PERFORMANCE, CARCASS WEIGHTS AND COST OF PRODUCTION OF BROILER CHICKENS FED BLACK SOLDIER FLY LARVAE MEAL DIETS

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ABSTRACT

This study investigated black soldier fly larvae meal (BSFLM) as a replacement for fish meal on growth performance and economy of production of broiler chickens. Black soldier fly larvae were processed, dried and milled. 250 Cobb 500 breed day-old chicks were randomly allotted at 50 chicks per treatment (five) in a Completely Randomized Design. The BSFLM was used to replace fish meal at graded levels 0, 25, 50, 75 and 100% and designated diets I, II, III, IV and V, and diets and water were fed to the chickens ad libitum. The result showed that the feed intake was significantly influenced ($p<0.05$) by the dietary treatments. The highest feed intake (5069.10 ± 43.42 g/bird) was recorded in bird-fed Diet I, while the lowest feed intake (4855.93 ± 130.69 g/bird) was recorded in bird-fed Diet IV. The highest final weight (2000.00 ± 50.00 g) and best feed conversion ratio (2.52 ± 0.13) were recorded in birds fed diets I and III, respectively. The highest dressed and eviscerated weights (91.19 ± 23.85 and 76.51 ± 10.59%) were recorded in birds fed Diet IV and III, respectively. The highest net profit/bird (₦3208.48) was recorded in bird-fed Diet V. The percentage of net profit/bird increased as the level of BSLM inclusion increased. It is concluded within the limit of this study that replacing FM with BSLM will reduce the high cost of finished feed, thereby increasing farmers' profit and making animal protein available to the populace.

Keywords: Economic, Fish meal, Growth, Insect meal, Broiler chicken

INTRODUCTION

The need for the replacement of expensive and unavailable feedstuffs with cheaper alternative in the formulation of poultry rations is now the interest of poultry nutritionist so as to cut production costs. Feed constitutes the major component cost of poultry production under intensive systems and this varies between 65 – 75% total costs of production (Adegbenro *et al.,* 2017). Feed formulation is more than merely adding ingredients together, it involves combining ingredients in proportions necessary to provide the animal with the proper amount of nutrients required at a particular time. The rising cost of fishmeal daily is the main reason for its scarcity. Currently, the cost of fish meal is ₦2,800.00 per kilogram. This input could be substantially reduced or completely substituted if black soldier fly larvae meal (BSFLM) is produced in large quantities from some plant-based organic wastes. Black soldier flies are small, harmless insects that have the potential to provide promising solutions to the high cost of animal feed and environmental pollution (waste management). Recent research has shown that black soldier flies may be instrumental in closing the loop between animal waste and animal feed (Watson *et al*., 2005). Black soldier fly larvae will eat nearly all kinds of organic waste ranging from animal waste to food scraps. The dry weight of Black Soldier Fly larvae (BSFL) contains up to 50% crude protein (CP), and 35% lipids and have an amino acid profile that is similar to that of fishmeal (Elwert *et al.,* 2010). Thus, this study was designed to evaluate the potential of BSFLM as an animal protein source in broiler chick diets.

MATERIALS AND METHODS

Experimental Site: The study was carried out at the Poultry Unit of the Teaching and Research Farms, The Federal University of Technology, Akure, Nigeria between February 03 and March 23, 2023. The University is located on (Latitude $7^0$18″N and Longitude $5^0$10″E) Akure, Nigeria (NIMET, 2014). The altitude is about 350.52m above sea level, the annual humidity is 75% and the temperature is 27^0C (Ashaolu and Adebayo, 2014).

Production of Black Soldier Fly Larvae Meal (BSFLM): Black soldier fly larvae were harvested from a location in Ilesha, Nigeria and were transported to Akure, Nigeria. The live larvae plus debris, were poured into buckets containing cold water and thoroughly washed before processing. During processing, the live larvae were poured into hot water at about 70 – 80^{o}C and stirred for about 3 – 5 minutes in order to make the larvae inactive. Filtered dead larvae were spread on nylon and solar dried to minimum moisture content. Dried larvae were then milled to produce BSFLM, and stored in an air-tight container prior to use.

Experimental Diets Production: A basal diet was produced to meet the nutritional requirement of broiler chicken. The fishmeal in the basal diet was replaced with BSFLM at 0, 25, 50, 75 and 100% and designated diets I, II, III, IV and V, respectively. The dietary ingredients as well as the formulated diets were analysed for their proximate compositions (AOAC, 2023). The gross composition of the experimental diets is shown in Table 1.

Experimental Layout and Feeding Trial: A total number of 300 day–old chicks of Cobbs 500 breed of broiler chicken were procured from Zartech Limited, Ibadan, Nigeria out of which 250 were assigned to five dietary treatments of five replicates and 10 chicks per replicate on the day of arrival in a completely randomized design (CRD). The right to conduct the research was granted by the Research Committee of the Department of Animal Production and Health, The Federal University of Technology, Akure, Nigeria.

Measurement of Growth Performance: At the beginning of the experiment the broiler chicks were weighed and the initial weight of each group replicate was balanced (±1 g) thereafter each group was fed their respective diet *ad libitum* from 1 – 21 days during which weekly feed consumption and weight gained were measured, while the feed conversion ratio was calculated as the ratio of feed consumed to weight gain.

Computation of Economic Viability: The cost of producing the experimental diets was estimated based on the current market prices for all the ingredients. The cost of feed consumed per chick was calculated by the cost of experimental diets multiply by total feed consumed. The total cost of production was calculated by adding the cost of day-old chicks, cost of feed consumed and cost of drug/vaccines. The net profit/started chick was calculated by subtracting the total cost of production from sales price of started chicks. The other expenses such as day-old chicks, drugs and vaccines were common for all the five treatments.

Data Analysis: All data collected on growth performance and carcass characteristics were subjected to one-way analysis of variance (ANOVA). Statistical Package for Social Science (SPSS) version 25.0 was used at p = 0.05 confidence level, to determine whether there were significant differences amongst the treatment means. Where significant difference occurred, means were separate using the least significant difference (LSD).

Table 1: Feed ingredients and gross composition of the experimental diets

Ingredients	Diet I	Diet II	Diet III	Diet IV	Diet V
Maize	53.45	53.45	53.45	53.45	53.45
Soybean meal	16.00	16.00	16.00	16.00	16.00
Groundnut cake	20.00	20.00	20.00	20.00	20.00
Fish meal	5.00	3.75	2.50	1.25	0.00
BSFLM	0.00	1.25	2.50	3.75	5.00
Lysine	0.20	0.20	0.20	0.20	0.20
Methionine	0.10	0.10	0.10	0.10	0.10
Bone	1.00	1.00	1.00	1.00	1.00
Limestone	2.00	2.00	2.00	2.00	2.00
Vitamin/Mineral Premix*	0.25	0.25	0.25	0.25	0.25
Oil	1.50	1.50	1.50	1.50	1.50
Salt	0.50	0.50	0.50	0.50	0.50
Total	100.00	100.00	100.00	100.00	100.00
Calculated Analysis					
Crude protein (%)	23.74	23.55	23.37	23.18	22.99
Metabolizable Energy (Kcal/kg)	3023.18	3037.43	3051.68	3065.93	3080.18
Calcium (%)	1.30	1.30	1.30	1.30	1.30
Phosphorus (%)	0.52	0.50	0.50	0.50	0.43
Lysine (%)	1.31	1.31	1.31	1.30	1.30
Methionine (%)	0.48	0.48	0.48	0.47	0.47

*BSFLM - black soldier fly larvae meal, *Each 2.5 kg of grower vitamins and mineral premix contains 800,000 IU of Vitamin A, 1600,000 IU of Vitamin D3; 5,000 IU of Vitamin E; 2000 mg of Vitamin K; 1500 mg of B1; 4000 mg of B2; 80g of manganese, 50 g of Zinc; 20 g of Iron; 5 g of Copper, 15000 mg of Niacin; 10 mg of B12; 5000 mg of Pantothenic acid, 5000 mg of Folic acid, 20 mg of Biotin, 125 mg of Antioxidant; 200 g of Selenium; 200 mg of Cobalt and 200 mg of Choline*

The experimental layout was a CRD with the model: $Y_{ij} = \mu + \alpha_i + e_{ij}$, where Y_{ij} is the observation of the jth chick in the ith treatment, μ is the overall population mean, α_i is the effect due to the level of BSFLM (0, 25, 50, 75, and 100%) and e_{ij} is the random error term.

RESULTS

This study revealed numerical differences in the growth performance of broiler chicks fed BSFLM-based diets. The influence of BSFLM-based diets on the performance of broiler chicks of age 1 – 42 days indicated that among all the growth parameters measured, only the total feed consumed was significantly influenced ($p \leq 0.05$) by the dietary treatments (Table 2). The highest final weight (2000.00 ± 50.00 g), highest weight gain (1959.25 ± 49.88 g) and the highest feed intake (5069.10 ± 43.42 g) were recorded in birds fed Diet I, while the lowest final weight (1900.00 ± 278.39 g), lowest weight gain (1859.17 ± 278.50 g) and the lowest feed intake (4855.93 ± 130.69 g) was recorded in chicks fed Diet IV. The best feed conversion ratio (2.52 ± 0.13) was recorded in bird-fed Diet III.

The carcass characteristics of broiler chickens fed BSFLM-based diets indicated that all the parameters measured were not significantly influenced ($p > 0.05$) by the dietary treatments (Table 3). The bird-fed Diet IV had the highest dressed weight (91.19 ± 23.85%) and highest wing (78.43 ± 5.04 g). The highest eviscerated weight (76.51 ± 10.59%) and the highest shank (42.63 ± 13.00g) were recorded in bird-fed Diet III. Bird-fed Diet I had the highest values of (25.04 ± 3.30 g), (208.11 ± 21.08 g) and (170.05 ± 17.42 g) for the head, breast and the back weights, respectively. The highest drumstick (103.06 ± 8.21 g) and thigh weights (108.94 ± 13.07 g) were recorded in bird-fed Diet V. The neck weights ranged between 29.56 ± 13.22 – 37.68 ± 4.63 g.

The organ characteristics of broiler chickens fed the experimental diets indicated that all the parameters measured were not significant influenced ($p > 0.05$) by the dietary treatments (Table 4). The results obtained did not follow any particular pattern. Bird-fed Diet V had the highest heart (5.07 ± 4.19 g/kg body weight - BW), liver (19.07 ± 4.93 g/kg BW), lungs (5.80 ± 0.62 g/kg BW), spleen (1.42 ± 0.83 g/kg BW) and abdominal fat (14.20 ± 5.08 g/kg BW).

Table 2: Growth performance of broiler chickens fed black soldier fly larvae meal-based diets

Parameters	Diet I	Diet II	Diet III	Diet IV	Diet V
Initial weight (g/bird)	40.75 ± 0.25	40.75 ± 0.25	40.83 ± 0.14	40.83 ± 0.14	40.75 ± 0.25
Final weight (g/bird)	2000.00 ± 50.00	1963.67 ± 264.58	1966.67 ± 152.75	1900.00 ± 278.39	1916.67 ± 152.75
Total weight gain (g/bird)	1959.25 ± 49.88	1922.92 ± 264.34	1925.83 ± 152.64	1859.17 ± 278.50	1875.92 ± 152.75
Total feed intake (g/bird)	5069.10± 43.42^{b}	4940.01 ± 208.69^{ab}	4857.97 ± 58.87^{a}	4855.93 ± 130.69^{a}	4950.07 ± 91.34^{ab}
Feed conversion ratio	2.59 ± 0.06	2.56 ± 0.12	2.52 ± 0.13	2.61 ± 0.12	2.64 ± 0.15

^{ab} = Means along the same row with different superscripts are significantly different ($p<0.05$)

Table 3: Carcass characteristics of broiler chickens fed black soldier fly larvae meal-based diets

Parameters	Diet I	Diet II	Diet III	Diet IV	Diet V
Live weight (g/bird)	2000.00 ± 50.00^{b}	1963.67 ± 264.58^{ab}	1966.67 ± 152.75^{ab}	1900.00 ± 278.34^{a}	1916.67 ± 152.75^{a}
Dressed weight (%)	90.90 ± 166.90	90.63 ± 227.91	90.54 ± 127.06	91.19 ± 23.85	90.99 ± 157.99
Eviscerated weight (%)	76.20 ± 141.00^{c}	68.58 ± 183.36^{a}	76.51 ± 10.59^{c}	76.35 ± 219.33^{c}	74.75 ± 146.44^{b}
Head (g/bird)	25.04 ± 3.30	24.46 ± 3.91	24.36 ± 7.63	24.57 ± 3.25	24.39 ± 2.83
Breast (g/bird)	208.11 ± 21.08^{b}	174.21 ± 16.88^{a}	196.34 ± 11.19^{ab}	199.15 ± 10.48^{ab}	197.58 ± 14.13^{ab}
Neck (g/bird)	30.45 ± 5.75^{ab}	30.38 ± 1.68^{ab}	29.56 ± 13.22^{a}	30.14 ± 17.07^{ab}	37.68 ± 4.63^{b}
Back (g/bird)	170.05 ± 17.42^{b}	144.15 ± 2.28^{a}	152.49 ± 27.31^{ab}	157.32 ± 17.10^{ab}	156.65 ± 6.62^{ab}
Wing (g/bird)	76.65 ± 9.47	77.71 ± 6.37	77.29 ± 7.32	78.43 ± 5.04	77.41 ± 5.76
Drumstick (g/bird)	101.44 ± 9.39	102.11 ± 8.00	100.21 ± 10.64	101.81 ± 3.48	103.06 ± 8.21
Shank (g/bird)	41.44 ± 2.74	41.35 ± 4.78	42.63 ± 13.00	40.98 ± 2.91	41.29 ± 3.99
Thigh (g/bird)	103.44 ± 14.47^{a}	115.78 ± 4.71^{c}	103.42 ± 27.50^{a}	106.08 ± 14.42^{b}	108.94 ± 13.07^{b}

^{abc} = Means along the same row with different superscripts are significantly different ($p<0.05$)

Table 4: Organ characteristics of broiler chickens fed black soldier fly larvae meal-based diets (g/kg body weight)

Parameters	Diet I	Diet II	Diet III	Diet IV	Diet V
Heart	4.57 ± 0.41	4.79 ± 0.57	4.84 ± 0.37	4.59 ± 0.94	5.07 ± 4.19
Liver	17.60 ± 4.29^{a}	17.93 ± 0.62^{a}	17.88 ± 10.31^{a}	18.64 ± 4.79^{b}	19.07 ± 4.93^{c}
Lungs	5.59 ± 0.45	5.53 ± 0.23	5.71 ± 2.67	5.67 ± 1.39	5.80 ± 0.62
Spleen	1.03 ± 0.10^{a}	1.26 ± 0.21^{ab}	1.26 ± 0.09^{ab}	1.02 ± 0.12^{a}	1.42 ± 0.83^{b}
Gizzard	16.44 ± 2.52^{b}	16.06 ± 1.25^{ab}	16.60 ± 6.71^{c}	16.09 ± 4.09^{ab}	15.94 ± 3.78^{a}
Pancreas	2.52 ± 0.33^{ab}	2.32 ± 0.52^{a}	3.06 ± 0.92^{b}	2.39 ± 0.04^{ab}	2.99 ± 0.11^{b}
Proventriculus	4.68 ± 1.01	4.72 ± 0.81	4.69 ± 4.54	4.40 ± 0.72	3.91 ± 0.12
Abdominal fat	12.96 ± 3.84^{b}	12.98 ± 1.63^{b}	12.35 ± 4.28^{a}	13.87 ± 6.26^{c}	14.20 ± 5.08^{c}

^{abc} = Means along the same row with different superscripts are significantly different ($p<0.05$)

The highest gizzard (16.60 ± 6.71 g/kg BW) was recorded in bird-fed Diet III.

The economics of broiler production using BSFLM-based diets as protein source and as a replacement for fish meal indicated that the highest cost of experimental diets (₦ 211.42/k g), and the highest total cost of production (₦ 1413.355) were recorded in Diet I, while the lowest cost of experimental diets (₦ 167.67/k g), and the lowest total cost of production (₦ 1280.79) were recorded in Diet V. The highest net profit/bird (₦ 3219.21) was recorded in bird-fed Diet V, while the lowest net profit/bird (₦ 3086.65) was recorded in bird-fed Diet I. Diet V had the highest percentage profit increase (4.12%) (Table 5).

Table 5: Economics of broiler chickens fed black soldier fly larvae meal-based diets

Parameters	Diet I	Diet II	Diet III
Cost of Day-old chick	520.00	520.00	520.00
Cost of experimental diet (₦/kg)	211.42	200.48	189.55
Total feed consumed (Kg/bird)	2.57	2.44	2.36
Cost of feed consumed (₦/bird)	543.35	489.17	447.34
Cost of drugs and vaccines (₦)	350.00	350.00	350.00
Total cost of production (₦)	1413.35	1359.17	1317.34
Sales price of birds (₦/bird)	4500	4500	4500
Net profit/bird produced (₦)	3086.65	3140.83	3182.66
Percentage Profit increase	0.00	1.72	3.02
Parameters	**Diet IV**	**Diet V**	
Cost of Day-old chick	520.00	520.00	
Cost of experimental diet (₦/kg)	178.61	167.67	
Total feed consumed (Kg/bird)	2.36	2.45	
Cost of feed consumed (₦/bird)	421.52	410.79	
Cost of drugs and vaccines (₦)	350.00	350.00	
Total cost of production (₦)	1291.52	1280.79	
Sales price of birds (₦/bird)	4500	4500	
Net profit/bird produced (₦)	3208.48	3219.21	
Percentage Profit increase	3.80	4.12	

DISCUSSION

Hermetia illucens larvae meal has been proposed as an emerging and innovative feed ingredient in poultry feeds (Cullere *et al*., 2016; 2018; Loponte *et al*., 2017; Altmann *et al*., 2018; Pieterse *et al*., 2019) in order to improve the sustainability of poultry meat production. The broiler chicks' growth performance indicated that BSFLM-based diets did not provide better performance than those fed diets containing conventional fish meal (Diet I). There were no significant differences (p>0.05) in the final weight, total weight gain and feed conversion ratio of the birds as this could be because the two test ingredients (fish meal and BSFLM) were both from animal origin. The BSFLM being an insect-based ingredient is rich in key nutrients such as a crude protein, fat, and minerals (Makkar *et al.* 2014), similar to fish meal. Kirimi *et al.* (2023) reported significant growth performance and carcass characteristics of broiler chicken fed BSFLM. This was justifiable because BSFLM an insect protein-source was used to replace a plant protein-source. The gradual reduction in the feed consumption which resulted in low weight gain and final weight of the birds may be due to pungent smell of the BSFLM used in diets II – V. The decline in feed intake with the inclusion of BSFLM agreed with the reports of Attivi *et al.* (2020) and Heita *et al.* (2023) who observed a decrease in feed intake at 6 and 8% inclusion levels of BSFLM. There was a significant difference in the feed intake, with the highest intake in Diet I followed by diets II and V, and the lowest feed intake recorded in birds fed diets III and IV. However, the result obtained in this study agreed with the finding of Elangovan *et al.* (2021) where they recorded no significant differences (p>0.05) in the growth performance traits of the broiler chickens fed with BSFLM-based diet. The carcass characteristics of broiler chickens fed BSFLM-based diets showed that birds fed Diet I had the highest live weight compared to the other diets. According to Fernandes *et al.* (2013), the improvement in carcass characteristics of broiler breeds in recent decades has been pronounced, resulting in substantial genetic gains. Particularly of importance is the yield of the breast and legs, since they are the most expensive cuts as they are well paid for in the market (Fernandes *et al.,* 2013). The dressed weight was highest in bird-fed Diet IV which substantiate the findings of Heita *et al.* (2023) where they observed that the dress-out percentage was highest in birds fed 5% BSFLM. The highest eviscerated weight was recorded in bird-fed Diet III which indicated that birds in other diets utilized their feed more for feather development and inedible viscera rather than for carcass development. This implies that the inclusion of BSFLM had a positive effect on the carcass yield of the bird (Heita *et al.,* 2023). Bird-fed Diet I had the highest values for the head, breast and the back weights, while the highest drumstick and thigh weights were recorded in bird-fed Diet V. Since the thigh is probably the most expensive and valued carcass components in the processing industry, there were no significant differences (p>0.05) in the weight of all the carcass parameters examined in this study. This observation was contrary to that of Schiavone *et al.* (2018) who observed increased thigh weight at 0, 5, 10 and 15% inclusion level of BSFLM in broiler diets. Deductively, from the above, the inclusion of BSFLM in broiler diets improved the carcass yield of broiler chickens (Heita *et al.,* 2023). Supplementation of broiler feeds with high protein alternatives such as BSFLM is a practical method of decreasing the ever-increasing costs of broiler finisher feeds available in the markets.

The result of the organ characteristics of broiler chickens fed BSFLM diets did not follow any particular trend with some organ weights increasing with increasing levels of BSFLM in the diets. The highest heart weight was recorded in bird-fed Diet V, and was in agreement with the findings of Esonu *et al.* (2006) who reported an increase in heart weight of broiler chickens fed BSLM at graded levels. Bird-fed Diet IV had the highest liver weight. The increase in liver weight was probably due to increased metabolism due to the high energy in BSFLM-based diets (Oluokun, 2000). The abdominal fat yield showed a linear response to increasing BSFLM-meal levels. The fat deposits increase with increased substitution of FM with BSFLM such that broiler chickens fed a diet with 100% BSFLM (Diet V) had the highest abdominal fat contents. This may have been due to increased dietary energy intake in excess of body requirements (Ghaffari *et al.,* 2007; Fouad and El-Senousey, 2014). In this case, as the birds increased in BW, the excess energy was deposited as abdomen. Excess fat has effect on the carcass quality. The increase in gizzard unlike in this study may be due to the bulkiness of the diets containing FM hence the bigger volume of the gizzard (Oluokun, 2000). The results obtained in this study are consistent with Esonu *et al.* (2006) and Fathalla *et al.* (2015) who reported an increase in heart and gizzard weights. In birds this may be attributed to an increased amount of work performed by these organs as a result of increased fibre digestion leading to organ hypertrophy (Ravindran and Abdollahi, 2021). Similar to the results obtained for carcass characteristics of the broiler chickens, all the parameters examined in this study showed no significant difference amongst the dietary treatments.

The cost of experimental diets and the total cost of production decrease progressively as the inclusion of BSFLM increases. The variation in the cost of feed production indicated that Diet V had the least cost of feed produced and the least cost of feed consumed. The results in this study agreed with findings of Onsongo *et al.* (2018) and Chia *et al.* (2019) who reported reduction in feed costs, and an increase in returns to investment with substitution of FM with BSFLM.

Conclusions: This present study has provided new data and knowledge on the potential use of BSFLM as alternative feedstuff in broiler chicken production. The main findings of the current research suggest that BSFL meal can be used to replace FM up to 100% level of inclusion in broiler chicken diets, without detrimental effects on growth performance, carcass weights and with economic benefits for broiler chicken producers. Based on results obtained from this study, BSFL meal can be considered as a suitable and affordable alternative protein feed resource in broiler chicken diets. However, important efforts should be made to evaluate new processing techniques of the BSFL meal, which is capable of improving the protein profile of larvae, thus potentially counteracting the negative effects on the nutritional value.

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