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Research Article

Proximate, Mineral, and Amino Acid Composition of *Hermetia illucens* Larvae Meal and Its Potential in Poultry Nutrition

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Abstract

The search for sustainable alternative protein sources in poultry nutrition has intensified due to environmental and economic concerns surrounding conventional ingredients like soybean and fish meal. Black soldier fly (*Hermetia illucens*) larvae (BSFL) meal represents a promising alternative. This study characterized the proximate composition, mineral content, and amino acid profile of BSFL meal produced under controlled conditions to evaluate its potential for broiler chicken diets. Proximate analysis was performed using standard methods of the *Association of Official Analytical Chemists*, minerals were determined via *Inductively Coupled Plasma–Optical Emission Spectroscopy* and *Atomic Absorption Spectrophotometry*, and amino acids were quantified using *High-Performance Liquid Chromatography* following derivatization. Results showed that BSFL meal contained high crude protein (54.42%) and fat (24.60%), with a gross energy of 5685.33 kcal/kg. The mineral profile included substantial levels of magnesium (3.100 g/kg), zinc (82.67 mg/kg), and iron (92.00 mg/kg), though potassium (0.677 g/kg) was relatively low. The amino acid profile was favourable, with lysine (6.07 g/100g) exceeding typical fishmeal ranges. However, methionine (2.14 g/100g), cystine (0.57 g/100g), and tryptophan (0.54 g/100g) were identified as limiting amino acids. The study concluded that BSFL meal possesses excellent potential as a high-protein and energy-dense ingredient for partial replacement of fishmeal or soybean meal in broiler diets. To optimize its use, strategic supplementation with synthetic methionine and tryptophan is recommended to address amino acid imbalances. These findings support the inclusion of BSFL meal as a sustainable component in poultry feed formulations.

Keywords

Alternative Protein Source, Amino Acid Profile, Black Soldier Fly Larvae Meal, Broiler Chicken Nutrition, Sustainable Poultry Feed

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1. Introduction

The global poultry industry faces mounting pressure to identify sustainable, cost-effective, and nutritious alternatives to conventional protein sources like soybean and fish meal, whose production is often associated with environmental degradation, price volatility, and ethical concerns as noted by the study of van Huis et al. [32]. The black soldier fly (*Hermetia illucens*) larvae (BSFL) have emerged as a promising candidate due to their high bioconversion efficiency of organic waste, rapid growth rate, and favourable nutritional profile (Diener *et al.* [7]), Makkar *et al.* [15] BSFL meal is recognized for its high protein and lipid content, but its comprehensive nutritional composition can vary significantly based on substrate, processing methods, and larval life stage (Barragan-Fonseca *et al.* [3]; Rumpold and Schlüter [26]. A precise characterization of its proximate, mineral, and amino acid composition is therefore critical to accurately assess its value in broiler chicken's feed formulation.

While several studies have profiled BSFL meal, reported data often showed considerable variation, underscoring the need for substrate-specific and process-specific analyses Surendra *et al*. [30]. Furthermore, a direct comparative analysis with established benchmarks like fish meal is essential to identify its strengths and limitations as a replacement. This study aimed to comprehensively characterize the proximate composition, mineral content, and amino acid profile of BSFL meal produced under defined conditions. The findings will be critically discussed within the context of existing literature, and the potential of this ingredient in broiler chicken diets will be evaluated based on its nutritional alignment with poultry requirements, as supported by recent research in poultry nutrition.

2. Materials and Methods

2.1. Maggot Meal Processing

Maggots (BSFL) were obtained from laboratory-scale production facilities at the Fisheries unit of the Faculty of Agricultural Sciences, Ekiti State University, Ado-Ekiti. The maggots were sun-dried and ground into fine powder using a laboratory mill, sieved through a 1 mm mesh in readiness for use in feed formulation.

2.2. Determination of Proximate Composition

Proximate analysis was conducted according to standard AOAC [1] methods. Moisture was determined by oven-drying at 105°C for 24 hours. Crude protein was analyzed using the Kjeldahl method (N × 6.25). Crude fat was extracted using petroleum ether in a Soxhlet apparatus. Crude fiber was determined by acid and alkali digestion. Ash content was determined by incineration at 550°C for 2 hours. Nitrogen-free extracts (NFE) were calculated by difference. Gross energy was determined using a bomb calorimeter (Parr Instrument Company [25]).

2.3. Determination of Mineral Elements

Samples were dried, ground, and digested using a wet digestion method with a mixture of nitric acid (HNO_3) and perchloric acid ($HClO_4$). Macrominerals (Calcium, Magnesium, Sodium, Potassium) and microminerals (Iron, Zinc, Copper, Manganese, Chromium) were analyzed using Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES) or Atomic Absorption Spectroscopy (AAS) as appropriate (Nóbrega *et al*, [19]). Chromium was analyzed using ICP-MS (Dufaill *et al.* [9]).

2.4. Determination of Amino Acids

Samples were freeze-dried, ground, and amino acids were extracted using a solvent mixture. Derivatization was performed using phenylisothiocyanate reagent to enable detection. Amino acid separation and quantification were achieved using High-Performance Liquid Chromatography (HPLC) with a C18 column and UV-Vis detection (Harris and Clark [11]).

3. Results

3.1. Proximate Composition of Maggot Meal

The proximate composition of the BSFL meal is presented in Table 1. The crude protein content was high at 54.42%. The crude fat content was 24.60%. Ash, crude fiber, and carbohydrate (NFE) contents were 6.07%, 6.23%, and 5.94%, respectively. The moisture content was low at 3.35%. The gross energy was determined to be 5685.33 ± 42.56 kcal/kg.

3.2. Mineral Composition of Maggot Meal

The mineral composition is shown in Table 2. The major minerals present were magnesium (3.100 g/kg), calcium (2.067 g/kg), sodium (1.057 g/kg), phosphorus (1.307 g/kg), and potassium (0.677 g/kg). The Ca:P ratio was 1.58:1. Among the trace minerals, iron (92.00 mg/kg) and zinc (82.67 mg/kg) were the most abundant, followed by manganese (32.00 mg/kg) and copper (14.05 mg/kg).

3.3. Amino Acid Profile of Maggot Meal

The amino acid profile of the BSFL meal is detailed in Table 3, with comparative ranges for fish meal provided. Key amino acids included glutamic acid (14.41 g/100g), aspartic acid (8.28 g/100g), leucine (6.40 g/100g), lysine (6.07 g/100g), and arginine (5.65 g/100g). The sulphur-containing amino acids, methionine and cystine, were 2.14 g/100g and 0.57 g/100g, respectively. Tryptophan was the limiting amino acid at 0.54 g/100g.

Table 1. Proximate composition of maggot meal.

Variables	Components (%)
Moisture	3.35±0.13
Fat	24.60±0.16
Fibre	6.23±0.12
Ash	6.07±0.14
Protein	54.42±0.08
Carbohydrate	5.94±0.05
Gross Energy (kcal/kg	5685.33±42.56

Samples analyzed in triplicate

Table 2. Mineral composition of experimental maggot meal.

Variable	Mean ± SEM
Calcium (g/kg)	2.067 ± 0.2028
Phosphorus (g/kg)	1.307 ± 0.1485
Potassium (g/kg)	0.677 ± 0.0623
Magnesium (g/kg)	3.100 ± 0.1732
Sodium (g/kg)	1.057 ± 0.0318
Iron (mg/kg)	92.00 ± 1.732
Manganese (mg/kg)	32.00 ± 1.155
Copper (mg/kg)	14.050 ± 0.7147
Zinc (mg/kg)	82.67 ± 1.453

Analysis carried out in triplicate

Table 3. Amino acid profile of maggot meal and fish meal.

Amino Acid	Content in maggot meal (g/ 100g)	Content in fish meal (g/ 100g)
Alanine	2.68±0.08	3.5-5.0***
Arginine	5.65±0.13	5.0-7.0*
Aspartic acid	8.28±0.11	5.5-8.0******
Cystine	0.57±0.02	0.5-1.2*******
Glutamic acid	14.41±0.20	8.0-12.0***
Glycine	4.32±0.16	3.5-6.0*****
Histidine	3.02±0.03	2.0-3.0**

Amino Acid	Content in maggot meal (g/ 100g)	Content in fish meal (g/ 100g)
Isoleucine	3.32±0.11	4.0-5.0***
Luecine	6.40±0.223	6.5–8.5***
Lysine	6.07±0.08	4.0-4.5***
Methionine	2.14±0.08	2.5-3.5****
Proline	3.16±0.09	2.5-4.5********
Phenylalanine	3.64±0.06	3.5-4.5***
Serine	3.28±0.09	5.5-8.0****
Threonine	2.05±0.03	3.8-4.5*****
Tyrosine	2.72±0.15	1.5-3***
Valine	3.19±0.21	4.5-5.5***
Tryptophan	0.54±0.03	1.0-1.5****

*Opstvedt *et al*. [24] **Tacon and Metian [31] *** NRC [21] ****Mohan *et al*. [8] *****Hertrampf *et al*. [12] ******Martínez-Llorens *et al*. [17] *******Spinelli *et al*. [28] ********Halver and Hardy [10].

4. Discussion

The crude protein content of 54.42% in this study is higher than the 40-44% reported for BSFL meal reared on poultry manure as reported by Newton *et al*. [23] but aligned closely with the 55-57% reported for larvae reared on nutrient-dense substrates like kitchen waste according to Wang and Shelomi [33]. This disparity underscored the profound influence of diet on larval body composition, as noted by the study of Barragan-Fonseca *et al*. [3] The value surpassed that of soybean meal (44-48%) but remained below high-quality fishmeal (60-72%) as noted by NRC [22]. The fat content of 24.60% is within the wide range (15-39%) reported in literature (Surendra *et al*. [30]. This high lipid level contributed to the impressive gross energy of 5685 kcal/kg, which is superior to soybean meal (4200 kcal/kg) and comparable to some high-energy feedstuffs, suggesting BSFL meal could enhance dietary energy density (Schiavone *et al*. [27]. The low carbohydrate and fiber contents are consistent with the biological composition of insects and advantageous for monogastric digestion (van Huis *et al*. [32]).

The mineral profile revealed both strengths and potential limitations. The calcium (2.07 g/kg) and phosphorus (1.31 g/kg) levels were moderate but lower than values (Ca: 5-15 g/kg; P: 7-9 g/kg) reported by St-Hilaire *et al*. [29] for BSFL reared on fish offal. This again highlighted substrate dependency. The Ca:P ratio of 1.58:1 is favourable for poultry, nearing the ideal range of 1:1 to 2:1 (NRC [20]. The magnesium content (3.10 g/kg) was notably high, which was consistent with findings by Martínez-Llorens *et al*. [17], and might contribute to enzymatic functions. However, the potassium level (0.68 g/kg) was lower than the 6-11 g/kg reported by Makkar *et al*. [15], which could be a substrate-specific characteristic. Trace mineral levels, particularly zinc (82.67 mg/kg) and iron (92.00 mg/kg), were substantial and comparable to or exceed those in fishmeal as documented by NRC [21], suggesting BSFL meal could contribute meaningfully to meeting the requirements of broilers for these critical microelements involved in immunity and metabolism according to Bao *et al*. [2].

The amino acid profile is critical for assessing protein quality. The BSFL meal demonstrated a high level of glutamic acid and aspartic acid, which is typical for insect protein as found in the report of Parr Instrument Company [25]. Of paramount importance for poultry, lysine (6.07 g/100g) exceeded the typical range for fishmeal (4.0-4.5 g/100g), positioning BSFL meal as an excellent lysine source, crucial for broiler growth as reported by Kidd *et al*. [13]. Similarly, arginine and histidine levels were adequate. However, the sulphur-containing amino acids methionine (2.14 g/100g) and cystine (0.57 g/100g) were at the lower end or below fishmeal ranges, identifying them as the first-limiting amino acids in this BSFL meal, a common finding in insect meals as noted in the study of Marono *et al*. [16]. Tryptophan (0.54 g/100g) was also low, potentially making it a second-limiting amino acid. Leucine and valine were slightly below typical fishmeal ranges, while isoleucine was more noticeably lower. This pattern suggested that BSFL meal, while an outstanding protein source, would likely require strategic supplementation with synthetic methionine, cystine, and possibly tryptophan and isoleucine in broiler diets to achieve an ideal amino acid balance, as recommended by Lemme *et al*. [14] for alternative protein sources.

The nutritional profile of this BSFL meal indicated significant potential for partial replacement of fishmeal or soybean meal in broiler diets. Its high protein and energy density could support rapid growth phases [6]. Studies have shown that

BSFL meal could replace up to 100% of soybean meal or 50-75% of fishmeal without adversely affecting growth performance, feed intake, or feed conversion ratio in broilers as reported by Cullere *et al*. [5] and Schiavone *et al*. [27]. The favourable lysine content supported muscle deposition, while the high levels of zinc and iron might bolster immune function and skin/feather health as noted bt Bao *et al*. [2]. However, successful inclusion hinged on addressing the identified amino acid deficiencies. As suggested by Biasato *et al*. [4], formulating diets based on digestible amino acids and supplementing with DL-methionine is essential to harness the full potential of insect meal. Furthermore, the chitin present in the exoskeleton, contributing to the fiber content, has been shown to possess prebiotic and antimicrobial properties that might positively modulate gut health in broilers as found by Mohan *et al*. [18]. Future research should focus on standardizing rearing substrates to produce more consistent mineral and amino acid profiles and conducting long-term broiler trials to evaluate carcass quality and economic viability at commercial scales.

Abbreviations

BSFL	Black Soldier Fly Larvae
ICP–OES	Inductively Coupled Plasma–Optical Emission Spectroscopy
AAS	Atomic Absorption Spectrophotometry
HPLC	High-Performance Liquid Chromatography
NFE	Nitrogen-Free Extracts
HNO_3	Nitric Acid (Chemical Formula)
$HClO_4$	Perchloric Acid (Chemical Formula)
ICP-MS	Inductively Coupled Plasma-Mass Spectrometry

Conflicts of Interest

The authors declare no conflicts of interest.

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