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RESEARCH PAPER

Bioconversion of organic wastes using black soldier fly

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Abstract: Experiment was conducted at Department of Entomology, University of Agricultural Science Dharwad, to evaluate feasibility to degrade organic wastes in laboratory condition. Organic wastes like Vegetable Waste (VW), Fruit Waste (FW), Unfed Crop Waste (UCW), Kitchen Waste (KW), VW + dung (3:1), FW + dung (3:1), UCW + dung (3:1), KW + dung (3:1) were added in tray with 700 maggots per tray. Organic wastes (feed) were supplied @ 220 mg/maggot/day and the total feed maintained was 500 g/tray which was sufficient for three days. Feed was supplied at three days interval up to 9th day and hence total feed used per tray was 1500 g. Results indicated that kitchen waste was significantly superior over the other treatments with high prepupal weight (317.97 mg/maggot), maximum bioconversion rate (14.56%) and high feed reduction rate (96.07%). The present study revealed that kitchen waste as feed for Black Soldier Fly, results in better pre pupal weight and higher waste reduction efficiency. Thus, the kitchen waste can be used for mass rearing of Black Soldier Fly to explore its potentiality as a bio agent for waste management.

Key words: Bioconversion rate, *Hermetia illucens*, Waste management

Introduction

In India, the substantial increase in industrialization, population growth, economic development and changing living standards has led to a significant rise in the generation of municipal solid waste. According to government estimates, the daily production of municipal solid waste in the country is approximately 1,15,000 metric tonnes, with the per capita daily waste generation varying from 0.2 kg to 0.6 kg, depending on the population size (Balasubramanian, 2018). A recent report by the Central Pollution Control Board (CPCB) indicates that biodegradable waste constitutes the majority, accounting for 52.32 per cent of the total garbage produced. Unfortunately, only a small fraction of the waste (12.45%) is processed using proper scientific methods, while the rest is indiscriminately dumped in open pits (Anon., 2013).

According to a study conducted by the Planning Commission in 2014, over 80 per cent of the waste collected in India is discarded in dump yards, posing risks to both human health and the environment. The prevalent waste disposal technique in India primarily involves land filling. However, these landfills lack essential components such as liners, proper foundations, cover soil, leachate management and treatment facilities, hence making them unsuitable for effective waste management. It is crucial to explore and promote new and financially sustainable waste management methods to reduce the environmental impact and improve public health (Anon., 2014).

Finding a circular economy-like strategy to waste management is what we need to do. The use of Black Soldier Fly (BSF), *Hermetia illucens* (Linnaeus) (Diptera: Stratiomyidae) is one such method for managing organic waste (Sharanabasappa *et al*., 2019). Selecting an appropriate fly species is important for maximizing the efficiency of the biodegradation process. When choosing the most appropriate fly species for bioconversion, factors like size, behavioral traits, fecundity, duration of maggot development, natural occurrence in the selected waste, pest status, adaptability to laboratory mass-rearing and any species-specific requirements (like adult diet) should be taken into account. Hence, present study was focused on determining the best organic waste that can be converted easily and also help in gaining weight of maggots.

Material and methods

The study was conducted under laboratory conditions at Department of Entomology, University of Agricultural Sciences, Dharwad. The maggots for the current study were sourced from the previously established colony in the Department which was collected from a commercial company. To assure the optimal maggot development, the newly hatched neonates were allowed to feed on the wheat flour (100 g/egg cluster) mixed with little amount of water (100-150 ml) until maggots were 5 days old. On sixth day onwards maggots were fed with particular organic substrate to evaluate the efficiency of BSF maggots to reduce the organic waste.

Plastic trays of dimension 45 cm × 30 cm ×10 cm were used for each treatment. Treatments were replicated three times and

Table 1. Treatment details for bioconversion studies

Tr. No.	Treatments
T_1	Vegetable waste
T_2	Fruit waste
T_3	Crop waste (unfed crop waste)
T_4	Kitchen waste
T_5	Vegetable waste + cattle dung (3:1)
T_6	Fruit waste + cattle dung (3:1)
T_7	Crop waste + cattle dung (3:1)
T_8	Kitchen waste + cattle dung (3:1)

Table 2. Performance of *Hermetia illucens* on different organic wastes

Tr. No.	Treatments	Pre pupal weight (mg/pre pupa)	Feed consumed (g/tray)*	Unusedfeed (g/tray)*
1	Vegetable waste	68.67 ± 3.94[e]	1336.29 ± 7.63[c]	163.71 ± 7.63[f]
2	Fruit waste	94.40 ± 2.80[c]	1167.77 ± 10.34[e]	332.23 ± 10.35[d]
3	Unfed crop waste	10.26 ± 1.62[g]	78.33 ± 7.64[h]	1421.67 ± 7.64[a]
4	Kitchen waste	317.97 ± 5.99[a]	1441.15 ± 7.47[a]	058.85 ± 7.45[h]
5	Vegetable waste + cattle dung (3:1)	50.10 ± 3.35[f]	1294.51 ± 12.86[d]	205.49 ± 12.86[e]
6	Fruit waste + cattle dung (3:1)	86.02 ± 3.17[d]	1084.82 ± 5.07[f]	415.18± 5.07[c]
7	Unfed crop waste + cattle dung (3:1)	12.99 ± 1.18[g]	128.23 ± 10.13[g]	1371.76 ± 10.13[b]
8	Kitchen waste + cattle dung (3:1)	279.56 ± 5.48[b]	1397.89 ± 6.33[b]	102.11 ± 6.33[g]
	S. Em (±)	3.01	6.96	6.96
	C.V. (@1 %)	3.29	0.88	1.721

Note: 1. Different letters within a column indicate significant differences across treatments by Duncan's Multiple Range Test at P=0.01
2. *: Feed used per tray (45 cm × 30 cm × 10 cm) was 1500 g

the treatment details are given in Table 1. In each tray, 6 days old 700 maggots were released using forceps. The fruit waste, vegetable waste and crop waste were chopped with knife and used as feed. Uniform feeding rate of 220 mg/maggot/day (Nana *et al*., 2018) was maintained. Hence, in each plastic tray, 500 g of each feed sufficient for 3 days feeding was maintained and maggots were released. After every 3 days 500 g feed was added in the respective tray till 9th day. Hence, at 9th day the total food supplied to each tray was around 1500 g. Trays were covered with muslin cloth to avoid egg laying by other flies. From 9th day onwards feed supply was stopped and entire set up was left undisturbed until 40 per cent of maggots reached pre pupal stage. Fruits used in the experiment comprised of muskmelon, banana, apple, papaya and sapota. While, the vegetable waste included tomato, cucumber, carrot, brinjal, okra, amaranths leaves, french bean, broad bean, cauliflower, broccoli and radish. Kitchen waste used in the experiment contained chapati, white rice, bread, cooked pumpkin, cooked potato, boiled chick pea, boiled cowpea and cooked beetroot. Crop waste used in the experiment was unfed cattle feed. Two days old cattle dung was used for the experiment.

The efficiency of BSF maggot to consume and reduce organic matter at uniform feeding rate (220 mg/maggot/day) was determined by calculation of Bio Conversion Rate (BCR), Feed Conversion Ratio (FCR), Feed Reduction Rate (%) as described previously by Diener *et al*. (2009).

$$\text{Bio Conversion Rate (BCR \%)} = \frac{\text{Total pre pupal weight on fresh weight basis}}{\text{Total feed added on fresh weight basis}} \times 100$$

$$\text{Feed Conversion Ratio (FCR)} = \frac{\text{Feed consumed on fresh weight basis}}{\text{Total pre pupal weight}}$$

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

Nutrient analysis of frass:

Harvested frass was kept for maturation till 30 days. Then it was shade dried for 2 days for the analysis of nutrients. Frass was analysed for three macronutrients N, P and K. Before the analysis, frass was subjected to pre digestion. Digested frass was analysed by using following methods.

1. Available nitrogen (N): Modified alkaline permanganate method (Subbaiah and Asija, 1956)
2. Available phosphorous (P_2O_5): Extraction with Olen's reagent and estimated in spectrophotometer (Jackson, 1973)
3. Available Potassium (K_2O): Extraction with neutral normal ammonium acetate and estimated in flame photometer (Jackson, 1973)

Results and discussion

The performance and bioconversion efficiency of black soldier fly maggots on different organic wastes was significantly different as indicated in Table 2, 3 & 4.

Pre pupal weight

It could be observed that the weight of the pre pupa was significantly different in various treatments. Kitchen waste resulted in highest pre pupal weight (317.97 mg/pre pupa) followed by kitchen waste + cattle dung (279.56 mg/pre pupa)

Table 3. Biomass conversion parameters for *Hermetia illucens* on different organic wastes

Tr.	Treatments	Bio Conversion Rate(%)	Feed Conversion Ratio	Feed No. Reduction Rate(%)
1	Vegetable waste	3.03	29.43	89.08
2	Fruit waste	4.26	18.27	77.85
3	Unfed crop waste	0.03	167.41	5.22
4	Kitchen waste	14.56	6.60	96.07
5	Vegetable waste + cattle dung (3:1)	2.18	39.77	86.30
6	Fruit waste + cattle dung (3:1)	3.83	18.89	72.32
7	Unfed crop waste + cattle dung (3:1)	0.06	137.22	8.55
8	Kitchen waste + cattle dung (3:1)	12.74	7.31	93.19

Table 4. Chemical attributes of black soldier fly frass obtained from different organic wastes

Tr. No.	Treatments	Quantity of frass obtained (g/1500 g feed)	Per cent frass obtained	Nitrogen content (%)	Phosphorous content (%)	Potassium content (%)
1	Vegetable waste	123.34 ± 2.60[f]	08.22	3.42	0.63	5.07
2	Fruit waste	292.77 ± 2.47[d]	19.52	3.21	0.54	4.50
3	Unfed crop waste	005.25 ± 0.59[g]	00.35	-	-	-
4	Kitchen waste	377.78 ± 2.05[b]	25.18	4.71	0.93	5.38
5	Vegetable waste + cattle dung (3:1)	203.19 ± 2.50[e]	13.54	3.11	0.44	4.17
6	Fruit waste + cattle dung (3:1)	321.51 ± 3.61[c]	21.43	3.00	0.47	3.88
7	Unfed crop waste + cattle dung(3:1)	009.11 ± 0.73[g]	00.60	-	-	-
8	Kitchen waste + cattle dung (3:1)	405.05 ± 3.76[a]	27.00	4.25	0.50	4.33
	S. Em (±)	2.01	-	-	-	-
	C.V. (@ 1%)	1.17	-	-	-	-

Note: Different alphabets within a column indicate significant differences across treatments by Duncan's Multiple Range Test at P = 0.01

while, the unfed crop waste had the lowest pre pupal weight (10.26 mg/pre pupa) probably because kitchen waste contain higher amount of protein, nutrients and easy to digest whereas, the unfed crop waste was very low in protein content and other nutrients. These findings are in line with many previous workers who obtained varying pre pupal weight with different food sources (Oonincx *et al*., 2015; Manurung *et al*., 2016; Naser *et al*., 2023).

Bio Conversion Rate (BCR) and Feed Conversion Ratio (FCR)

In the present study, the highest bioconversion rate (14.56 %) and lowest feed conversion ratio (6.60) was found in kitchen waste fed maggots compared to all other treatments which revealed the higher efficiency of kitchen waste for consumption and assimilation. In contrast, the lowest bioconversion rate (0.03%) and highest feed conversion ratio (167.41) was observed in unfed crop waste which inferred that large amount of unfed crop waste need to be fed to achieve a unit pre pupal weight and hence, the crop waste was found not suitable for rearing the black soldier fly commercially. These findings are similar to Nana *et al*. (2018), Nyakeri *et al*. (2017) and Lalander *et al*. (2019).

Feed reduction rate (FRR)

The feed reduction rate in the present study ranged from 5.22 to 96.07 per cent, with the highest value recorded in kitchen waste and the lowest in unfed crop waste. These findings are in agreement with Srikanth and Sharanabasappa (2021). Further, it was also observed that dung combination treatments had the lower feed reduction rate compared to the individual treatments as reported by Fadhillah and Bagastyo (2020).

Chemical attributes of black soldier fly frass obtained from different organic wastes

Quantity of frass obtained

Highest percentage of frass was obtained from the kitchen waste + cattle dung (27%) compared to all other treatments. Further, the dung combination treatments produced higher percentage of frass compared to the individual waste which might be because while harvesting of the frass the unfed dung particles also mixed with frass which was difficult to separate hence higher quantity of frass was obtained in dung combination treatments. Since, there was no much feeding activity of BSF maggots on unfed crop waste, lowest percentage (0.35%) of frass was obtained. Klammsteiner *et al*. (2020) and Scieuzo *et al*. (2023) obtained similar frass yield from different food sources.

N, P and K content

Frass obtained from kitchen waste showed highest percentage of NPK content followed by vegetable waste. Lalander *et al*. (2014), Setti *et al*. (2019) and Magee *et al*. (2021) reported varying per cent of N, P and K from frass obtained by feeding BSF maggots on different feeds. Cai *et al*. (2019) stated that in terms of nitrogen, phosphorus and potassium content, BSF maggot aided composting produces organic fertilizer of higher quality than conventional composting; however, the quality varies depending on the parameters of the waste stream.

Conclusion

The study on bioconversion of organic wastes revealed that black soldier fly maggots showed the ability to thrive on various waste materials, but their performance differed depending on the type of waste used. Among all the substrates tested, kitchen waste proved to be the most suitable, resulting in the highest average pre pupal weight (317.97 mg/pre pupa), maximum bioconversion rate (14.56%) and high feed reduction rate (96.07%). While, the crop waste was found not suitable for rearing the black soldier fly commercially. The highest frass quantity was obtained from kitchen waste with cattle dung (27%) and the lowest was noticed in case of unfed crop waste (0.35%). The nutrient composition of the frass also varied depending on the substrate, with kitchen waste frass recording the highest NPK content of 4.71 per cent nitrogen, 0.93 per cent phosphorus and 5.38 per cent potassium surpassing all other treatments.

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