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# BLACK SOLDIER FLY (*HERMETIA ILLUCENS*) LARVAE MEAL AS A SUBSTITUTE PROTEIN SOURCE IN FISH FEED

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## ABSTRACT

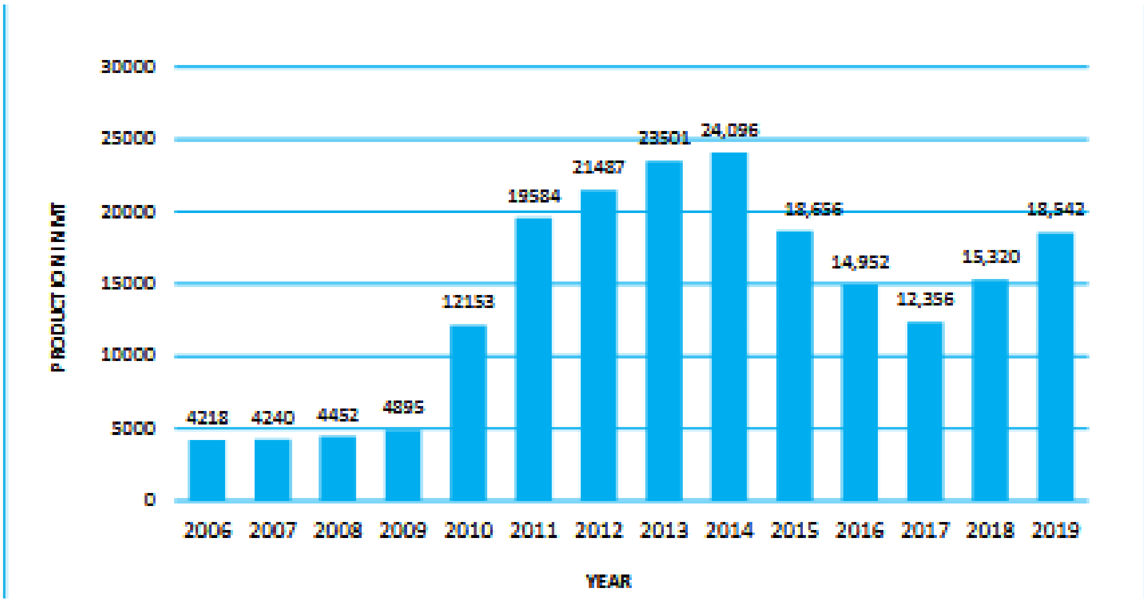
The world fastest-growing industry for producing food is aquaculture contributing to food security. Aquaculture is currently thought to provide 50% of the food fish needs, and by 2030, it's anticipated that this percentage will increase to 60–70%. Due to the cost and food-feed competition, the use of fish meal in aquaculture is progressively becoming unsustainable; therefore, there is a need to look for an alternate protein sources. The scarcity and the prohibitive cost of the fish meal renders the fish feed expensive, halting the growth of the sector, therefore an alternative protein sources which is cheaper and sustainable to relief overreliance on fishmeal and insects such as the Black soldier fly (*Hermetia illucens).* The black soldier fly (BSF), *Hermetia illucens*, is one of these insects that has a high protein and fat content and the micronutrients increasing its potential for use in the formulation of aqua feed. Both the protein content and the amino acid composition in *H .Illucens* larvae are comparable to those found in numerous protein-rich foods including fish meal. BSF has the capacity to convert organic waste into a rich supply of nutrients, including proteins, lipids, micronutrients and chitin, helps to lessen the strain on the environment and the possibility for pollution resulting from the buildup of organic waste. This review shows black soldier fly larvae as a substitute protein source in fish feed. The study recommends the farmers to adopt the use of BSF larvae meal in poultry keeping.

**Keywords:** Aquaculture, Black soldier fly and Fish-feed

## INTRODUCTION

The fastest-growing industry in the world for producing food is aquaculture. Nearly half of the world's seafood consumption comes from it. Aquaculture is currently thought to provide 50% of the food that fish needs, and by 2030, it's anticipated that this percentage will increase to 60–70% (Chanda et al., 2021). In recent decades, aquaculture has expanded, and farmed fish has seen an increase in global consumption (FAO, 2018). Global fisheries production increased by 174.0 Mt in total, of which 83.6 Mt came from aquaculture and 90.4 Mt from capture (FAO, 2022). The sector plays a significant role in the contribution to food and nutrition, which are increasing at an alarming rate due to the population increase, fostering food security and economic growth along the value chain. The aquaculture industry is expanding, mostly due to the feed industry. The world production of farmed fish climbed to 73.8 million tons in 2014 from 1.6 million tons in 1960 (Food and Agriculture Organization of the United Nations, 2017). Aquaculture's sustainability depends on affordable feed, which accounts for 60% of all operational expenses. Because of a variety of factors, including its high protein content, great amino acid profile, and outstanding digestibility and palatability, fish meal is an important part of every aqua-feed (Pereira et al., 2022). Kenya's fisheries industry plays a significant role in the nation's social and economic progress, even though it produces less than its potential (Kamau et al., 2021). The most important sources of fish include aquaculture (farmed fish) and ocean capture fisheries, with the latter having a considerably more significant role in the fish production systems in Kenya up to this point. Aquaculture has recently experienced significant growth. Kenya has made incredible strides toward promoting aquaculture. Kenya's Vision 2030, in addition to additional statutory, regulatory, and institutional frameworks, emphasizes the importance of aquaculture as a source of food security, the reduction of poverty, and the creation of jobs (Munguti et al., 2021). Through helpful government policies and significant government expenditure, aquaculture output in Kenya rose quickly from fewer than 1000 tons in 2006 to more than 24,000 tons by the middle of the 2010s (Obiero et al., 2019),) including in regions of the country where there is little historical production or consumption of fish (Ole-Moiyoi, 2017).

Between 150,000 and 300,000 metric tons (MT) of fish are estimated to be caught in Kenya's inland waters each year, mostly through commercial fishing. With a value of $237 million, overall fishery production in 2019 was 147,000 MT (KNBS, 2020). With the increasing adoption of semi-intensive and intensive fish production in the country, there has been an increase in demand for fish compound feeds to achieve optimal performance and profitability of the enterprise. The high cost of fish feed has been hampering the growth of the industry in Kenya (Munguti et al., 2021). Fish meal manufacturing is unpredictable and growing in demand, which raises market prices and the expense of production. Fish feed production costs should be reduced by replacing fish meal, either partially or entirely, with less expensive, protein-rich animal or plant sources (Hua et al., 2019). One interesting animal protein source that can be used in fish feed is insect meal, and in this case the black soldier fly, which has proven to be economically viable for mass production, sustainable, and environmentally friendly. As the largest class of species in the environment, insects are always available (Siva Raman et al., 2022).




Trends in aquaculture production in Kenya 2006-2019((Munguti et al., 2021)

A growing body of research and professionals have determined that incorporating insect meals in feed to increase feed and food security through formulation may be a creative strategy. Insects have been used as food for humans and are currently eaten as such in several regions of the globe (FAO, 2022b). However, using insect meal for fish feed is more popular with consumers since there is a degree of dislike for direct human ingestion in some communities rather than the ingestion of them. There has been a revival of interest in animal nutrition as a result of recent advancements, and the use of insects as animal feed ingredients is now widely recognized. Several studies have shown that edible insects are rich in protein and necessary amino acids, vitamins, and minerals. Insect meal can be used as feed for livestock and can also be used directly to treat organic waste-associated problems (Freccia et al., 2020), which is produced in large amounts and represents an environmental burden. The rearing of black soldier larvae leads to a significant reduction in waste moisture, waste volume, odor, and pollution potential. Insect meal from black soldier larvae (BSL) is included in the European Union Feed Material Register (Abd El-Hack et al., 2020). This study review aims to draw attention to the nutritional value of black soldier fly larvae (BSFL) and the feasibility of using it as a novel protein source in fish feed. It also highlights its contribution in terms of the bioconversion of organic waste into protein biomass by BSF.

**Fish Feed Industry in Kenya and Its Challenges**

Fish feeds is the most expensive animal feed in the Kenyan market today accounting for around 50%-70% of the total cost of production. Intensive and semi-intensive aquaculture systems which are being adopted by Kenyan farmers call for increased use of quality fish feed to achieve optimal performance (Munguti et al., 2021). Access to these quality and affordable fish feeds together with optimal utilization of the feed to maximize on profitability and viability of the enterprises. Most small-scale farmers fertilize their ponds with organic manure and locally available feed resources obtained from agro-processing. The high cost of the feed has led to low profitability of the fish enterprises (Okello et al., 2022). Fish meal has been used in fish diets because of its high protein content, and highly palatable and balanced amino acid composition but has been very expensive because of the overexploitation of fish in the natural sources (El-Sayed, 2020). In order to make the fish enterprise profitable for the farmers in Kenya to ensure accessibility of affordable quality feed to the farmers and the appropriate feeding management practices.

In Kenya, 90% of the cultured fish come from earthen ponds which are normally fertilized, and fish feed on agro-processing products. Before the inception of compounded feeds by the producers, they used to feed them on wheat bran, rice, cassava meal, and maize meal. These agro-processing products are low in protein, high in fiber, and not balanced with minerals and vitamins therefore less digestible, and less palatable resulting in low fish yield (Munguti et al., 2014). A study done at Sagana fish farm in Kenya on the growth performance of fish fed on different cereal bran showed that fish fed on maize bran had a better growth rate compared to those fed on rice and wheat bran thus the limitation of using brans in fish feed because of their high fiber content, low protein and less digestible (Munguti et al., 2021). The farmers have also tried to adopt homemade feed formulations using locally feed resources which have been faced with challenges because of the lack of understanding of the various nutrients requirements for various fish species and the nutritional limitations of various feed sources (Opiyo et al., 2018).

The increasing fish farming adoption in Kenya has been further boosted by the eight-year (2018-2025) Aquaculture Business Development USD 143.3 million funded by the International Fund, a program by the International Fund (IFAD) and the administration of Kenya (GoK). This project is currently promoting aquaculture among small-holders fish farmers and consolidating the fish production growth in aquaculture commerce and production (Munguti et al., 2022). The implementation of this program will ultimately result in higher demand for aqua-feeds, which calls for effective feeding management techniques. Additionally, increased production from aquaculture is associated with the ongoing use of high-quality feeds that adhere to the nutritional needs of cultured fish, as well as the ideal feeding management techniques (Jennings et al., 2016).

This increase in fish farming has created an opportunity for demand for fish feed. There has been seen as an opportunity by the feed manufacturers who have gone to a point of manufacturing low-quality feed for farmers. This prompted the government to establish fish farming standards to curb this behavior. All stakeholders in aquaculture, including the Kenya Fisheries Service (KeFS), the Kenya Marine and Fisheries Research Institute (KMFRI), the State Department of Fisheries, Aquaculture and the Blue Economy (SDF&BE), and commercial fish feed, participated in a number of negotiations that culminated in the development of fish feed standards (Munguti, Odame, et al., 2021). The fish feeding standards established are to ensure the formulation of high-quality fish feed for farmers and to address the challenges of low protein levels, the presence of aflatoxins, and short shelf-life. The availability and cost of fish feed still remain a challenge to most of fish farmers. Feeding standards for Kenya tilapia, catfish and trout were created (Lall & Dumas, 2022).
Commercial fish feed in Kenya, for Nile tilapia (*Oreochromis niloticus*) and the African catfish (*Clarias gariepnus*) contains 245-34% and 30%-40% crude protein respectively. For most grow-out fish which are fed twice per day morning and evening their feed contains 25%-30% crude protein and fingerlings are fed 3 times per day at 3% of their body weight with 30%-40% crude protein. Compounded feed gives better results compared to feeding maize bran (Munguti, Odame, et al., 2021).

Kenya aquaculture is evolving from traditional to more modern aquaculture systems, the sector is faced with various constraints that are hampering its growth and the sector from meeting its full potential of the sectors. The various challenges include Inadequate readily available, cheap, and quality fish seeds(fingerlings), inadequate availability of high quality and affordable fish feed, inadequate supportive infrastructure for example fish propagation hatcheries, fish feed industries, fish marketing systems, especially for rural producers, Lack of enough budgetary allocation in the aquaculture sector. Additionally, the weak collaboration between researcher's farmers, and extension workers and linkages slow the adoption rate of fish farming technologies, innovations and management practices and lack of accessibilities to good credit facilities and schemes for fish farmers. Farmers are also facing the constraints of predators which invade the fish ponds and cages and thieves and poor record keeping (Munguti, Obiero, et al., 2021b).

The formulation of fish feed has a high protein level therefore it's dependent on high-protein feed resources such as fishmeal. Fish meal is used to formulate fish feed but has been scarce and very expensive and therefore looking for an alternative protein source that is economical, sustainable, and digestible with high crude protein will render the enterprise more profitable (Hoerterer et al., 2022). The insects have proven to have a high crude protein level, highly palatable, with a balanced amino acid profile for use as fish feed to replace fish meal.

**Insect Meals as a Protein Source**

Insects have for ages been used as human and animal feed for animals that scavenge on the environment. Insects have recently been given a lot of attention as potential protein sources as human food and animal protein source. With the increasing human population accelerating protein demand has to be addressed with sustainable meat production (Huis, 2022). In 2018, 1.1 billion tons of compounded animal feeds were produced and the demand is projected to keep increasing (Wilkinson & Lee, 2017). The prices of feeds have been increasing because of the increasing prices of fishmeal and soybean meal which calls for the world to look for an alternative protein source that is sustainable and economical (Karlsen & Skov, 2022).

Insects usually have a biological capacity to convert quality low-quality organic material into high-quality protein sources at a lower culturing cost of water, and land and less greenhouse gas emission (Derler et al., 2021). The most common insects or their larvae cultured as protein sources include yellow mealworm (*Tenebrio molitor*), house fly(*Musca domestica*), and the black soldier fly (*Hermetia illucens*) compared with soybean meal, fishmeal, and other plant protein sources insects are characterized by relatively high protein content, more balanced amino acids and highly palatable(Lange & Nakamura, 2021). Black soldier fly (BSF) has proven potential for mass production. It can be cultured on organic waste and produce larvae that are rich in protein of 37%-63% crude protein, fat (4.8%-38.7%), and well-balanced amino acid and fatty acids profile. It is also rich in minerals and vitamins. It also contains chitin which confers antimicrobial properties and is also less digestible (Li et al., 2022).

When BSF larvae meal replaced soybean meal and fishmeal in the proportion of 10 to 56% in broiler quails and chicks there was no adverse effect on growth performance, carcass characteristics, and meat composition (Cullere et al., 2016). When the diet of piglets was replaced with 5-10% of BSF larval meal to replace soybean demonstrated no adverse effect on growth performance (Veldkamp & Vernooij, 2021). The inclusion of BSF larval meal in layers meal has a shown satisfactory prolonged laying period, increased egg production, and yellow yolk (Abd El-Hack et al., 2020). BSFL has been found to the benefits growth performance of juvenile carp (*Cyprinus Carpio var.Jian*), shrimp, (*L.vannanzi)* and Atlantic Salmon (*Salmo salar*).

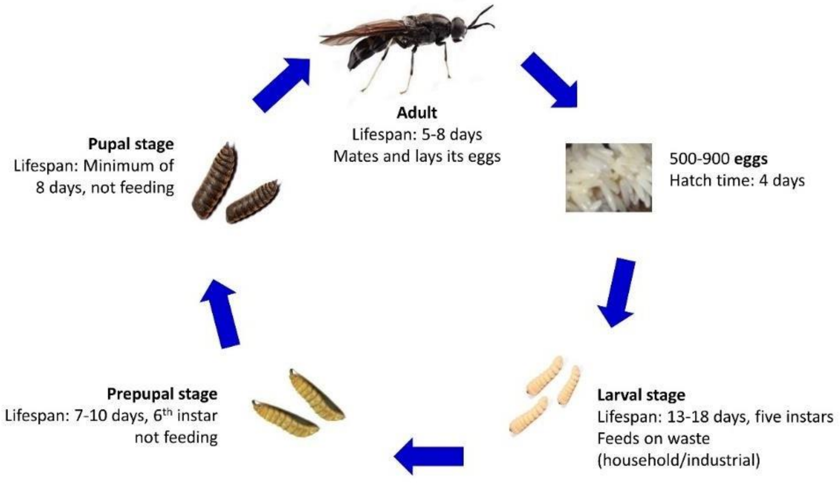
**Black Soldier Fly Larvae**

The black soldier fly (*Hermetia illucens*) belong to the Stratiomiydae family (Diptera) originated from South America and spread to temperate tropical and is now natural available within the environment and thrive in temperature of 25℃-30℃. An adult fly has a small and narrow head than the body with separated eyes in both sexes. The black soldier fly adults are sleek looking fly with a wasp like appearance and are black body with blue and green metallic reflection thorax and occasionally with a red-ended abdomen. They range between 15 and 22 mm in length (Miranda et al., 2019).The adults antennae are elongated with three segments head, thorax and abdomen and the legs are black with white coloration near the end of the legs, two wings which are membranous and folded horizontally in the abdomen and overlapped while resting and does not possess a stinger (Ushakova et al., 2016).

The male are longer than females but have smaller end genitals and wings and females have body lengths between 12-20mm and wings 8-14.8mm.There life cycle has five stages; egg, larvae, pupa, pre-pupae and adult which take about 22 days. The larvae and the pupal stage are the richest in nutrients which is also dependent on the rearing substrate with about 18-33% fats and 32-65.5% protein. The adults lack the mouthparts hence only take water, they are not involved in disease transmission (Lu et al., 2022).

**Black Soldier Fly Life Cycle**

The life cycle of the black soldier fly has five primary stages: the egg, larva, prepupal, pupal, and adult stages (Lu et al., 2022). The adult female fly lays between 500 and 900 eggs. The larval and pupal stages of the fly's life cycle last the longest, while the egg and adult stages are very brief. The eggs typically hatch in four days, though this depends on the season, location, and temperature. The larval phase lasts for six instars, with the largest instars measuring 20mm, and the smallest instars measuring 1.8mm (Liu et al., 2017). The larvae that hatch from the eggs begin feeding right away on a variety of organic materials, such as animal manure, rotting fruits and vegetables, and kitchen scraps (Purkayastha & Sarkar, 2021), with consumption rates rising significantly after the third instar . When the larvae reach the sixth instar, they undergo melanization, which gives them a darker cuticle and the insect stops eating during this stage and empties its digestive system. The pupal stage, during which larvae do not move or eat for at least 8 days, ends with the adult emergence. The adult fly feeds on water and relies on the fat reserves stored during the larval stage. The fly do not pollute the environment, harm to plants, homes, or restaurants instead (Mahmood et al., 2021) choosing to live in remote areas away from human habitat, mature, and mate. In 5-8 days, the fly mates, lays eggs, and shortly after ovipositing, the female dies (Ewusie et al., 2019).




Adopted : Rhuanito Ferrarezi

**Nutritional Value of Black Soldier Fly Larval Meal**

With great focus on the protein and fat content, the nutritional value of insects has been numerously researched. The protein and iron content of black soldier larvae diet are high. Its prospective use as animal feedstock is further supported by its fat content. The chemical composition of black soldier fly larvae (BSFL) meal will depend on the type of substrate diet and developmental stage can have an impact on its meals (Shumo et al., 2019). They can be utilized as either full-fat or defatted. Defatting removes fats and these increases the protein level of the meal (Heuel et al., 2021). The BSFL range from 35%-65.5% protein with an average protein level of 41% which is lower than that of soybean meal 45% crude protein and fishmeal 67.5% crude protein. Both full-fat and defatted BSFL has a good amino acid profile and considered more sustainable compared to soybean meal and fish meal (Esther, 2021). The most common essential amino acids were valine (average 40.1 g/kg, ranging from 28.2 g/kg to 67.9 g/kg), lysine (average 38.8 g/kg), and leucine (average 44.6 g/kg, from 27.8 g/kg to 78.3 g/kg). Even the valine content is larger than that of fish meal, and these three amino acid contents are higher than those of soybean meal. Methionine and tryptophan in the BSFL meal, are comparable to soybean meal and significantly less than fish meal, are the least abundant essential amino acids. Histidine and isoleucine contents are slightly greater than those of soybean meal and fish meal, ranging from 9.8 g/kg to 48 g/kg and 17.7 g/kg to 48 g/kg, respectively (Lu et al., 2022). Phenylalanine level varied from 16.4 g/kg to 77.6 g/kg, and threonine content varied from
16.2 g/kg to 45 g/kg, making them essentially identical to soybean meal and fish meal. Histidine and arginine levels are lower than those of soybean and fish meal (Lu et al., 2022; Ahiah, 2008).

The crude fat content of the full-fat BSFL meal range between 294g/kg-515.3g/kg which are comparably less than that of soybean (14g/kg and fish meal (103.6g/kg). For the defatted BSFL the crude fat decreased to an average of 69.2g/kg comparably less than soybean meal. They are rich in saturated and unsaturated fatty acids with the most abundant saturated fatty acids being the Lauric acid (C12:0) and the monounsaturated fatty acids the Oleic acid, linoleic acid and linolenic acids and palmitoleic acid. Lauric acid have antibacterial properties (Schiavone et al., 2017).

The ash content of the BSFL range from 27g/kg to 132g/kg with an average of 82.4g/kg which is relatively higher than that of soybean meal 71.9g/kg and lower than fish meal 171.5g/kg. BSFL are rich in calcium, copper, zinc, magnesium, iron etc. (Lu et al., 2022).

The Crude fiber content of the BSFL ranged from 41g/kg to 213g/kg with an average of 95.4g/kg which is slightly lower that of soybean meal 74.3g/kg and higher that of fishmeal 2.6g/kg (Lu et al., 2022).

The BSFL is made up of an exoskeleton which consists chitin whose active ingredient is chitosan which is about 61.7g/kg. Chitosan is a polysaccharide which confers immunological functions in the gut of the animal (Triunfo et al., 2022).

Table 1: Nutritional composition in g/kg dry matter

| | | BSFL MEAL | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **TYPE** | **DF** | **DF** | **DF** | **FF** | **FF** | **FF** | **FF** | **SBM** | **FM** |
| **Crude protein** | 665.0 | 554.2 | 216.0 | 431.0 | 411.0 | 439.0 | 275.4 | 494.4 | 675.3 |
| **Crude fat** | 46.0 | 98.5 | 63.0 | 386.0 | 301.0 | 294.0 | 515.3 | 14 | 103.6 |
| **Crude fibre** | | 74.0 | 70.0 | 41.0 | | 213.0 | | 74 | 2.6 |
| **Ash** | 93.0 | 81.0 | 93.0 | 27.0 | 93.0 | 132.0 | 65.9 | 71.9 | 171.5 |
| **Chitin** | 69.0 | 72.1 | 69.0 | 67.0 | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | (Schiavone et al., 2017) | (N.V, 2021) | (Yildirim-Aksoy et al., 2020) | (Spranghers et al., 2016) | (Shumo et al., 2019) | (Onsongo et al., 2018) | (Tyshko, 2021) | (Council et al., 2012) |

DF-defatted meal FF-full-fat meal SBM-soybean meal FM-fish meal

**Fig adopted:** (Lu et al., 2022)

**Black Soldier Fly Larvae Meal in Fish Feed**

Black soldier larvae meal was approved for use in the fish feed in Aquaculture by the European countries (Oteri et al., 2021). The harvested pupae and pre-pupae can be fed to the fish, poultry and pigs (Holeh, 2022). They are also potential substitute of the fish meal and soybean bean meal in the fish diets of the Turbot, rainbow trout, Atlantic salmon, pacific white shrimp and Jian carp and *Oreochromis niloticus* (Zhang et al., 2022). Numerous studies have looked into the usage of black soldier fly larvae meal (BSFL) as a potential source of protein in tilapia diets. The findings of the current study further show that feeding fish up to 100% of the BSFLM inclusion level (complete replacement of fish meal (FM)) had no negative impacts on Nile tilapia growth performance, somatic indicators, or survival rate(Tippayadara et al., 2021).

Mono-sex tilapia fed diets with BSFLM substituted with 50% of FM showed comparable growth performance and feed utilization to the control group (Shati et al., 2022). Atlantic salmon (*Salmo salar*) also indicated good growth response when they were subjected to a BSF larvae meal where they showed good feed utilization, nutrient digestibility and the sensory qualities of the fillets when the fish meal in their diets was totally or partially replaced with the BSF larvae meal (Fisher et al., 2020). The weight gain of fish fed fish meal was comparable to that of fish fed BSF larval meal 80 g/kg in channel catfish (Tippayadara et al., 2021), 15% in rainbow trout (Caimi et al., 2021) 20% in brown trout (Mikołajczak et al., 2022), and 50-200 g/kg in Atlantic salmon (Lys and Met) (Fisher et al., 2020). Higher inclusion levels (120-300 g/kg) significantly reduced fish growth in channel catfish, rainbow trout, and turbot, and more than 330 g/kg inclusion levels would significantly reduce the palatability of the diet, protein digestibility, feed intake, and growth performance in turbot (Mohan et al., 2022). Increased chitin in higher inclusion levels of black soldier fly larvae or pre-pupae would impair the fish's ability to digest meals and thrive (Tran et al., 2022). Juvenile Japanese seabass (*Lateolabrax japonicus*) also showed good growth performance, good intestinal antioxidant activity and better immune response to 64% defatted black soldier fly larvae meal as a replacement for fish meal (Wang et al., 2019). The growth of yellowtail fish was reduced when 10%- 30% of partially defatted black soldier fly meal replaced fish meal, the fat content in the black soldier fly may be causing the retardation yellowtail fish (Ido et al., 2021). To encourage excellent growth, black soldier fly prepupae raised on chicken waste and vegetable substrate can replace fish meal in rainbow trout (*Oncorhynchus mykiss*) diets up to 30% (Hoc et al., 2021) . Black soldier can also be used as a substitute for up to 25–50% of the fish meal in the diets of ornamental fish, particularly for guppy *(Poecillia reticulate*) (Sanjaya, Y.;Suhara, ;Nurjhani, Mimin;Halimah, Mimi, 2014).When the black soldier fly meal level was limited to less than 29% and 15%, respectively, it was possible to achieve 95% maximum whole body protein and lipid content in pacific white shrimp (*Litopenaeus vannamel).* The Pacific white shrimp species, which have good weight gains, specific growth rates, and food conversion, substitute black soldier fly larvae meal for fishmeal to a lesser extent than 25% (He et al., 2022).

**CONCLUSION**

Fish farming is growing at high rate in the country and the increasing demand for fish meat calls for higher production and intensive production necessitate feeding with high quality feed and the use of black soldier fly larvae meal has proven a good replacement for expensive fish meal and soybean meal in fish feed.

I recommend the farmers to adopt the culturing black soldier fly as a cheap sustainable source of protein and environmentally friendly protein source reducing the reducing gas emission.

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