

Effect of White Lupine-based Protein Concentrate on the Growth of Quails

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ABSTRACT

Plant-based feed is the primary protein source in poultry nutrition. It includes legume seeds, cakes and meals. White lupine is of particular interest, as its seeds contain up to 35% protein, but its use as feed is limited by the presence of alkaloids. This study evaluated the effects of white lupine protein concentrate as a dietary replacement for soybean meal in quail feed. Three groups of quail chicks at the age of 10 days were formed. The experiment lasted 38 days. Double-decker cages were used to keep birds in accordance with zootechnical standards. All the birds had free access to drinking bowl and feeder. Quails of all groups received factory-prepared compound feed (PK). Birds of the first group were fed compound feed (95%) and extruded soybeans (5%) (Positive control). Instead of soybeans, the diet of quails from the second group consisted of extruded seeds of the white lupine equivalent in protein. The third group of quails was fed lupine concentrate obtained by enzymolysis of extruded seeds of the white lupine. Observations of the survivability, physiological state, live weight dynamical changes in quails, and feed consumption were made in the course of the experiment. A positive effect on the growth dynamics, live weight gain and meat productivity of quails was observed after replacing extruded soybeans with white lupine processing products in the compound feed. Quail receiving compound feed with lupine protein concentrate had carcasses with breast and leg muscle weight higher by 19.63% and 10.63%, respectively ($P \leq 0.05$). The use of lupine feed additives did not have a negative effect on the physiological status and blood composition of quails. Compared with the control, the blood of quails that received lupine additives had hemoglobin and hematocrit levels higher by 9.8% and 3.7%, 21.8% and 7.6%, and decreased level of creatinine and bilirubin, urea, uric acid, liver enzymes, such as gamma-glutamyl transpeptidase (GGT), aspartate aminotransferase (AST), alkaline phosphatase (ALP) and alanine aminotransferase (ALT). The feasibility and economic efficiency of using lupine additives is confirmed by the fact that the consumption of compound feed per unit of live weight gain of quails in the second and third groups was reduced by 3.5% and 8.5%, respectively. Feed additives based on extruded and fermented white lupine seeds can be an alternative to soy products in feeding poultry, in particular quails.

Keywords: Protein, Soy, lupine, Extrusion, Enzymolysis, Protein concentrate, Quail, Blood, Productivity.

INTRODUCTION

Quail production has increased globally due to demand for high-quality protein sources. Quail meat has specific taste qualities, tender texture, juiciness, aroma, has dietary properties, which are explained by low-fat and the high protein content, as well as its amino acid

composition. All the parameters of the meat are maximally balanced and close to the standard. Therefore, quail meat is considered to be one of the most promising raw material categories in the technology of producing specialized food products, as well as functional and therapeutic and prophylactic products based on meat (Abraham et al. 2019).

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In this regard, further development of quail farming, increasing productivity and production volumes of dietary meat is an urgent task. Protein nutrition and the provision of essential amino acids are known to have a great impact on the productivity of poultry, including quail (Struți et al. 2021).

The main source of protein in poultry diets is plant feed: legume seeds, cakes and meals. White lupine is of particular interest. It outstrips peas, vetch and fodder beans in terms of the amount of crude protein (32-35%), contains virtually no trypsin inhibitors, and is comparable to soy in terms of protein quality and digestibility (Mendowski et al. 2019).

White lupine seeds with low content of alkaloid are a superb alternative resource of protein that helps monogastric animals to avoid dependence on soybean-based meal (Struți et al. 2021). In the literature, there are reports on the positive effect of lupine on the productivity of poultry (Abraham et al. 2019; Pietras et al. 2021; David et al. 2024).

A few experiments have shown the effectiveness of including white lupine in quail diets. Lupine content in the lupine-based meal could be raised up to 25% (percent of feed) by using enzymes in the feed of laying quails. At the same time, such parameters as physicochemical indicators of egg quality, egg weight, egg yield and feed conversion ratio did not change. In addition, the use of lupine significantly improved the carotenoid content of egg yolk, as well as the quality of yolk fats, by reducing cholesterol content and the level of fatty acids with atherogenic effect in favor of omega-3 (Struți et al. 2023).

In comparison to the birds from control group, presence of peeled lupine seeds as a component of laying quail diet had no effect on physicochemical indicators of egg quality, content of yolk cholesterol and efficiency of production (feed conversion ratio, feed consumption and egg yield). Improvement of the nutritional value of yolk lipids while using peeled lupine seeds may be explained by an increase in the content of polyunsaturated fatty acids. Consequently, it has been shown, that an increase in the hypocholesterolemic/hypercholesterolemic fatty acids ratio (h/H ratio) and a decrease in the level of thrombogenicity and atherogenicity, had a positive effect on the quality parameters of yolk lipids and made them more beneficial for consumer's health (Struți et al. 2021).

The widespread use of lupine is hampered by the presence of alkaloids (lupinine and lupinidine), which reduce palatability (Vishnyakova et al. 2020; Estivi et al. 2022; Rodés-Bachs and Van der Fels-Klerx 2023; Valente et al. 2023; Namdar et al. 2024). Among the key anti-nutritional agents that hinder the use of lupine in animal diet, alkaloids (like quinolizidine) and their specific carbohydrate composition deserve a special attention (Abraham et al. 2019).

The use of chemical reagents to remove alkaloids is labor-intensive and low-tech and is associated with high material costs and an unresolved problem of disposal of large volumes of spent chemicals used in the cleaning process (Rutskaya and Timoshenko 2023). Therefore, this is mainly achieved by water treatment (Ozkaya et al. 2021; Chamone and Ascheri 2023), ultrasound (Baltacıoğlu and Özcan Tarım 2024; Miano et al. 2019), heat treatment and extrusion (Manzocchi et al. 2023). In addition, extrusion

improves protein digestibility and protects protein from degradation in the rumen (Mendowski et al. 2019). Pre-heat treatment methods for lupine can be used not only to remove anti-nutritional substances, but also for further biotechnological seed treatment to obtain isolates, concentrates and hydrolysates of protein and amino acids. For these purposes, various methods were used (Zhong et al. 2021; Domínguez et al. 2023; Pasarin et al. 2023), most of the studies were devoted to the hydrolysis of the protein fraction of lupine seeds (Schlegel et al. 2019), in particular with proteolytic enzymes (Kamran et al. 2021). The purpose of such treatments was to obtain protein hydrolysates for the food industry (Großmann et al. 2019). At the same time, selective enzymatic hydrolysis can also be used to obtain protein concentrates, taking into account the carbohydrate composition of lupine (Samel and Wojciechowski 2024).

Thus, due to the global shortage of feed protein, technological developments in relation to non-traditional high-protein forage crops deserve further study and active implementation. Therefore, complex biotechnological processing of lupine for the purpose of obtaining high-protein feed for poultry farming is an important practical aim for agricultural science. Therefore, this study aimed to evaluate the effects of white lupine-based protein concentrates as dietary replacements for soybean protein in growing quail.

MATERIALS AND METHODS

Source materials and their processing

In this work, we used white lupine of the Dega variety and soybean of the Milyausha variety, samples of which were provided by the Tatar Research Institute of Agriculture, Federal Research Center "Kazan Scientific Center of the Russian Academy of Sciences". Lupine and soybean seeds were extruded in unchopped form in a single-screw extruder EM-150 (Russia) at the production site of the "GreenTex Scientific and Technical center" LLC (Kazan) enterprise. The extrusion temperature was 150°C, the processing time was 8-10s (Fedorova et al. 2023). Native lupine seeds, extruded lupine and soybean were ground in a VYUGA 3MT mill (Russia). The moisture content of the samples was measured on an AND MX-50 automatic analyzer (Japan). Total nitrogen concentration in the samples was analyzed by Kjeldahl technique (in a wet ashing unit from SELECTA, Spain), true protein - by the Barnstein method, fiber - by Henneberg and Stohmann method, fat - according to GOST 13496.15-2016 in a Soxhlet apparatus, ash - according to GOST 26226-95, starch - according to GOST ISO 6493-2015. To carry out enzymatic hydrolysis of lupine seeds, foreign enzyme preparations Novozymes (Denmark) were used.

Experimental design and animals

The Bioethics Committee of the Federal State Budgetary Scientific Institution "Federal Research Center "Kazan Scientific Center of the Russian Academy of Sciences" (FRC KazSC RAS, Kazan, Russia) approved the experimental protocol No. 11 (August 13, 2025, application No. 25/3). The animals were kept in accordance with EU Directive 2010/63/EU. Study of the

effect of feeding extruded lupine seeds and lupine protein concentrate obtained by enzymatic hydrolysis instead of extruded soybean seeds on the body of young quails was performed in accordance with methodology established by ARSRIPPI (2000) using the balanced group method on Texas quails (n=240). Three groups of 10-day-old quails were formed based on their live weight and gender (equal numbers of females and males). The experiment lasted 38 days.

Feeding and housing

Double-decker cages were used to keep birds in accordance with zootechnical standards. All the birds had free access to drinking bowl and feeder. The scheme of the experiment involved feeding commercial feed, which corresponded to zootechnical requirements, to the birds of all groups (Fedorova et al. 2023). The first group of quails (positive control) received 95% of compound feed and 5% of extruded crushed soybeans in their diet. Instead of soybeans, the second group of quails received crushed extruded lupine seeds with an equivalent amount of protein, and the third group of quails was fed lupine protein concentrate instead of soybeans with an equivalent amount of protein.

Sampling

Feed and feed additives were sampled in accordance with GOST ISO 6497-2014 "Animal feeding stuffs. Sampling" and the samples were stored in accordance with GOST 23462-2019 "Products of the compound feed industry, acceptance rules, packaging, marking, transportation and storage". GOST 51447-99 "Meat and meat Products. Methods of primary sampling" was used for sampling meat for chemical composition and quality determination. Organoleptic indicators and carcass weight of experimental poultry were determined in accordance with GOST R 51944-2002 "Poultry Meat. Methods for determining organoleptic indicators, temperature and weight" and GOST 9959-2015 "Meat and meat products. General conditions for carrying out organoleptic evaluation". Blood from quails was collected at the end of the experiment. Blood samples were taken in vacuum blood collection tubes with EDTA-K2 anticoagulant and vacuum blood collection tubes "coagulation activator with gel". By the end of the reporting period, a control slaughter of the poultry was carried out, during which the requirements of the Federal Law of the Russian Federation "On the Protection of animals from cruel treatment" (adopted by the State Duma on March 21, 2008) were followed.

Laboratory analysis

During the experiment, observations on the safety, physiological condition, and dynamics of live weight of the birds were made. The given and eaten feed was recorded daily, and the feed consumption per unit of live weight gain was calculated based on the feed palatability and live weight gain. Studies of the chemical and amino acid composition of the compound feed and additives were carried out at the Tatar Research Institute of Agriculture, the federal research center "Kazan Scientific Center of the Russian Academy of Sciences" on a NIRS™DMS 2500 analyzer (Denmark), calibrated using global data. ISIScan

Nova software was used for control.

After the slaughter, a pathological assessment of the organs and tissues, anatomical cutting of the carcasses, and morphometric analysis were carried out. The following were determined by weighing on a laboratory electronic scale HL-2000 (Japan) with an accuracy of 0.01 g: pre-slaughter live weight of the bird, slaughter weight (weight of the bloodless plucked carcass with the head, limbs, internal organs), weight of the semi-gutted carcass (weight of the carcass without intestines), weight of the gutted carcass (weight of the bloodless plucked carcass without the head, limbs, internal organs), yield of the gutted carcass (the ratio of the slaughter weight to the pre-slaughter live weight, expressed as a percentage), and the weight of the organs was determined: heart, liver, spleen, glandular and muscular stomach.

To determine the hemoglobin level (HGB) in the blood of experimental quails we applied colorimetric hemoglobin cyanide method with Mindray BS 240 spectrophotometer (China), and formed elements were determined in a Goryaev chamber. To determine the hematocrit (HTC), a scale and a capillary with whole blood, which was pre-centrifuged in a CritSpin centrifuge (USA), were used. Biochemical studies of blood serum were carried out on a Chemray-240 biochemical analyzer (China) with a Biovet-test reagent kit (Russia).

Statistical analysis

Statistical processing of the experimental data was performed in MS Excel, statistical significance of the results was calculated using Student's t-test, and the difference was considered significant at $P \leq 0.05$.

RESULTS

The results of the studies showed that the chemical composition of extruded soybeans and lupine, lupine concentrate differs somewhat in terms of crude protein, crude fat and starch content.

Crude protein content in extruded soybean seeds was 38.43%, the protein content in extruded lupine seeds was 5.82% less and amounted to 32.61%, in lupine concentrate it was 41.53%, which was 8.07% higher than in soybeans. The crude fat content in soybean seeds was 14.70%, in lupine seeds - 8.89%, in lupine concentrate - 7.89%. The starch content in soybean seeds was 6.09%, in lupine seeds - 12.65%, in lupine concentrate - 1.49%. A comparative assessment of content of amino acid in extruded soybean and lupine seeds, as well as lupine concentrate, was carried out for the purpose of further use in feed additives and compound feed for feeding agricultural poultry (Table 1).

Amino acid analysis of the samples showed that the content of replaceable and essential amino acids was 32.3% in extruded soybeans, 25.9% in extruded lupine seeds, and it was higher in lupine concentrate amounting to 42.0% (of the total protein).

In extruded soybean seeds, glutamine had the highest content from the fraction of non-essential amino acids – 6.04%; from the essential amino acid fraction, arginine – 2.54% and lysine – 2.21%. The amount of sulfur-containing amino acids was: methionine – 0.49% and cysteine – 0.57%. In extruded seeds of white lupine,

glutamine had the highest content from the fraction of non-essential amino acids - 4.57%, Aspartic acid - 2.24%, from the fraction of essential amino acids: arginine - 2.16%, leucine - 1.78%, valine - 1.60%. The amount of sulfur-containing amino acids was: methionine - 0.2% and cysteine - 0.51%. In lupine concentrate glutamine had the highest content from the fraction of non-essential amino acids - 9.80%; Aspartic acid - 4.32%, from the fraction of essential amino acids: arginine - 3.13%, lysine - 2.57%, leucine - 2.48%, valine - 2.16%. The amount of sulfur-containing amino acids was: methionine - 0.35% and cysteine - 0.84%. During the scientific experiment it was established that the use of extruded lupine seeds and lupine concentrate in quail feeding instead of soybeans did not have a negative effect on feed palatability, survivability, growth of birds and feed costs.

Table 1: Comparative amino acid composition of samples (in % of total protein)

Amino acid	Soybean extruded	Lupine extruded	Lupine concentrate
Alanine	1.473±0.006	1.115±0.015	1.73±0.01
Arginine	2.535±0.005	2.16±0.03	3.13±0.03
Aspartic acid	3.395±0.005	2.24±0.05	4.32±0.01
Cysteine	0.566±0.003	0.51±0.01	0.835±0.005
Glutamine	6.04±0.000	4.565±0.095	9.795±0.015
Glycine	1.485±0.005	1.36±0.000	1.665±0.005
Histidine	0.84±0.000	0.49±0.01	1.01±0.02
Isoleucine	1.62±0.01	1.36±0.000	2.1±0.02
Leucine	2.15±0.03	1.78±0.04	2.48±0.01
Lysine	2.205±0.025	1.62±0.01	2.57±0.03
Methionine	0.485±0.015	0.195±0.005	0.345±0.005
Phenylalanine	1.715±0.005	1.386±0.003	2.11±0.02
Proline	1.71±0.01	1.715±0.005	2.29±0.01
Serine	1.69±0.02	1.415±0.015	1.975±0.015
Threonine	1.39±0.01	1.08±0.01	1.6±0.02
Tryptophan	0.405±0.005	0.456±0.003	0.826±0.003
Tyrosine	1.015±0.005	0.895±0.005	1.13±0.01
Valin	1.605±0.005	1.595±0.015	2.16±0.01

Quails that received lupine concentrate were distinguished by growth energy which was a little higher. Quails of the first control group, which received extruded soybeans with compound feed, had the live weight of 83.07±1.22g at the age of 17 days, 24 days - 110.19±1.23g, 32 days - 142.18±1.71g, 40 days - 207.86±1.37g, 48 days - 273.09±1.96g. In the second

group, which received extruded lupine, the live weight of the birds at the age of 17 days was 85.25±1.27g, 24 days - 118.86±1.38g, 32 days - 147.68±1.87 g, 40 days - 215.41±2.99g, 48 days - 280.10±2.37g. In the third group, which received lupine concentrate, the live weight of quails at the age of 17 days was 85.46±1.27g, 24 days - 120.03±1.39 g, 32 days - 153.86±1.85 g, 40 days - 229.76±2.65g, 48 days - 293.90±3.22g. Thus, compared to the control, the analyzed indicator in the birds of the second and third groups was higher at the age of 17 days by an average of 2.7%, 24 days - by 7.8% and 9.2% ($P \leq 0.05$), 32 days - by 3.9% and 8.2% ($P \leq 0.05$), 40 days - by 3.6% and 10.5% and 48 days - by 2.6% and 7.6%, respectively.

The average daily gain in live weight of quails of the first group was 5.87g in quails of the second group it was 3.1% higher and amounted to 6.05g, in quails of the third groups the analyzed indicator was 6.41g, which was 9.2% higher than the control. The average live weight of quails in the second group was 7.01g or 2.6% higher than in the control group, and in the third group it was 20.8g or 7.6% higher ($P \leq 0.05$). The absolute increase in live weight of quails at the end of the experiment was: 223.14g in the control group, 229.92g in the second group, and 243.69g in the third group.

The inclusion of extruded lupine and lupine concentrate as a feed additive allowed reducing cost of for one unit of live weight gain of quails by 3.5% and 8.5%, respectively. The obtained experimental data on meat productivity of the experimental quails are presented in Fig. 1.

The birds of the second and third groups had better meat productivity, a significantly higher slaughter weight of 2.90-6.86% and a gutted carcass weight of 8.93-13.08% ($P \leq 0.05$). Comparing to control, the weight of muscles of the breast and leg in quails fed with lupine concentrate was higher by 19.63% and 10.63%, respectively ($P \leq 0.05$).

To determine the effect of feed additives on the physiological state of the experimental birds, we studied some morphological and biochemical blood parameters, since they are an indicator of health and productivity. Some external and internal factors can affect blood composition even under normal physiological conditions. The data obtained are presented in Table 2.

Table 2: Morphological and biochemical parameters of blood of experimental quails

Indicator	First group (control)	Second group	Third group
Hemoglobin (HGB), g/l	123.8±2.87	135.2±2.05*	128.44±2.92
Hematocrit (HTC), %	41.54±1.26	50.64±3.36*	47.71±1.51
Red blood cell count (RBC), $10^{12}/l$	2.78±0.57	2.86±0.15	2.96±0.14
Leukocyte count (WBC), $10^9/l$	2.91±0.23	5.63±0.76**	7.72±1.11
Platelets (PLT), thousands/ μl	58.6±13.07	65.4±7.21	72.2±4.60
Urea, mmol/l	1.48±0.42	1.30±0.14	1.26±0.17
Triglycerides, mmol/l	4.17±1.98	2.45±1.15	4.94±1.59
Alkaline phosphatase (ALP), U/l	846.4±26.40	713.2±15.80**	651.40±65.91
Aspartate aminotransferase (AST), U/l	248.56±11.06	204.28±10.04*	195.08±13.19
Alanine aminotransferase (ALT), U/l	24.80±0.66	6.36±0.27***	6.3±0.81
Gamma-glutamyl transpeptidase (GGT), U/l	4.60±0.41	1.86±0.82**	2.8±0.87
Uric acid, $\mu mol/l$	394.2±40.01	362.74±29.29	343.28±26.45
Creatinine, $\mu mol/l$	70.4±0.68	57.60±1.07***	53.00±1.82
Total bilirubin, $\mu mol/l$	8.1±0.51	2.68±0.33***	2.98±0.31
Calcium, mmol/l	2.96±1.00	2.92±0.52	4.79±1.44
Phosphorus, mmol/l	2.21±0.58	2.69±0.31	3.27±1.05

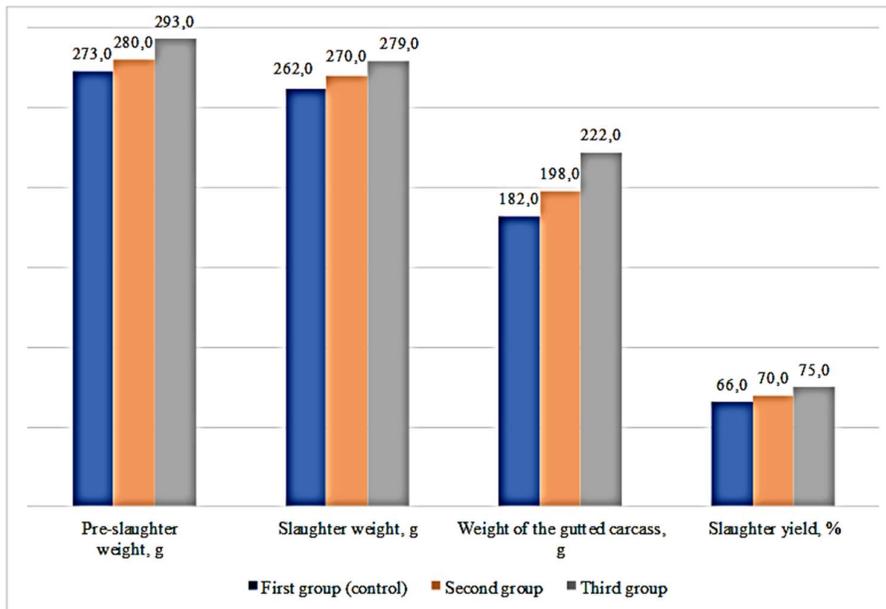


Fig. 1: Meat productivity indicators of experimental quails.

Hemoglobin and hematocrit levels in the blood of the second group of quails were significantly higher compared to the control by 9.8% and 21.8%, respectively, and amounted to 135.2 ± 2.05 g/l and $50.64 \pm 3.36\%$ ($P \leq 0.05$) by the end of the experiment. In the blood of the third group of birds, the hemoglobin and hematocrit concentrations were higher than in the control by 3.7% and 7.6%, and amounted to 128.44 ± 2.92 g/l and 47.71 ± 1.51 g/l, respectively. This indicates oxygen saturation of the blood and is confirmed by an increase in the number and volume of erythrocytes. In the control, the erythrocyte content was $2.78 \times 10^{12}/l$, in the second group it was $2.86 \times 10^{12}/l$, but the highest level was observed in the third group - $2.96 \times 10^{12}/l$. The number of leukocytes and platelets was slightly higher in the experimental groups, but remained within the physiological norm.

It is worth noting that the analysis of the biochemical parameters of blood serum showed a significant decrease in the content of creatinine and bilirubin, as well as of gamma-glutamyl transpeptidase (GGT), aspartate aminotransferase (AST), alanine aminotransferase (ALT) and alkaline phosphatase (ALP) in the blood of the birds of the second group, which received extruded lupine. In the blood samples from birds of the third group, which received lupine concentrate, these indicators were also lower than in the blood of the control bird. Thus, the ALP content in the control was 846.4 ± 26.40 U/L, in the second experimental group it was 18.6% less and amounted to 713.2 ± 15.80 U/L ($P \leq 0.05$), in the third group the lowest level of alkaline phosphatase was observed - 651.40 ± 65.91 U/L, which was 23.0% less than in the control. The activity of AST and ALT transaminases in the control group was 248.56 ± 11.06 U/L and 24.80 ± 0.66 U/L, in the second experimental group it was 204.28 ± 10.04 U/L and 6.36 ± 0.27 U/L, in the third experimental group - 195.08 ± 13.19 U/L and 6.3 ± 0.81 U/L, respectively.

The blood of birds of the third group was characterized by decreased level of creatinine and bilirubin which was lower by 1.3 and 2.7 times comparing to control, respectively. This indicated a normal functioning of liver.

It should be noted that the level of urea and uric acid in the blood of birds receiving experimental additives decreased. The blood of birds of the third group, which were fed with lupine concentrate, these indicators decreased compared to the control by 14.8% and 12.9%, compared to the birds of the second group, which were fed compound feed with extruded lupine, by 3.0% and 12.9%, respectively. This effect may be the reason of active assimilation of nitrogen from the diet and a positive balance of nitrogen in the quails' body.

DISCUSSION

The obtained experimental data confirm that feed additives based on processed lupine can be an alternative to soy products in feeding poultry, in particular quail. Processing of white lupine seeds by extrusion and subsequent enzymatic hydrolysis allows obtaining a concentrate with a crude protein content of 41.53% which has a balanced composition of amino acids. The content of replaceable and essential amino acids in extruded soybeans was 32.3%, in extruded lupine seeds - 25.9%, in lupine concentrate - 42.0% (of the total protein). At the same time, lupine concentrate outstripped extruded soybeans in the amount of all amino acids, with the exception of methionine. In soybeans, the content of methionine was 0.48%, and in protein concentrate it was 0.34%. The rich amino acid composition allows balancing the poultry diet and obtaining high productivity rates.

Therefore, the replacement of extruded soybeans in the compound feed with white lupine processing products had a beneficial effect on the growth dynamics, gain of live weight and quail's meat production. The average daily gain in quails that received lupine additives exceeded the control by 3.1% and 9.2%, positively affecting the live weight dynamics. The live weight of quails at the age of 17 days was higher than the control by an average of 2.7%, at the age of 24 days by 7.8% and 9.2% ($P \leq 0.05$), at the age of 32 days - by 3.9% and 8.2% ($P \leq 0.05$), at the age of 40 days - by 3.6% and 10.5% and at the age of 48 days - by 2.6% and

7.6%, respectively. By the end of the experiment, quails in the second group had the average live weight 2.6% higher than that of the control group, and 7.6% higher than that of the third group ($P \leq 0.05$). Thus, the absolute growth of live weight of quails during the experiment exceeded the control values by 3.04% and 9.21%. Therefore, the quails in the second and third groups had better meat productivity, significantly higher slaughter weight of 2.90-6.86% and gutted carcass weight of 8.93-13.08% ($P \leq 0.05$). The quails fed with lupine concentrate had breast and leg muscle weight higher by 19.6% and 10.6% ($P \leq 0.05$), respectively, indicating high protein absorption. Similar indicators of the beneficial effect of lupine feed on the body of poultry, including quails, were obtained (Abraham et al. 2019; Pietras et al. 2021; Struți et al. 2023; David et al. 2024).

The use of lupine feed additives did not have a negative effect on the physiological state and blood composition of quails. By the end of the experiment, compared to the control, the hemoglobin and hematocrit levels in the blood of quails of the second group were significantly higher by 9.8% and 21.8% ($P \leq 0.05$), and in the third group - by 3.7% and 7.6% ($P \leq 0.05$), respectively. This indicates the saturation of the blood with oxygen, which is confirmed by an increase in the number of red blood cells.

The obtained experimental data on biochemical blood parameters confirm the positive effect of lupine additives on metabolic processes. The analyses showed that the blood of the birds of the second and third groups that received lupine supplements had a decrease in creatinine and bilirubin levels, as well as liver enzymes, such as gamma-glutamyl transpeptidase (GGT), aspartate aminotransferase (AST), alkaline phosphatase (ALP) and alanine aminotransferase (ALT). It is known that liver enzymes play an important role in various metabolic processes, including the breakdown of fats, detoxification of harmful substances and participation in the digestion of feed.

An increase in their level in the blood indicates liver pathology. The data we obtained indicate proper functional activity of the liver in the birds that received lupine supplements. It should be noted that urea and uric acid level in the blood samples from birds that received the experimental supplements decreased. In the blood samples from the third group of birds, which were fed lupine concentrate, these indicators decreased by 14.8% and 12.9% comparing to the control, and by 3.0% and 12.9%, respectively, comparing to the second group, which received extruded lupine. This fact indicates nitrogen effectively absorbs from the diet and that bird's body has a positive nitrogen balance.

The feasibility and economic efficiency of using lupine additives is confirmed by the fact that the consumption of compound feed per unit of live weight gain in the second group and third group of birds decreased by 3.5% and 8.5%, respectively. Thus, our experimental data in general match the data of other researchers who believe that lupine is a promising agricultural feed crop for poultry farming and can replace soybeans (Struți et al. 2021).

Conclusion

The results of this study showed that feed additives based on extruded and fermented lupine can be an

alternative to soy products when feeding agricultural poultry, in particular quail. Processing white lupine seeds by extrusion and subsequent enzymatic hydrolysis allows obtaining a concentrate with a crude protein content of 41.53% which has a balanced composition of amino acids. Feeding extruded lupine and lupine concentrate improves the physiological state, thereby promoting the growth of live weight and meat productivity of young quails, as well as low feed consumption per unit of live weight gain, which is cost-effective.

DECLARATIONS

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