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RESEARCH

Effect of Black Soldier Fly (*Hermetia illucens* L.) Larvae Meal on the Productive Performance, Haematological Status, and Blood Biochemistry of Broiler Chickens under Tropical Conditions

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ABSTRACT

Purpose: *Soybean meal is the traditional protein source for poultry, but rising costs necessitate alternatives. This study investigated the effect of a strategic inclusion of Black Soldier Fly Larvae Meal (BSFLM), using 10% as a partial protein replacement during early phases and 1% during the finisher phase, on the productive performance and systemic health of Ross 308 broiler chickens under tropical conditions.*

Research Method: *A one-way ANOVA design was used with two treatments (Control vs. BSFLM). Each treatment comprised 132 birds divided into three replicates (n= 44). Diets for Pre-starter (1-10 d), Starter (11-22 d), and Finisher (23-42 d) phases included 10% BSFLM in the first two phases and 1% in the last. Productive parameters (initial body weight, final body weight, daily feed intake, body weight gain, feed conversion ratio, and mortality percentage), haematological, and blood biochemical were evaluated.*

Findings and Values: *BSFLM inclusion drastically reduced mortality (P < 0.05; 2.24% BSFLM vs. 20.45% Control). Growth performance showed a numerically higher final body weight, but the difference was not statistically significant (p=0.436). Haematologically, BSFLM prevented early anaemia, although both treatments exhibited extreme leucocytosis and thrombocytopenia. Biochemically, BSFLM stabilised glucose and improved protein and lipid profiles, however, both treatments showed signs of liver/kidney damage, likely due to heat stress and water quality issues (no residual chlorine and high nitrates). This study demonstrates BSFLM's practical value in enhancing early survival and metabolic stability.*

Keywords: *Black soldier fly larvae, Blood biochemistry, Broiler chicken, Haematology, Insect meal, Productive performance.*

INTRODUCTION

The sustained growth of the global population is driving an urgent search for food sources that offer high nutritional value and production efficiency. In this context, poultry production is of paramount importance, with a projected 70% increase in demand for animal-origin products

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by the year 2050 (Murawska *et al.* 2021). Currently, soybean meal (SBM) remains the primary protein source for broiler diets. However, this high-protein raw material faces increasing prices and significant environmental concerns, including deforestation and greenhouse gas emissions associated with its intensive cultivation (Sajjad *et al.* 2024). Consequently, there is a critical need to investigate sustainable alternative protein sources for the animal nutrition industry (Salahuddin *et al.* 2024).

The larvae of the black soldier fly, *Hermetia illucens* (BSFL), have emerged as one of the most promising alternatives due to their capacity to transform organic waste into nutrient-dense biomass (Saidani *et al.* 2025). BSFL meal (BSFLM) provides a robust nutritional profile, with crude protein levels ranging between 37–63% and a fat content between 7–39% on a dry matter basis. Notably, its amino acid profile is often superior to that of soybean meal (Murawska *et al.* 2021). Furthermore, BSFLM is rich in lauric acid, a medium-chain fatty acid with proven antimicrobial properties that may enhance intestinal health in poultry (Hartinger *et al.* 2021).

In broiler chickens, recent studies suggest that partial replacement of SBM at inclusion levels between 10% and 15% can improve growth and other productive parameters (Dabbou *et al.* 2018; Lee *et al.* 2024). For instance, Sajjad *et al.* (2024) indicated that inclusion levels up to 12% maintain performance without adverse effects. Nevertheless, Murawska *et al.* (2021) have noted that excessive inclusion levels may be unfavourable, potentially resulting in reduced feed intake, lower daily weight gain, and deterioration in carcass and meat quality.

Despite these advancements, further research is required to understand the physiological impact of BSFLM across all growth stages under specific environmental conditions. Therefore, this study was proposed to evaluate the incorporation of black soldier fly larvae meal into the formulation of balanced diets for Ross 308 broilers during the Pre-starter, Starter, and Finisher phases. The investigation specifically examines the impact of this inclusion on productive variables, haematological parameters, and blood biochemical markers as indicators of avian health and metabolic status.

MATERIALS AND METHODS

Experimental site and animals

The study was conducted at the Nicolino Ierrobueno Agricultural Production Unit, Girardot municipality, Aragua state, Venezuela. A total of 264 one-day-old unsexed (as-hatched) Ross 308 broiler chicks (sourced from Las Guasduas Hatchery, Purolomo C.A., Aragua State, Venezuela) were used. The birds were divided into two treatments: Control and Black Soldier Fly Larvae Meal (BSFLM), each with 132 birds distributed into three replicates of 44 birds each. The experiment followed a completely randomised design. Chickens were housed in experimental floor pens measuring 2.2 m × 2.2 m × 2.0 m (floor area of 4.84 m^2) with rice hull as bedding material at a stocking density of 10 chickens m^{-2}. Each pen was equipped with infrared heat lamps, manual bell-type waterers, and tube feeders. The lighting programme consisted of a natural photoperiod of approximately 12 hours of light and 12 hours of darkness (12L:12D) throughout the study. *Ad libitum* access to water and feed was provided.

Dietary treatments and management

The diets were formulated to be isoproteic and isoenergetic, meeting the nutritional requirements for each stage of the production cycle according to the Ross 308 broiler management handbook guidelines (Aviagen 2021). The feeding programme consisted of three phases: Pre-starter (1–10 d), Starter (11–22 d), and Finisher (23–42 d). The Control treatment consisted of a proprietary standard commercial basal diet primarily composed of yellow maize, soybean meal (48% crude protein), poultry by-product meal, L-methionine, L-threonine, soybean oil, choline chloride, and a vitamin-mineral premix. Due to commercial confidentiality, specific ingredient ratios are not disclosed; however, the diets were balanced to ensure nutrient consistency across treatments.

The BSFLM treatment consisted of the same basal formulation with a 10% dietary inclusion of BSFLM (w/w, as-fed basis) during the Pre-starter and Starter phases. For the Finisher phase, the inclusion level was adjusted to 1% to evaluate the carry-over effect of early supplementation on final performance.

The proximate composition of the experimental diets and the BSFLM is presented in Table 1. Chemical analyses were performed in duplicate to determine moisture, crude protein, crude fat, ash, crude fibre, calcium, and phosphorus following AOAC (2016) procedures.

Environment and water quality monitoring

Environmental parameters were monitored using a digital thermohygrometer (EXTECH Instruments, NH, USA, model 445715); the average ambient temperature was 30.5°C with 56.7% relative humidity. To ensure consistency in environmental conditions, drinking water quality was assessed (ISO 2019). Physicochemical analysis revealed suboptimal quality characterised by the absence of residual free chlorine (<0.3 mg/L), slightly acidic pH (6.32), and nitrate levels (34.53 mg/L NO_3) exceeding recommended limits.

Productive performance variables

The following variables were monitored: initial body weight (IBW), final body weight (FBW), daily feed intake (DFI), body weight gain (BWG), feed conversion ratio (FCR), and mortality percentage. A sample of 15 birds per treatment (11.4%) was weighed at regular intervals (days 1, 4, 7, 10, 14, 21, 22, 28, 35, and 42). Productive parameters were calculated based on phase boundaries (days 1, 10, 22, and 42). Feed intake was calculated by dividing total consumption by the number of days. Measurements were taken using a precision scale (0.01 g sensitivity).

Haematological and blood biochemical profile

Blood sampling was performed via cardiac puncture. Baseline samples were collected on day 1 prior to feeding. Due to the intensive monitoring design, one representative bird per treatment was sampled weekly. Birds were not fasted before sampling. Analyses followed ISO (2022) standards. Haematological parameters were determined using a Medonic analyser, with manual verification via Neubauer chamber and blood smears. Blood chemistry was analysed using a Selectra ProM system. These parameters were treated as descriptive indicators of biological trends rather than inferential statistics.

Statistical analysis

Productive variables (n=15 per treatment) were analysed using Statistical Product and Service Solutions (SPSS) IBM SPSS version 21 (IBM 2012). A completely randomised design was used, and a one-way Analysis of Variance (ANOVA) was performed according to the following model:

$$Y_i = \mu + T_i + \varepsilon_i \tag{1}$$

where Y_i = observed response; μ = overall mean; T_i = treatment effect; and ε_i = random error. Mean separation was performed using Tukey's test ($P < 0.05$). Mortality was analysed using the Chi-square (χ^2) test.

Due to the pilot nature of the physiological evaluation, haematological and biochemical parameters (n = 1 per treatment/week) were subjected to a descriptive longitudinal analysis to identify biological trends over time.

Formulas used to calculate the variables

$$DFI = \frac{\text{Feed offered (g)} - \text{Feed not consumed (g)}}{\text{Total number of birds}} \tag{2}$$

DFI: Daily feed intake

$$BWG = FBW(g) - IBW(g) \tag{3}$$

BWG: Body weight gain; IBW: Initial body weight; FBW: Final body weight

$$FCR = \frac{\begin{array}{c}\text{Quantity of feed consumed}\\ \text{during a period (g)}\end{array}}{\text{Weight gain during the same period (g)}} \tag{4}$$

Table 1. Bromatological composition of *Hermetia illucens* meal and experimental diets by feeding phase (as-fed basis).

Parameters	HI meal	Pre-Starter C	Pre-Starter B	Starter C	Starter B	Finisher C	Finisher B
Moisture (%)	9.11	9.50	8.53	9.35	9.51	11.42	10.53
Crude protein (%)	25.46	19.36	21.07	19.38	20.19	19.44	19.15
Crude fat (%)	31.26	7.88	9.16	10.27	12.95	9.56	9.80
Ash (%)	15.53	9.36	9.18	6.15	5.65	5.46	5.86
Crude fibre (%)	7.89	2.42	3.13	2.27	2.98	2.68	2.49
Calcium (%)	4.19	1.60	2.06	1.19	0.91	0.90	0.99
Phosphorus (%)	0.88	0.68	0.79	0.60	0.62	0.62	0.58

FCR: Feed conversion ratio

$$\%\ \text{Mortality} = \frac{\text{Total deaths}}{\text{Total population}} \times 100 \qquad (5)$$

RESULTS AND DISCUSSION

Production parameters

In the statistical analysis of BWG, compared between the Control and BSFLM treatments, there were no significant differences ($P > 0.05$). Table 2 summarises the productive variables by treatment and feeding phase, expressed as Mean ± Standard Deviation. Figure 1 illustrates the average body weight under both treatments across the three dietary phases.

At the Pre-starter phase, the BSFLM treatment exhibited numerically higher BWG compared to the Control treatment. This is consistent with the higher DFI observed in the BSFLM treatment during this same phase. However, in subsequent phases (Starter and Finisher), the Control treatment showed higher numerical values than BSFLM in weight gain.

The FBW parameters resulted in a higher cumulative FBW at the end of the fattening cycle (day 42) for the Control treatment. The FCR was consistently greater in the BSFLM treatment across all phases compared to the Control. Regarding mortality, the most significant finding was in the Pre-starter phase, where the BSFLM treatment showed a drastic reduction (2.24%) compared to the Control (20.45%). This resulted in a lower total cumulative mortality for the BSFLM treatment at the end of the experiment.

Growth performance and feed efficiency

The inclusion of 10% BSFLM during the early stages of the experiment (Pre-starter and Starter) showed that broiler chickens could effectively utilise insect-based protein without compromising their fundamental growth potential. Although no significant differences were observed in BWG between treatments ($P > 0.05$), the numerically higher weight gain and DFI in the BSFLM treatment during the Pre-starter phase suggest a high palatability of the insect meal, which encouraged early consumption.

This observation aligns with reports by Sajjad *et al.* (2024) and Vasilopoulos *et al.* (2024), who noted that the inclusion of *Hermetia illucens* larvae could improve feed intake during the early growth stages due to its attractive amino acid profile and fatty acid composition. However, the increase in FCR in the BSFLM treatment across all phases, along with a higher FBW in the Control treatment at day 42, indicates a lower efficiency in nutrient utilisation compared to the

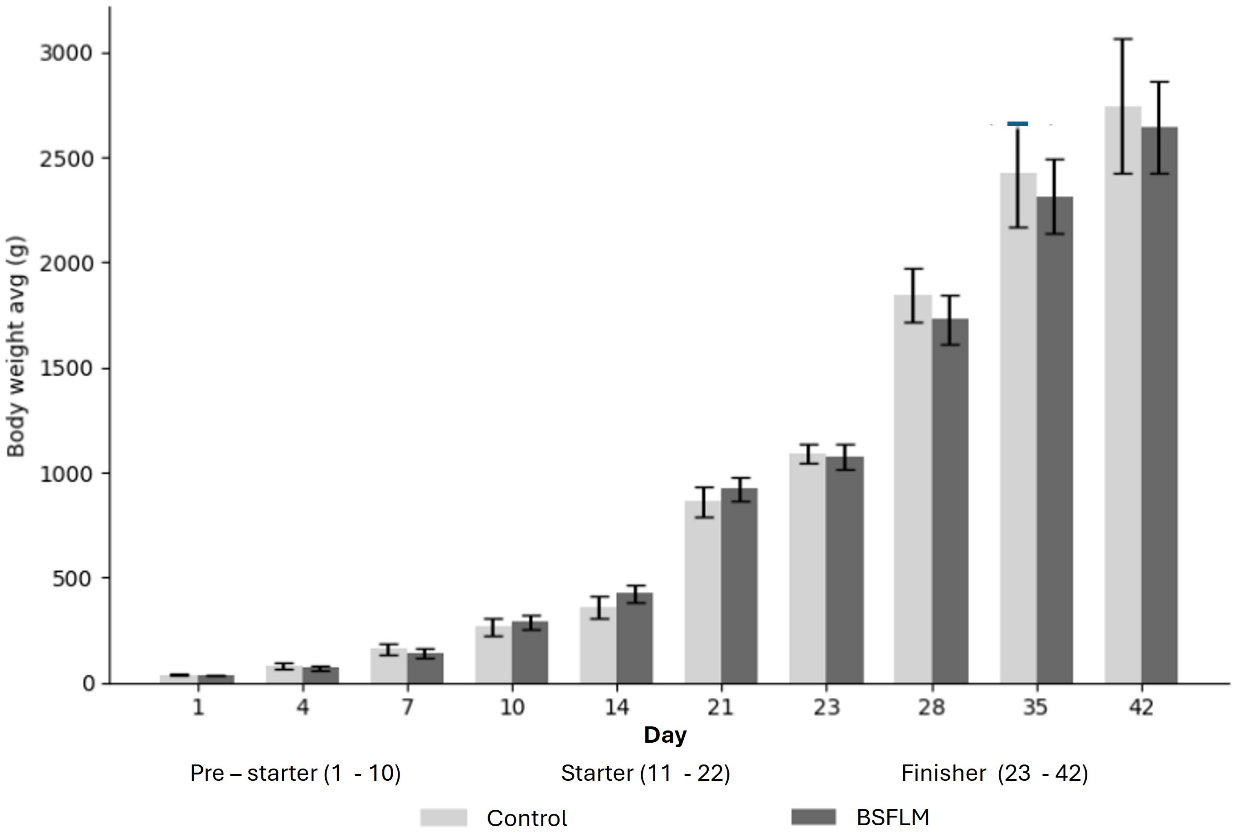

Figure 1. Comparison of average body weight (g) of broiler chickens between the Control and BSFLM treatments during a 42-day growth period.

Table 2. Productive performance parameters of broiler chickens by feeding phase and dietary treatment.

Parameter	Pre-starter		Starter		Finisher	
/Treatment	Control	BSFLM	Control	BSFLM	Control	BSFLM
IBW (g)	38.64 ± 0.83	38.46 ± 0.70	266 ± 81.57	290 ± 94.30	1092 ± 321	1077 ± 206
FBW (g)	266 ± 81.57	290 ± 90.30	1092 ± 321	1077 ± 296	2744 ± 348	2644 ± 401
DFI (g)	25.11 ± 7.59	36.26 ± 8.05	98.95 ± 20.33	83.10 ± 24.5	215 ± 22.77	205 ± 20.17
BWG (g)	227	252	826	786	1652	1567
FCR	0.75	0.94	0.99	1.04	1.53	1.96
Mortality (%)	20.45^b	2.24^a	6.06^b	0.00^a	0.00^a	0.75^b

soybean-based diet. This trend is consistent with findings by Dabbou *et al.* (2018) and Murawska *et al.* (2021), who suggested that high inclusion levels of full-fat insect meal might affect the digestibility of certain nutrients or that the chitin content could interfere with protein absorption, leading to a higher FCR despite a robust feed intake. IBW: initial body weight; FBW: final body weight; DFI: daily feed intake; BWG: body weight gain; FCR: feed conversion ratio. Data are presented as Mean $\pm$ Standard Deviation. Sample size: n = 15 birds per treatment for growth parameters. No significant differences were detected for growth variables ($p = 0.436$; $P > 0.05$). Mortality was analysed using the Chi-square (χ^2) test; different superscripts (a, b) within the same row and phase indicate significant differences ($P < 0.05$).

Survival and environmental stress mitigation

The most striking result of this study was the drastic reduction in mortality during the Pre-starter phase, where the BSFLM treatment recorded 2.24% compared to a critical 20.45% in the Control treatment. This finding is particularly relevant considering the challenging environmental conditions of the experiment, characterised by acidic water pH, high nitrate levels, and thermal stress. The high mortality in the Control treatment suggests a state of physiological vulnerability, likely exacerbated by oxidative stress and a compromised immune response, as described in models of chronic stress (White *et al.* 2022).

The superior survival rate in the BSFLM treatment can be attributed to the functional properties of *Hermetia illucens*. Previous studies have demonstrated that black soldier fly larvae contain antimicrobial peptides (AMPs) and a high concentration of lauric acid, which possess potent antibacterial and immune-boosting properties (El-Kaiaty *et al.* 2022; Salahuddin *et al.* 2024). These components may have acted as a “physiological shield,” allowing the chicks to withstand the early chemical stress from the water and the environmental heat. Furthermore, Adam *et al.* (2025) reported that insect-based diets can modulate the gut microbiota and enhance the bird’s resilience against environmental pathogens and stressors, which explains why the BSFLM treatment maintained population stability despite the adverse conditions.

Haematological profile

The haematological parameters for both treatments over the 42-day period are presented in Table 3. Due to the pilot nature of this evaluation ($n = 1$), results are described as temporal biological trends. Hemoglobin (Hb) and Erythropoiesis. During the Pre-starter phase, the BSFLM treatment exhibited higher Hb levels compared to the Control. In the Starter and Finisher phases, Hb levels in both treatments generally remained within the physiological range.

Leucocytes and Immune/Inflammatory Response. Both treatments showed extreme and sustained leucocytosis throughout the grow-out cycle. In the Pre-starter phase, BSFLM started with higher leucocyte counts (day 7) than the Control. In the Starter and Finisher phases, values remained extremely high in both treatments; although the Control showed a higher peak on day 14 followed by a drop on day 28, while BSFLM values were more stable.

Differential count. Regarding heterophils, BSFLM exhibited a numerical peak (66%) on day 7. Both treatments exhibited fluctuations during the Finisher phase. Lymphocytes showed a reduction (lymphopenia) in the BSFLM treatment on days 7 and 28, while the Control showed it on day 35 (42%). Eosinophils and Monocytes remained within or near physiological ranges for both treatments.

Thrombocytes. Both treatments showed low thrombocyte counts throughout the experiment. In the Pre-starter and Starter phases, both remained low, with a drop on day 28 for the Control. In the Finisher phase, both treatments showed a recovery trend on day 42.

Haematological profile and immune status

The haematological dynamics observed in this study reflect a state of high physiological demand, likely triggered by the environmental stressors mentioned previously. Although the

Table 3. Weekly haematological parameters of Ross 308 broiler chickens fed diets with BSFLM inclusion (n = 1).

			CONTROL			
Parameters / day	7	14	21	28	35	42
Haemoglobin (g/dL)	7.3*	11.6	10.4	9.7	8.0	10.4
Leucocytes (cell/μL)	29751	90871**	59583**	21450	31949	45117**
Heterophils (%)	51**	35	46	50	55**	46
Lymphocytes (%)	47	62	50	46	42*	52
Eosinophils (%)	1	1	2	2	1	1
Monocytes (%)	1*	2	2	2	2	1*
Thrombocytes (cells/μL)	2000*	3000*	3000*	1000*	2000*	10000*
			BSFLM			
Parameters / day	7	14	21	28	35	42
Haemoglobin (g/dL)	9.5	9.2	9.5	11.0	11.5	11.1
Leucocytes (cells/μL)	64614**	78580**	59821**	35660	35190	347370
Heterophils (%)	66**	42	51**	58**	45	52**
Lymphocytes (%)	30*	55	46	38*	52	45
Eosinophils (%)	2	1	2	1	2	2
Monocytes (%)	2	2	1*	3	1*	1*
Thrombocytes (cells/μL)	2000*	1000*	1000*	1000*	3000*	4000*

Reference ranges according to Garfia veterinary laboratory: Haemoglobin: 8.00–18.00 g/dL; Leucocytes: 4000–40000 cells/μL; Heterophils: 20–50%; Lymphocytes: 45–75%; Eosinophils: 0–2%; Monocytes: 2–10%; Thrombocytes: 15000–35000 cells/μL. * Below reference value. ** Above reference value.

results are described as temporal trends due to the pilot nature of the evaluation, the data provides significant insights into the birds' resilience. Erythropoiesis and Hemoglobin. Regarding Hb levels, the BSFLM treatment exhibited higher values during the Pre-starter phase compared to the Control. This suggests a better oxygen-carrying capacity during the most critical stage of the experiment. According to Hagan *et al*. (2022), variations in haemoglobin and packed cell volume can be influenced by the dietary protein source and its impact on iron availability. The stability of Hb levels within the physiological range during the Starter and Finisher phases for both treatments aligns with the finding that broiler chickens possess homeostatic mechanisms to maintain erythropoiesis even under suboptimal conditions (Kareem *et al*. 2024).

Leucocyte dynamics and the inflammatory response. A remarkable finding was the extreme and sustained leucocytosis observed in both treatments throughout the cycle. This systemic response is a clear indicator of the birds' reaction to the high nitrate levels and acidic pH of the water. According to Nwaigwe *et al*. (2020), a significant increase in total white blood cell counts is a primary haematological marker of environmental and chemical stress in poultry.

The fact that BSFLM started with higher leucocyte counts on day 7, but maintained more stable values compared to the sharp fluctuations in the Control treatment, suggests a more regulated immune response. These bioactive compounds in insect-based diets, such as chitin and antimicrobial peptides, can modulate the immune system by acting as "priming" agents (Grabowski *et al*. 2022)

Differential count and stress indicators. The numerical peak in heterophils (66%) in the BSFLM treatment on day 7, coupled with periods of lymphopenia, is characteristic of an acute stress response. According to Sufiriyanto *et al.* (2018), the heterophil-to-lymphocyte ratio is a gold-standard indicator of stress in broilers, where a high proportion of heterophils indicates an active defence against stressors. In this study, the more stable leucocyte levels in the BSFLM treatment during the Finisher phase may indicate that the larvae meal prevented "immune collapse" under chronic stress (White *et al.* 2022).

Thrombocytes. The low thrombocyte counts observed throughout the experiment in both treatments could be linked to the systemic inflammatory state. As recently highlighted by Islam *et al*. (2025), thrombocytes in birds play a dual role in both haemostasis and the innate immune response; therefore, their depletion may reflect active recruitment to inflammatory sites caused by water-induced chemical stress.

Blood biochemistry parameters

The results for blood biochemistry are summarised in Table 4. Day 1 represents the baseline value for both treatments, taken as a pool before diet assignment. Glucose. In the Control treatment, blood glucose levels consistently remained within the physiological range throughout the study, with a downward trend toward the end (195 mg/dL on day 28). A peak was observed on day 14 (321 mg/dL). In the BSFLM treatment, blood glucose levels rose on day 14 (413 mg/dL), exceeding the upper reference range. Urea and Creatinine. Regarding urea levels, the Control fluctuated considerably, showing peaks on day 1 (17.50 mg/dL), day 7 (5.70 mg/dL), day 28 (11.30 mg/dL), and day 42 (8.10 mg/dL). In contrast, urea levels in the BSFLM treatment, tended to stabilise starting on day 14 (4.90 mg/dL) and remaining relatively low on days 21 (4.8 mg/dL), and 42 (3.40 mg/dL), with an abrupt peak of 14 mg/dL on day 28. Regarding creatinine, both treatments started high (2.24 mg/dL) and rapidly decreased, stabilising within the reference range starting on day 7. A lower creatinine value was recorded for the Control on day 28 (0.14 mg/dL) Liver enzymes: Alanine Aminotransferase (ALT), Aspartate Aminotransferase (AST), and Bilirubin. For the Control, both ALT and AST showed high values throughout the study. In the BSFLM treatment, a downward trend was observed on day 21 (ALT: 28 U/L, AST: 137 U/L), followed by an increase on days 28, 35, and 42. Total bilirubin remained consistently above the normal range for both treatments, with an extreme peak for the BSFLM treatment on day 21 (6.20 mg/dL).

Total protein and Calcium. The Control treatment initially showed low total protein levels (1.82 g/dL) and fluctuated during the cycle, reaching 2.43 g/dL on day 35. In the BSFLM treatment, total protein values remained within the reference range for most of the study, except for day 14, when a value of 2.49 g/dL was recorded. Blood calcium remained within the normal range for most of the study in both treatments, with peak values on day 35 (11.97 mg/dL for Control and 11.83 mg/dL for BSFLM).

Lipid profile Cholesterol and Triglycerides. Cholesterol started high (249 mg/dL) and showed a rebound in the BSFLM treatment on day 21 (217 mg/dL). Triglycerides remained within range for most of the cycle, with a peak on day 7 (168 mg/dL) for the Control and a low value on day 42 (14 mg/dL). The BSFLM showed stability throughout the phases.

Metabolic and physiological response to insect-based nutrition The metabolic profile observed suggests that the inclusion of BSFLM facilitates a more stable nutrient homeostasis compared to the Control. The transient increase in glucose and cholesterol in the BSFLM treatment on days 14 and 21, respectively, may reflect a metabolic adaptation to the higher lipid content and energy density of the insect-based diet, a phenomenon also noted by Schiavone *et al*. (2017). The stabilisation of urea levels and the maintenance of total protein within reference ranges in the BSFLM treatment indicate a high biological value of the insect protein, promoting efficient nitrogen utilisation (Dabbou *et al*. 2018).

Furthermore, the downward trend in ALT and AST enzymes in the larvae-fed treatment during the growing phase suggests a potential hepatoprotective effect or, at least, a lack of dietary toxicity, which aligns with recent

Table 4. Weekly serum biochemical parameters of Ross 308 broiler chickens by dietary treatment (n = 1).

CONTROL							
Parameter / day	1	7	14	21	28	35	42
Glucose (mg/dL)	244	248	321	225	195*	248	219
Urea (mg/dL)	17.50**	5.70**	1.70*	3.90	11.30**	0.36*	8.10**
Creatinine (mg/dL)	2.24**	0.42	0.29	0.38	0.14*	0.18	0.24
ALT (U/L)	252**	10*	138**	157**	150**	260**	321**
AST (U/L)	287**	8*	302**	169	165	270	313**
Total bilirubin (mg/dL)	0.28**	0.78**	0.15**	0.69**	0.77**	0.46**	0.47**
Total protein (g/dL)	1.82*	2.59	2.06*	2.24*	2.83	2.43*	3.17
Calcium (mg/dL)	9.96	9.47	10.33	10.59	8.07	11.97**	9.07
Cholesterol (mg/dL)	249**	231**	167	142	174	141	89
Triglycerides (mg/dL)	51	168**	31	102	124	67	14*
BSFLM							
Parameter / day	1	7	14	21	28	35	42
Glucose (mg/dL)	244	292	413**	282	221	251	278
Urea (mg/dL)	17.50**	8.50**	4.90	4.80	14.00**	11.60**	3.40
Creatinine (mg/dL)	2.24**	0.21	0.19	0.25	0.19	0.30	0.24
ALT (U/L)	252**	76**	127**	28	254**	238**	354**
AST (U/L)	287**	150	145	137	363**	223	356**
Total bilirubin (mg/dL)	0.28**	0.67**	0.44**	6.20**	0.73**	1.21**	0.62**
Total protein (g/dL)	1.82*	4.31	2.49*	3.36	3.12	3.43	2.58
Calcium (mg/dL)	9.96	9.79	11.11**	11.16**	10.58	11.83**	9.76
Cholesterol (mg/dL)	249**	133	167	217**	139	147	108
Triglycerides (mg/dL)	51	115	125	176	102	50	72

Reference ranges according to Garfia veterinary laboratory: Glucose: 200–370 mg/dL; Urea: 2.50–5.00 mg/dL; Creatinine: 0.17–0.42 mg/dL; ALT (Alanine aminotransferase): 20–50 U/L; AST (Aspartate aminotransferase): 25–275 U/L; Total bilirubin: 0.006–0.12 mg/dL; Total protein: 2.50–4.50 g/dL; Calcium: 8.00–11.00 mg/dL; Cholesterol: 87–192 mg/dL; Triglycerides: 31–166 mg/dL.

* Below reference value; ** Above reference value. BSFLM: Black Soldier Fly Larvae Meal. Note: Values for Day 1 are identical for both treatments as they represent a single baseline measurement (n = 1) prior to the full implementation of dietary treatments.

findings by Saidani *et al*. (2025) regarding the safety of Hermetia illucens in broiler nutrition. The stability of the lipid profile, despite the initial cholesterol rebound, could be attributed to the presence of medium-chain fatty acids like lauric acid in the BSFLM, known to modulate lipid metabolism without inducing chronic hypercholesterolaemia (Toral *et al*. 2025)

CONCLUSION

Regarding productive performance, despite an initial advantage in the BSFLM treatment, the Control treatment showed higher BWG during the Starter and Finisher phases, resulting in a slightly higher FBW. However, the inclusion of BSFLM in the Pre–starter diet proved highly beneficial, as a drastic reduction in mortality was observed (20.45% in the Control vs. 2.24% in the BSFLM). This was accompanied by higher feed intake and weight gain during the first 10 days, suggesting improved haematological and metabolic stability during this critical phase.

Biochemical analyses revealed persistent hepatic and renal challenges in both treatments, evidenced by elevated ALT, AST, bilirubin, urea, and creatinine. These issues were not mitigated by the BSFLM inclusion, which showed even higher levels of liver enzyme elevations in the Finisher phase compared to the Control. These findings suggest the presence of external stressors, likely related to heat stress and water quality. The absence of residual free chlorine, the slightly acidic pH (6.32), and the very high nitrate levels (34.53 mg/L) represent a direct toxicological and sanitary concern. These water quality parameters likely contributed to the systemic health issues and leucocytosis observed, independent of the dietary treatments.

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