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Black Soldier Fly Production: An Innovative Solution to Municipal Waste Management and Sustainable Business Prospect in Bangladesh

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ABSTRACT

The Black Soldier Fly is a harmless, environment-friendly and beneficial insect whose larvae in the form of pre-pupae can be used in low and middle-income countries like Bangladesh to transform organic waste into valuable and affordable fisheries and animal feedstuff, which in turn, will help yield healthy poultry products-a source of good quality human protein. This article describes the fairly novel approach of bio-waste conversion by insect larvae, the BSF and its all potentials, including the value addition through sustainable revenue generation, and improving human nutrition. We conclude that being a poor densely populated country, Bangladesh can utilize this insect for managing municipality organic wastes, and with appropriate scaling up the initiative can become a sustainable business approach for livelihood, can save millions of foreign currencies for Bangladesh, and most importantly can help alter the dynamics between population, natural resources and climate change and its adaptation.

Introduction

Like many Low- and Middle-Income Countries (LMICs), rapid population growth continues to be a major underlying force of reducing the quality and quantity of natural resources in Bangladesh through overexploitation, intensive farming, depleting natural resources including the land for various reasons, for example, landfill by huge emitting wastes, and thus, re-utilizing wastes in a beneficial form could be a potential approach for Bangladesh to conserve limited natural resources. 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. Various pre-processed wastes, such as inedible parts of food crops or animals, wastes from food production and processing, the unsold portion from the markets, and post-consuming wastes, can be listed in this category. The wastes vary considerably in their configuration, comprising sugar cane pulp and bagasse, 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 is the single largest component of landfill waste in developed and developing nations alike, although more so in the latter (Mohee et al., 2015). Organic waste accumulation in urban and peri-urban areas has severe environmental pollution, human health hazards, and impacts. Insects' (for example, BSFs) ability to eat waste adds benefit outside of food and feed for organic-waste management (Lohri et al., 2017).

Insects at all life stages, especially in larval conditions, are rich sources of essential nutrients, protein, fat, and minerals, thereby, they have prospects as feed for humans and domestic animals like fish, poultry, duck, rabbits, and swine (Nogales-Mérida et al., 2018) with added advantage that their meals are less environmentally destructive and often cheaper than other animal feed ingredients, namely soy and fish meal. Currently, the BSF breeding 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. The development of the utilization technology, increasing the rearing technology's effectiveness and the prospect of obtaining valuable by products all encouraging the domestication and utilization of BSF. This article explored the potential of large scale BSF larvae production as a sustainable business approach and cost-effective solution to the municipal organic wastes in Bangladesh.

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 a Honeybee 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 a vector of any transformable contagious diseases (Tomberlin et al., 2002). The insect is 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 temperatures throughout its life cycle, except during the oviposition period (Barry, 2004). 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).

The life cycle of Black Soldier Fly

According to Newton et al. (2005), the BSF insect has five distinct life cycle phases: egg, larvae, pre-pupae, pupae, and adult. BSF completes its full life cycle between 40 to 44 days.The fertilized eggs hatch between 102 to 105 hours at 24°C temperature (Li et al., 2011). Newly hatched BSF larvae are opaque-white and actively crawl towards the substrate, where these feed on whatever food is available 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. Moreover, larvae can consume harmful pathogens and minimize harmful effects (Erickson et al., 2004). In 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 the mass-rearing of the insect and guide them for self-collection as pre-pupae (Diener et al., 2011). The weight of the larvae is about 0.2g and 25mm in length in the last stage,and 6mm in diameter. Despite being small, the larvae are tough and robust and can still survive extreme oxygen deprivation if need be (Sheppard et al., 2002). Another five substages must pass within the larval stage (Hall and Gerhardt, 2001).

Black Soldier Fly Organic Waste Processing System

The BSF organic waste processing facility consists of waste pre-processing. These few steps are-

- Particle size reduction-The size of organic waste is reduced as being devoured by BSFL.
- Dewatering-Sludge water is being reduced from waste as the maximum waste is being devoured by the larvae.
- Inorganic waste removal-Then the residual inorganic waste is being removed.
- BSFL bio-waste treatment
- Separation of BSFL from the process residue
- Refining larvae and residue into marketable products.

A basic BSF treatment process is shown in the figure below. This system consists of the larvero, which is a place where the larvae grow, while the fly house is where the adults reside and breed. A proper rearing environment that maintains healthy adult and larval BSF is essential to ensure a sufficient and continuous supply of offspring for organic waste treatment. Larvae and frass are the by-products produced in biomass by the end of the BSF treatment process, which can be converted into animal feedstuff and organic fertilizer. Overall, BSFs are particularly compelling since they offer a natural and cost-effective potential alternative for recycling biological waste.

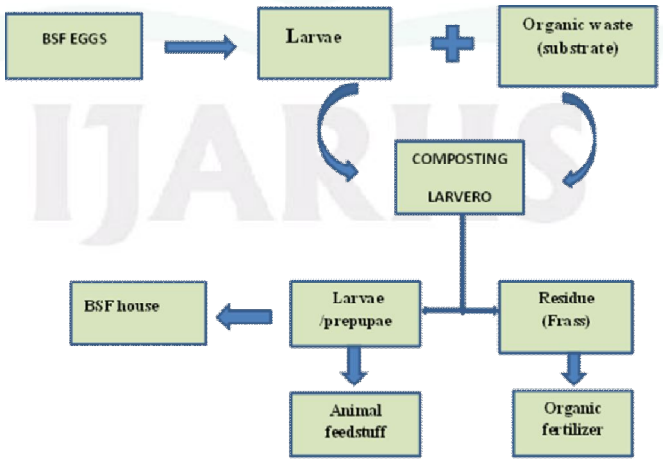
Environmental factors for growth

A past study reports that the BSF 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. The ecological requirements for the growth and reproduction of BSF are summarized in table 01.(Stefan Diener, 2011)

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/m2/s with optimal 110µmol/m2/s and wavelength 450-700 nm.

Why is the weather of Bangladesh favorable for BSF Culture

Bangladesh has a humid, warm climate influenced by pre-monsoon, monsoon and post-monsoon circulations and frequently experiences heavy precipitation and tropical cyclones. Bangladesh's historical climate has experienced average temperatures **around 26°C but range between 15°C and 34°C** throughout the year. The average relative humidity in Bangladesh remains up to80 percent from June to September. In some places, it varies from 60 percent to 70 percent. So the climatic condition of Bangladesh is completely favorable for the cultivation, breeding and production of BSF larvae.



BSF larvae as poultry feed

The BSF larvae grown on organic waste or kitchen residues have been shown a satisfactory result as a feed supplement for poultry chicks (Hale, 1973). It can be used as a replacement for the soybean meal

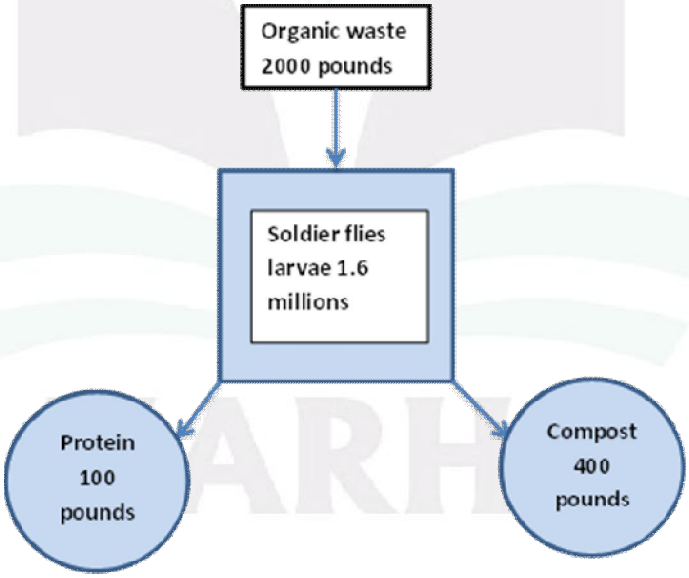
of 10-20% for broiler chicken showed production performance, feed efficiency, mortality, and carcass traits like those fed on commercial feed (Cullere et al., 2016). Fifty percent or complete replacement of soybean meal with moderately de-oiled BSF larval meal in the diet for egg-laying chicken did not modify their laying performance nor feed efficacy than standard organic diets for layers (Maurer et al., 2016). The high 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

BSF larvae can be used as a protein replacement in fish diets. Various research have been done on this sector and the outcome is positive. 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 (Tachysurusfulvidraco) (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).Bangladesh, being a riverine country, its fisheries resource is huge. It can be very beneficial for this country if BSF larvae can be used as a fish feed supplement.

Organic fertilizer from BSF larvae

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 imcompound for conventional fertilizer. The researchers found similar results from BSF biofertilizers and enhanced microbial fertilizers. Besides, scientists found similar growth between Chinese cabbages, one with BSF biofertilizer and the other with microbial fertilizer.



BSF eggs cost

Hatchers can sell the eggs at Tk150 per kilogram. In the second stage, larvae grow from the eggs in around 22 days. At this stage, the larvae are collected for poultry and fish farms. Each kilogram of larvae would cost Tk200.

BSF Farming in Bangladesh

There are around 100 individual farmers' simple initiatives of insect farming in the country with different experiences and learning but none of them conceptualized the problem and having

connection with waste management. For example, Duranta agriculture and cooperative affairs sub-committee member of Awami League - initiated organic farming on his ancestral land at Purbadhalaupazila in Netrokona district. Later, during the outbreak of the Covid-19 pandemic, he shifted his farm to the Keraniganj land. At the Sonamati Agro field, he cultivates vegetables besides farming fish and cattle. When Duranta started insect farming a year ago, the price of each kilogram of larvae was Tk. 4,000. But now, he sells 1kg of larvae at Tk500. Monthly, he harvests around one ton of larvae and pupae.

A Munshiganj-based poultry farmer Nuruzzaman collected 5kg pupae from the Sonamati Agro farm one month ago. The pupae grew into adults and bred eggs. Nuruzzaman now serves his broiler chicken with the larvae. He has a poultry farm of around 600 chickens. As the price of the conventional poultry feed became expensive – Tk 3,300 per 50kg bag - he started insect farming.

Municipal Waste Management: problems in managing both quantity and quality

The use of BSF for waste management has been introduced previously. BSF maggots have been used in agricultural settings to stabilize problematic wastes, including swine, bovine and poultry manures in climates that sustain BSF year-round: these settings include large chicken farm houses, pig farms and cow farms (Sheppard and Newton 1994; Axtell 1999). The BSF's ability to digest other wastes, including the organic portions of MSW, wastewater treatment sludge and fish rendering wastes, has been studied by other researchers.

Improving the quality of life of all farmers in an effort to make agriculture, poultry, fisheries and animal husbandry sustainable in our country- is the main goal of farming this BSF larva. The main objective is to help the country become self-sufficient by reducing the country's dependence on imports and producing high protein feed and organic fertilizer for fish, poultry and domestic animals through bio-conversion of household waste with the help of black soldier fly larvae.

Existing Problems in Waste Management

One-third of the food produced in the world today is wasted before it reaches people's tables. Studies show that High-income countries waste as much food as sub-Saharan Africa produces. These food wastes rot in landfills, releasing greenhouse gases, polluting the environment and causing human suffering, including disease. Combined, this food waste would make it the world's third-highest emitter of greenhouse gases, behind the United States and China.

The black soldier fly's main diet is organic matter. And our country is struggling with waste management. Black Soldier Fly could be a unique solution to this. According to an estimate from 2018, 30 thousand metric tons per day in eight divisional cities waste is produced. We can convert that waste into protein and fertilizer, which will play an effective role in meeting the protein requirements of our fish and poultry diets.

Antibiotics and Pesticides Problems

Antibiotics and toxic tannery waste are being used in poultry feed. As a result, human health is under threat; children and pregnant mothers are the most affected. Moreover, the use of pesticides, herbicides and excess chemical fertilizers on agricultural land is contaminating the vegetables that are being produced, which are causing kidney, liver and stomach diseases, and people are constantly dying. So it is time to think and do something alternative. In this case, the cultivation of black soldier fly larvae, the best friend of the farmer, can bring a sustainable environment.

Challenges of current organic waste management

Meeting the growing demand for food, feed and fuel and, in parallel, handling a significant amount of waste, particularly organic waste, has become a key global challenge (Surendra et al., 2016). Due to the perishable characteristics, low calorific value and high organic matter content, organic waste is only sometimes easy to dispose of in a sanitary landfill or by incineration. Moreover, landfill gases or GHGs are produced by breaking down organic waste in landfills. In terms of composition, landfill

gases are approximately 50% CH4, 50% CO2 and a small quantity of non-methane organic compounds (Coskuner et al., 2020; US EPA, 2021). Methane is a powerful GHG that traps heat in the atmosphere 28–36 times more efficiently than CO2 (US EPA, 2021; Valta et al., 2019). Landfill gases (CH4 and CO2) also lead to air pollution, smog and aggravating asthma (Ali et al., 2021; Gies, 2016).Managing organic wastes is more challenging due to their large natural and rapid biodegradability (Nanda and Berruti, 2021; Yin et al., 2014). Existing organic waste management practices, specifically land filling and waste disposal/stabilization through anaerobic digestion and composting, comply with environmental regulations but are high in cost and additionally induce adverse effects on the environment, such as groundwater and surface water pollution, GHG emissions and animal/human health issues (de Titto and Savino, 2019; Singh et al., 2020; Yin et al., 2014). On the other hand, due to the rapid growth of the global population, it is believed that relative affluence has led to a sharp increase in the demand for food, feed and fuel, as well as the production of waste. As a response to the growing pressure of organic waste, major environmental issues are believed to arise in the near future. Therefore, developing resource utilization strategies for organic waste in the recycling economy is crucial and needs to meet zero waste concepts in the future.

Solving Problems with Black Soldier Fly Larvae

Farmers, fish farmers, and poultry farmers can provide low-cost live feed and soil fertility-regulating micronutrients by adopting black soldier fly larvae farming. As a result, besides their financial savings, the household waste treatment also provides environmental protection, protein-rich live feed for fish and poultry, and high-quality microbial fertilizers. Apart from that Production of black soldier fly larvae in poultry or dairy farms and pet faeces provides both live feed and easy treatment of farm waste.

Sustainable Business Prospect

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 toward 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 thepeople 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, creating nuisance and health hazards (Diener et al., 2010; Taiwo and Otoo, 2013; Van Huis et al., 2013). This vast proportion of waste could be reused through BSF bioaccumulation. In such a venture, low-earning poor people, as well as women, could be employed in BSF farming. Gaining new, low-cost BSF production facilities will definitely pave employment opportunities for the marginal population and increase economic and social safety.

According to certain studies, food production will have to be increased by a whopping 70% by 2050 to feed every person on the planet. The need for protein consumption is ever-present in consumers, but by trying to meet that need, the current practices of the traditional meat industry result in a growing burden on the environment through excessive deforestation, water consumption, and a large carbon footprint.

Black soldier fly larvae farming and insect protein processing are not just good for the environment: it represents a profitable business opportunity for farmers. Compared to traditional livestock, BSFL farms can be set up much more easily, and raising the insects requires much less effort.

Conclusion

Black Soldier Fly is a very beneficial insect, having negligible negative consequences on the environment. Bangladesh, being a poor country, can utilize this insect in order to disintegrate municipal solid organic wastes, poultry and animal feed substitute and biofertilizer, and if appropriately scaled can become a sustainable business approach for livelihood, save millions of foreign currencies for Bangladesh, and most importantly can help alter the dynamics between population, natural resources and climate change and its adaptation.

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