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Bioconversion efficiency of black soldier fly on different organic wastes

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Abstract

The present investigation was conducted to evaluate the bioconversion efficiency of the black soldier fly (*Hermetia illucens* L.) on different organic wastes viz., kitchen waste, cattle waste and poultry waste under protected conditions at the Department of Entomology, Rajasthan College of Agriculture, Udaipur, during 2025-26. The experiment was carried out in a completely randomized design with seven replications. A total of 2000 five to eight day old larvae were reared in plastic trays and fed daily at a uniform feeding rate of 250 mg larva⁻¹ day⁻¹ using different organic substrates. The effects of substrates on larval period, prepupal weight, pupal duration, feed consumed and bioconversion parameters such as bioconversion rate (BCR), feed conversion ratio (FCR) and feed reduction ratio (FRR) were assessed. The results revealed significant variation among substrates. The shortest larval period (22.56 days) and pupal duration (10.15 days) were recorded on kitchen waste, whereas the longest larval (33.43 days) and pupal periods (16.50 days) were observed on cattle waste. Maximum prepupal weight (0.26 g) and total prepupal biomass (521.14 g) were obtained on kitchen waste, followed by cattle and poultry waste. Kitchen waste also recorded the highest bioconversion rate (5.21%) and feed reduction ratio (76.53%), indicating superior nutrient utilization and waste reduction efficiency. In contrast, cattle waste exhibited the highest feed conversion ratio (24.59%). The findings indicated that kitchen waste was the most suitable substrate for mass rearing and efficient bioconversion of black soldier fly larvae, highlighting its potential as a sustainable solution for organic waste management and nutrient recycling.

Keywords: Black soldier fly, *Hermetia illucens*, bioconversion, kitchen waste, organic waste management, nutrient recycling

Introduction

The Black Soldier Fly (*Hermetia illucens* L.) is a synanthropic, polysaprophagous and cosmopolitan insect belonging to the order Diptera, family Stratiomyidae and subfamily Hermetiinae (Marshall *et al.*, 2015) [15]. According to estimates by the Government of India, nearly 115,000 metric tonnes of municipal solid waste are generated every day, with per capita waste generation ranging from 0.2 to 0.6 kg per day, depending on population size. A recent report by the Central Pollution Control Board (CPCB, 2021) [6] indicates that biodegradable waste accounts for the largest share of total waste generated, at about 52.32 percent. However, only a small fraction (12.45%) of the collected waste is scientifically processed, whereas the majority is discarded in open dumping sites. Landfilling continues to be the primary method for disposing of organic waste, although it presents significant environmental hazards such as global warming and contamination of soil and water resources (Christensen *et al.*, 2010; Bhada and Hoornweg, 2012) [5, 3]. In many Indian cities, particularly those other than metropolitan areas, open dumping remains a common method for the disposal of municipal solid waste, posing serious environmental and public health concerns. The uncontrolled burning and decomposition of such waste result in the release of toxic substances and greenhouse gases into the atmosphere. To address these challenges, the adoption of a comprehensive strategy known as Integrated Solid Waste Management (ISWM) is essential. ISWM integrates multiple waste management techniques, including incineration, composting, anaerobic digestion, refuse derived fuel production, material recovery facilities and sanitary landfilling, to ensure sustainable and environmentally responsible waste management (Pujara *et al.*, 2019) [24].

Waste management has become an increasing challenge in many developing countries due to rising waste generation and limited financial and institutional capacity, especially among rural local authorities. BSF larvae have the remarkable capacity to decompose organic waste and recycle nutrients, making them highly valuable for managing food waste in confined systems. Both the larval and prepupal stages are rich in proteins, minerals and other essential nutrients, making them an excellent feed source for aquatic organisms and domestic livestock.

Materials and Methods

Experimental setup

The hatchlings were reared in plastic trays 30 cm (length) × 20 cm (width) × 7 cm (height) using different substrates for each treatment. Treatments were replicated seven times in CRD. In each tray, 2000 five to eight day old maggots were released using a camel brush. The different organic wastes viz., kitchen waste, cattle waste and poultry waste are used as feed. A consistent feeding rate of 250 mg larva⁻¹day⁻¹ was maintained (Nana *et al.*, 2018) [20]. Thus, 500 grams of each particular organic feed were added to each plastic tray daily until pupation. Each tray was covered with a net cloth to avoid egg laying by other flies and insects. In order to separate the prepupae from the remaining feed residue, they were sieved through a mesh screen with a diameter of 5 mm.

Bioconversion efficiency

By calculating the Bio Conversion Rate (BCR), Feed Conversion Ratio (FCR) and Feed Reduction Rate (FRR), the effectiveness of BSF larvae to consume and reduce organic matter at a uniform feeding rate (250 mg larva⁻¹day⁻¹) was ascertained, as described previously by different authors (Barry, 2004; Diener *et al.*, 2011; and Zhou *et al.*, 2013) [2, 7, 32].

$$\text{Bioconversion Rate (\%)} = \frac{\text{Total pre pupal weight}}{\text{Total feed added}} \times 100$$

$$\text{Feed reduction ratio (\%)} = 1 - \frac{\text{Feed residue left}}{\text{Total feed added}} \times 100$$

$$\text{Feed conversion rate} = \frac{\text{Feed consumed}}{\text{Total prepupal weight}} \times 100$$

Observations recorded

Wet or fresh weight measurements were made of the initial weight of the feed substrates and residual feed for each application. The total amount of feed supplied and the total amount of feed left were computed at the conclusion. Last instar (prepupa), pupal weights and the amount of feed consumed by BSF larvae were also recorded. Additionally, the larval period, pupal period and individual larval weight (n = 30) were noted.

Statistical analysis

The experiment was conducted in a completely randomized design and the obtained data were transformed using an appropriate method and analysed through Analysis of Variance.

Results and Discussion

Larval period

The substrates that the BSF larvae were fed had a major impact on their developmental time. When the larvae become prepupae, they cease feeding. The larval period when black soldier fly reared on kitchen waste, cattle waste and poultry waste is 22.56, 33.46 and 29.76, respectively (Table 1). The current results are consistent with those of Khan *et al.* (2025) [11] 10,000 larvae were raised on an artificial feed consisting of 25 percent wheat bran, 10 percent maize flour and 65 percent water after being fed a conventional colony diet for five days. This resulted in a development time of 18.0±0.00 days. Oddon *et al.* (2024) [22] found larval development periods of 16.0, 24.2, 16.3, 20.9, 16.7 and 17.3 days on diets D₁-D₆ (made up of brewers' spent grain, vegetable and fruit waste). The larval stage of BSF raised on cow dung substrate lasted 30.6 days, which is consistent with the findings of Myers *et al.* (2008) [19], who discovered a similar time range of 25.84 to 31.49 days for BSF larvae to reach the pupal stage on cow dung.

Mean individual larval weight at last instar (pre-pupa)

The black soldier fly reared on kitchen waste, cattle waste and poultry waste had mean prepupal weights of 0.26, 0.16 and 0.15 g, respectively. The total prepupal weight (2000 larvae) is 521.14, 324.57 and 301.43 g, respectively (Table 2). The current findings are similar to those of Khan *et al.* (2025) [11] found that BSF larvae fed an artificial diet had a fresh biomass of 1847.9±43.04 g per 10,000 larvae following an initial 5-day normal diet. Taufek *et al.* (2024) [31] observed that chicken feed produced the most larval biomass (56.67±0.88 g), followed by mixed substrate (52.67±2.33 g), soybean curd residue (48.67±3.48 g), fish waste (44.67±0.88 g) and vegetable waste (39.33±0.88 g). Singh *et al.* (2022) [27] revealed that T₁-fruits and vegetable mix (0.142 g) had the highest average larval weight, followed by T₂-wheat bran, soy and corn meal mix (0.13 g) and T₃-dairy manure (0.105 g). Srikanth and Sharanabasappa (2021) [29] measured individual pre-pupal weights of 0.2 g for kitchen garbage and 0.17 g for fruit waste. Myers *et al.* (2008) [19] found that BSF raised on cow dung substrate showed a mean weight growth of 0.10 g per prepupa during the prepupal stage.

Pupal period

The mean pupal duration was significantly minimal on kitchen waste (10.15 days), followed by poultry waste (14.71 days); however, the maximum pupal duration was recorded on cattle waste (16.50 days) (Table 1). The results of the present investigation are parallel with the findings of More and Bhamare (2025) [18] who reported a pupation rate of 77.12±1.96 percent on poultry waste. Mahmoud *et al.* (2025) [13] found that the pupation percentages of moist forms of spent larval substrate, topsoil, vermiculite, potting soil and wood shavings were 97.3%, 96.5%, 95.5%, 95.3% and 94.3%, respectively. According to Singh *et al.* (2022) [27], T₁: fruits and vegetable mix had the highest pupation rate (84%), followed by T₂: wheat bran, soy and cornmeal mix (55%) and T₃: dairy manure (44%). Miranda *et al.* (2020) [16] found that larvae fed the Gainesville diet had the highest prepupation rate (88%).

Feed consumed

The feed consumed by black soldier fly larvae when reared on kitchen waste, cattle waste and poultry waste is 7653.43, 7973.43 and 6254.29 grams, respectively. These results are

consistent with the investigation by Mohod *et al.* (2024) ^[17] who demonstrated that 2000 BSF larvae consume 18.57 kg of kitchen waste. Madari *et al.* (2023) ^[14] reported that the feed consumed by 700 larvae was 1441.15 g out of 1500 g of kitchen waste. Srikanth *et al.* (2021) ^[29] demonstrated that larvae ingested 14±52.70 kg of kitchen waste out of 19 kg. Srikanth and Sharanabasappa (2021) ^[29] discovered that BSF larvae ingested 14,000 grams (6000 BSFL) of kitchen waste. Nana *et al.* (2018) ^[20] reported that 2641.2±4.2 g is consumed by larvae out of 3000 g of chicken manure.

Bioconversion rate (BCR)

The bioconversion rate of BSF larvae on kitchen waste (5.21%) was higher than that of cattle waste and poultry waste, which are 2.31 and 2.32, respectively. This remarkable efficiency in intake and digestion highlights the usefulness of kitchen waste as a nutrient dense substrate for BSF rearing. Cattle and poultry waste have BCR percent that are less suitable for the mass rearing of BSF. These results are consistent with the findings of Chapagae *et al.* (2025) ^[4] who reported that the BCR by BSF larvae is 5.23±.37 (%) on kitchen waste. Mohod *et al.* (2024) ^[17] revealed that the BCR on kitchen waste at 2000 larvae is 5.13 percent. Ganvir *et al.* (2022) ^[9] reported that the BCR on kitchen waste was 3.7 percent. Sumba *et al.* (2026) ^[30] reported that the BCR of bovine manure was 0.8 percent at a feeding rate of 50 mg day⁻¹larva⁻¹. Gold *et al.* (2020) reported that the BCR on cow manure was 3.8 percent. Rehman *et al.* (2017) ^[26] reported that the dairy manure BCR was 4.19±0.09 percent. Sumba *et al.* (2026) ^[30] reported that the BCR of poultry manure is 3.9 percent at a feeding rate of 150 mg day⁻¹ larva⁻¹. Osei *et al.* (2025) ^[23] reported that the BSF larva BCR was 0.70±0.08 percent on poultry manure with wheat bran.

Feed conversion ratio (FCR)

The feed conversion ratio of black soldier fly larvae is higher when reared on cattle waste (24.59%), whereas poultry waste and kitchen waste FCR are 20.76 and 14.69 percent, respectively. These results are consistent with the

results of Ahmed *et al.* (2024) ^[1] who reported that FCR on kitchen waste was 10.41 percent, whereas on chicken manure it was 11.71 percent. Mohod *et al.* (2024) ^[17] reported that the FCR of BSF on kitchen waste was 13.55 percent at a feeding rate of 2000 larvae 20kg⁻¹ kitchen waste. Madari *et al.* (2023) ^[14] reported that FCR on kitchen waste was 6.60 percent. Nana *et al.* (2018) ^[20] reported that the BSF larva FCR on kitchen waste was 15.3 percent at a feeding rate of 220 gm day⁻¹larva⁻¹. Rehman *et al.* (2017) ^[25] reported that the FCR is high on dairy manure (10.29%) as compared to chicken manure (5.56%). Nyakeri *et al.* (2017) ^[21] reported that the FCR on chicken manure was 13.4 percent, which is greater than that of restaurant food waste which is 2.6 percent.

Feed reduction ratio (FRR)

The feed reduction ratio by black soldier fly was higher on kitchen waste (76.53%) as compared to cattle waste and poultry waste, which were 56.96 and 48.12 percent, respectively. These results align with the findings of Chapagae *et al.* (2025) ^[4] who reported that the waste reduction rate by BSF larvae on kitchen waste was 73.66±2.70 percent. Sumba *et al.* (2026) ^[30] reported that the BSF larvae waste reduction on poultry waste was 43.9 percent under 150 mg day⁻¹larva⁻¹. Ahmed *et al.* (2024) ^[1] reported that FRR (substrate reduction rate) on kitchen waste was high (47.02%), as compared to chicken manure (41.45%). Diola *et al.* (2023) ^[8] reported that the FRR (overall degradation) on chicken manure was 39.28 percent. Singh *et al.* (2021) ^[28] recorded a 72 percent FRR on kitchen waste. Rehman *et al.* (2019) ^[26] reported that the dry mass reduction of the dairy and chicken manure mixture was 41.98 percent. Lalander *et al.* (2019) ^[12] reported that the FRR on poultry waste is 60 percent. Nana *et al.* (2018) ^[20] reported that the BSF larva FRR on kitchen waste was 72.4 percent at a feeding rate of 220 gm day⁻¹ larva⁻¹. These findings highlight the significance of substrate selection in maximizing feed usage and support the view that substrate choice has a significant impact on feed reduction rates.

Table 1: Mean larval period, mean individual larval period and mean pupal period of black soldier fly reared on various organic wastes

Organic waste	Mean larval period (days)	Mean individual larval weight at last instar (g)	Mean pupal period(days)
Kitchen waste	22.56	0.26	10.15
Cattle waste	33.43	0.16	16.50
Poultry waste	29.76	0.15	14.71
S.Em±	0.524	0.002	0.206
C.D. at 5%	1.558	0.007	0.612

Table 2: Total prepupal weight, feed consumed, feed residue, BCR, FCR and FRR of black soldier fly reared on various organic wastes

Different wastes	Total prepupal weight (g)	Feed consumed (g)	Feed residue (g)	Bio conversion rate (%)	Feed conversion ratio (%)	Feed reduction ratio (%)
Kitchen waste	521.14	7653.43	2346.57	5.21	14.69	76.53
Cattle waste	324.57	7973.43	6026.57	2.31	24.59	56.96
Poultry waste	301.43	6254.29	6745.71	2.32	20.76	48.12
S.Em±	4.439	89.011	89.011	0.037	0.325	0.788
C.D. at 5%	13.188	264.466	264.466	0.111	0.967	2.340

Conclusion

Kitchen waste is the most effective substrate for mass rearing Black Soldier Fly (BSF) larvae, yielding the fastest development times, highest biomass weight, and superior

waste reduction efficiency compared to cattle and poultry waste.

Conflict of Interest: Authors have no conflict of interest.

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