunity, and increased doses of this trace element can strengthen and protect the body from some viral infections (Cano-Sancho et al., 2007; Chaudhary et al., 2016). According to P.I. Viktorov (2007), the introduction of cobalt, zinc, and manganese contributed to the increase in body weight by 8.2% and in average daily gain by 10.9%. Feeding of sows in the suckling period by a mixture of cobalt, zinc, copper, and iron salts contributed to better absorption of feed nitrogen, more intensive growth and development of pigs (Guryanov et al., 2019). Recent results show that trace elements have a strong effect on energy metabolism, pigs' productivity and improve the use of feed nutrients. At the same time, it should be noted that to date, few studies have been conducted with the use of complex chelate compounds of trace elements in the diets of growing pigs.
The purpose of our research was to determine the impact of two feeding premixes consisted from organic and mineral elements on metabolism and productivity of the growing pigs.

Materials and methods

Scheme and conditions of the experiment
During experiment, 80 pigs of large white breed at the age of 42 days with average live weight of 13.6±0.45 kg were distributed in two groups of analogues taking into account their sex and age. Conditions of pigs were the same throughout the whole experiment, lasted for 56 days. Feeding was dosed, program, dry mixed feed. The pigs were fed with post-starter compound feed (Table 1).

Table 1. Mixed fodder formula for growing pigs (% input)

Ingredient	Composition, %	
	C	E
Barley	50.75	50.75
Wheat	20.0	20.0
Extruded millet	8.0	8.0
Sunflower meal	4.0	4.0
Soybean meal	6.5	6.5
Fishmeal	7.2	7.2
Fat oil	1.25	1.25
Chalk	0.8	0.8
Precipitate	0.5	0.5
Standard premix P51-1	1.0	-
Premix “Bioplex TM”	-	1.0
	Content in 1 kg	
Metabolizable Energy, MJ	12.10	12.10
Crude protein, g	158.9	158.9
Digestible crude protein, g	120.9	120.9
lysine, g	7.5	7.5
Threonine, g	4.7	4.7
Methionine + cystine, g	4.87	4.87
Ca, g	7.8	7.8
P, g	6.5	6.5
salt, g	3.5	3.5
Fe, g	79.9	79.9
Cu, g	10	10
Zn, mg	49.8	49.8
Mn, mg	38.9	38.9
Co, mg	1.0	1.0
Vitamins: A, IU 10^3	3.5	3.5
D, IU 10^3	0.35	0.35
E, mg	30	30
B_1, mg	1.9	1.9
B_2, mg	3.0	3.0
B_3, mg	14.8	14.8
B_4, g	1.0	1.0
B_5, mg	60	60
B_{12}, μg	20	20

The pigs of the control group (C) received mixed feed with premix KS-1, which includes inorganic mineral additives (sulfuric acid heptahydrate iron FeSO4 7H2O, zinc sulfuric acid heptahydrate ZnSO4 7H2O, manganese sulfuric acid pentahydrate MnSO4 5H2O, copper sulfuric acid pentahydrate CuSO4 5H2O, selenite sodium Na2SeO3.
The pigs from experimental group (E) received the same mixed feed and experimental premix, in which, instead of inorganic salts of trace elements, "Bioplex TM" was introduced, containing iron chelate, copper chelate, manganese chelate, zinc chelate and selenium in the composition of Saccharomyces cerevisiae yeast. "Bioplex TM" has a powder form, which is convenient for mixing with other ingredients. Elements contamination in 1 kg of "Bioplex TM": iron - 50000 mg; zinc - 20000 mg; manganese - 15000 mg; copper - 5000 mg; selenium in the dry bard - 200 mg.

Table 2. Vitaminized and mineral premix for pigs up to 4 months (on extension, 1%)

Ingredient	Amount per 1 ton, g	
	C	3E
Vitamins: A, IU	500	500
D_3, IU 10^3	50	50
E, g	500	500
$K_{3,\ g}$	150	150
B_1, g	50	50
B_2, g	200	200
B_3, g	500	500
B_4, g	15000	15000
B_5, g	1300	1300
B_6, g	50	50
B_{12}, g	2.5	2.5
MnSO4, g	2500	-
Fe2(SO_4)3, g	6000	-
CuSO4, g	600	-
ZnSO4, g	7500	-
Se, g	15	-
“Bioplex TM”, g	-	10000
I, g	40	40
Co, g	50	50
Xylanase, glucanase, cellulase, g	Present	Present
Lysine, g	40950	40950
Methionine, g	29500	29500
Antioxidant, g	Present	Present
Extender (millers + chalky flour), kg	below 1000	below 1000

According to the results of individual weighing every 15 days determined the average daily, gross growth of live weight. The data obtained were used to determine the feed conversion factor, measured by calculating feed consumption per kilogram of live weight gain. From each group of growing pigs, three young hogs were taken with a body weight close to the average body weight in the group. Blood for hematological tests was collected in RusTech EDTA K3 6 ml sterile vacuum tubes. Hematological studies of whole blood (leukocytes, erythrocytes, hemoglobin, and hematocrit) were performed on an Vet abc (HORIBA) analyzer.
The indicators of nonspecific resistance of experimental animals (3 animals from each group) were determined in the laboratory of microbiology in whole blood according to generally accepted methods: bactericidal activity was determined by photonephalometric method, lysozyme activity by V.I. Mutovin method; phagocytic activity of blood cells was determined by determination of absorbing and digestive capacity of blood cells.
The assimilation of these elements was determined by direct quantitative measurement of trace elements containing them in organs in body tissues. The quantity of copper, zinc, iron, and manganese in liver, kidneys, pancreas, small intestine, stomach and bone marrow was determined in Federal Research Center for Animal Husbandry named after Academy Member L.K. Ernst. For this, three pigs from each group were slaughtered after 24 h of fasting.
Histological preparations were prepared according to the generally accepted Van Gizon method (1980). For fixation of organ and tissue samples 10% formalin solution was used. The slices for histological preparations were prepared on a rotary microtome (TermoShandon). Microcopying of histological preparations was carried out with the help of "Orthop", equipped with digital camera. Morphometric indices of various organs and tissues were analyzed using the ImageScope software (Moscow, LTD "Systems for Microscopy and Analysis").
The results of laboratory and production tests were analyzed using Statistica v. 10 software (StatSoft, 2013). The arithmetic mean and standard error mean, as well as one-factor dispersion analysis were calculated. Reliable statistical differences were significant at $P < 0.05$ and highly significant at $P < 0.001$.

Results

Growth rates, and feed costs for growth of growing pigs

Live weight and average daily growth of growing pigs from control and experimental groups was depending on trace element forms, used in feed ration (Table 3). In pigs, which received complex of organic trace elements in composition of "Bioplex TM" premix, the average daily live weight gain for the period of researches was authentically higher by 6.3% (P < 0.01) in comparison with the control variant.

Costs of energy exchange and raw protein per 1 kg of live weight gain of control and experimental pigs for the period of studies were 3.32 and 3.12 energetic feed units and 421.7 and 396.7 g or 6.4 and 6.3 % lower in comparison with the control variant.

Table 3. Live weight change and feed costs per 1 kg of weight gain (n=80)

Index	Group		SD	p
	C	E		
Age, days				
42	13.6	13.6	0.92	1.0
70	26.7	27.5	0.35	**0.0291**
98	40.5	42.2	2.45	0.1205
Average daily gain, 42-70 days, g	467.83	496.41	52.71	**0.0002**
Average daily gain, 70-98 days, g	492.88	525.29	34.5	0.3230
Average daily gain during entire growth period	480.42	510.69	142.67	**0.0039**

During research period, systematic monitoring of the animals' health was conducted. No diseases in animals were observed during the period of the research. All experimental pigs had good appetite. The state of digestion was judged by the consistency of feces. In experimental animals feces had a dense consistency and cylindrical shape, which showed no violations of the activity of intestinal peristalsis, which occurs in many gastrointestinal pathologies.

Blood morphological and immunological parameters

The blood composition, having a comparative constancy, is a labile system, thus reflecting the metabolic processes occurring in the body. However, the variability of the morphological composition of the blood is within certain limits, which are the physiological norm for each animal species. In general, the blood morphological parameters of growing pigs correspond to the reference values. We resutered that the additive "Bioplex TM" had appreciable influence on blood morphological indices in structure of mixed fodder of growing pigs of experimental group (Table 4).

Table 4. Dynamics of blood morphological indices

Indicator	Group		Mean SD	P
	C	E		
Erythrocytes, 10^{12}/L	5.36	6.30	1.31	**0.001**
Leucocytes, 10^9/L	20.56	23.70	14.72	0.080
Eosinophils, %	2.17	3.10	1.40	0.072
Segmentonuclear neutrophils, %	16.53	18.3	4.68	0.212
Lymphocytes, %	78.2	80.20	6.0	0.110
Mean corpuscular volume, %	55.1	66.1	181.5	**0.013**
Hemoglobin, g/L	77.33	88.97	203.0	**0.012**
Hematocrit, %	30.1	34.1	24.0	0.071

The level of erythrocytes in the blood of growing pigs that received organic form of microelements, on the average, was 6.2 × 1012/l, which is 4.8% (p < 0.001) higher compared to animals that received inorganic micronutrients, while the average volume of erythrocytes was also significantly changed to increase by 10.5% (p< 0.013). The main mass of erythrocyte dense substances is blood dye substance - hemoglobin. The amount of hemoglobin in the blood of growing pigs averaged 77.0-89.0 g/l, while in the group receiving chelate form of trace elements we observe a reliable increase by 15.6% (p < 0.012).

A certain number of lymphocytes, segmented neutrophils did not differ significantly from animals that received inorganic complex of trace elements, but these data were unreliable. Resistance of an organism is resistance to action of various pathogenic factors, which is provided by the whole complex of complex protective devices and includes cellular and humoral immunity. The data on non-specific resistance are given in Table 5.

Table 5. Immunological indicators of growing pigs

Parameter	Group		MS	P
	C	E		
Serum lysozyme, μg/mL	1.89	2.11	0.020	0.1361
Blood serum bactericidal activity, %	52.31	47.08	5.192	**0.0482**
Phagocytic activity, %	48.11	54.71	8.531	**0.0504**
Phagocytic index	2.47	2.74	0.028	0.1154
Phagocytic number	1.09	1.51	0.064	0.1121

In the blood of pigs from experimental group, there is no reliable difference in the content of lysozyme, when feeding them mineral and organic complex of trace elements. White blood cells have the ability to produce substances that act as neutralizing toxins - poisonous products of bacteria, because their protoplasm contains amylolytic, glycolytic, and mainly proteolytic and lipolytic enzymes. In our studies, the correlation between the increase in white blood cell concentration and the simultaneous increase in serum lysozyme by 11.6% compared to the control variant was established. In blood of growing pigs, which received organic complex of trace elements, reliable decrease in blood serum bactericidal activity by – 5.23 % ($p < 0.05$) and increase of phagocytic activity by – 6.6 % ($p < 0.05$) that reflects functional state of protective mechanisms of animals' organism was noted.

Content of trace elements in pig organs

We have investigated the content of iron, copper, zinc, manganese in the liver, kidneys, pancreas, stomach, small intestine, bone marrow of animals when feeding pigs to grow different forms of trace elements. The content of copper, zinc in the liver of animals who received "Bioplex TM" was on average 1% higher, while the content of zinc in the kidneys is 7.7% lower than the control version. It should be noted that in the stomach of animals who received the organic form of trace elements increased the content of copper - 27.8% ($P>0.043$), zinc - 22.6% ($P>0.042$), iron - 7.6% ($P>0.018$). The animals of the experimental group tended to increase copper and iron in the small intestine by 17.3% and 4.9% compared to control. Liver iron content in experimental group animals was 17.1% higher ($P>0.0181$) than in control. In pancreas and bone marrow, the trace elements content of experimental group animals was less than in control, but these data do not have reliable difference.

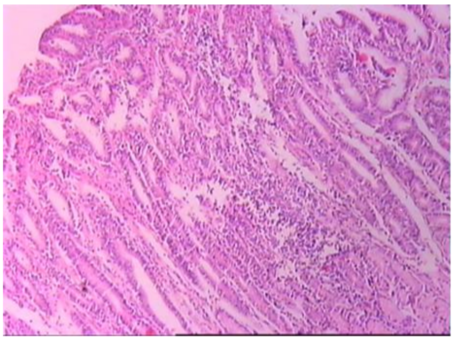
Table 6. Contents of trace elements in the liver, kidneys, pancreas, small intestine, stomach and brain, mg/kg

Organ	**Cu**		MS	P
	C	E		
Liver	4.51	4.55	0.002	0.3855
Kidney	4.81	4.77	0.015	0.7360
Pancreas	1.13	1.11	0.001	0.2878
Small intestine	1.33	1.56	0.013	0.0685
Stomach	1.26	1.61	0.024	**0.0457**
Bone marrow	0.88	0.81	0.002	0.1438
	Zn			
Liver	19.93	20.13	2.829	0.8912
Kidney	16.11	14.95	1.741	0.3410
Pancreas	18.61	16.98	1.572	0.1851
Small intestine	12.97	12.95	0.025	0.9033
Stomach	14.97	18.36	2.019	**0.0429**
Bone marrow	4.51	4.39	0.023	0.3754
	Fe			
Liver	104.07	121.89	31.90	**0.0181**
Kidney	26.17	24.05	11.423	0.4852
Small intestine	68.48	71.85	2.998	0.0759
Stomach	41.56	44.74	0.830	0.0129
Bone marrow	21.93	21.43	0.477	0.4311
	Mn			
Liver	3.44	3.41	0.044	0.8559
Kidney	4.18	4.03	0.044	0.4402

Therefore, feeding the organic complex of trace elements – "Bioplex TM" in the compound feed contributed to the increase of their content in the internal organs of growing pigs, which indicates a high intensity of metabolic processes and as a consequence, the disclosure of productive potential of experimental animals.

Histological changes in pig internal organs

In pigs, which received sulfates of trace elements: copper, iron, zinc, manganese, and sodium selenite, in histological preparations of the stomach wall mucous membrane, submucosa base and the muscular shell, consisting of several layers of longitudinal and transverse muscle bundles, separated by connective tissue layers, is well differentiated. The foldability of the stomach mucosa is poorly expressed, it forms low smoothed pile (Fig. 1a), the lining is represented by a cylindrical epithelium with dystrophic changes and sloughing of the cells of the fold tops.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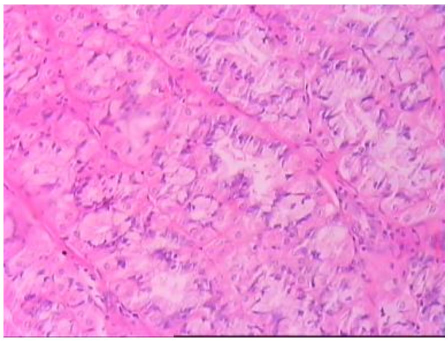
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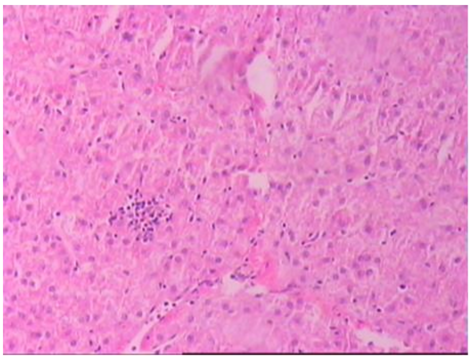
Fig. 1. Histological sections of growing pigs stomach (here and then a – group C, b – group E).

The zone of the stomach's own glands is wide; the structure of glands is usually represented by clearly defined cells of different types of secretion. The glands are uniform in shape and size, surrounded by thin layers of connective tissue. In the stroma of its own plate of mucous membrane submucosa base are diffusely scattered lymphocytes and individual lymphatic follicles. Quantitative fibers in thin layers surround groups of glands. The muscular shell is thick and has the same size muscle bundles, among which there are focal round-cell infiltrates, connective tissue layers are mature and quite thick collagen fibers.
In histological preparations, growing pigs of the experimental group (Fig. 1b), which received “Bioplex TM”, the structure of the stomach wall as a whole does not differ from the control, there are clearly differentiated mucous membrane, consisting of several layers of longitudinal and transverse muscle bundles, separated by connective tissue interlayers. It may be noted that the foldability of the stomach mucosa is better emphasized, there are high and sometimes branching pile, the lining is represented by a high cylindrical epithelium. The area of own stomach glands is less wide than in the control group, the structure, size and shape of glands are common. In the stroma of the own plate of mucous membrane and submucosa base there are lymphatic follicles, formed in some places in groups. Collagen fibers in thin layers surround the groups of glands. The muscular shell has no features.
In liver histological sections of pigs receiving inorganic form of trace elements, liver lobules have (Fig. 2a) polygonal shape and different sizes, clearly separated by connective tissue septum. In the region of the triads in the branches of the portal vein marked a moderately pronounced full-blooded, as well as in sinusoids mildly affected full-boded. Between hepatocytes there are small focal multiform-like cell infiltrates, represented by the cellular composition mainly lymphatic cells. Protein ducts contain traces of bile or free, the wall lined with cubic epithelium. According to the architectonics of the sections built correctly hepatocytes are grouped into beams, not much different in size, because in most cells cytoplasm picture of hyaline-drop protein dystrophy.
Nuclei are round-shaped, there are also single binary hepatocytes. In histological preparations of the experimental group, which received “Bioplex TM” (Fig. 2b), the architectonics of liver sections is not broken, sections of polygonal shape and slightly different in size, clearly separated by connective tissue septum.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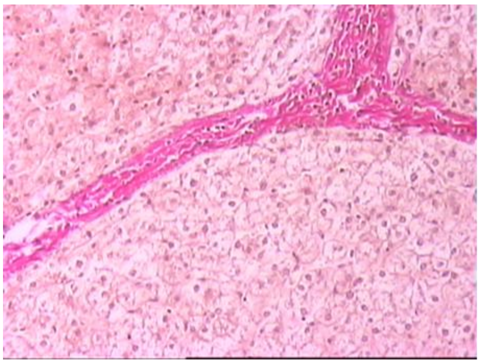
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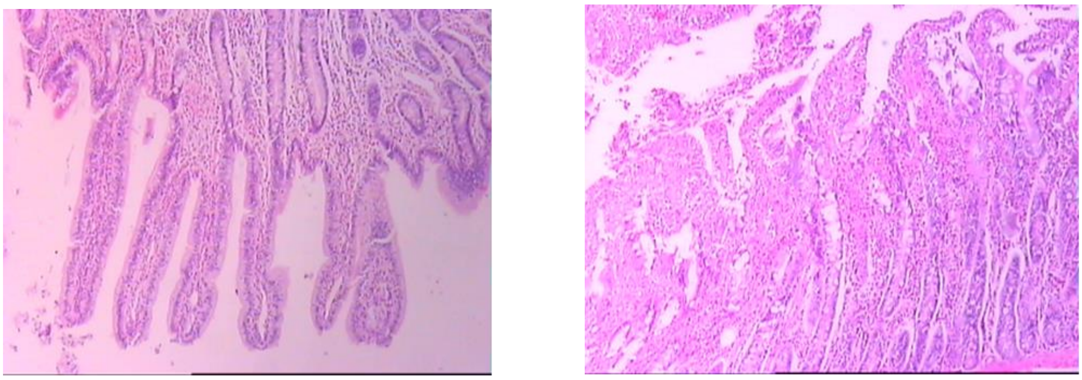
Fig. 2. Histological sections of growing pig liver.

In the area of triads in the branches of the portal vein and sinusoids are marked by a moderately pronounced full-blooded. Focal lymphatic clusters between hepatocytes or in the triads are not found, in one of the drugs noted mild diffuse round-cell infiltration. Protein ducts have no peculiarities. Hepatocytes are grouped in beams with transparent light cytoplasm; only in some cells of the cytoplasm have signs of protein dystrophy. Histological preparations of small intestine of control group (C, Fig. 3a), intestine wall is represented by all shells: mucosa with submucosal base, muscle and serous. In mucosa, identical sizes of lint and crypts with 1:1 ratio are clearly expressed. Lining the epithelium is cylindrical, no desquamation of the epithelium was found, no mucosa forming cells. In the capillaries of the mucous membrane is a moderate full-blooded, in the stroma there are histogenic and lymphatic elements, most drugs eosinophilic infiltration. The muscular shell consists of two differently directed bundles of smooth myocytes, surrounded by thin layers of connective tissue; the vessels are slightly full-blooded. The

wall of small intestine, of experimental animals (E) in histological preparation (Fig. 3), has well expressed shells: mucosa with submucosal base, muscle and serous.
Villi and crypts of mucous membrane are branched, with a ratio of 2:1 in favor of villi. Lining the epithelium is cylindrical; there is a pronounced desquamation of the epithelium along the tops of the pile, a lot of mucosa forming on the type of glass-shaped cells. In the capillaries of the mucous membrane, a moderate full-bloodedness is noted, in the stroma there are histogenic and lymphatic elements, as well as in some preparations diffusely located leukocytes. The muscular layer is within the limits.



a b

Fig. 3. Small intestine histological sections of growing pigs.

Discussion

The form of the studied additive had an impact on the live weight of pigs during the fattening period, a positive tendency of increasing the average daily weight gain when introducing into the diet of the organic form of trace elements: copper, iron, zinc, manganese, selenium was revealed. This form improves the absorption of trace elements, as it reduces the degree of their connection with nutrients that can form insoluble compounds with trace elements found in the form of free cations. Guryanov et al. (2019) reported that during the feeding by grain-grain diets, 12.5% of protein-vitamin-mineral additive with increased levels of Fe, Cu, Zn, Mn, Co, I, and Se contributed to 5.5-8.5% increase in average daily gain. Salautin et al. (2020) found that the addition of 10% complex of trace elements to the feed of growing pigs due to L-aspartic acid (Zn, Cu, Fe, Mn, and Co) from the norm increases the activity of most metabolic processes in the body and determines the most pronounced positive effect of feed assimilation and productive qualities. In addition, Gorlov et al. (2020) observed an increase in the average daily growth by 7.9% ($P<0.001$) during the whole period of growing and fattening (5-167 days). Studies conducted by Nadeyev et al. (2019) on feeding Cu and Fe metalloproteins have shown that the lower level of mineral substances in the form of organic combinations fully provides a high level of safety and productivity of pigs.
Erythrocytes serve as an oxygen carrier because they contain hemoglobin. In our studies, we found a reliable relationship between an increase of erythrocyte and hemoglobin by an average of 4%. The same results were obtained by a group of researchers from the Republic of Mordovia who studied the optimization of trace elements in feeding growing pigs, which contributed to the increase in blood red blood cells, hemoglobin, total protein and its fractions (Guryanov, 2018).
In the studies of I.V. Ziruk (2019), when studying the morphometric indices of the digestive canal of gilts with the inclusion of a complex of trace elements based on L-aspartic acid in the feed, no pathological changes in the structure of the digestive canal shells were revealed.
When assessing the efficiency of assimilation of complex chelate compounds and inorganic metals of trace elements for hematological blood parameters, Roshupkin (2019) reported that use of chelate complexes increased the content of Cu, Fe, Mn, Co, albumins, and total protein in the blood serum, and also increased the number of red blood cells and hemoglobin. We observed an increase in hematocrit by 13.3% in pig blood from experimental group under the influence of organic mineral additive "Bioplex TM". This can be considered as a favorable factor that enhances body protective reactions (Chabaev, 2019).
We also registered the increase of copper and zinc content in pig kidney and liver. Our data are consistent with those of Kirchgessner and Weser (1965). They reported the cuprum content in the liver was much higher after feeding by Cu in the form of amino acid, peptide or polypeptide complexes, than when feeding with sulfuric acid copper. Viktorov et al. (2007) studied the depositing of iron, manganese, zinc, copper, and titanium in the body of breeding pigs at different levels of trace oelement nutrition. Feeding with complex of trace elements promoted accumulation of manganese in organs and tissues of mumps. In muscles and lungs of pigs, the accumulation was insignificant, but in liver, spleen, and pancreas the manganese contamination was higher than in control animals. For example, the amount of manganese in the liver of 5-month-old pigs increased by 30 and 250 % in two groups respectively, in 9-month-old pigs - by 215 and 195 %, and in the spleen of 5-month-old pigs – by 84 and 354 %.
Fisher (2000) did not show a consistent effect of inorganic copper on the pigs' productivity. When feeding with the organic form of zinc, its concentration in serum of growing pigs was higher ($P<0.05$) than in the group of animals receiving zinc sulfate. The effectiveness of the two chelate sources of copper and zinc is similar in terms of growth intensity, and the excretion of copper and zinc with feces was lower in pigs that received the organic form of trace elements (Roschupkin, 2019). According to Bushev et al. (2020), it is necessary to use chelate complex compounds of biogenic trace elements instead of traditionally used iron dextrans for the prevention and treatment in growing pigs.

Conclusion

The results of the conducted research show that the retention of micronutrients in tissues depends on a specific complex of trace elements, even in the case of using only organic mixtures of trace elements. Inclusion of trace elements in the diet of organic complex improved blood saturation with subsequent increase of trace elements content in internal organs.

Addition of organic salts of trace elements "Bioplex TM" to the diet of growing pigs caused the highest content of trace elements in the liver, small intestine and stomach, and the lowest in bone marrow. The histological results indicated that the organic forms of trace elements are the most effective form of their delivery to meet the metabolic needs of the organism of growing pigs compared to other diets. These results show that the organic complex is an effective source of micronutrients and can be used in feeding pigs during the fattening period at a much lower level than the recommended norms of trace elements in the form of sulfates.

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