Acta fytotechn zootechn, 25, 2022(4): 285–293
http://www.acta.fapz.uniag.sk

Original Paper

Slaughter parameters of broiler chickens at different levels and ratios of arginine and lysine in the compound feed

Mykhailo Sychov[1], Igor Ilchuk*[1], Dmytro Umanets[1], Ivan Balanchuk[1], Ildus Ibatullin[2], Ruslana Umanets[3], Tetiana Holubietva[1], Volodymyr Otchenashko[1], Vadym Kondratiuk[1], Olena Tytariova[4], Oksana Kuzmenko[4], Oksana Orishchuk[5]

[1]*National University of Life and Environmental Sciences of Ukraine, Faculty of Livestock Raising and Water Bioresources, P.D. Pshenychnyi Department of Animal Nutrition and Feed Technology, Kyiv, Ukraine*
[2]*Institute of Food Resources, National Academy of Agrarian Sciences of Ukraine, Kyiv, Ukraine*
[3]*National University of Life and Environmental Sciences of Ukraine, Faculty of Livestock Raising and Water Bioresources, Department of Technologies in Poultry, Pig and Sheep Breeding, Kyiv, Ukraine*
[4]*Bila Tserkva National Agrarian University, Faculty of Biological Technology, Department of Technology of Feed, Feed Additives and Animal Feeding, Bila Tserkva, Ukraine*
[5]*Dnipro State Agrarian and Economic university, Department of parasitology and veterinary-sanitary expertise, Dnipro, Ukraine*

Article Details: Received: 2022-10-07 | Accepted: 2022-11-12 | Available online: 2022-12-31

https://doi.org/10.15414/afz.2022.25.04.285-293

The article presents the results of the research on the effect of different levels and ratios of arginine and lysine in the compound feed of broiler chickens on their meat productivity. We conducted the research by the group method, on 600 heads of Cobb-500 crossbred broiler chickens, divided into six research groups according to the principle of analogs. During the experiment, chickens consumed the compound feed that differed only in the content and ratio between essential amino acids: arginine and lysine. We established the efficiency of increasing the arginine-lysine ratio in the compound feed of broiler chickens to 1.10 at the age of 1–10 days; 1.06 at the age of 11–22 days and 1.07 at the age of 23–42 days. That contributed to an increase in the pre-slaughter live weight by 0.68–0.88% (p <0.05), the carcass weight before evisceration – by 0.97–1.27% (p <0.05), the semi-eviscerated and eviscerated carcass weight – by 0.39–2.24%, the breast muscle weight – by 8.95–11.47% (p <0.01), and the leg muscle weight – by 1.67–9.47% (p <0.05). The yield of the breast muscles increased by 1.64–2.18% (p <0.01), of the leg muscles – by 0.17–1.47% (p <0.05); the meatiness of the carcass, breast and legs increased, respectively, by 3.45% (p <0.05); 1.80 (p <0.05) and 1.64%; the yield of edible parts increased by 1.46–3.96% (p <0.05). Narrowing the arginine-lysine ratio, accordingly to 1.02; 0.97 and 0.98, led to a decrease in the yield of breast and leg muscles by 1.91 and 1.07%, respectively (p <0.05); the yield of internal fat increased by 0.40–1.10% (p <0.05); carcass meatiness decreased by 1.08–3.23% (p <0.01), breast meatiness – by 0.66–2.15% (p <0.05), leg meatiness – by 0.43–1.10% (p <0.01); the yield of edible parts decreased by 0.11 – 0.33%.

Keywords: arginine, lysine, chickens, slaughter parameters

1 Introduction

Formulation of a compound feed with the content of amino acids corresponding to the "ideal protein" is the crucial condition for the most effective use of the genetic potential of modern crossbred broiler chickens characterized by fast growth rates. In addition, amino acid nutrition is the main factor in ensuring poultry health and product quality (Nahm, 2002; Kryvenok et al., 2017a, Kryvenok et al., 2017b).

For decades, breeding broiler chickens aimed at improving feed efficiency and increasing breast muscle yield (Zuidhof et al., 2014). The process of selection led

***Corresponding Author:** Igor Ilchuk, National University of Life and Environmental Sciences of Ukraine, Faculty of Livestock Raising and Water Bioresources, P.D. Pshenychnyi Department of Animal Nutrition and Feed Technology, Gen. Rodimtseva 19 str., 03041 Kyiv, Ukraine; e-mail: ilchukigor@nubip.edu.ua https://orcid.org/0000-0003-0961-6613

to noticeable changes in the structure of the body and, therefore, in the need for nutrients, and especially in the need for amino acids. For instance, modern compound feeds for broiler chickens contain lysine levels higher than recommended (National Research Council, 1994) to ensure the special development of the breast muscles of modern crossbred chickens.

The concentration of lysine in commercial compound feeds for broiler chickens has increased in recent years (Dozier et al., 2008; Belloir et al., 2019). Recent guidelines for optimal levels of amino acids in compound feeds for broiler chickens indicate higher than recommended concentrations of lysine (Cobb-Vantress, 2018; Aviagen, 2019). However, if the level of a certain amino acid in the compound feed changes, the content of other amino acids should also undergo changes to maintain the ideal amino acid profile. Increasing the level of lysine in the compound feed without taking into account other important amino acids such as threonine or arginine can lead to deficiency of the latter (Kidd et al., 1997).

Arginine plays a crucial role in various metabolic, pathophysiological and immunological processes in poultry (Fernandes & Murakami, 2010; Fouad et al., 2012; Khajali & Wideman, 2010; Ibatullin et al., 2020). Due to the absence of the urea cycle, birds are unable to synthesize endogenous L-arginine and therefore this amino acid is indispensable (Tamir & Ratner, 1963). The need of chickens is provided exclusively by the dietary arginine, and consequently its amount in the compound feed should be sufficient.

There is a specific relationship between arginine and lysine, and any deficiency or excess can have a negative effect on plasma and muscle concentrations of these amino acids, and accordingly on growth performance. The antagonism effect is more pronounced with an excess of lysine (narrow ratio of arginine to lysine), and not arginine (wide ratio of arginine to lysine). Excess dietary lysine does not affect arginine uptake, but mainly inhibits renal reabsorption and stimulates renal arginase activity (Balnave & Brake, 2002; Zampiga et al., 2018).

The optimum ratio of arginine to lysine in the chicken feed is 1.14 during the first 3 weeks of rearing, 1.10 between 3 and 6 weeks, and 1.18 between 6 and 8 weeks (National Research Council, 1994). Baker (1997) recommends a narrower arginine-lysine ratio (1.05, 1.08, and 1.08, respectively, at 0–3, 3–6, and 6–8 weeks of growth). Balnave & Brake (2002) recommend an optimal arginine to lysine ratio of 0.90 to 1.18. Wu (2014) recommends a ratio of 1.05 at the age of 21 days and 1.08 at an older age. Some generators of broiler chicken crosses recommend similar arginine-lysine ratios, but they are narrower than those recommended by earlier researchers (Cobb-Vantress, 2018; Aviagen, 2019). Analysis of the amino acid composition of the body of 10-day-old chickens showed that the content of arginine is 111% relative to lysine, so the ratio of available arginine to lysine in the compound feed should be within 1.1 (Wu, 2014).

Considering the important functions of arginine, existing recommendations require revision and its level should be set according to the requirements of broiler chickens of modern hybrids. There is also a lack of scientific information on the effect of different ratios of arginine to lysine in broiler diets on the slaughter parameters and chemical composition of the products. L-arginine transforms into citrulline and nitric oxide with the participation of nitric oxide synthetase. Nitric oxide exerts marked vasodilator properties and increases blood flow to the breast muscles, which usually alleviates the hypoxic condition observed in myopathy (Fernandes & Murakami, 2010; Khajali & Wideman, 2010; Mutryn et al., 2015; Boerboom et al., 2018; Zampiga et al., 2019).

In view of this, the study on the effect of different arginine-lysine ratio in the compound feed for broiler chickens on their productivity and slaughter parameters is relevant.

2 Material and methods

We conducted the research on determining the optimal levels of arginine and lysine in the complete ration compound feed for broiler chickens of various ages in the research laboratory of feed additives of P.D. Pshenychnyi Department of Animal Nutrition and Feed Technology of the National University of Life and Environmental Sciences of Ukraine.

The object of the research were "Cobb-500" crossbred broiler chickens. We conducted the experiments by using the group method. During the main period lasting 42 days, taking into account the age of the chickens, we distinguished three sub-periods: 1–10; 11–22; 23–42 days, according to the scheme of the experiment (Table 1).

For the experiments, we selected 600 heads of 1-day-old broiler chickens, divided into six groups of 100 heads each according to the principle of analogues. When selecting analogues, we took into account the age and live weight of chickens.

The chickens lived in one room on the floor at a stocking density of 12 heads per one m^2. The feeding front was 2.5 cm; the drinking front was 1.5 cm. The air temperature and lighting of the room corresponded to the sanitary standards adopted in poultry farming.

Table 1 Scheme of the experiment

Content in 100 g of the compound feed	Group of broiler chickens					
	control	experimental				
	1	2	3	4	5	6
1st period – 1–10 days						
Arginine (%)	1.28	1.30	1.32	1.28	1.28	1.28
Lysine (%)	1.20	1.20	1.20	1.22	1.24	1.26
Ratio of arginine to lysine	1.07	1.08	1.10	1.05	1.03	1.02
2nd period – 11–22 days						
Arginine (%)	1.15	1.17	1.19	1.15	1.15	1.15
Lysine (%)	1.12	1.12	1.12	1.14	1.16	1.18
Ratio of arginine to lysine	1.03	1.04	1.06	1.01	0.99	0.97
3rd period – 23–42 days						
Arginine (%)	1.11	1.13	1.15	1.11	1.11	1.11
Lysine (%)	1.07	1.07	1.07	1.09	1.11	1.13
Ratio of arginine to lysine	1.04	1.06	1.07	1.02	1.00	0.98

Table 2 Composition of the compound feed for the experimental broiler chickens (%)

Component	Age of the birds (days)		
	1–10	11–22	36–42
Wheat grain	8.38	11.10	0.00
Maize grain	44.00	43.00	51.71
Pea grain	10.01	10.50	10.00
Soybean	13.70	15.00	20.00
Soybean meal	12.00	10.00	11.00
Fish meal	7.00	5.00	0.00
Vegetable oil	2.00	2.30	3.40
Table salt	0.18	0.17	0.34
Limestone	1.73	1.83	2.10
Monocalcium phosphate	0.00	0.10	0.45
Premix*	1.00	1.00	1.00

* premix contained powdered wormwood (*Artemisia capillaris*) (Ibatullin et al., 2022)
Composition of 1 kg of premix: manganese – 100 mg, zinc – 60 mg, iron – 10 mg, copper – 2.5 mg, cobalt – 1 mg, iodine – 0.7 mg, selenium – 0.1 mg; vitamins: A – 10,000 IU; D_3 – 2,000 IU, E – 30 mg, B_2 – 3 mg, B_3 – 10 mg, B_4 – 500 mg, B_5 – 30 mg, B_{12} – 0.05 mg; dried powdered wormwood – 500 g, filler (wheat bran) – up to 1,000 g

The chickens consumed the compound feed *ad libitum*. We regulated the level of lysine and arginine in poultry rations by introducing synthetic preparations of these amino acids into the compound feed.

According to the scheme of the experiment, the broiler chickens consumed the compound feeds, balanced in terms of exchange energy and all nutrients, in accordance with the norms recommended by the "Cobb" company. We regulated the set and amount of the main ingredients in the compound feed depending on the period of growing chickens (1–10, 11–22 and 23–42 days) and the required content of lysine and arginine in it.

The composition of the compound feed fed to the birds during the experimental period one can see in Table 2.

The compound feed was balanced in terms of all nutrients in accordance with the recommended norms and growing period (Table 3).

The content of the studied amino acids in the compound feed of the control group birds corresponded to the

Table 3 Nutrient and energy content of 100 g of the compound feed for the experimental broiler chickens

Indicator	Age (days)		
	1–10	11–22	23–42
Metabolizable energy (MJ)	1.28	1.29	1.33
Crude protein (g)	21.17	19.88	18.34
Crude fat (g)	7.00	7.37	9.03
Crude fiber (g)	3.61	3.63	3.91
Calcium (g)	1.00	0.96	0.90
Phosphorus (g)	0.52	0.49	0.45
Sodium (g)	0.20	0.17	0.16
Lysine* (g)	1.20–1.26	1.12–1.18	1.07–1.11
Methionine (g)	0.50	0.48	0.47
Methionine + cystine (г)	0.95	0.92	0.87
Threonine (g)	0.81	0.76	0.74
Tryptophan (g)	0.22	0.21	0.20
Arginine* (g)	1.28–1.32	1.15–1.19	1.11–1.15

* the content of lysine and arginine according to the scheme of the experiment

effective levels established in previous studies (Ibatullin et al., 2013; Ibatullin et al., 2014a; Ibatullin et al., 2014b; Ibatullin et al., 2015).

Determination of the chemical composition of the compound feeds we carried out in the laboratory of P.D. Pshenychnyi Department of Animal Nutrition and Feed Technology of the National University of Life and Environmental Sciences of Ukraine, according to traditional methods:

- crude protein – by means of the Kjeldahl method;
- crude fat – by means of the Rushkovskyi method, based on the determination of the amount of defatted residue in the Soxhlet apparatus, using benzene as a solvent;
- crude fiber – by means of the Henneberg and Shtoman method;
- amino acid content – by means of the automated analyzer AAA T-339 (producer Mikrotechna, Czech Republic) after protein hydrolysis with 6 N hydrochloric acid solution for 24 hours at a temperature of 110 °C. Standard solutions of amino acids produced by the company "Lachema" (Czech Republic) were used to carry out calibration tests, as well as quantitative evaluation of chromatograms;
- mineral element content – by means of the spectral analysis using the energy-dispersive X-ray fluorescence spectrometer "ElvaX" (producer Elvatech, Ukraine).

We determined the live weight of the broiler chickens by weighing on an AXIS A 5000 IV class scale (producer "AXIS", Poland).

At the end of the experiment, the birds were slaughtered (10 heads from each group) and the slaughter parameters studied.

We evaluated the slaughter characteristics of broiler chickens according to the following indicators:

- the live weight of the broiler chickens after a 12-hour starvation period;
- the carcass weight before evisceration – the carcass weight after being bled and plucked;
- the semi-eviscerated carcass weight – the carcass weight after being bled, plucked and eviscerated;
- the eviscerated carcass weight after being bled, plucked and eviscerated without head, legs, wings up to the elbow joint;
- the weight of the entire carcass edible parts;
- the weight of breast muscles, leg muscles, skin, internal fat, liver, lungs, kidneys, gizzard, heart.

We determined the weight of slaughter products using a VLKT-500 IV class scale (producer "Gosmetr", Russia).

Based on the indicators of slaughter weight and the weight of individual parts of the broiler chicken carcass, we evaluated the yield of slaughter products and indices of carcass meat parameters:

- the yield of semi-eviscerated and eviscerated carcasses – the ratio of the weight of semi-eviscerated and eviscerated carcasses to the pre-slaughter live weight, %;

- the yield of breast muscles, leg muscles, skin, internal fat, liver, lungs, kidneys, gizzard, heart – the ratio of the weight of the relevant slaughter products to the pre-slaughter live weight, %;
- the carcass meatiness – the ratio of the weight of all muscles to the weight of the eviscerated carcass, %;
- the breast meatiness – the ratio of the weight of the breast muscles to the weight of the eviscerated carcass, %;
- the leg meatiness – the ratio of the weight of the leg muscles to the weight of the eviscerated carcass, %;
- the yield of edible parts – the ratio of the weight of all muscles to the weight of the carcass before evisceration, %.

We carried out the biometric processing of data obtained during the research using MS Excel 2013 software by means of built-in statistical functions. Results are presented as mean ±standard deviation (x ±SD). The differences between Group of birds were calculated by *T*-Test. The following significance levels were used for the study: P <0.05; 0.01 and 0.001.

3 Results and discussion

The results of the effect of different levels and ratios of lysine and arginine in the compound feed on slaughter parameters of broiler chickens one can see in Table 4.

Analyzing the pre-slaughter live weight, we can conclude that it increased in chickens of the third experimental group due to an increase in the level of arginine in the compound feed and changes in the arginine-lysine ratio in different periods of growing up to 1.10, 1.06 and 1.07. Poultry of the third group exceeded the control by 0.88% (p <0.05). In contrast, an increase in the proportion of lysine and narrowing the arginine-lysine ratio in the compound feed of broiler chickens of the fourth, fifth and sixth groups in different age periods up to 1.05, 1.03 and 1.02 did not significantly affect the pre-slaughter live weight.

A similar tendency appeared for the carcass weight before evisceration – we noted an increase in this indicator by 1.27% (p <0.05) in broiler chickens of the third experimental group due to an increase in the arginine-lysine ratio to 1.07–1.10. However, narrowing the ratio to 1.02–1.05 resulted in a decrease of the carcass weight before evisceration of birds of the six group by 1.98% (p <0.05).

Table 4 Slaughter parameters of the broiler chickens (g) (x ±SD, n = 10)

Parameter	Group of birds					
	control	experimental				
	1	2	3	4	5	6
Pre-slaughter live weight	2,642.75 ±14.750	2,660.81 ±22.233	2,665.99 ±14.686*	2,638.04 ±39.241	2,637.95 ±61.979	2,616.94 ±46.30
Carcass weight before evisceration	2,460.41 ±18.604	2,484.19 ±11.407	2,491.78 ±12.079*	2,454.96 ±46.521	2,437.73 ±66.333	2,411.73 ±32.734*
Semi-eviscerated carcass weight	2,271.43 ±23.312	2,304.24 ±27.862	2,315.46 ±44.979	2,261.69 ±22.266	2,251.82 ±44.471	2,222.95 ±36.549
Eviscerated carcass weight	2,074.14 ±23.903	2,103.20 ±26.186	2,114.00 ±37.595	2,065.97 ±14.049	2,054.44 ±46.170	2,027.73 ±43.981
Weight of edible parts						
Breast muscles	542.50 ±14.541	604.71 ±76.010	591.03 ±19.897**	526.88 ±16.463	521.03 ±7.213*	487.18 ±28.668*
Leg muscles	457.65 ±8.029	465.29 ±19.987	501.01 ±19.927*	447.07 ±7.389	442.12 ±8.692*	425.30 ±13.156**
Skin	181.24 ±16.998	169.81 ±7.644	192.87 ±13.267	176.94 ±4.079	176.90 ±3.538	178.35 ±5.944
Internal fat	74.68 ±17.025	63.18 ±10.196	66.60 ±15.420	85.04 ±15.200	92.97 ±8.930	102.75 ±5.770*
Liver	65.26 ±16.472	66.49 ±13.669	73.68 ±13.305	73.68 ±8.702	70.09 ±9.119	65.93 ±7.244
Lungs	15.66 ±1.217	15.63 ±0.913	16.66 ±1.732	15.70 ±0.546	16.42 ±0.902	17.39 ±1.439
Kidneys	12.62 ±1.196	13.11 ±1.161	13.00 ±0.630	12.93 ±0.593	12.40 ±0.794	12.05 ±1.527
Gizzard	62.78 ±13.305	64.39 ±11.713	67.98 ±9.788	66.66 ±7.279	73.29 ±12.864	86.19 ±17.557
Heart	14.07 ±1.582	15.04 ±1.312	14.53 ±1.886	13.92 ±1.915	14.35 ±1.213	15.29 ±1.315

*p <0.05; **p <0.01 compared with the first group

The analysis of the weight of carcass edible parts showed an increase in the weight of breast muscles in broiler chickens of the third experimental group by 8.95% (p <0.01) compared to the control. In birds of the fifth and sixth groups, this indicator decreased by 3.96 (p <0.05) and 10.20% (p <0.05), respectively.

The weight of the leg muscles increased due to the increase of arginine in the compound feed of broiler chickens of the third experimental group – by 9.47% (p <0.05). This indicator decreased with an increase in the content of lysine in the compound feed of chickens of the fifth and sixth groups by 3.39 (p <0.05) and 7.07% (p <0.01), respectively.

Certain changes we observed in the weight of internal fat. In chickens of the sixth experimental group the weight of internal fat increased by 37.59% (p <0.05).

Other slaughter parameters did not undergo significant probable changes due to changes in the ratio between arginine and lysine in the compound feed.

The yield of slaughter products correlated to a certain extent with the slaughter weight and the weight of carcass edible parts (Table 5).

Analyzing the yield of edible parts, we can conclude that the yield of the breast muscles and the leg muscles naturally depended on the levels and ratios of the studied amino acids. This obviously confirms the most significant effect of arginine and lysine on protein metabolism and increasing nitrogen retention in the body with an optimal ratio between these amino acids. The yield of the breast muscles increased by 1.64% (p <0.01) due to the expansion of the arginine-lysine ratio in the compound feed of chickens of the third experimental group. The yield of the leg muscles increased compared to the control group by 1.47% (p <0.05). In contrast, when the arginine-lysine ratio was narrowed in the compound feed of broiler chickens of the sixth experimental group, the yield of the breast muscles decreased by 1.91% (p <0.05). The yield of the leg muscles decreased by 0.56–1.07% (p <0.05) in birds of the fifth and sixth experimental groups.

An inverse relationship to the accumulation of the muscle weight we observed for the yield of internal fat. This indicator decreased in birds of the sixth group by 1.10% (p <0.05).

The absence of significant, probable changes in the liver yield indicates the absence of a harmful effect of the studied ratios of amino acids on this organ and the body as a whole.

The yield of the gizzard, lungs, kidneys and heart changed the least under the influence of the studied factors, the difference was not significant, and sometimes absent and improbable.

Meatiness indices and yield of edible parts are the main indicators characterizing meat productivity (Table 6).

The analysis of the data clearly shows the growth of the indicators of meatiness and the yield of edible parts in

Table 5 Yield of slaughter products (%) (x ±SD, n = 10)

Indicator	Animal group					
	control	experimental				
	1	2	3	4	5	6
Yield of semi-eviscerated carcass	85.95 ±0.951	86.60 ±1.175	86.85 ±1.672	85.75 ±1.285	85.37 ±0.669	84.95 ±0.951
Yield of eviscerated carcass	78.49 ±1.013	79.05 ±0.902	79.30 ±1.307	78.33 ±1.043	77.89 ±0.829	77.49 ±1.013
Yield of edible parts						
Breast muscles	20.53 ±0.539	22.71 ±2.674	22.17 ±0.670**	19.98 ±0.664	19.76 ±0.419	18.62 ±1.022*
Leg muscles	17.32 ±0.331	17.49 ±0.759	18.79 ±0.739*	16.95 ±0.205	16.76 ±0.240*	16.25 ±0.449*
Skin	6.86 ±0.637	6.38 ±0.299	7.24 ±0.509	6.71 ±0.134	6.71 ±0.134	6.82 ±0.190
Internal fat	2.83 ±0.640	2.38 ±0.386	2.50 ±0.589	3.23 ±0.585	3.53 ±0.330	3.93 ±0.171*
Liver	2.47 ±0.626	2.50 ±0.530	2.77 ±0.506	2.80 ±0.351	2.66 ±0.377	2.52 ±0.246
Lungs	0.59 ±0.045	0.59 ±0.035	0.63 ±0.068	0.60 ±0.017	0.62 ±0.028	0.67 ±0.061
Kidneys	0.48 ±0.046	0.49 ±0.042	0.49 ±0.022	0.50 ±0.022	0.47 ±0.029	0.46 ±0.053
Gizzard	2.38 ±0.499	2.42 ±0.442	2.55 ±0.370	2.53 ±0.250	2.78 ±0.457	3.30 ±0.712
Heart	0.53 ±0.060	0.57 ±0.048	0.55 ±0.072	0.53 ±0.071	0.55 ±0.058	0.59 ±0.058

*p <0.05; **p <0.01 compared with the first group

Table 6 Meatiness indices (%) (x ±SD, n = 10)

Indicator	Animal group					
	control	experimental				
	1	2	3	4	5	6
Carcass meatiness	48.22 ±0.624	50.85 ±3.591	51.67 ±1.805*	47.14 ±0.777	46.89 ±0.776*	44.99 ±1.301**
Breast meatiness	26.16 ±0.785	28.73 ±3.290	27.96 ±0.771*	25.50 ±0.650	25.37 ±0.585	24.01 ±1.005*
Leg meatiness	22.07 ±0.353	22.12 ±0.759	23.71 ±1.233	21.64 ±0.223	21.52 ±0.216*	20.97 ±0.352**
Yield of edible parts	68.78 ±2.409	70.24 ±2.785	72.74 ±2.259*	68.67 ±1.344	69.11 ±1.033	68.57 ±1.422
Bone content	31.22 ±2.409	29.76 ±2.785	27.26 ±2.259*	31.33 ±1.344	30.89 ±1.033	31.43 ±1.422

*p <0.05; **p <0.01 compared with the first group

broiler chickens that consumed the compound feed with a wide arginine-lysine ratio. Thus, in birds of the third experimental group, the carcass meatiness increased by 3.45% (p <0.05), the breast meatiness – by 1.80% (p <0.05), and the yield of edible parts – by 3.96% (p <0.05).

Meatiness indices decreased in chickens that consumed the feed with a narrow arginine-lysine ratio. In broiler chickens of the fifth and sixth groups the carcass meatiness decreased by 1.33 (p <0.05) and 3.23% (p <0.01), and the leg meatiness – by 0.55 (p <0.05) and 1.10% (p <0.01). The breast meatiness decreased in chickens of the sixth experimental group by 2.15% (p <0.05).

Therefore, the analysis of the meat productivity of broiler chickens that consumed the compound feed with different ratios between arginine and lysine showed their influence on indicators of growth intensity and accumulation of muscle tissue. In this research we noted an increase in the pre-slaughter live weight by 0.88% (p <0.05) and the carcass weight before evisceration by 1.27% (p <0.05) due to the increase in the level of arginine and the expansion of the arginine-lysine ratio in the compound feed of broiler chickens along with the decrease of these indicators by 0.98 and 1.98% (p <0.05) due to the increase in the level of lysine and narrowing the arginine-lysine ratio. Changes in the live weight and the specified indicators follow from the changes in the weight and yield of the breast muscles and leg muscles, which increased by 8.95% (p <0.01) and 9.47% (p <0.05), respectively, due to the expansion of the arginine-lysine ratio, and decreased by narrowing the arginine-lysine ratio by 3.96–10.20% (p <0.05) and 3.39 (p <0.05) – 7.07% (p <0.05), respectively. Such an increase in the muscle weight can obviously be explained by an increase in the absorption and reabsorption of arginine, a decrease in arginase activity and an increase in the formation of citrulline (Boerboom et al., 2018) and nitric oxide (Fernandes & Murakami, 2010) in the blood and the vasodilator properties of the latter, which leads to an increase in blood flow to the muscles (Bodle et al., 2018). Zampiga et al. (2019) and Hurwitz et al. (1998) obtained similar data in their experiments – an increase in the weight of muscle tissue due to an increase in the level of arginine in the compound feed of broiler chickens.

In this research, there was an increase in the weight and yield of internal fat by 37.59% (p <0.05) with a narrow arginine-lysine ratio and a decrease in this indicator with an increase in the level of arginine in the compound feed of broiler chickens and an expansion of the arginine-lysine ratio. Such changes may follow from the better use of protein and more intense muscle growth in the birds with an optimal ratio between amino acids, which is close to the "ideal protein" of the feed. An imbalance between arginine and lysine led to a decrease in growth rates with a high protein content in the feed, which led to the transformation of excess protein into body fat. Similar results came out in studies on broiler chickens conducted by Hurwitz et al. (1998), who observed an increase in fat accumulation in the carcass with an increase in the level of protein in the compound feed and a decrease in the level of arginine and lysine. As the level of arginine increased, the fat weight of the carcass decreased (Hurwitz et al., 1998).

The meatiness of the carcass, breast and legs increased due to the expansion of the arginine-lysine ratio in the compound feed of broiler chickens because of the increase in the weight and yield of the breast and leg muscles. Due to this, the yield of the carcass edible parts also increased.

4 Conclusion

The research proved the effectiveness of increasing the arginine-lysine ratio in the compound feed of broiler chickens to 1.10 at the age of 1–10 days; 1.06 – at the age of 11–22 days and 1.07 – at the age of 23–42 days, which contributed to the increase of the pre-slaughter live weight by 0.88% (p <0.05), the carcass weight before evisceration – by 1.27% (p <0.05), the weight of breast muscles – by 11.47% (p <0.01), the weight of leg muscles – by 9.47% (p <0.05); the yield of breast muscles increased by 2.18% (p <0.01) and of the leg muscles – by 1.47% (p <0.05); the meatiness of the carcass and breast increased by 3.45% (p <0.05) and 1.80% (p <0.05), respectively; the yield of edible parts increased by 3.96% (p <0.05). Narrowing the arginine-lysine ratio to 1.02 at the age of 1–10 days; 0.97 – at the age of 11–22 days and 0.98 – at the age of 23–42 days, led to a decrease in the carcass weight before evisceration – by 1.98% (p <0.05), the weight of breast muscles – by 3.96–10.20% (p <0.05), the weight of leg muscles – by 3.39% (p <0.05) – 7.07% (p <0.01), the yield of breast muscles – by 1.91% (p <0.05), the yield of leg muscles – by 0.56–1.07% (p <0.05); the meatiness of the carcass decreased by 1.33 (p <0.05) – 3.23% (p <0.01), the meatiness of the breast – by 2.15% (p <0.05), the meatiness of the legs – by 0.55% (p <0.05)– 1.10% (p <0.01); the yield of internal fat increased by 1.10% (p <0.05).

References

Aviagen. 2019. *Ross Nutrition Specifications. All Plant Protein-Based Feeds*. Aviagen. Retrieved September 16, 2022 from https://eu.aviagen.com/assets/Tech_Center/Ross_Broiler/RossPlantProteinBasedBroilerNutritionSpecs2019-EN.pdf

Baker, D.H. (1997). Ideal amino acid profiles for swine and poultry and their applications in feed formulation. *BioKyowa Tech Rev*, 9, 1–24.

Balnave, D., & Brake, J. (2002). Re-evaluation of the classical dietary arginine: lysine interaction for modern poultry diets: a review. *Worlds Poult Sci J*, 58, 275–289. https://doi.org/10.1079/WPS20020021

Belloir, P., Lessire, M., Lambert, W., Corrent, E., Berri, C., & Tesseraud, S. (2019). Changes in body composition and meat quality in response to dietary amino acid provision in finishing broilers. *The Animal Consortium 2018*, 13(5), 1094–1102. https://doi.org/10.1017/S1751731118002306

Bodle, B.C., Alvarado, C., Shirley, R.B., Mercier, Y., & Lee, J.T. (2018). Evaluation of different dietary alterations in their ability to mitigate the incidence and severity of woody breast and white striping in commercial male broilers. *Poult. Sci.*, 97, 3298–3310. https://doi.org/10.3382/ps/pey166

Boerboom, G., van Kempen, T., Navarro-Villa, A., & Pérez-Bonilla, A. (2018). Unraveling the cause of white striping in broilers using metabolomics. *Poult Sci*, 97(11), 3977–3986. https://doi.org/10.3382/ps/pey266

Cobb-Vantress. 2018. *Cobb 500 broiler performance and nutrition supplement*. L-2114-08 EN: August 2018. Cobb-Vantress. Retrieved September 16, 2022 from. https://www.cobb-vantress.com/assets/5a88f2e793/Broiler-Performance-Nutrition-Supplement.pdf

Dozier, W.A., Kidd, M.T., & Corzo, A. (2008). Dietary amino acid responses of broiler chickens. *Journal of Applied Poultry Research*, 17(1), 157–167. https://doi.org/10.3382/japr.2007-00071

Fernandes, J.I.M., & Murakami, A.E. (2010). Arginine metabolism in uricotelic species. *Acta Sci Anim Sci.*, 32, 357–366. http://dx.doi.org/10.4025/actascianimsci.v32i4.10990

Fouad, A.M., El-Senousey, H.K., Yang, X.J., & Yao, J.H. (2012). Role of dietary L-arginine in poultry production. *Int J Poult Sci.*, 11, 718–729. http://dx.doi.org/10.3923/ijps.2012.718.729

Hurwitz, S., Sklan, D., Talpaz, H., & Plavnik, I. (1998). The Effect of Dietary Protein Level on the Lysine and Arginine Requirements of Growing Chicken. *Poultry Science*, 77, 689–696. https://doi.org/10.1093/ps/77.5.689

Ibatullin, I., Ilchuk, I., & Kryvenok, M. (2013). Productivity of broiler chickens at different levels of lysine in compound feed. *Animal husbandry of Ukraine*, 11, 31–35. http://nbuv.gov.ua/UJRN/TvUkr_2013_11_10

Ibatullin, I., Ilchuk, I., & Kryvenok, M. (2014a). Broiler chicken growth at different levels of arginine in the diet. *Scientific notes of the Kazan State Academy of Veterinary Medicine. N.E. Bauman*, 217, 102–109. https://cyberleninka.ru/article/n/rost-tsyplyat-broylerov-pri-raznyh-urovnyah-arginina-v-ratsione

Ibatullin, I., Ilchuk, I., & Kryvenok, M. (2014b). Digestibility of nutrients in broiler chickens at different levels of lysine in compound feed. *Bulletin of the Sumy National Agrarian University*, 2/1(24), 145–148. http://nbuv.gov.ua/UJRN/Vsna_tvar_2014_2%281%29__35

Ibatullin, I., Ilchuk, I., & Kryvenok, M. (2015). Efficiency of feed utilization by broiler chickens at different levels of arginine in compound feed. *Scientific Bulletin of the National University of Bioresources and Nature Management of Ukraine*, 205, 110–118. http://socrates.vsau.org/repository/getfile.php/10412.pdf

Ibatullin, I., Kryvenok, M., Ilchuk, I., Mykhalska, V., Getja, A., & Boyarchuk, S. (2020). Metabolism in replacement chickens at different ratios of arginine and lysine. *Ukrainian Journal of Ecology*, 10(5), 127–132. DOI: 10.15421/2020_217

Ibatullin, I. et al. (2022). Influence of Feeding Wormwood (*Artemisia capillaris*) on Quail Meat Productivity. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, 70(4–5), 307–316. http://dx.doi.org/10.11118/actaun.2022.023

Khajali, F., & Wideman, R.F. (2010). Dietary arginine: metabolic, environmental, immunological and physiological interrelationships. *Worlds Poult Sci J*, 66, 751–766. https://doi.org/10.1017/S0043933910000711

Kidd, M.T., Kerr, B.J., & Anthony, N.B. (1997). Dietary interactions between lysine and threonine in broilers. *Poult Sci*, 1997(76), 608–614. https://doi.org/10.1093/ps/76.4.608

Kryvenok, M.J., Ilchuk, I. I., & Mykhalska, V.M. (2017a). Optimal in-feed threonine and tryptophan ratio for replacement chickens: the theoretical background. *Ukrainian Journal of Ecology*, 7(3), 111–115. DOI: 10.15421/2017_57

Kryvenok, M. J., Ilchuk, I. I., & Mykhalska, V. M. (2017b). Prognosis of dietary Glycine needs of replacement chicks. *Ukrainian Journal of Ecology*, 7(4), 46–50. DOI: 10.15421/2017_85

Mutryn, M.F., Brannick, E.M., Fu, W., Lee, W.R., & Abasht, B. (2015). Characterization of a novel chicken muscle disorder through differential gene expression and pathway analysis using RNA-sequencing. *BMC Genomics*, 16(399), 1–9. https://doi.org/10.1186/s12864-015-1623-0

Nahm, K.H. (2002). Efficient feed nutrient utilization to reduce pollutants in poultry and swine manure. *Crit Rev Environ Sci Technol*, 32, 1–16. https://doi.org/10.1080/10643380290813435

National Research Council. (1994). *Nutrient Requirements of Poultry*. 9th revised ed., National Academies Press, Washington DC (176 p.) https://doi.org/10.17226/2114

Tamir, H., & Ratner, S. (1963). Enzymes of arginine metabolism in chicks. *Arch Biochem Biophys*, 102, 249–258. https://doi.org/10.1016/0003-9861(63)90178-4

Wu, G. (2014). Dietary requirements of synthesizable amino acids by animals: a paradigm shift in protein nutrition. *J Anim Sci Biotechnol.*, 5(34), 1–12. https://doi.org/10.1186/2049-1891-5-34

Zampiga, M., Laghi, L., Petracci, M., Zhu, Ch., Meluzzi, A., Dridi, S., & Sirri, F. (2018). Effect of dietary arginine to lysine ratios on productive performance, meat quality, plasma and muscle metabolomics profile in fast-growing broiler chickens. *Journal of Animal Science and Biotechnology*, 9(79), 1–14. https://doi.org/10.1186/s40104-018-0294-5

Zampiga, M., Soglia, F., Petracci, M., Meluzzi, A., & Sirri, F. (2019). Effect of different arginine-to-lysine ratios in broiler chicken diets on the occurrence of breast myopathies and meat quality attributes. *Poultry Science*, 98, 2691–2697. http://dx.doi.org/10.3382/ps/pey608

Zuidhof, M.J., Schneider, B.L., Carney, V.L., Korver, D.R., & Robinson, F.E. (2014). Growth, efficiency, and yield of commercial broilers from 1957, 1978, and 2005. *Poult Sci*., 93, 2970–2982. https://doi.org/10.3382/ps.2014-04291