

Effects of replacing soybean meal with perilla seed meal on growth performance, and meat quality of broilers

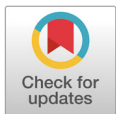
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Abstract

The purpose of this study was to evaluate effects of replacing soybean meal with perilla seed meal (PSM) on growth performance, proximate composition of meat, meat quality, and fatty acids composition of meat in broilers. A total of 60 one-day-old chicks of ROSS 308 (initial body weight of 44.8 ± 0.4 g) were randomly allotted to four treatment groups (15 replicate cages with 1 broilers per cage) in a period of 5 weeks. Dietary treatments included control (CON) basal diet (corn-soybean meal-based diets) and test diets in which PSM was included at 0.5% (T1), 1% (T2), or 2% (T3) to gradually replace soybean meal. At the end of experiment, all broilers were slaughtered for collecting breast and thigh meat. At 5 weeks, T2 and T3 treatment groups had higher ($p < 0.05$) body weights than CON and T1 treatment groups. Weight gain was increased ($p < 0.05$) in T2 and T3 treatment groups. Feed intake was decreased ($p < 0.05$) in T3 treatment group. Broilers in T2 treatment group had lower ($p < 0.05$) feed conversion ratio than those in other treatment groups. In proximate composition of breast meat, there was no significant ($p > 0.05$) difference in moisture and ash. Fat composition of breast meat was significantly ($p < 0.05$) increased in T2 and T3 treatment groups. Regarding meat quality, broilers fed T3 diet had higher ($p < 0.05$) water holding capacity than those fed other diets. Regarding fatty acids composition of thigh meat, broilers fed T3 diet had higher ($p < 0.05$) linolenic acid than those fed other diets. In conclusion, soybean meal replaced by 2% perilla seed meal in broiler diet can improve growth performance, meat quality, and fatty acids composition of thigh meat in broilers. Perilla seed meal can be a lot of potential alternatives feedstuff for soybean meal in this study.

Keywords: Feed stuff, Perilla seed meal, Growth performance, Meat quality, Fatty acids composition

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Competing interests

The authors declare no conflict of interest.

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Availability of data and material

Upon reasonable request, the datasets of this study can be available from the corresponding author.

Authors' contributions

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Ethics approval and consent to participate

The Animal Care and Use Committee of Chungbuk National University approved all the experimental protocols used in the current study.

INTRODUCTION

Chicken meat has lower cholesterol and saturated fatty acid content than other meats, but there have been many attempts to produce beneficial fatty acids for human body and produce chicken with less cholesterol and saturated fatty acids. In particular, as the effect of omega-3-unsaturated fatty acids on lowering blood lipid concentration and reducing the incidence of circulatory diseases have been reported [1,2], many researchers have been a great interest in the production of livestock containing omega-3-polysaturated fatty acids. Although attempts to lower cholesterol levels in eggs and meat have not been successful [3], however, many studies reported that the fatty acids composition in these poultry products is influenced by the dietary feed such as fish oil and fish meal [4,5], sesame oil and sesame meal [6,7]. For this reason, we consider feedstuff rich in omega-3-unsaturated fatty acids.

Perilla seed meal (PSM) is known to be enriched in compositions of omega-3 polysaturated fatty acids and bioactive compounds such as phytic acid, polysaccharides, phenolic compounds, and protein as a by-product made after extracting oil from perilla seeds [8]. The rich nutrient content and the use of by-product have received much attention recently to increase profitability [9,10]. In our analysis, PSM has been shown to be a potential protein (39.01%) source of feed. The use of PSM as feedstuff can be an alternative to soybean meal whose cost has increased in recent years [11]. However, studies on the use of PSM as a feedstuff in livestock are insufficient. Therefore, the aim of this experiment was to evaluate effects of replacing soybean meal with perilla seed meal on growth performance, and meat quality in *ROSS 308* broilers.

MATERIALS AND METHODS

Experimental protocols describing the management and care of animals were reviewed and approved by the Animal Care and Use Committee of Chungbuk National University.

Animals, facilities, and dietary treatments

A total of 60 healthy mixed sex 1-day-old *ROSS 308* broilers with an initial body weight (BW) of 44.8 ± 0.4 g were used in a 5-week experiment. Broilers were randomly blocked based on their initial BWs to four treatment groups. Each treatment group had fifteen replicate cages (1 broilers per cage). Water and feed were available *ad libitum*. The experiment was divided into two periods: a starter period (0 to 2 weeks of age) and a finishing period (2 to 5 weeks of age). Table 1 shows nutrient compositions of the perilla seed meal used in this study. Dietary treatments included a control (CON) corn-soybean meal based diets (basal diet) and three test diets in which perilla seed meal (Table 1) was included at 0.5% (T1), 1% (T2), and 2% (T3) to gradually replace soybean meal (Tables 2 and 3). To meet amino acid requirements, diets in the finishing period were supplemented with L-lysine and corn gluten meal. All diets were formulated to meet or exceed National Research council (NRC) [12] nutrient requirements for poultry.

Sampling and measurements

Individual broilers' BWs were recorded at the end of weeks 0, 2, and 5, and feed intake were recorded every day to determine weight gain (WG), feed intake (FI), and feed conversion ratio (FCR). All broilers of each treatment were selected at the end of the 5th week to collect breast and leg meat. Aponeuroses and skin were removed from breast and leg samples. They were then homogenized and submitted for proximate analysis. Moisture, fat, and ash contents were analyzed in triplicate. All analyses were carried out according to AOAC method [13]. Water holding capacity (WHC) was

Table 1. Chemical composition of perilla seed meal

Items	Content
Ingredients (%)	
Moisture	7.84
Crude protein	39.01
Crude fat	7.31
Ash	5.92
Calcium	0.50
Phosphate	1.37
Calculated composition	
Metabolizable energy (MJ/kg)	2,820
Lysine (%)	2.39
Methionine (%)	1.14
Cysteine (%)	0.43

determined following the method of Laakkonen et al. [14]. The pH values of breast meat were determined by using glass-electrode pH meter (WTH Measurement System, Ft. Myers, Florida, FL, USA). Drip loss, cooking loss, and shear force after cooking were measured according to the guide of Sirri et al. [15]. The breast meat color value was analyzed by using a reflectance spectrometry chroma meter (Yasuda Seiko, Minolta, Japan) to measure lightness (L^*), redness (a^*) and yellowness (b^*).

Table 2. Ingredient composition of starter diets (0–2 weeks)

Items	CON	T1	T2	T3
Ingredients (%)				
Corn	46.16	45.66	45.15	44.50
Soybean meal, 48% CP	36.04	35.54	34.05	34.02
Wheat	10.00	10.00	10.00	10.00
Wheat bran	4.50	5.00	5.50	6.00
Perilla seed meal	0.00	0.50	1.00	2.00
DL-Methionine	0.20	0.20	0.20	0.20
Choline chloride	0.20	0.20	0.20	0.20
Limestone	1.00	1.00	1.00	1.00
Dicalcium phosphate	1.50	1.50	1.50	1.50
Salt	0.20	0.20	0.20	0.20
Vitamin premix ¹⁾	0.10	0.10	0.10	0.10
Mineral premix ²⁾	0.10	0.10	0.10	0.10
Calculated composition				
ME (kcal/kg)	3,220	3,221	3,213	3,215
CP (%)	23.00	23.00	23.00	23.00
Lysine (%)	1.275	1.274	1.273	1.273
Methionine (%)	0.55	0.55	0.55	0.55
Ca (%)	0.80	0.80	0.80	0.80
P (%)	0.64	0.64	0.64	0.64

¹⁾ Provided per kg of complete diet: 12,000 IU of vitamin A; 2,500 IU of vitamin D₃; 25 mg of vitamin E; 0.7 mg of vitamin K₃; 1 mg of thiamin, 12 mg of riboflavin; 2 mg of pyridoxine; 0.03 mg of vitamin B₁₂; 35 mg of niacin; 10 mg of Ca-pantothenate; 0.5 mg of folic acid and 0.085 mg of biotin; 1,700 mg of ethoxyquin.

²⁾ Provided per kg of complete diet: 35 mg, Fe; 60 mg, Zn; 85 mg, Mn; 70 mg, Cu; 1.6 mg I; 0.1 mg, Se.

CON, basal diet; T1, replacing 0.5% soybean meal with perilla seed meal; T2, replacing 1% soybean meal with perilla seed meal; T3, replacing 2% soybean meal with perilla seed meal; ME, metabolizable energy; CP, crude protein.

Table 3. Ingredient composition of finishing diets (2–5 weeks)

Items	CON	T1	T2	T3
Ingredients (%)				
Corn	57.75	57.65	57.55	57.445
Soybean meal, 48% CP	28.00	27.50	27.00	26.00
Wheat	10.00	10.00	10.00	10.00
Corn gluten meal, 60% CP	0.80	0.90	1.00	1.10
Perilla seed meal	0.00	0.50	1.00	2.00
L-Lysine	0.140	0.145	0.150	0.155
DL-Methionine	0.21	0.205	0.20	0.20
Choline chloride	0.20	0.20	0.20	0.20
Limestone	1.00	1.00	1.00	1.00
Dicalcium phosphate	1.50	1.50	1.50	1.50
Salt	0.20	0.20	0.20	0.20
Vitamin premix ¹⁾	0.10	0.10	0.10	0.10
Mineral premix ²⁾	0.10	0.10	0.10	0.10
Calculated composition				
ME (kcal/kg)	3,283	3,280	3,278	3,273
CP (%)	20.04	20.05	20.05	20.03
Lysine (%)	1.151	1.153	1.154	1.152
Methionine (%)	0.527	0.526	0.524	0.525
Ca (%)	0.80	0.80	0.80	0.80
P (%)	0.64	0.64	0.64	0.64

¹⁾Provided per kg of complete diet: 12,000 IU of vitamin A; 2,500 IU of vitamin D₃; 25 mg of vitamin E; 0.7 mg of vitamin K₃; 1 mg of thiamin, 12 mg of riboflavin; 2 mg of pyridoxine; 0.03 mg of vitamin B₁₂; 35 mg of niacin; 10 mg of Ca-pantothenate; 0.5 mg of folic acid and 0.085 mg of biotin; 1,700 mg of ethoxyquin.

²⁾Provided per kg of complete diet: 35 mg, Fe; 60 mg, Zn; 85 mg, Mn; 70 mg, Cu; 1.6 mg I; 0.1 mg, Se.

CON, basal diet; T1, replacing 0.5% soybean meal with perilla seed meal; T2, replacing 1% soybean meal with perilla seed meal; T3, replacing 2% soybean meal with perilla seed meal; ME, metabolizable energy; CP, crude protein.

Fatty acids composition

Lipids were analyzed from thigh meat according to the method of Folch et al. [16]. Thigh meat (30 g) was blended with 150 mL of solution (chloroform : methanol = 2 : 1) and added 0.88% KOH. The solution was kept at room temperature for 2 hours and the upper phase was extracted. Then chloroform was evaporated using 99.9% N₂ gas and cooling. 1 mL of BF3-Methanol (Sigma Chemical, St. Louis, MO, USA) was added to the sample and heated at 70 °C for 30 min. After samples were cooled, 2 mL of Hexan (HPLC grade) and 5 mL of distilled water were added to the solution. The upper phase is rolled out after vortexing the samples. Fatty acid methyl ester dissolved in hexane was transferred to a GC vial and the fatty acids were analyzed using a capillary column (30 mm × 0.32 mm × 0.25 µm film thickness, Omegawax 320, Supelco, Bellefonte, PA, USA) of GC (Shimadzu Gas Chromatography 17-A, Tokyo, Japan).

The oven temperature was set to 200 °C and helium was divided by a 100:1 split ratio to serve as a carrier gas at linear flow of 0.79 mL/min. Fatty acids were determined by comparison with standard retention times and the relative amounts were identified in weight percent of total fatty acids.

Statistical analysis

All data were subjected to statistical analysis as a randomized complete block design using GLM procedures of SAS version 9.4 (SAS Inst., Cary, NC, USA). Differences in means among treatment groups were determined using Duncan's multiple range test with a *p* < 0.05 indicating statistical significance.

RESULTS

Growth performance

At 2 and 5 weeks, broilers fed with T2 or T3 had significantly ($p < 0.05$) higher BW than broilers fed with CON or T1 (Table 4). From 0 to 2 weeks, WG of broilers fed with T2 or T3 diet was increased ($p < 0.05$) compared to that of broilers fed with CON or T1 diet. Moreover, broilers in T2 treatment group had significantly ($p < 0.05$) higher WG than those fed with T3. FCR was significantly ($p < 0.05$) decreased for broilers fed with T2 or T3 diet. There was no significant difference in FI among groups. From 2 to 5 weeks, WG of broilers fed with T2 or T3 diet was increased. Regarding FI, broilers fed with T1 or T3 had significantly higher FI than those fed with T2 or CON. FCR was significantly increased for broilers fed with T1 or T2 diet.

In the overall period, broilers fed with T2 or T3 diet had significantly ($p < 0.05$) higher WG than broilers fed with CON or T1 diet. FI was increased ($p < 0.05$) for broilers fed with T3 diet while broilers fed with T2 diet had lower ($p < 0.05$) FI than those in other treatment groups. FCR was significantly decreased in broilers fed with T2 diet.

Proximate composition

There was no significant ($p > 0.05$) difference in moisture or ash composition of breast meat from broilers (Table 5). However, broilers fed with T2 or T3 diet had higher ($p < 0.05$) fat composition in breast meat than broilers fed with CON or T1 diet.

Meat quality

WHC was significantly ($p < 0.05$) increased in broilers fed with T2 or T3 diet (Table 6). However, there was no significant difference in other characteristics among groups.

Table 4. Effects of replacing soybean meal with perilla seed meal on growth performance of ROSS 308 broilers

Item	CON	T1	T2	T3	SE	p-value
Body weight (g)						
Initial BW	44.60	45.00	44.60	45.00	0.02	-
2 wks	194.33 ^b	190.67 ^b	203.67 ^a	200.00 ^a	2.21	0.031
5 wks	1,208.67 ^b	1,205.67 ^b	1,258.00 ^a	1,256.00 ^a	13.51	0.028
Week 0–2						
Weight gain (g)	149.73 ^c	145.67 ^c	159.07 ^a	155.00 ^b	4.35	0.036
Feed intake (g)	258.20	259.67	258.33	258.33	1.41	0.854
Feed conversion ratio (g/g)	1.72 ^b	1.78 ^a	1.62 ^c	1.67 ^c	0.07	0.037
Week 2–5						
Weight gain (g)	1,014.33 ^b	1,015.00 ^b	1,054.33 ^a	1,060.22 ^a	8.43	0.043
Feed intake (g)	1,717.33 ^c	1,777.00 ^a	1,735.33 ^b	1,829.33 ^a	10.24	0.041
Feed conversion ratio (g/g)	1.69 ^b	1.74 ^a	1.65 ^b	1.73 ^a	0.04	0.048
Week 0–5						
Weight gain (g)	1,164.07 ^b	1,160.67 ^b	1,213.40 ^a	1,215.22 ^a	14.87	0.025
Feed intake (g)	1,975.53 ^c	2,036.67 ^b	1,893.67 ^d	2,087.67 ^a	23.41	0.033
Feed conversion ratio (g/g)	1.72 ^a	1.76 ^a	1.67 ^b	1.73 ^a	0.04	0.018

^{a–d}Means in the same row with different superscripts differ ($p < 0.05$).

CON, basal diet; T1, replacing 0.5% soybean meal with perilla seed meal; T2, replacing 1% soybean meal with perilla seed meal; T3, replacing 2% soybean meal with perilla seed meal; SE, standard error.

Table 5. Effects of replacing soybean meal with perilla seed meal on proximate composition (%) of breast meat from ROSS 308 broilers

Item (%)	CON	T1	T2	T3	SE	p-value
Moisture	75.9	75.9	74.9	75.5	1.1	0.613
Fat	1.53 ^b	1.55 ^b	1.75 ^a	1.74 ^a	0.05	0.025
Ash	1.99	2.11	2.14	1.88	0.19	0.349

^{a,b}Means in the same row with different superscripts differ ($p < 0.05$).

CON, basal diet; T1, replacing 0.5% soybean meal with perilla seed meal; T2, replacing 1% soybean meal with perilla seed meal; T3, replacing 2% soybean meal with perilla seed meal; SE, standard error.

Table 6. Effects of replacing soybean meal with perilla seed meal on meat quality in ROSS 308 broilers

Item	CON	T1	T2	T3	SE	p-value
WHC (%)	63.2 ^b	63.7 ^b	65.6 ^a	65.8 ^a	0.8	0.033
pH	5.88	5.97	5.93	5.90	0.07	0.335
Drip loss (%)	3.14	3.28	3.18	3.11	0.14	0.486
Cooking loss (%)	14.94	15.63	14.52	15.02	1.30	0.508
Shear force (g/g)	2,245	2,335	2,263	2,332	57.00	0.222
Meat Color						
L*, Lightness	45.8	45.3	44.9	46.4	2.0	0.775
a*, redness	3.47	3.54	3.69	3.98	0.3	0.668
b*, yellowness	10.21	11.76	12.25	11.89	1.3	0.503

^{a,b}Means in the same row with different superscripts differ ($p < 0.05$).

CON, basal diet; T1, replacing 0.5% soybean meal with perilla seed meal; T2, replacing 1% soybean meal with perilla seed meal; T3, replacing 2% soybean meal with perilla seed meal; S.E, standard error; WHC, water holding capacity.

Fatty acids composition of thigh meat

Regarding fatty acids composition of thigh meat from broilers, linolenic acid content was increased ($p < 0.05$) in broilers fed with T3 diet (Table 7).

Table 7. Effects of replacing soybean meal with perilla seed meal on fatty acids composition of thigh meat produced from ROSS 308 broilers

Item (%)	CON	T1	T2	T3	SE	p-value
Myristic acid (C14:0)	0.84	0.80	0.80	0.80	0.01	0.068
Palmitic acid (C16:0)	18.42	18.87	18.35	18.22	0.38	0.678
Palmitoleic acid (C16:1n7)	6.23	5.38	5.60	5.72	0.27	0.291
Stearic acid (C18:0)	6.75	6.81	6.60	6.44	0.24	0.698
Oleic acid (C18:1n9)	44.42	44.42	44.48	44.40	0.45	0.991
Linoleic acid (C18:3n3)	15.37	16.00	16.33	15.95	0.26	0.216
γ-Linoleic acid (C18:3n6)	0.07	0.05	0.06	0.07	0.01	0.548
Linolenic acid (C18:3n3)	6.64 ^c	6.77 ^{bc}	6.98 ^b	7.55 ^a	0.04	0.001
Eicosenoic acid (C20:1n9)	0.35	0.34	0.34	0.37	0.02	0.659
Arachidonic acid (C20:4n6)	0.92	0.58	0.52	0.51	0.16	0.354
Saturated fatty acid	31.02	31.48	30.74	30.45	0.46	0.513
Unsaturated fatty acid	68.99	68.53	69.26	69.56	0.46	0.513
Monounsaturated fatty acid	51.00	50.13	50.42	50.49	0.54	0.737
Polyunsaturated fatty acid	17.99	18.48	18.86	19.06	0.35	0.293

^{a-c}Means in the same row with different superscripts differ ($p < 0.05$).

CON, basal diet; T1, replacing 0.5% soybean meal with perilla seed meal; T2, replacing 1% soybean meal with perilla seed meal; T3, replacing 2% soybean meal with perilla seed meal; SE, standard error.

DISCUSSION

In the present study, PSM showed potential as an alternative feedstuff for soybean meal. Moreover, it improved growth performance of broilers. In particular, FCR and WG were significantly increased when 1%–2% soybean meal was replaced by PSM. Perilla is a rich source of polyunsaturated fatty acids such as omega-6-fatty acids and omega-9-fatty acids (ω -9). It can be the best feedstuff for additional omega-3 polyunsaturated fatty acids [17]. Omega-3-fatty acids (ω -3) are a series of fatty acids, including eicosapentaenoic acid (EPA), α -linolenic acid, and docosahexaenoic acid (DHA) [18]. Shin et al. [19] have found that supplementation ω -3 and ω -9 fatty acid blends does not affect the accumulation of liver fat or the ratio of live weight to broiler liver weight. However, unlike results of our study, Oh et al. [20] have reported that supplementation of 10% PSM to 45-d Korean native chickens does not affect the growth performance in a 21-day experiment period. In addition, many studies have found that ω -3 and ω -9-enriched feedstuffs (full-fat flaxseed meal, canola seed meal, fish oil, etc.) do not affect the growth performance of broilers [19–23], although some studies have shown that sesame meal can replace soybean meal to improve the growth performance of broilers [24,25]. More research is needed to determine whether a seed meal is suitable for broiler diets. Based on results of this study, we can see a lot of potential of replacing soybean meal with PSM.

Regarding proximate composition of breast meat from broiler, many researchers have reported that increase of fat content in broilers is associated with the composition of dietary fatty acids. Hadi [26] have reported that 5% PSM supplementation in duck diet can improve the fat content of meat. Similarly, the supplementation of ω -3 and ω -9 in diet can improve the fat composition of breast meat in broiler [4,21,23,27,28].

In present study, the pH of the breast meat from broiler fed with PSM as a replacement was not significantly affected by such replacement. However, water holding capacity was significantly increased after soybean meal was replaced with PSM at 1% or 2%. Huff-Lonergan and Lonergan [29] and Jung et al. [30] have reported that WHC could be inactivated by oxidation not only by pH, but also by post-protein degradation initiated by the activation of μ -capain. In the current study, the antioxidative effect was not tested, although the substitution of PSM could improve breast meat quality of broilers.

Based on results of fatty acids composition of meat analysis in this study, the content of linolenic acid was increased after soybean meal was replaced with PSM at 1% or 2%. Such results are similar to previous studies showing that higher percentage of ω -3 can improve meat quality [23,31]. Hulan et al. [4] have reported that ω -3 in broiler meat can be improved by increasing levels of ω -3 in broiler diets. Feeding fat or vegetable seeds containing α -LNA can increase the absorption of linolenic acids, EPA, and DHA in poultry and chick tissues [32,33]. Oh et al. [20] have reported that the ratio of α -LNA in broiler's breast meat is increased more than three times in 10% PSM supplementation treatment compared to basal diet. Thus, PSM could be used as a feedstuff for the production of polyunsaturated fatty acid-enriched poultry meat.

CONCLUSION

Perilla seed meal can improve the growth performance and meat quality when it is used as an alternative of soybean meal in broiler feed. In addition, it can increase linolenic acid content in breast meat. Thus, it may be useful as a replacement for soybean meal.

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