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Effects of black soldier fly larvae (*Hermetia illucens*) maggot meal supplementation on haematological, serum biochemical and lipid indices of broiler chickens fed with low-cost diets

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Abstract

This study evaluated the effects of dietary supplementation of black soldier fly larvae (BSFL) maggot meal on haematology, serum biochemistry and lipid parameters of broiler chickens, and assessed its potential to improve the nutritional quality of low-cost poultry diets. A total of 120 day-old broiler chicks were used in a five-week feeding trial. After three weeks of brooding, birds were randomly assigned to five dietary treatments (A–E) with three replicates per treatment and eight birds per replicate. Group A (positive control) received a high-cost commercial feed without maggot meal supplementation, while Group B (negative control) received a low-cost commercial feed without maggot meal inclusion. Groups C, D and E were fed low-cost commercial feed supplemented with 1%, 2% and 3% maggot meal respectively. Comparing between the two control groups revealed that although the low-cost diet maintained normal haematological values, it resulted in lower serum lipid and nitrogen metabolism indicators, suggesting reduced nutrient density. Dietary inclusion of maggot meal up to 3% produced no adverse effects on haematological indices. Also, liver enzyme activities, kidney function indicators and serum protein fractions remained within normal physiological ranges. Birds fed 1–2% maggot meal diets showed lower cholesterol, triglycerides, low density lipoprotein (LDL) and very low density lipoprotein (VLDL) concentrations, indicating improved lipid metabolism. The findings demonstrate that black soldier fly larvae maggot meal can be safely incorporated into broiler diets and may serve as a nutritional enhancer capable of improving the metabolic value of low-cost poultry feeds.

Keywords: Broiler chickens; Black soldier fly larvae; Maggot meal; Haematology; Lipid metabolism; Sustainable poultry nutrition.

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Introduction

Poultry production plays an important role in addressing the increasing demand for animal protein in Nigeria and other developing countries (Arnaud & Ndogmi, 2023). Broiler chickens are particularly targeted and are important because of their rapid growth rate, short production cycle and high feed conversion efficiency, making them one of the most economical sources of animal protein (Aronu et al., 2023; Choi et al., 2023). However, feed cost remains the major limiting factor in poultry production, accounting for 70-80 percent of cost of production, particularly in developing countries where conventional protein ingredients such as soybean meal and fish meal are expensive and scarce. This has increased farmers interest in the use of low-cost feed formulations. However, such feeds may sometimes provide adequate maintenance nutrition but suboptimal metabolic performance.

In recent years, insect-based protein sources have gained increasing attention as viable substitutes for conventional feed ingredients such as fish meal and soybean meal. Among these, maggot meal, derived from the larval stage of flies, has shown considerable promise. Maggots can be efficiently reared on organic waste materials such as animal manure and poultry offal, providing an economical and environmentally friendly approach to protein production (Aisha et al., 2019). This dual-purpose system supports both waste management and resource recovery, aligning with the principles of circular bio-economy and agricultural sustainability (Tomberlin & Diener, 2009).

Nutritionally, maggots are rich in crude protein (30–60%) and possess a well-balanced amino acid profile, including essential amino acids like lysine, which are often limiting in plant-based protein sources (Liu et al., 2018). These properties position maggot meal as a sustainable alternative protein source for inclusion in poultry diets.

Several studies have reported that the incorporation of maggot meal in broiler diets can enhance growth performance, feed efficiency, and carcass quality (Iken et al., 2012; Akinwunmi et al., 2017). These improvements are largely attributed to the high-quality protein and bioavailable nutrients contained in maggots. Additionally, maggot farming contributes to environmental sustainability by reducing dependence on expensive protein ingredients and minimizing organic waste accumulation.

Despite these advantages, limited research has explored the physiological implications of maggot meal supplementation in poultry. Previous studies have primarily focused on growth and carcass traits, while haematological and serum biochemical parameters which serve as reliable indicators of metabolic and health status have received little attention. Therefore, this study was designed to evaluate the effects of

inclusion of maggot (larvae) meal from black soldier fly (BSF) in feed of broilers on haematological and biochemical parameters of broiler chickens, with the aim of assessing its potential as a safe and effective feed ingredient in sustainable poultry production.

Materials and methods

Location of study: The experiment was conducted at the demonstration farm of the Department of Animal Health and Production, Faculty of Veterinary Medicine, University of Nigeria, Nsukka. Nsukka is located in the derived savanna ecological zone of southeastern Nigeria at latitude 6°51'24"N and longitude 7°23'45"E, with an average elevation of approximately 550 meters (1,810 feet) above sea level.

Management of experimental birds

A total of 120 day-old broiler chicks were obtained from a commercial hatchery. After brooding for three weeks, the birds were randomly assigned to five dietary treatments, with three replicates per treatment and eight birds per replicate. The birds were raised on deep litter, under standard management practices. Feed and water were administered *ad libitum* throughout the experimental period. The experimental design was Completely Randomized Design (CRD) and the experiment lasted for five weeks, which commenced after three weeks of brooding and acclimatization.

Maggot meal preparation

Five kilogrammes of black soldier fly larvae were obtained from a commercial maggot production farm in Onitsha, Nigeria. The larvae were cultured using fermented organic waste substrates (which consisted of a combination of organic wastes from kitchen, vegetable market and restaurants, brewery wastes, and chicken offals), under controlled temperature and humidity conditions. Complete round of larvae production involved five stages starting with matured larvae, namely: larvae harvest and preservation; pre-pupae/pupae restocking and adult fly emergence, mating and egg laying; egg incubation and hatching; organic waste fermentation and lastly, larvae feeding and pre-pupae/pupae restocking, stages. The insectarium was repopulated weekly to ensure continuous BSF egg production.

Harvested larvae were washed with hot water, sun-dried for 72 hours and the full-fat dried maggot was subsequently milled into maggot meal. The processed meal was stored in airtight containers until inclusion in the experimental diets.

Dietary treatments

Five dietary treatments were used, namely:

Group A – High-cost commercial feed without maggot meal (positive control)

Group B – Low-cost commercial feed without maggot meal (negative control)

Group C – Low-cost commercial feed supplemented with 1% maggot meal

Group D – Low-cost commercial feed supplemented with 2% maggot meal

Group E – Low-cost commercial feed supplemented with 3% maggot meal

Table 1. Ingredients and nutrient composition of basal diet 1, high-cost-feed (Positive control)

Nutrient	Broiler starter	Broiler finisher
Metabolizable energy (Min.) (Kcal/Kg)	2900	≥3000
Crude protein (Min) (%)	22	20-22
Crude fat (Min) (%)	4	4
Crude fibre (Max) (%)	5	5

Table 2. Ingredients and nutrient composition of basal diet 2, low-cost-feed (negative control)

Nutrient	Broiler starter	Broiler finisher
Metabolizable energy (Kcal/Kg)	2800-2900	2900-3000
Crud Protein (%)	23	19
Fat/Oil content (%)	5-6	6-10
Crude fibre (%)	5	5

Haematological and serum biochemical analysis

At the end of the five weeks feeding trial, blood samples were collected from three randomly selected birds per replicate via the wing vein. Samples for haematological analysis were collected into EDTA tubes while those for serum biochemical analysis were collected into plain tubes; these were centrifuged before analysis.

Haematology

Packed cell volume (PCV) was determined using the microhaematocrit method (Cole, 1986); haemoglobin content (Hb) was determined following the cyanomethaemoglobin procedure as described by Jain (1986); Red blood cell count (RBC) was determined using the Neubauer haemocytometer method (Cole, 1986).

Serum Biochemical Analysis

Aspartate transaminase (AST), Alanine transaminase (ALT) and Alkaline phosphatase (ALP); uric acid, triglycerides and creatinine were determined using spectrophotometer and

standard diagnostic kits provided by Human GMBH (65202 Wiesbaden, Germany). High-density lipoprotein cholesterol was determined using the precipitation and enzymatic method as described by Burstein et al. (1970). Very low-density lipoprotein (VLDL) cholesterol was calculated by dividing the triglyceride concentration by five (VLDL = $\frac{1}{5}$ of Triglyceride) (Rifai et al., 2008), while the low-density lipoprotein (LDL)-cholesterol was calculated by subtracting HDL and VLDL from total serum cholesterol (Friedewald et al., 1972).

Statistical analysis

Data were analyzed using one-way analysis of variance (ANOVA) in SPSS version 22. Differences among treatment means were separated using Duncan's multiple range test (Obi, 2002), at a significance level of $p < 0.05$.

Results

Haematology: Comparing the positive and negative control groups in Table 3 showed that birds fed the low-cost diet maintained haematological values comparable to those fed the high-cost diet, indicating that the low-cost feed supported basic physiological functions. However, supplementation of the low-cost diet with maggot meal significantly increased performance of several metabolic indicators such as haemoglobin, total white blood cell (TWBC) counts, uric acid, creatinine and the lipids. Birds fed 1% and 2% maggot meal diets showed numerically higher haemoglobin values compared with the negative control (Table 3).

Serum liver enzyme activities showed no significant differences among treatment groups except for lower ALP activity at 1% inclusion (Table 4). Similarly, creatinine and uric acid values (Table 5) indicated enhanced protein metabolism in maggot-supplemented groups compared with the low-cost control.

Serum total protein indices did not significantly vary across treatment groups (Table 6).

However, birds fed the low-cost diet showed lower serum cholesterol, triglycerides (Table 7) and uric acid concentrations (Table 3) when compared with the positive control. Lipid profile analysis showed significantly lower total cholesterol, triglycerides, LDL and VLDL (Tables 7 and 8) in birds fed maggot-supplemented diets compared with both control groups. The HDL increased at 3% inclusion level (Table 8).

Table 3. Haematological parameters of broiler chickens fed diets containing different levels of Black soldier fly larvae maggot meal (mean ± SD).

PARAMETERS	Group A (0% BSFL, high-cost feed)	Group B (0% BSFL, low-cost feed)	Group C (1% BSFL, low-cost feed)	Group D (2% BSFL, low-cost feed)	Group E (3% BSFL, low-cost feed)
PCV (%)	24.93 (2.10)	24.90 (1.04)	25.13 (3.58)	23.97 (3.08)	20.93 (1.52)
Hb (g/dl)	7.89 (0.16)	7.87 (0.91)	8.78 (0.67)	8.19 (1.12)	8.19 (0.26)
RBC counts (10 ⁶ /μl)	2.50 (0.40)	2.52 (0.26)	2.62 (0.56)	2.45(0.49)	2.00 (0.10)
TWBC counts (10 ³ /μl)	39.77 (0.75)	53.00 (14.53)	66.17 (29.38)	52.83 (4.54)	64.17 (1.04)

Table 4. Serum liver enzyme activities of broiler chickens fed diets containing different levels of Black soldier fly larvae maggot meal (mean ± SD).

PARAMETERS	Group A (0% BSFL, high-cost feed)	Group B (0% BSFL, low-cost feed)	Group C (1% BSFL, low-cost feed)	Group D (2% BSFL, low-cost feed)	Group E (3% BSFL, low-cost feed)
ALT (IU/l)	10.91 (0.73)	10.62 (0.96)	10.61 (0.65)	10.05 (0.19)	10.82 (0.94)
AST (IU/L)	213.73 (143.87)	262.98 (173.15)	355.00 (207.66)	202.92 (142.90)	224.19 (115.71)
ALP (IU/L)	158.27 ^a (8.02)	142.12 ^{ab} (9.62)	121.12 ^b (23.20)	151.55 ^a (11.12)	160.70 ^a (5.91)

Different alphabetical superscript ^{a b} in a row indicates significant differences between the means of the groups, p < 0.05.

Table 5. Kidney function indicators of broiler chickens fed diets containing different levels of Black soldier fly larvae maggot meal (mean ± SD).

PARAMETERS (mg/dl)	Group A (0% BSFL, high-cost feed)	Group B (0% BSFL, low-cost feed)	Group C (1% BSFL, low-cost feed)	Group D (2% BSFL, low-cost feed)	Group E (3% BSFL, low-cost feed)
Creatinine	0.92 ^a (0.46)	0.64 ^{ab} (0.23)	0.22 ^b (0.05)	0.44 ^b (0.09)	0.41 ^b (0.15)
Uric acid	10.19 ^a (1.52)	4.55 ^{bc} (2.03)	3.91 ^b (1.23)	6.49 ^c (0.70)	4.11 ^{bc} (0.42)

Different alphabetical superscript ^{a b c} in a row indicates significant differences between the means of the groups, p < 0.05.

Table 6. Serum protein profile of broiler chickens fed diets containing different levels of Black soldier fly larvae maggot meal (mean ± SD).

PARAMETERS	Group A (0% BSFL, High-cost feed)	Group B (0% BSFL Low-cost feed)	Group C (1% BSFL) + low-cost feed	Group D (2% BSFL) + low-cost feed	Group E (3% BSFL) + low-cost feed
Total Proteins (g/L)	48.82 (0.23)	48.77 (7.56)	46.76 (5.87)	41.69 (6.12)	44.05 (4.47)
Albumins (g/L)	27.97 (2.41)	25.01 (2.06)	26.40 (1.66)	25.64 (1.56)	26.38 (0.56)
Globulins (g/L)	20.85 (2.57)	23.76 (8.73)	20.36 (4.23)	16.06 (4.61)	17.67 (4.13)

Table 7. Total cholesterol and Triglyceride profile of broiler chickens fed diets containing different levels of Black soldier fly larvae maggot meal (mean ± SD).

PARAMETERS (mg/dl)	Group A (0% BSFL, High-cost feed)	Group B (0% BSFL, low-cost feed)	Group C (1% BSFL) + low-cost feed	Group D (2% BSFL) + low-cost feed	Group E (3% BSFL) + low-cost feed
Total Cholesterol	121.65 ^a (14.22)	91.70 ^b (19.69)	86.80 ^b (5.85)	92.62 ^b (17.77)	121.01 ^a (8.84)
Triglyceride	212.02 ^a (32.36)	183.46 ^{ab} (14.50)	149.87 ^b (19.10)	157.89 ^b (13.11)	186.96 ^{ab} (24.45)

Different alphabetical superscript ^{a b} in a row indicates significant differences between the means of the groups, p < 0.05.

Table 8. Lipoprotein profile of broiler chickens fed diets containing different levels of Black soldier fly larvae maggot meal (mean ± SD).

PARAMETERS (mg/dl)	Group A (0% BSFL, High-cost feed)	Group B (0% BSFL, low-cost feed)	Group C (1% BSFL) + low-cost feed	Group D (2% BSFL) + low-cost feed	Group E (3% BSFL) + low-cost feed
HDL (mg/dl)	78.19 (3.46)	71.30 (10.08)	69.11 (6.22)	79.73 (23.47)	89.43 (12.16)
LDL (mg/dl)	43.47 ^a (16.19)	19.39 ^{bc} (10.35)	17.69 ^{bc} (3.16)	12.90 ^c (5.69)	31.58 ^{ab} (5.44)
VLDL (mg/dl)	42.41 ^a (6.47)	36.69 ^{ab} (2.90)	29.97 ^b (3.82)	31.58 ^b (2.62)	37.39 ^{ab} (4.89)

Different alphabetical superscript ^{a b} in a row indicates significant differences between the means of the groups, p < 0.05.

Discussion

The findings from this study indicate that dietary inclusion of maggot meal up to 3% did not adversely affect haematological or biochemical parameters of broiler chickens. Haematological values remained within normal physiological ranges for healthy broilers, as reported in literature (Oladele et al. 2001; Etim et al. 2014), indicating normal erythropoiesis and adequate oxygen transport capacity in experimental birds. The comparison between the two control groups provides important insight into the nutritional value of the diets used in this study. Although the low-cost diet maintained haematological values within normal physiological ranges, the reduction in lipid and nitrogen metabolism indicators observed suggest lower nutrient density compared with the high-cost diet.

The improvements observed following maggot meal supplementation suggest that insect protein may help correct nutritional limitations associated with low-cost poultry feeds. The higher haemoglobin values observed in birds fed maggot meal diets may be attributed to improved amino acid availability and better protein quality (Adeyemo et al. (2010), Akinwunmi et al. (2017) and Liu et al. (2018)). Higher TWBC counts observed in maggot-fed birds may be associated with bioactive components present in insect meals such as chitin, antimicrobial peptides and medium-chain fatty acids. These compounds have been reported to enhance immune function and gut health in poultry (Elahi et al. 2020; Gasco et al. 2020).

The absence of significant changes in ALT and AST levels indicates that maggot meal supplementation did not cause hepatic damage. This finding corroborates those of Adebayo et al. (2019) and Oloruntola et al. (2020), who reported that insect-based protein sources are biochemically safe for poultry. The lower ALP activity at 1% inclusion may suggest improved hepatic and biliary efficiency, while the increase at higher inclusion levels suggests a non-linear metabolic response (Esonu et al. 2018; Ogunwole et al. 2021). Lower creatinine and uric acid concentrations observed in maggot supplemented groups suggest improved protein utilization and efficient nitrogen metabolism. This trend aligns with the findings of Akinwunmi et al. (2017), who observed reduced creatinine values in broilers fed insect-based meals. Similarly, reduced uric acid concentrations in maggot-fed groups suggest enhanced protein metabolism and nitrogen utilization efficiency, consistent with the reports of Adeyemo et al. (2010) and Atteh & Ologbenla (1993).

The stability of serum albumin across all treatments suggests that liver function and protein metabolism were not compromised, corroborating the findings of Liu et al. (2018). This is particularly important in developing countries where feed cost constraints often necessitate the use of nutritionally marginal diets (Makkar et al. 2014; Gasco et al. 2020).

The improved lipid profile observed in broilers fed maggot meal diets may be attributed to the presence of bioactive compounds such as lauric acid and chitin, which have been reported to improve gut health, lipid metabolism and immune response in poultry (Benzertiha et al. 2020; Elahi et al. 2020). The reduction in LDL and VLDL concentrations that was observed in this study suggests improved lipid transport regulation and metabolic efficiency, which may translate into improved carcass quality and reduced excessive fat deposition (Ogunwole et al. 2021). The higher values of HDL observed at 3% inclusion suggests more efficient reverse cholesterol transport, facilitating the removal of excess cholesterol from tissue. The reductions observed in total cholesterol and triglyceride concentrations suggest improved lipid metabolism. This may be related to the presence of medium-chain fatty acids such as lauric acid in Black soldier fly larvae, which are known to improve lipid utilization efficiency (Kim et al. 2020). Furthermore, the ability of Black soldier fly larvae to convert organic waste into high-quality protein biomass highlights their importance in circular agricultural systems. Their utilization as feed ingredients aligns with global efforts toward sustainable livestock production through resource recycling and environmental management (Makkar et al. 2014; Tomberlin et al. 2015).

From a practical nutrition perspective, the findings of this study provide evidence that black soldier fly larvae meal can play a dual role in poultry feeding systems as both an alternative protein source and a functional feed ingredient capable of improving metabolic efficiency. The observation that maggot meal supplementation improved metabolic indicators in birds fed low-cost diets is particularly important for smallholder poultry production systems where feed cost constraints often limit diet quality. The ability of insect-derived protein to enhance the nutritional value of economically formulated diets suggests a promising strategy for improving productivity while maintaining affordability of poultry production (Liu et al. 2018). This supports the growing global interest in insect protein as a tool for achieving sustainable intensification of livestock production, particularly in resource-limited environments (Makkar et al. 2014; Awoniyi et al. 2003).

Taken together, the results suggest that black soldier fly larvae meal represents not only a replacement for conventional protein ingredients but also a strategic nutritional intervention capable of improving feed efficiency, metabolic stability and sustainability of broiler production systems.

Conclusion

The results of this study demonstrate that dietary supplementation with black soldier fly larvae maggot meal up to 3% is safe and does not adversely affect hematological or biochemical parameters of broiler chickens. The study

further shows that maggot meal supplementation can improve metabolic indicators in birds fed low-cost diets. These findings indicate that black soldier fly larvae meal represents a sustainable, nutritionally viable and cost-effective alternative protein source capable of improving the nutritional efficiency of poultry feeds. The present study therefore provides further evidence supporting the integration of insect-derived protein ingredients into sustainable poultry feeding strategies, particularly in developing countries where affordable feed resources remain a major constraint to production efficiency.

Recommendations

Based on the findings of this study, the following recommendations are proposed: First, is that black soldier fly larvae meal can be safely included in broiler diets at levels up to 3%. The next is that inclusion levels of 1–2% appear optimal for improving lipid metabolism. Also note that maggot meal may be particularly useful for improving the nutritional quality of low-cost poultry feeds. However, further studies should evaluate effects on growth performance, carcass quality and economic returns. Future research should also investigate higher inclusion levels and long-term feeding effects.

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Competing interest

The authors have no financial or non-financial interests to disclose.

Author contributions

Aronu Chinwe Justina conceived the study; all authors contributed to the study design. Material preparation, data collection and investigation were undertaken by Uka Chukwuemeka Victor and Ogeh Uchenna Idoko; Supervision and data compilation were done by, Aronu Chinwe Justina, Morgan Anne and Amaechina Ebele Chinelo. Ihedioha John Ikechukwu carried out laboratory and data analysis. The first draft of the manuscript was written by Kenneth-Chukwu

Oluchi Margret. All authors commented on previous versions, read and approved the final manuscript.

Ethics approval

All procedures involving animals were conducted in accordance with institutional guidelines for animal care at the University of Nigeria, Nsukka.

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