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Research Article

The Impact of Extruded-Expelled Soybean Meal on Carcass Traits and Intestinal Morphometry of Broiler Chickens

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Abstract | The processing method used to create the meal affects the nutritional value of soybeans for birds. The most popular approach is solvent-extracted soybean meal (SE-SBM). However, extruded-expelled soybean meal (EE-SBM) is mainly utilized in organic poultry feed. This study aimed to investigate the effect of adding EE-SBM to broiler chicken Ross® 308 feed formulations on carcass traits and histomorphological changes in the intestine. A total of 198 one-day-old Ross® 308 chickens were randomly distributed into three groups with different dietary treatments (66 birds per group). The dietary treatments were as follows: D1, control (soybean meal 46%); D2, D1 + EE-SBM (50 kg starter, 100 kg grower, and 200 kg finisher/ton); and D3, D1 + EE-SBM (100 kg starter, 150 kg grower, and 250 kg finisher/ton). The study results showed that the addition of EE-SBM to broiler diets had no significant effect on carcass traits, but pancreas weight (%) increased significantly ($P < 0.05$) in D3 and D1. Moreover, the jejunum diameter increased significantly ($P < 0.05$) in D1. The intestinal morphological examination revealed that EE-SBM had a beneficial effect, significantly increasing villi length, width, crypt depth, and the number of goblet cells. Regarding return from the breast and thigh, D2 and D3 had a non-significant numerical increase over D1. In conclusion, adding EE-SBM to broiler diets can improve intestinal morphometry and does not negatively affect carcass characteristics.

Keywords | Broiler chicken, Carcass characteristics, Extruded-expelled soybean meal, Intestinal morphometry

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INTRODUCTION

It is crucial to find alternative, high-quality feed supplies to address nutritional issues and improve sustainability in animal production (Sayed et al., 2019). Feed represents a significant portion of the total cost of rearing chickens, estimated as high as 70%. Additionally, up to 94% of the total feed cost meets energy and protein requirements Mwaniki and Kiarie (2018), with the remaining portion used for vitamin and mineral requirements and feed additives. As a result, soybeans have become a common substitute protein source in livestock diets due to their acceptable amino acid profile and high-quality oil content (Bingol et al., 2016). According to Foltyn et al. (2013), soybeans have an acceptable amino acid profile and contain 18–22% of high-quality oil with a high amount of linoleic acids. However, antinutritional factors (ANFs) in soybeans can reduce their use and digestibility. Studies, such as the one by Taslimi (2021), have investigated the impact of various heat treatments on the ANFs in soybeans and soybean meal to improve their nutritional value.

Extrusion is an effective method of processing soybeans, as it improves growth performance in broilers. Studies have found that extruded soybeans can replace soybean meal without negatively impacting the growth efficiency, mortality rates, or carcass characteristics (Subuh et al., 2002). Research has shown little interaction between the meal level of extruded soybean expellers and carcass traits. However, replacing conventional commercial SBM with extruded-expelled SBM in compound feed at all levels decreases the breast muscle yield of broilers in both absolute and relative terms. Carcass weights do not significantly change with soybean meals from expellers (Powell et al., 2011). Furthermore, Foltyn et al. (2013) reported that intestinal morphology showed decreases in the intestinal epithelial crypts and the villi length, with a significant increase in pancreatic mass from 120 g/kg of extruded soybeans.

The extrusion of soybean expellers after removing soybean oil may be a solution to the limited availability of non-genetically modified soybean seeds to produce solvent-extracted soybean meal (Sliwa, 2018). This study aimed to investigate the impact of extruded-expelled soybean meal (EE-SBM) in broiler chickens on carcass traits and intestinal morphology.

MATERIALS AND METHODS

This study was conducted at the Center for Experimental Animal Research at the Faculty of Veterinary Medicine, Benha University, Egypt. Ethical clearance for the study was obtained under the number (NO BUFVTM 01-08-22).

Management and housing

In this study, a total of 198 one-day-old Ross 308 broiler chicks were randomly divided into three groups, each with a density of 10 birds per square meter. The diets were formulated to be isocaloric and isonitrogenous according to the Ross® 308 Broiler Management Manual (2009) to me*et al*l the nutritional requirements of the broiler chicks throughout the 42 days of the experiment. The study was conducted under controlled microclimatic conditions, with the house's temperature, ventilation, and lighting being set and maintained according to institutional animal care and use guidelines. The house floor was covered with fresh, clean sawdust, forming a deep litter of 5 cm, which was turned over weekly. Each partition was equipped with one plastic manual feeder (with a capacity of 8 kg of feed) and one plastic waterer (with a capacity of 4 L) to ensure that the birds had access to feed and water at all times. Continuous light was provided to the chicks through compressed filament lamps during the first two days of breeding. The birds received a lighting regimen of 23 L/1 D during the entire period to reduce the chicks' activity. Heaters were added to the room to adjust the environmental temperature according to the age of the chicks. The brooding temperature began at 35°C and decreased by 2°C per week until it reached 24°C at the end of the 42-day experiment. Ventilation was adequate by using windows and negative-pressure fans to extract moisture, allowing the litter to dry and the birds' feces to expel carbon dioxide and ammonia. The broiler chicks were vaccinated against the three most common viral diseases (Newcastle, infectious bronchitis, and bursal disease). The ingredients and chemical composition of experimental diets are presented in Table 1.

Carcass traits parameters

By the end of the experiment, nine birds per group were sacrificed. The birds were selected randomly, fasted for 12 hours, given free access to water, and then weighed individually (pre and post-slaughter weights). Dressing Percentage and relative internal organ weights were calculated according to Biesek et al. (2020) and Wu et al. (2020). Furthermore, intestinal length and width were recorded.

Histopathology and morphometrical assessment of intestinal villi absorptive capacity sampling

A 2.5 cm section of the jejunum, duodenum, and ileum was sliced and rinsed with physiological saline. Nine samples were harvested from each group (n= 27). The tissues were fixed in 10% neutral-buffered formalin for three days. Then, the samples were washed in a series of alcohols, dehydrated, and embedded in paraffin. Using a Leica rotary microtome (RM 2145, Leica Microsystems, Wetzlar, Germany), sequential 5-mm longitudinal slices were cut and placed on glass slides. The slides were then stained with hematoxylin and eosin (H & E).

Morphometrical assessment of intestinal villi

The methods used in this study included measuring the villus height (VH) from the tip of the villus to the villus-crypt junction, the villus width from the midpoint of the villus, and the crypt depth (CD) from the crypt-villus junction to the base of the crypt using ImageJ analysis software (National Institutes of Health, MD, USA) (Xu et al., 2003). Additionally, goblet cell density was calculated as the number of cells per unit surface area (mm^2).

Statistical analysis

The SPSS statistical application (version 16 for Windows) (SPSS, 2007) was utilized to collect, organize, summarize, and analyze data.

Statistical model

$$Y_{tk} = (\mu + G_t + E_{tk})$$

Where Ytk is the observed value, μ is the overall mean, Gt is the effect of groups (D1, D2, and D3), and Etk is the effect of the random error present in the k-th observation on the t-th group.

Table 1: Ingredients % and chemical composition of experimental diets.

Ingredient %	Starter ration			Grower ration			Finisher ration		
	D1 (control)	D2	D3	D1 (control)	D2	D3	D1 (control)	D2	D3
Yellow corn	56.16	56	53.81	61.17	61.4	60.04	58.23	63.48	62.22
Soybean meal 46	35	32.9	29.2	28.9	21.4	20.5	31.6	7.1	8.1
Express soy bean meal	0	5	10	0	10	15	0	20	25
Wheat Bran	1.95	1.5	2.5	-	-	-	1.8	1.8	1.2
Corn gluten meal	1.7	-	-	4.3	3	0.45	-	3.9	-
Di calcium phosphate	1.45	1.44	1.4	1.28	1.27	1.25	1.04	1.04	1
Lime stone	1.35	1.35	1.37	1.29	1.29	1.29	1.23	1.24	1.23
Vegetable oil	0.45	-	-	1.3	-	-	4.6	-	-
DL-Methionine	0.35	0.35	0.35	0.29	0.27	0.28	0.3	0.21	0.23
L_Lysine	0.33	0.24	0.21	0.35	0.27	0.15	0.16	0.24	0.07
Vit & min premix1	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Sodium bicarbonate	0.29	0.25	0.23	0.23	0.22	0.16	0.18	0.2	0.12
Sodium chloride	0.22	0.25	0.26	0.21	0.24	0.28	0.27	0.25	0.3
L_Threonine	0.13	0.11	0.09	0.09	0.06	0.03	0.05	-	-
Choline chloride	0.1	0.1	0.1	0.1	0.1	0.09	0.09	0.09	0.08
Anticoccedia	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Antimycotoxin	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Cibenza starter	0.05	0.05	0.03	0.05	0.05	0.05	-	-	-
Niutrokeem extend	0.05	0.05	0.05	0.03	0.03	0.03	0.04	0.04	0.04
Anticolesterdia	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Antioxidants	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Phytase enzyme	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

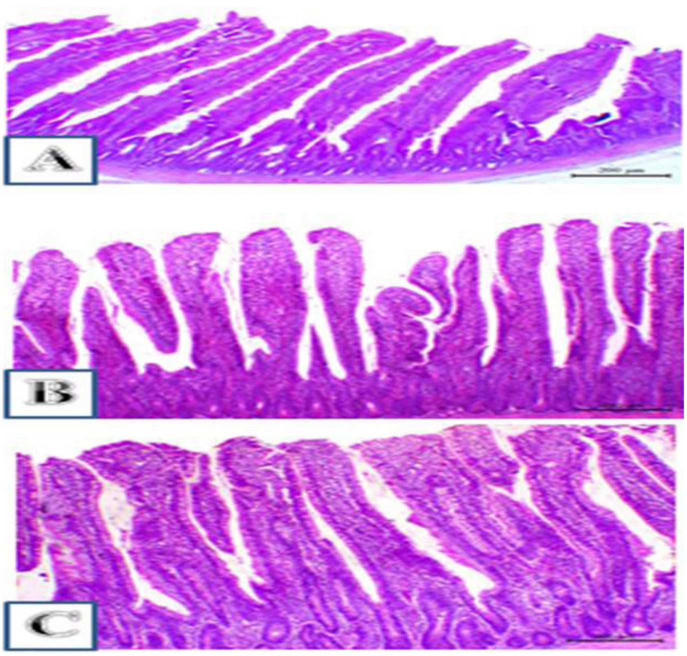

Figure 1: Effect of extruded-expelled SBM feeding in the diet of Ross®308 broiler chicken on morphometric parameters of the duodenum. Duodenum of D1 showing normal villi (A). Duodenum of D2 showing increased intestinal villi length (B). Duodenum of D3 showing marked increase of intestinal villi length (C).

Statistical method

The statistical method employed in this study was the one-way analysis of variance. The Duncan's range test in the SPSS program was used to determine significance. The data were presented as mean±SE, and statistical significance was set at $p < 0.05$.

RESULTS AND DISCUSSION

Carcass characteristics

As shown in Table 2, the results indicated insignificant changes ($p > 0.05$) in the dressing percentage and relative weights of the breast, liver, heart, gizzard, and kidney. However, the relative weight of the pancreas increased with the inclusion of EE-SBM in diet D3. The jejunal diameter exhibited a significant increase ($p \leq 0.05$) for diet D1 compared to diets D2 and D3. The return from the breast and thigh was non-significantly higher ($p > 0.05$) in diets D2 and D3.

Intestinal morphometry

Intestinal morphometric parameters, as presented in Table 3 and Figures 1, 2, and 3, demonstrated a gradual increase ($p < 0.01$) in villi length, crypt depth, and goblet cells with increasing levels of EE-SBM. However, villi width showed

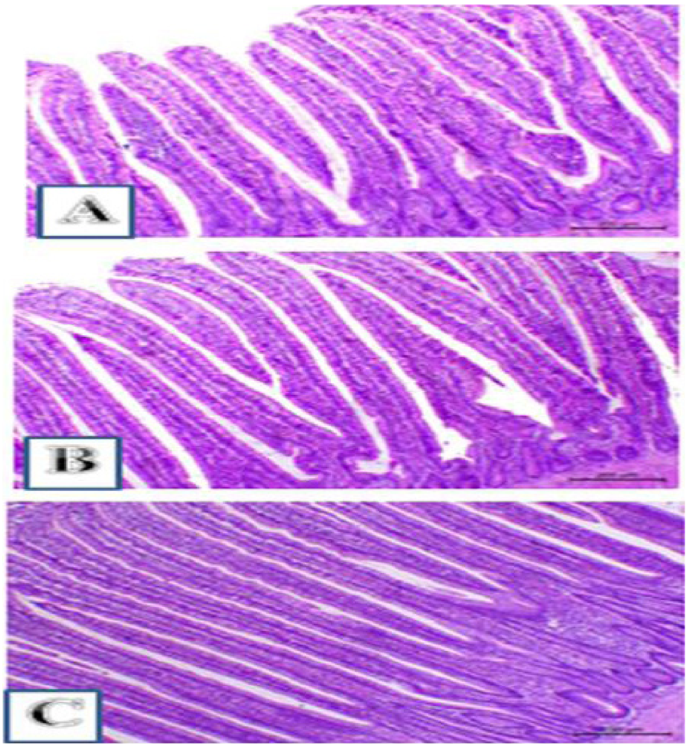

Figure 2: Effect of extruded-expelled SBM feeding in the diet of Ross®308 broiler chicken on morphometric parameters of the jejunum. Jejunum of D1 showing normal villi (A). Jejunum of D2 showing increased intestinal villi length (B). Jejunum of D3 showing marked increase of intestinal villi length (C).

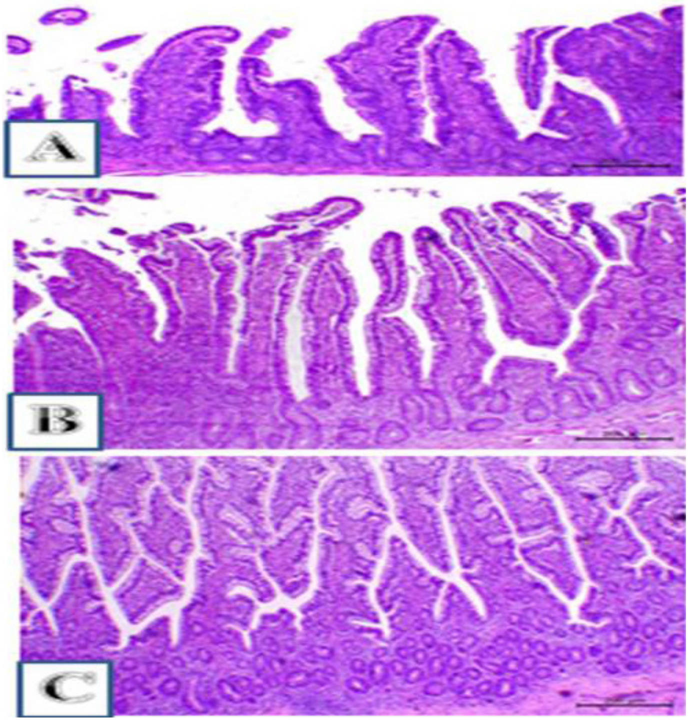

Figure 3: Effect of extruded-expelled SBM feeding in the diet of Ross®308 broiler chicken on morphometric parameters of the ileum. Ileum of D1 showing normal villi (A). Ileum of D2 showing increased intestinal villi length (B). Ileum of D3 showing marked increase of intestinal villi length (C).

Table 2: Effect of extruded expelled SBM feeding in the diet of Ross® 308 broiler chicken on carcass characteristics and return of some carcass parts.

Parameters	D1 (Mean±SE)	D2 (Mean±SE)	D3 (Mean±SE)	P value
Live weight (g)	1800±59.38^{a}	1858.30±62.76^{a}	1911.80±49.51^{a}	0.40
Dressed weight (%)	71.32±0.27^{a}	72.92±0.72^{a}	71.5±0.52^{a}	0.089
Weight after feathering (%)	92.57±0.32^{a}	93.2±0.17^{a}	93.14±0.18^{a}	0.12
Breast weight (%) without bone	22.14±0.53^{a}	22.29±0.73^{a}	22.09±0.61^{a}	0.971
Breast weight (%) with bone	25.67±0.45^{a}	25.31±0.82^{a}	24.98±0.63^{a}	0.759
Thigh weight (%)	25.33±2.31^{a}	27.9±0.75^{a}	28.29±0.37^{a}	0.295
Gizzard and crop weight (%)	3.09±0.17^{a}	2.79±0.13^{a}	2.99±0.11^{a}	0.319
Liver weight (%)	2.28±0.06^{a}	2.18±0.06^{a}	2.19±0.06^{a}	0.434
Heart weight (%)	0.49±0.02^{a}	0.52±0.03^{a}	0.5±0.02^{a}	0.593
Spleen weight (%)	0.1±0.01^{a}	0.1±0.01^{a}	0.12±0.01^{a}	0.273
Pancrease weight (%)	0.26±0.01^{ab}	0.25±0.02^{b}	0.29±0.01^{a}	0.08
Kidney weight (%)	0.49±0.04^{a}	0.48±0.03^{a}	0.53±0.03^{a}	0.55
Thymus weight (%)	0.55±0.05^{a}	0.44±0.05^{a}	0.5±0.03^{a}	0.208
Bursa weight (%)	0.16±0.01^{a}	0.19±0.01^{a}	0.19±0.02^{a}	0.442
Fat weight (%)	0.76±0.13^{a}	0.78±0.11^{a}	0.69±0.11^{a}	0.832
Cecum weight (%)	0.08±0.01^{a}	0.08±0.01^{a}	0.08±0.002^{a}	0.67
Intestinal length (cm)	89.11±3.38^{a}	88.61±2.41^{a}	91.7±4.05^{a}	0.785
Deudenum diameter (cm)	1.82±0.1^{a}	1.82±0.1^{a}	1.91±0.05^{a}	0.707
Jejunum diameter (cm)	1.72±0.08^{a}	1.42±0.09^{b}	1.49±0.08^{ab}	0.049
Ilium diameter (cm)	1.51±0.08^{a}	1.62±0.11^{a}	1.76±0.06^{a}	0.159
Return from breast	28±1.42	28.85±0.88	29.56±1.17	0.65
Return from thigh	13.7±1.37	15.55±0.67	16.23±0.5	0.15

Means carrying a, b, c significantly different among different groups of the same row.

Table 3: Effect of extruded-expelled SBM feeding in the diet of Ross®308 broiler chicken on morphometric changes of intestine.

Parameters		D1 (Mean±SE)	D2 (Mean±SE)	D3 (Mean±SE)	P value
Duodenum	Villi length	581.72±47.09 ^{c}	743.53±24.23^{b}	861.56±15.69^{a}	0.002
	Villi width	81.91±9.18 ^{a}	99.54±9.36 ^{a}	95.21±6.40^{a}	0.367
	Crypt depth	66.07±3.14 ^{c}	132.37±9.66 ^{b}	191.33±2.40^{a}	0.000
	Goblet cell	207.15±6.74 ^{c}	275.79±17.23 ^{b}	371.60±8.31^{a}	0.000
Jeujenum	Villi length	750.56±35.27 ^{c}	925.51±29.47 ^{b}	1493.80±70.28^{a}	0.000
	Villi width	79.51±5.99 ^{a}	80.19±7.73 ^{a}	87.55±8.86^{a}	0.723
	Crypt depth	111.90±5.73 ^{c}	206.11±11.82 ^{b}	289.18±16.95^{a}	0.000
	Goblet cell	316.69±2.57 ^{c}	439.21±11.10 ^{b}	567.30±33.45^{a}	0.000
Ilieum	Villi length	403.27±54.43 ^{b}	562.59±48.48 ^{b}	756.47±38.48^{a}	0.006
	Villi width	109.69±20.61^{a}	117.71±7.05 ^{a}	127.42±13.05^{a}	0.707
	Crypt depth	69.67±2.34^{c}	107.73^{b}±10.93 ^{b}	172.06±11.15^{a}	0.001
	Goblet cell	131.63±8.35^{c}	231.38^{b}±7.33 ^{b}	289.85±14.26^{a}	0.000

Means carrying a, b, c significantly different among different groups of the same row.

insignificant changes ($p > 0.05$) across all segments of the intestine (duodenum, jejunum, and ileum). As a result, the length of the jejunal villi increased significantly ($p < 0.001$) for diets D2 and D3 compared to diet D1. Additionally, the number of goblet cells in the jejunum was significantly higher ($p < 0.001$) for diets D3 and D2 compared to diet D1.

The primary source of protein in chicken diets is soybean meal, which makes up more than 50% of the total protein in feed (de Coca-Sinova et al., 2008; Kohlmeier, 1990).

Carcass criteria and internal organs

Carcass traits showed insignificant changes in the dressing percentage and the relative weights of the breast, liver, heart, gizzard, and kidney. In contrast, the relative weight of the pancreas increased with the inclusion of EE-SBM in diet D3. This might be attributed to the increased activity of trypsin inhibitors in the intestinal contents. Foltyn et al. (2013) found that 120 g/kg of extruded soybeans significantly increased pancreatic mass and trypsin inhibitor activity in the intestinal contents by more than 80% at 160 g/kg. The weight of the breast muscle did not differ significantly, as reported by Todorov (1999), who did not find any significant impact of extruding 20% soybeans in compound feed on broilers' internal organ yield, carcass weight, or breast muscle yield. These results agree with Powell et al. (2011), who reported that the source of soybean meal, either solvent-extracted or extruded-expelled, did not affect hot or chilled carcass weights. However, they reported that extruded soybean expellers reduced breast muscle mass to achieve the best breast meat output.

Additionally, the digestibility of amino acids must be considered. Sliwa (2018) mentioned there were no differences in broilers' performance or dressing percentages. Using soybean expellers in place of commercial soybean meal significantly decreased breast muscle weights, both absolute and relative. There were no significant variations between the broiler groups in the absolute and relative weights of the heart, gizzard, liver, and abdominal fat. Subuh et al. (2002) found that including 34% extruded whole soybeans in the diet did not negatively affect the broiler carcass weight, while Kidd et al. (1998) discovered a decrease in breast muscle weight during the starter breeding stage with lower feed intake. The supplementation of EE-SBM in the diet decreased breast muscle mass, possibly due to decreased digestibility of essential amino acids, such as lysine, which is essential for protein synthesis. Jahanian and Rasouli (2016) reported that carcass features were not affected, abdominal fat increased, and breast muscle yield was reduced when dietary soybean meal was replaced with 86% extruded soybean meal. In contrast, Janocha and Milczarek (2022) revealed a more significant proportion of the breast and leg muscles in broilers fed either soybean meal or soybean expeller cake when compared with birds fed extruded full-fat soybeans.

Intestinal morphology

The results revealed a gradual increase in the length of villi, crypt depth, and goblet cells in the duodenum, jejunum, and ileum with increasing EE-SBM. Because the small intestine is the primary site for enzymatic nutrition, digestion, and absorption, a healthy intestinal mucosa is required (Kiarie et al., 2013; Kiarie and Mills, 2019). The primary site of absorption is the intestinal villi, where the villus epithelial cells serve for both digestion and absorption. This is particularly advantageous for promoting enzyme activity and absorption (Montagne et al., 2004). Increased intestinal crypt depth in birds fed EE-SBM suggests activating cell mitosis to support larger villi, as mentioned by Kiarie et al. (2021). Heat treatment can lengthen the small intestine's villi and promote absorption to increase nutritional uptake (Foltyn et al., 2013; Xie et al., 2013). Mucin, produced by goblet cells, functions as a mechanical barrier (Pearson, 2005). An increased number of goblet cells indicates increased mucin secretion (Walk et al., 2011). These findings contrast with those of Foltyn et al. (2013), who found that the depth of the intestinal epithelial crypts and the length of the villi decreased in response to the addition of extruded SBM in the diet of chicks.

CONCLUSIONS AND RECOMMENDATIONS

EE-SBM up to 100, 150, and 200 kg in starter, grower, and finisher broiler chicken diets, respectively, did not affect the dressing percentage, as well as carcass characteristics, and improved the intestinal morphometric characteristics.

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NOVELTY STATEMENT

The main objective of this research is to investigate the effects of extruded and expelled soybean meal on carcass quality and intestinal morphology in broiler chicks. While previous studies have examined the use of fully extruded soybean meals, and some have discussed the use of extruded post-extraction soybean meal, fewer studies have considered using extruded soybean expellers in broiler nutrition. Although similar research has been conducted, this study focuses on using EE-SBM at different levels during different treatment phases in the diet of chicks.

AUTHOR'S CONTRIBUTION

NEK formulated the concept for this research. All authors contributed to the methodology. FSM provided resources and wrote the original draft. LSM performed the data analysis. All authors have read and approved the final manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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