DOI: https://doi.org/10.21323/2414-438X-2022-7-4-273-281

Available online at https://www.meatjournal.ru/jour
Original scientific article
Open Access

Received 17.11.2022
Accepted in revised 01.12.2022
Accepted for publication 10.12.2022

THE WAYS TO IMPROVE THE BIOLOGICAL AND MORPHOLOGICAL PARAMETERS OF YOUNG FATTENING PIGS

Ivan N. Mikolaychik[1],* Larisa A. Morozova[1], Alexander V. Iltyakov[1], Ekaterina S. Stupina[1], Olga P. Neverova[2], Tatyana I. Uryumtseva[3]
[1] Kurgan State Agricultural Academy by T. S. Maltsev, Kurgan, Russia
[2] Ural State Agrarian University, Yekaterinburg, Russia
[3] Innovative University of Eurasia, Pavlodar, Kazakhstan

Keywords: *young pigs, potassium iodide, bentonite, morphological composition of carcasses, slaughter and meat qualities of pigs, protein-quality index, fatty acids*

Abstract
Studies were carried out to find the new ways to improve the efficiency of iodine use for the young pigs. During the scientific and economic experiment it was found that bringing iodine to the physiological norm, in combination with introduction of 3% bentonite clay into the diets of young fattening pigs, provided a positive effect on the morphological composition of carcasses, slaughter parameters and meat quality of the pigs. So fattening the yelts with the diets with a physiological norm of iodine in combination with 3% bentonite clay allowed young pigs of the 3rd experimental group to reach a slaughter weight of 78.95 kg at the age of 8 months, which is 10.1% more than in the control group, and 4.2% and 2.5% more in comparison with the 1st and 2nd experimental groups. The slaughter yield in yelts of the 3rd experimental group increased by 2.43% ($P < 0.05$) compared to the control group. The largest (30.17 cm^2) area of the "rib eye" was recorded in the 3rd experimental group, which is 5.60% more than the control one, while the carcasses of pigs of the 3rd experimental group contained muscle tissue by 4.74% ($P < 0.05$) more than the same in the control group. Analysis of the Musculus longissimus showed a significant increase in protein content in the 3rd experimental group by 1.22% compared to the control group ($P < 0.05$). The protein-quality parameter was significantly higher in the muscle tissue of young pigs of the 3rd experimental group and amounted to 10.90 ($P < 0.05$), which is 1.12% higher than in the muscle tissue of the control group yelts. The maximum content of oleic acid was found in the lard of animals of the 3rd experimental group — 49.59, which is 1.28% ($P < 0.05$) higher than in the control group.

For citation: Mikolaychik, I. N., Morozova, L. A., Iltyakov, A. V., Stupina, E. S., Neverova O. P., Uryumtseva T. I. (2022). The ways to improve the biological and morphological parameters of young fattening pigs. *Theory and Practice of Meat Processing*, 7(4), 273-281. https://doi.org/10.21323/2414-438X-2022-7-3-273-281

Introduction

Protection of the national interests is becoming a national priority in terms of increasing international competition and the globalization of the world economy. This is defined in the new Strategy of Economic Security of the Russian Federation for the period up to 2030. In the current conditions, while the country is exposed to the sanctions policy of the Western countries, food security issues are the basis of national security and have acquired the special relevance [1–4].

The modern strategy of the state agrarian policy is to increase the volume of food products and enhance the efficiency of cattle husbandry [5, 6]. Swine breeding in Russia is the leading sphere of this industry in terms of increasing the volume of meat production. In 2020, farms of all categories produced 4,286.7 thousand tons of pork in slaughter weight. The main growth in production is provided by the large agricultural enterprises, which share accounts for 89.5% of the total volume of meat production. In 2020, the volume of pork imports amounted to 8.41 thousand tons, which indicates the achievement of full self-sufficiency in the national domestic market for this type of meat. By 2025 pork production in Russia presumable shall reach 6 million tons in live weight, which is than 500 thousand tons more than in 2020. The main goal of the industry is to increase domestic product consumption, increase competitiveness in the world market and improve the quality of the products [5, 7–9].

To assess the state of food security in the Russian Federation, we have taken into account the dynamics of meat consumption per capita. So, in 2021 in Russia, this figure reached 77 kg. This figure was achieved by a steady increase in consumers' demand for pork. It should be noted that over the past three years, pork has had a very significant impact on the dynamics of total meat consumption, in particular, the average pork consumption in 2021 reached 28.3 kg/person [10].

Efficient production of livestock products, and pig breeding in particular, is possible only with the application of scientifically based systems and methods of conducting the industry, first of all, full-fledged feeding that satisfies the needs of animals in all nutrients, including minerals [11, 12]. One of the most efficient methods is the introduction of high-energy feed additives and enzyme preparations into the diet [13, 14]. Ivanov S. A. found that the productivity of sows gets higher under the conditions of chelate compounds consumption [15]. It was found that the use of silicon-containing zeolite in the compound feed in an amount of 3% by weight contributes significantly to an increase in the dynamics of live weight gain and improvement of the metabolic processes of pigs [16]. A group of authors revealed the efficiency of bacterial strains *Bifidobacterium Teenagelis*, *Lactobacillus acidophilus* and oak bark extract as biologically active substances, added in the diet. The feed additive contributed to an increase in the antioxidant activity of the animal organism and the antimicrobial components of blood plasma [17]. Probiotics and phytobiotics show their efficiency too [18, 19]. Thus, the application of yeast probiotic supplements positively affects the content of erythrocytes, total protein, calcium and phosphorus in the blood of animals, as well as the number of lactobacteria and bifidobacteria in the intestine, increases live weight and increases rate of multiple pregnancy [20, 21]. Studies were conducted on the effect of including cellulose into the pigs feed in the amount of 1% and 2% of the total mass [22]. Pigs are most sensitive animals to the level of minerals in their diet. Among the vital elements of micro-mineral nutrition is iodine, which biological role in the animal body is exceptionally high and which is closely related to the function of thyroid gland, to the synthesis and metabolism of thyroid hormones, which in their turn regulate many physiological functions [23, 24].

Studies on the etiology of endemic goiter (hypothyroidism) in our country and abroad have shown that iodine does not act simply on its own. Its effect on the body does not follow a plain formula: iodine deficiency brings on endemic goiter, but it acts in rather difficult conditions, when other (additional) factors play an important role in the emergence, spread and strength of endemia [25]. In case of insufficient intake of iodine in the body of an animal, the processes of growth and development are violated; reproductive functions and productivity are reduced, though iodine excess in the diet leads to violation of the functional activity of the thyroid gland [26].

The role of iodine is especially great in those geographical areas where a deficiency of this trace element in soils, feed, and water is observed. Therefore, the use of iodine preparations in the diets of pigs is not only desirable, but quite necessary. Currently, in the practice of feeding farm animals, various methods of replenishing iodine deficiency are used [27–29]. Thus, studies have shown that the use of selenium and iodine preparations in combination with a probiotic for feeding the young pigs ensures optimal secretory activity of the thyroid gland [30]. The use of the preparation "Ioddar" provides a positive effect on the increase in the animals live weight [31].

Almost the entire preparations introduction is reduced to oral administration; however, the use of inorganic iodine salts is sometimes inefficient due to the high volatility of the element being added. In addition, when administered orally, iodine-containing drugs are exposed to an acidic environment in the gastrointestinal tract and are converted into indigestible forms. In this regard, it is necessary to find new ways to increase the efficiency of iodine digestion by young pigs. In our opinion, the binding, sorption and ion-exchange properties of bentonite clays can be used for this task.

The purpose of the research is to study the effect of potassium iodide and bentonite clay on the slaughter parameters and meat qualities of the young fattening pigs.

Materials and Methods

Ethical statement

This study is an integral part of scientific research conducted at the Department of Technology of Storage and Processing of Animal Products of the Federal State Budgetary Educational Institution of Higher Education "Kurgan State Agricultural Academy named after T. S. Maltsev" (state registration number AAAA-A16–116020210398–1).

Animals, Study Design

In order to accomplish the goal of research at the educational and scientific base of the Federal State Budgetary Educational Institution of Higher Education Kurgan State Agricultural Academy, a scientific and economic experiment was run on young white pigs. 4 groups of 4-month-old piglets were formed, 8 heads each. The animals were selected for the groups according to the principle of homogeneity, taking into account their age, live weight and origin.

Animal management was the same for all the pigs, and met the sanitary and hygienic and zootechnical requirements (GOST 28839–2017[1]). All animals were clinically healthy and were under the supervision of a veterinarian.

The conditions of the pigs feeding and managing were the same too. Feeding rations for young pigs were normalized taking into account the chemical composition and nutritional value of the feed based on the norms recommended by the Russian Academy of Sciences [32]. The only difference in feeding was that the yelts of the control group received the main diet with a natural level of iodine, consisting at the age of 4–6 months of the following (% by weight): barley — 50.5, wheat — 20, peas — 15, sunflower meal — 6, fodder yeast — 3, meat and bone meal — 3, fluorine-free phosphate — 2, table salt — 0.5; at the age of 7–8 months as follows: barley — 64.5, wheat — 15, peas —

[1] GOST 28839–2017 "Agricultural animals. Pigs. Zootechnical requirements for fattening". Moscow: Standartinform, 2017. Retrieved from https://docs.cntd.ru/document/1200146267 Accessed June 20, 2022. (In Russian)

11, sunflower meal — 3, fodder yeast — 3, meat and bone meal — 2, fluorine-free phosphate — 2, table salt — 0.5. The pigs of the 1st experimental group, in addition to the main diet, got potassium iodide with bringing the level of iodine to the physiological norm. The 2nd experimental groups got 97% of the main diet and 3% bentonite clay by weight of the feed. The 3rd experimental groups got 97% of the main diet, 3% bentonite and potassium iodide, with bringing iodine up to physiological norm.

Data collection

At the end of the scientific and economic experiment on fattening the pigs, part of them were transferred to control slaughter in order to determine the meat productivity (meat yield) of young pigs (3 pigs in each group) according to generally accepted methods. The slaughter parameters of pigs were determined in accordance with GOST 31476–2012[2] and GOST 31778–2012[3].

The slaughter yield was determined by the ratio of the slaughter weight to the pre-slaughter weight (slaughter weight is the weight of the carcass with the head, legs, internal fat, without liver and intestines; pre-slaughter weight is the weight of a live pig after 12 hours starvation).

The length of the carcass was measured from the anterior edge of the first cervical vertebra to the anterior edge of the pubic bone fusion. The thickness of the fat was determined over the 6–7th thoracic vertebra.

"Rib eye" parameters were determined as the area of the transverse section of the longest muscle of the back between the thoracic and lumbar regions (along the last rib). The weight of the rear third of the half-carcass was determined on the right half-carcass by a cut between the last and penultimate sacral vertebrae.

The composition of individual natural anatomical parts and the carcass as a whole was established by deboning the right side of the carcass, which had been preliminary chilled for 24 hours at a temperature of –2 to +4 °C. Based on the deboning, the absolute and relative content of bone and muscle tissue, as well as subcutaneous fat, was determined.

For chemical analysis and qualitative characteristics of the meat, a sample was taken from the *musculus longissimus* in the area of 10–13 thoracic and 1–2 lumbar vertebrae, bacon was sampled at the level of 6–7 ribs.

Laboratory studies were carried out on the basis of an accredited testing laboratory "Veles" of the individual entrepreneur Iltyakova D. V. (Chostoozerye village, Kurgan region, Russia) and in the laboratories of the Department of Storage and Processing Technologies of Livestock Products of the Kurgan State Agricultural Academy named after T. S. Maltsev (Lesnikovo village, Kurgan region, Russia). Chemical and biochemical parameters of the muscle tissue quality were established on the basis of these analyzes: moisture content was determined according to GOST 33319–2015[4] — by drying the sample to a constant weight at a temperature of 103 ± 2 °C; fat content was determined according to GOST 23042–2015[5] — by extracting a dry sample with ether in a Soclet apparatus; protein content was determined according to GOST 25011–2017[6] — by the method of determining total nitrogen according to Kjeldahl; mineral substances (ash) content was determined according to GOST 31727–2012[7] — by dry mineralization of the samples in a muffle furnace at a temperature of 450–600 °C.

The amino acid composition of the *musculus longissimus* was determined on the LC-20 *Prominence* device (Shimadzu, Japan) according to the method M-02–902–142–07 "Method for measuring the mass fraction of amino acids by high-performance liquid chromatography".

The fatty acid composition of bacon was analyzed on a gas chromatograph device "Crystal-2000M" (LLC NPF "Meta-chrome", Russia) in the laboratory of the Kurgan branch of the Federal Budgetary Institution "Tyumen Center for Standardization and Metrology" (Kurgan region, Kurgan, Russia) according to GOST R55483–2013[8].

The content of iodine in feed was determined according to the method developed by A. M. Bulgakov. The technique of determination consists in preparing the material for its ashing (grinding, mixing with potash, drying at 105–110 °C, ashing at 500–550 °C) followed by extraction, filtration, evaporation, and drying of the precipitate [33].

The growth intensity of fattened young pigs was controlled by monthly weighing, and based on the obtained data the average daily gains in live weight of pigs were calculated.

Statistical analysis

Scales for weighing carcasses and deboned meat; tape measures and rulers for measuring carcass length, other dimensions, fat thickness, rib eye area, etc. were supplied under a contract with LLC "Pribor-Service" (Tyumen,

[2] GOST 31476–2012 "Pigs for slaughter. Pork carcasses and semi-carcasses. Specifications". Moscow: Standartinform, 2013. Retrieved from https://docs.cntd.ru/document/1200095684 Accessed September 5, 2022. (In Russian)

[3] GOST 31778–2012 "Meat. Cutting pork into cuts. Specifications". Moscow: Standartinform, 2019. Retrieved from https://docs.cntd.ru/document/1200096913 Accessed September 5, 2022. (In Russian)

[4] GOST 33319–2015 "Meat and meat products. Method for determining the mass fraction of moisture". Moscow: Standartinform, 2019. Retrieved from https://docs.cntd.ru/document/1200123927 Accessed September 12, 2022. (In Russian)

[5] GOST 23042–2015 "Meat and meat products. Methods for determining fats". Moscow: Standartinform, 2019. Retrieved from https://docs.cntd.ru/document/1200133107 Accessed September 12, 2022. (In Russian)

[6] GOST 25011–2017 "Meat and meat products. Protein determination methods". Moscow: Standartinform, 2018. Retrieved from https://docs.cntd.ru/document/1200146783 Accessed September 12, 2022. (In Russian)

[7] GOST 31727–2012 "Meat and meat products. Method for determining the mass fraction of total ash". Moscow: Standartinform, 2019. Retrieved from https://docs.cntd.ru/document/1200098742 Accessed September 12, 2022. (In Russian)

[8] GOST R55483–2013 "Meat and meat products. Determination of fatty acid composition by gas chromatography". Moscow: Standartinform, 2019. Retrieved from https://docs.cntd.ru/document/1200103852 Accessed September 12, 2022. (In Russian)

Russia). During the research, measuring instruments were used that were verified and calibrated at the Kurgan branch of the Federal Budgetary Institution "Tyumen Center for Standardization and Metrology" (Kurgan Region, Kurgan, Russia).

The obtained digital data were processed by variation statistics methods. The obtained digital data were statistically processed using a computer with an Intel Core2 Quad processor (USA), licensed software package Microsoft Office 2007 (USA). Student's t-test was used to assess the significance of differences between the two means. Differences were considered statistically significant at $P<0.05$; $P<0.01$; $P<0.001$.

Results and discussion

Feeding provides a great influence on the quantitative and qualitative parameters of the meat productivity of pigs. The final stage of the technological process of fattening pigs is the slaughter of animals. Conducting a control slaughter of animals allows establishing the features of the development of the main tissues, internal organs, their chemical composition, and makes it possible to calculate the conversion of feed nutrients into the meat products. Data on the yield of the main slaughter products are presented in Table 1.

An analysis of the data of the control slaughter of animals indicates that the live weight of yelts before slaughter after starvation in the experimental groups significantly exceeded the weight of pigs in the control group, respectively, in the 1st experimental group by 2.94% ($P<0.05$), in the 2nd experimental group by 4.23% ($P<0.05$) and in the 3rd experimental group by 6.63% ($P<0.01$).

The animals of the 3rd experimental group featured the highest slaughter weight (78.95 kg), which is 10.1% more than in the control group, 4.2% and 2.5% more than the 1st experimental and 2nd experimental groups. Head weight in all groups was almost the same. In the 3rd experimental group the weight of the legs and skin exceeded the weight of the same parts in the control group by 7.9 and 20.8%, respectively. The mass of kidney fat of pigs in the 1st and 2nd experimental groups was almost the same, while in the 3rd experimental group it was 1.57 kg only, which is 0.23 kg less than in the control group. The mass of the hot carcass in the control group was 55.73 kg, in the 1st experimental group it was 3.9 kg more, and in the 2nd and 3rd groups it exceeded the weight of pigs from the control group by 5.17 and 6.4 kg, respectively.

An important parameter characterizing the slaughter parameters of fattened pigs is the slaughter yield, which exceeded by 1.96 and 2.3%, respectively, the yield in the 1st in the 2nd experimental groups in comparison with the control group. The animals of the 3rd experimental group featured the highest (75.07%) slaughter yield (2.43% more than in the control group).

The introduction of potassium iodide into the diet in combination with bentonite contributed to the increase and improvement of the meat qualities of pigs. The animals of the 3rd experimental group had the greatest carcass length, which exceeded the control group by 2.16% (Table 2).

The meatiness of pigs carcasses can be judged quite accurately by the thickness of the fat. The fat thickness over the 6th-7th thoracic vertebrae was the highest in the control group and amounted to 33.03 mm, in the 1st and 2nd experimental groups — 32.30 and 31.40 mm, which is more than in the 3rd experimental group, respectively, by 8.04; 5.66 and 2.71%.

Table 1. Yield of the main slaughter products ($\overline{X} \pm S\overline{x}$)

Parameter	Group			
	Control	1st experimental	2nd experimental	3rd experimental
Live weight before slaughter after starvation, kg	98.63 ± 0.65	101.53 ± 0.46*	102.80 ± 0.38*	105.17 ± 0.50**
Slaughter weight (carcass weight with skin, head, legs and kidney fat), kg	71.65 ± 0.81	75.75 ± 0.91*	77.05 ± 0.94*	78.95 ± 0.74**
Including weight of, kg:				
Head	5.57 ± 0.28	5.43 ± 0.14	5.55 ± 0.19	5.82 ± 0.17
Skin	6.97 ± 0.22	7.05 ± 0.13	7.10 ± 0.16	7.52 ± 0.14
Legs	1.58 ± 0.07	1.93 ± 0.13	1.75 ± 0.12	1.91 ± 0.11
Kidney fat	1.80 ± 0.12	1.71 ± 0.13	1.75 ± 0.12	1.57 ± 0.05
Hot carcass	55.73 ± 1.07	59.63 ± 0.92*	60.90 ± 0.67*	62.13 ± 0.43**
Slaughter yield, %	72.64 ± 0.40	74.60 ± 0.56*	74.94 ± 0.64*	75.07 ± 0.37*

* P < 0,05; ** P < 0,01

Table 2. Parameters of the pork qualities ($\overline{X} \pm S\overline{x}$)

Parameter	Group			
	Control	1st experimental	2nd experimental	3rd experimental
Carcass length, cm	95.73 ± 0.71	96.93 ± 0.73	97.07 ± 0.95	97.80 ± 0.81
The thickness of the fat over the 6th-7th thoracic vertebra, mm	33.03 ± 0.67	32.30 ± 0.81	31.40 ± 0.61	30.57 ± 0.43*
The area of the "rib eye", cm²	28.57 ± 0.35	29.07 ± 0.59	29.20 ± 0.74	30.17 ± 0.43*
Weight of rear third of half-carcass, kg	10.27 ± 0.38	11.77 ± 0.35*	11.90 ± 0.36*	12.10 ± 0.32*

* P < 0,05

The area of the "rib eye" increases most intensively in the first 5–6 months (especially within the period from the birth till the age of three months), and the area of fat over the "rib eye" begins to grow intensively from four months. The area of the "rib eye" was significantly larger in the pigs of the 3rd experimental group — 30.17 cm2 (P < 0.05), which was more than in the control group, the 1st and 2nd experimental groups by 5.60%, 3.78 and 3.32% respectively. The most valuable part of the pork half carcass is the rear third. Therefore, the quality of the carcass itself depends significantly on its mass and morphological composition. This parameter had significant differences. The yelts of the 3rd experimental group featured the largest weight of the rear third. In this group, compared with animals of the control group, of the 1st and 2nd experimental groups, the weight of the rear third of the half carcass was more by 17.82%, 2.8 and 1.68%, respectively.

The quality of pork depends on numerous factors, among which the most significant are genetic heredity and method of feeding. High-quality and rational feeding can influence not only on the weight and size of the animal, but also the ratio of tissues in its body.

The performed deboning of half-carcasses of pigs of the control group and experimental groups made it possible to define the absolute and relative amount of the main tissues of the body. Deboning results are shown below in Table 3.

Along with an increase in pre-slaughter weight, the ratio of meat, fat and bones undergoes major changes: the share of muscle tissue decreases when yelts are slaughtered at 60 kg from 66.22% down to 55.92% when yelts are slaughtered at 140 kg. The proportion of bones in the carcass does not change (it does not exceed 1%). Weighing before deboning the chilled carcasses showed a significant difference in all experimental groups. Thus, the weight of a carcass in the 1st experimental group exceeded the weight of a carcass from the control group by 3.97% (P < 0.05), the 2nd experimental group — by 5.57% (P < 0.05), the 3rd experimental group — by 7, 27% (P < 0.01). The analysis of soft tissues separated from bones showed that the content of muscle tissue in the carcasses of yelts from the control group was 30.36 kg, and in the 2nd, 3rd experimental groups this value was significantly higher — by 4.05 kg (P < 0.05) and 4.74 kg (P < 0.05), respectively. The carcasses of the experimental groups featured high percentage of fat and exceeded the control group: in the 1st experimental group by 0.91%, in the 2nd experimental group by 1.18%, in the 3rd experimental group by 2.01%. There were no significant differences between the groups in terms of the amount of bone tissue in the carcasses, although a tendency to increasing this parameter in the experimental groups was recorded.

The growth and development of an animal, the quantitative content of the main tissues in its body largely depends on the development of the main parenchymal organs that ran the metabolism in the body. The mass of internal organs represent the rate of the animal development. While the control slaughter, we took into account the absolute mass of the main organs, the results are presented below in Table 4.

The chemical composition of the muscle tissue of the body is greatly influenced by the full-fledged feeding of pigs, the provision of the diet with basic nutrients, while the balance of macro- and microelements has a significant impact.

Animals that received iodine in combination with bentonite had heavier internal organs than the animals in the control group.

The lungs of all slaughtered animals were pink, without pathology, with well-defined lobes. The alveolar tissue was well developed. The weight of the lungs in the experimental groups did not have a significant difference, but exceeded the control one: in the 1st experimental group the lungs were heavier by 1.12%; in the 2nd experimental — by 1.98%; in the 3rd experimental group — by 4.73%.

The heart of the pigs had dense texture, the color was dark red. The state of the endocardium and valves was normal. The mass of the heart of the animals of the experi-

Table 3. Composition of pig carcasses ($\bar{X} \pm S\bar{x}$)

Group	Weight of chilled carcass, kg	Meat		Fat		Bones	
		kg	%	kg	%	kg	%
Control group	54.10 ± 1.00	30.36 ± 0.96	56.10 ± 0.81	15.67 ± 0.26	28.40 ± 0.73	8.07 ± 0.48	14.92 ± 0.90
1st experimental group	58.07 ± 0.84*	32.75 ± 0.25	56.42 ± 0.60	16.53 ± 0.43	29.31 ± 0.98	8.79 ± 0.66	15.11 ± 0.92
2nd experimental group	59.67 ± 0.99*	34.41 ± 0.70*	56.89 ± 0.83	16.56 ± 0.44	29.58 ± 0.48	8.70 ± 1.19	14.52 ± 1.74
3rd experimental group	61.37 ± 0.41**	35.10 ± 0.64*	57.18 ± 0.67	17.38 ± 0.59	30.41 ± 1.09	8.89 ± 0.61	14.49 ± 1.05

*P < 0,05; **P < 0,01

Table 4. Weight of internal organs of the yelts, g ($\bar{X} \pm S\bar{x}$)

Parameter	Group			
	Control	1st experimental	2nd experimental	3rd experimental
Lungs	1163.67 ± 114.64	1176.67 ± 111.44	1186.67 ± 90.89	1218.67 ± 89.91
Heart	350.67 ± 40.13	349.33 ± 33.27	351.67 ± 32.64	358.33 ± 27.79
Liver	1468.67 ± 38.91	1552.00 ± 54.59	1591.33 ± 69.74	1628.67 ± 38.88*
Kidneys	328.33 ± 48.36	330.67 ± 24.70	323.33 ± 46.82	338.67 ± 41.58
Spleen	151.67 ± 9.06	156.33 ± 8.37	158.67 ± 3.48	168.33 ± 13.97

* P < 0,05

mental groups was almost the same and did not significantly exceed the control group.

The liver of all animals was dark red, the capsule was shiny, smooth, of dense texture, the edges of the liver were sharp. The weight of the liver was significantly higher in the animals of the 3rd experimental group and exceeded the weight of the liver of the control yelts by 160 g, or 10.89%.

The kidneys were dark brown in color, and had dense texture. The maximum mass of this organ was observed in the animals of the 3rd experimental group — 338.67 g, and the minimum in yelts of the 2nd experimental group — 323.33 g. The difference between them amounted to 15.34 g, or 4.74%.

The spleen of the animals was dark red. Lymph nodes had no visible differences. This organ did not have a significant difference and was larger in animals of the 3rd experimental group by 10.98% in comparison with the control group.

Thus in the animals, in whose diets iodine was brought to the physiological norm, the main internal organs were better developed, which ensured the enhancement of redox processes in the body of the pigs and the function of hematopoiesis.

To assess the meat qualities of pigs, the chemical composition of the longest back muscle was analysed (Table 5).

Table 5. Chemical composition of the *Musculus longissimus*, % ($\bar{X} \pm S\bar{x}$)

Parameter	Group			
	Control	1st experimental	2nd experimental	3rd experimental
Dry matter	27.63±0.43	27.72±0.39	28.14±0.60	28.26±0.33
Protein	18.35±0.34	19.12±0.25	19.24±0.54	19.57±0.27*
Fat	6.46±0.38	6.54±0.32	6.38±0.25	6.52±0.47
Ash	1.06±0.10	1.14±0.12	1.17±0.08	1.19±0.12

* P<0,05

The chemical composition of the *musculus longissimus* showed that the dry matter content in all experimental animals was practically the same. The amount of protein in the muscle tissue was significantly higher in the 3rd experimental group by 1.22% (P<0.05) in comparison with the same of the control group.

Fat tissue is desirable in a certain ratio to muscle tissue, since with a high fat content the relative amount of proteins in meat decreases and the digestibility of meat decreases also. The content of fat in muscle tissue in all groups was almost the same and amounted to 6.46%, 6.54, 6.38, 6.52%, respectively. The ash content of muscle tissue varied from 1.06% in the control group to 1.19% in the 3rd experimental group.

Considering that we studied the mineral supplement in the form of potassium iodide and bentonite, the question arises about its effect on the content of macro- and microelements in the muscle tissue of animals. The content of the main macronutrients in the *musculus longissimus* is presented below in the Table 6.

Table 6. The content of macronutrients in the muscle tissue of pigs, g/kg ($\bar{X} \pm S\bar{x}$)

Parameter	Group			
	Control	1st experimental	2nd experimental	3rd experimental
Calcium	0.19±0.02	0.22±0.06	0.26±0.04	0.29±0.02*
Phosphorus	1.90±0.10	2.03±0.18	2.10±0.12	2.23±0.09
Potassium	3.60±0.27	3.86±0.12	4.20±0.14	4.22±0.14
Sodium	0.42±0.01	0.43±0.02	0.43±0.03	0.46±0.05
Magnesium	0.26±0.02	0.27±0.02	0.31±0.02	0.33±0.03

* P<0,05

It should be noted that the calcium content in the muscle tissue of yelts in the 1st experimental group was 0.03%, in the 2nd experimental group by 0.07% and in the 3rd experimental group by 0.10% (P<0.05) more, in comparison with the control group. The amount of phosphorus in the muscle tissue of yelts of the 1st experimental group is 0.13% higher than in the control group, respectively, in the 2nd experimental group by 0.20% and in the 3rd experimental group by 0.33%, compared with the control group. The maximum (4.22 g/kg) content of potassium was recorded in the muscle tissue of young pigs of the 3rd experimental group, which is 0.62% more than in the control group. The content of sodium and magnesium in the muscle tissue of the experimental animals did not differ significantly, although there was a tendency for increase of this parameter in the experimental groups.

The content of the main trace elements in the *musculus longissimus* is presented below in the Table 7.

Table 7. The content of trace elements in the muscle tissue of pigs, mg/kg ($\bar{X} \pm S\bar{x}$)

Parameter	Group			
	Control	1st experimental	2nd experimental	3rd experimental
Iron	10.73±1.63	11.50±1.25	13.17±1.19	16.40±2.55
Manganese	0.23±0.03	0.23±0.03	0.23±0.03	0.27±0.07
Copper	0.13±0.03	0.13±0.03	0.17±0.07	0.17±0.03
Zinc	14.47±0.39	14.53±0.48	15.90±0.32*	17.32±0.46**

* P< 0,05; ** P < 0,01

The micro-mineral composition showed that the content of iron in the muscle tissue of pigs in the 1st experimental group was 0.77% higher, in the 2nd experimental group it was higher by 2.44% and in the 3rd experimental group it was higher by 5.67%, in comparison with the control group. The content of manganese in the muscle tissue of the 3rd experimental group was 0.27 mg/kg, which was 0.04% more than in the control group. Copper content in all groups was almost the same. The muscle tissue of the yelts of the control group contained 14.47 mg/kg of zinc, which was 0.06% less than in the 1st experimental group, by 1.43% (P<0.05) in comparison with the 2nd experimental group, and by 2.85% (P<0.01) than in the 3rd experimental group.

Amino acids are a whole class of organic compounds, represented in nature by more than 20 species with a range of properties. The main function of amino acids is their participation in the structure of proteins. Amino acids, absorbed into the blood from the intestines, are then transported to the cells of the body.

The table 8 below shows the content of amino acids in the muscle tissue of pigs.

Table 8. The content of amino acids in the muscle tissue of pigs, % ($\bar{X} \pm S\bar{x}$)

Parameter	Group			
	Control	1st experimental	2nd experimental	3rd experimental
Isoleucine	0.99±0.05	1.04±0.04	1.03±0.01	1.04±0.04
Threonine	0.91±0.03	0.88±0.01	0.91±0.03	0.94±0.04
Serene	0.75±0.02	0.73±0.00	0.74±0.01	0.77±0.03
Glycine	0.79±0.02	0.76±0.00	0.78±0.01	0.81±0.03
Alanine	1.38±0.04	1.33±0.01	1.35±0.03	1.41±0.06
Valine	1.21±0.04	1.17±0.01	1.19±0.02	1.25±0.06
Methionine	0.51±0.02	0.49±0.00	0.51±0.01	0.54±0.03
Leucine	1.41±0.08	1.49±0.06	1.46±0.01	1.47±0.05
Glutamine	3.95±0.12	3.82±0.03	3.88±0.07	4.06±0.17
Proline	0.56±0.03	0.53±0.01	0.54±0.02	0.59±0.05
Phenyl-alanine	0.75±0.03	0.72±0.01	0.74±0.02	0.77±0.03
Lysine	1.78±0.06	1.71±0.01	1.74±0.04	1.83±0.09
Arginine	1.23±0.04	1.20±0.02	1.21±0.02	1.25±0.05
Tryptophan	0.30±0.01	0.32±.01	0.32±0.01	0.33±0.02
Oxyproline	0.031±0.001	0.030±0.001	0.031±0.001	0.030±0.002
БКП	9.78±0.11	10.80±0.42	10.44±0.30	10.90±0.33*

* $P < 0,05$

From the data in the table above it can be seen that in the composition of the muscle tissue of the 3rd experimental group, the largest share of such amino acids belongs to methionine, lysine, tryptophan, which exceeded the control group by 0.03%, 0.05, 0.03%, respectively. In the muscle tissue of pigs, the protein-quality index exceeded the control group: in the 1st experimental group by 1.02, in the 2nd experimental — by 0.66 and in the 3rd experimental — by 1.12%.

The biological role of lysine, methionine, tryptophan, leucine, isoleucine, threonine, phenylalanine, histidine, valine and sometimes arginine is determined by the fact that they are included in all the most important proteins of the animal body, but are neither synthesized in the body, nor they can be replaced by other amino acids. Lack of one or more of the 10 essential amino acids in the diet adversely affects the condition of animals: the young animals stop growing and developing, while adult animals lose weight, eat food reluctantly, and are susceptible to various diseases. This is explained by the fact that with a lack of essential amino acids in the body, proteins of cells, blood and lymph cannot be synthesized, as these amino acids necessarily participate there.

There was no significant difference in the content of amino acids in the muscle tissue of yelts. However, the content of isoleucine, trionine and valine was maximal in the animals of the 3rd experimental group and exceeded the control by 0.05, 0.03 and 0.04%, respectively. In terms of the amount of methionine, the muscle of the 3rd experimental group exceeded the control group, the 2nd experimental group by 0.03%, and the 1st experimental group by 0.05%. The greatest amount of lysine was found in the muscle tissue of the 3rd experimental group. The control group featured less content of lysine by 0.05% than the 3rd experimental group, less than in the 1st experimental group — by 0.12% and in the 2nd experimental group — by 0.09%.

The chemical composition of fat is influenced by breed, age and degree of fatness. The main part of fat tissue is fats. Sometimes fats make up to 98% of its mass. Unlike other tissues, there is little water and protein in fat tissue. Table 9 below shows the chemical composition of pork fat.

Table 9. Chemical composition of fat (%), $\bar{X} \pm S\bar{x}$

Parameter	Group			
	Control	1st experimental	2nd experimental	3rd experimental
Dry matter	92.67±0.26	93.11±0.19	93.41±0.20	93.57±0.17*
Protein	1.45±0.05	1.65±0.08	1.63±0.04	1.77±0.10*
Fat	90.93±0.18	91.17±0.19	91.45±0.12	91.45±0.16
Ash	0.28±0.03	0.29±0.02	0.33±0.05	0.35±0.06

* $P < 0,05$

The data in the table above shows, that the pig fat of animals of the 3rd experimental group contained significantly more dry matter, fat and ash, respectively, by 0.90, 0.32, 0.07%, than in the control group. The greatest amount of protein was found in the fat of the 2nd and 3rd experimental groups, and exceeded the control group by 0.52%. The biological value of fat is determined by the content of polyunsaturated fatty acids, which are not synthesized in the human body, but play an important role in the physiological and metabolic processes of the body.

Pork is not only a source of complete protein, but also source of fatty acids that are not synthesized in the human body. The fatty acid composition of yelts' fat is presented below in the Table 10.

Table 10. Fatty acids composition of pork fat (%), $\bar{X} \pm S\bar{x}$

Acid	Group			
	Control	1st experimental	2nd experimental	3rd experimental
Lauric	1.53±0.03	1.55±0.01	1.58±0.02	1.60±0.02
Palmitic	14.04±0.73	14.27±1.03	14.86±1.11	15.93±0.65
Palmitoleic	18.18±0.47	18.89±0.60	18.82±0.70	18.92±0.49
Stearic	16.33±0.11	16.54±0.25	16.41±0.05	16.63±0.19
Oleic	48.31±0.32	49.04±0.63	48.70±0.30	49.59±0.27*
Linoleic	19.03±0.47	20.37±0.60	20.53±0.49	20.65±0.87

* $P < 0,05$

The data in the table above shows that the content of lauric acid in the yelts' fat in all groups was practically at the same level. The back fat of yelts of the control group contained 14.04% of palmitic acid, which is 0.23% less than in the 1st experimental group, by 0.82% less than in the 2nd experimental group and by 0.89% less than in the

3rd experimental group. The maximum content of oleic acid was found in the fat of animals of the 3rd experimental group — 49.59%, which is 1.28% ($P<0.05$) more than in the control group. The content of linoleic acid in the fat of yelts of the 1st experimental group was 1.34% higher than in the control group. In the 2nd and 3rd experimental groups the content of linoleic acid was higher by 1.50% and 1.62%, respectively than in the control group.

Conclusion

Summarizing the results of the studies, we can conclude that bringing iodine to the physiological norm in combination with addition of 3% of bentonite clay into the diets of young fattening pigs provided a positive effect on the morphological composition of carcasses, slaughter parameters and meat qualities of the pigs.

So feeding the yelts with a physiological norm of iodine in combination with 3% bentonite clay allowed the young pigs of the 3rd experimental group to reach a slaughter weight of 78.95 kg at the age of 8 months, which is 10.1% more than in control group and 4.2% and 2.5% in comparison with the 1st and 2nd experimental groups. The slaughter yield in yelts of the 3rd experimental group increased by 2.43% ($P<0.05$) compared to the control group. The largest (30.17 cm2) area of the "rib eye" was observed in the 3rd experimental group, which is 5.60% more than the control group, while the carcasses of pigs from the 3rd experimental group contained muscle tissue by 4.74% ($P<0.05$) more than the same of the control group.

Analysis of the *musculus longissimus* showed a significant increase in protein content in the 3rd experimental group by 1.22% compared to the control group ($P<0.05$). The protein-quality parameter was significantly higher in the muscle tissue of young pigs of the 3rd experimental group and amounted to 10.90 ($P<0.05$), which is 1.12% higher than in the muscle tissue of the yelts from the control group. The maximum content of oleic acid was observed in the fat of animals of the 3rd experimental group. It amounted to 49.59, which is 1.28% ($P<0.05$) more than in the control group.

REFERENCES

1. Minakov, A.V., Lapina, S.B. (2021). Ensuring the economic security of the state in the context of western sanctions. *Vestnik of Economic Security*, 2, 305–312. https://doi.org/10.24412/2414-3995-2021-2-305-312 (In Russian)
2. Barikaeva, A.F. (2019). Improvement of certain elements of the risk management system of food security in Russia. *Vestnik of Moscow University of the Ministry of Internal Affairs of Russia,* 1, 218–221. https://doi.org/10.24411/2073-0454-2019-10052 (In Russian)
3. Zhilina, E.V., Khunafina, E.A., Kuzyashev, A.N. (2020). Analysis and forecasting of the consumer market of meat and meat products in the Russian Federation. *Economics and Management: Research and Practice Journal*, 3(153), 41–47. https://doi.org/10.34773/EU.2020.3.8 (In Russian)
4. Tikhomirov, A. I. (2021). Development of pig breeding in Russia under the food embargo: Modern challenges and opportunities. *Pig Breeding*, 1, 4–7. https://doi.org/10.37925/0039-713X-2021-1-4-7 (In Russian)
5. Plaksin, I.E., Plaksin, S.I., Trifanov, A.V. (2022). Trends and prospects of pig breeding development in Russia. *AgroEcoEngineering*, 1(110), 155–168. https://doi.org/10.24412/2713-2641-2022-1110-155-168 (In Russian)
6. Butolina, E. A. (2021). *Pig production development trends.* In the collection: Youth science 2021: technology, innovation. Materials of the All-Russian scientific and practical conference of young scientists, graduate students and students, dedicated to the Year of Science and Technology in the Russian Federation. Perm, 275–277. (In Russian)
7. Minakov, I. A., Kuvshinov, V. A. (2021). Development of pig breeding in Russia: Trends and performance. *Science and Education*, 4(1), Article 254. (In Russian)
8. Demakova, E.A. (2021). Forecast for the development of the pig production market in Russia. *Economy, Labor, Management in Agriculture,* 7(76), 3–11. (In Russian)
9. Kovalev, Yu. I. (2021). *Pig breeding in Russia: Current situation and development prospects until 2025.* Proceedings of the All-Russian Research Institute of Experimental Veterinary Medicine. Ya. R. Kovalenko, 82, 324–328. (In Russian)
10. Khayrullina, O.I (2021). Trends in the production and consumption of the main types of meat in Russia. *Creative Economy*, 15(5), 2245–2260. https://doi.org/10.18334/ce.15.5.112098 (In Russian)
11. Frame, C. A., Huff-Lonergan, E., Kerr, B. J., Serao, M. R. (2021). Feeding oxidized chicken byproduct meal impacts digestibility more than performance and oxidative status in nursery pigs. *Journal of Animal Science,* 99(2). Article skab029. https://doi.org/10.1093/jas/skab029
12. Ellner, C., Martínez-Vallespín, B., Saliu, E.-M., Zentek, J., Röhe, I. (2021). Effects of cereal and protein source on performance, apparent ileal protein digestibility and intestinal characteristics in weaner piglets. *Archives of Animal Nutrition,* 75(4), 263–277. https://doi.org/10.1080/1745039X.2021.1958647
13. Morozova, L., Mikolaychik, I., Rebezov, M., Fedoseeva, N., Derkho, M., Safronov, S. et al. (2020). Improving the physiological and biochemical status of high-yielding cows through complete feeding. *International Journal of Pharmaceutical Research*, 12, 2181–2190. https://doi.org/10.31838/ijpr/2020.SP1.319
14. Mikhailova, L. R., Lavrentiev, A. Yu. (2022). *The use of an enzyme preparation in feeding young pigs.* In the collection: Scientific and educational environment as the basis for the development of the intellectual potential of agriculture in the regions of Russia. Materials of the II International Scientific and Practical Conference. Cheboksary, 276–278. (In Russian)
15. Ivanov, S.A. (2014). Effect of feed composition with chelated trace elements on productivity of sows. *Collection of Scientific Papers of the Stavropol Scientific Research Institute of Animal Husbandry and Feed Production*, 3(7), 323–326. (In Russian)
16. Mikhaylova, L.R., Zhestyanova, L.V., Lavrentiev, A. Yu., Sherne, V.S. (2021). Application of natural zeolites in mixed feeds of young pigs. *Agrarian Science*, 3, 43–47. https://doi.org/10.32634/0869-8155-2021-346-3-43-47 (In Russian)
17. Duskaev, G.K., Rakhmatullin, S.G., Kazachkova, N.M., Sheida, Y.V., Mikolaychik, I.N., Morozova, L.A. (2018). Effect of the combined action of *Quercus cortex* extract and probiotic substances on the immunity and productivity of broiler chickens. *Veterinary World*, 11(10), 1416–1422. https://doi.org/10.14202/vetworld.2018.1416-1422
18. Belookov, A.A., Belookova, O.V., Chukhutin, E.V., Gorelik, O.V. (2022). The efficiency of probiotics in industrial pig breeding. *Agrarian Science*, 7–8, 98–101. https://doi.org/10.32634/0869-8155-2022-361-7-8-98-101
19. Bagno, O. A., Prokhorov, O. N., Shevchenko, S. A., Shevchenko, A. I., Dyadichkina, T. V. (2018). Use of phytobioticts in farm animal feeding. *Sel'Skokhozyaistvennaya Biologiya,* 53(4), 687–697. https://doi.org/10.15389/agrobiology.2018.4.687eng
20. 20. Mikolaychik, I.N., Morozova, L.A., Kahikalo, V.G., Ovchinnikova, L. Yu., Yarmots, L.P., Karmatskikh, Yu.A. et al. (2020). Microbiological supplements for the metabolic rate correction in calves. *International Transaction Journal of Engineering, Management and Applied Sciences and Technologies*, 11(1), Article 11A02S. https://doi.org/10.14456/ITJEMAST.2020.39
21. Belookov, A.A., Belookova, O.V., Chukhutin, E.V. (2021). Experience in the use of probiotic drug in pig breeding. *Feeding*

of Agricultural Animals and Feed Production, 9(194), 45–50. https://doi.org/10.33920/sel-05–2109–04 (In Russian)
22. Cho, H. M., Kim, E., Wickramasuriya, S. S., Shin, T. K., Heo, J. M. (2021). Growth and gut performance of young pigs in response to different dietary cellulose concentration and rearing condition. *Animal Bioscience,* 34(10), 1653–1662. https://doi.org/10.5713/AB.20.0721
23. Mikolaychik, I.N., Morozova, L.A., Iltyakov, A.V. (2015). New in the production of environmentally safe pork. *Head of Animal Breeding,* 2, 21–28. (In Russian)
24. Chabaev, M., Nekrasov, R., Nadeev, V. (2013). Organic trace elements for industrial pig farming. *Compound Feed*, 6, 77–79. (In Russian)
25. Andersson, M., Karumbunathan, V. Zimmcrmann, M.B. (2012). Global iodine status in 2011 and trends over the past decade. *Journal of Nutrition*. (142), 744–750 https://doi.org/10.3945/jn.111.149393
26. Lazarus, J. (2014). Iodine status in Europe in 2014. *European Thyroid Journal*, 3, 3–6. https://doi.org/10.1159/000358873
27. Gerasimov, G.A., Haar, F., Lazarus, J.H. (2017). Overiew of iodine deficiency prevention strategies in the South-Eastern Europe and Central Asia Region: 2009–2016. *Clinical and Experimental Thyroidology*, 13(4), 16–22. https://doi.org/10.14341.ket9531
28. Haldimann, M. Alt A., Blanc, A., Bloundeau, K. (2005). Iodine content of food groups. *Journal of Food Composition and Analysis*, 18(6), 46l–471. https://doi.org//10.1016/j.jfca.2004.06.003
29. Zimmcrmann, MB., Andersson, M. (2012). Assessment of iodine nutrition in populations: past, present, and future. *Nutrition Reviews*, 70(10), 553–570. https://doi.org//10.1111/j.1753–4887 2012.00528.x
30. Rassolov, S.N., Voroshilin, R.A. (2019). Dynamics of thyroid hormones in pigs when immunonutrients are introduced into their diet. *Bulletin of the Russian Academy of Natural Sciences. West Siberian Branch,* 22, 120–127. (In Russian)
31. Ryzhova, D.D. (2019). Veterinary and sanitary evaluation of mutton after using biologically active feed additive “Yoddar”. *International Research Journal,* 5(83), 115–118. https://doi.org/10.23670/IRJ.2019.83.5.023 (In Russian)
32. Nekrasov, R. V., Golovin, A. V., Makhaev, E. A., Anikin, A. S., Pervov, N. G., Strekozov, N. I. et al. (2018). Nutrient requirements for dairy cattle and pigs. Moscow: FGBNU FNTs VIZH im. L. K. Ernst, 2018. (In Russian)
33. Bulgakov, A. M. (2005). Improved method for the determination of iodine in animal feed and tissues. *Zootechnics,* 8, 16. (In Russian)

AUTHOR INFORMATION

Ivan N. Mikolaychik, Doctor of Agricultural Sciences, Professor, Institute of Biotechnology, Kurgan State Agricultural Academy by T. S. Maltsev. Lesnikovo village, Ketovsky district, Kurgan region, 641300, Russia. Tel.: +7–912–522–64–64, E-mail: min_ksaa@mail.ru
https://orcid.org/0000–0001–5189–2174
* corresponding author

Larisa A. Morozova, Doctor of Biological Sciences, Professor, Institute of Biotechnology, Kurgan State Agricultural Academy by T. S. Maltsev. Lesnikovo village, Ketovsky district, Kurgan region, 641300, Russia. Tel.: +7–919–589–77–77, E-mail: morozova-la72@mail.ru
https://orcid.org/0000–0002–7393–300X

Alexander V. Iltyakov, Candidate of Technical Sciences, Docent, Institute of Biotechnology, Kurgan State Agricultural Academy by T. S. Maltsev. Lesnikovo village, Ketovsky district, Kurgan region, 641300, Russia. Tel.: +7–912–522–64–64, E-mail: minksaa@mail.ru
https://orcid.org/0000–0003–3203–7126

Ekaterina S. Stupina, Candidate of Agricultural Sciences, Docent, Institute of Biotechnology, Kurgan State Agricultural Academy by T. S. Maltsev. Lesnikovo village, Ketovsky district, Kurgan region, 641300, Russia. Tel.: +7–963–866–61–99, E-mail: m.kat91@icloud.com
https://orcid.org/0000–0001–9978–9686

Olga P. Neverova, Candidate of Biological Sciences, Docent, Department of Biotechnology and Food, Ural State Agricultural University. 42 Karl Liebknecht str., Yekaterinburg, 620075, Russia. Tel.: +7–912–634–94–62, E-mail: opneverova@mail.ru
https://orcid.org/0000–0002–2474–2290

Tatyana I. Uryumtseva, Candidate of Veterinary Sciences, Associate Professor, Department of Veterinary Medicine and Industrial Technologies, Innovative University of Eurasia. 45 Lomov str., Pavlodar, 140008, Republic of Kazakhstan. Tel.: +7–707–786–90–77, E-mail: vbh2@mail.ru
https://orcid.org/0000–0002–7980–8242

All authors bear responsibility for the work and presented data.

All authors made an equal contribution to the work.

The authors were equally involved in writing the manuscript and bear the equal responsibility for plagiarism.

The authors declare no conflict of interest.