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Research Article
Effect of Black Soldier Fly (*Hermetia Illucens*) Maggots Meal as a Substitute for Fish Meal on Growth Performance, Biochemical Parameters and Digestibility of Broiler Chickens

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Abstract

Background and Objective: The scarcity and high cost of fish meal has led researchers to evaluate the use of unconventional protein sources as substitutes for fish meal in poultry feed. This study investigated the substitution of Black Soldier fly for fish meal in broiler diets. **Materials and Methods:** A total of 225 fourteen-day old broilers were assigned to five treatment groups: A_0 (100% of fish meal and 0% of maggot meal), A_{25} (25% of fish meal and 75% of maggot meal), A_{50} (50% of fish meal and 50% of maggot meal), A_{75} (75% of fish meal and 25% of maggot meal) and A_{100} (0% of fish meal and 100% of maggot meal). Data were collected on feed intake, organ weights, biochemistry parameters and digestibility indices. **Results:** Birds in group A_{100} had the lowest feed intake and better feed conversion ratio. Gizzard weight of the birds in A_0 and A_{25} was similar but significantly lower ($p<0.05$) than those in A_{50}, A_{75} and A_{100}. Intestinal length of birds in A_{50}, A_{75} and A_{100} were significantly longer ($p<0.05$). No significant difference in serum total protein and cholesterol was recorded across the treatments whereas albumin concentration in the birds in group A_{100} was the highest ($p<0.05$). Triglycerides were in the following order: $A_0 = A_{25}$, $= A_{50}$ $A_{75} = A_{100}$. Uric acid concentration was significantly lower ($p<0.05$) in (A_0). **Conclusion:** Black Soldier fly maggot meal improved broiler productive performance without any deleterious effect and can be considered as a suitable alternative for fish meal.

Key words: Apparent digestibility, black soldier maggot, broiler chicken, feed conversion ratio, weight gain

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Feed cost accounts for 60-80% of poultry production[1], meaning that feed is one of the main challenges of production in poultry industry. This high cost of poultry feed is due to lower availability and high cost of animal protein sources such as fish meal[2]. Due to its high content of metabolizable energy, protein and amino acids, fish meal is used in poultry diets as the main source of animal protein[3]. Nowadays, fish is becoming a very precious and very important protein source to humans; therefore, Its utilization in animal feeds has become un affordable for the farmers. This financial implication makes it necessary for researchers to focus on unconventional alternative protein sources, including insects and their larva[2]. Studies conducted by Nsa *et al.*[4] have shown that termite meal used as a substitute for fish meal improved chicken growth performance.

There has been a search for unconventional protein sources for animal feed that are not yet in competition with human needs. Findings have shown that insect larvae especially house fly maggot are an excellent protein sources. Akpodiete *et al.*[5] and Agunbiade *et al.*[6] have replaced fish meal with fly maggots and obtained improved laying rate without any adverse effect on its egg quality. These results have been explained by Al-Qazzaz *et al.*[3] who have linked protein rich fly maggot meal with improved egg production. Okah and Onwujiariri[7] obtained higher weight gain and lower feed cost when 50% of fish meal was substituted with 50% of fly maggot meal in diets of broiler chickens.

Maggots can be raised by intensive rearing. The acceptability of the use of house fly maggots in feeds by the farmers and consumers has been low. The concern has been the living mode of the house fly, being a vector of pathogens, Newton *et al.*[8] emphasized the hesitation of farmers to use it. Conversely, Black Soldier fly (*Hermetia illucens*), has not yet been reported asa potential vector of pathogen[9]. Since 1990, there has been a vast program of Soldier Fly maggot production for the processing of organic wastes and for food and feed security[10,11]. Widjastuti *et al.*[12] reported that 50% substitution of fish meal with black soldier fly maggot resulted in improved egg production of quails. Black Soldier fly maggot has been used as a substitute for conventional protein ingredient such as fish meal[12]. The current study was designed to evaluate the effects of different levels of Black Soldier fly maggot meal with or without fish meal on growth performance and physiological response of broiler chickens.

MATERIALS AND METHODS

Experimental design: The experiment was carried out at the Experimental Unit of the Centre d'Excellence Regional sur les Sciences Aviaires (CERSA) of the University of Lomé, Togo. Fourteen-day-old Ross 308 broiler chickens were used for the study. Maggot meal was provided by West African Fish, Ghana. Animals were housed in open sided litter house with natural environment, ventilation, temperature and humidity.

Experimental design and management: A total of two hundred and twenty-five 14 day-old Ross 308 broilers chickens were allotted to 5 treatment groups viz.: A_0, A_{25}, A_{50}, A_{75} and A_{100} having 3 replicates of 15 birds for each. The 5 treatment groups were respectively fed with Diet 1-5 from the beginning to the end of a six-week experiment. The compositions of the diets are shown in Table 1 and 2. Diet 1 was the control diet

Table 1: Composition of the experimental diets fed during the growth stage of broiler chicks

	Diets				
Ingredients	A_0	A_{25}	A_{50}	A_{75}	A_{100}
White maize	65.00	65.50	65.50	65.00	64.60
Roasted soya bean meal	18.00	16.50	15.50	15.00	14.40
Wheat bran	3.00	3.00	4.00	5.00	6.00
Fish meal 40%	8.00	6.00	4.00	2.00	0.00
Oyster shell	1.00	1.00	1.00	1.00	1.00
Maggot meal	0.00	2.00	4.00	6.00	8.00
Lysine	0.50	0.60	0.60	0.60	0.70
Methionine	0.50	0.40	0.40	0.40	0.30
Concentrate	4.00	5.00	5.00	5.00	5.00
Calculated values					
Metabolizable energy (kcal)	3105.00	3111.60	311.93	3112.44	3112.28
Crude protein (%)	19.62	19.66	19.51	19.54	19.57
Crude fiber (%)	4.61	4.60	4.57	4.52	4.43
Fat (%)	7.26	7.32	7.56	7.80	8.70
Dry matter	91.23	91.17	91.34	91.37	90.97
Ash	9.57	8.63	8.04	5.45	5.40

Table 2: Composition of the experimental diets fed during the finisher stage of broiler chicks

	Diets				
Ingredients	A_0	A_{25}	A_{50}	A_{75}	A_{100}
White maize	72.00	71.00	71.00	71.00	71.00
Roasted soya bean meal	16.00	16.00	15.00	14.00	13.40
Wheat bran	2.00	3.00	3.20	4.20	4.80
Fish meal	8.00	6.00	4.00	2.00	0.00
Oyster shell	1.00	1.00	1.00	1.00	1.00
Lysine	0.50	0.50	0.50	0.50	0.50
Maggot meal	0.00	2.00	4.00	6.00	8.00
Methionine	0.50	0.50	0.30	0.30	0.30
Concentrate	0.00	0.00	1.00	1.00	1.00
Dry matter (%)	91.98	91.84	91.37	91.74	90.94
Calculated values					
Metabolizable energy (kcal)	3159.63	3160.31	3161.96	3162.29	3169.35
Crude protein (%)	17.53	17.63	17.69	17.54	17.51
Crude fibre (%)	4.65	4.62	4.58	4.54	4.49
Fat (%)	6.94	7.10	7.50	7.70	8.90
Ash (%)	9.68	8.71	8.32	5.59	5.56

with 0% of maggot meal and 100% of fish meal while Diet 2-5 contained respectively, 25% of maggot meal and 75% of fish meal, 50% of maggot meal and 50% of fish meal, 75% of maggot meal and 25% of fish meal and 100% of maggot meal and 0% of fish meal. Diets contained similar levels of energy, protein and fibre according to the development stages namely grower (Table 1) and finisher (Table 2) lasting for 4 weeks and 2 weeks, respectively. During the experiment, birds were fed *ad libitum* on experimental diet and water.

Growth and blood parameters evaluation: Each bird was weighed at the beginning (of the experiment)and at 56th day of age to determine weight gain. Moreover, daily feed intake was recorded within each group to determine the total feed intake from the beginning to the end of the experiment. Total weight gain and total feed intake were used to determine feed conversion ratio.

At the end of the experiment, 6 birds per group were slaughtered (2 birds per replicate) to collect liver, gizzard, intestine and blood. Liver and gizzard were weighed to determine relative organ weigh (organ weigh×100/body weight), intestine was measured to determine its length. Blood samples were centrifuged at 3000 rpm for 15 min to obtain serum. Serum was used to determine the concentration of total protein, albumin, triglycerides and uric acid by spectrophotometry using diagnosis standard kits provided by Human GMBH (65202 Wiesbaden, Germany).

Digestibility evaluation: On day 56, three birds from each replicate were isolated in three different cages for the digestibility analysis. After 72 h of adaptation, chickens were fasted for 24 h according to the method described by Hassan *et al.*[13] with the aim of emptying the digestive tract. They were provided light in the night after the fasting period and were then re-fed for 4 days. During this refeeding period, daily feed intake was recorded. However, from the second day of the refeeding period and onwards total faeces dropped by birds in each group was collected every morning and was immediately weighed and dried. The dried faeces were weighed and stored at 25°C. Samples of dried faeces and experimental diets were analysed according to the method of the association of official analytical chemists (AOAC)[14] to determine apparent digestibility of Dry Matter (DM), crude protein, ether extract and ash.

Statistical analysis: Data obtained were expressed as mean±standard error (SE) of mean and processed with the statistical software package Graph Pad. One-way ANOVA model was used to analyse the effects of experimental diets on growth, blood and digestibility parameters. If the p-value was statistically significant ($p<0.05$), further comparisons among groups were made according to Turkey's test.

RESULTS

Performance parameters: Table 3 shows the effect of Black Soldier Fly Maggot meal on feed intake, body weight gain and feed Conversion Ratio. Feed intakes were significantly lower in groups A_{75} and A_{100} ($p<0.05$) than groups A_0, A_{25} and A_{50} where consumption were similar. The body weight gain of group A_{100} was significantly higher ($p<0.05$) than the control group (A_0). However, the other groups A_{75}, A_{50} and A_{25} showed

Tables 3: Effect of Black Soldier fly maggot meal on feed intake, body weight gain and feed conversion ratio according to the treatment

	Groups				
Parameters	A_0	A_{25}	A_{50}	A_{75}	A_{100}
Feed intake (g)	3825.58±42.32^a	3800.90±66.30^a	3696.62±60.96^a	3223.67±42.86^b	3123.50±47.69^b
Body weight gain (g)	1719.03±24.15^b	1643.37±34.36^c	1522.19±35.15^d	1647.87±29.79^c	1770.84±40.05^a
Feed conversion ratio	2.22±0.27^a	2.31±0.32^a	2.42±0.29^a	1.95±0.20^b	1.76±0.16^b

$^{a,b,c\ et\ d}$ Within row, data sharing no common letter are different (p<0.05)

Table 4: Effect of Black Soldier fly maggot meal on relative organ weights and intestinal length according to the treatment

	Groups				
Organs	A_0	A_{25}	A_{50}	A_{75}	A_{100}
Liver weight	1.810±0.065^a	1.800±0.065^a	1.780±0.12^a	1.900±0.17^a	1.720±0.080^a
Gizzard weight	1.570±0.040^a	1.540±0.062^a	1.420±0.055^b	1.410±0.041^b	1.413±0.054^b
Intestine length (m)	2.605±0.064^a	2.567±0.057^a	2.352±0.045^b	2.351±0.093^b	2.384±0.078^b

$^{a,b\ et\ c}$Within row, data sharing no common letter are different (p<0.05)

Table 5: Effect of Black Soldier fly maggot meal on blood biochemical parameters according to the treatments

	Groups				
Parameters	A_0	A_{25}	A_{50}	A_{75}	A_{100}
Total protein (g L^{-1})	33.56±1.28^a	33.94±3.28^a	35.62±1.75^a	29.61±2.27^a	35.87±1.95^a
Albumin (g L^{-1})	13.53±0.71^b	11.17±0.77^c	9.48±0.63^d	12.08±0.86^c	16.43±1.48^a
Uric acid (mg dL^{-1})	11.00±0.57^a	8.14±0.30^b	6.69±0.29^c	5.89±0.36^{cd}	5.54±0.30^d
Triglycerides (g L^{-1})	0.55±0.12^b	0.44±0.04^b	0.38±0.15^b	1.68±0.39^a	1.80±0.10^a

$^{a,b,c\ et\ d}$ Within row, data sharing no common letter are different (p<0.05)

Table 6: effect of black soldier fly maggot meal on apparent digestibility according to the treatment

	Groups				
Nutrients	A_0	A_{25}	A_{50}	A_{75}	A_{100}
Dry matter	79.16±0.5^a	78.30±0.75a	78.12±1.2^a	79.2±0.2^a	79.50±0.27^a
Crude protein	78.19±0.4^a	73.79±0.34^b	67.59±0.27^c	74.1±0.2^b	78.35±0.42^a
Ether extract	80.16±0.13^a	79.80±0.40^a	79.84±0.33^a	79.96±0.57^a	80.17±0.12^a
Ash	58.29±0.23^a	57.90±0.45^a	58.12±0.34^a	57.79±0.67^a	58.35±0.32^a

$^{a,b,\ et\ c}$ Within row, data sharing no common letter are different (p<0.05)

significantly lower value than the control (A_0). Feed conversion ratio decreased significantly when inclusion level of maggot meal reached 50 and 100% whereas lower levels of inclusion did not differ from that of control.

Relative organ weights: Table 4 shows the effects of maggot meal on liver and gizzard relative weights and intestine length. Maggot meal had no effect on liver weight. Gizzard weights were similar in the birds in A_0 and A_{25} treatment group but significantly higher than those of A_{50}, A_{75} and A_{100} compared with the control (A_0) and A_{25} (p<0.05). On the other hand, length of intestine in bird in A_{50}, A_{75} And A_{100} groups were significantly longer as compared to A_{25} (p<0.05).

Blood parameters: Effects of maggot meal on total protein, albumin, uric acid, triglycerides and cholesterol, concentrations of broiler chickens are shown in Table 5. Serum total protein and cholesterol concentrations were not affected by dietary treatments. Albumin concentration of the birds in A_{100} group (p<0.05) was significantly higher (p<0.05) than those in the control (A0). Birds in A_{25}, A_{50} and A_{75} treatments also had lower values than the control (A_0). The value of those in A_{50} treatment group was however significantly lower than that of the A_{25} and A_{75} group which were similar (p<0.05). Uric acid concentration in the treatments with maggot meal was significantly lower than that of control group (A_0). The concentrations of uric acid decreased significantly with increase in substitution levels of maggot meal (p<0.05). Triglycerides in control group were similar to those in A_{25} and A_{50} treatments but significantly lower (p<0.05) than those of A_{75} and A_{100} treatments whose values were similar.

Apparent digestibility of nutrients: Table 6 shows the effect of black soldier fly maggot meal on apparent digestibility . Dry Matter, ether extract and ash were not affected by maggot meal incorporation into the diets. Crude protein digestibility

of A_0 and A_{100} groups were similar but significantly higher ($p<0.05$) than those of the other groups. About digestibility level, values were comparable between groups A_{25} and A_{75} and were higher than those of control group ($p<0.05$).

DISCUSSION

The performance of animals depends on feed composition and feed intake, as well as the digestion and absorption processes[15]. In this study, although feed intake was reduced in A_{100} group, body weight gain and feed efficiency were enhanced. This demonstrates that there was no adverse effect of Black Soldier maggot meal on the palatability of broilers' diets. The reduction in feed intake observed in this study (A_{75} and A_{100}) might be as a result of improved digestion and metabolism activities of maggot meal, thus, meeting the nutrients requirements at lower feed intake. In accordance with our findings, khan *et al.*[16] reported that the substitution of soya meal with maggot meal decreased significantly feed intake while body weight increased in treated group. Results of Mohammed *et al.*[17] revealed that, Black soldier maggot contained a high percentage of protein, metabolizable energy, crude fat, dry matter and a good profile of amino acids. Thus, the improvement of chicken body weight in the current study was due to those essential nutrients contained in Black Soldier maggot meal. Moreover, the growth performance of broilers in group A_{100} can be linked to the high digestibility of Black Soldier meal. However, our result indicated that the combination of the two protein sources (maggot and fish meal) in the diet of broiler chickens resulted in low weight gain especially at the combination of 50/50 in the feed. A possible explanation for the decreased body weights of the birds may be as a result of specific interaction between fish and maggot meal when combined as in A_{25}, A_{50} and A_{75}. Similar results were obtained by Awoniyi *et al.*[18] when broiler chickens were fed diets with fish meal and maggot meal at different substitution rates (0, 25, 50, 75 and 100%). The chickens on 50% group showed a significantly reduction in body weight gain. Further studies are needed to identify the underlying mechanisms which involved in this depressed productivity.

Total protein is an important biomarker of physiological and pathological status of animals and it is influenced by the quantity and quality of feed. Yaman *et al.*[19] showed that albumin is the main plasma proteins considered as source of amino acids for synthesis of tissue proteins in the period of quick somatic growth of birds. In the current study, although total proteins were comparable among treatments, albumin concentration was significantly higher in birds fed with 100% of Black Soldier maggot meal as a substitute of fish meal. The increment in serum albumin concentration observed in A_{100} group may be due to high content of essential nutrients in Black Soldier meal[17] which might have improved health, nutrients uptake and subsequently live body weight of the chickens.

According to Sturkie[20], excess production of NH_4^+ in avian species, derived from the degradation of amino acids is converted into uric acid for excretion. Plasma uric acid levels can thus be considered as a major nitrogenous waste product. In the present study, uric acid was significantly lower in birds fed 100% black soldier maggot meal. These results suggest efficient protein utilization. This can explain the high body weight gain and low feed conversion ratio of the birds compared to the other treatment groups as the elimination of excess nitrogen is an energy-consuming process.

Triglycerides are the main product of the hepatic lipogenesis in the chicken[21]. The increased triglyceride levels in the plasma in A_{100} group could be a result of a stimulated hepatic lipogenesis. Although birds fed 100% of Black soldier meal had higher serum triglycerides, liver weight was comparable among the three treatment groups. This indicates the absence of lipid accumulation in this organ, as it is the main site for fatty acid synthesis in the chicken[22]. On the other hand the triglycerides are used for oxidation to produce more energy. Thus the chickens of this group would have more energy for metabolism process and this may also partly explains their better growth performance.

CONCLUSION

The results obtained from this trial suggest that Black Soldier maggot meal can substitute fish completely as a protein alternative in broiler diet. The combination of Black Soldier meal and fish meal reduced the bird's performance probably through specific interaction between nutrients from these two sources of protein. Black Soldier maggot can be considered as a suitable alternative for fish as protein source for broiler and should be encouraged.

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