PERIÓDICO TCHÊ QUÍMICA
ARTIGO ORIGINAL

EFEITO DE COMPOSTOS ORGÂNICOS E INORGÂNICOS DE IODO NA PRODUTIVIDADE DE PORCOS E NA QUALIDADE DA CARNE

EFFECT OF ORGANIC AND INORGANIC IODINE COMPOUNDS ON PIG PRODUCTIVITY AND MEAT QUALITY

ИЗУЧЕНИЕ МЯСНОЙ ПРОДУКТИВНОСТИ И КАЧЕСТВА МЯСА ПРИ ИСПОЛЬЗОВАНИИ В РАЦИО-НАХ СВИНЕЙ НА ОТКОРМЕ ОРГАНИЧЕСКИХ И НЕОРГАНИЧЕСКИХ СОЕДИНЕНИЙ ЙОДА

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RESUMO

O objetivo deste estudo foi desenvolvido para examinar a eficiência de vários compostos de iodo nas dietas alimentares de porcos. O impacto dos compostos inorgânicos e orgânicos de iodo - iodato de potássio e proteína do leite iodado, que faz parte do aditivo alimentar "ProstTM" ("Innbiotech", Rússia) - no crescimento, produtividade e rendimento de carne magra porcos de engorda foram estudados. A composição físico-química e o valor biológico da carne foram estudados. O acúmulo de iodo no tecido muscular dos animais foi avaliado. Verificou-se que a proteína do leite iodado contribuiu para um crescimento mais intensivo do que a fonte inorgânica de iodo. Especificamente, os animais alimentados com a forma orgânica de iodo foram superiores em termos de peso de carcaça e valor de produção de tecido muscular e de gordura. Comparados ao grupo controle, os grupos experimentais de porcos demonstraram um rendimento de tecido muscular de 0,45%. Verificou-se também que fontes orgânicas de iodo têm um impacto positivo na composição química da carne; os animais alimentados com a forma orgânica de iodo superaram os que receberam iodo inorgânico em termos de substância seca da carne, teor de proteínas e teor de gordura. O nível de iodo no tecido muscular de porcos que receberam iodo orgânico foi consideravelmente mais alto, superando aqueles que receberam a fonte de iodo inorgânico em termos da presença de aminoácidos essenciais em seu tecido muscular.

Keywords: *iodo, iodato de potássio, proteína do leite iodado, alimentação de suínos, qualidade da carne.*

ABSTRACT

The aim of this study was designed to examine the efficiency of various iodine compounds in pigs' diets. The impact of inorganic and organic iodine compounds – potassium iodate and iodated milk protein, which is a part of the "ProstTM" feed additive ("Innbiotech", Russia) – on the growth, meat productivity and lean meat yield of fattening pigs was studied. The physico-chemical composition and biological value of the meat were studied. The accumulation of iodine in animal muscle tissue was assessed. It was found that iodized milk protein contributed to more intensive growth than the inorganic iodine source. Specifically, animals fed the organic form of iodine were superior in terms of carcass weight and yield value of muscle and fat tissue. Compared to the control group, the experimental groups of pigs demonstrated a muscle tissue yield of 0.45%. Organic sources of iodine were also found to have a positive impact on the chemical composition of meat; animals fed the organic form of iodine surpassed those receiving inorganic iodine in terms of their meat's dry substance, protein content and fat content. The level of iodine in the muscle tissue of pigs receiving organic iodine was considerably higher, and these pigs surpassed those receiving the inorganic iodine source in terms of the presence of essential amino acids in their muscle tissue.

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Keywords: *iodine, potassium iodate, iodated milk protein, pig feeding, quality of meat.*

АННОТАЦИЯ

В работе проведено исследование эффективности использования в рационе свиней в период откорма различных соединений йода. С этой целью было изучено влияние неорганического соединения йода в форме йодата калия и органического - в виде молочного йодированного белка, входящего в состав кормовой добавки “Прост^{TM}” (“Иннбиотех”, Россия), на динамику живой массы и интенсивность роста откармливаемых свиней, выход постного мяса. Исследованы физико-химический состав, биологическая ценность мяса. Оценено накопление йода в мышечной ткани животных. В результате исследования установлено, что использование органической йодсодержащей добавки способствовало более интенсивному росту молодняка свиней по сравнению с животными, в рацион которых входил йод в неорганической форме. Животные, получавшие с кормом молочный йодированный белок, отличались большей массой. Выход мышечной ткани у животных опытных групп был достоверно выше по сравнению с контролем на 0,44%. Опытные животные достоверно превышали контроль по содержанию в мясе сухого вещества, белка и жира. В мышечной ткани свиней, получавших в составе основного рациона йодсодержащую добавку в органической форме, содержание йода было значительно выше по сравнению с животными контрольной группы. Опытные животные превосходили контроль по содержанию незаменимых аминокислот в белках мышечной ткани.

Ключевые слова: *йод, йодат калия, молочный йодированный белок, откорм свиней, качество мяса*.

1. INTRODUCTION

Problems with food quality affect complex aspects related to the economy, the social sphere, environment, and the development of the agro-industrial complex. The search for progressive and efficient technologies for feeding animals based on the latest scientific advancements and providing for the use of new bioavailable and stable fodder supplements with iodine is topical given the present conditions of intensifying meat production.

Providing agricultural animals with all the necessary essential nutrients, including mineral substances, is mandatory for increasing meat productivity and improving meat quality (Gorlov *et al*., 20054 Savenko *et al*., 2006). Georgievskii (1981), Underwood (1977), and Annenkov (1981) suggested that iodine is a vital microelement. According to reports from EFSA (2005) and SCF (2002), iodine deficit influences thyroid function, causing a decrease in the quantity of hormones the thyroid produces. As a result of protein, carbohydrate, and lipid exchange, iodine deficiency leads to problems in the reproductive system, decreased resistance to viruses, and a number of diseases, as well as excess mortality among livestock stores (Kondrakhin, 1989; McDowell, 2003). Lisitsyn *et al*. (2007), Flachowsky (2007), Flynn *et al*. (2003) and Mahan (1990) noted that iodine deficiency in feeds contributes to a decrease in the iodine content of agricultural animal products. Given that food products of animal origin are the main dietary iodine source for humans, iodine supply for agricultural animals is not only important to their production and health but also has social importance.

Studies by Khaziakhmetov (2006), Godfrey (1988), and Rojas-Cano *et al*. (2014) focused on the impact of natural and complex synthetic vitamin and mineral agents on the productivity and metabolism of pigs. Rossi *et al*. (2010) and Schöne *et al*. (1988) noted the importance of improving feed additives and sought new prospective preparations with the potential to enhance the efficiency of pig breeding.

Inorganic forms of iodates and iodides are the most common iodine-containing feed additives (Iodobrom, Russia, Ajay-SQM Chile SA, Chile, Sichuan Jindian Chemical Company Limited, China, Deepwater Chemicals Corporation, USA). However, the propensity of iodide ions to photochemically or catalytically (in the presence of ions of transition metals) oxidize down to molecular iodine leads to a considerable loss of iodine during the storage of animal feed (Kuznetsov *et al*., 1992). In addition, during the storage of premixes and finished feed, some of the iodide ions are converted into copper iodide, CuI, that is insoluble in water, which reduces the biological availability of iodine (Sedykh & Minko, 1975). The above difficulties are caused by the specifics of iodides' chemical behavior. The use of iodates does not solve the problem since they are known to rapidly convert to iodides in the presence of reducing agents. The most appropriate method uses resistant and easily assimilable organic iodine compounds as the micro-element feed additive (Banoch *et al.*, 2012).

The objective of this study was to investigate the effects of feeding fattening pigs, either an inorganic iodine compound in the form of potassium iodate or an organic compound in the form of iodate milk protein on meat productivity and quality.

2. MATERIALS AND METHODS

The care and use of animals under experiment were performed in accordance with ethical norms and principles and in strict accordance with the research protocol and current regulatory documents (GOST 33044-2014, 2015; National Research Council, 1996; Directive 2010/63/EU, 2010). The study was approved by the Ethics Committee of Orel State University of Economy and Trade (Orel, Russian Federation).

Yorkshire pigs that were 4 months of age were used in this experiment. Three groups of 20 pigs were formed. Groups were selected according to the counterparts' principle. The length of the experiment was 104 days, including 5 days for the preparatory period and 99 days for the principle period. All groups of pigs were fed the same diet. The combined feed contains wheat, barley, corn, soybeans, peas, wheat meal, fish meal, yeast, and mineral and vitamin additives. The chemical composition of the feed was balanced for all major nutrients and adjusted for periods of fattening.

The pigs in the reference group were fed a diet supplemented with 1.4 mg of iodine per head per day. The pigs in the first experimental group were fed the "Prost^{TM}" diet supplemented with 0.7 mg of iodine per head per day. The pigs in the second experimental group were fed the "Prost^{TM}" diet supplemented with 1.4 mg of iodine per head per day.

The "Prost^{TM}" feed additive, which was made by "Inbiotech", Russia, is intended for enriching combined feed with organic iodine or for direct introduction into the diet of farm animals and poultry. The feed additive contains 7 g/kg of iodine. "Prost^{TM}" consists of dextrose (glucose) monohydrate (66%) and iodized milk powder protein. Iodinated protein is obtained using the method patented by Ljublinskij *et al.* (2002), which involves mixing protein raw material with an aqueous solution of inorganic iodine with enzyme treatment. A mixture of skim and fresh milk proteins of various natural origins was used as the raw protein material. Iodinated milk protein contains iodine in bound form as mono– and diiodotyrosines, which are similar to natural organic iodine compounds.

This feed additive is characterized by resistance to light and heat; thus, it has a high degree of stability in long-term storage.

Sanitary, hygienic, and zootechnical requirements were complied with; the animals were clinically healthy and were kept and cared for in identical conditions.

The intensity of the growth and development of stores was defined according to the results of monthly weighing and calculation of absolute (by the difference between the final and initial weight of the animal in kg), and daily average (by dividing the absolute increase by the number of days of the experiment, g) body weight. Once a month, clinical and physiological indicators (body temperature, pulse rate, and breath rate) were measured before and after weighing.

After 104 days, the pigs were slaughtered, and body weight before slaughter, in kg; carcass weight (the weight of the animals after slaughter and evisceration, including viscera and internal raw fat in kg); slaughter yield (the ratio of the dead weight to the weight of the animal before slaughter, in percent); hot and chilled (after 24 hours of storage at 4±2°C) carcass weight in kg; carcass yield (the ratio of the hot carcass weight to the weight before the slaughter, in percent); weight of muscle tissue , fat, bones, and internal fat in kg; thickness of fat above the 6 & 7th chest vertebrae in mm; meatiness index (ratio of the muscle weight to the bone weight); and lean index (the ratio of the muscle weight to the fat weight) was determined.

To conduct chemical analysis, samples of the longissimus dorsi muscle were collected. The moisture content of the samples was determined by drying the hitch until its weight remained constant at a temperature of 105 ± 2 °C. Fat content was determined by extracting it from the dry hitch using ether and a Soxhlet extraction apparatus. The protein content was determined using Kjeldahl's method for determining total nitrogen content (GOST 25011-81). The mineral content was determined by mineralizing the samples in a muffle furnace at 550 ± 25°C for 5 to 6 hours and determining the percentage of ash in the weight of the initial sample. The content of amino acids was determined using an automatic amino acid analyzer LC 3000 manufactured by Eppendorf – Biotronilc (Germany). The total iodine content was determined by preliminary preparation of the sample by alkaline mineralization, followed by the analysis of the aqueous solution of the mineralized sample using cathodic inversion voltammetry. In the process of sample mineralization, followed by ultraviolet irradiation of the mineralized sample solution, all forms of iodine are converted into iodide ions. Iodide ions are concentrated on a silver-modified electrode in the form of slightly soluble settlement, followed by cathode sludge recovery with linearly changing potential. The resulting cathodic peak with a negative potential of 0.4±0.05 V is the analytical signal. The content of iodide ions in the solution of the prepared sample is determined by adding to a tested mixture of iodide ions. The iodotyrosine content was determined by drying and degreasing the samples, enzymatic hydrolysis of the sample with Streptomyces griseus proteases, extracting, and clearing iodotyrosines from the sample using the method of solid-phase extraction, followed by derivatization of the extract, and analysis by high-performance liquid chromatography coupled with a mass spectrometer. Analytes are identified by the absolute time of retention of chromatograph iodotyrosine peaks recorded in multiple reaction monitoring modes. The content of iodotyrosines is determined by the area of the chromatograph peaks in the analyzed samples.

Water-binding power was determined by pressing a weighed amount of meat on a sheet of filter paper with a 1 kg weight for 10 minutes, followed by determination of the weight of pressed-out moisture against the area of the wet stain. Weight loss during heat treatment was determined by the relative percent difference of the weight of meat (50 g) before and after heat treatment at 100°C for 60 minutes. pH was determined with a potentiometer and the aid of a pH-meter at a depth of 4-5 cm. Sensory meat evaluation was determined by a 5-point scale; for meat, by five criteria (appearance, smell, taste, texture, and juiciness), where 1 is the worst, and body weight is the best; and for both, by four criteria (appearance, smell, taste, and richness), where 1 is the worst, and 4 is the best. The biological value of the protein was determined by amino acid score, calculated as the ratio of the content of certain essential amino acids in the studied protein (g/100 g of protein) to the content of this amino acid in the reference protein (g/100 g of the reference protein) established by the FAO/WHO (Lipatov *et al.*, 2001).

The data were statistically analyzed, and a validity test was applied at three levels of probability (Glants, 1998). A bilateral paired Student's t-test was used for assessing the statistical significance of the method of a statistical hypothesis, which was a special case of ANOVA used for assessing the importance of the differences between the two datasets (Banoch *et al.*, 2012). The comparison was made at the 5% level of significance (P<0.05).

The t value was calculated according to Equation 1 (Nürnberg *et al.*, 1998):

$$t_{emp} = \frac{X_{1av} - X_{2av}}{\sqrt{\frac{S^2}{n} + \frac{S^2}{n}}}, \quad \text{(Eq. 1)}$$

where

X is the mean,

S^2 is the combined estimate of variance,

and n is the sample size.

$$S^2 = \frac{1}{2}(S_1^2 + S_2^2), \quad \text{(Eq. 2)}$$

where $S_{1(2)}$ is the standard deviation.

If $t_{emp} < t_{crit}$, the null hypothesis is accepted; otherwise, the alternative hypothesis is accepted (t_{crit} is the reference value). The critical value of t depends on the significance level and on the number of degrees of freedom. The number of degrees of freedom k was determined by Equation 3.

$$k=2\,(n-1) \quad \text{(Eq. 3)}$$

A significance level of 5% (P<0.05) was adopted.

3. RESULTS AND DISCUSSION

3.1. Dynamics of Body Weight and Intensity of Pigs' Growth

Bodyweight is the most important indicator of the meat productivity of animals.

The research results indicated that the bodyweight of animals in the experimental groups was higher than that in the control group (Table 1).

The bodyweight of animals in group I was significantly higher (5 kg or 4.42%) (P<0.05) than that of animals in the control group.

The absolute gain and an average daily gain in body weight of pigs in group I was higher (4.4%) than that of pigs in the control group.

No significant difference was observed in the bodyweight of animals in group II compared to that in the control group.

Clinical and physiological indicators of the animals were also measured during the weighing process. It was found that their body temperature increased slightly, as did pulse and breathing rate. However, the changes in these indicators remained within the normal physiological range in all groups.

3.2. Slaughter Characteristics and Meat Characteristics of the Experimental Pigs

Three pigs from each group were slaughtered to assess meat productivity. The results showed that the introduction of iodated milk protein to the diet of pigs did not have a significant impact on their slaughter characteristics (Table 2).

The slaughter yield (72%) and carcass yield (70%) of pigs in the control group and experimental groups I and II were similar.

To a large extent, morphological composition defines the market and food value of pig carcasses. In the process of this study, it was determined that the meat and fat content of pig carcasses varied according to the iodine compounds they consumed (Table 3).

Thus, compared to pigs in the control group, the pigs in experimental groups had improved muscle tissue yield of 0.45% (P<0.05). The fat yield of pigs was significantly higher, by 0.39%, in experimental group I and lower, by 0.1%, in experimental group II compared to that in the control group.

The meatiness index of pigs in the control group was lower than those of experimental groups I and II by 7% and 3.1%, respectively (P<0.05). The lean index was significantly lower in experimental group I, by 13%, and significantly higher in experimental group II, by 4.6%, compared to that in the control group.

The obtained data indicate higher meat productivity in pigs treated with the organic form of iodine.

3.3. Processing Characteristics, Chemical Composition and Biological Value of the Meat

This study explored the technological characteristics of the meat that determine, to a certain degree, its culinary and gastronomic characteristics (Table 4).

No significant differences in processing characteristics were found between the experimental groups. Thus, the influence of iodine on the functional and technological characteristics of pork is not confirmed.

In the course of sensory analysis, the appearance, odor, taste, texture, and juiciness of cooked meat and the appearance, smell, taste, and richness of broth were evaluated on a 5-point scale. No difference between the groups was established by these indicators. The overall score of cooked meat was between 4.0 and 4.25 points, and that of broth was between 4.36 and 4.56 points.

Among the objective methods for characterizing the quality of meat, the analysis of its chemical composition is one of the most useful (Table 5).

The pork from groups I and II contained significantly greater quantities of dry substance than that from the control group, by 5.82% (P<0.05) and 4.73% (P<0.05), respectively; similarly, the protein content was 1.4% (P<0.05) and 1.1% (P<0.05), respectively, greater than the control group, as was the fat content: 4.47% (P<0.05) and 3.7% (P<0.05), respectively. Higher fat content in the meat of animals receiving an organic source of iodine can be taken as evidence of its more active participation in lipid exchange compared to iodine from inorganic sources. These results confirm the findings of Nürnberg *et al.* (1998).

The total iodine content and mono- and diiodotyrosine content of pigs in groups I and II were considerably higher than those of pigs in the control group. The total iodine content in the muscle tissue of animals from experimental groups I and II was higher than that of animals from the control group by 26.8% (P<0.05) and 72.1% (P<0.05), respectively. Monoiodotyrosines were 200% and 419% higher, and diiodotyrosines were 386% and 724% higher in groups I and II, respectively, than those in the control group. In the calculation of balance in the supply and utilization of iodine in the body of the animals, we relied on the results of Franke *et al.* (2008), who reported that the bulk of ingested iodine is accumulated in the thyroid gland and the muscle tissue of pigs. The accumulation of iodine in bone tissue is not significant (Lipatov *et al.*, 2001). Calculations showed the benefits in the first experimental group. A total of 12.4% of the total iodine supplied in the feed remained in the muscle tissue of the animal, which is more than that of the second experimental group (7.3%) and 3.3 times more than that of the reference group. Flachowsky (2007) stated that iodine accumulation in animal tissues does not exceed 1% of the total amount introduced with food. The content of all forms of iodine in the muscle tissue of experimental group II animals was significantly higher than that of animals in group I and the reference group. These results confirm the conclusions of various researchers regarding the better absorption and more intensive accumulation of iodine from organic sources in the bodies of animals. For example, Banoch *et al*. (2012) observed a similar effect when alga Chlorella spp., which is rich in iodine, was added to pig feed rather than potassium iodide, without noticing any significant influence of iodine introduced with the feed on the quality of pork.

Not only the quantity of protein in the meat but also its quality is of substantial importance. This factor is characterized by the amount of essential amino acids in the protein and the degree to which this approaches the optimal levels recommended by the FAO/WHO (Lipatov *et al*., 2001). Figure 1 shows the amino acid content of the proteins.

The results of the present study show that the amount of essential amino acids contained in the muscle tissue of animals in the control group was significantly lower than that of the animals in experimental groups I and II (16.7% and 7.1%, respectively, $P < 0.05$). It was also determined that animals in groups I and II surpassed the animals in the control group in terms of the content of almost all essential amino acids, except phenylalanine and threonine in experimental group I and leucine, isoleucine, and phenylalanine in experimental group II. The most considerable benefit that experimental group I animals had over control pigs were in levels of the amino acids lysine (45.9%), isoleucine (14%), methionine (140%), and valine (27.4%). Experimental group II pigs surpassed control group animals mostly in terms of lysine (38.8%) and methionine (139.5%) content.

Table 6 shows the biological values of the studied samples. Essential amino acids were higher in the experimental group I and II animals than those in control group animals. In the experimental group I, the score of only one amino acid (valine) was lower than 100%. Limited amino acids in the proteins of control group animals include methionine + cysteine and valine and isoleucine in the proteins of experimental group II animals. Overall, indices of essential amino acids/nonessential amino acids and essential amino acids/total amino acids were higher in the proteins of animals from experimental groups I and II.

Thus, the results clearly demonstrate that the meat of animals fed iodine in the form of iodated milk protein was of higher biological value than that of animals given iodine in an inorganic form.

This study has clearly demonstrated the practical advantages of using an organic form of iodine, namely, iodated milk protein (an ingredient of the "Prost^{TM}" feed additive produced by "Innbiotech", Russia), over inorganic sources in the diet of fattening pigs.

The use of the organic iodine-containing additive at an estimated level of 0.7 mg of iodine per day contributed significantly to the more intensive growth of pigs in comparison with animals whose diet contained iodine in an inorganic form.

The introduction of an additive containing iodized milk protein into the diet of pigs had a positive effect on their meat productivity, which can be observed in the greater yield of muscle and adipose tissues in pigs in the experimental groups compared to the yield in pigs in the control group.

The positive impact of the organic iodine source on the chemical composition of the pork was also demonstrated. Animals in experimental groups I and II surpassed those in the control group in terms of the dry substance, protein content, and fat content of their meat.

Animals in the experimental groups also surpassed those in the control group in terms of the content of essential amino acids in the proteins of their muscle tissue, demonstrating the higher biological value of the meat.

The level of iodine in the muscle tissue of pigs in both groups receiving an organic iodine feed additive was significantly higher than that of the animals in the control group. It should be noted that doubling the dosage of organic iodine introduced with the feed in the form of the feed additive "Prost^{TM}" does not increase the share of iodine in the muscle tissue or cause any significant improvement in the quality of the carcass or meat. Therefore, a dosage of 0.7 mg of iodine per head per day is recommended for pork producers.

A number of questions related to using organic forms of iodine require further investigation. Research aiming at clarifying the basic physiological and biological mechanisms of fixing and metabolizing inorganic and organic iodine in the bodies of animals is of great scientific interest.

4. CONCLUSIONS

This study thus demonstrates the advantages of using an organic form of iodine – namely, iodated milk protein – in the process of raising pigs.

According to the ICCIDD (International

Council for the Control of Iodine Deficiency Disorders) report completed in 2011, the population in Russia is experiencing iodine deficiency; the median iodine urinary excretion (IUE) is observed to be in the range of 50 and 99 µg/l vs. the normative lower limit of 100 µg/l [Bost *et al*., 2014). Pork with an iodine content of 112-153 µg/kg can be a reliable source of iodine in the diet of Russian people.

5. ACKNOWLEDGMENTS

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Table 1. *Body Weight and Weight Gain* ***(n=20)***

Indicator	Group		
	Control	Group I	Group II
Body weight, kg:			
at the beginning	47.55±7.52	49.65±7.77	48.95±8.98
at the end	113.25±6.63	118.25±7.41*	115.59±8.07
Body weight gain, kg:			
Absolute	65.7±2.08	68.6±1.9*	66.64±3.68
Average daily, g	631.69±19.96	659.6±18.27*	640.81±35.37

* The difference in indicators is statistically significant (P<0.05) compared to the control group

Table 2. *Slaughter Characteristics of Experimental* ***Pigs (n=3)***

Indicator	Group		
	Control	Group I	Group II
Body weight before slaughter, kg	110.09±3.1	111. 68±2.79	110.21±3.52
Hot carcass weight, kg	77.09±2.07	78.18±2.0	77.12±2.5
Internal fat weight, kg	2.23±0.21	2.53±0.2	2.48±0.13
Slaughter weight, kg	79.32±1.89	80.71±2.16	79.6±2.61
Thickness of fat on the level of the 6-7th scapula vertebrae, mm	22.27±1.86	24.42±3.35	23.1±2.65

Table 3. *Morphological Composition of Experimental* ***Pigs****' Carcasses (n=3)*

Indicator	Group		
	Control	Group I	Group II
Chilled carcass weight, kg	75.76±2.07	76.87±2.0	75.79±2.49
Muscle tissue weight, kg	63.49±1.82	64.76±1.62	63.85±1.95
Muscle tissue yield, %	83.8±0.11	84.25±0.12*	84.25±0.21*
Fat weight, kg	1.92±0.08	2.25±0.07*	1.85±0.10
Fat yield, %	2.54±0.03	2.93±0.01*	2.44±0.05*
Bones' weight, kg	10.35±0.18	9.85±0.32	10.09±0.44
Bone yield, %	13.66±0.14	12.82±0.12*	13.31±0.15*
Fleshing index	6.14±0.07	6.57±0.07*	6.33±0.09*
Leanness index	33.02±0.37	28.74±0.14*	34.54±0.85*

* The difference in indicators is statistically significant (P<0.05) compared to the control group

Table 4. *Processing Characteristics of Experimental* ***Pigs****' Meat*

Indicator	Group		
	Control	Group I	Group II
Water binding capacity, %	62.62±4.5	63.88±4.68	64.9±3.63
Loss of weight during thermal conditioning, %	35.57±0.92	35.35±0.68	35.12±0.49
pH (24 hours after slaughter)	6.13±0.11	6.05±0.48	6.19±0.14

Table 5. *Chemical Composition of Experimental* ***Pigs****' Meat*

Indicator	Group		
	Control	Group I	Group II
Moisture, %	74.51±0.52	68.69±0.62	69.78±0.54
Dry substance, %	25.49±0.39	31.31±0.41*	30.22±0.35*
Protein, %	22.15±0.56	23.55±0.26*	23.25±0.37*
Fat, %	2.23±0.49	6.7±0.35*	5.93±2.02*
Ashes, %	1.11±0.05	1.06±0.02	1.04±0.08
Total iodine, mkg/100 g	8.83±0.72	11.2±0.98*	15.2±0.62*
Monoiodotyrosine, ng/ 100 g	9.53±1.66	28.57±3.04*	49.5±4.91*
Diiodothyrosine, ng/ 100 g	2.2±0.95	10.71±1.23*	18.13±4.37*

* The difference in indicators is statistically significant (P<0.05) compared to the control group

Table 6. *Indicators of Biological Value of Muscle Tissue Proteins*

Indicator	Group		
	Control	Group I	Group II
Amino acid score, %			
Lysine	98.33±6.17	137.66±4.24*	136.01±5.95*
Leucine	127.12±3.38	127.88±2.41	117.29±3.82*
Isoleucine	99.06±3.83	108.37±3.19*	79.72±3.78*
Phenylalanine + Tyrosine	151.52±7.78	133.87±3.48*	137.87±2.43*
Methionine + Cysteine	66.68±6.26	108.99±11.01*	116.42±8.62*
Valine	80.36±4.93	98.24±8.42*	87.49±4.39
Threonine	154.86±7.55	143.33±12.8	157.89±8.44
Amino acid index of essential amino acids /nonessential amino acids	0.516±0.005	0.616±0.017*	0.571±0.007*
Amino acid index of essential amino acids /total amino acids	0.340±0.002	0.381±0.006*	0.363±0.003*

* The difference in indicators is statistically significant (P<0.05) compared to the control group

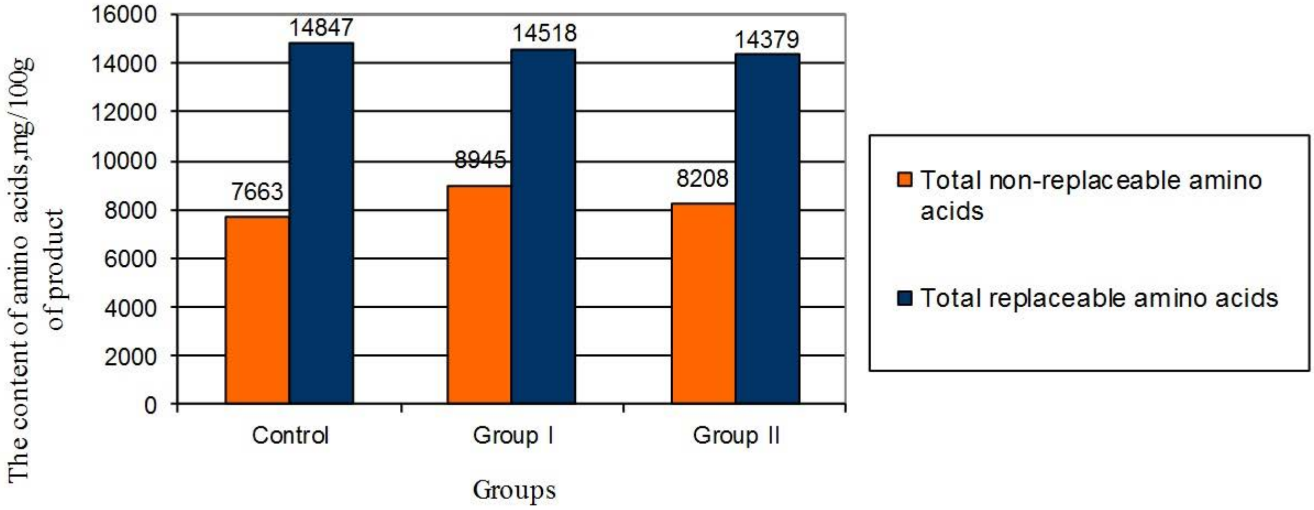

Figure 1. *The ratio of basic amino acids (mg/100 g of product) in pork*