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Original Article

Effects of Lupin Kernel (Lupinus angustifolius) and Faba Bean (Vicia faba) on Growth Performance and Hepatic Fatty Acid Profiles in Broiler Chicks

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ABSTRACT

This study was conducted to evaluate the effect of feeding lupin kernel and faba bean as an alternative to soybean meal on the growth performance, blood profiles, relative organ weight, and hepatic fatty acid composition of broiler chicks. A total of 525, 1-day-old Ross 308 male chicks were randomly assigned into five groups with seven replicates. The treatments consisted of five experimental diets; corn-soybean meal without lupin or faba bean (as control), diets with lupin 5% or 10%, and diets with faba bean 5% or 10%. The body weight (BW) and average daily gain (ADG) were not significantly different among the groups during starter period. However, BW and ADG of chicks fed diets with 10% lupin and faba bean were significantly higher than those of 5% lupin and faba bean during grower period ($p<0.01$). The feed conversion ratio was significantly lower in the group fed diets with 10% lupin and faba bean than the control during total rearing periods ($p<0.001$). There were no significant differences in blood profiles among the groups. As for the hepatic fatty acid composition, the levels of total polyunsaturated fatty acids and total ω6 in chicks fed lupin and faba bean were significantly higher than the control. It was suggested that dietary lupin and faba bean could enhance the incorporation of the beneficial fatty acids into liver fraction. In conclusion, supplementation of lupin and faba bean up to 10% can be used as an alternative to soybean meal in broiler diets.

INTRODUCTION

Feed cost accounts for about 65-75% of poultry production, so there have been many attempts to lower feed cost. One of these attempts was to replace expensive feedstuffs with cheaper, more abundant by-products (El-Deek *et al.*, 2020). Soybean meal is a major protein source used in broiler feed worldwide and is a frequently used raw material because of its high crude protein and amino acid contents (Hejdysz *et al.*, 2019). However, as the price and supply of soybean meal are changing rapidly in the global market, attention is focused on developing and applying new raw materials that can replace soybean meal (Abd El-Hack *et al.*, 2017).

Faba bean (*Vicia faba* L.) is a legume mainly produced in temperate regions such as Canada and it produces more per unit area compared to other legumes. Faba bean grains have a starch content of 43% and crude protein content of about 28% (FAO, 2020), which is evaluated to be excellent as an alternative raw material that can replace soybean meal, a major protein ingredient constituting broiler feed. One of the benefits is that starch digestion occurs slowly, which is expected to help improve gut health and function (Regassa & Nyachoti, 2018). In addition, the protein level is moderately high and the amino acid content is similar to soybean meal except for the sulfur-containing amino acids. (Hejdysz *et al.*, 2019). There were no adverse or undesirable effects concerning body weight development, carcass quality, and fattening parameters when 20% faba bean was fed in broilers (Nolte *et al.*, 2020).

Lupin (blue-lupin, *Lupinus angustifolius*) is a world-wide common legume with annual production of 1.2 million tonnes in 2011 and a year-round plant (Kaczmarek *et al.*, 2014; Al-Sagan *et al.*, 2020). In poultry, the energy and amino acid digestibility of lupin is relatively low, but it can be used without negative effects if it undergoes an appropriate value evaluation as it contains few anti-nutritional factors such as alkaloids, phytates, protease inhibitors and lectins (Lee *et al.*, 2016; Zapletal *et al.*, 2020). Through the extrusion process, fat digestibility and nitrogen retention in chickens were improved and the apparent metabolizable energy was enhanced (Hejdysz *et al.*, 2018). Lupin grains can be used as an alternative protein source due to their high protein and oil content (Mera-Zúñiga *et al.*, 2019). In a previous study, laying hens fed diets with 15% lupine resulted in a similar performance compared with those fed the soybean meal based diet (Lee *et al.*, 2016).

This study was conducted to evaluate the effects of lupin kernel and faba bean, as a partial substitute of soybean meal, on growth performance, blood profiles and fatty acid composition in broiler chicks.

MATERIALS AND METHODS

The experimental procedure was approved by the Institutional Animal Care and Use Committee of Konkuk University (KU21140).

Animals, diets, and management

Five hundred twenty-five one-day-old feather-sexed Ross 308 male broiler chicks were allocated to five treatments with seven repetitions, and 15 chicks per repetition. The randomized block design was used so that the average weight of each pen was similar. The chicks were housed in 35 floor pens (width × length × height: 180 × 180 × 200 cm) on rice straw litter. They were initially reared at 33ºC and room temperature was gradually decreased to reach 20ºC and maintained there after. Experimental diets and water were provided *ad libitum* during experimental period.

The lupin kernel and faba bean used in this study were provided by local feed factory and first analyzed for their chemical compositions according to the methods of AOAC (2000)(Table 1). Amino acid contents in lupin kernel and faba bean were determined by amino acid analyzer (Hitachi Instruments Service Co., Ltd., Tokyo, 151, Japan) following hydrolysis in 6 N HCl for 22 h at 110°C (Spackman *et al.*, 1958). Methionine and cystine were determined on samples that had been oxidized in performic acid prior to acid hydrolysis according to the method of Moore (1963). The digestible amino acid values and nitrogen-corrected apparent metabolizable energy (AMEn) were estimated through previous studies (Nalle *et al.*, 2010; Woyengo & Nyachoti, 2012; Kaczmarek *et al.*, 2014; Mera-Zúñiga *et al.*, 2019). Corn-soybean meal based diet was formulated to be similar to the recommended levels for Ross 308 (2018) and used as a control group. The experimental diets containing 5 or 10% lupin kernel and faba bean at the expense of corn and soybean meal were formulated to meet and exceed the nutrients requirement. The lupin kernel and faba bean were heat treated (at 90°C for 10 minutes) prior to use. The starter diet was fed from the start date to 15 days, and the grower diet was fed from the 16thday to the end of experiment. All diets were formulated to contain similar levels of AMEn, crude protein, and lysine and TSAA (Table 2 and 3).

Table 1 – Nutritional compositions of lupin kernel and faba bean.

Components	Lupin kernel	Faba bean
Analytical values, %		
Moisture	9.31	14.82
Crude protein	30.27	27.60
Crude fat	10.20	1.42
Crude fiber	13.77	3.48
Crude ash	3.57	3.07
Amino acids, %		
Lysine	1.49	1.62
Methionine	0.25	0.22
TSAA	0.81	0.53
Threonine	1.12	0.88
Tryptophan	0.25	0.22
Arginine	2.97	2.41
Fatty acids, % of total fatty acid		
C16:0	15.5	17.3
C18:0	6.5	4.3
C18:1 ω9	23.2	23.9
C18:2 ω6	45.8	38.4
C18:3 ω3	6.5	12.1
Calculated values, %		
Dig.lysine	1.24	1.45
Dig. methionine	0.21	0.19
Dig. TSAA	0.68	0.41
Dig. threonine	0.89	0.72
AMEn, kcal/kg	2,050	2,450

Table 2 – Ingredients and chemical compositions of experimental diets (Stater).

Components	Treatments[1]				
	Control	T1	T2	T3	T4
Ingredient, %					
Corn	49.56	46.75	43.95	46.83	44.10
Wheat	5.00	5.00	5.00	5.00	5.00
SBM	36.23	33.22	30.22	33.52	30.81
Lupin kernel	-	5.00	10.00	-	-
Faba bean	-	-	-	5.00	10.00
Soybean oil	4.85	5.62	6.38	5.24	5.62
DL-methionine, 98%	0.31	0.32	0.33	0.33	0.35
L-lysine HCl, 78%	0.26	0.29	0.31	0.26	0.26
L-threonine, 98%	0.12	0.13	0.14	0.14	0.15
Limestone	1.66	1.65	1.64	1.66	1.67
MCP	1.21	1.20	1.20	1.20	1.20
Choline Cl, 50%	0.08	0.10	0.12	0.10	0.12
Salt	0.28	0.28	0.28	0.28	0.28
Vitamin Premix[2]	0.15	0.15	0.15	0.15	0.15
Mineral Premix[3]	0.15	0.15	0.15	0.15	0.15
Phytase	0.05	0.05	0.05	0.05	0.05
$NaHCO_3$	0.08	0.08	0.08	0.08	0.08
Chemical composition calculated					
CP, %	21.00	21.00	21.00	21.00	21.00
Crude fiber, %	3.00	3.48	3.96	3.19	3.38
Ca, %	0.90	0.90	0.90	0.90	0.90
Avail. P, %	0.40	0.40	0.40	0.40	0.40
Total Lys, %	1.37	1.37	1.37	1.37	1.37
Total TSAA, %	0.99	0.99	0.99	0.99	0.99
Total Thr, %	0.90	0.90	0.91	0.90	0.90
AMEn, kcal/kg	3,050	3,050	3,050	3,050	3,050

[1]Control, Corn-SBM based diet without lupin kernel and faba bean; T1, diet with 5% lupin kernel; T2, diet with 10% lupin kernel; T3, diet with 5% faba bean; T4, diet with 10% faba bean.

[2]Vitamin mixtures provided the following nutrients per/kg feed: vitamin A, 13500 IU; vitamin D_3, 3300 IU; vitamin E, 22.5 IU; vitamin K_3, 3 mg; vitamin B_1, 2.25 mg; vitamin B_2, 7.5 mg; vitamin B_6, 4.5 mg; vitamin B_{12}, 0.03 mg; pantothenic acid, 15 mg; niacin, 45 mg; biotin, 0.225 mg; folic acid, 15 mg; antioxidant 66%, 4.5 mg.

[3]Mineral mixtures provided the following nutrients per/kg feed: Fe, 60 mg; Co, 0.075 mg; Cu, 60 mg; Mn, 90 mg; Zn, 75 mg; I, 1.5 mg; Se, 0.15 mg.

Table 3 – Ingredients and chemical compositions of experimental diets (Grower).

Components	Treatments[1]				
	Control	T1	T2	T3	T4
Ingredient, %					
Corn	53.62	50.82	48.01	50.90	48.18
Wheat	5.00	5.00	5.00	5.00	5.00
SBM	31.81	28.81	25.80	29.09	26.38
Lupin kernel	-	5.00	10.00	-	-
Faba bean	-	-	-	5.00	10.00
Soybean oil	5.86	6.62	7.39	6.24	6.63
DL-methionine, 98%	0.24	0.25	0.26	0.26	0.28
L-lysine HCl, 78%	0.06	0.09	0.11	0.07	0.07
L-threonine, 98%	0.03	0.04	0.05	0.04	0.05
Limestone	1.64	1.62	1.61	1.64	1.65
MCP	1.00	0.99	0.99	0.99	0.98
Choline Cl, 50%	0.07	0.09	0.11	0.09	0.11
Salt	0.28	0.28	0.28	0.28	0.28
Vitamin Premix[2]	0.15	0.15	0.15	0.15	0.15
Mineral Premix[3]	0.15	0.15	0.15	0.15	0.15
Phytase	0.05	0.05	0.05	0.05	0.05
$NaHCO_3$	0.05	0.05	0.05	0.05	0.05
Chemical composition calculated					
CP, %	19.00	19.00	19.00	19.00	19.00
Crude fiber, %	2.86	3.34	3.82	3.05	3.24
Ca, %	0.85	0.85	0.85	0.85	0.85
Avail. P, %	0.35	0.35	0.35	0.35	0.35
Total Lys, %	1.10	1.10	1.10	1.10	1.10
Total TSAA, %	0.87	0.87	0.87	0.87	0.87
Total Thr, %	0.74	0.75	0.75	0.74	0.74
AMEn, kcal/kg	3,150	3,150	3,150	3,150	3,150

[1] Control, Corn-SBM based diet without lupin kernel and faba bean; T1, diet with 5% lupin kernel; T2, diet with 10% lupin kernel; T3, diet with 5% faba bean; T4, diet with 10% faba bean.

[2] Vitamin mixtures provided the following nutrients per/kg feed: vitamin A, 13500 IU; vitamin D_3, 3300 IU; vitamin E, 22.5 IU; vitamin K_3, 3 mg; vitamin B_1, 2.25 mg; vitamin B_2, 7.5 mg; vitamin B_6, 4.5 mg; vitamin B_{12}, 0.03 mg; pantothenic acid, 15 mg; niacin, 45 mg; biotin, 0.225 mg; folic acid, 15 mg; antioxidant 66%, 4.5 mg.

[3] Mineral mixtures provided the following nutrients per/kg feed: Fe, 60 mg; Co, 0.075 mg; Cu, 60 mg; Mn, 90 mg; Zn, 75 mg; I, 1.5 mg; Se, 0.15 mg.

Growth performance

The body weight (BW) and feed intake for each pen were measured at once a week and average daily gain (ADG) was calculated through the weight of each pen measured weekly. Average daily feed intake (ADFI) was calculated through the weight of remaining amount of the feeder for each pen measured weekly. Feed conversion ratio (FCR) was calculated by comparing the feed intake (FI) and BW gain during the experiment period. Mortality rates were corrected for each rearing period during starter and grower phases. Based on the weekly weight, the predicted days to achieve 1.5 kg BW was calculated according to the growth curve to compare efficiency of the different feeding programs.

Measurement of blood profiles

At the end of the experiment (the 4th week of the experiment), one chick corresponding to the average weight was selected for each repetition group (7 chicks per treatment), blood was collected from the brachial vein, and stored in a serum separation vacuum tube, and the serum were obtained by gentle centrifugation (2,000 x *g* for 15 min) and stored at -20°C until analysis. Glutamic pyruvic transaminase (GPT) and glutamic oxaloacetic transaminase (GOT) in serum samples were measured according to the colorimetric method as previously described (An *et al.*, 2016). Blood urea nitrogen (BUN), creatine (CRE), albumin (ALB), and triacylglycerol (TG) were analyzed using an automatic dry biochemical analyzer (FujifilmDRI CHEM 7000i, Japan). Total cholesterol (TCHO) was analyzed using a kit for measuring total cholesterol (AM202, Asan Pharmaceutical). High density lipoprotein-cholesterol (HDL-C) was analyzed using HDL cholesterol analysis kit (AM203, Asan Pharmaceutical). HDL-C was subtracted from total cholesterol and calculated as the sum of very low density lipoprotein-cholesterol (VLDL-C) and low density lipoprotein-cholesterol (LDL-C).

Organ characteristics

At the end of the experiment, seven chicks per treatment were selected, individually weighed, and sacrificed. Organs, including liver, spleen, bursa of Fabricius, breast meat (excluding skin), and thigh meat (including bones), were rapidly removed and weighed and their weights were expressed as grams of organ per 100 g BW.

Fatty acids composition

One-step extraction/methylation method was used to analyse fatty acid in the liver (Garcés & Mancha, 1993). After homogenizing the sample and freeze-drying, 2 ml of the methylation mixture (MeOH :benzene : 2,2-dimethoxy-propane : H_2SO_4 = 39 : 20 : 5 : 2) and 1 ml of heptone were added, shaken, and extracted at 80°C for 2 hours. The fatty acid composition was measured by gas chromatography (Agilent 7890A, Agilent, USA) using 120 mm × 0.25 mm × 0.25 μ capillary column (DB-23, Agilent). The initial column temperature was set at 110°C and increased to 250°C at 12°C/min. The injector and detector were set at 250°C and 280°C, respectively. The peaks were identified by comparison with standard mixture of fatty acid methyl ester (Supelco 37 Component FAME Mix, Supelco, USA). Pentadecanoic acid was used as Internal standard.

Statistical analysis

Each pen was considered an experimental unit. The experimental data were analyzed using the SAS Software (SAS Inst. Inc., Cary, NC). The fixed variable of the model was the experimental diet, and the random variable was set to repetition. The experimental unit of growth performance was the pen, and other analysis items were the individual. If treatment effect was significant, differences between treatment means were evaluated using Duncan's multiple range test. Statistical significance was considered at $p<0.05$.

RESULTS AND DISCUSSION

Growth performance

Table 4 shows the dietary effects of lupin kernel and faba bean on growth performance of broilers chicks. In the starter period, there were no statistically significant differences in BW and ADG among groups. The ADFI in chicks fed diets with lupin and faba bean was significantly lower than the control, except for T1 group ($p<0.05$). On the other hand, the FCR in groups fed diets with 5% or 10% lupin kernel and 10% faba bean were significantly lower than that of the control ($p<0.05$). The BW and ADG in chicks fed 10% lupin and faba bean were higher than chicks fed 5% lupin and faba bean during the grower period ($p<0.01$). The

Table 4 – Growth performance of broiler chicks fed diets with lupin kernel and faba bean.

Items	Treatments[1]					SEM	*p*-value
	Control	T1	T2	T3	T4		
Initial BW, g	41.2	41.2	41.3	41.2	41.2	0.024	0.932
Starter period, 0-15 d							
BW, g/bird	628.9	644.2	620.8	617.8	634.2	4.070	0.247
ADG, g/bird/d	36.7	37.7	36.2	36.0	37.1	0.254	0.246
ADFI, g/bird/d	44.6[a]	42.7[ab]	41.7[b]	42.3[b]	42.2[b]	0.337	0.049
FCR	1.22[a]	1.13[b]	1.15[b]	1.17[ab]	1.14[b]	0.009	0.014
Grower period, 16-28 d							
BW, g/bird	1623.8[ab]	1606.1[b]	1655.0[a]	1591.7[b]	1654.3[a]	7.237	0.008
ADG, g/bird/d	82.9[bc]	79.9[d]	85.8[a]	81.0[cd]	84.4[ab]	0.525	<0.001
ADFI, g/bird/d	109.1[a]	106.3[b]	105.7[b]	108.2[ab]	109.3[a]	0.451	0.022
FCR	1.32[a]	1.33[a]	1.23[b]	1.33[a]	1.30[a]	0.009	<0.001
Total period							
ADG, g/bird/d	56.5[ab]	55.8[b]	57.5[a]	55.3[b]	57.3[a]	0.250	0.014
ADFI, g/bird/d	72.3[a]	70.0[bc]	69.1[c]	70.5[bc]	71.0[ab]	0.294	0.007
FCR	1.28[a]	1.26[ab]	1.20[c]	1.27[a]	1.24[b]	0.007	<0.001

[1] Control, Corn-SBM based diet without lupin kernel and faba bean; T1, diet with 5% lupin kernel; T2, diet with 10% lupin kernel; T3, diet with 5% faba bean; T4, diet with 10% faba bean.

[a-d] Mean in the same row with different superscript differ significantly ($p<0.05$).

ADFI was significantly lower in chicks fed diets with lupin ($p<0.05$). The group fed diet with 10% lupin kernel had the lowest FCR as compared with those of the other groups. The ADG in chicks fed 10% lupin and faba bean were higher than chicks fed 5% lupin and faba bean during total rearing period ($p<0.05$). The ADFI in group fed control diet was significantly higher than other groups, except for T4 group ($p<0.01$). The FCR in groups fed diet with 10% lupin kernel and faba bean were significantly improved compared to the control group ($p<0.001$).

The dietary effect of lupin and faba bean on the days to achieve 1.5 kg BW is presented in Table 5. The days to achieve 1.5 kg BW for control group was estimated to be 26.56 days. The tentative days of reaching 1.5 kg BW in T1 and T2, which were fed diets with lupin, were estimated to be 26.73 and 26.40 days, respectively. The corresponding days in chicks fed diets with 5% or 10% faba bean were 26.92 and 26.34 days, respectively.

Table 5 – The predicted days to achieve 1.5 kg body weight of broiler chicks fed diets with lupin kernel and faba bean.

Treatments[1]	Prediction equation[2]	Predicted days to achieve 1.5 kg BW
C	$y = 1.653x^2 + 11.009x + 41.2$	26.56
T1	$y = 1.5599x^2 + 12.876x + 41.2$	26.73
T2	$y = 1.769x^2 + 8.5617x + 41.3$	26.40
T3	$y = 1.6066x^2 + 10.951x + 41.2$	26.92
T4	$y = 1.7132x^2 + 10.246x + 41.2$	26.34
SEM		0.067

[1] Control, Corn-SBM based diet without lupin kernel and faba bean; T1, diet with 5% lupin kernel; T2, diet with 10% lupin kernel; T3, diet with 5% faba bean; T4, diet with 10% faba bean.

[2] x = rearing day, y = body weight.

Previous results on the dietary effects of lupin kernel and faba bean on performance, as an alternative for soybean meal for broiler diet, have been contradictory. Nalle *et al.* (2010) found that when four different varieties of faba bean were fed to broilers, there were no differences in BW gain, FI and FCR compared to the corn-soybean meal control group. The FI of chicks fed extruded faba bean was significantly lower than that of the control during the total experimental period, and the FCR was also significantly improved, although there was no significant difference in BW gain (Hejdysz *et al.*, 2019). On the contrary, FCR was significantly higher for broiler chicks fed faba bean and barley mix or lupin as compared with the wheat-soybean meal control diet with no differences in FI and BW gain (Olukosi *et al.*, 2019). This discrepancy may be attributed to differences in dietary energy and amino acids density, inclusion levels and application of energy values of lupin and faba bean. In the present study, ADFI or FCR were lowered by feeding 10% lupin and faba bean during total rearing period. This is probably because the AMEn of lupin and faba bean were underestimated. The tentative days of reaching 1.5 kg BW of broilers chicks fed two levels of lupin and faba bean were similar to those fed the corn-soybean meal diet. This result suggested that lupin and faba bean are good sources of energy, crude protein and amino acids and can be included at 10% level as a partial replacement for corn and soybean meal for broiler diets.

Blood profiles and relative weight of organs

The blood profiles of broiler chicks fed diets with varying levels of lupin and faba bean are presented in Table 6. There were no significant differences in BUN, CRE, ALB, and activities of GOT and GPT. The levels of TG, TCHO and HDL-C were not also affected by dietary treatments.

Table 6 – Blood profiles of broiler chicks fed diets with lupin kernel and faba bean.

Items[2]	Treatments[1]					SEM	*p*-value
	Control	T1	T2	T3	T4		
GOT, U/L	180.3	159.3	159.5	168.7	146.9	5.759	0.459
GPT, U/L	4.75	4.83	4.58	5.14	4.93	0.174	0.899
BUN, mg/dℓ	1.05	1.13	1.05	1.13	1.13	0.024	0.688
CRE, mg/dℓ	0.14	0.13	0.13	0.15	0.14	0.003	0.461
ALB, g/dℓ	0.87	0.90	0.90	0.99	0.80	0.030	0.410
TG, mg/dℓ	28.3	24.3	20.0	27.7	25.3	1.007	0.070
TCHO, mg/dℓ	96.4	100.3	94.9	102.6	107.7	2.400	0.476
HDL, mg/dℓ	51.9	58.1	50.9	64.3	61.0	1.940	0.127
VLDL+LDL, mg/dℓ	46.8	44.5	43.9	42.2	38.3	2.170	0.810

[1]Control, Corn-SBM based diet without lupin kernel and faba bean; T1, diet with 5% lupin kernel; T2, diet with 10% lupin kernel; T3, diet with 5% faba bean; T4, diet with 10% faba bean.

[2]GPT, glutamic pyruvic transaminase; GOT, glutamic oxaloacetic transaminase; BUN, blood urea nitrogen; CRE, creatine; ALB, albumin; TG, triacylglycerol; TCHO, total cholesterol; HDL-C, high density lipoprotein-cholesterol; VLDL-C, very low density lipoprotein-cholesterol; LDL-C, low density lipoprotein-cholesterol.

Zapletal *et al.* (2020) reported that serum cholesterol and TG were significantly lowered when whole lupin was fed to broilers as a substitute for soybean meal. Tomaszewska *et al.* (2018) also found that TCHO was significantly lowered in chicks fed low tannin faba bean. They explained that the changes in the concentration of TCHO and TG, which decreased probably due to the higher amount of fiber in the experimental diets. In this study, chicks fed diet lupin and faba bean had TCHO and TG comparable to those of chicks fed control diet, and this disparate effect on serum TCHO and TG may be because dietary crude fiber levels are similar between the groups. In addition, there were no influence of the lupin and faba bean on most of the analyzed serum profiles in broiler chicks. The latter result agreed with that from Tomaszewska *et al.* (2018) who found no significant difference in serum GOT, GPT and CRE of chicks fed diets with faba bean.

The relative weight of organs of broiler chicks fed diets with lupin and faba bean are presented in Table 7. There were no influence of lupin kernel and faba bean on weight of liver, spleen, bursa of Fabricius, breast and thigh in 28-day-old broiler chicks. Biesek *et al.* (2020) found that no significant difference in the weight of breast in chicks fed diets with lupin and faba bean instead of SBM. Przywitowski *et al.* (2016) also reported that no significant difference in the relative weights of breast, thigh, and liver in chicks fed diets with two kinds of faba bean. Thus, these results suggest that lupin kernel and faba bean can partially replace corn and soybean meal without any detrimental effects on blood profiles and organ weights.

Table 7 – Relative weights of various organs of broiler chicks fed diets with lupin kernel and faba bean.

Items	Treatments[1]					SEM	*p*-value
	Control	T1	T2	T3	T4		
	g/100 g BW						
Spleen	0.09	0.09	0.12	0.10	0.10	0.004	0.085
Liver	1.78	1.79	1.78	1.72	1.88	0.020	0.518
Bursa of Fabricius	0.22	0.23	0.27	0.20	0.25	0.008	0.132
Right Breast	10.73	10.23	10.17	10.32	10.08	0.114	0.425
Right Thigh	9.65	9.73	9.65	9.71	9.57	0.073	0.975

[1]Control, Corn-SBM based diet without lupin kernel and faba bean; T1, diet with 5% lupin kernel; T2, diet with 10% lupin kernel; T3, diet with 5% faba bean; T4, diet with 10% faba bean.

Hepatic fatty acids composition

The hepatic fatty acid composition of broiler chicks fed diets with lupin kernel and faba bean is shown in Table 8. In the control group, the levels of C16:0 and ∑saturated fatty acids (SFA) were significantly higher than those of other groups ($p<0.001$). The levels of C18:2 ω6, ∑polyunsaturated fatty acids (PUFA), and total ω6 of chicks fed diets with lupin and faba bean were significantly higher than those of the control ($p<0.05$). The chicks fed diets with lupin and faba bean had higher levels of C18:3 ω3 than the control, except for lupin 5% group. By supplementation of faba bean (T3 and T4), the levels of C18:0 and ∑SFA was significantly or numerically decreased as compared with other groups.

This result agreed with Cazzato *et al.* (2014) who reported that the levels of C18:2 ω6, ∑MUFA, and ∑PUFA were significantly increased when lupin and faba bean fed to broiler chicks. Dietary dehulled faba bean has been reported to decrease in the levels of C16:0, C18:0, and ∑SFA and to increase in ∑PUFA in guinea fowl breast meat (Tufarelli & Laudadio, 2015). Laudadio *et al.* (2011) also found that the level of C18:2 ω6, ∑monounsaturated fatty acids (MUFA) and ∑PUFA were significantly increased when dehulled-micronized faba bean was fed to broiler chickens. As expected, the fatty acid profile of lupin and faba bean were reflected in the hepatic fatty acid composition. The liver of avian plays an important role in digestion and metabolism, regulating the production, storage and released of lipids (Hermier, 1997). Due to poorly developed intestinal lymphatic system in birds, dietary fatty acids are drained directly into the portal blood system as exogenous lipoprotein which are termed portomicron (Zaefarian *et al.*, 2019). Our results clearly show that feeding lupin kernel and faba bean increased PUFAs while decreasing SFA in the hepatic tissue. It is well known that dietary intake of PUFA is effective in lowering blood lipids level (Grudy & Denke, 1990). Dietary lupin kernel and faba bean will have a positive effect on nutritional quality of edible meats with respect to increasing the deposition of PUFAs into tissue lipids.

The present study showed that feeding of lupin kernel and faba bean in broiler feed could improve

Table 8 – Hepatic fatty acid composition of broiler chicks fed diets with lupin kernel and faba bean.

Items	Treatment[1]					SEM	p-value
	Control	T1	T2	T3	T4		
C16:0	21.32^{a}	19.27^{b}	18.03^{bc}	18.72^{bc}	17.30^{c}	0.316	<0.001
C16:1	1.08^{a}	0.90^{a}	0.45^{b}	1.02^{a}	0.82^{a}	0.073	0.002
C18:0	24.26^{a}	23.60^{a}	24.41^{a}	21.06^{b}	22.76^{ab}	0.591	0.036
C18:1 ω9	15.76	13.45	12.65	15.13	14.21	0.727	0.540
C18:2 ω6	22.96^{c}	25.21^{b}	28.52^{a}	25.24^{b}	25.54^{b}	0.537	<0.001
C18:3 ω6	0.41	0.46	0.57	0.63	0.55	0.044	0.153
C18:3 ω3	0.83^{c}	1.01^{bc}	1.34^{a}	1.12^{ab}	1.10^{abc}	0.064	0.008
C20:3 ω6	0.90^{bc}	1.37^{a}	0.83^{c}	1.21^{ab}	1.44^{a}	0.065	0.004
C20:4 ω6	9.76	11.57	10.21	12.55	13.06	0.639	0.435
C22:0	0.76^{b}	0.77^{b}	0.88^{a}	0.69^{b}	0.71^{b}	0.023	0.002
C20:5 ω3	0.31^{ab}	0.44^{a}	0.24^{b}	0.46^{a}	0.45^{a}	0.032	0.033
C22:6 ω3	1.65	1.96	1.87	2.18	2.07	0.149	0.805
∑SFA	46.34^{a}	43.64^{b}	43.32^{b}	40.47^{c}	40.77^{c}	0.713	<0.001
∑MUFA	16.84	14.35	13.10	16.15	15.02	0.785	0.444
∑PUFA	36.82^{b}	42.01^{a}	43.58^{a}	43.38^{a}	44.21^{a}	0.763	0.014
total ω3	2.79	3.41	3.45	3.76	3.62	0.156	0.309
total ω6	34.03^{b}	38.61^{a}	40.13^{a}	39.62^{a}	40.58^{a}	0.629	0.006
ω3/ω6	0.08	0.09	0.09	0.10	0.09	0.003	0.478

[1]Control, Corn-SBM based diet without lupin kernel and faba bean; T1, diet with 5% lupin kernel; T2, diet with 10% lupin kernel; T3, diet with 5% faba bean; T4, diet with 10% faba bean.

[a-c]Mean in the same row with different superscript differ significantly (p<0.05).

growth performance without adversary effects of broiler chicks. In addition, it was suggested that dietary lupin kernel and faba bean could enhance the incorporation of the beneficial fatty acids into the tissues.

CONFLICT OF INTERESTS

We declare that we have no financial or personal relationships with other organizations that can inappropriately influence our work.

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