

Review Article

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Black Soldier Fly Larvae in Broiler Nutrition: Nutritional Value, Growth Performance, and Physiological Implications – A Systematic Review

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ABSTRACT

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The escalating cost and competition for conventional feed ingredients such as maize and soybean meal have intensified the search for sustainable alternative protein sources in poultry nutrition. Black soldier fly larvae (BSFL; *Hermetia illucens*) have emerged as a promising candidate due to their high nutrient density and environmental sustainability. This review synthesizes current literature on the nutritional composition of BSFL and evaluates its effects on growth performance, carcass characteristics, meat quality, hematological indices, intestinal morphology, and gut microbiota in broiler chickens. On a dry matter basis, BSFL typically contains 35–55% crude protein and 15–40% lipid, along with appreciable levels of essential amino acids and minerals. Feeding trials indicate that inclusion levels up to 10% generally maintain or improve growth performance, whereas higher levels may impair productivity due to reduced digestibility and chitin content. BSFL inclusion alters meat fatty acid profiles, particularly increasing lauric acid, and has minimal adverse effects on physiological parameters. Overall, BSFL represents a viable partial replacement for conventional protein sources, though further standardization of processing and inclusion strategies is required.

Introduction

The global poultry sector is one of the fastest-growing segments of animal agriculture, driven by rising demand for affordable and high-quality protein.

However, this expansion has been accompanied by increasing dependence on conventional feed ingredients such as maize and soybean meal, which are also critical components of human food systems. This competition

has resulted in escalating feed costs and raised concerns regarding sustainability and food security. In this context, insects have gained considerable attention as alternative feed resources. Among them, black soldier fly larvae (BSFL; *Hermetia illucens*) are particularly promising due to their ability to efficiently convert organic waste into high-value biomass (Čičková, 2015). BSFL production requires minimal land and water resources and contributes to circular bioeconomy systems. Furthermore, BSFL possess a favorable

nutritional profile, including high protein content and bioactive lipids, making them suitable for inclusion in poultry diets (Abd El-Hack, 2020).

Although a growing body of literature has examined the use of BSFL in broiler nutrition, results vary depending on inclusion levels, processing methods, and dietary formulation. Therefore, a systematic synthesis of available evidence is required to evaluate its practical applicability. This review aims to critically assess the nutritional composition of BSFL and its effects on broiler growth performance, carcass traits, meat quality, physiological parameters, and gut health.

Nutritional Composition of Black Soldier Fly Larvae

The nutritional composition of BSFL is highly variable and depends on factors such as substrate, larval stage, and processing methods. On a dry matter basis, BSFL typically contains 35–55% crude protein, 15–40% ether extract, 10–20% ash, and 5–15% crude fibre (De Marco, 2015; Mwaniki, 2018). The relatively high ash content reflects significant mineral concentrations, particularly calcium and phosphorus.

The amino acid profile of BSFL is generally comparable to conventional protein sources. Lysine levels range between 3–6% of dry matter, while methionine is relatively lower, typically 0.5–1%, which may necessitate supplementation in formulated diets (Ruhnke, 2018). Essential amino acids such as leucine and valine are present in substantial amounts, supporting muscle growth and protein deposition.

The lipid fraction of BSFL is characterized by a high proportion of saturated fatty acids, particularly lauric acid (C12:0), which may constitute 20–60% of total fatty acids (Schivone, 2019). Lauric acid possesses antimicrobial properties and may influence gut health. In addition, BSFL contains palmitic acid (C16:0), oleic acid (C18:1), and smaller amounts of polyunsaturated fatty acids.

Mineral content is another notable feature of BSFL. Calcium levels may range from 2–5% of dry matter, significantly higher than most plant-based feed ingredients, while phosphorus levels typically range between 0.5–1% (Mwaniki, 2018). This characteristic makes BSFL particularly valuable in poultry diets, where calcium balance is critical.

Inclusion Levels and Diet Formulation

The inclusion level of BSFL in broiler diets is a critical determinant of performance outcomes. Experimental studies have evaluated a wide range of inclusion levels, from low-level supplementation (2–5%) to complete replacement of conventional protein sources (Murawska, 2021; Onsongo, 2018).

Most studies indicate that inclusion levels up to 10% can be safely incorporated without adverse effects on growth performance (Dabbou, 2018). At moderate inclusion levels (5–10%), BSFL may even improve feed efficiency and weight gain, likely due to its high digestible protein and energy content. However, higher inclusion levels (above 15–20%) have been associated with reduced performance, primarily due to lower protein digestibility and the presence of chitin, which can interfere with nutrient utilization (Biasato, 2020).

Processing methods significantly influence the nutritional value of BSFL. Defatting increases crude protein concentration and improves digestibility, while full-fat BSFL contributes additional energy but may alter fatty acid profiles. Therefore, diet formulation must consider both the compositional variability and the specific production goals.

Effects on Growth Performance

Growth performance is the primary indicator of the suitability of BSFL as a feed ingredient. Numerous studies have evaluated parameters such as body weight gain, feed intake, and feed conversion ratio (FCR).

(Murawska, 2021) reported that broilers fed BSFL-based diets exhibited comparable body weight to control groups at moderate inclusion levels, although higher inclusion levels resulted in reduced growth. Similarly, (Dabbou, 2018) observed improved body weight gain at 10% inclusion, with diminishing returns at higher levels.

Feed conversion ratio is generally maintained or improved at low to moderate inclusion levels. However, excessive inclusion may negatively affect FCR due to reduced nutrient digestibility (Biasato, 2020).

Overall, the evidence suggests that BSFL can effectively replace a portion of conventional protein sources without compromising growth performance when included at appropriate levels.

Carcass Characteristics

Carcass traits are economically important indicators of production efficiency. Studies evaluating the effects of BSFL on carcass characteristics generally report minimal adverse effects.

(Attivi, 2020) found no significant differences in liver weight or dressing percentage across dietary treatments. Similarly, (Schiavone, 2019) reported that moderate inclusion levels (up to 10%) improved carcass weight and breast yield, while higher inclusion levels did not confer additional benefits. Overall, BSFL inclusion does not negatively impact carcass characteristics, although responses may vary depending on dietary formulation and inclusion level.

Meat Quality and Fatty Acid Profile

BSFL inclusion influences the chemical composition and fatty acid profile of broiler meat. Several studies have reported increased protein content in meat from birds fed BSFL-based diets (Schiavone, 2019).

A notable effect is the alteration of fatty acid composition, particularly the increase in lauric acid and other saturated fatty acids. While this may enhance oxidative stability, it may also influence the nutritional profile of the meat. (De Souza Vilela, 2021) reported significant changes in fatty acid composition with increasing BSFL inclusion.

The overall impact on meat quality is complex and depends on the balance between saturated and unsaturated fatty acids. Nevertheless, BSFL inclusion does not adversely affect sensory properties or overall meat quality.

Hematological and Physiological Parameters

Hematological parameters provide insight into the physiological status of birds. Most studies indicate that BSFL inclusion does not significantly affect parameters such as red blood cell count, white blood cell count, hemoglobin concentration, and packed cell volume (Dabbou, 2018; Bellezza, 2021).

These findings suggest that BSFL does not induce physiological stress or toxicity and can be safely incorporated into broiler diets.

Intestinal Morphology and Gut Health

The structure and function of the gastrointestinal tract are critical for nutrient absorption and overall health. Studies on intestinal morphology have produced mixed results.

Some studies report increased villus height and improved villus-to-crypt ratio, indicating enhanced absorptive capacity (Dabbou, 2018). Others report no significant differences between control and BSFL-fed groups (Biasato, 2020). These variations may be attributed to differences in inclusion levels and dietary composition.

BSFL may also influence gut microbiota. (Velten, 2018) reported changes in microbial populations, including increases in beneficial bacteria. However, most studies indicate that BSFL has a neutral to mildly positive effect on gut microbiota composition.

The incorporation of BSFL into broiler diets offers several advantages, including high nutrient density, sustainability, and functional bioactive compounds. However, its effectiveness depends on appropriate inclusion levels and processing methods.

The primary limitation of BSFL is the variability in composition and the presence of chitin, which may reduce digestibility at high inclusion levels.

Therefore, partial replacement strategies are recommended rather than complete substitution of conventional protein sources.

Future research should focus on improving digestibility through processing techniques, optimizing amino acid supplementation, and standardizing production systems to ensure consistent nutritional quality.

In conclusion, Black soldier fly larvae represent a promising alternative protein source in broiler nutrition. When included at moderate levels ($\leq 10\%$), BSFL supports growth performance, maintains carcass quality, and does not adversely affect physiological parameters. However, higher inclusion levels may compromise performance due to reduced digestibility and nutrient imbalance. Standardization of processing methods and inclusion strategies is essential for the successful integration of BSFL into commercial poultry production systems.

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Author Contributions

Dr. A. Ashok: Conceived the original idea and designed the model. Dr. A. S. Pranav Bhalaji: computational framework and analysed the data and wrote the manuscript

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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