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Understanding the life cycle and benefits of black soldier fly and its prospect in Bangladesh

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Abstract

Black soldier fly *Hermetia illucens* (Diptera: Stratiomyidae), an insect that most commonly used as animal feed, consume copious amounts of organic waste to develop their bodies, which are composed of 40–48% protein, 30–38% fat, and a variety of vital minerals. While the higher fat content of black soldier fly may be a necessary component for the manufacture of organic fertilizer, the higher protein content may be utilized to either fully or partially replace the very costly fishmeal. In addition, the black soldier fly eliminates some hazardous bacteria and insect pests and has a better capacity to convert organic waste. The population of world continues to rise, hence there is a rising demand for animal proteins, surpassing supply and leading to the production of organic waste. Larvae may also remove trace elements like copper and zinc, and produce high-value products with low quantities of heavy metals. There are new and inventive applications for black soldier fly byproducts in fields like bioplastics, medicine, and renewable energy. Black soldier fly pre-pupae samples were processed and examined by a number of researchers in Bangladesh to determine their proximate compositions, minerals, amino acids, and fatty acids. Pre-pupae of cultivated black soldier flies have a significant concentration of certain minerals (Ca, Ni, and Co), suggesting that they might serve as a valuable source of mineralized animal feed. Significant amounts of both necessary and non-essential amino acids were found in the pre-pupae, indicating that the cultured black soldier fly was in a healthy state. Pre-pupae were found to be a potential source of essential fatty acids. Their cultivation required minimal resources, making it affordable for local farmers. Additionally, with the global rise in demand for insect-based feed, Bangladesh could position itself as a supplier in this emerging industry. Expansion of this sector could drive job creation and improve food security. The aim of this review is to understand the prospects of this emerging technology, evaluates its constraints and respond to open research questions by means of lab scale experiments in Bangladesh.

Keywords: *Hermetia illucens*, rearing, challenges, aquaculture, animal feed, waste management

Introduction

The rapid population growth of the world is driving the need for sustainable protein sources. Animal-based foods (dairy products, eggs, fish, and meats) and plant-based foods (cereals, beans, potatoes, vegetables and fruits) are the main sources of protein for human consumption (Wu *et al.* 2014). In Bangladesh, total fresh water fish production is 40.53 lakh metric tonnes (DoF 2024) and contribution in GDP is 2.8%. In case of poultry industry total production is 3857.04 lakh with GDP of 1.5% (BBS 2023). On the other hand, another big sector, livestock contributes around 1.80% in GDP where total production is 453.595 million (BBS 2024). However, these sectors face many problems, such as fresh water fish production constraints including–lack of quality seed, disease outbreaks, environmental degradation, pollution, predation, inadequate infrastructure, improper management practices, traditional cultural strategies and others. Some major problem of poultry industry are disease outbreaks like bird flu, high feed prices, lack of access to credit, competition from imports, market volatility, poor management, qualities of chicks-vaccines, security of investment etc. Furthermore, livestock deals with the challenges like animal diseases, climate change, poor quality feed, lack of pasture, scarcity of water resources, poor veterinary care, lack of organized market, inadequate business plan, poor technology adaption, gender inequality and others. A wide range of insect species are being utilized in aquaculture, poultry, and livestock industry as feed ingredients. Among them black soldier fly has vast potential to contribute in these sectors. Black soldier fly, (*Hermetia illucens,* Diptera: Stratiomyidae) is a harmless insect. Due to their ravenous desire for organic waste, such as food scraps and agricultural leftovers, these larvae reduce trash buildup by turning them into usable biomass (Surendra *et al.* 2015). Black soldier fly larvae have a remarkable nutritional profile and abundant

in vitamins, minerals, vital amino acids, and protein sources like soybean meal and fish meal (Barragan *et al*. 2017). A key component of the black soldier fly larvae has potential for bioconversion which is their capacity for material reduction. Through digestion, these larvae have an amazing capacity to decrease the weight and amount of organic waste. Farmers and small business owners may become more resilient to market swings and natural dangers by developing new value chains and making extra money from the sale of pre-pupae gathered for animal husbandry or other uses. Conversion of organic refuge by saprophages has been an issue over the last few decades (Elissen *et al*. 2006). The Conversion of organic refuse by saprophyges initiative, which uses the BSFL technique, converts waste and remaining organic biomass into secondary raw materials, such as molecules of interest for green chemistry (Santangelo *et al.* 2024). Changing to different poultry species, such water flows, which may be reared with different feed (snails, water hyacinth), is one way to combat excessive feed prices. The fly has potential to utilize and boost the economy of low and middle income nations. Based on the commercial production and unitization, it is utmost need **t**o learn about the current status of rearing method, and to understand the future opportunities, prospects and challenges of black soldier fly rearing in Bangladesh.

Black soldier fly

The harmless insect black soldier fly, *Hermetia illucens*, is a true fly (Diptera) of the family Stratiomyidae. This insect has the potential to address two vital issues in modern agriculture: it can handle organic wastes responsibly, provide an alternate source of protein for animal feed, and produce a large number of byproducts and fertilizers (Taiwo and Otoo 2013). The black soldier fly was first identified in France by Chevin (1986) in the southeast, then by Dauphin (2003) in the southwest, and Richoux (2009) in the Rhone valley (Richoux 2009) in the vicinity of Poitiers (Maquart *et al.* 2020). The fly originated in 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 five unique life cycle phases of the black soldier fly insect are egg, larvae, pre-pupae, pupae and adult (Newton *et al*. 2005). Black soldier fly takes 40–44 days to complete the whole life cycle . The fertilized eggs hatch at a temperature of 24°C in 102–105 hours (Tumpa *et al*. 2021). Larvae that have just hatched are opaque-white in color and eagerly move toward the substrate to feed on whatever food is accessible at that stage of their lives. The larvae achieve maturity in about two weeks (Sheppard *et al*. 2002, Myers *et al*. 2008).

Egg: Eggs are usually creamy yellow in color and take 4 days to incubate and hatch under optimum conditions of around 20°C to 30°C (Newton *et al*. 2005).

Larva: Because of photophobic nature, the larvae have a dull, yellowish hue just after hatching and attempt to hide from light (Newton 2015). For the majority of their existence, it consume food scraps and manure wastes, quickly converting them into calcium, protein, and fat. The ideal temperature range for larvae to effectively use feed is between 27 and 33˚C (Alvarez 2012). Lower temperatures are probably feasible since the metabolism of larvae and feeding activity will provide some heat, enabling their growth in colder regions (Newton 2015). Larvae attain full size (20 to 25 mm) in about 4 weeks at ideal conditions; but, if temperature and sufficient nourishment are not available, it may take up to 2-4 months (Newton 2015). The moisture level of ideal feed varies from 60% to 90% which is crucial for the growth of black soldier fly.

Pre-pupa: When the black soldier fly larvae (12.5 mm-long grubs) reach their maximum size (Burtle *et al*. 2012), the larvae cease eating, turn black, and harden their skin; at this stage, known as the pre-pupa stage. Migratory larvae secrete chemicals that other maggots can follow which form a migration pattern. This pattern depends on humidity and temperature also (Myers *et al*. 2008).

Pupa: In addition to becoming drier, the pupation location needs ambient humidity values of around 60% in order for the adults to emerge. Pupation may take five to seven days,

depending on the surrounding humidity and temperature (Myers *et al*. 2014).

Adult: After 10–14 days at 27–36 ˚C, adults emerge from their pupae cases (Myers *et al*. 2014). The adults rely on the lipids accumulated from the larval stage for their activities and do not eat; instead, they consume water or other liquids when available (Newton 2015). Two days after emerging from the pupal stage, adults mate (Myers *et al*. 2014) and after copulation, females deposit their eggs in dry cracks and crevices close to their larval home The fly is similar in size to a honeybee, measuring between 13 and 20 mm, and it only lives for 6 to 10 days in adulthood. As they are photophilic, adult flies need temperatures between 5˚C and 35 ˚C as well as bright sunshine spectrums in order to facilitate mating (Newton *et al*. 2005)..

Importance of black soldier fly

It can take the place of 10%–20% soybean meal for broiler chickens that exhibit similar productivity, feed efficiency, mortality, and carcass characteristics as chickens given commercial feed (Cullere *et al*. 2016). Moreover, Arango *et al.* (2005) recommended that based on their mineral needs, the black soldier fly larvae contain a reasonable quantity of minerals for domestic bird diet.

Larvae as fish feed: In Bangladesh, total aquaculture production is 4.62 million metric tonnes (DoF 2021). Black soldier fly larvae can be used as a protein replacement in fish diets. Various researches have been done on this sector and the outcome is positive. Bangladesh has abundant fisheries scope where black soldier fly larvae can be utilized as a supplement to fish diet.

Larvae as poultry feed: Poultry industry size in Bangladesh is approximately over 3.7 million (BBS 2023). Black soldier fly larvae grown on organic waste or kitchen residues, have been shown a satisfactory result as a feed supplement for poultry chicks (Hale, 1973). In the experimental diets, black soldier fly larvae or pre-pupae were substituted for soybean meal (47.4%) and soybean oil (100%) (Kawasaki *et al*. 2019). For broiler chickens that demonstrated similar production performance, feed efficiency, mortality, and carcass features as those fed on commercial feed, it can be used in place of the 10%–20% soybean meal (Cullere *et al*. 2016).

Recycle food waste: Nguyen *et al.* (2015) found that the pre-pupae stage of this insect can be harvested and used as a valuable nutritious feed for animal livestock. Five waste types with a wide range of organic source matter were specifically chosen to evaluate the consumption and reduction ability of black soldier fly larvae. *H. illucens* was able to reduce all waste types. Among them waste reduction was highest in fruits and vegetables (30%) and lowest in manure waste (13%) while others included fish rendering (22%), kitchen waste (20%), and pig liver (15%).

Organic fertilizer from black soldier fly larvae: Choi *et al*. (2009) reported that the bioconversion of food waste produced promising results relating to the use of the waste residue as an imcompound for conventional fertilizer. Menino *et al*. (2021) found that black soldier fly showed a significant effect on ryegrass production with increase amount of organic matter and fertilizer with a constant increase of dehydrogenase activity.

Table 1. Mineral composition of black soldier fly pre-pupae on a dry matter basis

Mineral composition (mg kg-1) ± MU			
Elements	Concentrations	Elements	Concentrations
Na	0.26 ± 0.03	Mn	62.8 ± 4.4
P	1570.9 ± 282.8	Cu	8.26 ± 0.59
Ca	42,151 ± 3540.7	Co	0.26 ± 0.02
K	5838.3 ± 1261.1	Ni	0.97 ± 0.08
Fe	152 ± 12.2		
Zn	31.8 ± 3.69		

Financial benefits of black soldier fly larvae

Municipal waste management problems: Large chicken farm houses, pig farms, and cow farms are among the agricultural settings where black soldier fly maggots have been employed to stabilize troublesome wastes, such as swine, bovine, and poultry manures, (Sheppard and Newton 1994, Axtell 1999). An estimate from 2019 states that highest waste collection in Dhaka reach up to 89,235 tons in one month (Anonymous 2020). We can effectively satisfy the protein requirements of our fish and poultry diets by turning that waste into fertilizer and protein.

Solving antibiotics and pesticides problems: Poultry feed contains both harmful tannery waste and antibiotics which is harmful for human health. In addition, the overuse of chemical fertilizers, herbicides, and pesticides on agricultural land contaminates the vegetables being produced, leading to illnesses of the stomach, liver, and kidneys and a steady death toll. In this instance, the black soldier fly larvae can contribute to a sustainable ecosystem through farming (Pal *et al*. 2023).

Environmental factors for growth: A past study reports that the black soldier fly is sensitive to the abiotic factor of the environment (Mutafela 2015). The required parameters may vary with the development stages. The factors include temperature, relative humidity, light, diet, and pupation substrate.

Bangladesh has a favorable weather for black soldier fly culture : Bangladesh has a warm, humid climate that is regularly affected by tropical cyclones and high precipitation. The annual rainfall is about 237.6 cm. It is also subject to pre- monsoon, and post-monsoon circulations. In the past years, the average temperature of Bangladesh has been about 26°C, with annual variations between 15°C and 34°C. Bangladesh has up to 80% relative humidity on average between June and September. In some places, it varies from 60 % to 70 %. The climate of Bangladesh is therefore ideal for the development, incubation, and hatching of black soldier fly larvae.

Current status of the rearing of black soldier fly in Bangladesh : Ferdousi *et al*. (2022) reared black soldier fly pre-pupae to be used as a feed source for livestock and fish. Larvae of black soldier fly with organic waste substrates were collected from the municipal dustbins situated at the laboratory road area of Dhaka metropolitan city, Bangladesh in July 2019. The experiment was conducted at 28 ± 5°C with 50–65 ± 10% relative humidity under a photoperiod of 14 h light and 10 h dark period. The gathered larvae were placed with substrate in a 10-liter plastic container with a cover that had four openings in the top. Next, the larvae container was set on top of a plastic dish that had sawdust inside of it. Mature larvae, also known as pre-pupae, ceased eating after 6–8 days and congregated in the sawdust. These were then gathered in a plastic container after being sieved to remove the pre-pupae from sawdust. The first harvest weighed 30 g on the sixth day, whiles the second and third harvests, which came on the seventh and eighth days, weighed 60 g and 20 g, respectively. For the analysis of nutrients in the laboratory, the black soldier fly pre-pupae were killed by freezing and stored at - 20°C until analysis.

Several laboratories of the Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka, Bangladesh, processed and triple-analyzed all samples of the black soldier fly pre-pupae for proximate compositions, minerals, amino acids, and fatty acids. These were then oven-dried at about 70˚C for 48 h. The dried samples were powdered in a quartz mortar with a pestle and collected to store at - 4˚C for further analysis.

The mineral composition of the black soldier fly pre-pupae is shown in Table 2. The level of Ca found the highest and the concentrations of Ni and Co were also higher. A considerable presence of some minerals (Ca, Ni, and Co) in cultured black soldier fly pre-pupae indicates that it may be used as a good source of mineralized animal feed (Ferdousi *et al.* 2022).

Leucine and methionine had the greatest and lowest amounts, respectively, among the necessary amino acids depicted in Table 2 of the black soldier fly pre-pupae. Glutamic acid and cysteine had the highest and lowest concentrations among the non-essential amino acids, respectively. The pre pupae were discovered to have significant levels of both necessary and nonessential amino acids, including alanine, arginine, aspartate, glycine, and proline. This suggested that the cultivated black soldier fly pre-pupae were in a healthy state (Ferdousi *et al.* 2022).

Table 2. Amino acid profile of black soldier fly pre-pupae on a dry matter basis

Amino acids (Essential)	Contents (g kg-1)	Amino acids (Nonessential)	Contents (g kg-1)
Histidine	9.2	Alanine	18.4
Isoleucine	13.1	Arginine	17.1
Leucine	21.3	Aspartate	29.1
Lysine	18.3	Cysteine	0.9
Methionine	1.3	Glutamic acid	33.1
Phenylalanine	8.2	Glycine	19.1
Threonine	9.8	Proline	17.2
Tryptophan	2.8	Serine	10.7
Valine	16.7	Total amino acids	246.3

Total unsaturated fatty acid (TUFA) content was found to be less than half that of total saturated fatty acid (TSFA) level in Table 3. Lauric acid (C12:0) was discovered to be the largest quantity among the TSFA, while Pentadecyclic acid (C15:0) was found to be the lowest. Compared to the other measured unsaturated fatty acids, the quantities of monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) in the TUFA were found to be almost similar. PUFA and linolenic acid were the two types of TUFA that had the largest and the lowest levels, respectively. It is possible to think of the increased black soldier fly pre-pupae as a reliable supply of important fatty acids. (Ferdousi *et al.* 2022).

Black soldier fly eggs cost

Hatchers can charge Tk 150 per kilogram for their eggs. The larvae are now gathered for fish and poultry farms. The cost of one kilogram of larvae would be Tk 200.

Black soldier fly farming in Bangladesh : There are perhaps a hundred small-scale insect farming efforts across the nation, each with a different background and set of lessons learned, but none of them have connected waste management to the issue at hand. For instance, Duranta, a member of the agricultural and cooperative affairs subcommittee, started organic farming on his ancestral property in Purbadhala upazila in the Netrokona district. Later, he moved his property to the Keraniganj area during the Covid-19 epidemic. He gathered around a ton of larvae and pupae each month. The larvae are now served with Nuruzzaman's broiler chicken. There are about 600 hens on his farm. He began bug farming when the cost of traditional chicken feed increased to Tk 3,300 every 50-kilogram bag.

Sustainable business prospect : Food insecurity, a lack of protein, malnutrition, and poor sanitation are predicted to be the main worldwide dietary issues by 2050 (FAO, 2013). The constantly growing human population, together with a variety of agricultural farms, municipal markets, homes, supermarkets, industries, animal rising, and human settlements, create an enormous amount of

Table 3. Fatty acid profile (%) of black soldier fly pre-pupae on a dry matter basis

Fatty acids	Contents (%)	Fatty acids	Contents (%)
Decanoic acid (C10:0)	0.71	Palmitoleic acid (C16:1)	2.03
Lauric acid (C12:0)	45.26	Oleic acid (C18:1)	13.74
Myristic acid (C14:0)	6.90	Monounsaturated fatty acids	15.77
Pentadecyclic acid (C15:0)	0.10	Linoleic acid (C18:2) (Omega-6)	15.33
Palmitic acid (C16:0)	12.85	Linolenic acid (C18:3) (Omega-3)	1.64
Stearic acid (C18:0)	1.44	Polyunsaturated fatty acids	6.97
Total saturated fatty acids	67.26	Total unsaturated fatty acids	32.74

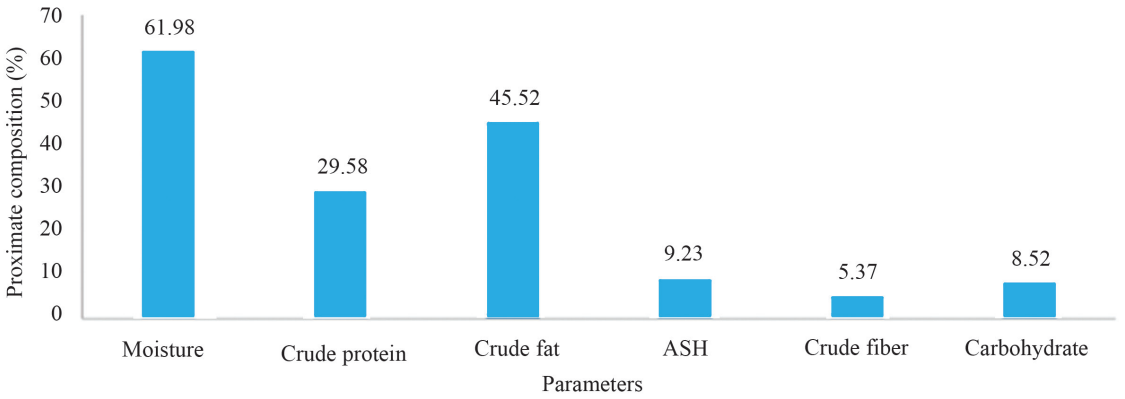


Figure 1. Proximate composition (mean ± SE) of black soldier fly pre-pupae on a dry matter basis.

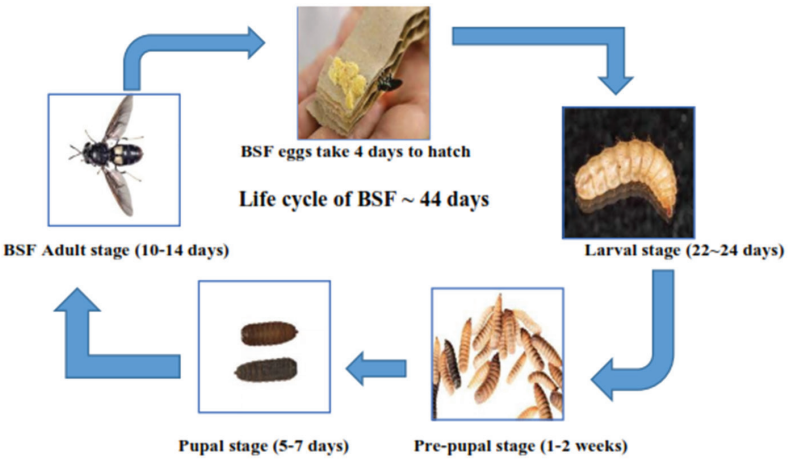


Figure 2. Life cycle of black soldier fly.

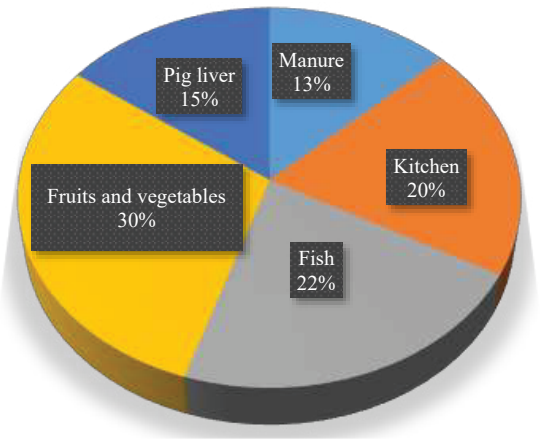


Figure 3. Waste reduction (%) by black soldier fly pre-pupae.

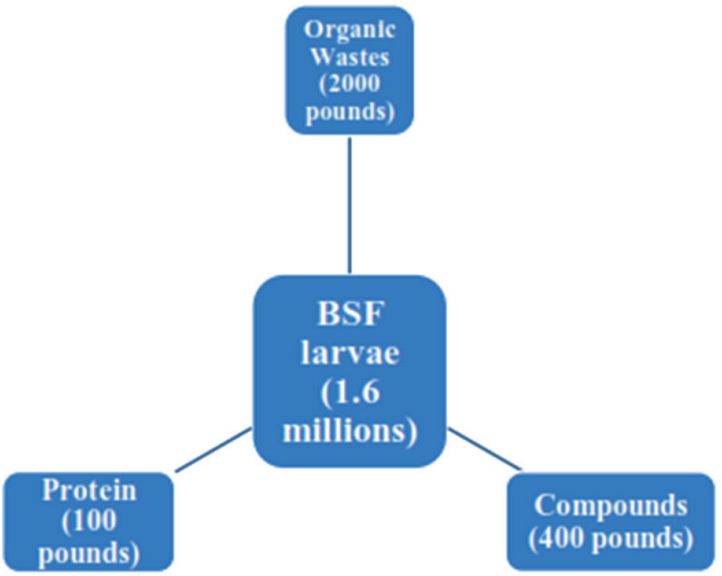


Figure 4. Efficiency of black soldier fly in waste management.

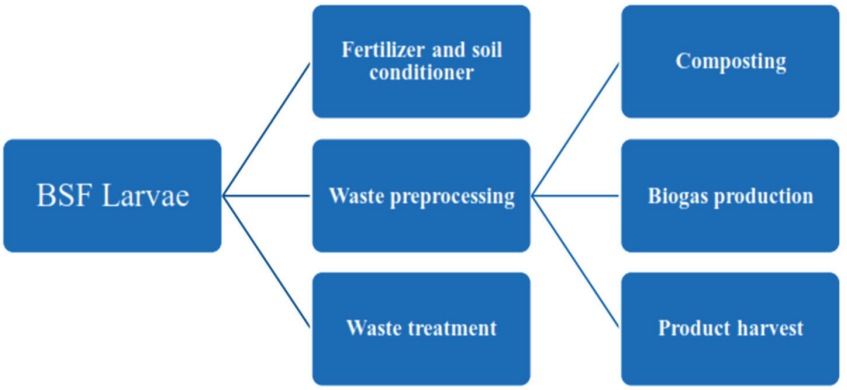


Figure 5. Conventional waste processing system using black soldier fly larvae.

organic waste (Van Huis *et al*., 2013). Black soldier fly bioaccumulation might be exploited to repurpose this substantial amount of garbage. Women and low-income impoverished individuals might be employed in black soldier fly farming under such an initiative. Obtaining new, affordable black soldier fly production facilities would undoubtedly boost social and economic safety by creating job possibilities for the marginalized community. A staggering 70% increase in food production is required by 2050, according to some projections, in order to feed everyone on the world.

Prospects of rearing black soldier fly in Bangladesh

Sustainable waste management: Larvae of black soldier flies break down complex organic waste materials such proteins, carbohydrates, lipids, and cellulose using specific digestive enzymes. The breakdown of waste is accelerated by this procedure.

Alternative protein source: In animal feed for fish, shrimp, pigs, and poultry, black soldier flies are utilized as an alternate source of protein. For instance, there is no adverse effect on chicken development, meat quality, or biochemical markers when less than 20% black soldier fly is added to chicken feed.

Circular economy model: Black soldier fly depends on organic waste, significantly reducing landfill reliance and the associated environmental issues. The black soldier flies then becomes a valuable resource – a nutrient-rich source of protein for poultry, fish, and even pet food.

Reduced environmental impact: Black soldier fly conserve water by utilizing less water than traditional livestock. Frass, which is a result of processing black soldier flies, can be utilized as an organic fertilizer. By boosting carbon content and enhancing water and mineral retention, frasses can enhance soil health. Organic waste conservation can lower greenhouse gas emissions, particularly methane.

Bioconversion technology: Black soldier fly larvae can convert organic waste into biomass that is high in protein and fat. It is a viable source of safe compost. Additionally, larvae can extract trace elements like copper, zinc, and create high-value products with low-heavy metal concentrations.

Research and innovation: Innovative applications of black soldier fly byproducts are emerging, including areas like bioplastics, pharmaceuticals, and renewable energy. Research is exploring the potential uses of chitin, lipids, and other compounds derived from black soldier fly, opening doors to new, sustainable industry solutions.

Food security: The black soldier fly, which is primarily used in animal feed, has a significant potential to provide a sustainable supply of nutrients for human use (Bessa *et al.* 2020). Their ability to transform waste materials into premium proteins, lipids, and minerals has led to significant research and cultivation.

Commercial interest and investment: Black soldier fly paved a way of significant commercial sectors such as, animal feed, fertilizer production, waste management, and cosmetics manufacturing.

Challenges of rearing black soldier fly in Bangladesh and solutions

Although accessibility and finding top-notch fodder for the black soldier fly larvae are significant obstacles, black soldier fly larvae can flourish on a range of organic resources including manure, food waste, and vegetable scraps.

Infrastructure: Black soldier fly farming requires specialized infrastructure, such as equipment for processing, waste management systems, and facilities for growing larvae.

Funding: Securing funding can be a challenge for farmers who may not have access to traditional financing options. Alternative funding sources, such as microloans or crowd funding, can provide a means for farmers to access the capital they need to start their businesses.

Regulatory barriers: Among the regulatory obstacles faced by farmers include obtaining permits and licenses to operate, abiding by environmental requirements, and safety and health rules. Simplifying the regulatory process and advocating for supporting policies can aid in addressing these issues.

Collaboration and knowledge-sharing: Creating a network of farmers or hosting industry gatherings may provide farmers a platform to exchange best practices, gain knowledge from one another, and work together on initiatives.

Awareness and support for black soldier fly farming: To address this issue, collaborations with neighborhood non-governmental organizations and educational initiatives might be formed to increase awareness and give farmers information.

Mass production scaling: Scaling up production to meet commercial demands can be challenging. Maintaining consistent and large-scale production of black soldier fly larvae requires efficient farming practices.

Feedstock quality and availability: The quality and availability of organic waste or feedstock significantly impact the growth and development of black soldier fly larvae. Inconsistent or poor-quality feed can lead to variations in larval development and nutritional content.

By-product utilization: Efficiently utilizing all by-products of black soldier fly rearing, such as frass and residual biomass, is important for maximizing the economic and environmental benefits of the process.

Disadvantages and constraints of rearing black soldier fly : The major drawback of black soldier fly for biodegradation is that it needs a warm habitat, which in temperate countries might be challenging or energy-intensive to maintain.

The very tiny parasitic wasps lay their eggs in young black soldier flies. The wasp eggs laid within the larvae of the black soldier fly will hatch, and the subsequent progeny will eat the fly until it is killed. Although they are not known as a disease vector, adult soldier flies are a potential mechanical vector of various pathogens.

Conclusion

The black soldier fly is a very helpful insect with very few detrimental effects on the ecosystem. Bangladesh, an impoverished nation, can use this insect to breakdown organic waste from municipal solid wastes, replace animal and poultry feed, and create biofertilizer. This mini-review provides a comprehensive summary of the most recent research on artificially rearing black soldier fly, the effects of various waste types and their co-digestion or waste stabilization performance, the effects of different organic waste fermentation with microorganisms in conjunction with black soldier fly, and the commercial applications of this technology. To guarantee prompt reaction to new developments and difficulties, it is imperative that this research be conducted with close collaboration between researchers, plant operators, and regional planners through tightly knit information exchange networks.

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