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Efficient Recycling of Domestic Cooked Food Waste into Hermicompost Using Black Soldier Fly Larvae

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ABSTRACT

Economic progress, urban expansion, and enhanced quality of life in India have led to the formation of densely populated megacities and a significant increase in municipal solid waste generation. Such waste consists of a substantial volume of residues from food waste, kitchen waste originating from residential complexes, restaurants, and remnants of agricultural activities. Consequently, handling municipal solid waste has become a critical issue. Though composting is being practiced as an eco-friendly means of recycling organic waste, it is laborious and time-consuming. In the recent past, researchers have suggested the use of black soldier fly larvae (BSFL) as an effective solution for solid waste management. This study aims to assess the degradation potential of BSFL, which is gaining attention in recycling technology due to its composting capabilities, and its ability to produce soil amendments suitable for agricultural purposes. To evaluate the ability of BSFL to degrade different types of organic wastes, with a focus on cooked food waste, the compost formed after 14 days of degradation was analyzed based on elemental composition and other parameters. Comparative examinations were made with different vermicompost samples and hermicompost produced using BSFL to check the effect on plant growth. The analysis showed a higher percentage of nitrogen (4.21%), and phosphorus (0.5%) in hermicompost. The C:N ratio was 12:1 which is suitable for agronomical purposes. This study concludes that, BSFL are useful as versatile bioconversion agents of cooked food waste and provide a promising organic recycling strategy for sustainable waste management.

1. INTRODUCTION

Food wastage is a significant global issue, generating approximately 1.3 billion tonnes annually. This statistic was highlighted by the Food and Agriculture Organization (FAO), which reported that a staggering one-third of the world's food production for human consumption is wasted annually (FAO, 2019). However, the consequences of improper food waste disposal are not just alarming in terms of large quantity; they also extend to environmental and health concerns. The inadequate management of solid waste, leads to the occupation of valuable landfill space, resulting in the proliferation of diseases and the emission of unpleasant odours, as noted by Hoornweg and Bhada-Tata (2012). It's important to recognize that landfills contribute significantly to the production of methane gas through anaerobic decomposition. Methane is a potent greenhouse gas, estimated to be 25 times more impactful than carbon dioxide when released directly into the atmosphere (Abdelfattah et al., 2021).

These environmental challenges associated with food waste and its disposal have led to concerns about the eco-friendliness of current waste management practices. This prompts a re-evaluation of waste minimization strategies, where composting has been the traditional approach and has its own merits and demerits. Composting, a long-practised

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process, results in humus that enhances plant growth and reduces organic waste.

This is like vermicomposting, which also occurs through the interaction of microorganisms and earthworms in an aerobic setting, as described by Domínguez et al. (2000). Both methods contribute to sustainable waste management and soil enrichment. However, both composting and vermicomposting demands considerable space, high temperatures, and time. It may also face challenges such as vermin and odours. Vermicomposting introduces additional challenges, including the need to keep worms alive and separating worms from compost before use, adding to its complexity (Mahmood et al., 2021; Amuah et al., 2022). Sharma et al. (2024) have reviewed the potential of composting technology in recycling and reuse of organic matter for increasing the soil fertility perhaps they expressed the concern towards maturity, stability and quality of compost as there is no uniformity and global guidelines for compost.

Enebe and Erasmus (2023) have enumerated the merits of vermicomposting technology and some of the limitations such as labour intensive operation, require large area of land, waste processing is slow, vermicompost harvesting is difficult as it requires separating of earthworms from compost, cold environmental conditions will slow down the treatment process and accelerate the time. In light of inherent limitations of conventional composting and vermicomposting, an innovative solution emerges: Hermicomposting, by utilizing the larvae of black soldier fly (BSF). The black soldier fly, scientifically known as *Hermetia illucens* (Diptera: Stratiomyidae), is a slender fly measuring about 20 mm in length. Native to the southeastern United States, it's also found in tropical, subtropical regions and southern Europe (Müller et al., 2017). Belonging to the Hermetiinae subfamily within the Diptera order, this widely distributed species is of note for its exceptional ability to convert organic waste, including food waste, into valuable resources. For many years, researchers worldwide have suggested utilizing the larvae of the black soldier fly (*Hermetia illucens*) as a method to break down organic materials like food waste, thereby avoiding their fraction getting into landfills (Diener et al., 2011; Gabler, 2014).

Research shows that BSFL can reduce biowaste by up to 96.1% in weight and 89.0% in volume, as observed in a study by Mahmood et al. (2021).This remarkable capability primarily originates from the robust mouthparts of the BSFL and their higher enzymatic activity in the gut compared to other fly species. As a result, BSFL excels in decomposing food waste with remarkable efficiency (Cho et al., 2020). BSF is also a valuable resource insect known for its exceptional ability to efficiently convert various types of organic waste materials, including livestock manure like poultry or dairy waste. The impressive versatility in the food sources that *Hermetia illucens* can consume results in a diverse composition of its frass (the excrement of larvae), which holds noteworthy implications for soil enrichment. This frass contributes essential nutrients and organic matter to the soil, leading to shifts in the microflora within the soil and influencing plant behaviour, as elucidated by Schmitt and de Vries (2020). Extensive studies have depicted that the compost obtained from the BSFL can significantly enhance the growth, yield, and nutritional quality of vegetable crops, particularly in conjunction with mineral fertilizers, as reported by Anyega et al. (2021).

Notably, research findings indicate that the BSF's life cycle and larvae can effectively reduce heavy metal content in the feed through degradation. Even at significantly high concentrations, the impact of heavy metal elements on the growth of the BSF remains minimal (Diener et al., 2015). This further underscores the unique and valuable role that the BSF plays in waste management and environmental sustainability.

The BSF can efficiently convert organic waste materials like livestock manure (poultry or dairy waste). This conversion process yields larval biomass that boasts a substantial content of protein and fat, as highlighted in research by Rehman et al. (2023). This is particularly significant for poultry, as their dietary requirement of 18-20% crude protein, with specific composition challenges that grain feed alone cannot meet. Furthermore, the insect gut microbiota plays a pivotal role in various aspects, such as providing nutrients, stimulating the immune system, eliminating harmful microorganisms, influencing sex determination and hormonal signalling, and even affecting behaviours. The gut also proves crucial in breaking down challenging substances like lignin, polysaccharides, and resistance genes. This gut microbiota can be likened to a distinct "organ" with its metabolic capabilities, contributing to waste decomposition and producing beneficial substances for the host (Jiang et al., 2019). A notable ecological benefit lies in the potential reduction of harmful bacteria, such as *Escherichia coli* or *Salmonella*, through the utilisation of BSF larvae in processing livestock manure, as highlighted by Rehman et al. (2023).

According to Müller et al. (2017), the larvae of *Hermetia illucens*, with their protein content of 42%, can serve as suitable feed for poultry and pig breeding, The chitin-rich outer covering derived from various stages of the BSF's life cycle, including larval moulting, adult emergence, and the adult flies adds considerable nutritional value to hermicompost, notably enhancing its nitrogen content, as noted by Terrell (2022). This underscores the far-reaching positive effects that the BSF and its byproducts can have on sustainable agriculture and waste management practices.

By connecting the dots between global food waste issues, environmental implications, and evolving waste management methods, it's evident that exploring advanced techniques like hermicomposting holds promise for a more sustainable and efficient approach to tackling food waste. This approach serves the purpose of redirecting these materials away from overburdened landfills, as highlighted by previous studies of Diener et al. (2011) and Gabler (2014). Considering the above facts and as per the suggestions of researchers worldwide, this study was intended to utilise BSFL as a viable method to break down organic waste materials, including domestic food waste as well as garden waste.

2. METHODOLOGY

2.1 Area of study

The research was conducted on the campus of the JSS Science and Technology University, Mysore, India. The BSF eggs were allowed to hatch out in a constructed room with a temperature of 30°C and relative humidity of 60-65% and trays were enclosed by mosquito nets to protect waste and larvae from predators and unfavourable weather conditions.

2.2 Black soldier fly

BSF eggs were procured from a black soldier fly insect farming training facility. On 1st day around 2gms of eggs were placed over a mesh as shown in Figure 1(a) and Figure 1(b). This mesh was kept over a tray containing poultry feed and wheat bran. After 2 days, the eggs hatched out and baby larvae, as shown in Figure 1(c) had fallen to the pre-feed. The hatched BSFL were kept in the pre-feed for 2 more days and then transferred to boxes containing different solid waste samples.

2.3 Treatment of waste samples

Initially, three different types of wastes *viz.* garden waste, kitchen raw waste, and cooked food waste were observed for the degradation rate. Garden waste consists of dry leaves and small pieces of plants and trees on the campus. Kitchen raw waste and cooked food waste were collected from the college campus hostel. The kitchen raw waste consisted of vegetables and fruits peel whereas kitchen cooked food waste comprised of leftover wheat breads, dosas, rice, sambar with lentils and pulses, and other foods.

Along with the three sample boxes, a control box without larvae was kept for each sample to compare the degradation rate. Initially, larvae to feed ratio was 1:10 which means for 15 g of worms, 150 g of feed was supplied in the form of organic waste. Since a faster rate of degradation was observed in cooked waste after 14 days, further studies were conducted with cooked food waste.

The hatched larvae were transferred to a container, with cooked food waste as feedstock as shown in Figure 1(d). The larvae to feed ratio was 1:2 which means for 1.5 kg of larvae, 3 kg of feed was supplied. After complete degradation, nutritional value of the compost was analysed.

2.4 Comparative study of vermicompost and hermicompost samples

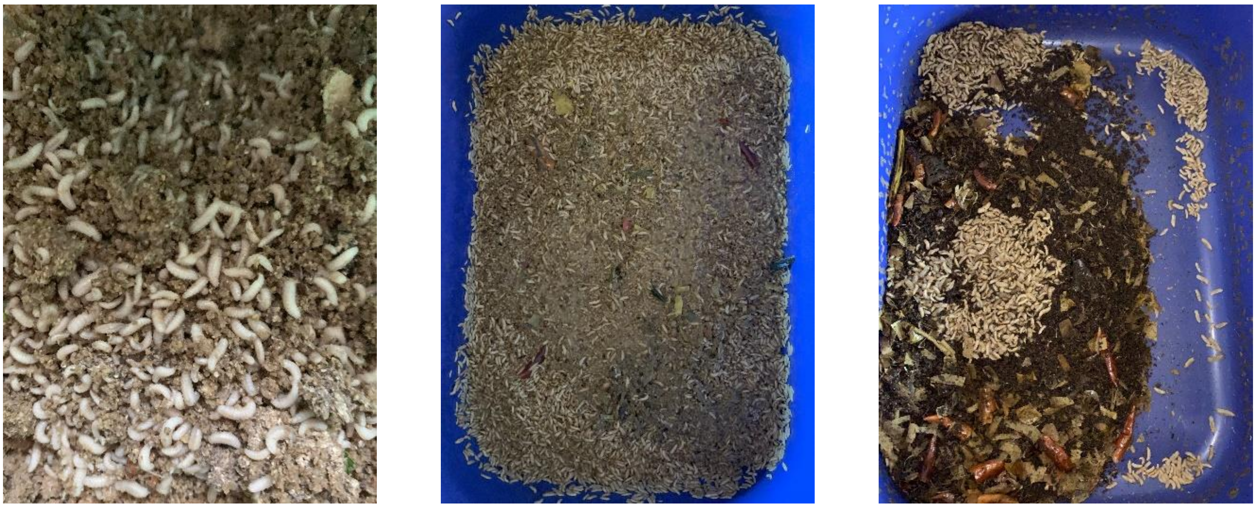
The comparative studies were carried out and different samples of vermicompost were procured from different suppliers for the study. The details of the vermicompost bought from different places are as follows:

1. Leafy Tales Organic Vermicompost Fertilizer Manure (VC-1): Manufactured at Gurgaon
2. IFFCO Urban Gardens Nutri-Rich Vermicompost Manure (VC-2): Manufactured and Marketed by Aquagri Processing Pvt Ltd., New Delhi
3. Local Zoo Vermicompost (VC-3): Manufactured at Zoological Garden, Mysuru
4. Anitha Nursery Vermicompost (VC-4): Manufactured at Mysuru
5. Bhudevi Farm Vermicompost (VC-5): Manufactured at Mysuru
6. Hermicompost: Compost formed by degradation of cooked food waste by BSFL

(a) Eggs placed over a mesh

(b) BSFL eggs

(c) BSFL under microscope



(d) Hatched larvae feeding on cooked food waste

(e) Adult BSFL feeding on cooked food waste

(f) Hermicompost formed after 14 days of degradation

Figure 1. Treatment of cooked food waste using BSFL.

2.5 Analysis of compost

The elemental analysis was done for both hermicompost and vermicompost samples. For the analysis, above mentioned five compost samples collected from various vendors and hermicompost produced from this study were analysed for the parameters of pH, nitrogen (N), phosphorous (P), potassium (K), sodium (Na), and organic carbon(C).

The pH test was done using a digital pH meter. The dry sample was used for nitrogen and carbon analysis. Nitrogen analysis was done using the Energy Dispersive X-Ray Spectroscopy (EDAX) method as per standard guidelines. Organic carbon analysis was done by following the dry combustion method of Nelson and Sommers (Bhat et al., 2017).

For the other parameters, aqueous form of sample was required, hence, the sample preparation was done by dissolving 5 g of sample in 50 mL of water and Whatman filter paper was used for sample filtration. The dilution factor of 0.1 is considered for the calculation. Phosphorous analysis was done by following the standard procedure using Spectrophotometer (Stănescu et al., 2021). Potassium and Sodium analysis were carried out using a flame photometer (Banerjee and Prasad, 2020).

2.6 Plant growth studies using vermicompost and hermicompost samples

The two hundred saplings of tomato were procured from the local nursery. The saplings were transferred to the grow bags containing red soil and coco peat. They were kept in cooler area with a temperature of 30°C, humidity between 65-70% and bright light conditions. Different vermicompost and hermicompost samples were added to the respective pots later. Control plants without compost were also maintained in the study. The length of the plants grown in different varieties of compost and control plants was measured regularly to check the effect of compost on plant growth.

3. RESULTS AND DISCUSSION

3.1 Analysis of elemental composition of vermicompost and hermicompost samples

3.1.1 Total organic carbon concentration

The primary physio-chemical attributes of well-aged compost revolve around its organic matter and organic carbon content, as they serve as the foundation for all other vital macro and micronutrients. Furthermore, these attributes enhance various aspects of soil quality, including cation exchange capacity, biodiversity, and soil aggregation, thus impacting its chemical, biological, and physical characteristics positively (Muhamed and Umer, 2023). The composition of organic carbon in the composts was analysed by dry combustion method of Nelson and Sommers (Bhat et al., 2017). The organic carbon content was found to be 48.83%, the highest among all the composts as shown in Figure 2. A similar study shows the composition percentage of organic carbon to be 38.61% in composted BSF frass fertilizer (Anyega et al., 2021). Using poultry feed and wheat bran as pre feed and cooked food waste such as rice, which is rich in carbohydrates as feed for BSFL for composting might be the reason for increased carbon concentration in the compost. Lalander et al. (2019) are also of the opinion that poultry feed had the highest C/N ratio in their study with different feedstock for BSFL.

3.1.2 Total nitrogen concentration

The composition of nitrogen (N) in the compost produced by BSFL was studied using the EDAX method. The N content in the hermicompost was found to be 4.21% which was the highest among all the compost samples. Sarpong et al. (2019) have opined that the rise in nitrogen concentrations over time might be attributed to the reduction in the dry weight of organic matter (re-concentration) in the substrate due to larvae decomposition. Another possible explanation for this increase is the biochemical activities of the larvae and the secretion of nitrifying bacteria from their gut (Bernal et al., 2009). This observation aligns with findings from a study by Kim et al. (2011). The rest of the vermicompost samples was found to be in the range of 1 to 3.3%. Based on a database of samples from the U.S. Composting Council's Compost Analysis Proficiency Program (Sullivan et al., 2018), it is reported that to produce a good crop, the range of N in compost is 1 to 2%. If the total N content of compost is less than 1 percent, then N fertilization must be considered as a supplement after compost application. Whereas, if total N exceeds 2 percent, the compost can replace a portion of typical N fertilizer input for crop production. Nitrogen fertilizers lead to nitrate water pollution and greenhouse effect with nitrous oxide, nitrogen oxides, and ammonia, contributing to global warming and ozone layer depletion (Byrnes, 1990). Hermicompost which is rich in N composition due to the variety of the feed given to BSFL can be used not only as a compost but as a portion of N fertilizer thus, reducing negative impact on the environment by reducing the use of chemical fertilizers.

3.1.3 Total phosphorus concentration

The composition of phosphorous (P) in the compost produced by BSFL was studied using Spectrophotometry. Based on the reports of samples from the U.S. Composting Council's Compost Analysis Proficiency Program, to produce a good crop, the range of P should be 0.3 to 0.9% (Sullivan et al., 2018). The highest P percentage was observed in hermicompost sample of 0.5% which is in the optimal range for any compost. Since the hermicompost quality falls within the standard quality in agriculture, it is suitable for plant growth. The optimal percentage of potassium in the compost reported in this current study was analogous to the results (0.5%) found in composted BSF frass fertilizer (Anyega et al., 2021). Also, P availability from compost compares favourably with that of conventional phosphorus fertilizers (Crohn et al., 2013). To conserve the environment and cut costs on fertilizers, growers can decrease their phosphorus fertilizer usage in correlation with the P contribution provided by compost (Crohn, 2016).

3.1.4 Total potassium concentration

The composition of potassium (K) in the compost produced by BSFL was studied using flame photometry. According to the report of Sullivan et al. (2018), to produce a good crop, the range of K is 0.5 to 1.5%. If K exceeds 1.5 percent, the compost feedstocks can include manure, food waste, or grass clippings. This compost K is considered equivalent to fertilizer K as a source of K for plants. The K content in hermicompost was found to be 1.84% and the highest content was seen in VC-1. Since the quality of compost almost fell within the standard quality in agriculture, it is acceptable for plant growth.

3.1.5 Total sodium concentration

The composition of sodium (Na) in the compost produced by BSFL was studied using flame photometry. The Na content in all the samples was found to be within the optimum range. Na hermicompost was found to be 0.14% and the highest was observed in the VC-1 sample (Table 1). Compost containing more than 1 percent Na is considered to be quite high in concentration, and excess levels of Na can lead to sodicity and phytotoxicity problems (Crohn, 2016). Also based on a database of samples from the U.S. Composting Council's Compost Analysis Proficiency Program (Sullivan et al., 2018), to produce a good crop, the range of Na should be below 0.6%.

Table 1. Elemental composition and pH of vermicompost and hermicompost samples

Sample	OC (%)	N (%)	P (%)	K (%)	Na (%)	pH
VC-1	35.0	3.27	0.05	6.60	0.17	7.75
VC-2	21.6	1.38	0.02	1.90	0.10	7.20
VC-3	47.6	1.41	0.03	0.10	0.10	7.86
VC-4	31.7	1.80	0.03	0.13	0.03	7.98
VC-5	24.6	2.36	0.01	0.52	0.03	7.25
HC	48.83	4.21	0.50	1.84	0.14	7.03

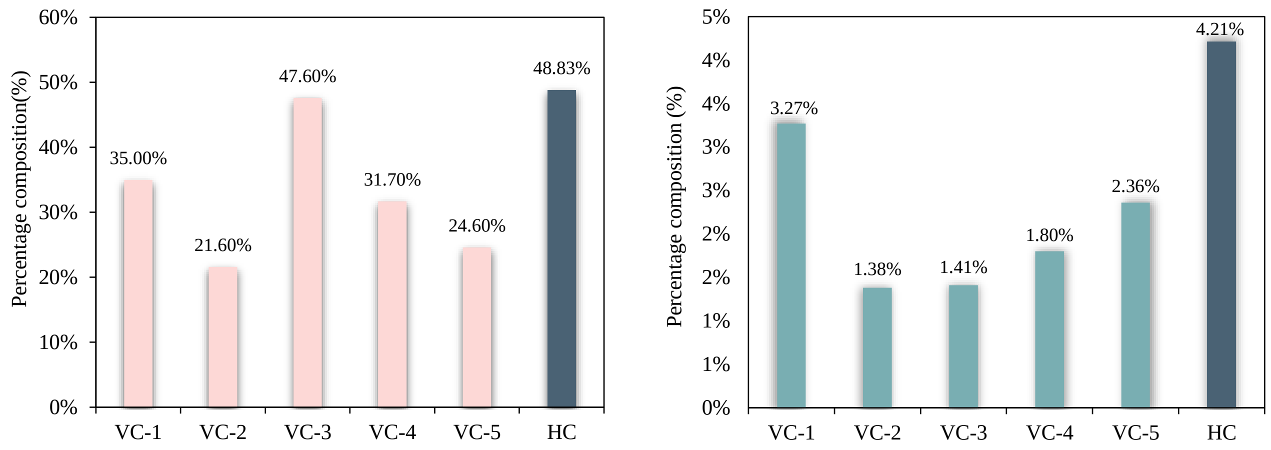
VC-1: Leafy Tales Leafy Organic Vermicompost Fertilizer Manure, VC-2: IFFCO Urban Gardens Nutri-Rich Vermicompost Manure, VC-3: Local Zoo Vermicompost, VC-4: Anitha Nursery Vermicompost, VC-5: Bhudevi Farm Vermicompost, HC: Hermicompost

3.2 Analysis of pH for vermicompost and hermicompost samples

To ensure the high performance of a composting process, optimum level of pH 5.5-8.0 is required. The increase in pH level at the early stages of the composting process is because of an increase in the volume of ammonia released due to protein degradation. Decrease in pH level at the later stage of composting was caused by the volatilization of ammoniacal nitrogen and H^+ released due to microbial nitrification process by nitrifying bacteria (Eklind and Kirchmann, 2000). Among all the five vermicompost and hermicompost samples, a pH range of 7.03-7.98 was observed which was indeed in optimum level as shown in Figure 2(f).

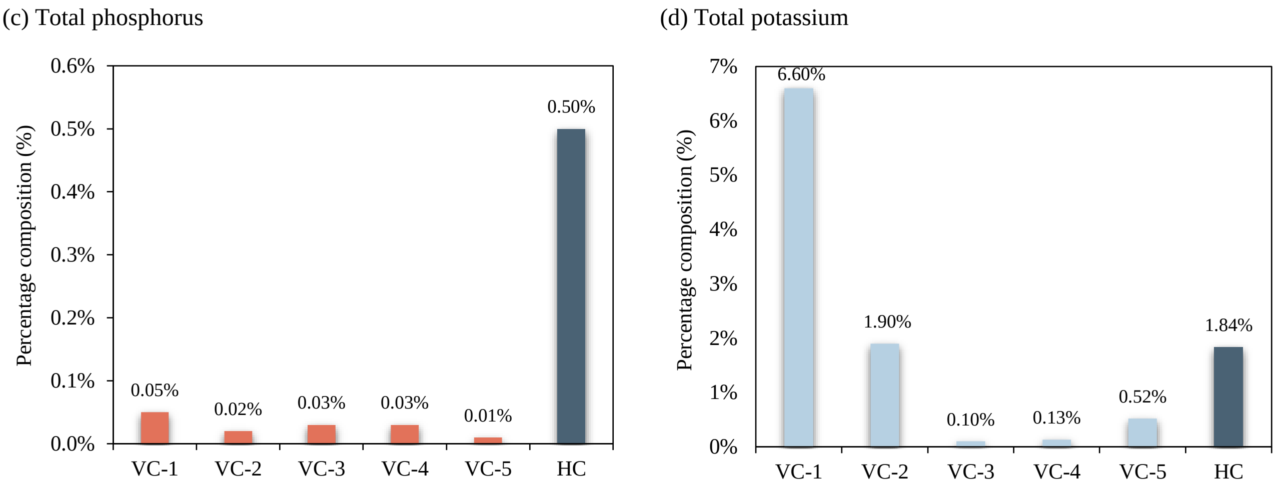
3.3 C:N ratio of all the samples

The carbon-to-nitrogen ratio is crucial in composting process because microorganisms need a good balance of carbon and nitrogen to be active. The ratio directly affects the speed and efficiency of the process and determines the quality of the resulting compost. High C:N ratios can lead to prolonged composting duration and low C:N ratios can enhance nitrogen loss.

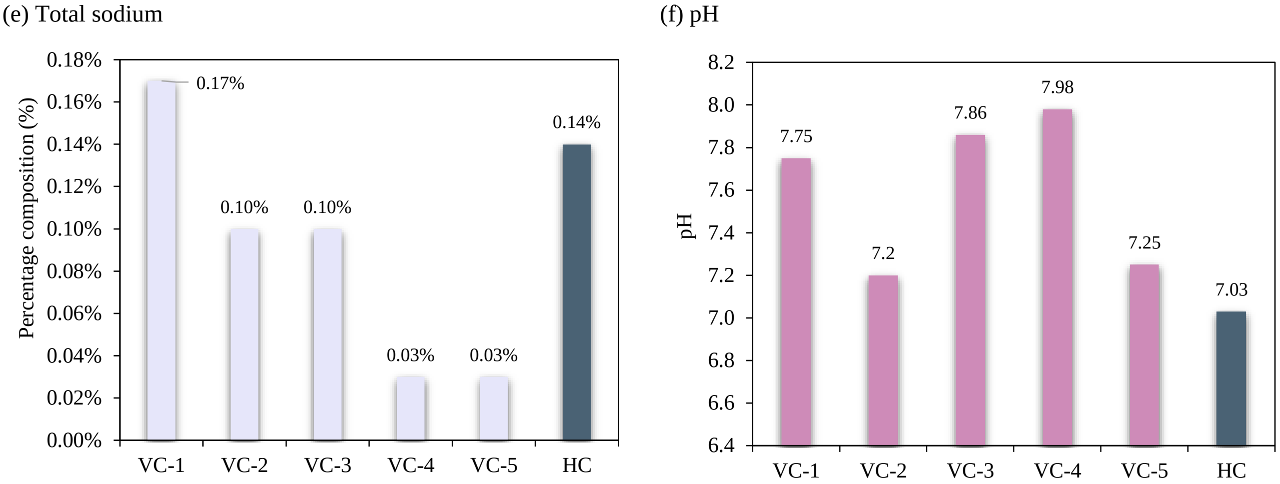

(a) Organic carbon

(b) Total nitrogen

Figure 2. Graphs representing Elemental composition and pH of all composts. Graph (a), (b), (c), (d) and (e) represents the percentage composition of total organic carbon, total nitrogen, total phosphorus, total potassium, and total sodium respectively. Graph (f) represents the pH of different compost samples.


(c) Total phosphorus

(d) Total potassium


(e) Total sodium

(f) pH

Figure 2. Graphs representing Elemental composition and pH of all composts. Graph (a), (b), (c), (d) and (e) represents the percentage composition of total organic carbon, total nitrogen, total phosphorus, total potassium, and total sodium respectively. Graph (f) represents the pH of different compost samples (cont.).

Table 2. C:N ratio of the samples

Sample	C:N Ratio
VC-1	10:1
VC-2	15:1
VC-3	34:1
VC-4	18:1
VC-5	10:1
HC	12:1

VC-1: Leafy Tales Leafy Organic Vermicompost Fertilizer Manure, VC-2: IFFCO Urban Gardens Nutri-Rich Vermicompost Manure, VC-3: Local Zoo Vermicompost, VC-4: Anitha Nursery Vermicompost, VC-5: Bhudevi Farm Vermicompost, HC: Hermicompost

It has been reported that a carbon-to-nitrogen (C:N ratio) value of 15 or below is highly preferable for agronomic purposes (Jereb, 2004; Pan et al., 2012). They have also suggested there where C:N ratio is less than 20, it is likely to cause the mineralization of organic nitrogen to inorganic which is suitable for plants. Therefore, the C:N ratio of hermicompost is within the limit as shown in Table 2 which strongly suggests that the larvae compost obtained is satisfactory for agricultural purposes. Any compost with a C:N ratio greater than 30 is likely to immobilize nitrogen if applied to soil (Bernal et al., 2009). Only one sample VC-3 had high carbon content, the rest are within the desirable range.

The plant growth studies with different compost samples exhibited significant differences in the plant height and number of leaves. The initial plant height was almost same within the range of 15-20 cm. Weekly observations were made for 5 weeks for all the compost samples with control. During this observation, it was noticeable that plants applied with hermicompost had grown significantly more when compared to all other vermicompost and control. The plant height in the 5th week of hermicompost plants as shown in Table 3 was in the range of 43-46 cm and with approximately 28 leaves, whereas other vermicompost samples had an average height of 40 cm with an average number of 25 leaves. And control exhibited a slower growth of 32 cm plant height and 20 leaves. This indicates that the nutritional composition of hermicompost and the uptake of those nutrients by the tomato plants were superior when compared to that of vermicompost.

Table 3. Effect of hermicompost and selected vermicompost samples on the growth of tomato plants

Parameter	Compost	Time				
		1st week	2nd week	3rd week	4th week	5th week
Plant height	VC-1	26.67 ± 1.58^{e}	30.66 ± 1.70^{d}	35.46 ± 2.19^{d}	39.06 ± 1.98^{d}	42.16 ± 1.92^{d}
	VC-2	21.63 ± 3.92^{b}	26.00 ± 4.01^{b}	30.70 ± 3.72^{b}	34.50 ± 3.83^{b}	38.23 ± 3.48^{b}
	VC-3	24.13 ± 3.49^{c}	27.63 ± 3.98^{c}	32.80 ± 3.46^{c}	37.03 ± 3.41^{c}	40.80 ± 3.37^{b}
	VC-4	24.00 ± 3.60^{c}	28.90 ± 4.44^{a}	34.00 ± 4.15^{a}	38.23 ± 3.49^{c}	41.73 ± 3.34^{b}
	VC-5	22.23 ± 4.62^{a}	27.43 ± 4.06^{b}	31.96 ± 4.24^{a}	36.70 ± 4.31^{a}	39.90 ± 4.37^{a}
	HA	24.83 ± 1.95^{e}	31.20 ± 1.60^{d}	37.63 ± 1.85^{e}	42.63 ± 1.92^{d}	46.53 ± 1.20^{e}
	HB	19.87 ± 2.48^{d}	26.96 ± 1.73^{d}	33.20 ± 1.05^{g}	38.16 ± 1.06^{e}	43.06 ± 1.19^{e}
	Control	21.06 ± 0.90^{f}	24.13 ± 1.02^{e}	26.66 ± 1.55^{f}	28.76 ± 1.97^{d}	31.70 ± 2.61^{c}
Number of leaves	VC-1	11.67 ± 1.52^{e}	21.33 ± 1.52^{e}	21.33 ± 1.52^{d}	24.00 ± 1.00^{c}	26.00 ± 1.00^{c}
	VC-2	10.67 ± 1.15^{f}	19.66 ± 2.30^{c}	20.00 ± 2.64^{b}	21.00 ± 1.00^{c}	25.00 ± 2.00^{a}
	VC-3	12.00 ± 2.00^{d}	19.00 ± 2.64^{b}	20.33 ± 1.15^{e}	22.66 ± 1.52^{b}	24.33 ± 2.08^{a}
	VC-4	12.00 ± 2.64^{c}	20.66 ± 1.52^{e}	21.33 ± 2.08^{c}	23.00 ± 1.00^{c}	26.00 ± 1.00^{c}
	VC-5	10.00 ± 3.60^{b}	16.66 ± 3.51^{a}	21.66 ± 1.52^{d}	22.66 ± 1.52^{b}	25.33 ± 1.52^{b}
	HA	11.33 ± 1.52^{e}	18.33 ± 2.08^{d}	21.00 ± 1.00^{e}	23.00 ± 1.00^{c}	28.00 ± 1.00^{c}
	HB	13.67 ± 4.50^{a}	20.33 ± 1.52^{e}	23.66 ± 1.52^{d}	23.66 ± 1.52^{b}	28.33 ± 0.57^{d}
	Control	9.33 ± 0.57^{g}	17.00 ± 1.00^{f}	16.00 ± 3.46^{a}	18.66 ± 2.08^{a}	20.00 ± 1.00^{c}

VC-1: Leafy Tales Leafy Organic Vermicompost Fertilizer Manure, VC-2: IFFCO Urban Gardens Nutri-Rich Vermicompost Manure, VC-3: Local Zoo Vermicompost, VC-4: Anitha Nursery Vermicompost, VC-5: Bhudevi Farm Vermicompost, HA and HB are two samples of hermicompost.

4. CONCLUSION

The study initially aimed to transform various types of waste, including cooked waste, kitchen waste and garden waste. A rapid degradation rate was observed in samples with BSF larvae compared to control boxes without larvae. The highest degradation occurred after 14 days in cooked waste, surpassing the degradation of kitchen waste and dry waste. The BSFL demonstrated a greater waste degradation capacity during their 2 to 3 weeks larvae stage. This highlights the potential of BSF larvae to degrade cooked food waste within two weeks, in contrast to the longer time taken by other biological degradation.

Comparative examinations were made between hermicompost and vermicompost samples. The pH levels fell within the optimal range of 5.5-8.0, with hermicompost having the lowest pH at 7.03. Hermicompost also exhibited the highest carbon percentage (48.83%) compared to other vermicompost samples. Similarly, hermicompost showed superior nitrogen (4.21%), and phosphorus (0.5%) whereas vermicompost samples showed lesser quantity. Subsequent plant growth studies also showed that the plants had significantly better growth when provided with hermicompost than with vermicompost.

The objectives of this study were to assess the BSFL composting potential and to analyse the quality of hermicompost produced for agricultural purposes. The analysis indicated that hermicompost had a better C:N ratio compared to vermicompost samples. The parameters confirmed rapid decomposition and mineralization by BSFL, with the compost meeting standard quality for agricultural uses. Further studies are to be conducted to analyze physiochemical characteristics of the substrate and hermicompost, effect of climatic conditions and hermicompost on growth of different vegetable crops in varied seasons. Also, continued research to implement hermicomposting at domestic level and municipal level to bring in positive impacts of BSFL potential in food waste recycling for a cleaner and greener society.

REFERENCES

Abdelfattah EA, Abd El-Monem DH, Mahmoud AH, Aboelhassan AM, Ibrahim NY, Abdallah DB, et al. The various vulnerable products and services from organic waste management using black soldier fly, *Hermetia illucens*. Zoological and Entomological Letters 2021;1(1):44-56.

Anyega AO, Korir NK, Beesigamukama D, Changeh GJ, Nkoba K, Subramanian S, et al. Black soldier fly-composted organic fertilizer enhances growth, yield, and nutrient quality of three key vegetable crops in Sub-Saharan Africa. Frontiers in Plant Science 2021;12:Article No. 680312.

Amuah EEY, Fei-Baffoe B, Sackey LNA, Douti NB, Kazapoe RW. A review of the principles of composting: Understanding the processes, methods, merits, and demerits. Organic Agriculture 2022;12(4):547-62.

Banerjee P, Prasad B. Determination of concentration of total sodium and potassium in surface and ground water using a flame photometer. Applied Water Science 2020;10(5):Article No. 113.

Bernal MP, Alburquerque JA, Moral R. Composting of animal manures and chemical criteria for compost maturity assessment: A review. Bioresource Technology 2009;100(22): 5444-53.

Bhat SA, Singh J, Vig AP. Instrumental characterization of organic wastes for evaluation of vermicompost maturity. Journal of Analytical Science and Technology 2017;8:1-12.

Byrnes BH. Environmental effects of N fertilizer use: An overview. Fertilizer Research 1990;26:209-15.

Cho S, Kim CH, Kim MJ, Chung H. Effects of microplastics and salinity on food waste processing by black soldier fly (*Hermetia illucens*) larvae. Journal of Ecology and Environment 2020;44(1):Article No. 7.

Crohn DM, Chaganti VN, Reddy N. Composts as post-fire erosion control treatments and their effect on runoff water quality. Transactions of the ASABE 2013;56(2):423-35.

Crohn DM. Assessing compost quality for agriculture. University of California [Internet]. 2016 [cited 2023 Oct 20]. Available from: https://anrcatalog.ucanr.edu/pdf/8514.pdf.

Diener S, Studt Solano NM, Roa Gutiérrez F, Zurbrügg C, Tockner K. Biological treatment of municipal organic waste using black soldier fly larvae. Waste and Biomass Valorization 2011;2:357-63.

Diener S, Zurbrügg C, Tockner K. Bioaccumulation of heavy metals in the black soldier fly, *Hermetia illucens* and effects on its life cycle. Journal of Insects as Food and Feed 2015;1(4):261-70.

Domínguez J, Edwards CA, Webster M. Vermicomposting of sewage sludge: Effect of bulking materials on the growth and reproduction of the earthworm *Eisenia andrei*. Pedobiologia 2000;44(1):24-32.

Food and Agriculture Organization of the United Nations (FAO). The State of Food and Agriculture: Moving Forward on Food Loss and Waste Reduction. Rome, Italy: FAO; 2019.

Eklind Y, Kirchmann H. Composting and storage of organic household waste with different litter amendments. II: nitrogen turnover and losses. Bioresource Technology 2000;74(2): 125-33.

Enebe MC, Erasmus M. Vermicomposting technology: A perspective on vermicompost production technologies, limitations and prospects. Journal of Environmental Management 2023;345:Article No. 118585.

Gabler F. Using Black Soldier Fly for Waste Recycling and Effective *Salmonella* spp. Reduction [dissertation]. Swedish: Swedish University of Agricultural Sciences; 2014.

Hoornweg D, Bhada-Tata P. What a waste: A global review of solid waste management. Urban Development Series Knowledge Papers 2012;15:87-8.

Jiang CL, Jin WZ, Tao XH, Zhang Q, Zhu J, Feng SY, et al. Black soldier fly larvae (*Hermetia illucens*) strengthen the metabolic function of food waste biodegradation by gut microbiome. Microbial Biotechnology 2019;12(3):528-43.

Jereb G. Biodegradable Municipal Solid Waste Management [dissertation]. Polytechnic Nova Gorica, School of Environmental Sciences; 2004.

Kim W, Bae S, Park K, Lee S, Choi Y, Han S, et al. Biochemical characterization of digestive enzymes in the black soldier fly, *Hermetia illucens* (Diptera: Stratiomyidae). Journal of Asia-Pacific Entomology 2011;14(1):11-4.

Lalander CD, Diener S, Zurbrügg C, Vinnerås B. Effects of feedstock on larval development and process efficiency in waste treatment with black soldier fly (*Hermetia illucens*). Journal of Cleaner Production 2019;208:211-9.

Mahmood S, Zurbrügg C, Tabinda AB, Ali A, Ashraf A. Sustainable waste management at household level with black soldier fly larvae (*Hermetia illucens*). Sustainability 2021;13(17):Article No. 9722.

Muhamed JN, Umer MI. Nutrients contents and physical properties of hot composting of local organic waste in Duhok City, Iraq Kurdistan Region. The Seybold Report 2023;18(3):486-98.

Müller A, Wolf D, Gutzeit HO. The black soldier fly, *Hermetia illucens*: A promising source for sustainable production of proteins, lipids and bioactive substances. Journal of Biosciences 2017;72(9-10):351-63.

Pan I, Dam B, Sen SK. Composting of common organic wastes using microbial inoculants. 3 Biotech. 2012;2:127-34.

Rehman KU, Hollah C, Wiesotzki K, Rehman RU, Rehman AU, Zhang J, et al. Black soldier fly, *Hermetia illucens* as a potential innovative and environmentally friendly tool for organic waste management: A mini review. Waste Management and Research 2023;41(1):81-97.

Sarpong DE, Oduro-Kwarteng S, Gyasi SF, Buamah R, Donkor E, Awuah E, et al. Biodegradation by composting of municipal organic solid waste into organic fertilizer using the black soldier fly (*Hermetia illucens*) (Diptera: Stratiomyidae) larvae. International Journal of Recycling of Organic Waste in Agriculture 2019;8:45-54.

Schmitt E, de Vries W. Potential benefits of using *Hermetia illucens* frass as a soil amendment on food production and for environmental impact reduction. Current Opinion in Green and Sustainable Chemistry 2020;25:Article No. 100335.

Sharma A, Soni R, Soni SK. From waste to wealth: Exploring modern composting innovations and compost valorization. Journal of Material Cycles and Waste Management 2024;26(1):20-48.

Stănescu AM, Grigore A, Sîrbu C, Mihalache D, Rujoi B, Marin N. Estimation of measurement uncertainty for phosphorus spectrophotometric determination in organo-mineral fertilizers. Scientific Papers. Series A. Agronomy 2021;64(2):145-51.

Sullivan DM, Bary AI, Miller RO, Brewer LJ. Interpreting Compost Analyses. Oregon State University Extension Catalog [Internet]. 2018 [Cited 2023 Oct 25]. Available from: https://catalog.extension.oregonstate.edu/em9217.

Terrell C. Examining Black Soldier Fly (*Hermetia illucens*) Composting for Urban Ag Specialty Crop Production [dissertation]. Purdue University; 2022.