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Exploring the Feasibility of Insect-Based Feed Ingredients for Broiler Chickens

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ABSTRACT Recent concerns regarding environmental impact and rising feed costs have intensified the search for sustainable protein and lipid sources in animal nutrition, particularly for poultry, swine, and aquaculture. Among the various alternatives under investigation, insects have gained significant attention due to their low environmental emissions and favorable nutritional characteristics. Numerous insects, such as mealworms, grasshoppers, crickets, housefly maggots, silkworm pupae, bloodworms, and black soldier fly larvae (BSFL), have been evaluated as potential feed ingredients for broiler diets. These insects are valued for their high concentrations of protein, lipids, and bioactive components with antimicrobial functions. Among various insects, BSFL have attracted particular attention for their ability to convert organic waste into biomass and for their lipid, which is rich in medium-chain fatty acids such as lauric acids. This review evaluates the existing literature involving BSFL to assess their impact on broiler diets. Previous studies have reported that BSFL powder, meal, and oil can partially or fully substitute conventional protein and lipid sources without compromising growth performance in broiler chickens. Moreover, inclusion of BSFL has been shown to influence fatty acid composition and meat quality depending on the form (powder, full-fat meal, defatted meal, and oil) and inclusion level. Therefore, BSFL are regarded as one of the most promising candidates for sustainable broiler diets.
(Key words: alternative feed ingredient, black soldier fly larvae, broiler chicken, growth performance, insect)

INTRODUCTION

The global population is expected to reach approximately 8.6 billion by 2050 and 11.2 billion by 2100 (Rastegaripour et al., 2024). Along with this demographic growth, global meat consumption is also projected to rise. Between 2021 and 2030, the world's population is predicted to grow by 11%, while meat consumption is estimated to increase by 14% compared to the 2018－2020 baseline (Farchi et al., 2017; Godfray et al., 2018). Despite the rising demand for animal-derived foods, the production of grains that serve as essential feed ingredients has been declining (Lee et al., 2024a). Moreover, the total area of arable and grazing land has continuously decreased due to conversion into forest, industrial plantations, and urban infrastructure (Ramankutty et al., 2018). In addition, global warming has triggered climate-related shifts in precipitation and temperature patterns, directly influencing agricultural productivity (Prajapati et al., 2024). These environmental changes disrupt crop growth cycles and ultimately reduce yields (Verma et al., 2025). Consequently, reduced crop productivity has intensified competition for major feed ingredients, particularly corn and soybean, and led to stricter limitations on their utilization (Adedeji et al., 2021).

The increasing demand for meat inevitably heightens the demand for protein and energy sources in animal feed (Smith et al., 2024). Protein is an essential nutrient that influences growth performance, reproduction, and overall productivity in livestock. However, the prices of conventional protein sources such as soybean meal have risen sharply due to limited farmland, market fluctuations, and competition with human food supply chains (Onsongo et al., 2018; Kim et al., 2021; Xiao et al., 2025). Fish meal has also been one of the primary animal protein sources (Rawski et al., 2020). However, overfishing driven by increasing demand has threatened many wild fish populations and caused a rise in fish meal prices (Nogales-Mérida et al., 2019). In addition, the continued expansion of the aquaculture industry has been constrained by limited global fish meal production and growing competition from the livestock and industries (Xiao

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et al., 2018). In addition, traditional lipid sources, including tallow, lard, and poultry fat, as well as soybean oil, corn oil, and sunflower oil, are extensively used in feed formulations (Ravindran et al., 2014). In particular, soybean oil provides high metabolizable energy but remains expensive and constrained in availability. In contrast, tallow is relatively cost-effective, but its rendering process contributes substantially to greenhouse gas emissions (Fascina et al., 2009; Okur, 2020). Therefore, exploring sustainable alternative sources of protein and lipid is essential to ensure stable livestock production and feed supply under the current global resource constraints.

INSECTS AS ALTERNATIVE FEED INGREDIENTS

With the increasing scarcity and rising cost of conventional protein and energy sources in animal feed, insects have emerged as promising alternative ingredients for sustainable feed production (Bovera et al., 2018; Lee et al., 2024b). Insects offer distinct advantages: they can be mass-produced in compact spaces without the need for arable land, and they efficiently convert organic waste into nutrient rich biomass (Kim et al., 2019). Compared to conventional livestock, insect farming produces substantially lower greenhouse gas and ammonia emissions (Steinfeld et al., 2006). Livestock production, including the transport of livestock and feed, accounts for approximately 18% of global anthropogenic greenhouse gas emissions. However, insects emit lower levels of greenhouse gases and ammonia (Oonincx et al., 2010). Moreover, insects provide valuable nutrients including high levels of protein, fatty acids, vitamins, and minerals. Thus, insects are suitable substitutes for protein and lipid sources (Jang et al., 2019; Adedeji et al., 2021). Commonly farmed insect species for feed include the mealworms, grasshoppers, crickets, housefly maggots, silkworm pupae, bloodworms, and black soldier fly larvae (BSFL).

1. Mealworm

Mealworms (*Tenebrio molitor*) are cosmopolitan insects commonly found in stored grain and food products (Bovera et al., 2015). Mealworms have a life cycle of approximately three months, progressing through egg, larval, pupal, and adult stages (Hwang et al., 2015). The larvae and pupal stages contain high protein levels and are easy to rear (Ghaly and Alkoaik, 2009). In a previous study, *Tenebrio molitor* was reported to contain approximately 63% crude protein (CP) on a dry matter (DM) basis (Adámková et al., 2016). Mealworms can thrive on various organic wastes, converting them into nutrient-dense biomass with relatively low energy input, minimal land use, and reduced environmental impact (Khusro et al., 2012; Makker et al., 2014). As a result, they are already produced commercially as feed for pets, reptiles, birds, and fish (Makker et al., 2014). Moreover, the chitin content of mealworms is relatively low, ranging from 4.7% to 4.9% (Song et al., 2018), which is lower than that of grasshoppers (4.7% to 11.8%) and crickets (8.7%) (Wang et al., 2008; Kaya et al., 2015). Nutritionally, the ratio of polyunsaturated fatty acids (PUFAs) to saturated fatty acids (SFAs) in mealworms is comparable to that of vegetable oils (Martínez-Pineda et al., 2024). In particular, mealworms contain substantial amounts of linoleic acid (32.4%) and oleic acid (36.8%) (Wu et al., 2020; Martínez-Pineda et al., 2024). However, mealworms have relatively low levels of omega-3 PUFAs, which may limit their application as a functional ingredient (Liu et al., 2025). In addition, their protein quality is comparable to soybean meal, although they are relatively low in Met, which may not fully meet the amino acid requirements of poultry (Ramos-Elorduy et al., 2002).

2. Grasshopper

Grasshoppers (*Acrididae*) are hemimetabolous insects that resemble adults during their immature stages, gradually developing wings and reproductive organs at the final molt (Konopova et al., 2011). Although some grasshoppers are agricultural pests capable of forming crop damaging swarms (Dakhel et al., 2020), their utilization in feed or pest control programs could simultaneously reduce pesticide use and environmental contamination (Khusro et al., 2012). Grasshoppers have been reported to contain approximately 52% CP on a DM basis, and this value remains relatively consistent throughout their growth (Nginya et al., 2019). In a previous study, grasshoppers were found to contain higher levels of amino acids such as Arg, His, Thr, Trp, and Gly compared with fish meal (Lee et al., 2024b). In addition, they contain essential fatty acids, particularly omega-3 and omega-6, which play important roles in immune system and reproductive health (Alagawany et al., 2019). However, the exoskeleton of grasshoppers contains a substantial amount of chitin, ranging from 4.71% to 11.84% on a DM basis (Kaya et al., 2015). Chitin is considered one of the major factors responsible for reduced nutrient digestibility (Dourado et al., 2020). Koh and Iwamae (2013) reported that broiler chickens are able to digest chitin, as they produce the enzyme chitinase in parts of the gastrointestinal tract, particularly in the proventriculus. The digestibility of chitin is generally around 30% but may vary depend on its sources (Khempaka et al., 2011).

3. Cricket

Crickets (Gryllidae) have a short life cycle of 60 to 70 days, and a female can lay between 200 and 1,500 eggs within 21 days (Nikkhah et al., 2021). Traditionally, crickets have been used as feed for animals such as reptiles, fish, and birds, but they are now recognized as potential ingredients for livestock and human consumption (Park et al., 2013). They contain high CP content (approximately 57%) and a variety of essential amino acids, including Met, Lys, His, Val, and Leu (Jayanegara et al., 2017; Phesatcha et al., 2023). In addition, they are rich in PUFAs, such as linoleic acid and oleic acid (Rodríguez-Párraga et al., 2025). Oleic acid has been associated with blood pressure regulation through its role in guanine nucleotide-binding protein-mediated signaling pathways (Terés et al., 2008; Massimo et al., 2009). Crickets are also rich in iron, hemoglobin synthesis (Astuti and Komalasari, 2020), and contain a notable amount of chitin (approximately 8.7 g per 100 g), a compound known to enhance immune function and improve disease resistance (Harikrishnan et al., 2012; Astuti and Komalasari, 2020). Owing to their high CP and chitin contents, crickets offer greater nutritional value than BSFL or mealworms (Wang et al., 2005; Jayanegara et al., 2017). However, excessive dietary chitin can exert lipid lowering and cholesterol reducing effects, which may decrease body fat deposition in broiler chickens (Koide, 1998; Hossain and Blair, 2007; Ou et al., 2025).

4. Housefly Maggot

Housefly (*Musca domestica*) is holometabolous insect with four life stages: egg, larva, pupa, and adult (Park et al., 2003). Although it is a potential vector of pathogens, its larvae are economically valuable due to ability to convert organic waste into high protein biomass (Pretorius, 2011; Niu et al., 2017; Eggink et al., 2022). Zulkifli et al. (2022) highlighted that small body size of houseflies allows them to be reared in confined spaces. At poultry farms, housefly maggots are used for waste reduction and manure recycling (Ei Boushy et al., 1985), with treatment efficiencies reaching 70% to 75%, leaving about 25% to 30% of processed material as usable fertilizer (Ei Boushy et al., 1985; Ahmad et al., 2022). Housefly maggots possess bioactive compounds with antibacterial, antiviral, antioxidant, and anti-tumor properties (Gong et al., 2005). In addition, extracts from housefly maggots have been reported to contain antibacterial peptides (Bexfield et al., 2004; Park et al., 2010; Park, 2023), highlighting their potential value as functional feed additives. Nutritionally, dried maggots and pupae contain approximately 56.9% and 60.7% CP on a DM basis, respectively (Onifade et al., 2001). Moreover, their protein and amino acid compositions are comparable to those of fish meal (Onifade et al., 2001). However, during metamorphosis, crude protein content tends to decrease, whereas lipid content increases (Aniebo and Owen, 2010). Housefly maggot contain high concentrations of linoleic acid and oleic acid (Jansen-Alves et al., 2025). Although the adult houseflies are known vectors of pathogenic microorganisms, the use of housefly maggots in poultry feed may raise public health concerns, primarily due to potential contamination during rearing and processing. However, these risks can be minimized through appropriate rearing and processing methods (Awoniyi et al., 2004).

5. Silkworm Pupae

Silkworm (*Bombyx mori*) pupae, a by-product of the silk industry, are often discarded after silk reeling despite their nutritional potential (Das and Sutradhar, 1971; Ncobela and Chimonyo, 2015). This practice contributes to environmental waste accumulation (Miah et al., 2020). Silkworm pupae contain 60% to 75% protein, which is comparable or superior to soybean and fish meal (Markker et al., 2014), along with significant amounts of calcium, phosphorus, Lys, and Met (Habib and Hasan, 1995). They also contain valuable oil rich in unsaturated fatty acids, particularly oleic acid and α-linolenic acid (Rodríguez-Ortiz et al., 2024). α-Linolenic acid has been reported to exhibit various bioactive properties, including anticancer, anti-inflammatory, antioxidant, anti-obesity, neuroprotective, and gut microbiota-modulating effects (Yuan et al., 2022). However, due to its high degree of unsaturation, α-linolenic acid is known to be oxidatively unstable (Wang et al., 2025). The oxidative degradation of a-linolenic acid is a major limitation in the utilization of oils rich in this fatty acid for food and nutraceutical applications (Kotake-Nara et al., 2002).

6. Bloodworm

Bloodworms (*Chironomus* spp.) have a four-stage holometabolous life cycle, with aquatic egg, larval, and pupal stages, and a terrestrial adult phase (Armitage, 1995). Chironomidae larvae are commonly referred to as bloodworms due to their cylindrical, worm-like bodies and red coloration, which is related to the presence of hemoglobin (Cranston, 2004). They inhabit stagnant or slow-moving freshwater environments and primarily feed on decomposing organic matter and detritus (Armitage, 1995; Cranston, 2004; De Haas et al., 2006; Callisto et al., 2007). In addition, bloodworms possess hemoglobin that enables them to absorb and store oxygen efficiently under hypoxic conditions (Sulistiyarto et al., 2014). Organic waste materials used for bloodworm cultivation include chicken manure, cow dung, duck waste, and vegetable residues (Hamidoghli et al., 2014; Kumar, 2016; Podder et al., 2018). In particular, chicken manure has been utilized for the mass production of bloodworms (Shaw and Mark, 1980). Bloodworms contain 52% to 55% protein on a DM basis and 4.5% to 9.7% crude fat, making them an energetically adequate feed source for fish (Thipkonglars et al., 2010; Naser and Roy, 2012). In addition, they are rich in PUFAs, which are essential for the growth and reproduction of most marine organisms (Lytle et al., 1990). However, because bloodworms feed on algae and detritus, they may serve as potential reservoirs for zoonotic agents such as *Salmonella*, *Vibrio cholerae*, *Campylobacter jejuni*, and *Escherichia coli* (Rouf and Rigney, 1993; Broza and Halpern, 2001; Moore et al., 2003).

7. Black Soldier Fly Larvae

Black solider fly (BSF; *Hermetia illucens*) is widely distributed in tropical and temperate regions with optimal temperatures between 25 to 30°C (Siddiqui et al., 2022). Its holometabolous life cycle, comprising egg, larval, pupal, and adult stages, lasts approximately 37 to 41 days (Singh and Kumari, 2019). A single female can lay around 1,000 eggs, which hatch within 3 to 4 days (Kim et al., 2008; Muraro et al., 2024). In addition, BSFs have many commercial values given the large number of eggs and high hatching rate similar to that of mealworms (Kim et al., 2008). Only the BSFL stage requires feeding, and BSFL can grow on a wide range of organic substrates, such as decaying plant material, food waste, and animal manure (Amrul et al., 2022). In addition, BSFL have gained considerable attention for their ability to convert livestock manure and other organic wastes into larval biomass rich in protein and fat (Liu et al., 2017; Shorstkii et al., 2020). As BSFL consume a wide range of organic substrates, they are likely to acquire both beneficial and pathogenic microorganisms, which may subsequently be transmitted to animals through feed (De Smet et al., 2018; Khamis et al., 2020; Tanga et al., 2021; Siddiqui et al., 2025). BSFL contain approximately 32% to 53% crude protein and 18% to 33% crude fat (St-Hilaire et al., 2007; Yu et al., 2009). Due to their high protein and lipid content, BSFL are increasingly utilized as feed ingredients in livestock, aquaculture, and pet food industries (Lu et al., 2022). BSFL are also rich in SFAs, particularly lauric acid (Ewald et al. 2019; Srisuksai et al., 2024). Lauric acid has been reported to exert antimicrobial effects on gut bacteria (Zeitz et al., 2015; Schiavone et al., 2017; Somparn et al., 2024). However, high SFA content in BSFL can alter the lipid profile of animal products, which may be associated with an increased risk of cardiovascular disease in human (Katidi et al., 2023; Yazdanparast et al., 2025).

Among insects, BSFL are considered one of the most promising sources of sustainable protein and lipids due to their high reproductive rate, efficient waste bioconversion capacity, and fatty acid composition. Therefore, this review aims to evaluate the potential of BSFL as an alternative source of protein and lipids in broiler diets.

NUTRITIONAL AND FUNCTIONAL VALUE OF BLACK SOLDIER FLY LARVAE AS A FEED INGREDIENT

The BSFL has gained significant attention as a sustainable feed ingredient owing to their remarkable capacity to convert diverse organic residues, such as spoiled feed, food waste, and livestock manure, into nutrient-dense larval biomass (Liu et al., 2017; Khan et al., 2018; Heita et al., 2023). This bioconversion process effectively reduces the amount of organic waste and mitigates related environmental impacts, while simultaneously contributing to the production of alternative protein sources (Dorper et al., 2021; Dzepe et al., 2021). BSFL contains approximately 32% to 53% CP and 18 to 33% fat (St-Hilaire et al., 2007). However, these values vary throughout their life cycle; crude fat content tends to increase, whereas CP decreases from the early to late larval stages (Liu et al., 2017). The essential amino acid profile of BSFL includes Met (0.66% to 0.92%), Val (2.20% to 2.82%), Lys (2.34% to 2.75%), and Arg (1.73% to 2.65%) (Alafif et al., 2025). Thus, BSFL are characterized by an optimal composition of essential amino acids and fatty acids for poultry nutrition (Veldkamp and Bosch, 2015; Li et al., 2016; Lock et al., 2016). In addition, the exoskeleton of BSFL is composed of chitin, a long-chain polymer of N-acetyl-glucosamine, which has been proven to be highly versatile for various medical, industrial, and biotechnological applications (Finke, 2007; Puvvada et al., 2012). Their lipid composition is particularly abundant in medium-chain fatty acids (MCFAs), with lauric acid and myristic acid being the predominant components (Ushakova et al., 2016; Benzertiha et al., 2020). Lauric acid, in particular, serves as a precursor for monolaurin, which functions as a potent antimicrobial agent (Suryati et al., 2023). Furthermore, lauric acid has been linked to enhanced growth performance, improved feed efficiency, and better meat quality in broiler chickens (Zeitz et al., 2015; Schiavone et al., 2017; Pappula et al., 2021). Although the overall fatty acid composition of BSFL can vary depending on the type of rearing substrate (Kierończyk et al., 2020; Riekkinen et al., 2022), the larvae are capable of synthesizing lauric acid irrespective of dietary substrate composition, thereby maintaining a relatively stable concentration (Benzertiha et al., 2020).

1. Effects of Black Soldier Fly Larvae Powder Supplementation in Broiler Diets

The physical properties of alternative feed ingredients affect feed formulation as well as decisions regarding feed storage and management on farms (Pornsuwan et al., 2023). BSFL powder is typically produced by drying the larvae (most commonly through hot-air or freeze-drying methods), followed by grinding them into a fine powder (Choi et al., 2013; Herawati and Permata, 2023; Pornsuwan et al., 2023). BSFL powder has been increasingly used as a sustainable protein source in broiler diets (Choi et al., 2013). Numerous studies have investigated its impact on growth performance in broiler chickens. Choi et al. (2013) reported that dietary supplementation of 3% or 6% BSFL powder did not significantly affect body weight (BW), BW gain (BWG), feed intake (FI), and feed conversion ratio (FCR) in broiler chickens (Table 1). However, dietary supplementation with 6% BSFL powder increased breast muscle weight compared with the other treatments (Choi et al., 2013). Similarly, Herawati and Permata (2023) observed that dietary supplementation of 5%, 10%, 15%, or 20% BSFL powder did not influence BW in broiler chickens. Lee et al. (2024c) reported that broiler chickens fed diets containing 1% and 2% BSFL did not show significant differences in BWG, FI, and feed efficiency. However, dietary supplementation with 2% BSFL powder increased fatty acid composition of breast meat, such as myristic acid and eicosapentaenoic acid (Lee et al., 2024c). On the other hand, dietary inclusion of BSFL powder at levels of 2%, 4%, and 6% has been reported to increase BW and BWG, while decreasing serum parameters such as triglyceride and uric acid (El-Kaiaty et al., 2022). Despite the absence of significant change in growth performance, these findings suggest that BSFL powder can partially replace conventional protein ingredients such as soybean meal without adverse effects on productivity, indicating its potential as a sustainable feed component in broiler production.

Table 1. Effects of dietary supplementation with black soldier fly larvae (BSFL) powder in broiler chickens[1]

Sources	Inclusion level	Optimal inclusion level	Positive effects[2]	References
BSFL powder	30 and 60 g/kg	60 g/kg	Carcass trait (breast meat weight↑)	Choi et al. (2013)
	20, 40, and 60 g/kg	60 g/kg	Growth performance (BW↑, BWG↑), Serum parameter (TP↑, HDL↑, TCHO↓, TG↓, LDL↓, uric acid↓)	El-Kaiaty et al. (2022)
	50, 100, 150, and 200 g/kg	-	No significance	Herawati and Permata (2023)
	10 and 20 g/kg	20 g/kg	Fatty acid composition of breast meat (EPA↑)	Lee et al. (2024c)

[1] BSFL, black soldier fly larvae; BW, body weight; BWG, body weight gain; TP, total protein; HDL, high-density lipoprotein; TCHO, total cholesterol; TG, triglyceride; LDL, low-density lipoprotein; EPA, eicosapentaenoic acid.
[2] The symbol '↑' represented an increase, while '↓' denoted a decrease.

2. Effects of Black Soldier Fly Larvae Meal Supplementation in Broiler Diets

Full-fat BSFL meal is produced by drying the larvae and subsequently grinding them into a meal (Onsongo et al., 2018; Attia et al., 2023; Adegbenro et al., 2024). On the other hand, defatted BSFL meal is obtained by subjecting the dried larvae to an oil extraction process, after which the remaining press cake is ground into a meal (Kim et al., 2022; Mat et al., 2022). BSFL meal has gained increasing attention as a high protein ingredient in broiler diets, offering a sustainable alternative to conventional sources such as soybean meal and fish meal (Mat et al., 2022). Attia et al. (2023) found that inclusion of 3% full-fat BSFL meal during the starter phase and 5% during the finisher phase did not significantly influence BWG among dietary treatments (Table 2). However, dietary full-fat BSFL meal supplementation increased FI compared with diets containing soybean meal or fish meal. Onsongo et al. (2018) demonstrated that partial replacement of soybean meal and fish meal with full-fat BSFL meal at inclusion levels of 13.8%, 27.4%, and 42.0% showed no significant differences in BW, BWG, average daily feed intake (ADFI), and FCR in broiler chickens. Adegbenro et al. (2024) also reported that dietary supplementation with 1.25%, 2.5%, 3.75%, and 5% full-fat BSFL meal did not significantly affect BW, FI, and FCR in broiler chickens. Likewise, Murawska et al. (2021) found that higher substitution levels of 50%, 75%, and 100% of soybean meal with full-fat BSFL meal decreased BW and ADFI. Nonetheless, substituting 50% of soybean meal with full-fat BSFL meal did not affect average daily gain (ADG) and FCR in broiler chickens (Murawska et al., 2021). Afam-Ibezim et al. (2025) observed that substituting 25%, 50%, 75%, and 100% of fish meal with full-fat BSFL meal did not affect BW, ADG, ADFI, and FCR in broiler chickens. In contrast, Kirimi et al. (2023) demonstrated that replacing 50%, 75%, and 100% of soybean meal with full-fat BSFL meal decreased FCR in broiler chickens. However, substituting 25%, 50%, 75%, and 100% of soybean meal with BSFL meal did not show significant BW, ADG, and ADFI (Kirimi et al., 2023). Dietary supplementation with 4%, 8%, and 12% defatted BSFL did not affect ADG, ADFI, and FCR in broiler chickens. However, broiler chickens fed diets containing 4% defatted BSFL had greater BW compared with the other treatments (Mat et al., 2022). On the other hand, Kim et al. (2022) observed that replacing 50% of soybean meal with defatted BSFL meal in diets resulted in reduced BW, ADG, and ADFI in broiler chickens. Similarly, La Mantia et al. (2024) reported that replacing 50% and 100% soybean cake with defatted BSFL decreased BW and thigh weight. Schiavone et al. (2019) also observed that dietary inclusion levels of 5%, 10%, and 15% defatted BSFL meal decreased BW and carcass weight. Overall, these studies suggest that moderate inclusion levels of BSFL meal can replace conventional protein sources without compromising growth performance, whereas excessive replacement may negatively influence BW and FI. Therefore, these findings highlight the importance of optimizing inclusion levels to balance nutritional adequacy and cost-effectiveness in broiler diets.

Table 2. Effects of dietary supplementation with black soldier fly larvae (BSFL) meal in broiler chickens[1]

Sources	Inclusion level	Optimal inclusion level	Positive effects[2]	References
Full-fat BSFL meal	50, 100, and 150 g/kg	-	No significance	Onsongo et al. (2018)
	Starter: 200, 300, and 400 g/kg Grower: 170, 250, and 340 g/kg Finisher: 130, 200, and 270 g/kg	Starter: 200 g/kg Grower: 170 g/kg Finisher: 130 g/kg	Meat quality (TBARS↓)	Murawska et al. (2021)
	Starter: 30 g/kg Finisher: 50 g/kg	Starter: 30 g/kg Finisher: 50 g/kg	Growth performance (FI↑)	Attia et al. (2023)
	62.5, 125, 187.5, and 250 g/kg	187.5 g/kg	Growth performance (FCR↓), Carcass trait (thigh weight↑)	Kirimi et al. (2023)
	12.5, 25, 37.5, and 50 g/kg	-	No significance	Adegbenro et al. (2024)
	5, 10, 15, and 20 g/kg	-	No significance	Afam-Ibezim et al. (2025)
Defatted BSFL meal	50, 100, and 150 g/kg	50, 100, and 150 g/kg	Meat quality (breast meat color, a*↑)	Schiavone et al. (2019)
	Starter: 75 and 150 g/kg Grower: 70 and 140 g/kg Finisher: 65 and 130 g/kg	Starter: 150 g/kg Grower: 140 g/kg Finisher: 130 g/kg	Relative length and weight (↑entire digestive tract length↑, ileum length↑, duodenum weight↑), Serum parameter (LDL↓), Renal and muscle function (CPK↓)	Kim et al. (2022)
	40, 80, and 120 g/kg	40 g/kg	Growth performance (BW↑)	Mat et al. (2022)
	120 and 256 g/kg	120 and 256 g/kg	Fatty acid composition of thigh meat (lauric acid↑, ɣ-linolenic acid↑)	La Mantia et al. (2024)

[1] BSFL, black soldier fly larvae; TBARS, thiobarbituric acid reactive substance; FI, feed intake; FCR, feed conversion ratio; a*, redness; LDL, low-density lipoprotein; CPK, creatine phosphokinase; BW, body weight.
[2] The symbol '↑' represented an increase, while '↓' denoted a decrease.

3. Effects of Black Soldier Fly Larvae Oil Supplementation in Broiler Diets

BSFL oil is produced by drying the larvae, followed by grinding and extracting oil from the dried material (Haskaraca et al., 2025). BSFL oil is a rich source of MCFAs, particularly lauric acid, and has been investigated as a sustainable lipid alternative in broiler diets (Kim et al., 2020). Schiavone et al. (2018) demonstrated that replacing 50% or 100% soybean oil with BSFL oil had no significant influence on ADG, ADFI, and FCR in finisher broiler chickens. In contrast, Aslam et al. (2025) observed that dietary supplementation with BSFL oil resulted in less FCR compared with diets containing palm oil, poultry fat, and tallow (Table 3). Azizah et al. (2024) reported that the addition of 0.5% BSFL oil in diets decreased FCR compared with the basal diet. Kierończyk et al. (2023) found that dietary inclusion of 3%, 6%, and 9% BSFL oil increased BWG and decreased FCR in broiler chickens. Dietary supplementation with 3% and 6% BSFL oil increased FI, while FI decreased in broiler chickens fed diets containing 9% BSFL oil (Kierończyk et al., 2023). Kim et al. (2020) observed that dietary inclusion of 3% corn oil, coconut oil, and BSFL oil resulted in no significant differences in BWG and FI of broiler chickens. However, dietary supplementation with 3% BSFL oil showed less FCR compared to 3% corn oil (Kim et al., 2020). Kierończyk et al. (2024) demonstrated that dietary inclusion of soybean oil and BSFL oil had no significant effect on BWG, FI, and FCR in broiler chickens. Similarly, Schiavone et al. (2017) reported that replacing 50% and 100% of soybean oil with BSFL oil did not affect BW, ADFI, ADG, and FCR in broiler chickens.

Table 3. Effects of dietary supplementation with black soldier fly larvae (BSFL) oil in broiler chickens[1]

Sources	Inclusion level	Optimal inclusion level	Positive effects[2]	References
BSFL oil	Starter: 21.9 and 58.5 g/kg Finisher: 34.5 and 69 g/kg	Starter: 21.9 and 58.5 g/kg Finisher: 34.5 and 69 g/kg	Fatty acid composition of breast meat (lauric acid↑)	Schiavone et al. (2017)
	30 g/kg	30 g/kg	Growth performance (FCR↓), Serum parameter (TAC↑)	Kim et al. (2020)
	Starter: 7, 14, 21, and 28 g/kg Finisher: 3.5, 7, 10.5, and 14 g/kg	Starter: 21 g/kg Finisher: 10.5 g/kg	Plasma parameter (T-SOD↑, IL-2↑), Duodenum morphology (CD↓, VH:CD↑)	Chen et al. (2022)
	30, 60, and 90 g/kg	30 g/kg	Growth performance (BWG↑, FI↑, FCR↓), Meat quality (drip loss↓)	Kierończyk et al. (2023)
	5 g/kg	5 g/kg	Growth performance (FCR↓)	Azizah et al. (2024)
	Starter: 30 g/kg Grower: 30 g/kg Finisher: 45.2 g/kg	-	No significance	Kierończyk et al. (2024)
	Starter: 34 g/kg Finisher: 51.5 g/kg	Starter: 34 g/kg Finisher: 51.5 g/kg	Growth performance (FCR↓)	Aslam et al. (2025)

[1] BSFL, black soldier fly larvae; FCR, feed conversion ratio; TAC, total antioxidant capacity; T-SOD, total superoxide dismutase; IL-2, interleukin 2; CD, crypt depth; VH:CD; villus height to crypt depth ratio; BWG, body weight gain; FI, feed intake.
[2] The symbol '↑' represented an increase, while '↓' denoted a decrease.

However, substituting 50% and 100% of soybean oil with BSFL oil increased fatty acid composition of breast meat such as lauric acid and myristic acid (Schiavone et al., 2017). Chen et al. (2022) observed that substituting 25%, 50%, 75%, and 100% of soybean oil with BSFL oil did not show significant differences in ADG, ADFI, and FCR in broiler chickens. However, replacing 50% and 75% of soybean oil with BSFL oil increased total superoxide dismutase and interleukin-2 (Chen et al., 2022). Taken together, these findings indicate that BSFL oil can effectively replace conventional vegetable and animal fats in broiler diets without decreasing growth performance. Moreover, its high MCFA content, especially lauric acid, may confer additional benefits related to gut health and antimicrobial activity, making BSFL oil a promising sustainable lipid source for broiler production.

CONCLUSION AND FUTURE PERSPECTIVES

The continuous increase in global meat consumption, combined with the scarcity of traditional feed resources such as soybean meal and fish meal, underscores the urgent need for sustainable protein and lipid alternatives in broiler diets. Among the various insects, particularly BSFL, have emerged as one of the most promising options due to their remarkable ability to convert organic waste into nutrient rich biomass containing high concentrations of protein, fat, and functional bioactive compounds. Numerous studies have demonstrated that BSFL meal and oil can partially replace conventional feed ingredients without compromising growth performance in broiler chickens. However, the variability in nutrient composition depending on rearing substrate, processing methods, and inclusion levels remains a challenge that requires further optimization. Large-scale industrialization will also depend on improving production efficiency, ensuring microbial safety, and addressing consumer perception and regulatory approval for insect-based feed ingredients. Therefore, BSFL represent a viable and environmentally responsible solution to the feed-food competition, offering strong potential to support a more sustainable and resilient broiler industry in the near future.

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