Original Research Article

STUDIES ON THE BIOCONVERSION EFFICIENCY OF BLACK SOLDIER FLY LARVAE WITH VEGETABLE, FRUIT AND FOOD WASTE

ABSTRACT

Ever increasing organic waste generation worldwide necessitates sustainable management strategies and Black Soldier Fly Larvae (BSFL) is becoming an innovative biological tool for sustainably managing organic waste and serving as a supplement in animal feed production. Studying the bioconversion efficiency of BSFL on various types of organic waste would be helpful in organic waste management planning. Hence an investigation was made with vegetable, fruit, and food waste bioconversion using BSFL. The study revealed Substrate Reduction (% SR) of 60 to 67 percent, Efficiency of Conversion of Digested feed (ECD) of 9.2 to 10.8 percent, Bio Conversion Rate (BCR) of 4.8 to 5.7 percent, and Waste Reduction Index (WRI) of 3.75 to 4.18. Among the different substrates used, BSFL grown in fruit waste had the highest SR %, ECD %, BCR %, and WRI. The results suggest that BSFL-based bioconversion can be an effective and environment-friendly waste management and resource recovery technique to significantly lower the volumes of organic wet waste while converting it into high-value biomass and leading to a circular economy model.

KEYWORDS: Black soldier fly, Bioconversion efficiency, Organic wet Waste management, Waste reduction indices, Waste to Biomass conversion

1. INTRODUCTION

Black soldier fly larval (BSFL) farming is getting popularized nowadays as an innovative approach to waste to wealth, which is said to meet 12 out of 17 sustainable development goals (Fonseca et al., 2020). This process involves employing larvae of BSF *Hermetia illucens* L. (Diptera: Stratiomyidae). This larva is a voracious feeder of organic wet waste (Zheng et al., 2012). BSF larvae consume around 8-10 times their body weight and transform them into protein and fat and store them in their bodies.

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The management of biowaste, resulting from agricultural processes, urbanization, and population growth, has become a global concern with profound implications for food security, poverty alleviation, and the environment. The improper disposal, subpar treatment, and unregulated landfilling of biowaste in low- and middle-income nations pose significant threats to the environment and public health (Mishra & Suthar, 2023). According to the Food Waste Index Report by (Dutta et al. (2021), an alarming quantity of 931 million tonnes of food waste was generated in 2019, accounting for 17% of total global food production. This food waste is distributed across various sectors, with 61% occurring in households, 26% in food service establishments, and 13% in retail. Alongside the pressing issue of food waste generation, the exponential growth of the global population has led to an increased demand for animal-based protein (Van Huis et al., 2015). This heightened demand, in turn, triggers the overexploitation of natural resources. Insect-based bioconversion has emerged as a solution, gaining significant attention for several reasons.

BSF reduces the volume of biowaste, mitigating the need for landfilling and decreasing greenhouse gas emissions associated with waste decomposition. The protein-rich larvae can be used as a sustainable source of animal feed, reducing the pressure on traditional protein sources like soy and fishmeal, which often rely on resource-intensive agricultural practices. Additionally, the resulting frass (larval waste) from BSF bioconversion is a nutrient-rich fertilizer, closing the loop in nutrient cycling and promoting soil health (Matheka et al., 2022). This evaluative study holds immense significance in the context of evaluating the bioconversion efficiency of the BSF when it comes to processing food waste, vegetable waste, and fruit waste.

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2. MATERIALS AND METHODS

2.1. Procurement of Organic Waste

This study was carried out at the Department of Environmental Science, Tamil Nadu Agricultural University, Coimbatore by procuring organic wet waste materials from three key locations in the same regions: Uzhavar Sandhai (Farmers' Market, Cowley-Brown Road), a local fruit stall (Lawley Road) and student mess (University Mess, TNAU).

2.2. Rearing of Larvae

A total of 10 g of BSF eggs from Hindustan Protein, Palladam, Coimbatore, was procured and incubated in the hatchery unit. Newly hatched larvae were nurtured using four different feedstocks viz., rice bran powder, wheat bran powder, poultry feed, and wheat bread. Formulations were prepared to meet nutritional needs for the initial five days, a critical period in larval development. The five days old larvae were introduced to process three types of organic waste viz., fruit waste, vegetable waste, and food waste, ensuring a feeding rate of 200 mg/larva/day (Permana et al., 2018).

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2.3. Waste Processing

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The collected waste undergoes a pretreatment process before being fed to BSFL. The organic waste pre-processing such as particle-size reduction, excess water removal and inorganic waste elimination were required for the biowaste treatment, which promotes the larval growth and improve the substrate digestion (Myers et al., 2014) (Amrul et al., 2022). The inorganic waste materials like large chunks of plastic packaging materials were removed during waste processing as larvae take longer time for degradation and hazardous for their further growth (Dortmans et al., 2017). The fruit, vegetable and food waste used in this study were shredded and chopped into 2 cm after the removal of non-biodegradable materials. Additionally, the moisture content was reduced to 60%, optimizing conditions for efficient BSFL consumption. Initial weight and volume measurements were recorded to establish baselines for evaluating subsequent reductions during bioconversion. Pre-treatment techniques for enhancing substrate biodegradability and nutrient viability (Rehman et al., 2017).

2.4. Experimental Setup

This study utilized five-day-old BSFL for each treatment, in triplicates to minimize the error. Rearing took place under controlled conditions, maintaining a relative humidity range of 40-60% and a temperature of 32°C ± 3°C. Rectangular trays (60 x 45 x 15 cm) were used to maintain a controlled environment for larval development (Myers et al., 2014). This experimental setup is aimed at assessing the larvae's bioconversion efficiency in processing different organic waste types. Using a pestle and mortar, whole insects were ground before analysis. The insect samples were dried in a drying oven at 100°C to determine their moisture content using Equation (1) (AOAC, 1990).

$$Moisture\ content = \frac{(A+B-C)}{B} \times 100 \qquad (1)$$

A - Crucible weight, B - Sample weight, C – Weight of crucible after oven drying process.

The experiment spanned until 70% of the larvae had transformed into prepupae, concluding after 22 days post-hatching (Mahmood et al., 2023). The trays containing the larvae were weighed to determine both the final larval weight and the residual weight, which comprised the frass (larval excrement) and any unprocessed waste. **Fig 1** explains the methodology of bioconversion experiments.

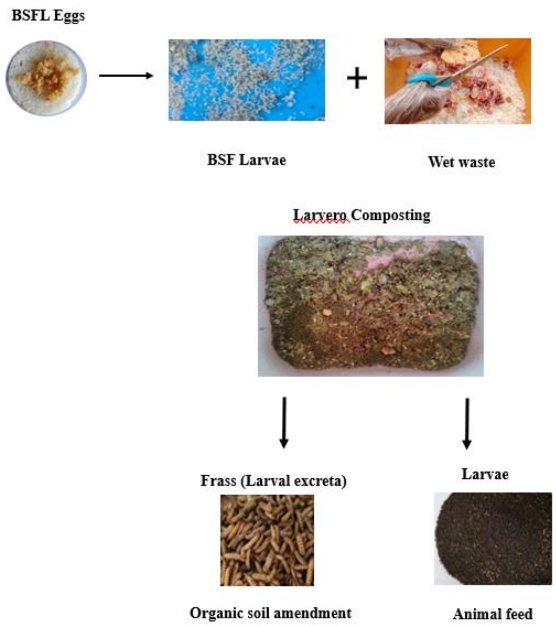

Fig 1. Methodology of bioconversion experiments

2.5. Waste reduction indices

The Waste Reduction Index (WRI) serves as a metric for assessing the larvae's efficiency in diminishing feeding substrates, with higher values indicative of a heightened capability to reduce organic matter (Diener et al., 2009). The waste reduction index (WRI) can be used to assess BSFL's ability to decompose waste within a certain period (Eq. (2) & (3)).

$$D = \frac{w - R}{w}; \qquad (2)$$

Where **D** is a percentage of degraded waste weight, **W** is a total amount of waste used, **R** is a final residual weight after the completion of the experiment, **t** is a duration of the experiment

$$WRI = \frac{D}{t} \times 100; \quad (3)$$

The efficiency of conversion of digested food (ECD) by larvae during the rearing period is calculated using eq. (4) given by (Pliantiangtam et al., 2021).

$$ECD = \frac{Larval\ and\ prepupae\ weight\ (g)}{Distributed\ substrate\ (g) - Residual\ substrate\ (g)} \quad (4)$$

The bioconversion rate (Waste to Biomass conversion **)** of BSFL is calculated according to (Gold et al., 2020) using the eq. (5)

$$BCR = \frac{Larvae_{gain}(g)}{Feed_{mass}(g)} \times 100 \quad (5)$$

The substrate reduction are calculated according to (Jucker et al. (2020) using the following eq. (6)

$$SR = W - \frac{R}{W} \times 100 \quad (6)$$

W = total amount of feed provided, R = remaining substrate

3. Results and Discussion

3.1. Waste reduction indices

This study reveals the versatile efficiency of BSFL in reducing fruit, vegetable, and food waste over the observed days. The reported WRI values further illustrate this variation, with fruit waste yielding the highest reduction index of 4.18, followed by vegetable waste (3.83), and food waste (3.75). These results are similar to 4.36 WRI in fruit peel waste (Priyambada et al., (2021) whereas 4.77 and 2.72 WRI were observed in fruit and vegetable wastes respectively (Zulkifli et al., 2023). These results highlight the significance between waste type and the duration of the bioconversion process, emphasizing the need for approaches to optimizing the efficacy of BSFL in waste reduction and bioconversion initiatives. **Table 1** provides a comprehensive overview of the biomass obtained and the efficiency of digestible feed conversion (ECD %) for three organic waste types (vegetable waste, fruit waste, and food waste) that are utilized in BSFL bioconversion. Examining each waste type individually reveals distinct performance characteristics. Fruit waste stands out with the highest biomass obtained at 0.80 kg *(dw)* and ECD of 10.8%, indicating superior conversion efficiency of digestible feed into valuable biomass. Vegetable waste follows closely with a biomass of 0.72 kg and an ECD of 9.7%, whereas food waste exhibits a slightly lower biomass of 0.68 kg and an ECD of 9.2% with a significant difference.

Table 1. The waste reduction indices of fruit waste, vegetable waste, and food waste.

Feedstock	Substrate reduction (SR %)	Efficiency of conversion of digested food (ECD %)	Waste to Biomass conversion (BCR %)	Waste Reduction Index (WRI)
Vegetable waste	61.3	9.7	5.1	3.83
Fruit waste	67	10.8	5.7	4.18
Food waste	60	9.2	4.8	3.75

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The bioconversion rates also known as waste to biomass conversion for BSFL fed with three organic wastes were determined based on the weight change from larval initiation to the point where 50% of larvae transitioned into prepupae. The bioconversion rate of BSFL in vegetable waste, fruit waste, and food waste was observed to be 5.1%, 5.7%, and 4.8% respectively. These results suggest high significance in converting larval biomass, emphasizing the larvae's adaptability and effectiveness in bio-converting different organic waste substrates which is similar to the findings of (Lalander et al., 2019).

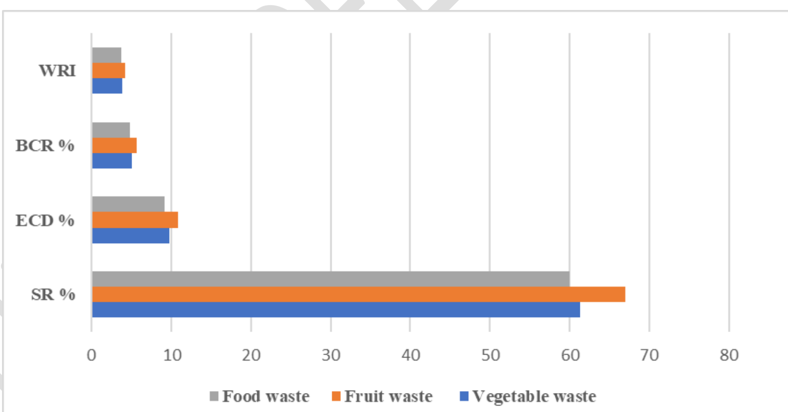

Fig. 2 Organic wet waste bioconversion with BSFL

The SR value of vegetable waste, fruit waste, and food waste by BSF were 61.3%, 67%, and 60% respectively (Fig. 2). These results showed high statistical significance among the different feedstock ($p< 0.05$) which was similar to the results of reduction efficiency in fruit waste combined with sludge

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in an equal ratio (50-70%) (Mishra and Suthur (2023). Total organic carbon and the carbon-to-nitrogen ratio significantly decreased as a result of BSF larvae, whereas the feedstock's total nitrogen, total phosphorus, and total potassium contents increased (Mishra and Suthur (2023). Therefore, BSFL-induced bioconversion proved to be an efficient method for organic waste management.

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4. Conclusion

The current study highlights the remarkable potential of BSFL in bio-converting wet organic wastes, (fruit waste, vegetable waste, and food waste) achieving a significant substrate reduction of 60 to 67 percent in 20 days. The waste reduction index, efficiency of conversion of digested food, and bioconversion rate exhibited the bioconversion efficiency of BSFL with the highest efficiency recorded in fruit waste as 4.18, 10.8%, and 5.7% respectively. Notably, the waste reduction index reflects the percentage decrease in waste over time, with fruit waste exhibiting the highest reduction, followed by vegetable waste and food waste. This hierarchy suggests that BSFL is particularly proficient at processing fruit waste, possibly owing to its composition and nutritional content. However, further studies may be taken up to further enhance of Bioconversion Rate by optimizing the climatic and substrate/waste characteristics.

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Reference

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