

EFFECTS OF BLACK SOLDIER FLY (*Hermetia illucens* L.) ON NUTRIENT DIGESTIBILITY, GROWTH PERFORMANCE, AND BLOOD PARAMETERS OF DARAG NATIVE CHICKENS

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ABSTRACT

Rising feed costs constrain native chicken production. Black soldier fly larvae meal (BSFLM) are a biologically suitable alternative, but their use is limited by insufficient digestibility data for diet formulation. This study evaluated the effects of 0, 5, 10, and 15% BSFLM on growth performance, blood traits, and income over feed cost (IOFC) of Darag chickens during the grower stage, and determined its nutrient and energy values. Sixty birds were assigned in a randomized complete block design to four diets with five replicates of three birds per cage for 42 days. Growth performance was optimal at 15% BSFLM. Overall feed intake, body weight gain, average daily gain, and average daily feed intake increased linearly, whereas feed conversion ratio decreased linearly as BSFLM inclusion increased. The 15% diet also yielded the highest IOFC. Serum biochemical and hematological parameters were unaffected. Using the total collection method, apparent total tract digestibility of dry matter, crude protein, crude fat, ash, and gross energy was 72.54%, 88.37%, 56.95%, 34.70%, and 80.47%, respectively. Apparent metabolizable energy and nitrogen-corrected apparent metabolizable energy were 5,012.80 and 4,199.12 kcal/kg DM, respectively. Thus, 15% BSFLM improved growth performance and economic returns in Darag grower chickens.

Keywords: apparent total tract digestibility, black soldier fly larvae meal, blood, Darag, growth performance

INTRODUCTION

Darag native chicken is an important local poultry genetic resource in Western Visayas, Philippines, contributing to rural livelihood and valued by consumers for its distinct meat flavor, leanness, and suitability for traditional food products (Dusaran and Pabulayan, 2015; Cabarles *et al.*, 2012). The productivity of this native chicken remains constrained by disease occurrence, limited management inputs, and rising feed costs. This is most pronounced during the grower stage when birds require adequate nutrient supply to reach marketable weight. The grower phase of Darag chickens begins at 2 months of age and continues until birds attain typical harvest weight, about 800–900 g live weight within three to four months (Cabarles, 2018).

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Darag chickens are commonly raised under a free-range traditional production system, where their way of feeding involves pecking and foraging available feed resources. This feeding ecology provides a biological basis for exploring insect-derived feed ingredients to complement their natural dietary behavior. Black soldier fly (BSF), *Hermetia illucens* L., is an efficient organic waste-converting insect capable of producing edible larval biomass rich in protein (37–63%) and fat (7–39%) (Meneguz *et al.*, 2018; Liu *et al.*, 2017). Due to its nutrient profile, BSF larvae meal (BSFLM) has gained attention as an alternative feed ingredient and was reported to be optimally used at 15% for broilers and layers (Nayohan *et al.*, 2022). However, bird responses to BSFLM remain variable due to differences in diet formulation, age, strain, and production system (Abd El-Hack *et al.*, 2020). This variability should be addressed because information on its feeding value and physiological response remains limited for Darag native chickens. This study determined the effects of BSFLM on the growth performance, blood parameters, and economic viability, and measured its nutrient digestibility and energy values in the grower stage of Darag.

MATERIALS AND METHODS

Ethical approval

The research protocol was reviewed and approved by the University of the Philippines Los Baños Institutional Animal Care and Use Committee (CAFS-2023-010).

Animals, design, and experimental diets

The experiment was conducted in the research facility of West Visayas State University – Calinog Campus, Iloilo, from April to early June of 2023. Sixty Darag chickens at the grower stage (57 - 63 d) were used in the study for 42 days. The birds were allocated into four dietary treatments with different inclusion levels (0, 5, 10, and 15%) of black soldier fly larvae meal (BSFLM). This was arranged in a randomized complete block design (RCBD) with five replications (3 birds/replication) wherein birds were blocked based on their initial body weights. In the absence of nutrient recommendations for Darag grower chickens, the dietary treatments were formulated to be isocaloric and isonitrogenous using Cobb 500 grower recommendations as reference values, as shown in Table 1. The proximate composition of the BSFLM is shown in Table 2. This was obtained from an insect meal manufacturer located at Purok 2, Tacunan, Davao City, Philippines. All the diets were prepared in mash form.

Table 1. Diet composition and calculated nutrient analysis for grower diets.

Ingredient, %	Control	5%	10%	15%
Yellow Corn	59.93	60.44	61.99	62.12
SBM US HP (46.5%)	32.33	27.82	23.15	18.63
BSFLM	0.00	5.00	10.00	15.00
Coconut Oil	4.13	2.90	1.33	0.22
Limestone	0.95	0.96	0.97	0.98
MDCP	1.79	1.80	1.80	1.84

Table 1 continued . . .

Ingredient, %	Control	5%	10%	15%
Vitamin Premix	0.15	0.15	0.15	0.15
Mineral Premix	0.15	0.15	0.15	0.15
Refined Iodized Salt	0.30	0.30	0.30	0.30
Toxin Binder	0.10	0.10	0.10	0.10
L-lysine HCL	0.03	0.05	0.06	0.12
DL- Methionine	0.21	0.27	0.32	0.40
Mold inhibitor	0.05	0.05	0.05	0.05
Phytase	0.01	0.01	0.01	0.01
Total	100	100	100	100
<i>Calculated Nutrient Analysis</i>				
DM, %	90.52	90.60	90.59	90.72
AMEn, kcal	3150	3150	3150	3150
CP, %	20	20	20	20
Ca, %	0.80	0.80	0.80	0.81
P(avail), %	0.40	0.40	0.40	0.40
Crude Fiber, %	2.57	2.43	2.31	2.15
Crude fat, %	6.85	7.22	7.29	7.78
% Lys (Available)	1.17	1.16	1.14	1.16
% Met (Total)	0.54	0.60	0.66	0.74
¹ Estimated Feed Cost (₱/kg)	46.54	45.72	44.57	44.13

¹Feed cost is based on the following feed ingredients cost: Corn = ₱ 34/kg; Soybean meal (SBM) = ₱ 42/kg; Black soldier fly larvae meal (BSFLM) = ₱ 45/kg; Coconut oil = ₱ 150/kg; Micro-ingredients (include: limestone, monocalcium di-phosphate (MDCP), mineral, vitamin, and amino acid supplements, and feed additives) = ₱ 478.40/kg.

Table 2. Proximate composition of the actual BSFLM used in the study.

Component	Analyzed value, %DM
Dry Matter (%)	95.82
Crude Protein (%)	32.95
Crude Fat (%)	34.86
Ash (%)	22.51
Crude Fiber (%)	6.53
Gross Energy (kcal/kg)	4488.82

Growth performance parameters

Birds and feeds from the start and end of the experimental period were weighed to determine feed intake and body weight gain. The body weight of the chickens was determined at 2-week intervals while the orts were recorded daily. The growth parameters collected were

the feed intake (FI), body weight (BW), body weight gain (BWG), and feed conversion ratio (FCR) at 2-week intervals and for the whole experimental period. The average daily feed intake (ADFI) and average daily body weight gain (ADBWG) were calculated by dividing each accumulated FI and BWG by the total number of experiment days. Each cage was considered one replicate, and there was a total of 5 replicates for each treatment; data were calculated using cage mean values.

Blood and serum parameters

Hematology and biochemical serum profile analyses were conducted on the 35th day of the experiment. Before collecting blood samples, all birds underwent a 12-hour feed-fasting period (Rubio *et al.*, 2019). Two birds were randomly selected from each cage for blood collection. A total of 10 blood samples were collected from each treatment. A total of 2 mL of whole blood from the brachial vein of each chicken was collected using a one cc syringe and was abruptly dispensed in a 0.5 mL K₂EDTA tube (Kelly & Alworth, 2013). The excess blood was vacuumed in serum separator tubes with gel and clot activator. EDTA tubes were inverted 8 times to ensure anticoagulation prior to storage, and serum separator tubes were kept standing to sustain their contact with the clotting activators in the gel. The stored blood samples in EDTA were analyzed within 2 hrs after collection using PKL PPC 610 Hematology Analyzer at the Central Philippine University Center for Product Development, Iloilo City. Hematological parameters measured included the total white blood cells (WBC), red blood cells (RBC), and hemoglobin (Hb). For the measurement of the serum parameters, blood samples were centrifuged at $1,500 \times g$ for 15 mins, and the sera were transferred to 0.5ml microcentrifuge tubes. The sera were stored in a Biobase deep freezer at -80 °C before analysis. The analysis was performed using a BC 300 Semi-automated Biochemistry analyzer and commercial kits (AGAPPE, Cham, Switzerland) following the manufacturer's protocols for determining glucose, total protein, creatinine, uric acid, and cholesterol.

Economic analysis

The income over feed cost (IOFC) was estimated to determine the economic performance of using BSFLM on Darag chickens at the grower stage. The cost of feeds and the return from sales of the live weight of the native chickens were recorded to calculate the IOFC following the formula of Mandey *et al.* (2017) with some modifications, as shown in the formula below:

$$\text{IOFC} = [(\text{Average liveweight, kg}) \times (\text{Liveweight price, ₱/kg})] - [(\text{Average feed intake, kg}) \times (\text{feed cost, ₱/kg})] \quad \text{Equation 1}$$

The liveweight price (₱ 230/kg) was based on the average farmgate price of live native chicken as reported in the Chicken Situation Report, April-June 2022 of the Philippine Statistics Authority (PSA, 2022).

Determination of nutrient digestibility and energy values

At the end of the 42-day dietary treatment period, 16 Darag birds were randomly selected from the same batch of birds to determine the digestibility coefficients of BSFLM. The birds were weighed individually and transferred to cages (50 x 37 x 40 cm). Birds

were paired according to the closeness of their weights and were allotted to 2 experimental feeding groups. The indirect method was used in the diet design to determine the nutrient digestibility coefficients of the BSFLM. The experimental diets included a basal diet, as shown in Table 3, and a diet substituted with 30% of the BSFLM (Alafif *et al.*, 2025). The total collection method was used to determine nutrient digestibility coefficients of BSFLM. The feeding period of the experimental diets lasted for 10 days, with 6 days for the adaptation period and 4 days for the excreta collection. Birds underwent a 12-hour fasting period on the 6th day of adaptation before the excreta collection (Kim *et al.*, 2022). Excreta were collected using cage trays wherein feathers and portions of excess feed were carefully removed before scraping the excreta. The excreta were weighed and collected daily and stored at -20°C . The total excreta samples for 4 days were thawed, and the pooled excreta from each experimental diet was homogenized into a slurry using a blender for 5 minutes (Amerah *et al.*, 2008). The excreta were dried using a UN30 lab oven (Memmert, Germany) at 60°C for 72 hrs (Kim *et al.*, 2022). Dried excreta were ground, sieved using a 0.5 mm sieve, and stored in an airtight plastic container while awaiting analysis.

Table 3. Composition of the basal diet (g/kg)

Ingredient	%
Yellow Corn	60.85
¹ SBM US	32.48
Coconut oil	3.26
Limestone	0.94
² MDCP	1.77
Vitamin Premix	0.20
Mineral Premix	0.20
Refined Iodized Salt	0.30
Total	100.00

¹SBM = Soybean meal

²MDCP = Monocalcium diphosphate

Nutrient analysis and calculations

The contents of dry matter (DM), ether extract (EE), crude protein (CP), and gross energy (GE) in feed and excreta were analyzed for the determination of the apparent total tract digestibility (ATTD) and energy concentration of the experimental diets and insect meal. Proximate analyses were performed according to AOAC (2005) Official Methods: Method 954.01 (CP), Method 954.02 (EE), and Method 930.15 (DM). The analysis was conducted at the Feed Chemical Analysis Laboratory of the Department of Agriculture in Iloilo City. The gross energy in the feed and excreta was determined using a 6400 Automatic Isoperibol Calorimeter at the Animal Nutrition Analytical Service Laboratory (ANASL) of the University of the Philippines Los Baños (UPLB). The ATTD of the nutrients and the energy concentration of the test ingredient were calculated using the method of Schiavone *et al.* (2017) and De Marco *et al.* (2015). The ATTD of DM, CP, EE, and GE for the basal diet and BSFLM were calculated as follows:

$$ATTD_{\text{Diet}} = \frac{\text{Total X ingested} - \text{Total X excreted}}{\text{Total X ingested}} \times 100 \quad \text{Equation 2}$$

$$ATTD_{\text{BSFLM}} = \frac{ATTD_{\text{BSFLM diet}} - (ATTD_{\text{Basal diet}} \times 0.70)}{0.30} \times 100 \quad \text{Equation 3}$$

where X was represented by DM, CP, CF, Ash, and GE.

The energy concentration, Apparent Metabolizable Energy (AME) and nitrogen (N)-corrected AME (AMEn), of the basal diet and test ingredient was calculated using the following formula:

$$AME_{\text{diet}}(\text{kcal kg}^{-1}) = \frac{(\text{Feed Intake} \times GE_{\text{diet}}) - (\text{Excreta Output} \times GE_{\text{Excreta}})}{\text{Feed Intake}} \quad \text{Equation 4}$$

$$AME_{\text{BSFLM}}(\text{kcal kg}^{-1}) = \frac{AME_{\text{BSFLM diet}} - (AME_{\text{Basal diet}} \times 0.70)}{0.30} \quad \text{Equation 5}$$

$$AMEn_{\text{diet}}(\text{kcal kg}^{-1}) = AME_{\text{diet}} - 8.73 \times \text{N retained (g/kg)} \quad \text{Equation 6}$$

$$AMEn_{\text{BSFLM}}(\text{MJ kg}^{-1}) = \frac{AMEn_{\text{BSFLM diet}} - (AMEn_{\text{Basal diet}} \times 0.70)}{0.30} \quad \text{Equation 7}$$

$$N_{\text{retention}} = \frac{N_{\text{diet}} - N_{\text{excreta}}}{N_{\text{diet}}} \quad \text{Equation 8}$$

For the calculation of AMEn, the AMEs were adjusted for zero N retention using a correction factor of 8.73 kcal per g of retained N (Hill and Anderson, 1958).

Statistical analysis

Data were analyzed in a randomized complete block design using the PROC MIXED procedure in SAS OnDemand for Academics (SAS Institute Inc., Cary, NC). The LSM were calculated for each treatment using the Tukey-Kramer test. Linear and quadratic effects of BSFLM inclusion level were determined using orthogonal polynomial contrast. Significance was declared at $P < 0.05$. The average and the standard error of the mean were included.

RESULTS AND DISCUSSION

Growth performance

Feeding grower chickens with a 15% level of inclusion of BSFLM significantly increased the growth performance of Darag native chickens at the grower stage, as shown in Table 4. Positive linear associations were observed for the over-all FI ($y = 15.219x + 1486.9$, $R^2 = 0.2592$), BWG ($y = 6.01x + 343.18$, $R^2 = 0.1728$), ADWG ($y = 0.1431x + 8.171$, $R^2 = 0.1728$), and ADFI ($y = 0.3624x + 35.402$, $R^2 = 0.2592$) and a negative linear relationship was observed for the FCR ($y = -0.0425x + 4.639$, $R^2 = 0.2368$) in 42 days. The FI is expected to increase by 15.219 g from 1486.9 g for every 10 g increase in the inclusion of BSFLM in

the grower diets. Also, this indicates the FCR decreased from 4.63 to 4.00 when the inclusion level of BSFLM is at 15%. Notably, the highest feed intake was observed in birds fed with a 15% inclusion level of BSFLM, which was significantly higher ($P < 0.05$) compared to birds fed with diets without BSFLM. The BSFLM improved the body weight (BW) of Darag chickens by up to 432 g for the whole 6-week duration of the diet trial, achieving almost 715 g at the same age when 15% of BSFLM was incorporated. Also, the daily weight increment of chickens increased by 34.41% if BSFLM was included up to 15% in the grower diets for 42 d. The highest BWG (153.37 g) was recorded in birds fed with 15% BSFLM and was significantly higher than the birds fed with 0% BSFLM (98.36 g). Overall, the BWG of Darag chickens at the grower stage improved ($P = 0.005$) when BSFLM was added to their diets. The increasing inclusion levels of BSFLM did not have a significant effect on the BWG of Darag chickens, but the FCR was significantly lower ($P = 0.048$) in birds fed with BSFLM, in contrast with birds fed without BSFLM.

This study revealed that BSFLM was palatable to Darag chickens. This response started after a month of feeding the experimental diets, indicating their adjustment phase when fed with BSFLM. The report of van der Aar *et al.* (2017) suggests that enhancing intestinal integrity has a marked stimulation on feed intake. This may be associated with the lauric acid, chitin, and high glutamic acid that indirectly stimulated feed intake by their functional properties in strengthening intestinal integrity. In the study of Navasero *et al.* (2022), the BSFLM contained high glutamic acid content (4.4 mg per 100 g of BSFLM), which is correlated with the umami flavor. However, there is still an unclear association with its sensory stimulatory effects on birds. The results conformed with the meta-analysis by Nayohan *et al.* (2022), suggesting that chitin reduced the dry matter digestibility and stimulated the pecking behavior of birds, supporting their nutritional needs.

The observed growth-promoting effects of the inclusion of BSFLM may be associated with its underlying mechanism in improving chicken gut health through stimulation of butyrate production. The report of Kim *et al.* (2022) showed that inclusion of BSFLM increased butyrate-producing bacteria under the Lachnospiraceae family. Butyrate acts as an energy source for the enterocytes, favoring the proliferation of the mucosal cells (Mahmood & Guo, 2020). Chitin exhibited prebiotic functions when utilized at minimal levels and enriched the chitinase activity in broilers (Borrelli *et al.*, 2017). The BSFLM contains, on average, 27 g per kg of chitin (Eggink *et al.* 2022); thus, chickens fed with a 15% level of inclusion of BSFLM consumed approximately 46.06 g of chitin in the whole experimental period. Moreover, the presence of antimicrobial peptides (AMPs), such as defensin-like peptides 2 and 4 (DLP2 and DLP4), as identified by Li *et al.* (2017) and Park *et al.* (2015), exhibits cellular permeability against pathogenic microorganisms like *Staphylococcus aureus*. Additionally, the rich fat content in insect meal (38.34%) suggests a potential reservoir of bioactive compounds, including AMPs, which could be synthesized and stored within the larvae's body fat (Arrese & Soulages, 2010). The favorable growth responses of Darag chickens do not confirm that the experimental diets met their precise nutrient requirements since commercial broiler nutrient specifications may differ in nutrient levels and balance from their actual requirements.

Income over feed cost (IOFC)

Table 5 presents the economic analysis for the use of BSFLM on the grower stage of Darag. The calculated feed costs were highest at the maximum inclusion level of BSFLM.

Sales of live weight were higher at a 15% BSFLM level of inclusion. The income over feed cost (IOFC) increased by 30.96% when BSFLM was included at 15% compared with the 0% inclusion level of BSFLM. Despite having the exact feed cost, the IOFC of the birds fed with BSFLM improved due to their high live weight yield. Notably, inclusion of BSFLM improved the IOFC compared to diets without BSFLM.

Table 4. Inclusion levels of black soldier fly larvae meal (BSFLM) on the growth performance of Darag chickens in the grower stage at 2-week intervals

Item	BSFLM level of inclusion, %				ANOVA	Polynomial Contrast	
	0	5	10	15	P-value	Linear	Quadratic
³ FI, g							
² d 0-14	419.00	428.14	485.53	485.47	0.283	0.077	0.882
d 15-28	534.50	554.25	571.53	592.57	0.503	0.143	0.982
d 29-42	527.80	610.27	595.20	627.77	0.089	0.032	0.372
d 0-42	1481.30 ^b	1613.34 ^{ab}	1652.27 ^{ab}	1705.80 ^a	0.044	0.008	0.459
⁵ BW, g							
² d 0	275.20	284.74	282.67	284.07	0.637	0.360	0.493
d 14	381.20	441.20	429.40	426.34	0.273	0.228	0.173
d 28	498.20	556.00	534.27	562.67	0.226	0.113	0.525
d 42	596.57 ^b	666.65 ^{ab}	666.87 ^{ab}	716.03 ^a	0.005	0.001	0.585
⁵ BW gain, g							
² d 0-14	106.00	133.67	146.73	142.27	0.342	0.127	0.362
d 15-28	117.00	114.80	104.87	136.33	0.653	0.554	0.358
d 29-42	98.36 ^b	144.23 ^a	132.60 ^{ab}	153.37 ^a	0.010	0.005	0.228
² d 0-42	321.36 ^b	415.50 ^{ab}	384.20 ^{ab}	431.96 ^a	0.023	0.012	0.328
⁶ FCR							
² d 0-14	3.74	3.23	3.51	3.44	0.647	0.630	0.427
d 15-28	5.82	5.20	5.71	4.76	0.599	0.385	0.795
d 29-42	5.40	4.54	4.62	4.12	0.080	0.021	0.551
² d 0-42	4.71	4.26	4.35	3.97	0.135	0.037	0.854
⁴ ADFI, g	35.270 ^b	38.413 ^{ab}	39.340 ^{ab}	40.614 ^a	0.044	0.008	0.459
⁷ ADWG, g	7.651 ^b	9.892 ^{ab}	9.147 ^{ab}	10.284 ^a	0.023	0.012	0.329

^{a,b} means within a row with different superscripts are differ significantly ($P \leq 0.05$)

¹Chickens fed with different inclusion levels (0, 5, 10, and 15%) of black soldier fly larvae meal (BSFLM)

²d 0 indicates bird is approximately 60 days-old

³FI = feed intake

⁴ADFI = average daily feed intake

⁵BW = body weight

⁷ADWG = average daily weight gain

⁶FCR = feed conversion ratio

Table 5. Economic performance of Darag Chicken fed varying levels of BSFLM.

Items	¹ Dietary Treatments			
	BSFLM Inclusion levels, %			
	0	5	10	15
² Average Feed Cost (₱)	68.94	73.75	73.64	75.28
³ Sales of Liveweight (₱)	137.21	153.33	153.38	164.69
⁴ IOFC (₱)	68.26	78.95	79.73	89.40

¹Black soldier fly larvae meal (BSFLM) price = ₱ 45.00/kg

Feed price per treatment (0% BSFLM - ₱ 46.54/kg; 5% BSFLM - ₱ 45.72/kg; 10% BSFLM - ₱ 44.57/kg; 15% BSFLM - ₱ 44.13/kg)

¹Chickens fed with different inclusion levels of black soldier fly larvae meal (BSFLM)

²Average feed cost was computed using this formula: Total Feed Intake (kg) x Feed cost (₱/kg)

³Sales of Liveweight (LW) was calculated based on liveweight price of ₱ 230

⁴Income over feed cost (IOFC) = Sales of LW - Average Feed cost.

Table 6. Inclusion of black soldier fly larvae meal on the hematological parameters of chickens at d 35 from d 0.

Item	BSFLM level of inclusion, %				ANOVA	Polynomial Contrast	
	0	5	10	15	P-value	Linear	Quadratic
RBC, 10 ¹² /L	2.431	2.483	2.339	2.472	0.667	0.9578	0.6592
WBC, 10 ⁹ /L	130.22	139.4	127.06	132.4	0.359	0.797	0.697
Hb, g/dL	11.68	11.675	11.1	11.545	0.647	0.555	0.554

Blood parameters

Dietary inclusion of BSFLM up to 15% did not affect the RBC, WBC, and Hemoglobin (Hb) of Darag native chickens ($P>0.05$) as shown in Table 6. Also, there were no observed significant linear and quadratic responses. Dietary protein levels directly influence blood constituent synthesis (Mohamed *et al.*, 2012). The study by Hafsah *et al.* (2021) showed that the RBC (1.94 to 2.53) of native chickens increased as the protein level of their diets increased from 18 to 21%, supporting that the RBC of chickens did not significantly differ, as the diets used in birds in this study were formulated in an iso-nutrient manner. The hemoglobin (Hb) of the birds fell in the normal range (10.2 - 15.1) according to Samour (2006), and was comparable with the reported values in the study of Taer and Taer (2023) for *Bisaya* native chickens in the Philippines (9.92-13.32). The stable RBC, WBC, and Hb among the treatments indicate that oxygen-carrying capacity and erythropoiesis were maintained, while diets did not induce marked immune stress as expressed in their WBC (Dean, 2005). The variations in the hematological activities of the birds could be attributed to their age, gender, and reproductive status (Etim *et al.*, 2014). In this study, it could be speculated that the observed differences cannot be due to dietary factors and could be attributed to the gender of birds, genotypes, and environmental conditions (Odunitan-

Wayas *et al.*, 2018).

The recorded serum profiles indicated no observed significant changes in the use of BSFLM up to 15%, as shown in Table 7. No dose-dependent response was observed, suggesting stable measured metabolic responses across BSFLM inclusion levels. Stable glucose and creatinine levels indicate no measurable effects on circulating energy and renal indicators. Uric acid is a product of nitrogen metabolism. The uric acid levels expressed by birds fell below the normal range (2.20 - 13.90 mg/dL) based on the report of Arzour-Lakehal and Boudebz (2021). These low levels may be associated with poor protein utilization influenced by the hydration status and post-fast effects (Donsbough *et al.*, 2010). Serum cholesterol is an indicator of the lipid metabolic status of birds. A study by Bovera *et al.* (2018) showed a 13.6% reduction in cholesterol when soybean meals were substituted by 50% in layers at 40 weeks of age due to the increased level of chitin that reduced lipid absorption. The report of Hossain and Blair (2007) also observed that serum cholesterol was reduced when chitin was added at 50 g for broilers. In contrast to this study, the 15% level used in the study, regarding its chitin intake, might not be sufficient to have a hypolipidemic response from birds.

Table 7. Effects of black soldier fly larvae meal on the biochemical parameters of chickens at d 35 from d 0.

Item	BSFLM level of inclusion, %				ANOVA	Responses to BSFLM	
	0	5	10	15	P-value	Linear	Quadratic
Glucose, g/L	1.713	1.905	1.838	1.877	0.947	0.706	0.76
Creatinine, mg/dL	7.414	7.798	7.997	7.234	0.423	0.83	0.125
Uric Acid, mg/dL	0.184	0.302	0.276	0.17	0.686	0.874	0.241
Cholesterol, g/L	0.244	0.251	0.259	0.23	0.4766	0.555	0.195

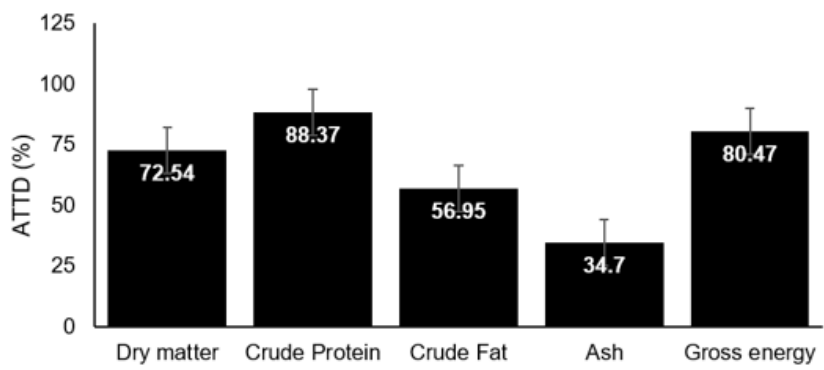


Figure 1. The apparent total tract digestibility (%) of dry matter (DM), crude protein (CP), crude fat (CF), ash, and gross energy (GE) of black soldier fly larvae meal (BSFLM) in Darag chickens at grower stage.

Nutrient digestibility and energy values of black soldier fly larvae meal

Figure 1 shows the apparent total tract digestibility (ATTD) for DM, CP, CF, ash, and GE of the BSFLM on the grower stage of Darag chickens. The calculated nutrient retention of BSFLM on Darag chickens was high in CP (88.37%), GE (80.47%), and DM (72.54%). This reported protein digestibility was not corrected for endogenous N losses and may have overestimated the actual dietary protein utilization of birds. Meanwhile, low nutrient retention was observed in CF (56.95%) and ash (34.70%) of the BSFLM. The energy retention of BSFLM on Darag at the grower stage, expressed in AME and AMEn, was high, 5,012.80 and 4,199.12 kcal/kg, respectively.

No previous studies were identified that determined nutrient retention expressed as % ATTD and the metabolizable energy of BSFLM for grower stage of Darag native chickens. The insect meal used in this study is non-defatted, as expressed in its high CF (38.34%). According to Kierończyk *et al.* (2022), the black soldier fly larvae are high in lauric acid. Also, the black soldier fly's antimicrobial peptides are housed in its body fat (Arrese & Soulages, 2010). The digestibility of fat, however, was only 54%. A reduction in lipase activity and intestinal absorption of free fatty acids (FFAs) due to high chitin. In the study of Bovera *et al.* (2018), it was apparent that birds' reduced plasma cholesterol levels were due to the disrupted absorption of lipids. The positive charge of chitin was claimed to attract the bile and free fatty acids in the intestine.

Regardless of the high ash content of the BSFLM used in this study, the mineral components of the BSFLM were not highly digestible for Darag chickens. The mineral component in the basal mixture was enough to supply its nutritional needs, provided that the formulation was based on the requirements of Cobb broilers. Also, the BSFLM might have elevated levels of Ca that did not align with the Ca:P ratio in the diet, which could have reduced the mineral bioavailability (Matin *et al.*, 2021).

As illustrated in Figure 2, BSFLM exhibited high energy values for Darag with an AME = 5,012.80 kcal/kg and AMEn = 4,199.12 kcal/kg. This explains that the inclusion of coconut oil was 18 times lower when BSFLM was at 15%. The highest predictor variable of AMEn in chickens is its CF (72%), followed by the CP component (Martínez Marín *et al.*, 2023). Given the low digestibility of CF, it could be speculated that Darag chicken could have an active chitinase. This suggests that even at high CF, the BSFLM is digestible in Darag chickens.

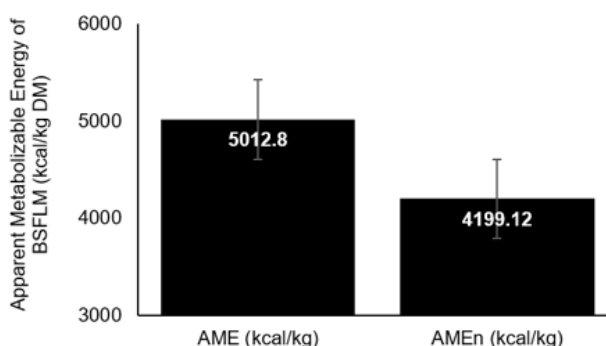


Figure 2. Apparent metabolizable energy (AME) of the black soldier fly larvae meal (BSFLM) and the AME with nitrogen correction (AMEn) of Darag chickens at grower stage.

CONCLUSION

The findings of this study demonstrate that BSFLM is a suitable feed ingredient for Darag chickens at the grower stage. The inclusion of BSFLM significantly improved the growth performance of Darag chickens (FI, BWG, and FCR) and increased the income over feed cost (IOFC). The BSFLM can be used at up to a 15% level of inclusion in grower diets. Positive linear associations were established for the overall FI, ADWG, and ADFI, and a negative linear relationship was observed for the FCR after 42 days. Its inclusion up to 15% did not markedly influence the measured blood and serum parameters. This study provides essential data on the ATTD of DM, CP, CF, ash, and GE together with the AME and AMEn of BSFLM for the formulation of the diet that is specific to Darag chickens.

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