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Exploring Black Soldier Fly-Based Waste Management in India: Insights from a Student Survey

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Our ever-growing global food production and food consumption rates produce a large quantity of organic waste such as agricultural residues, livestock waste, food scraps, etc. Annually, 1 billion metric tons of food waste are generated worldwide. In India, each person is responsible for generating 55 kg of waste per year. A large portion of this waste goes untreated, which poses a variety of harmful effects on the environment and human society, such as soil and water contamination, the release of greenhouse gases (methane, CO2, etc.), and increased risk of disease spread. To mitigate the impacts of organic wastes, the adoption of natural waste conversion methods is vital. The Black Soldier Fly (*Hermetia illucens*) offers a sustainable solution through its larvae (BSFL), which efficiently decompose organic waste and also produce a variety of valuable products. The decomposition rate of Black Soldier Fly Larvae (BSFL) is rapid, and they are highly adaptable to diverse waste environments, which makes them uniquely suited for scalable resource recovery. Field studies demonstrate their ability to decompose waste while producing nutrient-rich compost, protein-dense animal feed (32.53% protein content by dry weight), bio-oil (>60% polyunsaturated fatty acids), and antimicrobial compounds. These outputs help address gaps in waste management and resource scarcity. For example, from 10 tonnes of food-waste input, 300 kg of dried larvae and 3,346 kg of compost are produced. Integration of BSFL for organic waste decomposition will reduce the burden on centralized waste management systems. Decentralized BSFL units will enable waste processing to be done at the site of waste generation itself, reduce dependency on landfills, and help generate income through compost, feed, or oil sales. By integrating Black Soldier Flies into agricultural systems, this approach not only solves the issue of environmental harm but also takes care of the ecological and economic needs of a nation.

Keywords: Black Soldier Fly Larvae (BSFL), Organic waste, Waste decomposition, Resource recovery

Problem statement

The organic waste generated through daily human activities across agricultural, municipal, and industrial sectors poses a significant threat to sustainability across the globe. Agricultural activities produce a large amount of waste, primarily including livestock excreta, crop residue, etc., followed by sewage, food processing products such as sugar mill effluents and paper-pulp residues, etc. (Parvaze & Kumar, 2019). At the same time, households and industries also contribute notably: around 7–10 billion tonnes of solid wastes are produced each year throughout the world, with an average of 0.74 kg per person on a daily basis and a range from 0.11 to 4.54 kg based on specific regions (Neeraj et al. 2023). The problem of organic waste is further exacerbated by food waste discarded by households. An Indian household produces around 55 kg of food waste per capita annually. This translates to a total of 78.2 million tonnes of food waste per year, which is around 40% of the total food

produced in India (Kashyap, 2024). The percentage value of total wasted food out of total food produced in the USA is lower (27%) than India's, but the actual value is 63 million tonnes (ReFED 2025). The negative impacts of this waste are profound. The production, processing, transportation, etc., activities of food production release greenhouse gases, which are emitted for no purpose when all the food goes to waste (UBQ 2024). Also, when this waste decomposes in landfills, it releases more greenhouse gases. Methane, a greenhouse gas released in landfills, is 25 times more potent than carbon dioxide and persists in the atmosphere for 12 years (Lewis, 2022). Organic wastes not only aids in climate change but are also involved in the loss of natural resources: the land, freshwater, etc. As an example, crops raised on land degraded due to improperly managed agricultural waste—like livestock slurry and industrial effluents—absorb toxic compounds from contaminated soil, subsequently entering human food chains at a later time (NetSol Water Solutions, 2024). Sources of freshwater, which are important for both drinking and agricultural purposes, are also affected by leachates from landfills and untreated sewage sludge (UBQ 2024). The land used for dumping is wasted in two manners: firstly, the land could be utilized for other beneficial purposes, and secondly, it is being degraded due to dumping itself (Lewis, 2022). This large-scale production of organic waste is a direct threat to global sustainability frameworks. The United Nations Sustainable Development Goals (SDGs), particularly SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 6 (Clean Water and Sanitation), are jeopardised by unchecked organic waste. Although partial solutions exist, such as biogas plants, they introduce secondary challenges, such as careful disposal of the slurry produced to avoid soil and groundwater contamination. There is a dire need for the development of new methods or increased awareness about newly developed practices for the treatment of organic waste.

Study

To confront the growing problem of organic waste, A survey was conducted among some students of Chaudhary Charan Singh Haryana Agricultural University, Hisar. The survey was done with the following objectives:

I. To study the existing waste management behaviours in the surveyed community.
II. To check the awareness of the Black Soldier Fly (BSF) in the surveyed community.
III. To study the extent of knowledge among those aware of the Black Soldier Fly.
IV. To study the willingness to adopt the Black Soldier Fly for organic waste management.

The survey was done on a total of 40 students. The questions were designed to be in line with the objectives, and the results were also evaluated on the same objectives.

I. Existing Waste Management Behaviour

a) Among the 40 respondents, only 37.5% segregated their wastes regularly at home, the rest either didn't segregate wastes (17.5%) or they segregated their wastes occasionally (45%).
b) Only 25% of the respondents were satisfied with their area's management system (rated it as "good" or "excellent") and the rest either considered it as "average" (45%) or were not happy with their area's management system (30%, rated as "poor" or "very poor").
c) When respondents were asked about the various challenges faced during the waste disposal, the majority of them were not satisfied with the pickup services of their area's management system (60%) and 35% agreed that there was no system in place.

The data suggest that the majority of the people are dissatisfied with existing waste management systems due to bad pickup services and the absence of proper disposal mechanisms. There is also a lack of personal efforts on the waste management, indicated by low segregation rates.

II. Awareness and Knowledge of Black Soldier Fly (BSF)

a) 40% of the total respondents were aware of the BSF larvae and among those aware only a small percentage were really familiar with the uses of the BSF larvae (7.5%).

b) Those among the aware, only 7.5% knew three or more different applications (Waste management, Animal feed, Fertilizer, Bio-oils) of the BSF larvae.

The findings reveal that only a minority of people are aware of the Black Soldier Fly and the in-depth knowledge of the application of BSF is also very limited. This reflects a big knowledge gap which should be addressed to improve the adoption status of the BSF technology.

III. Willingness to Adopt Black Soldier Fly Technology

a) 35% of the respondents were recommending BSF as a solution to the waste problems in India while 45% were unsure.
b) Only 12.5% of respondents were not willing to install a BSF unit if supported by the government and the rest were either willing (42.5%) or they were unsure (45%).
c) A majority of the respondents were agreeing to implement the BSF into national schemes like Swachh Bharat or Startup India (70%) while the rest were neutral.
d) 62.5% of respondents agreed that Black Soldier Fly should be introduced in school/college curriculums and the rest were unsure, but no one disagreed.

The results demonstrate that although there's low awareness of the Black Soldier Fly, there is great promise for its acceptance. The majority of people were open to government-led implementation and in support of integrating BSF in national-level programs.

Conclusion

The Black Soldier Fly technology has the capability to become a sustainable and effective method for organic waste management in India. However, to implement it successfully, there is a need to bridge the existing knowledge gap by educational initiatives and government-based programs. With the proper support, Black Soldier Fly can play a big role in tackling India's waste management challenges.

Implications/Results

The survey was conducted to address the problem of organic waste in India by implementing the Black Soldier Fly (BSF) technology as a viable solution. The goal of this initiative is to mitigate the present environmental degradation scenarios due to organic waste while producing economic benefits alongside. The Black Soldier Fly (*Hermetia illucens*) is a species of Diptera belonging to the Stratiomyidae family (Soldier Flies). Its life cycle closely resembles the standard life cycle of an insect, which is composed of 4 stages: egg, larva, pupa and adult. The larva of the Black Soldier Fly is of primary importance due to its role in organic waste management. These larvae are ravenous feeders of organic matter, including kitchen scraps, garden waste, animal manure, human excreta, agricultural residues, and even decomposing carcasses. The length of the larval stage can vary from 18 to 36 days, depending on the quantity & quality of the available organic as well as prevailing environmental conditions. Adults of these flies do not feed on anything and only depends on the energy reserves gathered during the larval stages, due to which, they do not pose any danger to crops, do not transmit disease and are harmless to humans as they cannot bite or sting. Beside their waste management capabilities, the larvae also have multiple other advantages such as:

1. **Sustainable Feed**: The larvae act as a protein-rich alternative to traditional poultry and aquaculture feed. At the pupal stage, they comprise 32.53% protein, 22.10% lipids, and 21.56% ash (by dry weight), positioning them as a nutritious and ecologically sound option.
2. **Human Consumption**: Comparable to fishmeal or poultry feed, Black Soldier Fly larvae can be converted into protein-enriched food products for human diets, offering a sustainable strategy to address global food insecurity.
3. **Oil Extraction**: Oil extracted from the larvae is abundant in polyunsaturated fatty acids (over 60%) and saturated fats (up to 37%), with linoleic acid (C18:2 n-6 cis) constituting the primary component. This oil exhibits potential for nutritional and industrial applications.

4. **Antimicrobial Properties**: The larvae synthesise peptides with antimicrobial efficacy against bacteria, fungi, parasites, and viruses, creating avenues for pharmaceutical research and development.
5. **Housefly Control**: By transforming organic waste into a liquid-like substrate, Black Soldier Fly larvae render environments unfavourable for housefly larvae, effectively curbing pest populations naturally.

In the context of organic waste decomposition, Black Soldier Fly technology is exceptionally efficient. It can convert 10 tonnes of organic waste into 300 kg of protein-rich biomass and 3,346 kg of compost. The Black Soldier Fly can be implemented as decentralised model of organic waste management, reducing dependency on landfills. If this technology reaches on a larger scale, it has potential to transform organic waste into a circular economy resource, balancing ecological preservation with socioeconomic advancement.

Challenges and perspectives

Sustainable organic waste management with the help of Black Soldier Fly (BSF) technology, like decentralised organic waste processing along with other applications like protein-rich feed production, or implementing it into agriculture systems for nutrient cycling, faces serious challenges like lack of awareness, incompetent infrastructure, and limited economic incentives. The survey also showed that a majority portion (85%) of the surveyed population associates insects with uncleanliness or disease, indicating low willingness to adopt insect-based solutions to organic waste. To tackle these challenges, there is need of collaborative efforts of governments, agricultural institutions, and communities to adopt Black Soldier Fly based waste management systems. Organization of training programs to increase awareness, establishment of decentralised BSF processing units, and showing the waste treatment potential of BSF can help in addressing the issue ground level. Ultimately, expansion of BSF technology on a larger scale holds promise for mitigating environmental degradation and enhancing the resource recovery efficiency.

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