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Assessing The Scope of Black Soldier Fly Larvae (Hermetia Illucens) Incorporating It into Sustainable Development

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Abstract

Solid waste management is critical to reducing pollution, recycling, and the amount of bulk solid waste dumped, as well as to educating households and addressing the energy crisis that results from population growth. Like other developing nations, India's economic development initiatives produce an excessive amount of waste, which is then disposed of by the side of the road. This reckless human negligence practice poses numerous environmental risks and contributes to the phenomenon of global warming. It has been reported by the Central Pollution Control Board (CPCB) that there is a significant discrepancy in the wastewater generated, collected, and treated. It is possible to transcend organic solid wastes like rotting fruits and vegetables, leftovers from slaughterhouses, fish wastes, pig and cattle dung, etc., into an alternative source of energy. A feasibility study of three generations of Black Soldier Fly (BSF) was conducted and their performance with prevailing atmosphere were analysed by Linear regression. Results shows that BSFs were significantly affected with variations in atmospheric parameters ($R=0.557$, $R^2=0.312$, $P=<0.05$). The aim of the study is to gain comprehensive understanding of the practical ways to use BSFs to convert organic solid wastes into alternative energy sources.

Keywords: Black soldier fly, organic solid waste, economic, global warming, alternative source, regression.

Introduction

Black Soldier Fly (BSF) larvae are being increasingly studied for their nutritional value and potential applications, particularly in animal feed and waste management (Siddique et al., 2022) due to their high protein content and efficient conversion of organic waste into biomass (Rana et al., 2015, Mithun et al., 2020) in growing countries environmental awareness is critical to avoid the complications which is caused by improper waste management techniques. It is witnessed Piles of wastes near the suburbs of the municipality resulting from the negligence of adopting proper collecting and disposing wastes from residential buildings, schools, colleges, hostels, lodges, public gatherings, cultural festive, etc., there is a compulsion to implement appropriate solid waste management methods to avert health hazards which can arise from these waste materials. Developed countries incorporated suitable methods to recycle of solid

wastes through policy making (Bazmi et al., 2011).

Open dumping sites acts as a hub of disease spreading pathogens (Kwun Omang **et al** 2021), in addition it also causes environmental issues such as degradation of land, pollution of water bodies near dumping yard, bad odour occurs wastes such as fish wastes, chicken wastes, etc., left behind by wandering animals and birds. Further it tends to affect the quality of ground water through leaching of harmful chemical substances and heavy metals (Igboama et al., 2022).

The Black Soldier Fly (BSF) larvae offers a unique and environment friendly solution to managing solid waste while simultaneously providing an alternative source of energy (Kim et al., 2021). These larvae have an exceptional potential to efficiently consume organic solid waste, including food scraps, agricultural by-products, and other biodegradable materials (Pastor et al., 2015). As the larvae feed on this waste, they undergo rapid growth and transformation, converting the organic matter into protein-rich biomass. Gut microbiome in BSF larvae has the potential to reduce the amount of heavy metals such as Co and Zn (Tao li et al., 2024) present in the organic solid wastes. The process of incorporating BSF larvae to manage solid waste not only reduces the volume of waste sent to landfills but also generates valuable biomass (Newton et al., 2005; Bondari et al., 1981; Bonelli et al., 2020) that can be utilized as a sustainable alternative energy source. BSFL rich in protein and fats (Barragan-Fonseca et al., 2018) can serve as feedstock for animal feed production or even biofuel conversion (Surendra et al., 2016). Additionally, the residual after the larvae consume the organic matter is significantly reduced in volume and often transformed into nutrient-rich compost (D Sarpong 2019), further contributing to environmental sustainability.

Maggots known as Black Soldier Fly (BSF) are considered a suitable candidate for these forward-thinking goals. According to observations of BSF larvae (BSFL), they grow quickly throughout their life cycle and feed on organic solid wastes. According to the Indian National Census, 45.5% of the population (2021–2022) is employed in agriculture, which accounts for the majority of rural residents' income. India's agriculture is heavily dependent on the country's climate, and it requires a significant amount of labour and capital, both of which are counterproductive to the industry's goal of profit and worsen the financial burden on the families who depend on it. This will enable sustainable economic growth to occur alongside traditional agricultural practices, while also attempting to reduce the cost of multiple capital requirements.

Life cycle of BSFs

Figure 1: Life cycle of Hermetia illucnes

1. **Egg Stage:** The life cycle begins when adult female BSFs lay eggs in egg woods placed inside the love cage. These eggs are carefully collected and then placed on tissue paper, it would take 3 to 4 days to hatch under optimal conditions, then they mobilize themselves where the substrate is kept it was mostly decaying organic solid wastes.
2. **Larva Stage:** The hatched BSFL are vigorous eaters and they were provided with sufficient feedings and covered with mosquito nets to prevent them from any harmful creatures would hunt them. Limited range of solid wastes are only adopted throughout the study trials periods. It is the beginning stage where the larvae undergo multiple instars when the grow.
3. **Pupa Stage:** As the BSFL reaches pupa stage it isolates from the substrate, if it is wet to a dry place. Coir pith usually serves this purpose, spread under the plastic container. Some of them required to be picked up manually. Transformation from larva to fly takes place at this phase. Transition to pupa stage consists of 6 instars.
4. **Adult fly:** Emergence of adult flies inside the love cage where the pupae stage larvae are placed would take up to days to months when the optimal atmospheric conditions prevail at rearing station. Hydration facility is provided for the flies.

Morphology of BSFL

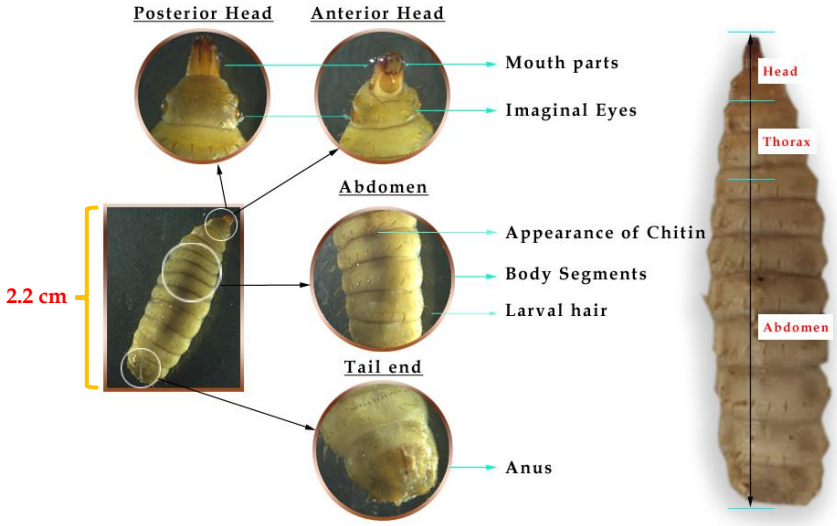


Figure 2 : Optical Microscopic images of BSFL

SWOT Analysis of BSFL

Strength:

BSFL consists of all the essential amino acids which are building blocks of protein and rich in fatty acids. They can consume a wide variety of solid wastes and converts into an alternative source of energy by keeping the economic circle in flow. Hence BSFL reduces environmental impact by converting organic solid wastes into superior quality of insect meal for various animals. Chitin which is drawn form BSFL has the scope of being used as bio degradable packaging material which can reduce plastic burden on the environment (Soetemans et al., 2020) , it also possess other characteristics such as metal bio sorbent (Zlotko et al., 2021), acts as an antibacterial and antioxidant agent, air permeability of chitin could be utilized in the desired field of technology (Xioang et al., 2023, Pedrazzani et al., 2024). Lipid content in the BSFL constitutes for up to 40% of their body weight, Fatty acids largely depends on the diet which

they feed on . Predominantly lauric acid a medium-chain fatty acid extensively researched for its health benefits in animal feed industries (Pimentel et al., 2017, Hoc et al., 2020, Nekrasov et al., 2022).

Weakness

Environmental conditions play a crucial role in the rearing of BSFL, it requires continuous monitoring of a suitable environment, if any volatility occurs in the process it greatly affects the performance and reproductive rate of the larva and adult flies respectively (Salam et al., 2022, Ferronato et al., 2024). Another important factor is that the availability of feedstock for BSFL, any fluctuation on sourcing organic solid wastes due to seasonal variations mitigates the larvae growth and overall production (Lalander et al., 2019, Montevecchi et al., 2023). Implementing BSFL production on large scale may require high capital and labour investments this cost could rise the price of the products derived from the larvae farming method (Raman et al., 2022).

Opportunities

Protein content in BSFL constitutes more than 40 % of their body mass which serves great source of amino acids rich feedstock for animals (Zozo et al., 2022). BSFL oil extracted from the fatty acids present in their body composition exhibited a improved quality of feed conversion ratio in broiler chickens over study conducted for a month (Kim et al., 2020), bio diesel can be produced from fatty acids of BSFL by harvesting them in their earlier instar (Wong et al., 2019). BSFL can be used as a feedstock for aquaculture because of their higher nutritional values, in particular defatting process improves the macro and micro nutrient composition (Saputra et al., 2023). Full fat BSFL introduced in post – weaning of pigs did not result in any adverse effect on performance and chitin improved digestibility, further it reduced dependency of ***Lactobacillus*** in their colon (Håkenåsen et al., 2021). Heavy metals present in organic solid wastes does not accumulates in BSFL which ensures it is safe animal feed (Bohm et al., 2022)**.** BSFL farming can promote entrepreneurship as an attempt to reduce poverty due to unemployment from producing wide variety of products such as compost, bio-diesel, fish meal cake (Choudhury et al., 2020, Pal et al., 2023). BSFL has the potential can be used as food for human food because (Bessa et al.,2020). It can serve as a sustainable source of energy by exhibiting great waste reduction rate and it keeps the circular economy alive (Cattaneo et al., 2024).

Threats

Social stigma especially in India prevents people from adopting insect based farming and eating them as a great source of protein. Climate change which is exacerbated by natural phenomena called El-Nino during the observation period affected negatively the entire globe particularly the tropical regions are the worst hit. Heat wave during the summer season brought unprecedented adverse effect on all the living beings, it had significant influence on insect's life cycle. Major threats are arise in the form of composition of wastes given to the BSFL, notably carbohydrates rich wastes causes overwhelming fungi growth it could pose great growth risks to them. Other pathogens are also may contribute to decline in larvae population at any stage of their life cycle. Government policies and regulations must be eased for insect farming by identifying its great potential in the multiple sectors and should promote public awareness.

Optimal Rearing conditions of BSFL

SL.NO	PARAMETERS	OPTIMAL CONDITION (FOR GROWTH AND OVIPOSITION)	CITES
1	Temperature	27.5 °C to 37.5 °C (lower & upper thresholds are 15°C and 40°C respectively)	Chia et al., 2018; Anshika et al., 2022; Salam et al., 2022.
2	Relative Humidity	60% - 70% (Avg)	Dortmans et al., 2021; Holmes et al., 2012.
3	Moisture content	40% - 85% (Avg)	Bekker et al., 2021; Chen et al .,2019.
4	Light intensity	110 $\mu molm^2S^{-1}$ to 135 $\mu molm^2S^{-1}$	Park et al., 2016 ; Zhang et al., 2010
5	pH	6.0 – 10.0 (Avg)	Meneguz et al., 2018; Salam et al ., 2022.

Table 1 : Shows the optimal rearing conditions of BSFs

Feasibility study

The population dynamics of black soldier fly larvae (BSFL) were closely observed in a realistic study that lasted four months (**February 2024 – July 2024**). From a considerable amount of starting population (as reference of decedents), the BSFL larvae showed stunted growth and significantly reduced consuming ability despite adequate resources and feedstock. Initial observations on BSFL exhibited vigorous feeding rate and waste reduction performance as well. The main cause of this slow population drop was unfavourable weather. Three generations of BSFL has emerged throughout the course of the study, however by the third generation, the larvae had significantly reduced motility even healthier previously refused to consume, which finally resulted death at pre-pupa and pupae stages. This result emphasizes how important environmental conditions are to the survival and viability of BSFL colonies. The ideal rearing atmospheric condition of BSFL is compared with the actual weather that transpired at the rearing location.

Characteristics of Rearing setup and Substrate (RC)

The rearing facility is located under a metal-roofed shelter, which protects the well-ventilated plastic rearing substrate from direct sunlight and rain. A mating cage for the adult flies that emerge from the pupae of Black Soldier Larvae has been installed within this shelter. The flies are given sugar or honey syrup to ensure that they are properly hydrated. To keep outside animals out, the building is reinforced with steel mesh on all sides. The atmosphere inside the shelter is greatly influenced by the weather outside the setup. The rearing substrate, which facilitates the BSFL's feeding and growth, is daily checked and enhanced with a restricted range of foods. In addition, water is added when higher moisture levels are required, and rice husk is added as needed to absorb excess moisture.

Feeding pattern

An adequate quantity of waste was collected from the local fruit vendors. The wastes are usually rich in fiber except citrus fruits, whose skin is peeled and mixed with enough water within the rearing substrate every other day until the larvae reach their pre-pupae stage, at which point cessation of feed exists.

Methodology

Temperature and relative humidity are important determinants of larval activity, environmental parameters are expressed in relative terms. Observations was made on a judgement of the performance of the larvae on waste reduction rate, survivability, emergence as adult flies, and their ovipositional capacity on a Likert scale of 0 to 5. (5 = Excellent; 0 =Catastrophe). The parameters prevailed throughout the generations are averaged and presented in chart 1 (in which T_{max} = Maximum temperature, T_{min} = Minimum temperature, RH = Relative Humidity).

Analysis

Linear Regression analysis (IBM SPSS) with ANOVA at 0.05 confidence level was performed with parameters and observed performance scores of each three generations to establish a relationship against the null hypothesis (H_0).

Findings and discussion

Results ($R=0.557$, $R^2=0.312$, $P=<0.05$) indicates there was moderate influence of temperature and humidity on performance and its statistically significant. Throughout the study trials of three generations, it was witnessed drastic changes in atmospheric parameters which largely affected the larvae performance and their ovipositional capacity in their adult stage. Humidity plays a vital role on feeding, rapid decrease in atmospheric humidity absorbs the moisture from substrate which eventually resulted in caking of substrate, where larvae are trapped, immobile and died. Excessive substrate moisture also resulted increased larvae mortality. Over feeding resulted in stunted growth, proper substrate thickness and adequate ventilation to avert ammonia attack is imperative.

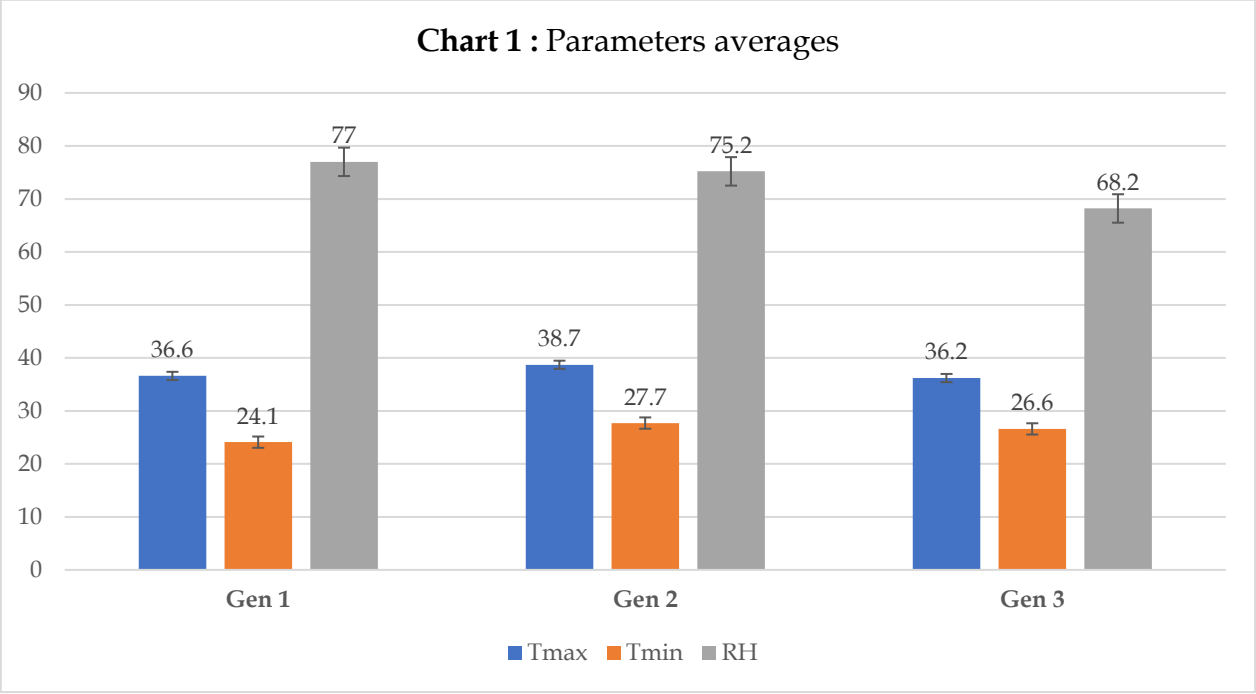
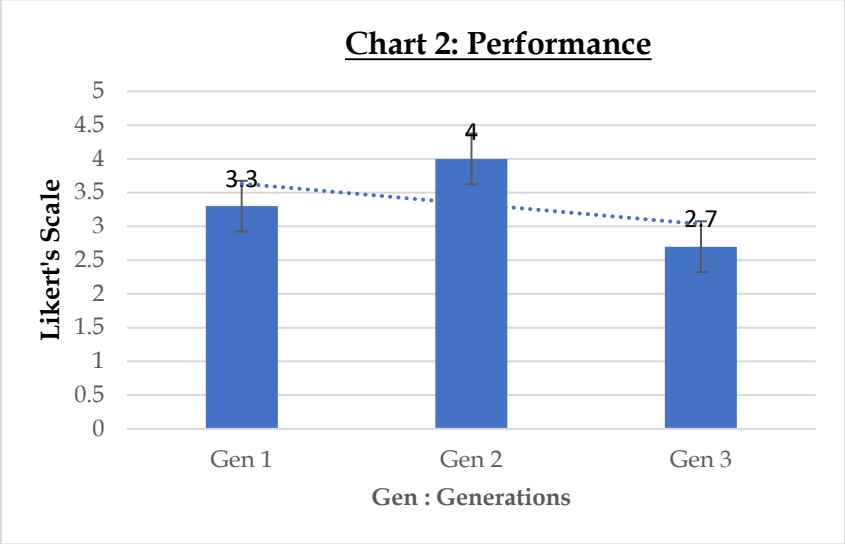


Chart 1 : Parameters averages

T_{max} and T_{min} are in °C

Relative Humidity in %



Generations	R	R^2	(ANOVA) P
Gen 1	0.564	0.319	significant (<0.05)
Gen 2	0.523	0.274	significant (<0.05)
Gen 3	0.586	0.344	significant (<0.05)
Average	0.557	0.312	significant (<0.05)

Table 2 : Shows the Regression analysis values of each generation of BSFs

Conclusion

The feasibility study trials revealed problems in rearing setup and the optimal environmental conditions for the BSFL, despite the continue monitoring third generation of eventually ended up in an absolute mortality. In consecutive studies these problems will be addressed and rectified, additionally innovative opportunities on larvae will be assessed, gradually maximizing the productions similar to a food processing industry will bolster the circular economy and will reduce the burden of unemployment.

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