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Effect of dehulled lupin seeds in feed mixture on muscle protein quality of ducklings

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Abstract: The aim of the study was to prepare and test the effect of diets with 50% and 100% replacement of soybean meal with dehulled seeds of white lupin (*Lupinus albus*) variety Zulika. One hundred and eighty Cherry Valley duckling were divided to control group (C) and two experimental groups E_{50} (50% replacement of soybean meal with dehulled white lupin meal) and E_{100} (100% replacement of soybean meal with dehulled white lupin meal). There were evaluated the production parameters and the amino acid spectrum of breast and thigh muscles up to 42 days of age. The effect of diets containing lupin meal had no negative effect on the yield of duckling. In particular, positively can be evaluated higher growth rate in the experimental groups compared to the control (C 3.22 ± 0.28 kg, E_{50} 3.40 ± 0.27 kg, E_{100} 3.48 ± 0.28 kg), at the same time significantly lower mortality in the experimental groups compared to the control (C 5.88%, E_{50} 1.47%, E_{100} 1.49%) and, except for E_{100}, minimal differences in feed conversion ratio (C 2.33 kg/kg, E_{50} 2.27 kg/kg, E_{100} 2.71 kg/kg). Feeding diets based on lupin meal resulted in the reduction of most essential and non-essential amino acids ($P \leq 0.05$) in the dry matter content of both breast and thigh muscle (E_{50}, E_{100}). Lupine meal-based diets positively influenced ducks' health, which was reflected by lower mortality rate in the experimental groups. Therefore, the results show that diets based on lupin meal had a positive effect on the health and welfare of intensively fattened ducks and that they affected positively the economic aspect of breeding.

Keywords: amino acids; duck; fattening; *Lupinus albus*; utility

There is a noticeable deficit of protein sources in the feed industry and the trend of demand for protein sources is increasing. For this reason, the team have long been monitoring the nutritional value of individual varieties of Lupinus albus (Strakova et al. 2006; Strakova et al. 2008) for the possibility of using its seeds as a source of protein in particular, but also as a source of high-quality oil in animal nutrition (Suchy et al. 2019; Kutlvasr et al. 2022).

The task is to support the production of domestic protein feed, to strengthen self-sufficiency in protein commodities and to use protein from European vegetable sources. More than 75% of the plant protein commodities used in the feed indus-

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try is currently provided by imports of soybean products. The European Union is highly dependent on imports, particularly from the USA and South America. World soya production is increasingly based on genetically modified varieties which are not allowed, or they are subject to the European Union regulations. This dependence on imports, along with the instability of agricultural commodity prices, leaves the European Union in a very vulnerable position. In this context, white lupin products appear to be promising for the feed industry.

Consumers are increasingly concerned about food quality and safety, and this is important for future food production, especially if we do not want to increase costs of basic raw products. According to recent studies, lupin has been ranked among eight promising plant protein sources for both feed and food production (Linnemann and Dijkstra 2002; Dijkstra et al. 2003). Lupin seeds do not contain any antinutritional factors such as trypsin inhibitors and saponins. As reported by Kurlovich et al. (2002) or Sujak et al. (2006), cultivated lupin varieties contain fewer antinutritional factors compared to, for example, pea or soybeans. As reported by Mera-Zuniga et al. (2019), dehulling lupin seeds resulted in an increase of proteins (25.0% to 31.1%) and amino acids. Ensuring the possibility of replacing soybean with lupin in livestock feed is highly desirable.

From this point of view, the experiments published by Roth-Maier and Paulicks (2003), Rubio et al. (2003), Mieczkowska et al. (2005) can be considered beneficial.The above-cited authors have achieved positive results in their experiments with the use of lupin seed meal in diets intended for ducklings and pointed out the possibility of improving the nutritional value of the seeds by supplementing sulphur amino acids, dehulling the seeds and using appropriate enzyme supplements due to the higher content of non-starch polysaccharides in seeds. A few publications have documented results showing the improved health status of animals fed lupin seeds in the diet, manifested by lower mortality, improved vascular endothelial function and lower blood cholesterol levels (Martins et al. 2005; Viveros et al. 2007).

A similar issue was addressed by Biesek and Kuzniacka (2020), who compared the resulting performance parameters, carcass and meat quality in ducks fed yellow lupin (*Lupinus luteus*) as a protein source instead of soybean meal.

For the above reason, the aim of the present study was to verify the possibility of using dehulled lupin seeds in optimised complete diets (50% and 100% replacement of soybean meal) and to assess the effect of these diets on selected yield parameters and muscle quality of ducklings.

MATERIAL AND METHODS

Welfare statement

When calculating the number of individuals per unit area, the standard of 15, 10 and 5 individuals/1 m^2 area was respected. The experiment was carried out in an accredited stable of the University of Veterinary Sciences Brno in accordance with current legislative rules and approved by the Ethics Committee of the Central Commission for Animal Welfare at the Ministry of Agriculture of the Czech Republic.

Duckling husbandry

Biological monitoring of Cherry Valley ducklings was carried out in the accredited barn of the Veterinary University Brno. The supplier of ducklings was PERENA, s.r.o. (Chlumec nad Cidlinou, Czech Republic), which imports breeding Cherry Valley ducks from England. Fattening of ducks was done without sex differentiation, in each group there were 50% females and 50% males. Each experimental group consisted of 60 birds with two replicates and the fattening was carried out until the 42nd day of duck age. Three dietary groups of ducklings were used in the experiment: control (C) group and two experimental groups E_{50} and E_{100} with 50% and 100% replacement of soybean meal with white lupin (Zulika variety) meal, respectively. The seed of white lupine was industrially (mechanically) "dehulled" on the principle of grinding off. Complete feed mixtures were balanced and optimised including additivesby a company producing commercial feed mixtures for poultry (ZZN Pelhrimov a.s., Czech Republic). The Zulika variety was selected as the most promising variety of white lupin suitable nutritionally and in relation to possible cultivation in the soil and climatic conditions of the Czech Republic. The selection of the suitable white lupin variety and the recommended percentage replacement of soybean extracted meal by lupin

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meal are based on the solution of the project NAZV MZe CR QJ1510136.

In ducklings, the light regime was 23 h of light and 1 h of darkness at the beginning of the fattening phase, and 18 h of light and 6 h of darkness during the growing phase. Commercially produced complete feed mixtures and drinking water were given to ducklings *ad libitum* throughout the fattening period via tube feeders and drinkers. Commercially produced feed mixtures were given to the ducklings in a crushed form (VKCH Start) and then in a granular form (VKCH1, VKCH2, VKCH3). For the commercial preparation of feed mixtures, the following ingredients were used: soybean meal, white lupin meal (Zulika), maize, wheat, rape meal, sunflower meal (major part dehulled), soybean oil and feed additives on the basis of synthetic amino acids, vitamins, minerals and enzymes. Utility Model No. 31532 (Strakova et al. 2018) was used for the preparation of complete feed mixtures. In the experiment, the following feeding schedule was used: days 1–10 of fattening (VKCH Start), days 11–20 of fattening (VKCH1), days 21–35 of fattening (VKCH2) and days 36–42 of fattening (VKCH3). Besides the above-mentioned nutrients, the feed mixtures were analysed (in accordance with the analytical procedures of the Central Institute for Supervising and Testing in Agriculture) for basic nutrients. Changes in the content of basic nutrients in g/kg of dry matter are written in group order C, E_{50} and E_{100}. Nutrients for VKCH start: crude protein 250, 243, 274 g/kg; fat 40.2, 37.3, 67.3 g/kg; fibre 26.3, 24.5, 17.4 g/kg; ash 62.0, 61.5, 55.6 g/kg; ME 12.9, 12.9, 13.8 MJ/kg; for VKCH1: crude protein 221, 224, 215 g/kg; fat 37.5, 45.7, 53.5 g/kg; fibre 27.2, 27.0, 22.7 g/kg; ash 60.2, 56.0, 57.4 g/kg; ME 12.8, 13.0, 13.2 MJ/kg; for VKCH2: crude protein 191, 181, 187 g/kg; fat 35.1, 42.1, 51.1 g/kg; fibre 27.1, 25.1, 27.3 g/kg; ash 52.2, 45.1, 48.7 g/kg; ME 12.7, 13.0, 13.1 MJ/kg; for VKCH3: crude protein 179, 164, 174 g/kg; fat 38.3, 45.4, 51.2 g/kg; fibre 32.8, 27.9, 28.6 g/kg; ash 50.5, 45.5, 45.7 g/kg; ME 12.8, 13.0, 13.0 MJ/kg.

Nutritional composition of white lupin and complete feed mixtures

For accuracy of comparison, the individual nutritional parameters were expressed in g per 1 kg of dry matter, which was determined by drying the sample at 105 °C under prescribed conditions. Complete analyses were carried out after the sample drying; only the analysis of crude protein (CP) content, in which nitrogen was determined by the Kjeldahl method using the Buchi analyser (Centec automatika, spol. s.r.o., Prague, Czech Republic) multiplied by a coefficient of 6.25. As part of the analyses, the sample was analysed for amino acid content, after acid hydrolysis, by an automatic amino acid analyser AAA 400 (INGOS a.s., Prague, Czech Republic) based on the colour-forming reaction of amino acids with the oxidising agent ninhydrin. From the spectrum of analysed amino acids, the attention was focused on Asp, Thre, Ser, Glu, Pro, Gly, Ala, Val, Met, Ile, Leu, Tyr, Phe, His, Lys, Arg.

Performance indicators and selected breast and thigh muscle indicators

Feed conversion ratio, live weight and mortality of ducks were monitored during the experiment. From 20 selected ducks (selected according to the average slaughter weight) from each group (10 females and 10 males), the right breast and thigh muscles were sampled at the end of fattening (day 42). Subsequently, the dry matter of the muscle was determined for crude protein and amino acid composition. The analytical part of the work was carried out in the laboratory of the Faculty of Veterinary Hygiene and Ecology of the University of Veterinary Sciences Brno according to the procedure described for the analysis of complete feed mixtures.

Statistical methods

Unistat v5.6 for Excel was used for the statistical analysis of the data. Evaluation of mean values and their differences was performed by multiple comparisons using the Tukey-HSD testat a significance level of $P \leq 0.05$. Each indicator is characterised by the value of the mean (x) and standard deviation (± SD).

RESULTS AND DISCUSSION

Table 1 shows the average values of crude protein and amino acid content of whole seed and dehulled seed of white lupin var. Zulika and indicates the dif-

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Table 1. Crude protein (CP), sum of amino acid (essential eAA, non-essential nAA and total AA) contents of seed and dehulled seed of white lupin variety Zulika in g/kg of dry matter, including the difference between seed and dehulled seed

Zulika	Seed	Dehulled seed	Difference
CP	387	445	−58.0
Σ eAA	144	181	−37.0
Σ nAA	202	268	−66.0
Σ AA	346	449	−103.0

ference between these products. The feed mixtures for fattened Cherry Valley ducks were optimised based on dehulled white lupin seed and differences between the tested feed mixtures in the monitored parameters are presented in Table 2.

Substitution of soybean meal statistically influenced the live weight development of ducklings. At the end of fattening (day 42), the mean live weight of Cherry Valley ducks was 3.22 ± 0.28 kg for C, 3.40 ± 0.27 kg for E_{50}, and 3.48 ± 0.28 kg for E_{100}. Statistically significant differences ($P \leq 0.05$) were noted between the mean live weight values on the 42nd day of age between the C and E_{50} groups and C and E_{100} groups. Similar results for fattened ducks were obtained by Strakova et al. (2015), when feed mixtures were prepared based on white lupin, Amiga variety. The authors recorded average live weight values ranging from 3.03 kg to 3.14 kg in females on the 42nd day of age, while in males the average live weight was observed to range from 3.02 kg to 3.15 kg. For the studied groups of fattened ducks, mortality was 5.88% for C, 1.47% for E_{50} and 1.49% for E_{100}. The improvement in the health status (as assessed by mortality) may be related to the oligosaccharide content of lupin seeds and higher arginine content in lupin protein as reported by Geigerova et al. (2017) according to their results.

Table 2. Changes in crude protein and amino acid (essential eAA, non-essential nAA and total AA) content in g/kg of dry matter of VKCH Start, VKCH1, VKCH2 and VKCH3 feed mixtures when replacing soybean meal with dehulled lupin seed meal, difference between feed mixtures C and E_{50} and C and E_{100}

	C	E_{50}	Difference	E_{100}	Difference
Feed mixture: VKCH Start					
CP	250	243	7.00	274	−24.0
Σ eAA	113	113	−0.00	126	−13.0
Σ nAA	133	128	5.00	139	−6.00
Σ AA	246	241	5.00	266	−20.0
Feed mixture: VKCH1					
CP	221	224	−3.00	215	6.00
Σ eAA	95.0	101	−6.00	100	−5.00
Σ nAA	114	117	−3.00	113	1.00
Σ AA	209	219	−10.0	214	−5.00
Feed mixture: VKCH2					
CP	191	181	10.0	187	4.00
Σ eAA	85.0	80.9	4.10	88.5	−3.50
Σ nAA	105	99.7	5.30	105	0.00
Σ AA	190	180	10.0	193	−3.00
Feed mixture: VKCH3					
CP	179	164	15.0	174	5.00
Σ eAA	76.8	70.1	6.70	75.9	0.90
Σ nAA	98.4	89.7	8.70	94.9	3.50
Σ AA	175	159	16.0	170	5.00

C – control; CP – crude protein; E_{50} – 50% replacement of soybean meal with dehulled lupin seed meal; E_{100} – 100% replacement of soybean meal with dehulled lupin seed meal

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Similar research was done by Jerabek et al. (2018), who optimised the content of white lupin seeds, Zulika variety, in diets for fattened Cherry Valley ducks and evaluated the effect of lupin meal-based diets on duck biochemical parameters. Considering the results of biochemical analyses, the authors stated that dietary replacement of soybean meal with lupin meal of Zulika variety did not have a negative effect on the evaluated biochemical parameters of blood plasma and recommended lupin seeds as a suitable feed ingredient for fattening the Cherry Valley ducks. The addition of white lupin seeds at an optimal level to feed mixtures and their effect on animal health, specifically biochemical indicators (as markers of possible physiological changes), was addressed by Yang et al. (2017). An important economic indicator of poultry fattening is feed consumption per kg of live weight (conversion). Overall, for ducks, the feed conversion was lowest in the E_{50} group (2.27 kg/kg) and highest in the E_{100} group (2.71 kg/kg) compared to the C group (2.33 kg/kg) for the fattening period. The higher feed conversion ratio in the E_{100} group may be explained by the fact that lupin meal was used as the only dominant protein source in the E_{100} group. From the obtained results of yield, it can be said that the experimental feed mixtures did not negatively affect the production efficiency, the E_{50} mixture showed better production results compared to the control, which along with low mortality also affected the efficiency of fattening. In accordance with the results of this study, Biesek and Kuzniacka (2020) reported that yellow lupin seeds in feed mixtures for ducklings,as a high-protein ingredient of feed mixtures, did not affect most nutritional parameters or physicochemical indices of their muscles. They concluded that lupin meal could be proposedas a partial alternative to soybean meal.

Geigerova et al. (2017) investigated the effect of dietary white lupin (variety Zulika) on the composition of the gut microbiota in broiler chickens and ducklings. Broiler chickens and ducklings received diets based on soybean meal (control group) and diets with 50% and 100% replacement of soybean meal with lupin meal. The addition of lupin to the diets of broiler chickens and ducklings did not significantly affect the observed bacterial microflora in the gastrointestinal tract, but the complete replacement of soy meal with lupin meal significantly ($P < 0.05$) increased the lactobacilli counts in the caecum. The results of Geigerova et al. (2017) indicate that the partial dietary replacement of soybean meal with lupin meal did not significantly affect the live weight of broiler chickens and ducklings. The authors suggested that using lupin as the only protein source may lead to a reduction in the live weight of broiler chickens and ducklings. However, the results of this study did not confirm this fact.

The results in Table 3 show that there were no statistically significant differences in the average dry matter and crude protein content of the breast or thigh muscle of fattened ducks between the control and experimental groups (C and E_{50}, C and E_{100}). Results of breast muscle essential amino acids (eAA) and non-essential (nAA) amino acids show (see Table 4) that compared to the control, the experimental diets affected the content of individual amino acids in breast muscle. For both groups of amino acids, the mean values were significantly ($P \leq 0.05$) lower in the breast muscle of E_{50} and E_{100} groups compared to the control. For most amino acids, the amino acid content in the breast muscle of ducks decreased with increasing amounts of lupin in the diet. This fact is confirmed by the results in Table 5, where the statistically significantly ($P \leq 0.05$) highest content of all amino acids (∑ AA) was in the breast and thigh muscle of the control group (791 g/kg), significantly ($P \leq 0.05$) lower in the E_{50} group (727 g/kg) and significantly ($P \leq 0.05$) lowest in the E_{100} group (670 g/kg). Based on the results of eAA (Table 6) and nAA (Table 4) analysis of thigh muscle dry matter it can be con-

Table 3. Mean values of dry matter (DM) and crude protein (CP) in the breast and thigh muscle of ducklings in g/kg of dry matter

Variable	Group	Breast muscle	Thigh muscle
DM	C	234 ± 7.15	275 ± 14.7
	E_{50}	236 ± 8.73	279[a] ± 18.3
	E_{100}	236 ± 6.37	266[b] ± 10.9
CP	C	816 ± 24.6	685 ± 33.2
	E_{50}	816 ± 27.2	679 ± 36.2
	E_{100}	820 ± 15.3	692 ± 37.9

[ab]Means with a letter are significantly different at $P \leq 0.05$; $n = 20$

C – control; E_{50} – 50% replacement of soybean meal with dehulled white lupin meal; E_{100} – 100% replacement of soybean meal with dehulled white lupin meal

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Table 4. Mean values of non-essential amino acids in the breast and thigh muscle of ducklings in g/kg of dry matter

Variable	Group	Breast muscle	Thigh muscle
Aspartic acid	C	77.3^{a} ± 4.29	63.9^{a} ± 5.50
	E_{50}	73.8^{a} ± 6.13	55.2^{b} ± 3.98
	E_{100}	66.5^{b} ± 4.75	54.6^{b} ± 65.1
Serine	C	31.0^{a} ± 2.90	25.0^{a} ± 2.42
	E_{50}	31.1^{a} ± 2.17	23.1^{b} ± 1.83
	E_{100}	27.6^{b} ± 1.78	22.7^{b} ± 2.60
Glutamic acid	C	120 ± 5.51	102 ± 9.09
	E_{50}	121^{a} ± 6.48	100 ± 8.66
	E_{100}	115^{b} ± 6.57	104 ± 10.3
Proline	C	37.4^{a} ± 4.89	37.2^{a} ± 1.73
	E_{50}	34.6^{a} ± 3.60	29.1^{b} ± 2.42
	E_{100}	28.8^{b} ± 4.24	27.7^{b} ± 1.98
Glycine	C	40.5^{a} ± 1.86	37.4^{a} ± 2.01
	E_{50}	37.4^{a} ± 3.36	31.9^{b} ± 1.56
	E_{100}	34.3^{b} ± 2.94	32.1^{b} ± 2.00
Alanine	C	54.0^{a} ± 2.82	45.2^{a} ± 3.25
	E_{50}	50.8^{bc} ± 4.02	38.9^{b} ± 2.43
	E_{100}	47.8^{bd} ± 3.79	44.2^{a} ± 4.19
Tyrosine	C	23.8^{a} ± 2.31	20.6^{a} ± 3.00
	E_{50}	23.6 ± 3.39	19.8 ± 2.42
	E_{100}	21.5^{b} ± 2.85	18.4^{b} ± 2.73

$^{a–d}$Means with a letter are significantly different at $P \leq 0.05$; $n = 20$

C – control; E_{50} – 50% replacement of soybean meal with dehulled white lupin meal; E_{100} – 100% replacement of soybean meal with dehulled white lupin meal

cluded that compared to the control, the experimental diets had a statistically significant ($P \leq 0.05$) effect on the reduction of the content of individual amino acids in thigh muscle. For most of the eAA, their mean values were significantly ($P \leq 0.05$) lower in the thigh muscle of ducks from E_{50} and E_{100} compared with the control, except for phenylalanine. Most of the nAA were lower ($P \leq 0.05$) in E_{50} and E_{100} compared to the control, except for glutamic acid. The above results also correspond with the total content of ∑ eAA and ∑ nAA as shown in Table 5. For ∑ eAA, their total ctablontent in the thigh muscle of ducks in groups E_{50} and E_{100} was significantly ($P \leq 0.05$) lower (259 g/kg and 272 g/kg) compared to the control (323 g/kg), similarly for ∑ nAA in the E_{50} and E_{100} groups (298 g/kg and 304 g/kg) compared to the control (332 g/kg).

Table 5. Mean values of essential (∑ eAA), non-essential (∑ nAA) and total amino acids (∑ AA) in the breast and thigh muscle of ducklings in g/kg of dry matter

Variable	Group	Breast muscle	Thigh muscle
∑ eAA	C	407^{a} ± 22.9	323^{a} ± 52.9
	E_{50}	354^{bc} ± 28.3	259^{b} ± 23.6
	E_{100}	327^{bd} ± 21.4	272^{b} ± 21.0
∑ nAA	C	384^{a} ± 16.2	332^{a} ± 23.7
	E_{50}	372^{a} ± 23.6	298^{b} ± 20.4
	E_{100}	342^{b} ± 22.8	304^{b} ± 21.3
∑ AA	C	791^{a} ± 33.8	655^{a} ± 74.5
	E_{50}	727^{bc} ± 50.3	557^{b} ± 43.0
	E_{100}	670^{bd} ± 43.6	576^{b} ± 41.8

$^{a–d}$Means with a letter are significantly different at $P \leq 0.05$; $n = 20$

C – control; E_{50} – 50% replacement of soybean meal with dehulled white lupin meal; E_{100} – 100% replacement of soybean meal with dehulled white lupin meal

As for the dry matter composition of duckling breast and thigh muscle, it can be concluded that diets containing lupin meal resulted in a decrease in the content of individual muscle amino acids, which may be related to the increased muscle fat content in the breast (C 86.2 g/kg, E_{50} 91.8 g/kg, E_{100} 88.2 g/kg) and thigh (C 245 g/kg, E_{50} 264 g/kg, except E_{100} 225 g/kg) muscle of Cherry Valley ducklings. Similar conclusions in fattening the broiler chickens were reached by Kutlvasr et al. (2022), Kutrlvasr (2023), where the qualitative composition of lupin oil led to an increase in the quality of the chicken muscle fat, as assessed by their muscle fat composition. The degree of digestibility and utilisation of nutrients from feed mixtures and their subsequent effect on the nutritional value of animal products is co-determined by several factors, which may include: the conversion of the feed conversion efficiency, which reflects the nutrient intake and production efficiency of the feed mixture and the combination of dietary protein sources, which may show the physiological requirement of AA in the organism. An important factor may also be the content of individual eAA and their relative proportions and/or the fibre content, which co-determines the digestibility and utilisation of nutrients by the organism. Last but not least the fat content may influence the protein or AA content of the animal product, where protein content and fat content are inversely related. Physical processes like heat

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Table 6. Mean values of essential amino acids in the breast and thigh muscle of ducklings in g/kg of dry matter

Variable	Group	Breast muscle	Thigh muscle
Threonine	C	37.8^{a} ± 1.33	30.8^{a} ± 3.08
	E_{50}	35.4^{bc} ± 2.70	26.0^{b} ± 2.02
	E_{100}	32.2^{bd} ± 2.32	26.0^{b} ± 2.07
Valine	C	39.4^{a} ± 2.89	30.3^{a} ± 5.03
	E_{50}	36.1^{bc} ± 3.82	26.1^{b} ± 2.69
	E_{100}	32.5^{bd} ± 3.41	27.3^{b} ± 3.19
Methionine	C	13.6 ± 4.26	13.4^{a} ± 5.67
	E_{50}	13.2 ± 4.78	9.8^{b} ± 3.37
	E_{100}	13.0 ± 3.37	10.0^{b} ± 3.39
Isoleucine	C	40.4^{a} ± 2.10	33.1^{a} ± 5.11
	E_{50}	35.6^{b} ± 2.65	28.0^{b} ± 3.16
	E_{100}	35.6^{b} ± 2.52	30.7 ± 2.27
Leucine	C	68.5^{a} ± 4.51	53.4^{a} ± 9.53
	E_{50}	57.2^{b} ± 7.32	45.3^{b} ± 7.12
	E_{100}	59.6^{b} ± 3.69	51.7^{a} ± 3.94
Phenylalanine	C	20.8^{b} ± 3.31	18.5 ± 2.32
	E_{50}	23.2^{a} ± 2.43	17.1 ± 2.54
	E_{100}	20.9 ± 3.88	17.9 ± 2.70
Histidine	C	27.7^{a} ± 2.04	21.4^{a} ± 3.39
	E_{50}	26.0^{a} ± 2.23	18.4^{b} ± 2.07
	E_{100}	23.8^{b} ± 2.58	20.1 ± 1.75
Lysine	C	95.4^{a} ± 11.6	69.3^{a} ± 21.9
	E_{50}	71.9^{bc} ± 9.59	52.4^{b} ± 4.08
	E_{100}	64.2^{bd} ± 4.03	53.5^{b} ± 4.62
Arginine	C	63.9^{a} ± 4.07	53.1^{a} ± 6.73
	E_{50}	56.4^{bc} ± 9.99	36.5^{b} ± 6.31
	E_{100}	45.9^{bd} ± 3.81	35.1^{b} ± 4.04

$^{a–d}$Means with a letter are significantly different at $P \leq 0.05$; $n = 20$

C – control; E_{50} – 50% replacement of soybean meal with dehulled white lupin meal; E_{100} – 100% replacement of soybean meal with dehulled white lupin meal

treatment affect primarily the antinutritional substances of soybean products, while heat treatment of lupin products may lead to the better utilisation of dietary nutrients.

CONCLUSION

From the results it can be said that the addition of lupin meal to the diet fed during fattening positively influenced the growth and average slaughter weight at 42 days of duck age. Lupin diets (E_{50} and E_{100}) had a positive effect on the mortality of ducks during fattening, which was reflected by their significantly lower mortality in the experimental groups. The production efficiency of the experimental diets was not negatively affected. The results presented in this study show that there are not any significant differences in the average crude protein content of the breast muscle of fattened ducks between control and experimental ducks. It can be concluded from the results of the amino acid analysis of breast and thigh muscle dry matter for eAA and nAA that compared to the control, the mean values of these amino acids were significantly lower in the breast and thigh muscle of experimental ducks. The lower contents of individual eAA and nAA are related to their lower contents in lupin meal-based diets compared to soybean meal-based diets. This fact is supported by the results for most individual amino acids (as the amount of lupin in the diet increases, the amino acid content in duck breast muscle decreases). It can be stated that in feed mixtures used for fattening of ducklings, soybean meal can be replaced by dehulled lupin meal, both 50% and 100%. The 50% replacement is considered as optimal, which in practice provides better optimisation of the feed formulation due to the combination of two protein sources.

Conflict of interest

The authors declare no conflict of interest.

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