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Black soldier fly larvae: multidimensional prospects in household waste management, feed, fertilizer and bio-fuel industries of Bangladesh

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ABSTRACT

Overexploitation pressure on natural resources increases gradually to meet the protein demand for aquaculture, livestock, and pet animal feed production. To minimize the pressure sustainably, live feed, i.e., insects and their larvae, could be the most promising alternative source of protein. The most widely used insect as animal feed is Black Soldier Fly Larvae (BSFL) (Hermetia illucens L.), fed on organic waste voraciously while building their body composition of 40-48% protein, 30-38% fat and a range of essential minerals. The higher amount of protein content could be used either as the complete or partial replacement of highly expensive fishmeal, wherein the higher value of fat content of BSFL could be an essential source for biodiesel production. Besides, the BSFL has higher organic waste conversion capability and reduces certain harmful bacteria and insect pests. The insect utilization is, however, hindered by limited information on BSF production strategies. However, the ever-increasing world population has catapulted the demand for animal proteins beyond supply and organic waste generation. This review will shed light on the biological and cultural features of BSFL, its role in eco-friendly waste management and its potential in fish, poultry and livestock feed industries of Bangladesh.

Key Words: *Black soldier fly larvae (BSFL), Waste management, Animal feed and Future aspect.*

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I. Introduction

The world population is rapidly growing with time, while the food demands for the up growing population are increasing exponentially. The food demand meeting challenge motivates overexploitation of renewable and non-renewable resources, which may cause the scarcity of non-renewable resources. Therefore, the re-utilization of wastes in a beneficial form could be a potential

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approach to conserve limited resources and dependency on raw materials. Organic waste is the single largest component of land fill waste in developed and developing nations alike, although more so in the latter (Mohee et al., 2015). Various pre-processed wastes such as unpalatable parts of food crops or animals, wastes from food production and processing, the unsold portion from the markets, and post-consuming wastes can be named under this category. The wastes vary considerably in their configuration, comprising sugar cane pulp and bagase, coconut husks, coffee grounds, fruit and vegetable peels, rotten market fruits, livestock that died during transportation, accident, diseases, slaughterhouse offal and blood, fish offal etc. Organic waste accumulation in the urban and peri-urban areas has severe environmental pollution, human health hazards, and esthetic value impacts. Insects at all life stages, especially in larval conditions are rich sources of essential nutrients, protein, fat, and minerals. Therefore, they have prospects as feed for humans and domestic animals like fish, poultry, duck, rabbits, and swine (Nogales-Mérida et al., 2018). However, Insect meals are less environmentally destructive and often cheaper than other animal feed ingredients, namely soy and fish meal. Insects' ability to eat waste adds another benefit outside of food and feed: organic-waste management (Lohri et al., 2017). Currently, the BSF rearing technology is becoming popular around the world. It embraces the circular economy concept by simultaneously solving two global problems: feed protein deficiency and organic waste utilization. According to the Food and Agriculture Organization of the United Nations (FAO), almost a third of all food produced (1.6 billion tons per year) in the world is wasted. Several methods of waste dumping, burning, and composting to reduce the piles of organic wastes are known. In the rearing process of BSF and ontogenesis stages to produce various feed products, chitin-containing by-products and agricultural fertilizers need to be considered. Therefore, with the development of the utilization technology, increasing the rearing technology's effectiveness and obtaining valuable biopolymers-chitin and chitosan would be possible. In a view to encouraging domestication and utilization of *BSFL* general biology, culture and various potentials of the insects have been discussed in the article.

II. Black soldier fly (BSF)

The BSF is a harmless insect belonging to the family, Stratiomyidae, with the potential to solve two of modern burning agricultural problems, namely, serve as an alternative protein source for animal feed and judicially manage organic wastes, and producing lots of by-products and agricultural fertilizers (Taiwo and Otoo, 2013). The fly is like Honey bee in size, ranging from 13 to 20mm, and having a short lifespan of 6 to 10 days in adult conditions. Notably, it is not harmful or vector of any transformable contagious diseases (Tomberlin et al., 2002). The insect is now available in different parts of the world (Banks, 2014), especially in tropical and sub-tropical warmer temperate countries (Diener et al., 2011). However, the BSF can tolerate extreme temperature throughout its life cycle, except during the oviposition period (Barry, 2004). The fly originated from North America, but climate change and human activities, animals, goods, foods, and fruit transportation worldwide facilitated its spread to other continents such as Europe, Asia, and Australia (Olivier, 2009; Leek, 2017).

Life cycle of black soldier fly

The BSF must complete different stages in its whole life cycle, i.e., undergo a complete transformation process. According to Newton et al. (2005), the BSF insect has five distinct life cycle phases: egg, larvae, pre-pupae, pupae, and adult. The insect completes its full life cycle between 40 to 44 days, showed in Figure 01 (Fok, 2014). The fertilized eggs hatch between 102 to 105 hours at 24°C temperature (Li et al., 2011). Newly hatched BSF larvae are creamy-white and actively crawl towards the substrate, where they vigorously feed on available food during this life phase. It takes approximately two weeks for the larvae to reach maturity (Sheppard et al., 2002; Myers et al., 2008). The BSF can convert organic waste into high-quality protein and fat biomass during the larval and pupal phases. In this bioconversion process, the wastes are reduced substantially, and larvae can consume harmful pathogens and minimize harmful effects (Erickson et al., 2004). During the pre-pupal stage, the mouthpart is turned into a hook-like structure for moving around called the 'wondering phase.' After their mouthpart has changed, they cannot accept feed and try to leave the substrate and position themselves for pupation. Their inherent behavior of not consuming food during pre-pupation can be utilized in mass-rearing of the insect and guide them for self-collection as pre-pupae (Diener et al., 2011). The larvae weigh about 0.2g and 25mm in length in the last stage and 6mm in diameter. Despite the small size, the larvae are tough and robust and can still survive extreme oxygen deprivation if need be (Sheppard et al., 2002). Another five sub-stages must pass within the larval stage (Hall and Gerhardt, 2001).

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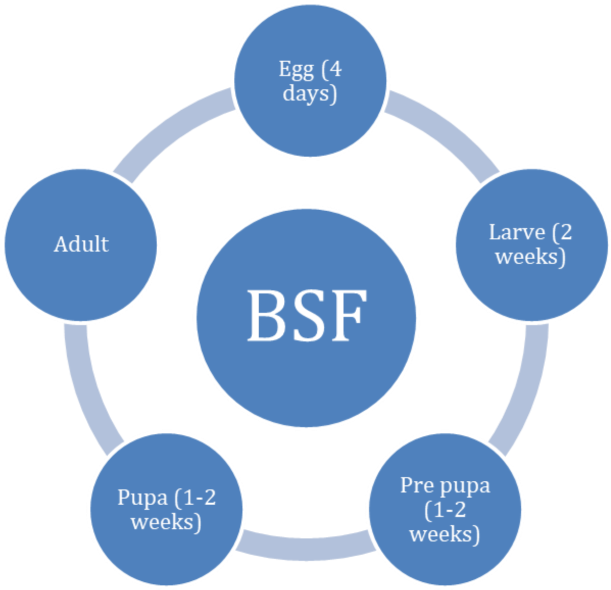

Figure 01. Life cycle of Black soldier gly (Fok, 2014)

Environmental factors for growth

The past study reports that the BSF is sensitive to abiotic factor of the environment (Mutafela, 2015). The required parameters may vary with the development stages. Therefore, to achieve successful breeding in confinement, the conditions need to be monitored and regulated to ensure the fly's requirements. The factors include temperature, relative humidity, light, diet, and pupation substrate. The ecological requirements for the growth and reproduction of BSF are summarized in table 01.

Table 01. Environmental parameters for growth and reproduction of Black soldier fly (Mutafela, 2015).

Lifecycle Parameters	Egg	Larvae under 4 days old	Larvae over 4 days old	Prepupa/ pupa	Adult
Duration (days)	4	0-4	4-14	10-14	5-8
Temperature (◦C)	<26	26-29	26-35	25-30	27-30
Relative humidity	<60	65-75	65-75	Low	30-70
Light intensity	-	Photophobic	Photophobic	Photophobic	Photophobic, mating occurs between 60-200 μmol/m^2/s with optimal 110μmol/m^2/s and wavelength 450-700 nm.

Waste management by BSF

Essentially, waste treatment by the BSF consists of feeding organic waste to BSF larvae to produce energy-rich larvae and organic fertilizer. Several features of BSF make the insect mostly eye-catching for valorizing municipal wastes. The BSF larvae's voracious appetite for decaying organic matter enables efficient conversion of a wide range of organic waste materials. The shortness of the BSF's lifecycle allows its frequent reproduction, therefore ensuring a steady source of larvae to convert the organic waste and a reliable supply of energy-rich larvae that can be used as animal feed. The BSF's flexibility enables its rearing with any food waste and makes its utilization in garbage treatment with less effort. As the larvae after full-grown crawling out of the waste by themselves; therefore, prepupae can be easily harvested. An optimized waste reduction and biomass production require the manipulation of biological attributes of the BSF to take advantage of the natural features of the BSF in waste management. Besides, waste should be treated reliably and consistently to stabilize the treatment and production processes and facilitate operations (Zurbrügg et al., 2018). The roles of BSF in conventional waste management are demonstrated in Figure 02.

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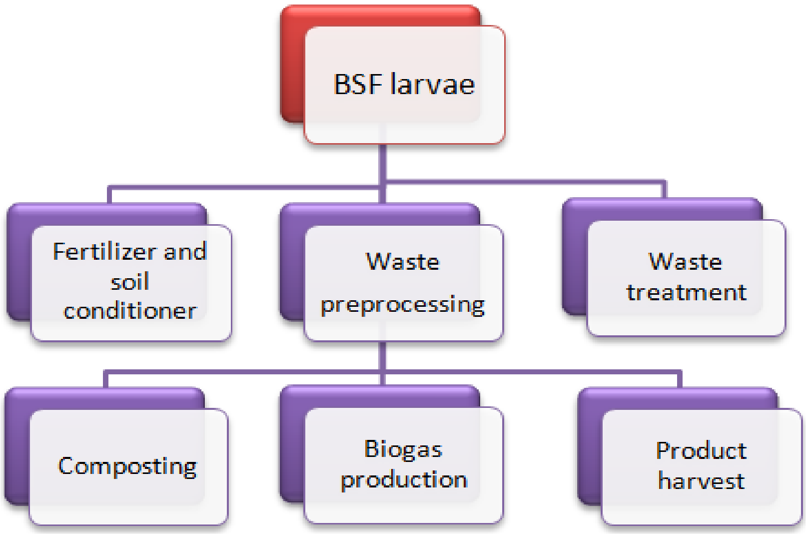

Figure 02. Conventional waste processing system using BSF (Manyara, 2018)

Beneficial culture of BSF

The bioconversion technology involves the artificially growing *BSFL* larvae on separated bio-wastes. The BSF larvae grow on the waste piles from which they extract nutrients and reduce the waste mass. The larvae's polyphagous nature and robust digestive system enable them to feed on a wide range of decaying organic materials both of animal and plant origin. In contrast, the voracious appetite facilitates large amounts of organic waste consumption during their growth cycle (Mutafela, 2015). As a result, the environmental-friendly remediation potential through BSFL is described as one of the most encouraging and sustainable methods of handling organic waste (Zheng et al., 2013). A result of the process, high-quality animal protein as BSF larvae, is harvested and processed into animal feed and a human food supplement. The residual waste can also be processed further to soil enrichment to enhance microorganism-rich fertilizer. The purification of leftover feeds by the sterile and antifungal bustle of BSFL makes it harmless for crop production use (Humphrey, 2009; Everest Canary and Gonzalez, 2012; Banks et al., 2013; Nguyen et al., 2015).

BSF larvae as poultry feed

The BSF larvae grown on pig waste or kitchen residues have been shown a satisfactory result as a feed supplement for juvenile chicks (Hale, 1973). Partial replacement of the soybean meal of 10-20% for broiler chicken showed the production performance, feed efficiency, mortality, and carcass traits like those fed on commercial feed (Cullere et al., 2016). Fifty percent or complete replacement of soybean meal with moderately de-oiled BSF larval meal in the diet for egg laying chicken did not modify their laying performance nor feed efficacy than standard organic diets for layers (Maurer et al., 2016). The high apparent digestible energy and the amino acid apparent ideal digestibility coefficients of BSF larval meal make it a valuable constituent for the formulation of broiler feeds (De Marco et al., 2015). Moreover, Arango et al. (2005) recommended that the BSF larvae have a moderate amount of mineral content for domestic birds' nutrition, according to their mineral requirements (NRC, 1993).

BSF larvae as fish feed

Protein replacement in fish diets has been investigated by several authors using BSF meals, larvae and prepupae. The fish species which were used in the BSFL meal-based research are Channel catfish (*Ictalurus punctatus*), Nile tilapia (*Oreochromis aureus*), Hybrid tilapia (Nile tilapia, *Oreochromis niloticus*) crossed with Sabaki tilapia (*Oreochromis spilurus*), Rainbow trout (*Oncorhynchus mykiss*), Atlantic salmon (*Salmo Salar*), Turbot (*Psetta maxima*), Walking catfish and Yellow catfish (*Tachysurus fulvidraco*) (Bondari and Sheppard, 1981; Furrer, 2011; Sealey et al., 2011; Kroeckel et al., 2012; Tanushri et al., 2014; Zhang et al., 2012; Lock et al., 2015; Rana et al., 2015).

Most of these research outcomes showed that only a low level of dietary BSFL had shown a similar parallel performance to that of fish-fed traditional conventional feedstuff, which may be explained by high larval protein and minerals content (Zhang et al., 2019). Fish feed in high inclusion level (>33%)

knock-off fish growth, palatability of the diet, and fish's protein digestibility (Kroeckel et al., 2012). The type of substrate types on which BSF larvae were reared brought up and the processing handling method might have affected their fishes' utilization. For example, a BSFL meal was included in the Atlantic salmon diet and replaced at least 50% in the Atlantic salmon diet without affecting the growth performance or fillet quality (Lock et al., 2015).

The insect meal increases the amount of fat in fish muscle and changes the lipid nature of fishes considerably more significant than a fish meal (St-Hilaire et al., 2007), hence, the taste of the fish fillets with a partial replacement of fish meal by insect meal (10-50%) in the diet of fishes does not affect the fatty acids (FA) profiles, aroma, and flavor significantly to the level that is perceived by the consumers (Makkar et al., 2014). For instance, no difference in organoleptic properties was found in Atlantic salmon (Lock et al., 2015) or rainbow trout (Sealey et al., 2011) fed up with 50% BSF meal.

BSF larvae as animal feed

BSF larval meal is a suitable feed ingredient in pig diets because of its high-level amino acids and calcium contents and good palatability. The live BSF larvae and prepupae have been used to feed the animals like the alligators (*Alligator mississippiensis*) (Bodri and Cole, 2007) and highland frogs (*Leptodactylus fallax*) (Dierenfeld and King, 2008). The complete replacement of formulated feed by live BSF larvae to the young alligators resulted in lesser feeding and growth than the formulated feed. Besides, when BSF larvae are fed to the Mountainous chicken frogs, poor nutritional assimilation results. It appears that whole BSF larvae may be less beneficial for the animals that swallow their food entirely, as the frog and alligator. For instance, the digestibility of calcium rich BSF larvae in mountain frogs was only 44% compared to 88% of BSF larvae that had been used as "processed" (Dierenfeld and King, 2008). On the contrary, the BSF larvae have been successfully used in captive animals feeding and breeding for the lizards and amphibian species, mostly as the source of mineral contents (Dierenfeld and King, 2008). On the other hand, the frass of BSF that reared on dried grains was assessed as feed for the Giant River prawn (*Macrobrachium rosenbergii*), resulted in similar performance as regular prawn feed with better economic outcomes (Tiu, 2012).

Bio-diesel production from BSF larvae

The biodiesel from BSF larvae can be extracted and being explored. Several studies have been carried out on the fatty acids profile of BSF larvae lipid and fat-fed on several feeds and wastes, such as food leftover (Surendra et al., 2016; Zheng et al., 2012), fruit waste (Leong et al., 2016), sewage slurry (Leong et al., 2016), domestic animals manure (Li et al., 2011b), palm canal cake (Leong et al., 2016) and rice stubble (Zheng et al., 2012), could be appropriate for biodiesel production. This review presented biodiesel production from the different feedstock. Newton et al. (2005) reported that biodiesel's manufacture from the oil of BSF larvae nurtured on swine dung would produce as much energy as anaerobic assimilation of a similar type of manure. Moreover, the biodiesel's energy properties produced from the oil of BSF larvae fed on animal manure are equivalent to supplementary biodiesels of rapeseed oil-based biodiesel (Li et al., 2011b). According to Zheng et al. (2012), the biodiesels manufactured from BSF larvae developed on rice hay and hotel leftover food meet most European environmental standards. The oil properties of BSF larvae-based fat are associated with those of rapeseed-oil-based biodiesel.

Chitin production from BSF larvae

The amino acid levels in BSF larvae are high, even more, significant than the soymeal or the FAO Reference value of Protein (Makkar et al., 2014). Further, the high level of protein and lipid contents of BSF larvae can be utilized to exploit animal nourishing and biodiesel production. Another valuable industrial product that could be extracted from BSF larvae is chitin, a leading component of the larvae's exoskeleton. From the commercial point of view, chitin is an exciting compound because it shows high nitrogen content (6.9%) related to artificial cellulose (Diener, 2010; Caruso et al., 2013). The chitin is used as a chelating agent in medications, cosmetics, biotechnologies, phytosanitary, and other industrial products (Kumar, 2000; Caruso et al., 2013; Younes and Rinaudo, 2015). Extraction of chitin from BSF larvae and marketing in the markets could increase the profit derived from the maggots. Nevertheless, the financial viability of the extraction of chitin from BSF larvae has not yet been examined (Diener, 2010). As the past research did not discuss the profit that could be projected from chitin production of

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BSF larvae, it is hard to judge whether BSF larvae constitute a reliable source of chitin, linked to crab and shrimp shells, that are so far the primary commercial sources of chitin (Younes and Rinaudo, 2015).

Organic fertilizer from BSF larvae

Limited studies have explored the efficacy of BSF waste residue, raw materials, or post-processed agricultural fertilizer for soil amendments. Choi et al. (2009) reported that the bioconversion of food waste produced promising results relating to the use of the waste residue (no information regarding the post-treatment) as an ancillary compound for conventional fertilizer. The researchers did not observe any significant difference between the BSF waste residue's biochemical composition and an enhanced microbial fertilizer. Besides, scientists reported that the growth performances and chemical composition of Chinese cabbages grown on BSF residue were like cabbages grown with commercial fertilizer. Likewise, agronomic experiments conducted in Ghana showed that the application of BSF bio-fertilizer at the rate of10 tonnes/ha together with inorganic fertilizer could increase the crop production up to 55% compared to the application of inorganic fertilizer alone for various local short-cycle cash crops, especially shallots (onion) and maize.

Furthermore, applying BSF bio-fertilizer alone obtained better results than poultry manure combined with inorganic fertilizer (Adeku, 2015; Murray, 2016; Quilliam et al., 2017). On the other hand, Newton and his colleagues (2005) found poor growth performance of basil (*Ocimumb asilcum*) and sudangrass (*Sorghan sudanense*) grown on swine manure processed by BSF larvae mixed with either mud or sand. The result could be attributed to the immaturity of the waste residue obtained from the BSF larvae rearing process, as reported by Dortmans et al. (2017) and Lohri et al. (2017), which results in oxygen depletion in the soil following its application and inhibits plant growth (Brinton and Evans, 2001). Therefore, the waste must undergo a maturation phase (Dortmans, 2015; Lohri et al., 2017; Dortmans et al., 2017).

Financial benefit of BSF larvae

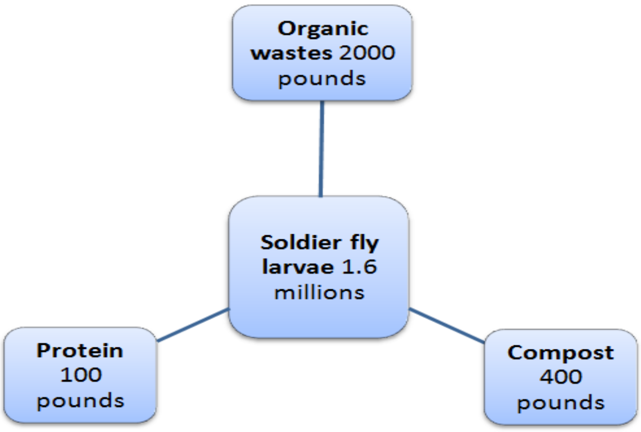

Figure 03. Efficiency of BSFL in waste management (JK Tomberlin et al., 2015)

Most of the financial benefits are associated with the BSF larvae rearing skill because this handling method valorizes low-value biological waste into high-value protein and minerals at comparatively low cost (Spranghers et al., 2017; Diener et al., 2010). The significant economic benefits advised in the literature are the returns from the sales of the larvae and possibly the waste deposit and cost savings on controlling the organic waste due to bulk and noxious waste reduction (Barry, 2004; Amatya, 2008; Alvarez, 2012). Consequently, to calculate the financial benefits of a BSF handling skill for manure production, Amatya (2008) used two indicators, i.e., the bulk of waste reduction and the financial outcome of the larvae. Amatya (2008) also recommended evaluating the cost-effectiveness reduction of the putrescent waste, related to the BSF rearing process, which is economical and improving the financial assessment, carried out by Newton et al. (2005). There we can compare some of the other farms and their yearly income with BSF culture. In an investigation, a soldier fly colony of modest size converted 2000 pounds of waste into 100 pounds of protein and 400 pounds of compost in a week, shown in Figure 03. Besides, BSFL showed a far better land utilization efficiency and yields in protein production per acre per year than many other protein sources. The excellent output of BSF in waste conversion and protein production yield rate are shown in the following Figure 03 and Figure 04, respectively:

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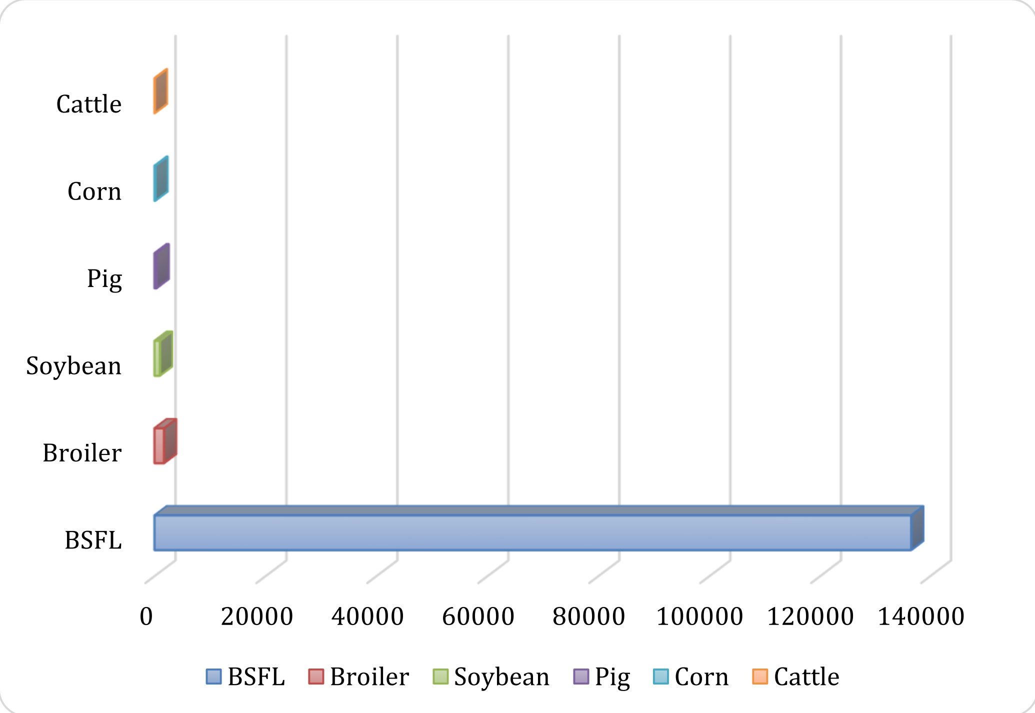

Figure 04. A comparison of land utilization efficiency and protein production (yield per acre per year) adapted from Tomberlin et al. (2015).

BSF larvae impact on environment

The most valuable protein-rich component for domestic animal feed is the soybean meal. Conversely, farming crops for livestock feeding puts stress on land and other resources, particularly in highly populated countries. Subsequently, these areas need to convert agricultural land or deforestation that threatens the tropical and sub-tropical forests, which are the harbors of biodiversity and supply necessary environmental facilities. Besides this harmful impact on the environment, conventional supply protein sources for humans are also not favorable from the financial perspective. On the other hand, waste management is most important for the environment as well as human health. As an alternative to animal feed products producing maggot meals from high-polluting waste piles or less cost food processing by-products, the BSF larvae are nearly five times more environmentally friendly than manufacturing traditional crops-based feed products (Smetana et al., 2016). In this process, the nutrient leakage reduction of the contamination-prone waste can be 50-60% (Newton et al., 2005). The BSF larvae-based biodiesel production shows a higher conversion rate (460 L $tonne^{-1}$ of larvae, DW) and yields (30-50×10^6 L ha^{-1} $year^{-1}$) compared to typical crop-based biodiesel production (FAO 2008; Li et al., 2011b; Zheng et al., 2013). Considering the odor reduction by BSFL due to short waste processing period, less bacterial activity as larvae consume most of them, exposing and dehydrating the waste, scientists conclude that the BSF larvae culture has an immense beneficial effect environment (Newton et al., 2005).

Social impact of BSF larvae

Conventional food production systems such as agriculture, aquaculture, and livestock rearing cannot cope with the current food demand (Foley et al., 2011, Mekonnen and Hoekstra, 2012). As we tend towards 2050, food insecurity, shortage of protein, malnutrition, and sanitation inferiority are expected to be the major global dietary challenges (FAO, 2013). However, the situation will worsen in developing countries like Africa and Asia, where population growth is exponential and accounted for 98% of the people globally categorized as food insecure in 2011-2013 (FAO, 2013). The overwhelming amounts of organic waste are generated by the rapidly increasing human population from diverse agricultural farms, municipal markets, households, supermarkets, industries, animal rearing and human settlements (VanHuis et al., 2013). The waste includes agricultural farm by-products, pre, and post-consumer food leftovers, expired manufactured foods, industrial waste streams, market waste, animal manures, and human faeces. In most developing countries, up to two-thirds of the generated organic waste is neither collected nor treated created nuisance and health hazards (Diener et al., 2010; Taiwo and Otoo, 2013; Van Huis et al., 2013). This vast proportion of wastes could be reused through BSF bioaccumulation. In such venture, low earning poor people, as well as women, could be employed in BSF farming. Gaining

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new, low-cost BSF production facilities will definitely pave employment opportunities to the marginal population and increase economic and social safety.

Present status of BSF larvae farming

The reckless price hike of the conventional fish and poultry feeds and the vulnerability of the concerned industries have brought BSF larvae culture under the shade of light for mass investment worldwide as an alternative feed source (Taiwo and Otoo, 2013). The present study of BSF larvae farming tries to complete the global black soldier fly market and demand various product types and applications. According to the market investigation of Meticulous Research (2019), the global black soldier fly market is segmented on product type (protein meal, bio-fertilizer, whole dried larvae, larvae oil, chitin/chitosan), application (animal feed, agricultural fertilizer, pet food, and others), and geography (North America, Europe, Asia-Pacific, Latin America, the Middle East, and Africa). Originally, Europe is likely to witness the rapid growth of BSF farming during the prediction period. The fast growth of BSF research in this region and attributed to the government approvals for using BSF larvae as animal feed and pet food; sanction funding and investments in BSF research and industry; and the presence of many entrepreneurs. There are some factors such as a large supply of organic wastes from agriculture, food and beverage sectors; high demand for protein-rich animal feed; also, supportive policies provided by the administration for BSF farming, are positive people to do BSF insect farming and their utilization in domestic animals and birds food, feed, and various industrial applications. Some of the progressive organizations working in the global black soldier market are Agri Protein (South Africa), Bioflytech (Spain), Enterra Feed Corporation (Canada), Entobel(Vietnam), Entofood (Malaysia), Entomo Farm (France), Enviro Flight (US), Hexafly (Ireland), F4F (Chile), Hermetia GmbH (Germany), Innova Feed (France), Protenga (Malaysia) and Protix (The Netherlands), etc. Notably, some pilot projects have been run in Bangladesh Agricultural University (BAU) to utilize BSFL in fish and poultry feed.

Future prospect of BSF larvae based animal feed and waste management

The cost-beneficial effects of BSF culture have drawn attention to people to utilize their wastes in a useful manner (Surendra et al., 2016). The growing interest of people in BSF culture is due to BSF farming's profit without any investment. Nowadays, many farmers started their BSF culture by using their wastage, mainly kitchen wastes. Moreover, people are more concerned about their health and the protection of the environment. For that, organic products from an eco-friendly culture system have a good market demand. From this point of view, we can forecast that for some days, we can see the transformation of Kitchen wastes and use it for BSF culture (Matan, 2020). The main attraction of this culture is using only home trash materials that we do not usually use. For that reason, it will be more popular with homemakers and agro-based people within a few days in countries like Bangladesh.

On the other hand, environment specialists claim that aquafeed hampers the ecological balance and other environmental systems. Many fish are caught to produce the fish meal for fish and poultry feed production, which becomes a threat to fish biodiversity and caused many species extinction. To solve this problem by keeping a balanced environment, we should search for an alternative protein source for feed production, while BSF larvae protein could be a potential replacement for fish meal (Belghit et al., 2018). It is recommended to promote the larvae culture in the early future to keep the ecological balance. We need to explore its use, benefit, culture, and other standard techniques for this positive change.

III. Conclusion

The BSF larvae have various applications ranging from those that help the natural ecosystem (waste management, reduction of foul odors, landfill usage, greenhouse gas emissions, and environmental degradation) to global food security, making it one of the valuable insects. The insect will provide food security and malnutrition directly and passively by reducing the demand for currently used fish feeding ingredients such as "Omena" and cultivation of soybeans, which can be used for direct human consumption. The BSF larvae possess numerable hopes and potential to bioconversion organic waste into justifiable and cheap animal feed, addressing numerous problems at once. The government should play a significant role in encouraging people to culture BSF for economic and environmental development.

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IV. References

[1]. Adeku, C. N. (2015). Report on black soldier fly biofertilizer trial at Irrigation Development Centre, Ashaiman, Ghana. Available at http://docplayer.net/54852094-Report-on-black-soldierfly-biofertilizer-trial-at-irrigationdevelopment-centre-ashaiman-ghana-by-charles-nuku-adeku-13-thjan-2015.html (accessed on January 22, 2020).

[2]. Alvarez, L. (2012). The role of black soldier fly, *Hermetia illucens* (L.) (Diptera: Stratiomyidae) in sustainable waste management in northern climates. PhD dissertation. University of Windsor. https://scholar.uwindsor.ca/etd/402

[3]. Amatya, P. (2008). Economics of black soldier fly (*Hermetia illucens*) in dairy waste management. MSc thesis. College of Graduate Studies, Tarleton State University.

[4]. Arango, G. P., Vergara, R. A. and Mejía, V. H. (2005). Compositional, microbiological and protein digestibility analysis of the larva meal of *Hermetia illuscens* L. (Diptera: Stratiomyiidae) at Angelópolis-Antioquia, Colombia. Revista Facultad Nacional de Agronomía Medellín, 57, 2491–2500.

[5]. Banks, I. J. (2014). To assess the impact of black soldier fly (*Hermetia illucens*) larvae on faecal reduction in pit latrines. Doctor Thesis, London School of Hygiene and Tropical Medicine.

[6]. Banks, I. J., Gibson, W. T. and Cameron, M. M. (2013). Growth rates of black soldier fly larvae fed on fresh human faeces and their implication for improving sanitation. Tropical Medicine & International Health, 19(1), 14–22. https://doi.org/10.1111/tmi.12228

[7]. Barry, T. (2004). Evaluation of the economic, social, and biological feasibility of bioconverting food wastes with the black soldier fly (*Hermetia illucens*), dissertation, August 2004; Denton, University of North Texas Libraries, Texas. https://digital.library.unt.edu/ark:/67531/metadc4639/ (accessed July 4, 2021),

[8]. Belghit, I., Liland, N. S., Waagbø, R., Biancarosa, I., Pelusio, N., Li, Y., Krogdahl, Å. and Lock, E.-J. (2018). Potential of insect-based diets for Atlantic salmon (*Salmo salar*). Aquaculture, 491, 72-81. https://doi.org/10.1016/j.aquaculture.2018.03.016

[9]. Bodri, M. S. and Cole, E. R. (2007). Black soldier fly (*Hermetia illucens* Linnaeus) as feed for the American Alligator (*Alligator mississippiensis* Daudin). The Georgia Journal of Science, 65, 82-88.

[10]. Bondari, K. and Sheppard, D. C. (1981). Soldiers fly larvae as feed in commercial fish production. Aquaculture, 24, 103–109. https://doi.org/10.1016/0044-8486(81)90047-8

[11]. Brinton, W. F. and Evans, E. (2001). How compost maturity affects container grown plants. Biocycle, 42(1), 56-60.

[12]. Canary, E. G. and Gonzalez, L. (2012). Design and management of a process to recycle organic waste with larva *hermetia illucens* to produce larva meal. *Universidad de la Sabana, Faculty of Engineering. Master in Design and Process Management. Chia (In spanish, English abstract)*.

[13]. Caruso, D., Devic, E., Subamia, I. W., Talamond, P. and Baras, E. (2013). Technical handbook of domestication and production of diptera Black Soldier Fly (BSF) *Hermetia illucens*, Stratiomyidae.

[14]. Choi, Y., Choi, J., Kim, J., Kim, M., Kim, W., Park, K., Bae, S. and Jeong, G. (2009). Potential usage of food waste as a natural fertilizer after digestion by *Hermetia illucens* (Diptera: Stratiomyidae). International Journal of Industrial Entomology, 19(1), 171-174.

[15]. Cullere, M., Tasoniero, G., Giaccone, V., Miotti-Scapin, R., Claeys, E., De Smet, S. and DalleZotte, 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(12), 1923-1930. https://doi.org/10.1017/S1751731116001270

[16]. De Marco, M., Martínez, S., Hernandez, F., Madrid, J., Gai, F., Rotolo, L. and Schiavone, A. (2015). Nutritional value of two insect larval meals (*Tenebrio molitor* and *Hermetia illucens*) for broiler chickens: apparent nutrient digestibility, apparent ileal amino acid digestibility and apparent metabolizable energy. Animal Feed Science and Technology, 209, 211-218. https://doi.org/10.1016/j.anifeedsci.2015.08.006

[17]. Diener, S., Gutiérrez, F. R., Zurbrügg, C. and Tockner, K. L. E. M. E. N. T. (2010). Are larvae of the black soldier fly-*Hermetia illucens*-a financially viable option for organic waste management in Costa Rica? In Proceedings of Sardinia. Twelfth International Waste Management and Landfill Symposium. S. Margherita di Pula, Cagliari, Italy; 5 - 9 October 2009.

[18]. Diener, S., Zurbrügg, C., Gutiérrez, F. R., Nguyen, D. H., Morel, A., Koottatep, T. and Tockner, K. (2011). Biological Treatment of Municipal Organic Waste using Black Soldier Fly Larvae. Waste and Biomass Valorization volume, 2, 357-363. https://doi.org/10.1007/s12649-011-9079-1

[19]. Dierenfeld, E. S. and King, J. (2008). Digestibility and mineral availability of Phoenix worms, *Hermetia illucens*, ingested by mountain chicken frogs, *Leptodactylus fallax*. Journal of Herpetological Medicine and Surgery, 18(3), 100-105. https://doi.org/10.5818/1529-9651.18.3-4.100

[20]. Dortmans, B. (2015). Valorization of organic waste – effect of the feeding regime on process parameters in a continuous black soldier fly larva composting system. MSc thesis. SLU, Swedish University of Agricultural Sciences. https://solvita.com/wp-content/uploads/2014/04/Swedish-Uni-of-Ag-Science_Dortmans_2015.pdf

[21]. Dortmans, B., Diener, S., Verstappen, B. M., Zurbrügg, C. (2017). Black soldier fly biowaste processing - a step-by-step guide. Dübendorf, Switzerland: Eawag: Swiss Federal Institute of Aquatic Science and Technology.

[22]. Erickson, M. C., Islam, M., Sheppard, C., Liao, J. and Doyle, M. P. (2004). Reduction of Escherichia coli O157: H7 and *Salmonella enterica serovar Enteritidis* in chicken manure by larvae of the black soldier fly. Journal of Food Protection, 67, 685–690. https://doi.org/10.4315/0362-028X-67.4.685

[23]. FAO (2016). Fishery and aquaculture country profiles – Ghana. Country profile fact sheets. Food and Agriculture Organization of the United Nations, Fisheries and Aquaculture Department. Available at http://www.fao.org/fishery/facp/gha/en (accessed on November 8, 2017).

[24]. FAO, I. (2013). WFP, The State of Food Insecurity in the World 2013—The Multiple Dimensions of Food Security. F.A.O. Rome. http://www.fao.org/3/a-i3434e.pdf

[25]. Fok, G. (2014). Black soldier fly larvae composting. Utubersidad.com, (Accessed 11 November 2017). https://core.ac.uk/download/pdf/188224301.pdf

[26]. Foley, J. A., Ramankutty, N., Brauman, K. A., Cassidy, E. S., Gerber, J. S., Johnston, M., Mueller, N. D., O'Connell, C., Ray, D. K. and West, P. C. (2011). Solutions for a cultivated planet. Nature 478, 337. https://doi.org/10.1038/nature10452

[27]. Food and Agriculture Organization of the United Nations (FAO) (2008). The state of food and agriculture: Biofuels: prospects, risks, and opportunities. FAO. http://www.fao.org/3/i0100e/i0100e

[28]. Furrer, T. (2011). Finding an adequate tilapia feed for rural fish farmers in Mombasa. Zürich University of Applied Sciences - ZHAW, Zürich.

[29]. Hale, O. M. (1973). Dried *Hermetia illucens* larvae (Diptera: Stratiomyidae) as a feed additive for poultry. Journal of the Georgia Entomological Society, 8, 16-20.

[30]. Hall, R. D. and Gerhardt, R. R. (2001). 8-Flies (Diptera). In Medical and Veterinary Entomology, (Elsevier), pp. 127–145. https://doi.org/10.1016/B978-012510451-7/50010-4

[31]. Humphrey, J. H. (2009). Child undernutrition, tropical enteropathy, toilets, and handwashing. The Lancet, 374, 1032–1035. https://doi.org/10.1016/S0140-6736(09)60950-8

[32]. Kroeckel, S., Harjes, A.-G., Roth, I., Katz, H., Wuertz, S., Susenbeth, A. and Schulz, C. (2012). When a turbot catches a fly: Evaluation of a pre-pupae meal of the Black Soldier Fly (*Hermetia illucens*) as fish meal substitute—Growth performance and chitin degradation in juvenile turbot (*Psetta maxima*). Aquaculture, 364, 345–352. https://doi.org/10.1016/j.aquaculture.2012.08.041

[33]. Kumar, M. N. V. R. (2000). A review of chitin and chitosan applications. Reactive & Functional Polymers, 46, 1-27. https://doi.org/10.1016/S1381-5148(00)00038-9

[34]. Leek and Aidan (2017). The future of insect bioconversion products in poultry feeds. A Nuffield Farming Scholarships Trust Report, Award sponsored by Micron Bios systems. https://www.agricology.co.uk/resources/future-insect-bioconversion-products-poultry-feed

[35]. Li, Q., Zheng, L., Cai, H., Garza, E., Yu, Z. and Zhou, S. (2011a). From organic waste to biodiesel: Black soldier fly, *Hermetia illucens*, makes it feasible. Fuel, 90, 1545-1548. https://doi.org/10.1016/j.fuel.2010.11.016

[36]. Lock, E. J., Arsiwalla, T., and Waagbø, R. (2014, May). Insect meal: A promising source of nutrients in the diet of Atlantic salmon (*Salmo salar*). In Abstract Book Conference Insects to Feed The World. The Netherlands, 14-17 May 2014.

[37]. Lohri, C. R., Diener, S., Zabaleta, I., Mertenat, A., Zurbrügg, C. (2017). Treatment technologies for urban solid biowaste to create value products: A review with focus on low- and middle-income

settings. Reviews in Environmental Science and Biotechnology, 16, 81–130. https://doi.org/10.1007/s11157-017-9422-5
[38]. Makkar, H. P. S., Tran, G., Heuzé, V. and Ankers, P. (2014). State-of-the-art on use of insects as animal feed. Animal Feed Science and Technology, 197, 1-3. https://doi.org/10.1016/j.anifeedsci.2014.07.008
[39]. Manyara, N. E. (2018). Optimization of production of black soldier fly larvae (Doctoral dissertation, university of science and technology). https://nexs.ku.dk/english/research-files/phd/phd-2018/Evans-Thesis.pdf
[40]. Market Research (2019). Black Soldier Fly Market –Global Opportunities Analysis and Industry Forecast (2019-2030), https://www.marketresearch.com/Meticulous-Research-v4061/.
[41]. Matan, S. (2020). Potential of Black Soldier Fly Production for Pacific Small Island Developing states. Animals, 10(6), 1038. https://doi.org/10.3390/ani10061038
[42]. Maurer, V., Holinger, M., Amsler, Z., Früh, B., Wohlfahrt, J. and Stamer, A., *et al*. (2016). Replacement of soybean cake by *Hermetia illucens* meal in diets for layers. Journal of Insects as Food and Feed, 2, 83-90. https://doi.org/10.3920/JIFF2015.0071
[43]. Mekonnen, M. M. and Hoekstra, A. Y. (2012). A global assessment of the water footprint of farm animal products. Ecosystems, 15, 401–415. https://doi.org/10.1007/s10021-011-9517-8
[44]. Mohee, R., Mauthoor, S., Bundhoo, Z. M., Somaroo, G., Soobhany, N., Gunasee, S. and Bundhoo, M. A. Z. (2015). Current status of solid waste management in small island developing states: A review. Waste Management, 43, 539–549. https://doi.org/10.1016/j.wasman.2015.06.012
[45]. Murray, F. (2016). Final project completion report research challenge fund projects. Available at http://www.stir.ac.uk/media/schools/naturalscience/aquaculture/aquasect/documents/Ento-Prise_RCF_ GranteeFinalReport_Final.pdf (accessed on September 28, 2017).
[46]. Mutafela, R. N. (2015). High Value Organic Waste Treatment via Black Soldier Fly Bioconversion: Onsite Pilot Study. Industrial Ecology, Royal Institute of Technology, Stockholm.
[47]. Myers, B. R., Saimi, Y., Julius, D. and Kung, C. (2008). Multiple unbiased prospective screens identify TRP channels and their conserved gating elements. Journal of General Physiology, 132(5), 481--486.
[48]. Newton, L., Sheppard, C., Watson, D.W., Burtle, G. and Dove, R. (2005). Using the black soldier fly, *Hermetia illucens*, as a value-added tool for the management of swine manure. Anim. Poult. Waste Manag. Cent. N. C. State Univ.
[49]. Nogales-Mérida, S., Gobbi, P., Józefiak, D., Mazurkiewicz, J., Dudek, K., Rawski, M., Kieron´czyk, B. and Józefiak, A. (2018). Insect meals in fish nutrition. Reviews in Aquaculture, 11, 1080–1103. https://doi.org/10.1111/raq.12281
[50]. Olivier, P. A. (2009). Utilizing lower life forms for the bioconversion of putrescent waste. Black Soldier Fly Blog-Off. https://nexs.ku.dk/english/research-files/phd/phd-2018/Evans-Thesis.pdf
[51]. Quilliam, R., Adeku, C. N., Maquart, P. O., Newton, R. and Murray, F. (2017). Insect frass fertilizer: A novel soil amendment for resource-poor peri-urban farmers. Agricultural Research for Development (Agri4D) Conference 2017: Rural Transformation and Urbanization, September 20-21, 2017. Uppsala, Sweden: Swedish University of Agricultural Sciences (SLU).
[52]. Rana, K. M. S., Salam, M. A., Hashem, S. and Islam, M. A. (2015). Development of black soldier fly larvae production technique as an alternate fish feed. International Journal of Fisheries and Aquatic Studies, 5, 41-47.
[53]. Sealey, W. M., Gaylord, T. G., Barrows, F. T., Tomberlin, J. K., McGuire, M. A., Ross, C. and St-Hilaire, S. (2011). Sensory analysis of rainbow trout, *Oncorhynchus mykiss*, fed enriched black soldier fly prepupae, *Hermetia illucens*. Journal of the World Aquaculture Society, 42, 34–45. https://doi.org/10.1111/j.1749-7345.2010.00441.x
[54]. Smetana, S., Palanisamy, M., Mathys, A. and Heinz, V. (2016). Sustainability of insect use for feed and food: Life Cycle Assessment perspective. Journal of Cleaner Production, 137, 741-751. https://doi.org/10.1016/j.jclepro.2016.07.148
[55]. Spranghers, T., Ottoboni, M., Klootwijk, C., Ovyn, A., Deboosere, S., De Meulenaer, B., Michiels, J., Eeckhout, M., De Clercq, P. and De Smet, S. (2017). Nutritional composition of black soldier fly (*Hermetia illucens*) prepupae reared on different organic waste substrates. Journal of the Science of Food and Agriculture, 97(8), 2594-2600. https://doi.org/10.1002/jsfa.8081
[56]. St-Hilaire, S., Sheppard, D. C., Tomberlin, J. K., Irving, S., Newton, G. L., McGuire, M. A., Mosley, E. E., Hardy, R. W. and Sealey, W. (2007b). Fly prepupae as a feedstuff for rainbow trout, *Oncorhynchus mykiss*. Journal of the World Aquaculture Society, 38(1), 59-67. https://doi.org/10.1111/j.1749-7345.2006.00073.x

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[57]. Surendra, K., Olivier, R., Tomberlin, J. K., Jha, R. and Khanal S. K. (2016). Bioconversion of organic wastes into biodiesel and animal feed via insect farming. Renewable Energy, 98, 197–202. https://doi.org/10.1016/j.renene.2016.03.022

[58]. Taiwo, A. and Otoo, E. A. (2013). Accelerating Decomposition Rate of Fresh Faecal Materials from a Farrow-to-Finish Swine Farm with Black Soldier Fly Larvae (*Hermetia illucens*). In 2013 Kansas City, Missouri, July 21-July 24, 2013, (American Society of Agricultural and Biological Engineers), p. 1.

[59]. Tanushri, D. N., Shaharior, H. and Salam, M. A. (2014). Asian catfish fry (*Clarias batrachus*) rearing with wheatgrass powder mixed formulated feed in plastic half drum. International Journal of Fisheries and Aquatic Studies, 1(5), 162-168.

[60]. Tiu, L. (2012). Enhancing sustainability of freshwater prawn production in Ohio. Ohio State Univ. South Cent. Newsl. Fall, 11.

[61]. Tomberlin, J. K., Sheppard, D. C. and Joyce, J. 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, 379–386. https://doi.org/10.1603/0013-8746(2002)095[0379:SLHTOB]2.0.CO;2

[62]. Van Huis, A., van Itterbeek, J., Klunder, H., Mertens, E., Halloran, A., Muir, G., Vantomme, P. (2013). Edible insects – Future prospects for food and feed security. FAO Forestry Paper 171. Rome: Food and Agriculture Organization of the United Nations.

[63]. Younes, I. and Rinaudo, M. (2015). Chitin and chitosan preparation from marine sources. Structure, properties, and applications. Marine Drugs, 13(3), 1133-1174. https://doi.org/10.3390/md13031133

[64]. Zhang, Y., Han, B. and Ezeji, T. C. (2012). Biotransformation of furfural and 5hydroxymethyl furfural (HMF) by *Clostridium acetobutylicum* ATCC 824 during butanol fermentation. New Biotechnology, 29, 345–351. https://doi.org/10.1016/j.nbt.2011.09.001

[65]. Zheng, L., Crippen, T. L., Singh, B., Tarone, A. M., Dowd, S., Yu, Z., Wood, T. K. and Tomberlin, J. K. (2013). A survey of bacterial diversity from successive life stages of black soldier fly (Diptera: Stratiomyidae) by using 16S rDNA pyro sequencing. Journal of Medical Entomology, 50, 647–658. https://doi.org/10.1603/ME12199

[66]. Zheng, L., Houa, Y., Li, W., Yanga, S., Li, Q. and Yu, Z. (2012). Biodiesel production from rice straw and restaurant waste employing black soldier fly assisted by microbes. Energy, 47(1), 225-229. https://doi.org/10.1016/j.energy.2012.09.006

[67]. Zurbrügg, C., Dortmans, B., Fadhila, A., Vertsappen, B. and Diener, S. (2018). From pilot to full scale operation of a waste-to-protein treatment facility. Detritus, 01, 18-22.

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