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Review Article

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Black Soldier Fly (BSF): A Cost Effective Alternate Protein Source for Sustainable Livestock Production

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Abstract

Recycling of organic waste material or bio-waste is still fairly limited in low and middle income settings, although this is by far the largest fraction of all generated municipal wastes such as households, commercial and institutional activities in urban population. Further, expansion of intensive and profitable livestock production are constrained by increasing feed costs, especially the protein ingredients. Both of these factors lead to the need for alternative feed ingredients that are cheap, good quality animal protein sources and do not require extensive land and would be available. Black Soldier Fly (BSF) can remarkably able to transform any kind of organic waste biomass into protein rich larvae which can meet the demand of reliable protein. In contrast to other dipteran species, BSF is not considered as pest and its larvae can reduce populations of harmful bacteria. They feed on organic resources *i.e.,* fruit remains, animal manure, vegetables and brewers' spent grains and convert into high-quality insect protein and fat. They contain high amount of crude protein, fat, calcium, phosphorus and magnesium and larval meal has been satisfactorily used in livestock and fish feed. Replacement of soyabean and fish meal with BSF larvae is evidently cost effective and significant in terms of body weight gain in broiler, hen day egg production in layers and growth in growing pigs. However, dietary inclusion of BSF larvae meal needs more attention to the total fat content of the diet and its undesirable effect on the nutritional composition or flavor of meat and eggs.

1. Introduction

Land conversion is one of the factors that threaten the availability of feed for both cereals and forages which causes farmers to depend on feed ingredients for animal protein sources. The protein rich ingredients *i.e.* soyabean for ever increasing poultry industry is competing with human foods at both availability and pricing. Both of these factors lead to the need for alternative feed ingredients that are cheap, good quality animal protein sources and do not require extensive land and would be available. Further, urban solid waste management is considered one of the most immediate and serious environmental issues as the severity of this challenge will increase due to of rapid urbanization and population growth. Recycling organic waste material or bio-waste is still fairly limited in low and middle income settings, although this is by far the largest fraction of all generated municipal wastes such as households, commercial and institutional activities in urban population. Evidently, Black Soldier Fly (BSF) can remarkably able to transform any kind of organic waste biomass into protein rich larvae which can be good substitute to meet the demand of reliable protein for a global population projected to 9.8 billion (3%) by 2050. The BSF larvae because of its easy production system, rapid growth, efficient conversion to organic waste, can provide high-value feedstuffs as they are rich in protein (37-63%) and have a better amino acid (AA) profile than soybean meal (Barragan-Fonseca *et al.,* 2017). In addition, they contain a greater amount of lipids (15-49%), calcium (8%), phosphorus (2%), sodium (0.1-0.3%) and magnesium (1%) which can be isolated and used for the preparation of biodiesel, while the rest of the defatted meal could be used as a protein rich source for the feed for fish, poultry and pig industry (Chia *et al.,* 2019). The use of BSF larvae and pre-pupa in place of major protein rich ingredients augment the growth rate in broilers, enhance laying performance and egg quality in layer birds. This source also bears upper hand in the fattening and optimum growth in pork industry. Pertinent to this fact, bio-waste conversion by Black Soldier Fly (BSF) larvae has become the novel approach since past decades. The promising opportunities of using the harvested BSF larvae as a source of protein for livestock feed, thus, providing a valuable alternative to conventional feed.

Article History

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2. What is Black Soldier Fly (BSF)?

2.1. Distribution and Morphology

The Black Soldier Fly *(Hermetia illucens)* is of the dipteran family Stratiomyidae. In recent decades, this fly has encountered in nature worldwide in the tropical and sub-tropical areas between the latitudes of 40 °S and 45 °N. This small creature resembles very close in size, color and appearance to the organ pipe mud dauber wasp and its relatives (UF, 2019). The fly's antennae are elongated and the hind tarsi are pale as in wasp. Its larvae can be differentiated from blowfly or housefly larvae by a thin gray-black stripe on their posterior ends.

2.2. Reproduction

The egg starts a BSF life cycle and at the same time marks the end of the previous life stage. An adult female fly lays between 206 and 639 eggs at a time and eggs are typically deposited in crevices or on surfaces above or adjacent to decaying waste biomass (Sheppard *et al.,* 2002). Freshly emerged larvae (after 4 days) are 1.0 mm in size and able to reach a length of 25 mm by the end of larval stage when it weighs of 0.10 to 0.22 grams. Interestingly, the larval stage lasts from 18 to 36 days depending on the food substrates provided to the larvae, of which the post feeding (pre-pupal) stage lasts around 7 days (Tomberlin *et al.,* 2002). The two most important factors, low temperature and lack of food can delay the length of the larval stage. However, the BSF larva is a very resilient organism and has the ability to extend its life cycle under un-favorable conditions. The larval stage is the only stage during which the BSF feeds and, therefore, it is during this time of larval development that enough fat reserves and protein are stored that allow the larvae to undergo pupation, emerge as flies, find mates, copulate and (as a female) lay eggs before dying.

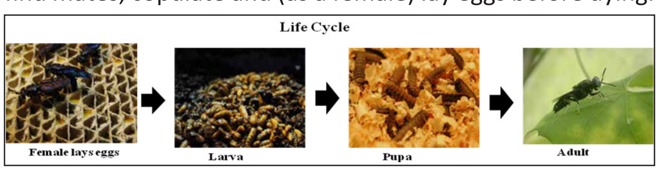

Figure 1: Stages of life-cycle of the Black Soldier Fly (*Hermetia illucens*)

The pupation (transformation from pupa to fly) is initiated when the pre-pupa finds a suitable location and the environment remain warm, dry and shaded. A successful pupation takes around 2-3 weeks and ends when the fly

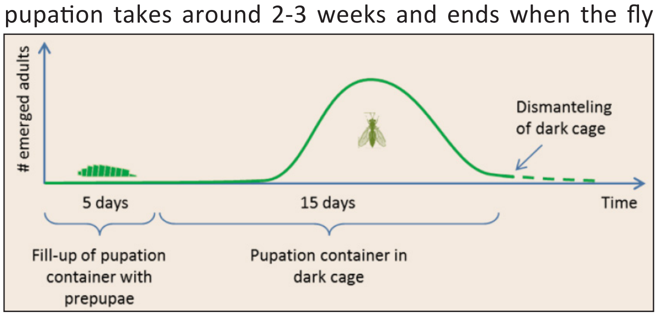

Figure 2: Dynamics of pupation and emergence of black soldier fly

emerges from its pupa shell. The fly lives for about one week during this short life, it mates and lay eggs. Interestingly, only a source of water or a humid surface is required to stay hydrated and abundant amount of natural light with temperature (25-32 °C) are important to end their life cycle.

It has been observed that the flies prefer to copulate in the morning light and after that they search for an ideal location to lay their eggs as.

Table 1: Nutrient composition in % dry matter basis of black soldier fly larvae e with or without exoskeleton (Nafisah *et al.*, 2019)

Component	BSF larvae		
	exoskeleton	No exoskeleton	Fermented *B. subtilis*
Ash	20.58	11.04	12.32
Crude Protein	42.99	30.82	42.05
Ether extract	36.13	56.21	10.30
Crude Fibre	20.27	4.29	13.18
Neutral detergent fibre	35.53	38.23	14.78
Acid Detergent Fibre	29.27	7.49	9.58

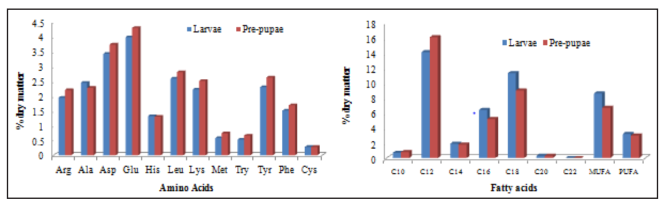

Figure 3: The content of amino acids and fatty acids in % dry matter of Black Soldier Fly larvae and pre-pupae (Kawasaki *et al.*, 2019)

Adults can live typically 47-73 days when provided with water and food, such as sugar in captivity or nectar in the wild or survive for about 8-10 days on fat reserves gathered during larval stage with water (Bruno *et al.,* 2019).

3. Features of BSF Technology for Bio-Waste Management

Adult black soldier flies, despite having a wasp-like appearance, lack biting appendage for stinging thus, they are not pests rather like other flies. They are often found near compost/ rotting organic material and based on nutritional value and ability for eco-friendly production, the BSF larvae is quickly emerging as a viable alternate livestock feed resource.

• The larvae consist of ± 35% high quality protein and ± 30% crude fat and are an important feed resource for chicken and fish farmers. Feed trials have confirmed it as being a suitable alternative to fish meal.

• Feeding organic waste to larvae has been shown to inactivate disease transmitting bacteria *i.e.*, *Salmonella* spp. which implies minimizing the risk of human health hazards mainly through material reduction (± 80%) rather than through pathogen inactivation.

• The costs of waste transport and landfills for bio-waste generation can thus, be reduced drastically and such organic waste treatment could furthermore reduce open dumping which is still an unfortunate reality in low- and middle-income settings.
• The residue, a substance similar to compost, contains nutrients and organic matter and when used in agriculture, helps to reduce soil depletion.
• A high waste-to-biomass conversion rate of up to 25% on wet weight basis has been demonstrated which is a satisfactory output quantity from a business perspective.
• There is no need for sophisticated high-end technology to operate such a facility; therefore, it is suitable for low-income settings that rely mostly on simple technology and un-skilled labour.

4. Environmental Conditions and Food Sources for the BSF Larvae

4.1 Warm Climate

The ideal temperature is between 24-30 °C. If too hot, the larvae will crawl away from the food in search of a cooler location. If too cold, the larvae will slow down their metabolism, eat less and develop slower.

4.2 Shaded Environment

Larvae avoid light and will always search for a shaded environment, away from sunlight. If their food source is exposed to light, they will move deeper into the layer of food to escape the light.

4.3 Water Content of the Food

The food source has to be quite moist with water content between 60-90% so that the larvae can ingest the substance.

4.4 Nutrient Requirements of the Food

Substrates rich in protein and easily available carbohydrates result in good larval growth. Ongoing research indicates that waste may be more easily consumed by the larvae if it has already undergone some bacterial or fungal decomposition process.

4.5 Particle Size of the Food

As the larvae have no chewing mouthparts, access to nutrients is easier if the substrate comes in small pieces or even in a liquid or pasty form.

4.6 Food Sources for BSF Treatment

a) Municipal Waste	• Municipal organic waste • Food and restaurant waste • Market waste
b) Agro-industrial waste	• Food processing waste • Spent grains • Slaughterhouse waste
c) Manure and faeces	• Poultry manure • Pig manure • Human faeces • Faecal sludge

5. Process of Bio-Waste Processing

An engineered BSF processing facility can be designed and operated to achieve bio-waste organic product based on the natural life cycle of BSF. The technology for bio-waste processing includes five main steps, such as,

• BSF rearing unit

• Waste receiving and pre-processing unit

• BSF waste treatment unit

• Product harvesting unit

• Post-treatment unit (larvae refining and residue processing)

The solution consists of feeding segregated bio-waste to BSF larvae, which have been reared in a nursery. Larvae grow on the waste feedstock and reduce the waste mass. At the end of the process, larvae are harvested and, if necessary, post-processed into a suitable animal feed product. The waste residue can also be further processed and potentially sold or used as soil amendment with fertilizing properties.

Larvae are generally very tolerant when it comes to feeding substrates which contains 60-90% water and organic material with specific particle size. The larvae strongly depend on symbiotic microorganisms which degrade cell structures and make nutrients available for the larvae to take up. With sub-optimal feed, however, development time will be extended and the final larval weight will be lower.

The bio-wastes should be purely organic and biodegradable. It should be free from hazardous or toxic and inorganic substances *i.e.*, Acids, solvents, pesticides, detergents and heavy metals in order to avoid their effect on all the living organisms. The particle size should be smaller than 1-2 cm in diameter to speed up BSF processing and increasing the surface area fosters the growth of the associated bacteria. Necessarily, ventilation is pre-requisite to enable continuous flow of oxygen supply for the well being of the larvae.

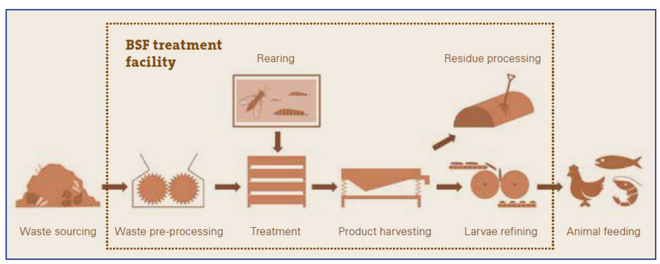

Figure 4: Technology based different units of a black soldier fly (BSF) treatment system

However, the economic viability of a BSF processing facility will depend on a range of local conditions *i.e.*, (a) Scale and respective capital and operating costs of the facility, (b) Climate (temperature, humidity), (c) Potential revenue from waste processing (tipping fees), (d) Sales revenue from larvae derived products (*e.g.*, whole larvae, protein meal, larval oil, *etc*.), (e) Sales of the waste residue as soil amendment or its use in a biogas plant.

6. BSF Larvae as Alternate Protein Source for Livestock

Black soldier fly (BSF) larvae and pre-pupae could be raised on agricultural by-products and household organic waste and satisfactorily used as poultry feed, offering a potential sustainable way to recycle untapped resources of waste. Since, BSF larvae do not absorb pesticides or mycotoxins (Wang and Shelomi, 2017), have been suggested as alternative sources of protein to corn and soybean meals and hence, as potential ingredients for chicken feed (Maurer *et al.,* 2016).

The use of defatted BSF meal to laying hens was shown to increase the eggshell thickness and strength (Park *et al.,* 2013). The complete replacement of soybean meal with BSF larvae meal was shown to alter the caecal microbiota in laying hens as the exoskeleton (chitin) modulates gut microbiota and short chain fatty acids (SCFA) production (Borrelli *et al.,* 2017). Although, replacement of soyabean meal with BSF larvae or pre-pupae meal do not affect body weight, egg laying rate and the depth of crypts in the small intestine of laying hen but caution should be taken to ensure that all fatty acids including linoleic acid are provided at adequate levels (Kawasaki *et al.,* 2019).

Schiavone *et al.* (2017) demonstrated that defatted BSF larvae meals can be considered as an excellent source of apparent metabolizable energy (AMEn) and digestible AA for broilers, thus potentially resulting into a better efficient nutrient digestion. Cullere *et al.* (2016) showed that the inclusion of 10% and 15% of defatted BSF larvae meal in the diet of growing quails (from 10-28 days of age) led to comparable productive performances and carcass traits with those of quails fed conventional soyabean meal and oil based diets. It appears that the inclusion of 10% larvae meal in partial substitution of soybean meal is suitable, as a feed ingredient, for broiler chicken diets during the starter period.

Similar to fish and chicken, BSF larvae meal can successfully replace fish meal as a sustainable protein-rich ingredient in growing pig diet as reflected in the growth performance and feed conversion ratio. According to Ramos-Elorduy *et al.* (2002), the texture, palatability and inclusion of is within acceptable limits with high level of digestibility in growing pigs as evident in poultry species. The values for RBC, Hb, MCH and RDW fell within the physiological range for pigs which is an indication of good health implying the quality of the diets fortified with BSF larvae meal.

7. Conclusion

The BSF larvae because of its easy production system, rapid growth, efficient conversion to organic waste biomass, can provide high-value feedstuffs as they are rich in protein and have a better amino acid profile than soybean meal. In addition, they contain high amount of fat and minerals which can be isolated and used for the preparation of biodiesel, while the rest of the defatted meal could be used as a protein rich source for the feed for fish, poultry and pig industry. The partial or full replacement of soyabean or fish meal can evidently be used for better production performance in poultry, fishery or pig industry. However, further investigation is needed to determine the highest dietary inclusion level of BSF oil that can be added to poultry diets, paying close attention to the total fat content of the diet and its fatty acid composition. In addition, the effect of feeding BSF larvae and pre-pupae to poultry should be further investigated to detect any undesirable effect on the nutritional composition or flavor of meat and eggs.

8. References

Barragan-Fonseca, K.B., Dicke, M., van Loon, J.J.A., 2017. Nutritional value of the black soldier fly (*Hermetia illucens L.*) and its suitability as animal feed: a review. *Journal of Insect as Food and Feed* 3, 105-120.

Borrelli, L., Coretti, L., Dipineto, L., Bovera, F., Menna, F., Chiariotti, L., Nizza, A., Lembo, F., Fioretti, A., 2017. Insect-based diet, a promising nutritional source, modulates gut microbiota composition and SCFAs production in laying hens. *Scientific Reports* 7, 1-11.

Bruno, D., Bonelli, M., Cadamuro, A.G., Reguzzoni, M., Grimaldi, A., Casartelli, M., Tettamanti, G., 2019. The digestive system of the adult Hermetia illucens (Diptera: Stratiomyidae): morphological features and functional properties. *Cell and Tissue Research* 378(2), 221-238.

Chia, S.Y., Tanga, C.M., Osuga, I.M., Alaru, A.O., Mwangi, D.M., Githinji, M., Subramanian, S., Fiaboe, K.K.M., Ekesi, S., van Loon, J.J.A., Dicke, M., 2019. Effect of Dietary Replacement of Fishmeal by Insect Meal on Growth Performance, Blood Profiles and Economics of Growing Pigs in Kenya. *Animals* 9, 705.

Cullere, M., Tasoniero, G., Giaccone, V., Miotti-Scapin, R., Claeys, E., De Smet, S., Dalle Zotte, A., 2016. Black soldier fly as dietary protein source for broiler quails: apparent digestibility, excreta microbial load, feed choice, performance, carcass and meat traits. *Animal* 10, 1923-1930.

Kawasaki, K., Hashimoto, Y., Hori, A., Kawasaki, T., Hirayasu, H., Iwase, S., Hasizume, A., Ido, A., Miura, C., Miura, T., Nakamura, S., Seyama, T., Matsumoto, Y., Kasai, K., Fujitani, Y., 2019. Evaluation of Black Soldier Fly (*Hermetia illucens*) Larvae and Pre-Pupae Raised on Household Organic Waste, as Potential Ingredients for Poultry Feed. *Animals* 9, 98.

Liland, N.S., Biancarosa, I., Araujo, P., Biemans, D., Bruckner, C.G., Waagbø, R., 2017. Modulation of nutrient composition of black soldier fly (*Hermetia illucens*) larvae by feeding seaweed-enriched media. *Plos One* 12(8), e0183188.

Maurer, V., Holinger, M., Amsler, Z., Früh, B., Wohlfahrt, J., Stamer, A., Leiber, F., 2016. Replacement of soybean cake by Hermetia illucens meal in diets for layers. *Journal of Insects as Food and Feed* 2, 83-90.

Nafisah Ainun, N., Mutia, R., Jayanegara A., 2019. Chemical composition, chitin and cell wall nitrogen content of Black Soldier Fly (*Hermetia illucens*) larvae after physical and biological treatment. *Materials Science and Engineering* 546, 420-428.

Park, S.O., Park, K.H., Park, B.S., Nam, S.H., Choi, C.Y., 2013. Effect of dietary black soldier fly (*Hermetia illucens* (Diptera: Stratmyidae)) pupa on egg production in laying hens. *Korean Journal of Nature Conservation* 7, 136-141.

Ramos-Elorduy, J., González, E.A., Hernández, A.R., Pino, J.M., 2002. Use of Tenebrio molitor (Coleoptera: Tenebrionidae) to recycle organic wastes and as feed for broiler chickens. *Journal of Economic Entomology* 95, 214-220.

Schiavone A., De Marco, M., Martínez, S., Dabbou, S., Renna, M., Madrid, J., Hernandez, F., Rotolo, L., Costa, P., Gai, F., Gasco, L., 2017. Nutritional value of a partially defatted and a highly defatted black soldier fly larvae (*Hermetia illucens L.*) meal for broiler chickens: apparent nutrient digestibility, apparent metabolizable energy and apparent ileal amino acid digestibility. *Journal of Animal Science and Biotechnology* 8, 897-905.

Sheppard, D.C., Tomberlin, J.K., Joyce, J.A., Kiser, B., Sumner, S.M., 2002. Rearing Methods for the Black Soldier Fly (Diptera: Stratiomyidae). *Journal of Medical Entomology* 39(4), 695-698.

Tomberlin, J.K., Sheppard, D.C., Joyce, A., 2002. Selected Life-History Traits of Black Soldier Flies (Diptera: Stratiomyidae) Reared on Three Artificial Diets. *Annals of the Entomological Society of America* 95(3), 379-386.

University of Florida, 2019. Black soldier fly – *Hermetia illucens*. Institute of Food and Agricultural Sciences, 2009-07-14. Retrieved 2019-10-08.

Wang, Y.S., Shelomi, M., 2017. Review of black soldier fly (*Hermetia illucens*) as animal feed and human food. *Foods* 6, 91.