

Grub to gains: A black Soldier Fly (*Hermetia illucens*) Larvae Pellet Supplemented with Turmeric Extract Proximate Analysis for Poultry Feed

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ABSTRACT: Conventional poultry-feed proteins such as soybean meal and fish meal face rising costs and supply constraints, driving interest in insect-based alternatives. Black soldier fly (BSF) larvae meal is a nutrient-dense, sustainable protein source increasingly explored for poultry diets. This study aimed to compare the proximate composition of a BSF larvae meal-based pellet, supplemented with 3% turmeric (*Curcuma longa*) extract, against two commercial feeds (Feed X and Feed Y), and to make a preliminary observation of final body weight in a small pilot feeding trial. Moisture, crude protein, crude fat, crude fiber, and ash were determined using standard procedures and compared statistically. In the 14-day pilot trial (n = 5 chickens per group, initial weight approximately 300 g, ad libitum feeding), only final body weight was recorded. The BSF pellet showed significantly higher crude protein (36.62%) and fat (10.98%) and significantly lower moisture (9.62%) than both comparison feeds, and lower fiber (5.56%) than Feed X. Its ash content (9.14%) was lower than that of Feed X and similar to that of Feed Y. Final body weight did not differ significantly among groups (BSF pellet 355.8 g; Feed X 340.2 g; Feed Y 347.8 g; p = 0.690). In conclusion, the BSF larvae meal-based pellet contained higher protein and fat than the commercial feeds without synthetic supplementation, whereas the pilot trial was too small and short to assess growth performance, which requires adequately powered, longer trials.

KEYWORDS: Black soldier fly larvae; protein; proximate analysis; turmeric; phytogenic feed additive.

1. INTRODUCTION

Protein remains the most expensive and often the most limiting component in poultry feed formulation. Conventional protein sources such as soybean meal (SBM) and fish meal are subject to price volatility, land-use pressure, and, in the case of fish meal, concerns over the sustainability of marine-capture fisheries used for its production [1]. These constraints have intensified the search for alternative protein sources that can be produced locally, at lower environmental cost, and without directly competing with human food supply.

Insect-derived meals, particularly those from the black soldier fly (*Hermetia illucens*, BSF), have emerged as one of the most promising alternatives [2]. BSF larvae can be reared on a wide range of organic side-streams and food waste, converting low-value biomass into a larval product rich in protein, fat, and chitin [3,4]. Reported crude protein content of BSF larvae meal ranges broadly from approximately 32% to over 58% of dry matter depending on rearing substrate, larval developmental stage, and post-harvest processing such as defatting [3-5]. Numerous feeding trials in broilers and layers have shown that BSF larvae meal can replace a substantial proportion of soybean meal or fish meal without adverse effects on growth performance at

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moderate inclusion levels [6-11], although high inclusion levels and the chitin content of the larval exoskeleton have been associated with reduced nutrient digestibility and metabolizable energy in some studies [6,7,12].

Despite the growing body of literature on BSF larvae meal as a feed ingredient, relatively few studies provide a direct, statistically supported empirical proximate comparison between a BSF larvae meal-based pellet and locally available commercial or native poultry feeds [13], particularly for formulations that exclude vitamin-mineral premixes or synthetic amino acids. Such comparisons are practically useful because a high-protein BSF-based pellet of this kind would typically be used as a concentrate rather than fed as a complete daily ration, to reach the crude protein levels recommended for different poultry production phases [14].

Beyond protein source substitution, phytogetic feed additives such as turmeric (*Curcuma longa*) have gained attention as natural alternatives to antibiotic growth promoters in poultry production. Turmeric's principal bioactive compound, curcumin, has been associated with improved feed intake, growth performance, antioxidant capacity, and immune response in broiler chickens [15]. Graded dietary turmeric powder inclusion (0–4.5%) has been reported to significantly increase body weight gain and improve feed conversion ratio relative to unsupplemented diets, with 3% inclusion among the levels associated with favorable performance outcomes [16], while curcumin has also been proposed to enhance nutrient utilization by promoting protein synthesis via enzymatic pathways [17]. Combining a high-protein BSF larvae meal-based pellet with a functional phytogetic additive such as turmeric therefore represents a plausible strategy for simultaneously addressing protein density and appetite/growth-promoting properties in a single feed product, although this specific combination has not, to our knowledge, been previously evaluated.

The objective of this study was therefore to describe the composition and production process of a BSF larvae meal-based poultry feed pellet supplemented with 3% turmeric (*Curcuma longa*) extract without synthetic additives, compare its proximate composition against two commercial reference feeds, and make a preliminary observation of the final body weight of chickens fed this formulation in a small pilot feeding trial.

2. MATERIALS AND METHODS

2.1. Material

Three poultry feeds were compared in this study: two commercial reference feed (Feed X and Feed Y), and a BSF larvae meal-based pellet. Feed X and Feed Y were purchased from online shop at Tangerang Selatan and South Jakarta. The BSF larvae were cultivated from boarding school MTs N 41 Al Azhar Asy-Syarif South Jakarta. The soybean meal, fish meal, corn meal, rice bran, vegetable oil, limestone, and dicalcium phosphate were purchased from online shop at South Jakarta. The turmeric (*Curcuma longa*) extract were produced at Phytochemistry Laboratory, Faculty of Pharmacy, Universitas Pancasila.

2.2 BSF Larvae Production: From Egg to Larvae Meal

The BSF larvae meal used in the pellet was produced through a closed-loop rearing cycle, from egg collection through to processed meal. Adult BSF flies were maintained in a mating cage under ambient light at approximately 28–32 °C and 60–70% relative humidity [3,4]. Female flies were provided a fluted/corrugated cardboard oviposition substrate positioned beside an organic attractant; egg clusters laid within the substrate's grooves were collected daily and transferred to a hatching tray containing a moist starter substrate.

Following hatching, larvae were reared on an organic waste-based substrate (a mixture of fruit and vegetable residues and other food by-products) maintained at 60–70% moisture content and an ambient temperature of 27–30 °C. Larvae were reared for approximately 14–18 days until reaching the late-instar/pre-pupal stage, identifiable by darkening of the cuticle and reduced feeding activity, at which point crude protein and lipid content are reported to approach their maximum [3,4]. Pre-pupal larvae were harvested by self-migration onto an inclined collection ramp and were subsequently rinsed with clean water to remove residual substrate debris.

Harvested larvae were blanched in hot water (approximately 90–100 °C for a few minutes) to inactivate microbial and enzymatic activity, then oven-dried at 60–70 °C until a stable, low moisture content was reached. Dried larvae were mechanically pressed to remove a portion of the larval lipid fraction, yielding a defatted larvae meal, before being milled and sieved to a uniform particle size for inclusion in the pellet formulation.

This defatting step accounts for the residual crude fat level (10–15%) characteristic of the defatted BSF larvae meal used in this study [6,8].

2.2. Pellet Production Process

The BSF pellet was composed of dried BSF larvae, soybean meal, fish meal, corn meal, rice bran, vegetable oil, limestone, and dicalcium phosphate, supplemented with turmeric (*C. longa*) extract at 3% inclusion (w/w). The relative composition of the BSF pellet was reported in **Table 1**. The formulated mash was processed into pellets following a standard feed-pelleting sequence: weighing of ingredients; pre-grinding of coarse ingredients (corn, rice bran) to a uniform particle size; dry mixing of all ingredients; addition of vegetable oil during mixing; steam conditioning at 70–85 °C for 2–3 minutes to gelatinize starch and act as a natural binder while providing microbial reduction; pelleting through a ring-die or flat-die pellet mill, with die diameter adjusted to the intended poultry phase; immediate cooling; supplementary drying where necessary to reach a final moisture content of ≤12%; screening to remove fines; and packaging in airtight containers for storage.

2.3. Proximate Analysis for Pellet Feed

2.3.1. Determination of moisture content

A 5 g portion of each sample was placed into a previously cleaned petri dish and oven-dried at 105.5 ± 1.5 °C for four hours [20–21]. After the dish was allowed to cool in a desiccator, its weight was recorded, and moisture content was computed as the proportion of weight lost during drying, expressed as Eq.1:

$$\text{Moisture (\%)} = [(W2 - W3) / (W2 - W1)] \times 100 \quad (\text{Eq.1})$$

where W1 is the mass of the empty dish, W2 is the combined mass of the dish and sample prior to drying, and W3 is the mass after drying.

2.3.2. Determination of crude protein content

Crude protein was quantified through the Kjeldahl procedure [22–23]. A sample mass of 0.5 g (for cake and maize samples) or 1 g (for feed samples) was digested in 12 cm³ of concentrated sulfuric acid with 0.8 g of copper sulfate catalyst, heated at 420 °C for 45 minutes. The resulting digest was diluted with 75 cm³ of distilled water, then subjected to steam distillation into 25 cm³ of 4% boric acid solution, followed by titration of the distillate against 0.1 N hydrochloric acid. Crude protein content was then obtained from Eq.2:

$$\text{Protein (\%)} = [(A - B) \times N \times 1.4007 \times 6.25] / W \quad (\text{Eq.2})$$

where A and B denote the HCl volumes used in titrating the sample and the blank, respectively, N is the normality of the HCl, W is the sample mass, and 6.25 is the standard nitrogen-to-protein conversion factor.

2.3.3. Determination of Ash Content

A 5 g sample was placed in a pre-heated crucible, initially charred over a heater plate, and then fully incinerated overnight in a muffle furnace at 550 °C [21]. Following cooling in a desiccator, ash content was calculated using Eq.3 as the residue mass expressed as a percentage of the original sample mass:

$$\text{Ash (\%)} = (\text{Weight of ash} / \text{Weight of initial sample}) \times 100 \quad (\text{Eq.3})$$

2.3.4 Determination of Fat Content

Crude fat was extracted using the Soxhlet method [24–25]. A 5 g sample was subjected to continuous extraction with petroleum ether in a Soxhlet apparatus for 6 hours, after which the extracted fat was oven-dried at 75 °C until its weight stabilized. Fat content was then expressed as the mass of extracted fat relative to the original sample mass:

$$\text{Fat (\%)} = (\text{Weight of extracted fat} / \text{Weight of initial sample}) \times 100 \quad (\text{Eq.4})$$

2.3.5 Determination of Crude Fiber Content

Fat-free samples were first boiled in 1.25% sulfuric acid for 30 minutes, rinsed, and then boiled again in 1.25% sodium hydroxide for a further 30 minutes. The washed residue was dried at 105.5 °C and subsequently ashed at 550 °C, with crude fibre determined gravimetrically as the loss in weight between these steps [26]:

$$\text{Fiber (\%)} = [(W2 - W3) / W1] \times 100 \quad (\text{Eq. 5})$$

where W1 is the initial sample mass, W2 is the mass after washing and drying, and W3 is the mass of the resulting ash.

2.4 Feeding Trial Design

A short-term pilot feeding trial was conducted to obtain a preliminary indication of the final body weight of chickens fed the three study feeds. Fifteen chickens (*Gallus gallus domesticus*) 14 weeks old, of the Java strain, with an initial body weight of approximately 300 g, were allocated into three groups (n = 5 per group), each receiving one of the three feeds, Feed X, Feed Y or the BSF pellet as the sole diet. Chickens were randomly allocated to the three groups, and the five chickens of each group were housed together in a cage with adequate space. Feed and water were provided ad libitum daily for 14 days. Only the individual final body weight of each bird was recorded at the end of the trial period; feed intake, individual baseline body weight, body weight gain, and feed conversion ratio were not measured and are therefore not reported. No mortality occurred in any group during the trial. All animal procedures were reviewed and approved by the institutional ethical clearance committee of the Faculty of Pharmacy, Universitas Pancasila, Jakarta, Indonesia.

2.5 Statistical Analysis

Differences in moisture, ash, protein, fat, and fiber content among the feeds were assessed using one-way analysis of variance (ANOVA), followed by Tukey's significant difference (HSD) post-hoc test for pairwise comparisons where the overall ANOVA was significant. A significance level of $\alpha = 0.05$ was used throughout. Data are presented as mean $\pm$ standard error of the mean (SEM). For the proximate composition, n = 5 refers to five repeated analytical determinations of each feed; for body weight, n = 5 refers to five individual chickens per group; because the five birds of each group shared one cage, feed and cage effects are confounded and the birds were treated as replicates.

3. RESULTS

3.1 BSF Pellet Composition

Table 1 presents the ingredient composition of the BSF larvae meal-based pellet evaluated in this study.; turmeric extract was included at 3% (w/w) as a phytochemical additive.

Table 1. Ingredient composition of the BSF larvae meal-based pellet

Ingredient	Amount (%w/w)
BSF larvae flour	40
Soybean flour	28
Fish flour	8
Corn flour	13
Rice bran	4
Vegetable oil	2
Mineral supplement (limestone and dicalcium phosphate)	2
Turmeric extract	3

3.3 Comparative Proximate Analysis

A proximate analysis was performed on the BSF pellet and benchmarked against two comparison feeds: Feed X and Feed Y. Because turmeric extract was included at a minor proportion (3% w/w) and contributes primarily bioactive curcuminoids rather than bulk macronutrients, its inclusion is not expected to materially alter the basic proximate profile relative to the base ingredient mix described in Section 3.1.

Table 2. Comparative proximate composition of Feed X, Feed Y, and BSF pellet feeds (data presented in mean $\pm$ SEM, n = 5)

Parameters	Feed X	Feed Y	BSF Pellet
Moisture (%)	11.43 $\pm$ 0.33	13.58 $\pm$ 0.27	9.62 $\pm$ 0.43
Total ash (%)	12.31 $\pm$ 0.213	8.92 $\pm$ 0.37	9.14 $\pm$ 0.24
Total protein (%)	13.65 $\pm$ 0.50	18.80 $\pm$ 0.35	36.62 $\pm$ 0.85
Total Fat (%)	2.95 $\pm$ 0.19	4.80 $\pm$ 0.27	10.98 $\pm$ 0.72
Total Fiber (%)	7.75 $\pm$ 0.29	6.07 $\pm$ 0.08	5.56 $\pm$ 0.22

The overall one-way ANOVA was significant for all five parameters (Table 2). For protein, all three feeds differ significantly from one another, with the BSF pellet separated from Feed X by the largest effect observed anywhere in this dataset. For fat, all three feeds differ significantly from one another, although the Feed X-vs-Feed Y difference is comparatively modest and only narrowly significant. For moisture, all three feeds differ significantly from one another, with the BSF pellet having the lowest moisture content and Feed Y the highest. For ash, Feed X was significantly higher than both Feed Y and the BSF pellet, while Feed Y and the BSF pellet do not differ significantly from each other. For fiber, Feed X differs significantly from both Feed Y and the BSF pellet, while Feed Y and the BSF pellet do not differ significantly from each other.

3.4 Feeding Trial: Final Body Weight

Following the 14-day feeding trial, final body weight (g) was recorded for chickens in each group ($n = 5$ per group; initial body weight ≈ 300 g). Data are presented in Table 3.

Table 3. The final body weight (g) after 14 days of ad libitum feeding ($n = 5$ per group)

Parameter	Feed X	Feed Y	BSF Pellet
Body weight	340.2 $\pm$ 13.80	347.8 $\pm$ 13.39	355.8 $\pm$ 10.37

Mean final body weight was numerically highest in the BSF pellet group, followed by Feed Y and Feed X. However, one-way ANOVA indicated no statistically significant difference in final body weight among the three feeds ($F(2, 12) = 0.38$, $p = 0.690$), and no pairwise comparison reached significance. Given the small group size ($n = 5$) and short duration, this trial is considered a pilot observation and does not permit conclusions on growth performance.

4. DISCUSSION

The proximate dataset positions the BSF pellet as a fundamentally different feed category from Feed X and Feed Y rather than a marginal variant of either, consistent with the broader literature describing BSF larvae meal's growth performance, digestibility, and physiological effects across broiler studies [2]. Its measured crude protein content was significantly higher than both Feed X and Feed Y, more than double that of Feed X and nearly double that of Feed Y, placing it well outside the range typically formulated for complete poultry diets (16–23% CP across starter, grower, and layer phases) [14]. This is consistent with a product intended for use as a concentrate rather than fed as a stand-alone diet. From a physiological standpoint, this protein density is only useful insofar as its amino acid profile complements, rather than merely adds bulk to, the diet it is blended into. BSF larvae meal is reported to carry a relatively balanced essential amino acid profile, though it is comparatively limited in methionine relative to soybean meal [3–5].

The BSF pellet had the lowest moisture content of the three feeds (9.62%), significantly lower than both Feed X and Feed Y and below the $\leq 12\%$ ceiling generally recommended for stored pelleted feed, which is favorable for storage stability. Because proximate values are expressed on an as-fed basis, differences in moisture shift the reported percentages of the other fractions. Daramola and Omokpariola [19] documented a moderate negative correlation between moisture and protein content in commercial poultry feed, so the lower moisture of the BSF pellet may contribute slightly to its higher as-fed protein value. On a dry-matter basis, however, the protein contents are approximately 40.5% (BSF pellet), 15.4% (Feed X), and 21.8% (Feed Y), so the difference between the feeds is not attributable to moisture.

The BSF pellet's measured fat content was significantly higher than both Feed X and Feed Y, more than triple that of Feed X and over double that of Feed Y. This is consistent with the substantial residual lipid typically retained in BSF larvae meal even after partial defatting, as widely reported in the literature [3,4]. Nutritionally, this elevated lipid fraction contributes meaningfully to metabolizable energy density, which is advantageous when the pellet is diluted into a basal ration, since it partially offsets the energy dilution that typically accompanies high-protein ingredient inclusion. Trials in which BSF larvae meal and fat completely replaced soybean cake and oil in laying hen diets reported no adverse effect on performance despite a similarly altered fat profile [9], supporting the feasibility of higher BSF-derived fat inclusion in practice. Mechanistically, BSF larval fat is characterized by a substantial proportion of medium-chain saturated fatty acids, notably lauric acid, which differs functionally from the fatty acid profile of conventional feed fats;

dietary lauric acid supplementation has been shown to shift the serum metabolome and gut microbiome of broilers in ways associated with reduced pathogen load [28], and functional-feed studies using BSF larvae have linked this fraction to improved intestinal health and humoral immunity [29], though not one this dataset can confirm without accompanying performance or microbiological data. The countervailing concern is oxidative stability: even at the low moisture content measured here, a fat fraction this size warrants attention to oxidative stability during storage, which was not assessed in this study.

Ash content of the BSF pellet (9.14%) was significantly lower than that of Feed X and did not differ significantly from Feed Y, reflecting the balance of all pellet ingredients, including the plant-based components and the 2% limestone and dicalcium phosphate, rather than the larval meal alone. At the ingredient level, insect-derived meals are consistently reported to carry higher ash than conventional plant proteins, attributable to both genuine mineral content and the presence of chitin-bound residues that behave partially like inorganic matter under furnace incineration [3,4]. This has a direct practical implication: precision-fed rooster assays have shown that calcium and phosphorus concentrations, and their digestibility, vary considerably across BSF larvae meal preparations depending on defatting method [30], meaning a high-ash, high-chitin ingredient contributes calcium and phosphorus but not necessarily in a ratio or bioavailable form matched to poultry skeletal or eggshell requirements, particularly given the absence of a corrective vitamin-mineral premix in this formulation.

The fiber result reinforces this same methodological nuance. BSF pellet fiber was significantly lower than Feed X but did not differ significantly from Feed Y, when in fact the Weende crude fiber method (sequential dilute acid and alkali digestion) does not fully capture chitin's resistance profile, which differs structurally from plant cellulose and lignin [26]. A recent review emphasizes that chitin plays a genuinely dual role in monogastric nutrition: it is a digestibility-limiting structural polysaccharide on one hand, yet a potential prebiotic and immunomodulatory compound on the other, with its net effect depending heavily on inclusion level and processing [12]. Supporting this, broiler trials feeding whole (non-defatted, higher-chitin) BSF larvae have reported measurable shifts in nutrient utilization and acceptance relative to processed meal [10], while studies replacing soybean meal with commercial BSF larvae meal have documented altered cecal short-chain fatty acid concentrations consistent with partial microbial fermentation of chitin-derived substrates in the hindgut [11]. The practical takeaway is that crude fiber alone is an insufficient proxy for chitin's true nutritional or functional contribution in this feed; a more specific assay (acid detergent fiber, or direct glucosamine-based chitin quantification) would be needed to characterize this fraction properly.

Among the five measured parameters, moisture was the one in which the BSF pellet was significantly lower than both comparison feeds and below the general $\leq 12\%$ limit, which is favorable for storage stability given the moisture–fungal-growth-risk relationship described in the literature cited above [19]. Taken together, the dataset indicates that the BSF pellet contains significantly higher protein and fat than both Feed X and Feed Y, together with lower moisture, ash lower than Feed X and comparable to Feed Y, and fiber lower than Feed X. Because proximate analysis does not describe amino acid composition, digestibility, or oxidative stability, these properties remain to be characterized.

Turmeric extract was included in this formulation at 3% (w/w) based on literature precedent suggesting that dietary turmeric supplementation in this general range can improve feed intake, body weight gain, and feed conversion efficiency in broiler chickens, alongside antioxidant and immunomodulatory benefits [15–17]. Graded turmeric powder inclusion levels (0–4.5%) have been shown to significantly increase body weight gain and improve feed conversion ratio in broilers, with 3% inclusion among the levels associated with favorable performance outcomes in that trial [16]. Curcumin, the principal bioactive compound in turmeric, has also been proposed to enhance nutrient utilization by promoting protein synthesis via enzymatic pathways [17], which could plausibly complement the elevated protein and fat density of the BSF pellet described here by improving its digestive utilization, and turmeric-containing herbal extracts have separately been associated with improved antioxidant capacity and immune response in broilers [15].

To obtain a preliminary indication of the acceptance of the BSF-turmeric pellet, a 14-day pilot feeding trial was conducted in which chickens (initial weight ≈ 300 g) were fed each of the three study feeds ad libitum ($n = 5$ per group). Final body weight did not differ significantly among the three feeds ($F(2, 12) = 0.38$, $p = 0.690$), and the differences between group means (at most 15.6 g) were small relative to the variation among individual birds (SD approximately 23–31 g). A sensitivity calculation ($\alpha = 0.05$, 80% power, pooled SD ≈ 28 g) indicated that with five birds per group only a difference of roughly 60 g between the extreme groups could

have been detected reliably. The results therefore neither support nor exclude an effect of the BSF-turmeric pellet, or of turmeric, on growth.

This study has several limitations. (1) The feeding trial was a pilot with five chickens per group and a duration of 14 days, which gives low statistical power and does not allow conclusions on growth performance. (2) Only final body weight was measured; feed intake, individual baseline body weight, body weight gain, and feed conversion ratio were not recorded, so differences in final weight cannot be separated into effects on intake, efficiency, or initial size. No mortality occurred in any group. (3) The BSF pellet contained 3% turmeric extract and no turmeric-free BSF pellet group was included, so the contribution of turmeric cannot be separated from that of the BSF larvae meal. (4) The feeds differ in composition and were not formulated to be nutritionally equivalent, so differences in outcome cannot be attributed to a single ingredient. (5) The proximate values are repeated determinations of the analysed feed samples, so the comparisons apply to the specific feeds analysed and do not capture batch-to-batch variation. (6) With $n = 5$, the normality and equal-variance assumptions of ANOVA can be verified only with limited power. (7) The five chickens of each group were housed together in a single cage, so feed and cage effects are confounded and the birds are not fully independent observations.

Future studies should use a randomized design with an adequate sample size and a longer feeding period, individual baseline body weights, daily feed intake, calculation of body weight gain and feed conversion ratio, mortality records, and a turmeric-free BSF pellet group to determine whether the BSF-turmeric pellet affects growth performance.

5. CONCLUSION

The BSF larvae meal-based poultry feed pellet contained substantially higher crude protein (36.62%) and fat (10.98%) than the two commercial feeds (Feed X, 13.65% and 2.95%; Feed Y, 18.80% and 4.80%) and had lower moisture (9.62%), without vitamin-mineral or synthetic amino acid supplementation. In a small pilot trial, final body weight did not differ significantly among the feeds (355.8, 340.2, and 347.8 g for the BSF pellet, Feed X, and Feed Y, respectively). The effect of this pellet on growth performance remains to be established in adequately powered, longer feeding trials.

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REFERENCES

- [1] M. E. Abd El-Hack, M. E. Shafi, W. Y. Alghamdi, S. A. Abdelnour, A. E. Noreldin, et al., "Black soldier fly (*Hermetia illucens*) meal as a promising feed ingredient for poultry: A comprehensive review," *Agriculture*, vol. 10, no. 8, p. 339, 2020, doi: 10.3390/agriculture10080339.
- [2] M. Salahuddin, A. A. A. Abdel-Wareth, K. Hiramatsu, J. K. Tomberlin, D. Luza, and J. Lohakare, "Flight toward sustainability in poultry nutrition with black soldier fly larvae," *Animals*, vol. 14, no. 3, p. 510, 2024, doi: 10.3390/ani14030510.
- [3] S. Lu, N. Taethaisong, W. Meethip, J. Surakhunthod, B. Sinpru, T. Sroichak, P. Archa, S. Thongpea, S. Paengkoum, R. A. P. Purba, and P. Paengkoum, "Nutritional composition of black soldier fly larvae (*Hermetia illucens* L.) and its

- potential uses as alternative protein sources in animal diets: A review," *Insects*, vol. 13, no. 9, p. 831, 2022, doi: 10.3390/insects13090831.
- [4] T. Spranghers, M. Ottoboni, C. Klootwijk, A. Olyn, S. Deboosere, B. De Meulenaer, J. Michiels, M. Eeckhout, P. De Clercq, and S. De Smet, "Nutritional composition of black soldier fly (*Hermetia illucens*) prepupae reared on different organic waste substrates," *J. Sci. Food Agric.*, vol. 97, no. 8, pp. 2594–2600, 2017, doi: 10.1002/jsfa.8081.
- [5] N. Matin, P. Utterback, and C. M. Parsons, "True metabolizable energy and amino acid digestibility in black soldier fly larvae meals, cricket meal, and mealworms using a precision-fed rooster assay," *Poultry Science*, vol. 100, no. 7, p. 101146, 2021, doi: 10.1016/j.psj.2021.101146
- [6] S. Chobanova, N. Karkelanov, S. C. Mansbridge, I. M. Whiting, A. Simic, S. P. Rose, and V. R. Pirgozliev, "Defatted black soldier fly larvae meal as an alternative to soybean meal for broiler chickens," *Poultry*, vol. 2, no. 3, pp. 430–441, 2023, doi: 10.3390/poultry2030032.
- [7] M. I. Cutrignelli, M. Messina, F. Tulli, B. Randazzo, I. Olivotto, L. Gasco, R. Loponte, and F. Bovera, "Evaluation of an insect meal of the Black Soldier Fly (*Hermetia illucens*) as soybean substitute: Intestinal morphometry, enzymatic and microbial activity in laying hens," *Res. Vet. Sci.*, vol. 117, pp. 209–215, 2018, doi: 10.1016/j.rvsc.2017.12.020
- [8] S. Dabbou, F. Gai, I. Biasato, M. T. Capucchio, E. Biasibetti, D. Dezzutto, M. Meneguz, I. Plachà, L. Gasco, and A. Schiavone, "Black soldier fly defatted meal as a dietary protein source for broiler chickens: Effects on growth performance, blood traits, gut morphology and histological features," *J. Anim. Sci. Biotechnol.*, vol. 9, p. 49, 2018, doi: 10.1186/s40104-018-0266-9
- [9] M. Heuel, C. Sandrock, F. Leiber, et al., "Black soldier fly larvae meal and fat can completely replace soybean cake and oil in diets for laying hens," *Poultry Science*, vol. 100, no. 9, p. 101034, 2021, doi: 10.1016/j.psj.2021.101034.
- [10] M. M. Seyedalmoosavi, M. Mielenz, S. Görs, P. Wolf, G. Daş, and C. C. Metges, "Effects of increasing levels of whole Black Soldier Fly (*Hermetia illucens*) larvae in broiler rations on acceptance, nutrient and energy intakes and utilization, and growth performance of broilers," *Poultry Science*, vol. 101, no. 12, p. 102202, 2022, doi: 10.1016/j.psj.2022.102202.
- [11] P. M. Fruci, P. M. Kithama, P. E. G. Kiarie, P. S. Shao, H. Liu, E. Topp, and M. S. Diarra, "Effects of partial or complete replacement of soybean meal with commercial black soldier fly larvae (*Hermetia illucens*) meal on growth performance, cecal short chain fatty acids, and excreta metabolome of broiler chickens," *Poultry Science*, vol. 102, no. 4, p. 102463, 2023, doi: 10.1016/j.psj.2022.102463.
- [12] L. Abenaim and B. Conti, "Harnessing chitin from edible insects for livestock nutrition," *Insects*, vol. 16, no. 8, p. 799, 2025, doi: 10.3390/insects16080799.
- [13] U. Elahi, C. C. Xu, J. Wang, et al., "Insect meal as a feed ingredient for poultry," *Animal Bioscience*, vol. 35, no. 2, pp. 332–346, 2022, doi: 10.5713/ab.21.0435.
- [14] National Research Council, *Nutrient Requirements of Poultry*, 9th rev. ed. Washington, DC, USA: National Academy Press, 1994, doi: 10.17226/2114.
- [15] F. A. Aderemi and O. M. Alabi, "Turmeric (*Curcuma longa*): An alternative to antibiotics in poultry nutrition," *Translational Animal Science*, vol. 7, no. 1, p. txad133, 2023, doi: 10.1093/tas/txad133.
- [16] P. M. Eko, K. D. Afolabi, and G. E. Enyenihi, "Growth performance, carcass quality, organ weights and haematology of broilers fed graded dietary levels of turmeric (*Curcuma longa* L.) powder as feed additive," *Animal and Veterinary Sciences*, vol. 8, no. 3, pp. 65–70, 2020, doi: 10.11648/j.avs.20200803.14.

- [17] D. Xu, X. Wang, W. Shi, and Y. Bao, "Lonicera flos and Curcuma longa L. extracts improve growth performance, antioxidant capacity and immune response in broiler chickens," *Frontiers in Veterinary Science*, vol. 11, p. 1388632, 2024, doi: 10.3389/fvets.2024.1388632.
- [18] AOAC International, *Official Methods of Analysis of AOAC International*, 18th ed. Gaithersburg, MD, USA: AOAC International, 2005.
- [19] A. A. Daramola and D. O. Omokpariola, "Proximate analysis and aflatoxin contamination in poultry feeds: A comparative study of two feed companies in Jos and Kaduna, Nigeria," *Discover Food*, vol. 5, p. 93, 2025, doi: 10.1007/s44187-025-00367-w.
- [20] S. S. Nielsen, "Moisture content determination," in *Food Analysis Laboratory Manual*, S. S. Nielsen, Ed. Cham, Switzerland: Springer, 2017.
- [21] L. J. Mauer, "Moisture and total solids analysis," in *Nielsen's Food Analysis*, P. Ismail and S. S. Nielsen, Eds. Cham, Switzerland: Springer, 2024.
- [22] A. Jonas-Levi and J. J. Martinez, "The high level of protein content reported in insects for food and feed is overestimated," *J. Food Compos. Anal.*, vol. 62, pp. 184–188, 2017, doi: 10.1016/j.jfca.2017.06.004.
- [23] S. H. Hwang, M. Koo, S. Jo, and Y. S. Cho, "A comparison study of crude protein contents obtained utilizing the Kjeldahl method and Dumas combustion method in foods," *Anal. Sci. Technol.*, vol. 33, no. 3, pp. 143–150, 2020, doi: 10.5806/AST.2020.33.3.143.
- [24] D. B. Patiño, O. T. Toomer, T. C. Vu, E. O. Oviedo-Rondon, R. Mian, M. Frinsko, S. Hall, R. Kelly, J. Mann, and M. Joseph, "Influence of extruded soybean meal with different fat contents and varying oleic acid content on floating fish feed quality and composition," *Anim. Feed Sci. Technol.*, vol. 317, p. 116088, 2024, doi: 10.1016/j.anifeedsci.2024.116088.
- [25] N. F. Saputri and A. A. Putri, "Proximate analysis on Nile Tilapia artificial feed from shrimp waste," *Eduvest-J. Univ. Stud.*, vol. 4, no. 10, pp. 9601–9606, 2024, doi: 10.59188/eduvest.v4i10.39014.
- [26] G. Ferreira and N. Thiex, "Symposium review: Fiber and in vitro methods, analytical variation, and contributions to feed analysis," *J. Dairy Sci.*, vol. 106, no. 6, pp. 4464–4469, 2023, doi: 10.3168/jds.2022-22407.
- [27] B. V. McCleary and C. McLoughlin, "Measurement of available carbohydrates in cereal and cereal products, dairy products, vegetables, fruit, and related food products and animal feeds: First action 2020.07," *J. AOAC Int.*, vol. 104, no. 6, pp. 1465–1478, 2021, doi: 10.1093/jaoacint/qsab019.
- [28] Y. Wu, H. Zhang, R. Zhang, G. Cao, Q. Li, B. Zhang, et al., "Serum metabolome and gut microbiome alterations in broiler chickens supplemented with lauric acid," *Poultry Science*, vol. 100, no. 12, p. 101315, 2021, doi: 10.1016/j.psj.2021.101315.
- [29] O. Sjöfjan, A. Ardiantoro, I. N. Cahyawati, A. I. Jihana, M. H. Natsir, Y. F. Nuningtyas, and D. N. Adli, "Microwave-dried black soldier fly larvae enhance growth, intestinal health, and humoral immunity in broiler chickens: A functional feed approach," *Veterinary World*, vol. 18, pp. 1840–1849, 2025, doi: 10.14202/vetworld.2025.1840-1849.
- [30] N. Matin, P. L. Utterback, and C. M. Parsons, "Phosphorus digestibility and relative phosphorus bioavailability in two dried black soldier fly larvae meals and a defatted black soldier fly larvae meal in broiler chickens," *Poultry Science*, vol. 100, no. 8, p. 101221, 2021.