JWPR
Journal of World's Poultry Research

2022, Scienceline Publication
J. World Poult. Res. 12(1): 01-07, March 25, 2022

Review Paper, PII: S2322455X2200001-12

DOI: https://dx.doi.org/10.36380/jwpr.2022.1

Nutritive Value of Black Soldier Fly *(Hermetia illucens)* as Economical and Alternative Feedstuff for Poultry Diet

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Received: 10 January 2022
Accepted: 26 Februray 2022

ABSTRACT

Recently, insects have gained importance as viable protein-rich feedstuff with better productivity and feed efficiency for livestock and pet animal feeds. The most potential species are the black soldier fly (*Hermetia illucens*), yellow mealworm (*Tenebrio molitor*), and common house fly (*Musca domestica*). Amongst these insects, the black soldier fly (*Hermetia illucens)* contains high protein and fat with the amino acid profile in *H. illucens* larvae equivalent to that of various protein-rich feedstuffs, such as fish meal and soybean meal. This review aimed to illustrate the reputation of black soldier fly larva meal as a substitute to conservative, expensive, and ecologically threatening crops by guaranteeing a productive, inexpensive, organic, and perpetual source of non-conventional protein feedstuff for poultry production of broilers and layers. It can be concluded that the black soldier fly sometimes has very similar and significant effects on the productivity, health, and product quality of birds, compared to soybean and fishmeal.

Keywords: Black soldier fly, Nutritive potential, Productivity

INTRODUCTION

The demand for food is probably to upsurge by 70% by the year 2050 because the population of people is being increased to 9.5 billion by that time worldwide (FAO, 2009a). The trend of people has been changed from vegetable-based protein to animal-based protein foodstuff, including milk, fish, meat, and eggs, and this inclination is predictable to heighten over time (Hunter et al., 2017). The inclination towards diets categorized by the increased utilization of animal products tends to increase the demand for animal feed ingredients and this trend probably continues in the near future. Moreover, conventional feedstuffs are being replaced by unconventional feed resources (Belghit et al., 2019). Eating habits are changing extensively due to commercial development and relocation from the countryside to metropolitan regions In developing states, the livestock sector can play a major role in sagging inadequate living standards and enhancing food security (Armanda et al., 2019). Furthermore, corn and soybean meal, the most important requirements for chick feed, may be predisposed by global warming, climate change, and nutritional expenses, thus prompting worldwide food security (Nkukwana, 2018). The high price of soybean has grown into a solemn concern for the economic stability of poultry farming, predominantly in unindustrialized states. Any sort of livestock farming feed budget includes at least 70% of the production expenses (Pica-Ciamarra et al., 2015) which specifies that cost-effective feed and their accessibility could impart an efficacious role in farming (Dumont et al., 2019). Soybean and fish meal increase the expenses of the feeds because human beings are also the consumer of soybean and fish (Kelemu et al., 2015). Fishmeal is being used in nurturing livestock and is also the most important source of protein for fish husbandry (Olsen, 2011). Furthermore, the intensification of soybean cultivation exclusively in the tropic areas could trigger land grabbing and deforestation as well as other adverse public and ecological concerns (Muscat et al., 2020). According to FAO (2017), about 70% of the fish was used for producing fish meal and fish oil in 2012. For the last century, the cost of fish meal globally enhanced up to 200%, approximately 1700 USD per 1000 Kg of the fish meal. Although there are potentials for fish meal replacement in animal nutrition, they are

To cite this paper: Ali Shah SR and Çetingül IS (2022). Nutritive Value of Black Soldier Fly *(Hermetia illucens)* as Economical and Alternative Feedstuff for Poultry Diet. *J. World Poult. Res.*, 12 (1): 01-07. DOI: https://dx.doi.org/10.36380/jwpr.2022.1

generally plant-based and hence of poorer protein digestibility and lower amount of essential amino acid content (FAO, 2009b). Therefore, imperative solutions should be designed to substitute conservative costly feed ingredients with cheaper, eco-friendly, high protein quality ones with ease of digestibility (Goldansaz et al., 2017). Insects have been produced as nutriment for humans since the prehistoric era and also they are presently being used in the human diet in many parts of the world. (Feng et al., 2018). Black soldier fly (BSF) larvae (*Hermetia illucens)*, the common house fly (*Musca domestica),* yellow mealworm (*Tenebrio molitor) a*re the insect species that have been used widely as auspicious unconventional feedstuffs of protein for animal feed (van Huis, 2017). These species can be grown on animal dung, coffee bean pulp, apple pulp, orange pulp, vegetable and fruit wastes, dried distillers grains with soluble, animal corpses, fish offal, rotten eggs, bakery product wastes, and restaurant wastes (Mutungi et al., 2019). However, rearing of the larva on livestock dung, poultry fecal droppings, and dead animal corpse are strictly banned by European Union, and consequently, such larva cannot be used for animal feeding with perspective to food safety. These insect species have the potential to turn the organic wastes into high protein biomass and the remaining substrates act as natural fertilizers for crops (Shelomi, 2020).

This review is intended to explicate the reputation of BSF larva meal as a replacement to conventional feedstuffs, including soybean meal, fish meal, soybean fats, and coconut fats in terms of productivity, gut health, blood chemistry, feasibility, and environmental impact, regarding its utilization in animal feedstuffs.

Scope in Turkey

Turkish scientists believe that black soldier fly larva is an excellent example of sustainable bioconversion because it is not just breaking down the wasted food the larva help with, they also serve as excellent livestock feed. The scientists assume that commercial production of black soldier fly larva will bring down animal feed costs and provide much-needed relief to farmers. Scientists claim that these worms have an exceptionally high nutritional value and are one of the richest sources of protein on earth. One larva can consume 100 mg of feed per larvae per day, which is the best ratio for organic wastes and it produces high-grade organic compost (Diener et al., 2011). For one m^2 of larvarium, BSF larvae need 3-5 kg per day for market wastes and one larva needs 100 mg chicken feeds per day (Diener et al., 2009). Scientists consider it a perfect replacement for chemical fertilizers. Turkey imports 90% of its chemical fertilizers and about 5.5 million tons of fertilizers are consumed each year in Turkey (MFAL, 2015). According to the World Bank, the global livestock feed industry has a worth of 370 billion USD. Livestock feed accounts for 70% of global food production costs and in the last decade, the price of livestock feed has increased by 200% (World Bank, 2013).

Nutritional value of black soldier fly larva

Black soldier larvae meal has an ironic amount of protein and fat, which strengthens the probability of using it in livestock, aquatic, and pet animal feed (Malla and Opeyemi, 2018). The nutritive potential of BSF varies concerning the substrates used for its growth and developmental stage during harvest.

Crude protein and amino acids

Crude protein increases just after hatching, it gradually decreases over time as it would be around 38-39% on day 14 of the larval stage. It then increases and reaches 45-46% and 56-57% at the pre-pupa and pupa harvested stages, respectively (Liu et al., 2017). De-fattening of BSF increases the protein content more than the full-fat BSF larva meal (Veldkamp and Bosch, 2015). The crude protein of fully defatted BSF is reported to be 66% that is higher than incompletely defatted BSF reported as 55% (Schiavone et al., 2017; Crosbie et al., 2020) and these values were nearly parallel to meat and fish meal. The lowermost documented crude protein content of BSF is 35-36% (De Marco et al., 2015) and is similar to and higher than plant-originated protein stuff, including sunflower, cottonseed, and linseed meal, wheat distillers grains, and beans (Sauvant et al., 2002). The limiting amino acids in poultry cereal-originated diets containing soybean and corn are lysine, methionine, and threonine and insects have extraordinary levels of these essential amino acids. As compared to corn gluten meal 60%, BSF larva has a higher content of leucine, lysine, and arginine (Liu et al., 2017). Histidine is reported to be four times greater in BSF than fish meals. As far as non-essential amino acids are concerned, the amounts of proline, alanine, and tyrosine are more in BSF, compared to soybean and fish meal (Taufek et al., 2021).

Crude fat

The fatty acids obtained from insects are more suitable and nutritious, compared to soybean and palm kernel cake without any unfavorable outcomes on productivity, digestibility, and intestinal health (Gasco et al., 2019a). On the first day after hatching, BSF larva has crude fat of about 5% that tends to rise gradually during development and reach 28-30% at the pupa stage (McGuckin et al., 2011). Lauric acid, a saturated fatty acid having antimicrobial action, is 35-50% of total fatty acids in BSF (Oonincx et al., 2015). In a study, BSF fed to freshwater Atlantic salmon reduced deposits of lipids in the liver (Belghit et al., 2019). Myristic acid is also higher in BSF, compared to soybean meal (Leni et al., 2017). According to Hoc et al. (2020), the fatty acid content of BSF is high in Saturated fatty acids (C12:0, C14:0, C16:0), and moderate in MUFA, and about 15% of it is PUFAs, and it was similar to the obtained results reported by Zarantoniello et al. (2020). Higher levels of linoleic acid (31.4%) and α-linolenic acid (1.6%) were found at the end of the first week of development, compared to day 14 of development when it was found to be 7% and 1.5%, respectively (Paul et al., 2017). Rendering to substrate for BSF larva growth, a reasonable content of oleic acid (10-15%) is reported in BSF (Michaelsen et al., 2009).

Vitamins and minerals

BSF contains a significant amount of calcium, iron, zinc, phosphorous, and Vitamin E which has noteworthy significance in animal nutrition (Liland et al., 2017). The content of Vitamin E in the pre-pupa stage (3.2 mg/100g) is reported to increase at day 14 tends to be approximately 6.7 mg/100g. Some of the minerals like calcium and phosphorous were double in the early stage, compared to the final stage while sodium, zinc, and iron content were more at the mature stage (Liu et al., 2017). BSF larva fed with horse fecal droppings showed almost 915 mg/100 g of phosphorous at the mature stage that is normally 320 mg/100 g on the chicken feed but the larva grown on fecal droppings are restricted by European Union and it should not be used in animal feed because of chances of disease transmission (Moula et al., 2018).

Implications in poultry

Affirmative outcomes have been observed about insects in relation to animal well-being and performance, gut health characteristics, and product preeminence (FAO, 2019; FAO, 2021). The use of insects as a substitute for soybean and fish meal has been increased for the last decade because they have immunity-enhancing bioactive constituents, including antimicrobial peptides, lauric acid, and chitin. (Gasco et al., 2018). The commercialization of insect farming has led to the establishment of a number of enterprises in India, Canada, the USA, North and South Korea, China, Japan, Italy, Australia, South Africa, Netherlands, and Europe since 2000 (Hubert, 2019). The development of the insect raising business is predominantly interrelated to the advancement in the *Hermetia illucens* (HI) Larva production (Ipema et al., 2020). According to Salomone et al. (2017), HI larva has progressed very rapidly in its production and processing, for example, the net weight of HI larva shifted from 8 thousand tons in 2015 to 14 thousand tons in 2016. This ensures the decline of the dumping expenses of biological wastes and conversion to worthy alternative protein feedstuffs in animal feed production, and hence, validate the continuous supply of healthy and organic animal-based protein stuffs in terms of meat and eggs for human consumption (Alexander et al., 2017). As insects are eaten unsurprisingly by a lot of animals, including fowls, ducks, quail, chukar partridge, pheasants, turkey, pigeons, doves, parrots, parakeet, cat, dogs, pigs fish, and shrimps, it is assumed that these adapting insects can be considered as a persistent and economical source of protein (De Castro et al., 2018). The BSF larva contains 40-50% crude protein, 35-40% lipids, and amino acid content that is very comparable to soybean meal and fish meal (Nyangena et al., 2020). Black soldier fly larvae serve as natural protein feedstuff for poultry, fish, shrimps, pets, and pigs (Nyakeri et al., 2017). The adult BSF can be alive for two weeks deprived of ingesting anything since fatty reserves developed during larval stages and can even live longer when water is being provided for their mating (Chia et al., 2020). Black soldier fly does not act as a vector for disease transmission and BSF larva has the potential of decreasing *E. coli* and *Salmonella enterica* in cow dung and poultry feces because of the secretion of special sort of chemicals that repel these pathogens (Liu et al., 2017). For the last decade, insects are intensely explored as prospective protein alternatives in broiler feed presenting optimistic effects on the growth and health of the birds (Józefiak et al., 2016). In a feeding trial where the hen was fed with BSF larva meal as a full replacement to soybean meal, the results showed higher content of butyric acid, a volatile fatty acid that prevents intestinal mucosa from wear and tears, due to microbial alteration by chitin in caeca, compared to the control group (Borrelli et al., 2017). Leiber et al. (2018) conducted research on layers and broilers by half replacement of soybean with BSF larva meal and they found no significant variance among all groups of layers on feed efficiency and egg quality and among all groups of broilers there was no substantial difference on weight gain and carcass parameters. According to Secci et al. (2020), hy-line brown layers fed with partially defatted BSF larva meal as a 25%

replacement to soybean depicted better egg quality parameters as compared to control. Similarly, soybean meal was replaced fully with defatted BSF larva meal in shaver white hens with no significant effect on egg production, feed intake, and haugh unit. Similarly, defatted BSF as a replacement to soybean meal increased body weight, eggshell thickness, and yolk color in Shaver white layers compared to the control (Mwaniki et al., 2020).

According to Moniello et al. (2019), more acetate and butyrate production along with better egg quality was reported in BSF-fed layers when compared to the soybean meal fed layers. The meat of rabbits nourished with the diets containing fats of BSF and yellow meal worn (*Tenebrio molitor)* was less vulnerable to oxidative damage and it was reported that the level of MDA (malondialdehyde), a marker of oxidative stress, in meat was 0.23 mg/kg of meat, compared to control as 0.40mg/kg (Gasco et al., 2019b). A study was conducted on broilers where they were fed with BSF larva as a replacement to the fishmeal and meat quality. The results showed a significant increase in meat protein level and muscle yield of the breast, compared to control, and no effect on the thigh and abdominal fat content were observed between all groups (Mlaga et al., 2020). In a study on broilers fed with BSF as compared to soybean meal, the carcass quality characteristics, including pH, color, flavor, juiciness, tenderness, cooking loss, and thawing loss were the same amongst all of the experimental groups (Pieterse et al., 2019). Full fat and extruded BSF larva meal in layers have presented a high percentage of laying eggs with no dissimilarity on egg quality parameters amongst all tentative groups (Jansen, 2018). Insects are not only being utilized in poultry but they are also successfully being used in quail, turkey, and duck farming. In a research trial soybean meal was replaced with BSF meal and its effects were seen on turkey carcass characters, growth, and health parameters. The results showed a better physiological response, immune status, compared to control, with no significant difference among all groups on productive parameters and carcass characteristics except gizzard weight that was more in BSF fed group, compared to control (Lalev et al., 2020). The negative effects of BSF larvae on productivity depend upon the inclusion level of BSF. For example, in a study defatted BSF larvae meal was used as 25% and 50% replacement of soybean meal in Hy-line brown layers. The results showed that the eggshell thickness and albumin foaming capacity were decreased significantly in the 50% replacement group as compared to the control and 25% replacement group (Secci et al., 2020). Similarly in Shaver White hens, 10% and 15% defatted BSF larvae meal as a substitute for soybean meal indicated that BSF larva improved eggshell thickness and yolk color but the FCR and egg mass reduced along with increased body weights (Mwaniki et al., 2020). In research on broiler (Ross 308) chicks at hatching fed with 50% and 100% replacement of soybean oil with BSF fat, it was concluded that the level of saturated and monounsaturated fatty acids in breast meat was highest in the 100% replacement group as compared to control and 50% replacement group. Polyunsaturated fatty acids decreased significantly in 100 replacement (22.74%) which was 27.84% for 50 % replacement to soybean oil and 29.49% for the control group. In short, 50 % replacement of soybean oil was more acceptable, compared to 100% replacement (Kim et al., 2020). Similarly in another study on 21 day-old broilers (Ross 308), 50 % and 100% replacement of soybean oil were done with BSF fat until 48 days of the age. The results showed that there was no significant difference between the performance and hematological parameters. Only little histopathological findings were obtained in the 100% replacement group. Consequently, it was safer to use 100% BSF only during the finisher stage rather than in chicks at hatching (Schiavone et al., 2018).

CONCLUSION

Insects have gained emergent utilization in livestock feed as an alternative protein feedstuff. Insects decrease environmental pollution in terms of little greenhouse gases emission and efficient utilization of bio-wastes. Instantly, the production of the insect as feed and decline of carbon-based wastes, such as cafeterias waste, domestic waste, and food street waste can support the giveaway of the ecological encumbrances and enhance natural standards to these types of wastes. To accomplish this objective, there is a need to choose appropriate insects for extensive production with better amino acid profile, growth performance, feed conversion, reduced mortality, and morbidity. From this standpoint, BSF is an exceptional candidate because it is very cheaper to rear larva on biowastes. Concerning feed safety and security issues, BSF larvae should not be grown on animal dungs and corpses. It has been concluded from the present-day literature that BSF larva is represented as a potential feed ingredient for poultry as a substituent for soybean or fish meals. Moreover, to prevent any negative impact of BSF larvae on animal production and product quality, it should be partially replaced with conventional feedstuffs during the growing stages. However, more exploration must be done to evaluate the highest inclusion levels of BSF larvae meal deprived of undesirable consequences on animal welfare, immunity, gut health, productivity, meat and egg quality, and consumer preferences.

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