Original Research

Journal of Advanced Veterinary Research
(2024) Volume 14, Issue 1, 122-129

Potential effect of dietary additions of express soybean and full-fat soybean on carcass characteristics and meat quality of Hubbard chicken

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ARTICLE INFO

Recieved: 12 November 2023

Accepted: 13 December 2023

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Keywords:

Hubbard chicks
Extruded expelled soybeans
Full-fat soybeans
Carcass trait
Meat quality

ABSTRACT

This research was conducted to determine to what extent variable processing methods of soybeans influence broiler rearing by using expeller soybean (EESB), full-fat soybean (FFSB), and solvent soybean meal (SBM) on the characteristics of carcass and flesh quality in Hubbard efficiency plus chicks. A total of 225 chicks (1- day -old) were allocated to five groups: (45 chicks/each). Five dietary treatments were formulated as follows: T1 (basal diet containing SBM 46%, T2 (basal diet+ EESB in the level of 7.5% starter, 15% grower, and 30% finisher), T3 (basal diet+ EESB in the level of 5% starter, 10% grower, and 20% finisher), T4 (basal diet + FFSB in the level of 7.5,% starter, 15% grower, and 30% finisher), and T5 (basal diet + FFSB in the level of 5% starter, 10% grower, and 15% finisher). On day 35, five birds from each group were slaughtered for carcass traits. The result indicated a non-significant difference ($p > 0.05$) in carcass trait and return from carcass except spleen decreased significantly in T4. According to the fatty acid profile of breast meat, stearic, margaric, and octadecanoic decreased significantly in T2 compared to T3 and T5. In contrast, alpha-linolenic increased in FFSB groups. Regarding the amino acids profile, threonine, isoleucine, and histidine increased significantly in T3. Leucine, alanine, proline, and arginine significantly increased in T5. Muscle fiber diameter increased significantly in FFSB groups. In conclusion, the inclusion of EESB and FFSB does not negatively affect carcass traits nor causes any fundamental change in meat quality.

Introduction

Current animal production transformation to operate more sustainably is especially important to meet feeding challenges, so there is a necessity for more extendable feed sources of good quality (Sayed *et al.*, 2019). Producers were forced to use vegetable protein as soybeans in poultry diets after outlawing the use of animal nitrogenous concentrate in chicken feed (Bingol *et al.*, 2016). Soybeans are considered an excellent source of oil and protein in broiler chickens. They contain a crude protein of 38% and oil of 20%. Therefore, they are considered the most economical because they do not require the use of additional oils for the diet (Leeson and Summers, 2008). Soybeans contain a high amount of protein that is characterized by a balanced amino acid profile, making them excellent feed alternatives to animal proteins and considered the most used vegetable protein in animal feed, but raw soybean meal contains anti-nutritional factors that decrease its utilization and digestibility (Alagawany *et al.*, 2017). These anti-nutritional elements, such as protease inhibitors, antivitamins, lectins, tannins, saponins, phytate, non-starch oligosaccharides, and polysaccharides, affect animal performance negatively (Nabizadeh, 2018). To reduce the effect of these substances, soybeans must be subjected to heat treatment and high pressure, but care must be taken in heat treatment to avoid damaging protein and other essential nutrients (Rada *et al.*, 2017).

Full-fat soybean (FFSB) is manufactured from the mechanical cracking of soybean seeds without oil extraction (Van Eys, 2004). Therefore, by employing FFSB, it may be possible to revoke the price of oil extraction and permit the use of regionally generated oil as well as protein ingredients in chicken diets (Stein *et al.*, 2008). At the same time, the extrusion-expeller process is used to extract oil from soybeans, resulting in the manufacture of soybean expellers and soy oil (Wang and Johnson, 2001). In this process, high-shear dry extrusion changes complex carbohydrates, breaks down cell walls, deactivates antinutrients, improves protein and fat digesting efficiency, lessens gut viscosity, and minimizes wet excretions. The next step is a mechanical process that results in a partially defatted soy meal and soy oil using a screw press (Meyer and Bobeck, 2021). According to Subuh *et al.* (2002), extrusion is the optimum method for processing soybeans, and broiler development performance is enhanced when extruded soybeans are consumed. The authors concluded that the extruded soybeans could replace soybean meal without having any unfavorable consequences on carcass features, as well as growth efficiency.

This study sought to examine the outcomes of partial soybean substitution with expeller soybeans and extruded full fat at various levels on carcass traits, including the dressing percentage, relative organ weight, return from different parts of the carcass, as well as the assessment of meat quality by determining the profile of fatty acids, amino acid, and histomorphology of the breast meat of broiler chickens.

Materials and methods

Under the ethical number (NO BUFVTM 05-12-22), this study was conducted at the Center of Experimental Animal Research, Faculty of Veterinary Medicine, Benha University, Egypt.

Birds and housing

A total of 225 (1-day-old) Hubbard efficiency plus broiler chicks were allocated at random into five groups in three replicates, with 15 chicks per replicate and 45 chicks per group. All experimental treatment chicks were raised in the same sanitary and environmental circumstances. Fresh, clean, deep litter made of wood shavings served as the flooring. Water and food were always available during the experiment. The feeding schedule during the trial period was distributed into three stages: Starter (day 1: 10), grower (day 11: 22), and finisher (day 23: 35).

Experimental diet

Five iso-nitrogenic isocaloric diets were formulated for all groups as follows: T1 (control group received a basal diet containing traditional SBM), T2 (received Express® SBM at the level of 7.5% starter, 15% grower, and 30% finisher), T3 (received Express® SBM at the level of 5% starter, 10% grower, and 20% finisher), T4 (received a diet containing full-fat

Table 1. Ingredients and chemical composition of the basal diet (as feed basis)

Ingredient		Starter (day 1-10)					Grower (day 11-22)					Finisher (day 23-35)				
	Unit	T1	T2	T3	T4	T5	T1	T2	T3	T4	T5	T1	T2	T3	T4	T5
Yellow corn	%	53.13	54.18	54.38	52.78	53.84	56.68	57.62	58.37	55.06	57.22	61.12	58.63	60.94	54.32	60.43
Wheat bran	%	1.5	1.5	2	1.4	1.9	1.5	1.4	1.4	1.4	1.4	1.6	1.9	2.5	3	0.8
Soybean meal 46	%	35	27.7	28.5	29.9	28.9	33.7	19.9	23.4	23.5	24	26.6	4.8	7.8	6.1	15.9
Express soymeal	%	-	7.5	5	-	-	-	15	10	-	-	-	30	20	-	-
Full- fat soymeal	%	-	-	-	7.5	5	-	-	-	15	10	-	-	-	30	15
Vegetable oil	%	1.45	-	-	-	-	1.95	-	-	-	-	2.24	-	-	-	-
Limestone	%	1.36	1.37	1.37	1.4	1.4	1.33	1.34	1.34	1.4	1.39	1.25	1.27	1.27	1.42	1.33
Dicalcium phosphate	%	1.6	1.6	1.6	1.55	1.58	1.47	1.45	1.46	1.37	1.42	1.22	1.15	1.19	1	1.14
Corn gluten meal	%	4.2	4.5	5.4	3.65	5.6	1.75	1.9	2.5	0.74	2.9	4.4	1.2	5	2.7	3.8
Vit & min mixture	%	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Sodium chloride	%	0.23	0.23	0.23	0.23	0.23	0.23	0.25	0.24	0.24	0.23	0.23	0.3	0.25	0.24	0.23
DL-Methionine	%	0.32	0.29	0.29	0.32	0.3	0.32	0.27	0.28	0.32	0.3	0.24	0.18	0.18	0.25	0.24
Sodium bicarbonate	%	0.29	0.27	0.29	0.28	0.28	0.24	0.2	0.23	0.23	0.27	0.26	0.11	0.2	0.28	0.25
L_Lysine	%	0.33	0.3	0.35	0.3	0.38	0.25	0.19	0.24	0.2	0.3	0.28	-	0.2	0.19	0.25
Choline chloride	%	0.11	0.1	0.11	0.09	0.1	0.1	0.09	0.09	0.07	0.08	0.1	0.07	0.09	0.05	0.07
Ant-mycotoxin	%	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Emulsifier	%	-	-	-	-	-	0.05	0.02	0.05	0.05	0.05	0.05	0.02	0.02	0.02	0.05
L_Threonine	%	0.11	0.09	0.1	0.1	0.12	0.06	0.00	0.02	0.05	0.07	0.05	-	-	0.05	0.05
Ant-oxidants	%	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.1
Energy enzyme	%	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Ant-colesterdia	%	0.01	0.01	0.01	0.01	0.01	0.01	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	0.01	0.01	0.01	0.01	0.01	0.01
Protease enzyme	%	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Calculated nutrient																
ME	Kcal/kg	3,018.61	3,013.92	3,000.57	3,001.64	3,001.91	3,100.66	3,101.52	3,101.36	3,101.32	3,100.86	3,201.32	3,205.57	3,218.72	3,206.19	3,202,33
Crude Protein	%	23.11	23.11	23.12	23.10	23.15	21.28	21.26	21.26	21.26	21.25	20.02	20.02	20.12	20.08	20.02
Digestible protein	%	19.83	19.69	19.72	17.45	18.25	18.18	17.88	17.96	13.42	14.95	17.09	16.67	16.78	7.67	12.34
Crude fat	%	4.00	3.05	2.65	4	3.54	4.53	3.5	3.26	5.22	4.44	5.00	4.39	3.99	7.95	5.43
Digestible fat poultry	%	2.17	2.62	2.53	2.10	2.22	2.18	3.02	2.80	2.02	2.18	2.39	3.84	3.51	2.00	2.27
Crude Fiber	%	2.36	2.56	2.51	2.62	2.53	2.36	2.76	2.62	2.89	2.67	2.26	3.16	2.84	3.38	2.73
Lysine	%	1.40	1.40	1.40	1.40	1.40	1.29	1.29	1.29	1.29	1.29	1.15	1.15	1.16	1.15	1.15
Lysine Dig	%	1.27	1.27	1.28	1.26	1.27	1.17	1.17	1.18	1.15	1.17	1.05	1.04	1.05	1.02	1.03
Methionine	%	0.67	0.66	0.66	0.67	0.67	0.64	0.62	0.63	0.63	0.63	0.56	0.54	0.54	0.56	0.55
Methionine Dig	%	0.64	0.62	0.63	0.64	0.63	0.61	0.58	0.59	0.60	0.59	0.53	0.49	0.50	0.53	0.52
Methionine + Cystine	%	1.05	1.05	1.06	1.06	1.05	0.99	0.99	0.99	0.99	0.98	0.90	0.90	0.91	0.91	0.90
Methionine + Cystine Dig	%	0.95	0.95	0.95	0.95	0.95	0.90	0.89	0.89	0.88	0.88	0.81	0.81	0.81	0.79	0.80
Threonine	%	0.97	0.97	0.97	0.96	0.96	0.85	0.85	0.85	0.85	0.85	0.79	0.86	0.81	0.79	0.79
Threonine Dig	%	0.83	0.83	0.83	0.82	0.83	0.73	0.72	0.72	0.73	0.73	0.67	0.72	0.68	0.67	0.67
Tryptophan	%	0.26	0.27	0.26	0.27	0.26	0.25	0.26	0.25	0.26	0.24	0.22	0.25	0.23	0.23	0.22
Tryptophan Dig	%	0.23	0.23	0.23	0.23	0.22	0.22	0.23	0.22	0.22	0.21	0.19	0.22	0.20	0.20	0.19
Calcium	%	1.00	1.00	1.00	1.00	1.00	0.95	0.95	0.95	0.95	0.95	0.85	0.85	0.85	0.85	0.85
Available Phosphorus	%	0.50	0.50	0.50	0.50	0.50	0.47	0.47	0.47	0.47	0.47	0.42	0.42	0.42	0.42	0.42
Digestible phosphorous	%	0.37	0.35	0.36	0.35	0.35	0.35	0.31	0.33	0.31	0.32	0.31	0.24	0.26	0.22	0.26
Chloride	%	0.23	0.23	0.24	0.23	0.24	0.22	0.22	0.22	0.22	0.23	0.22	0.22	0.22	0.22	0.22
Sodium	%	0.17	0.17	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.17	0.16	0.16	0.16	0.17	0.16
Potassium	%	0.89	0.90	0.88	0.90	0.86	0.87	0.89	0.87	0.88	0.83	0.75	0.90	0.78	0.78	0.75
Dietary electrolyte balance	me\kg	233.36	235.53	227.44	207.62	199.93	225.82	233.14	226.26	173.78	178.94	195.57	233.76	201.82	92.84	141,49
Choline	ppm	1,726.05	1,677.07	1,704.10	1,699.98	1,680.78	1,617.66	1,601.51	1,592.80	1,620.94	1,601.42	1,525.11	1,500.19	1,492.60	1,571.75	1,493,88

SBM at the level of 7.5% starter, 15% grower, and 30% finisher), and T5 (received a diet containing full-fat SBM at the level of 5% starter, 10% in grower, and 15% finisher). according to Hubbard's requirement (2022), all nutrients were addressed, as indicated in Table 1. The proximate analysis was performed on samples of soybean meal, Expeller soybean meal, and FFSB, as shown in Table 2.

Carcass characteristics

Five chicks were slaughtered according to the Islamic method on the last day of the experiment (on day 35) after 12 hours of fasting from the feed with free access to water. Then, carcass features, such as the weights of breast, thigh, dressed carcass, immune organs, liver, heart, gizzard, and abdominal fat, were measured, and recorded as a percentage of live body weight (Biesek *et al*. 2020).Returns from carcass parts as breast price (LE), thigh price (LE), liver and gizzard price (LE), neck and back price (LE), and total price (LE) were calculated according to Salih *et al*. (2023).

Fatty acid and amino acid profile

After slaughtering birds, the skin was removed, and samples were taken from the pectoralis major muscle for the detection of fatty acid (FA) and amino acid (AA) profiles in meat.

Free FA was determined by gas chromatography (GC) (Ahmed *et al*., 2016). Additionally, amino acids were detected by high-performance liquid chromatography (HPLC) using the precolumn phenyl isothiocyanate (PITC) derivatization technique according to the method of Heinrikson and Meredith (1984).

Muscular histomorphology

Muscular histomorphometry was carried out in accordance with the method's instructions of Abudabos *et al*. (2018). The left pectoralis major muscle was cut into 4 cm^2 samples, immersed in 10% neutral-buffered formalin, and treated using the paraffin embedding method. The sample

Table 2. Chemical composition of commercial SBM, express SBM, and full-fat SBM (as feed basis)

Chemical composition	unit	Traditional SBM	Express SBM	Full-fat SBM
Metabolizable energy	kcal/kg	2345	2595	3258
Moisture		10.01	8.45	6.29
Crude protein		46.48	39.32	34.84
Ether extract		2.5	10.2	19.4
Crude fiber		4.1	5.5	4.2
Ash		7.3	5.9	5.7
Total phosphorus		0.57	0.57	0.41
Phytic phosphorus	%	.34 0	0.31	0.25
Trypsin inhibitor factors		1.7	3.7	10.8
Ammonia		1.96	1.97	1.97
KOH Solubility		77.9	77.1	83.3
Reactive lysine		2.5	2.18	1.77
Reactive lysine/lysine		87.65	88.02	84
Indispensable amino acids (%in CP)				
Arginine		7.04	7.29	7.14
Histidine		2.54	2.59	2.53
Isoleucine		4.54	4.45	4.57
Leucine		7.4	7.43	7.32
Lysine	%	5.95	6.19	6.02
Methionine		1.27	1.32	1.32
Phenylalanine		4.99	4.88	4.97
Threonine		3.82	3.9	3.76
Tryptophan		1.33	1.36	1.32
Valine		4.67	4.69	4.72
Dispensable amino acids (%in CP)				
Alanine		4.23	4.27	4.31
Aspartate		11.14	11.1	11.06
Cysteine		1.38	1.42	1.45
Glutamate	%	17.55	17.49	17.35
Glycine		4.13	4.2	4.23
Proline		4.88	4.89	4.98
Serine		4.91	4.93	4.93

was sliced into 5-m longitudinal slices that were fixed on slides. Then, hematoxylin and eosin (H&E) staining was applied to the slides. The average diameter of muscle fibers was measured according to Shah *et al.* (2019). The images of cross and longitudinal sectional muscle fiber were taken using a microscope attached to the camera, and the histomorphometry analysis was carried out using the Image J analysis software.

Statistical analysis

SPSS (IBM Corp. Released 2019. IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp) (SPSS, 2019) was used to collect, organize, summarize, and perform a statistical analysis of the experiment's data. Using the Shapiro-Wilk test, the normality of the variable distribution was determined. The results for each group were presented as mean and standard error in the case of using one-way ANOVA to analyze the normally distributed data. Tukey's test was used to determine if differences between mean values were significant. However, in the lack of normality, data were analyzed using the non-parametric Kruskal-Walli's technique, and the results were presented as the median and interquartile ranges for each group. Differences were considered statistically significant at the level of $P < 0.05$.

Results

Carcass characteristics

The effect of dietary treatments on dressing percent, in addition to the weight of thigh, breast, gizzard, liver, immune organs, intestinal length, and width, are shown in Table 3 and Figure 1 that indicated a non-significant difference ($p > 0.05$) except for the percentage of the spleen which decreased significantly when compared to others.

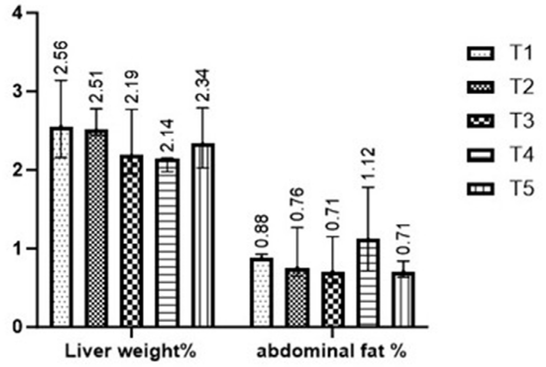

Fig 1. Effect of dietary inclusion of extruded expelled soybean (ESBM) and extruded full-fat soybean (EFFSB) on liver and abdominal fat percent of chicken.

Fatty acid and amino acid profile

The profile of fatty acid was highly affected by the addition of EESB (extruded expelled soybean) and EFFSB (extruded full-fat soybean), as shown in Table 4. Breast meat revealed Palmitic C16, which did not change among all experimental groups, while other saturated fatty acids recorded significant differences. Additionally, T2 decreased significantly in mysteric C14, stearic C17, and margaric C18 compared to T3 and T5. Other treated groups did not change from T1. Eicosadienoic C20:2, linoleic C18:2, y-linolenic eicosanoic C20:1, and arachidonic C20:4 did not change among all experimental diets, while palmitoleic C16:1, octadecanoic C18:1, myresto-vaccenic C14:1, and alpha-linolenic C18:3-n3 showed significant differences as T2 decreased in octadecanoic C18:1. T4 decreased in myresto-vaccenic C14:1. Moreover, other groups did not change from the control group for all non-saturated fatty acids, except alpha-linolenic C18:3-n3, which increased in full-fat groups.

Table 3. Effect of dietary inclusion of extruded expelled soybean (ESBM) and extruded full-fat soybean (EFFSB) on the relative weight of dressed carcass, different organs, immune organs, return from different organs, and intestinal length and width of chickens.

	T1	T2	T3	T4	T5	P value
Live body weight (gm)	2052.6 [a] ±108.35	1956.4 [a] ±102.25	1917.6 [a] ±94.81	2062.8 [a] ±129.16	1942.4 [a] ±137.68	0.85
Dressed carcass (%)	75.9 [a] ±0.64	75.91 [a] ±1.24	74.44 [a] ±0.53	75.63 [a] ±0.67	75.9 [a] ±1.03	0.71
Breast weight (%)	26.37 [a] ±0.52	26.09 [a] ±0.97	26.9 [a] ±0.91	27.04 [a] ±0.89	28.18 [a] ±0.85	0.47
Thigh weight (%)	29.66 [a] ±0.43	30.07 [a] ±0.57	28.22 [a] ±0.41	28.61 [a] ±0.63	29.03 [a] ±0.67	0.15
Gizzard weight (%)	1.64 [a] ±0.07	1.72 [a] ±0.11	1.82 [a] ±0.15	1.74 [a] ±0.09	1.88 [a] ±0.11	0.57
Heart weight (%)	0.47 [a] ±0.03	0.46 [a] ±0.01	0.43 [a] ±0.03	0.53 [a] ±0.04	0.44 [a] ±0.01	0.09
Relative weight of immune organs						
Thymus (%)	0.43 [a] ±0.02	0.33 [a] ±0.08	0.31 [a] ±0.04	0.33 [a] ±0.07	0.24 [a] ±0.03	0.20
Bursa (%)	0.1 [a] ±0.01	0.17 [a] ±0.02	0.16 [a] ±0.02	0.16 [a] ±0.01	0.14 [a] ±0.04	0.23
Spleen (%)	0.15 [a] ±0.01	0.13 [ab] ±0.02	0.18 [a] ±0.02	0.08 [b] ±0.01	0.13 [ab] ±0.02	0.00
Return from different organs of carcass						
Breast price (LE)	43.33 [a] ±2.51	41.12 [a] ±3.37	41.36 [a] ±2.78	44.74 [a] ±3.58	43.68 [a] ±3.04	0.90
Thigh price (LE)	24.42 [a] ±1.58	23.54 [a] ±1.36	21.65 [a] ±1.15	23.58 [a] ±1.43	22.67 [a] ±2.05	0.76
Liver& gizzard price (LE)	4.35 [a] ±0.16	4.2 [a] ±0.21	3.89 [a] ±0.21	4.02 [a] ±0.23	4.13 [a] ±0.39	0.75
Neck& back price (LE)	6.1 [a] ±0.27	5.79 [a] ±0.33	5.55 [a] ±0.26	6.19 [a] ±0.45	5.44 [a] ±0.36	0.47
Total price (LE)	78.19 [a] ±4.32	74.66 [a] ±5.09	72.45 [a] ±4.09	78.52 [a] ±5.28	75.92 [a] ±5.66	0.90
intestinal length and width						
Intestinal length (cm)	136.4 [a] ±10.27	146.8 [a] ±5.49	155.9 [a] ±9.71	158.9 [a] ±9.42	150.8 [a] ±7	0.41
Duodenal length (cm)	23.8 [a] ±1.24	25.8 [a] ±0.66	24.2 [a] ±1.28	26 [a] ±2.28	26 [a] ±1.7	0.74
Duodenum diameter (cm)	1.72 [a] ±0.14	1.92 [a] ±0.12	1.76 [a] ±0.07	1.84 [a] ±0.12	1.74 [a] ±0.11	0.72
Jejunum length (cm)	58.6 [a] ±3.66	63 [a] ±2.72	66.5 [a] ±2.13	69.1 [a] ±4.51	65.8 [a] ±2.87	0.25
Jejunum diameter (cm)	1.58 [a] ±0.16	1.8 [a] ±0.11	1.56 [a] ±0.09	1.66 [a] ±0.1	1.4 [a] ±0.09	0.2
Ileum length (cm)	54 [a] ±8.07	58 [a] ±2.97	65.2 [a] ±6.83	63.8 [a] ±3.92	59 [a] ±4.07	0.62
Ileum diameter (cm)	1.3 [a] ±0.07	1.56 [a] ±0.07	1.6 [a] ±0.14	1.38 [a] ±0.13	1.5 [a] ±0.11	0.31

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

The result of the analysis of amino acids in the breast muscle of a broiler chick is shown in Figures 2, 3, and 4. Regarding essential amino acids, i.e., valine, lysine, and methionine were not altered among different treated groups. Other essential amino acids showed great significance among different groups, such as threonine, leucine, and isoleucine. They increased significantly in T3 and T5 compared to T2 and T4. In addition, phenylalanine recorded a significant increase in T1 but decreased in T2 and T3. Serine and tyrosine are non-essential amino acids that did not show any difference among different treated groups, while alanine, proline, cysteine, glycine, aspartic acid, and glutamic acid showed significant differences. T2 decreased in alanine and cysteine, but T5 decreased in proline, glycine, and aspartic acid. Glutamic acid showed a marked increase in T3, and the control group compared to T5 and other groups.

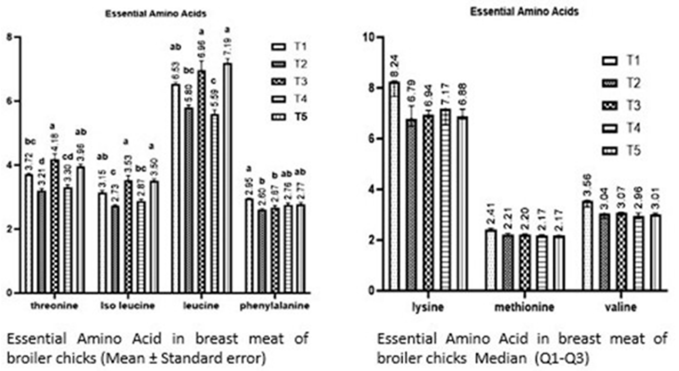

Fig 2. Effect of dietary inclusion of extruded expelled soybean (ESBM) and extruded full-fat soybean (EFFSB) on essential amino acids in broiler chicks.

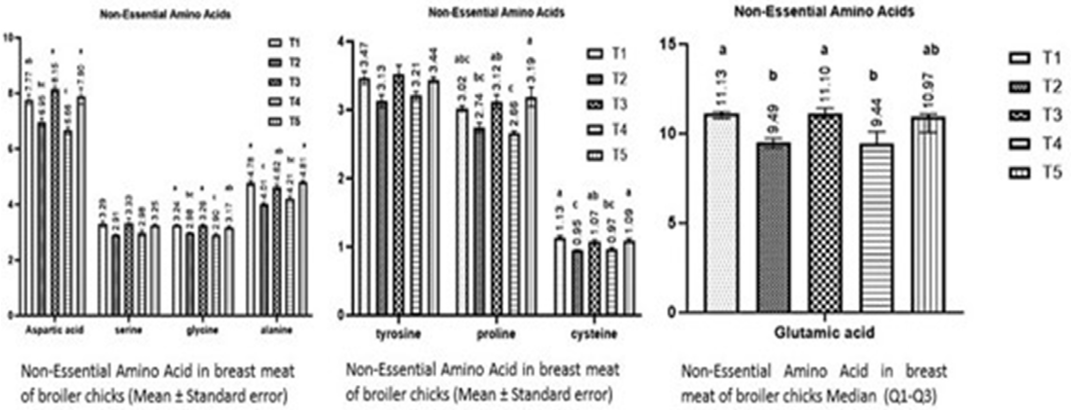

Fig 3. Effect of dietary inclusion of extruded expelled soybean (ESBM) and extruded full-fat soybean (EFFSB) on non-essential amino acids in broiler chicks.

Table 4. Effect of dietary inclusion of extruded expelled soybean (ESBM) and extruded full-fat soybean (EFFSB) on fatty acid profile.

	T1	T2	T3	T4	T5	P value
	Mean±Standard Error					
	Saturated Fatty Acids					
Palmitic C16	29.43 ^{a} ±1.22	28.77 ^{a} ±0.39	30.37 ^{a} ±0.07	28 ^{a} ±1.07	30.3 ^{a} ±0.72	0.26
Margaric C17	0.14 ^{bc} ±0.0	0.13 ^{c} ±0.0	0.15 ^{a} ±0.0	0.14 ^{abc} ±0.0	0.15 ^{ab} ±0.0	0.00
	Non-saturated Fatty Acids					
Palmitoleic C16:1	5.1 ^{bc} ±0.06	5.57 ^{ab} ±0.13	5.47 ^{abc} ±0.03	5 ^{c} ±0.2	5.67 ^{a} ±0.03	0.01
Octadecanoic C18:1	31.37 ^{a}±0.47	27.43 ^{b} ±0.33	35.1 ^{a} ±0.32	33.6 ^{a} ±1.61	34.8 ^{a} ±0.7	0.0
Eicosadienoic C20:2	0.16 ^{a} ±0.0	0.16 ^{a} ±0.0	0.17 ^{a} ±0.0	0.16 ^{a} ±0.01	0.17 ^{a} ±0	0.13
	Median (Q1-Q3)					
	Saturated Fatty Acids					
Myristic acid C14	0.87 ^{ab} (0.81-0.90)	0.74 ^{b} (0.73-0.75)	0.91 ^{a} (0.87) (0.93)	0.72 ^{b} (0.72-74)	0.90 ^{a} (0.89-0.91	0.02
Pentadecylic acid C15	0.07^{ab} (0.07-0.07)	0.07 ^{ab} (0.07- 0.07)	0.08 ^{a} (0.07-0.08)	0.05 ^{b} (0.05-0.05)	0.07 ^{a} (0.07-0.07)	0.02
Stearic acid C18	5.40 ^{ab} (5.20-5.70)	4.80 ^{b} (4.70-4.90)	5.70 ^{a} (5.705.90)	5.70 ^{a} (5.20-5.90)	5.90 ^{a} (5.70-6.00)	0.04
	Non-saturated Fatty Acids					
Myresto-vaccenic C14:1	0.21 ^{a} 0.20-0.21	0.20 ^{ab} (0.19-0.20)	0.20 ^{a} (0.20-0.22)	0.17 ^{b} (0.17-0.19)	0.21 ^{a} (0.20-0.22)	0.03
Linolic C18:2	12.40 ^{a} 12.30) (12.90)	12.00 ^{a} (9.70) (12.10)	13.10 ^{a} (12.40) (13.30)	11.80 ^{a} (11.70) (12.50)	12.80 ^{a} (12.60-13.40)	0.06
Y linolenic C18:3-n6	0.10 ^{a} (0.10-0.11)	0.08 ^{a} (0.08-0.10)	0.11 ^{a} (0.11-0.11)	0.09 ^{a} (0.09-0.11)	0.11^{a} (0.11-0.11)	0.06
Alpha linolenic C18:3-n3	0.67 ^{b} (0.64-0.69)	0.58 ^{b} (0.55-0.61)	0.69 ^{ab} (0.69-0.73)	0.73 ^{a} (0.73-0.74)	0.71 ^{a} (0.69-0.74)	0.02
Eicosanoic C20:1	0.41 ^{a} (0.41-0.44)	0.44 ^{a} (0.41-0.45)	0.44 ^{a} (0.42-0.46)	0.32 ^{a} (0.31-0.32)	0.43 ^{a} (0.43-0.44)	0.07

Means carrying $^{a, b, c}$ are significantly different among different groups of the same row.

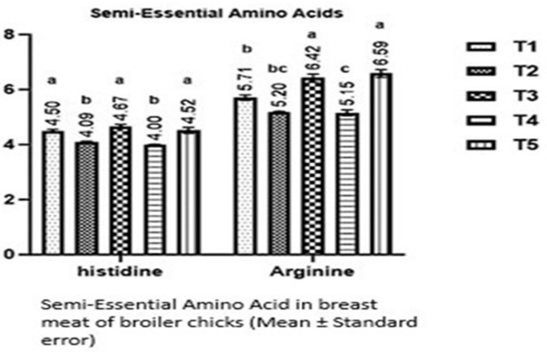

Fig 4. Effect of dietary inclusion of extruded expelled soybean (ESBM) and extruded full-fat soybean (EFFSB) on semi-essential amino acids in broiler chicks.

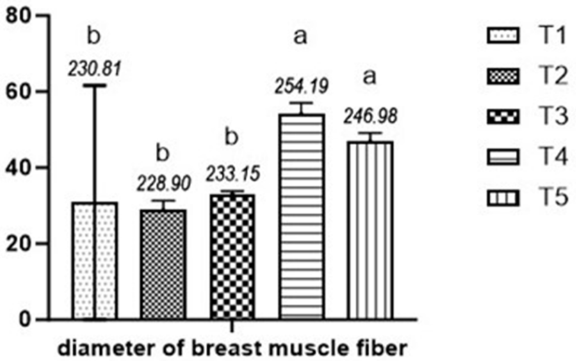

Fig 5. Effect of dietary inclusion of extruded expelled soybean (ESBM) and extruded full-fat soybean (EFFSB) on diameter muscle fiber.

Histomorphology of breast meat

The impact of various types of SBM on muscle histomorphology for measuring the diameter of myofibril is shown in figures 5, 6, and 7. The result revealed that muscle fiber diameter was significantly ($P < 0.05$) higher in groups fed FFSB meal (T4 and T5) compared to groups fed extruded expelled SBM and the control group. The examination of the slide under the microscope noted a marked increase in the diameter of myofibril in the cross-section in T4 and T5, as shown in Figure 3. There was marked hypertrophy of myofibers in the longitudinal section in T4 and T5, as shown in Figure 6.

Discussion

According to carcass traits the result revealed non-significant differences in the dressing percentage and the weights of the breast, liver, gizzard, immune organs, and intestinal length and width. The result indicated a non-significant difference ($p > 0.05$) in carcass trait and return from carcass except spleen decreased significantly in T4 compared to T1 and T3. The percentage of the dressed carcass and thigh ranged from the highest level in T2 to the lowest level in T3. These results showed some similarity to Salih *et al.* (2023), who reported that the addition of EESBM in broiler diets at different levels gave non-significant differences in carcass criteria and internal organs.

Janocha *et al.* (2022) showed no effect of complete substitution of commercial SBM with expeller cake soybean or full-fat soybean on dressing percent; however, the group fed SBM and EESBM showed an increase in musculature and a decrease in fat content when compared with the FSBM diet, but the lowest heart, liver, and gizzard percent were observed in chickens receiving soybean expeller cake-containing diet. Alsaftli *et al.* (2015) found that adding full-fat soybean at a different level in the diet of turkey had no influence on the percentage of dressed carcass, breast,

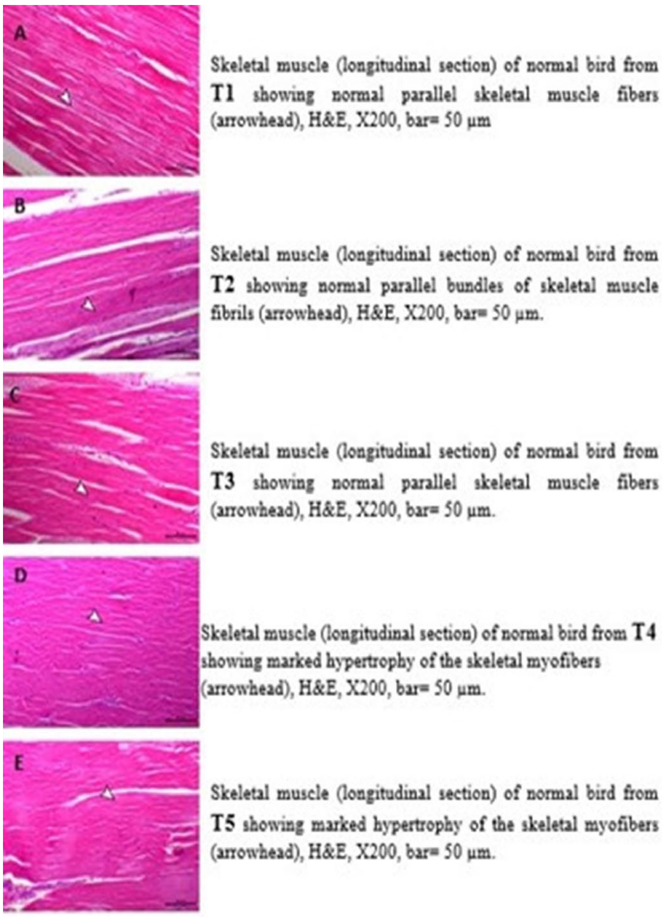

Fig 6. Effect of dietary inclusion of extruded expelled soybean (ESBM) and extruded full-fat soybean (ESBM) on muscle fiber histomorphology in longitudinal section.

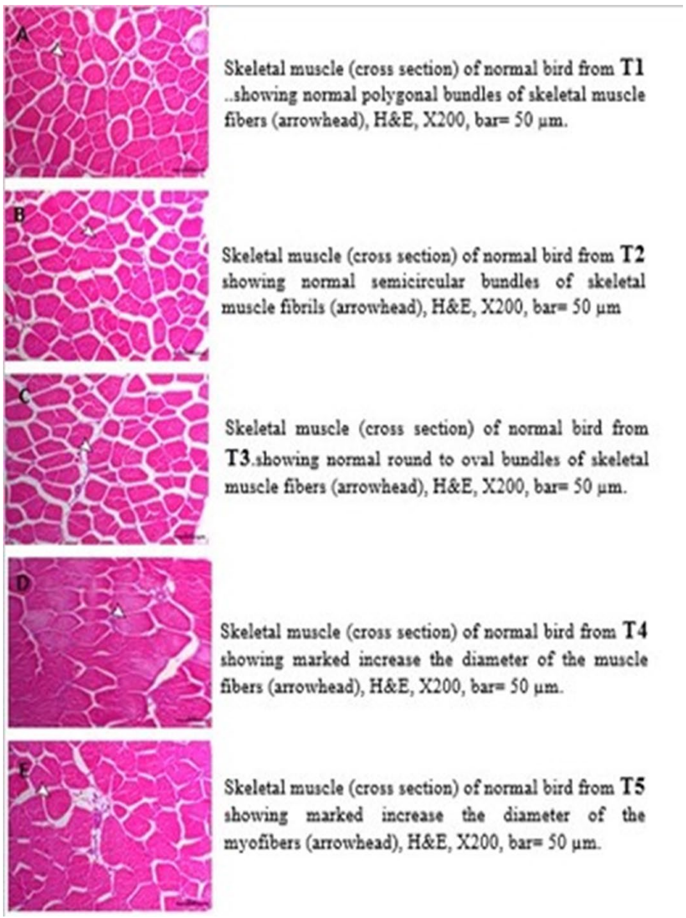

Fig. 7. Effect of dietary inclusion of extruded expelled soybean (ESBM) and extruded full-fat soybean (ESBM) on muscle fiber histomorphology in cross-section.

thigh, and liver. They attributed this result to all experimental and control diets formulated in iso-nitrogenic and iso-caloric. They added that no negative impact on carcass output could happen if the diet's ratio of nutrients to calories was consistent. Tammam (2015) added full-fat soybeans at different levels in the broiler diet and observed non-significant differences between experimental groups of chicks fed in the carcass yield, weight of internal organs, abdominal fat, and carcass cuts.

In addition, El-Faham *et al.* (2012) found that partially replaced commercial SBM with full-fat SBM at different amounts in the starter and grower diets of broiler chicks and noted a marked increase in breast and a marked decrease of the thigh in broiler diet containing FFSBM at 4 and 6% and 10 and 12%. Śliwa and Brzóska (2018) found that the mass of the heart, stomach, liver, and spare fat recorded no significance between different groups. In contrast, there was a significant decrease in breast muscles of broiler chicken fed extruded expeller soybeans that replaced solvent soybeans at variable levels. Some researchers disagreed with our results, such as Taslimi *et al.* (2021), who recorded a marked increase in carcass percentage, breast, and thigh weight in broiler-fed extruded soybeans, which was due to the increased bioavailability of amino acids from this protein source. The reason for this increase could be due to highly bioavailable amino acid in expeller soybeans and the increased level of lysine that could be considered a limiting factor for muscle that increased the weight of dressed carcass (Leeson and Summers, 2001; 2005). This could improve the relative weight of ready-to-cook carcasses and improve economics.

Chicken flesh is one of the most valuable sources of protein and fatty acids that humans need. The composition of broiler meat has a substantial effect on diet modification. From the perspective of human health, it is widely accepted that one of the most important markers of meat quality is its FA content (Smet *et al.*, 2008). In the present study, we examined the effects of express soybean meal and full-fat soybean meal express soybean meal on the AA and FA profiles of broiler chickens. Breast meat revealed that palmitic C16 did not change among all experimental groups, while other saturated fatty acids recorded significant differences. Additionally, T2 decreased significantly in mysteric, stearic, and margaric compared to T3 and T5. Other treated groups did not change from T1. Eicosadienoic C20:2, linoleeic C18:2, y-linolenic eicosanoic C20:1, and arachidonic C20:4 did not change among all experimental diets. At the same time, palmitoleic C16:1, octadecanoic C18:1, myresto-vaccenic C14:1, and alpha-linolenic C18:3-n3 showed significant differences as T2 decreased in octadecanoic C18:1, and T4 decreased in myresto-vaccenic C14:1. Moreover, other groups did not change from the control group for all non-saturated fatty acids, except alpha-linolenic C18:3-n3 that increased in full-fat groups. Some researchers compared the effect of full-fat soybean and extruded expeller soybean meal. For example, Janocha *et al.* (2022) used extruded full-fat soybean meal and soybean expeller cake as the only source of protein in the diet of broiler chicks and noted a decrease in the content of palmitic, stearic, and saturated fatty acids (SFA) and hypercholesterolemic fatty acids in breast muscles of extruded full-fat soybean group compared to muscles from other groups. Moreover, there was a significant decrease ($p < 0.05$) in the content of oleic acid (C18:1) and monounsaturated fatty acids (MUFA), while the content of linoleic acid, linolenic acid, and polyunsaturated fatty acids (PUFA) recorded the highest level in the meat from the EFS group in comparison to SBM and soybean expeller cake groups. Milczarek and Osek (2019) noted a significant decrease in saturated FA and simultaneously the elevated level of PUFA in the muscle of broiler fed diet containing extruded full-fat soybean meal compared to the soybean meal and distillers dried grains with soluble (DDGS) groups. Saturated fatty acids are recommended to be as low as possible, according to the European Food Safety Authority, since their intake is positively connected to blood levels of cholesterol, low-density lipoprotein (LDL), and the occurrence of cardiovascular disease (European Food Safety Authority 2010). However, much research found no connection between the consumption of saturated FAs and the development of cardiovascular disease (Chowdhury *et al.*, 2014).

Meat and meat derivatives are major protein sources, and protein quality is mostly determined by the amount of AAs present. Therefore, our study was concerned with the determination of amino acids in breast meat to detect the impact of full-fat SBM and express SBM on the amino acid profile of breast meat. Our results showed essential amino acids, such as valine, lysine, and methionine, were not altered among different treated groups. Other essential amino acids showed great significance among different groups, such as threonine, leucine, and isoleucine, which increased significantly in T3 and T5 compared to T2 and T4. In addition, phenylalanine recorded a significant increase in T1 but decreased in T2 and T3 compared to T4 and T5. Serine and tyrosine are non-essential amino acids that did not show any difference among different treated groups, while alanine, proline, cysteine, glycine, aspartic acid, and glutamic acid showed significant differences. T2 decreased in alanine and cysteine, but T5 decreased in proline, glycine, and aspartic acid. Glutamic acid showed a marked increase in T3, and the control group compared to T5 and other groups.

The typical amount of protein in poultry meat is up to 20%, and essential amino acids exceed 40% of the total AAs (Kim *et al.*, 2017). Ramane *et al.* (2011) added that lysine, leucine, aspartic, and glutamic acids are essential amino acids (EAAs) present in high amounts in broiler meat. AAs are often regarded as the primary source of taste compounds. Glu has been proven to have a significant influence on the flavor of chicken flesh (Huang *et al.*, 2011). In our results, glutamic acid mainly increased in (T3). This enhanced the meat preference in this group. The taste of the meat can be significantly influenced by flavor amino acids (FAA), such as glutamic acid (Glu), aspartic acid (Asp), and serine (Ser) (Xu *et al.*, 2017).

The meat of broiler chicken is considered the most important animal protein of high quality. The qualities of muscle fiber have a crucial role in determining the quality and quantity of meat (Weng *et al.*, 2022). Additionally, the quality and quantity of the meat are both affected by the morphologic and morphometric properties of meat fibers (Ismail and Joo, 2017). This research results showed that muscle fiber was increased in groups fed full-fat soybean meal compared to the groups fed extruded expelled SBM and control group. There was a marked increase in diameter (cross section) and marked hypertrophy (longitudinal section) in T4 and T5. Our result was supported by Tůmová and Teimouri (2009), who found that an increase in the size of breast muscle fiber produces meat of high quality. In addition, the muscle size was more closely correlated with fiber size than with fiber number. It appears that the selection of broilers with an emphasis on increased breast production resulted in the development of thicker and broader pectoralis major muscles, mostly through an increase in fiber length and diameter without a discernible change in the number of fibers (Guernec *et al.*, 2003). While research by Scheuermann *et al.* (2004) revealed that fiber hypertrophy was a prerequisite for a rise in muscle volume, it suggested that elevated muscle fiber number might be a factor in enhanced breast output. In contrast, Chen *et al.* (2007) indicated that an increase in the diameter of muscle fiber in broilers resulted in tougher meat than an increase in the number of muscle fibers. The previous result was explained by Dransfield and Sosnick (1999), who found that increased growth rates led to increased glycolytic fiber percentage and muscle fiber diameter, as well as decreased proteolytic potential in the muscles, which led to increased muscle toughness.

Conclusion

Partial substitution of traditional SBM with full-fat SBM and expeller-SBM showed no effect on carcass trait except for the percentage of the spleen, which increased in response to the presence of expeller-SBM in the diet up to 7.5, 15, and 30% in starter, grower, and finisher broiler chicken diets. Additionally, the inclusion of EESB and FFSB does not cause any fundamental change in meat quality. From the point of view of human nutrition and health, the inclusion of full-fat SBM in diets up to 5, 10, and 20% in starter, grower, and finisher make improvements in meat quality through increased non-saturated FAs, non-essential AAs, and diameter of muscle fiber.

Acknowledgments

The authors are grateful to the Faculty of Veterinary Medicine, Benha University, for supporting this work.

Conflict of interest

The authors declare that they have no conflict of interest.

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