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Biodegradation of kitchen waste into organic fertilizer using the black soldier fly (*Hermetia illucens*) larvae

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ABSTRACT

The black soldier fly (Hermetia illucens) (Diptera: Stratiomyidae) larva is belived to be a potential means to degrade organic matter such as food waste and divert the waste away from landfills. Thus the experiment on biodegradation by composting kitchen waste into organic fertilizer using the black soldier fly (Hermetia illucens) larvae was conducted at AICRP on PHET of Dr P.D.K.V Akola with an objectives to investigate the decomposition efficiency of the black soldier fly larvae on kitchen waste and obtaining the organic compost. The experiment had 10 different feeding rates of BSFL were tested against a common substrate which was kitchen waste. In each container fixed quantity of kitchen waste was kept i.e. 20 kg and 6 days old larvae of BSF larvae were released in the proportion of 500 larvae to 5000 larvae as per treatments. 100 gm samples from each treatment, waste and compost were analyzed for various parameters. The study showed that by adding 2000 larvae per 20 kg kitchen waste for 22 days in batch feeding, gives a higher percent Substrate reduction (87.95%), and higher feed consumption (18.57 %). The study revealed that the % organic carbon, N, P, K were observed within the range of 24.02-29.56%, 1.35-1.63%, 0.64-0.80% and 1.32-1.49% respectively. Compost obtained from T4 i.e. (2000 larvae per 20 kg kitchen waste) was recorded of best quality compost with favourable EC, ph, nitrogen, phosphorous and potassium. Although it is cost effective, short duration procedure but there are certain drawbacks such as unavailability of sophisticated machinery, skilled labour and establishing optimal humidity, temperature and mating conditions to facilitate BSF development are also a challenges.

Keywords: *BSFL, Kitchen waste, organic fertilizer, biodegradation, compost*

INTRODUCTION

India is the most populated country in with more than 1.42 billion population contributing 17.76% of the world's total population. On the contrary, India shares only 5% of the world's area accounting 3,185,263 km^2. Out of total population, 64% lives in rural areas; while 36% lives in urban areas (United Nations Population Division estimates 2023). Currently, 1,27,486 tons per day of municipal solid waste is being generated due to various household activities and other commercial & institutional activities (CPCB, 2012).

According to the United Nations Development Programme, up to 40% of the food produced in India is wasted. About 21 million tonnes of wheat are wasted in India and 50% of all food across the world meets the same fate and never reaches the needy. In fact, according to the agriculture ministry, INR 50,000 crores worth of food produced is wasted every year in the country. The total agricultural residue wastes are expected to be 92 million tonnes per year in India [2]. According to the Press Information Bureau, India generates 62 million tonnes of waste (mixed waste containing both recyclable and non-recyclable waste) every year, with an average annual growth rate of 4% (PIB 2016). Daily 10 to 15 tons of food and vegetable waste from approximately 500 restaurants and delivered to the plant.

The waste produced in India has high organic content, i.e., about 50% in comparison to 30% produced by developed nations [9].

A: Solid waste: Any waste other than human excreta, urine & waste-water, is called solid waste. Solid waste in rural areas generally includes- house sweeping, kitchen waste, garden waste, cattle dung & waste from cattle sheds, agro waste, broken glass, metal, waste paper, plastic, cloths, rubber, waste from markets & shopping areas, hotels, etc. Solid waste can also be defined as the organic and inorganic waste materials produced by households and commercial & industrial establishments that have no economic value to the owner. Also, the natural sources of plant nutrients are being depleted and some are non-renewable (e.g. phosphorus), and we surpass the planetary boundaries of reactive nitrogen (N) in the atmosphere [15], harvesting nutrients from biodegradable materials, as a measure to recover them [8], become increasingly important [7]. Thus cycling of nutrients and bio-economy are the only potential solutions for these problems.

For several years, researchers globally have proposed using the larvae of the black soldier fly (*Hermetia illucens*) (Diptera: Stratiomyidae) as a potential means to degrade organic matter such as food waste to divert the materials away from the limited landfills [4] [5]. The black soldier fly (BSF) is a wasp like fly distributed over the tropical and temperate regions of the world [13]. The main areas of emphasis include different types of composting practices adopted in the Indian Scenario, i.e.co-composting of various biodegradable wastes; gaps identified in

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the composting process and perspectives for its effective implementation; various aspects associated with BSF; utilization of BSF in the diverse field and its effective application in the decomposition of biodegradable wastes. It is cost effective, short duration process but there are certain drawbacks such as unavailability of sophisticated machinery, skilled labour and establishing optimal humidity, temperature and mating conditions to facilitate BSF development are also a challenges. The natural diet of BSF larvae (BSFL) includes animal manures, human excreta, fruit and vegetable wastes, and carrion [14]. BSFL consume this bio waste, convert it into larval biomass, and leave behind a residue, with characteristics similar to immature compost [16] [17].

In the waste management chain, there have been value-addition efforts where wastes have been transformed to other valuable resources, thereby reducing the need for fresh raw materials. One such approach is in the Black Soldier Fly (BSF) bioconversion of organic wastes. Organic wastes such as animal wastes, household wastes, commercial wastes (from stores, shops, markets, hotels, etc.) and institutional wastes (schools, hospitals, etc.) are usually generated in large quantities, and are potential environmental pollutants and human health hazards if not handled well.

Because of the above, the objectives of the study are to investigate the decomposition efficiency of the black soldier fly larvae on kitchen waste and obtain the organic compost.

MATERIALS AND METHODS

Experimental site

The experimental site was located in the campus All India Coordinated Research Project on PHET of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra during 2020-2023.

Construction of Infrastructure and rearing chamber:

The separate experimental set was prepared which involved an iron rack for rearing of BSF flies. Two iron cages (6 x 3m) were constructed and covered with a wire mesh all around. One cage was covered with white mesh, while another was covered with black cloth. The mesh was aimed at allowing light inside as well as preventing the flies from escaping. The wooden strips were prepared and placed in a chamber covered with white net for collection of BSF eggs. White net-covered cages were used for rearing of black soldier fly larvae. Black cage was used for rearing of pupa.

The experiment was conducted in a completely randomized block design. The experiment was carried out in an iron rack (6 × 3 m) which is enclosed by mosquito nets. The cages were placed on top of a table (0.5 m height) and exposed daily to direct sunlight for approximately 12 h. In the cages, transparent plastic bows (10 L) containing organic waste were used to attract the BSF females for oviposition. A pre-feed placed inside a plastic bowl was covered with perforated black polythene to prevent direct exposure to sunlight and loss of excessive moisture. The hatched eggs remained in the pre-feed for 4 days. The young larvae (4–6 days old) were collected and counted manually. The hatched larvae were kept in a container, with wetted poultry feed given under the prevailing temperature of 25.5–26.8 °C and relative humidity at 60–85%. To supply the colony of new adult, 300 adult black soldier flies were attracted to the system and the same procedure was followed as described above.

Rearing of Black soldier fly larvae

BSF Larvae Experiment

Initially, a total 20kg of kitchen waste in batch-type feeding was given to larvae. The larvae composting experiments were conducted in plastic Containers. The plastic trays were filled with kitchen waste. The 6-7 days old BSF larvae as per treatment were released into the containers each containing 20 kg of kitchen waste. Feeding was performed only once during the whole experiment which lasted for about 21 days; based on the BSF life cycle time from larval to prepupal stage. The top of the plastic trays was covered thoroughly with mosquito nets, to prevent the predators such as ants, reptiles, birds and other insects from damaging and breeding, them with the containers.

Kitchen waste from hostels within the campus of Dr PDKV Akola was collected and used for the experiment.The treatment comprised of 20 kg kitchen waste kept in 10 different plastic containers in which different numbers of larvae were released as per treatment shown in Table No.1. The plastic trays were covered with mosquito nets, to prevent any invasion from other insects or pests. When larvae attained the pre-pupal form they were shifted to the rearing chamber. The system was monitored continuously for a period of 22 days according to the life cycle of the BSF. 100 gm sample each from the waste and compost were analyzed for various parameters. The compost parameter i.e. PH, EC, Total organic carbon , Nitrogen %, Phosphorous percent and potassium percent in waste composition was measured at the end of the experiment to understand the quality of compost product. The analysis of compost parameters were done at Soil Science Department, Dr. PDKV, Akola. The substrate reduction, bioconversion rate, survival rate and feed conversion rate were calculated by following formulae.

$$\text{Substrate Reduction (\%)} = \frac{\text{Total feed added} - \text{Residue feed after treatment}}{\text{Total feed added}} \times 100$$

$$\text{Feed (FCR)} = \frac{\text{Feed consumed}}{\text{Total prepupal biomass}}$$

$$\text{Bioconversion rate (\%)} = \frac{\text{Total prepupal mass}}{\text{Total feed added}} \times 100$$

$$\text{Surviaval rate \%} = \text{Survivors/samples} \times 100$$

Sample = No, of larvae used/ Number of recorded larvae/prepupa

(Source: [1], Gibson & Cameron, 2014; [3])

Statistical analysis

The data was subjected to one-way ANOVA to determine significant differences between larvae treatments, within the same feeding treatments. Tukey HSD method was used for mean separation between treatments at 95% confidence level. CRD for compost analysis.

Following Observations were recorded for experiment:

Dependent Parameters:

1. PH
2. Total Organic Carbon
3. Total Nitrogen
4. C:N ratio

Other Observations

At the end of experiment i.e. after 60 days following parameters will be recorded.

1. Final wt of compost
2. Total P
3. Total K

RESULT AND DISCUSSION

The results obtained during the study of biodegradation by composting kitchen waste into organic fertilizer using the black soldier fly (*Hermetia illucens*) larvae are shown in the Table 1. Out of the initially added 20 kg feed total feed consumed was within the range of 17.41- 18.57 kg whereas the % substrate reduction was observed within the range of 76.13 – 86.87%. Maximum feed consumption was observed in treatment T4 and T10 (18.57 kg) while the least feed was consumed in T1 (17.41 kg). The highest and lowest % substrate reduction was observed for treatment T4 (87.95%) i.e. 2000 larvae per 20 kg kitchen waste and T1 (76.13) i.e 500 larvae per 20 kg kitchen waste respectively. A pattern was observed that substrate reduction declined with increased larvae rate up till treatment T4 i.e 2000 larvae per 20 kg kitchen waste. Feed conversion ratio (FCR) indicates the proportion of digested food that is assimilated and therefore ends up as biomass, and the lower value indicates higher efficiency of conversion of substrate to biomass. Thus, a higher FCR indicates that the substrate is digestible but of little nutrient value and therefore largely excreted.

The higher feed conversion rate was observed for T1 which was 18.27 % whereas the lowest Feed conversion rate was observed in T10 (12.13) which was at par with treatment T4 (13.55%) T8 (13.79%) and T9 (13.58%). The bioconversion rate shows the conversion of substrate into prepupal yield. The Bioconversion rate was maximum in treatment T10 (11.88%) followed by treatment T8 (6.37%), T9 (5.83%) and T4 (5.13%) T6 (5.13%) respectively. The lowest Bioconversion rate was observed in T1 (1.42 %) i.e. 500 larvae per 20 kg kitchen waste. Bioconversion rates generally indicate the efficiency of consumption of a substrate by the larvae. Whereas the feed conversion ratio (FCR) indicates the proportion of digested food that is assimilated and therefore higher FCR indicates that the substrate is digestible but of little nutrient value and therefore largely excreted. This indicates that BSFL were fairly effective in reducing the substrate quantity and transformation of nutrients consumed into biomass. The low digestibility of the substrate is due to the addition of larvae. Prepupa yield obtained was maximum in treatment T10 (1162.96 g) followed by treatment T8 (926.85g), T9 (707.22g) T7 (649.10g), T5 (529.22g) and T4 (508.67g) respectively. The total substrate obtained was in the range of 1.26 to 2.20 kg from 20 kg of kitchen waste. It shows that that more solid reduction as well as equally substrate found in treatment from T1 to T5. Final compost was less in Treatment T4 i.e. 192.33g. The survival rate was in the range of 73.68 to 90.92 per cent. Maximum survival rate in treatment T1 (90.92 per cent) due to low population of larvae while lowest survival rate was found in treatment T10 (68.55 per cent) due to more population of larvae.

Diet reduction was observed within the same range as mentioned above i.e 59.4 – 72 % for different substrates Substrate reduction was observed within the range of 49.5 - 55.3 % when gathered from different sources [10]. Bioconversion rate ranges from 3.7 – 11.8% for different substrates [11].

Table 2 revealed that for larval compost the PH range ranged from 6.55 to 8.82. The PH was equally effective in all the treatments. The significantly highest nitrogen % was found in treatment T8 (1.63 %) while the lowest was found in T1 (1.35 %). The highest phosphorous was observed in T9 (0.80%), followed by T6, T7, T8, T8, T5, T3 and T1 respectively.

The highest K was obtained from treatment T3 to T10 (0.71, 0.76, 0.78, 0.79, 0.78 and 0.80) respectively, which is equally effective in all the treatments.

The lowest K were obtained in T1 (1.32%) and T2 (1.66%). The highest C:N ratio was observed in Treatment T1 (23.85) and T2 (20.04), However the minimum C:N ratio were observed from T3 (17.81), T4 (16.12), T5 (15.50) T6 (15.53), T7 (15.04), T8 (14.73), T9 (15.06) and T10 (15.08). C: N ratio is less than 20 is likely to cause the mineralisation of organic nitrogen to inorganic which suitable for plants. The Carbon content ranged from 24.02 to 29.56 %. Highest carbon content was observed in treatment T1 (29.56 %) with least number of larva per 20 kg of waste while lowest was observed in T8 (24.02 %).

Similarly, the results has been found in within the PH rage was observed 6.2 – 7.4 for different feeding rates. Whereas the Total phosphorus was observed in the range of 0.75- 0.90% for different feeding rates [13]. Studies found that on completion of lifecycle of black soldier fly ph and total nitrogen content of compost was 7.03±0.03 and 1.525±0.01% respectively whereas the C:N ratio decreased over the time [12]. With a major environmental impact during the pre-treatment of food waste at a mass-rearing of BSFL, the life cycle assessment (LCA) of food waste to BSF conversion facility yields a low global warming potential (GWP) score of 17.36 kg CO2 per tonne of functional unit in terms of environmental sustainability [6].

CONCLUSION

From the above experiment it was concluded that by adding of 2000 larvae per 20 kg kitchen waste for 22 days in batch feeding, gives a higher percent Substrate reduction (%), higher feed consumption and lower feeding conversion rate. Compost obtained by giving treatment T4 i.e. (2000 larvae per 20 kg kitchen waste) was recorded as good quality compost with favorable nitrogen, phosphorous and potassium.The substrate reduction values obtained in the current study indicate that all the regimes were effective at waste reduction. Further research cab be carried out to evaluate the utilization of BSFL as an organic fertilizer for crop nutrition.

FUTURE SCOPE

Alleviation of environmental waste is a significant challenge at the local and global levels, to address this issue for effective sustainably, the Black Soldier Fly (BSF) emerged as a potential solution to convert the environmental waste in to valuable biomass.

CONFLICT OF INTEREST

The author declares no conflicts of interest.

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DATA AVAILABILITY

The data generated during the study are available as a preprint on the Research Square website with DOI: 10.21203/rs.3.rs-4297462/v1. That data is generated from raw data which is available from the corresponding author on reasonable request.

Figure 1. Constructed Rearing Chamber for BSF larvae

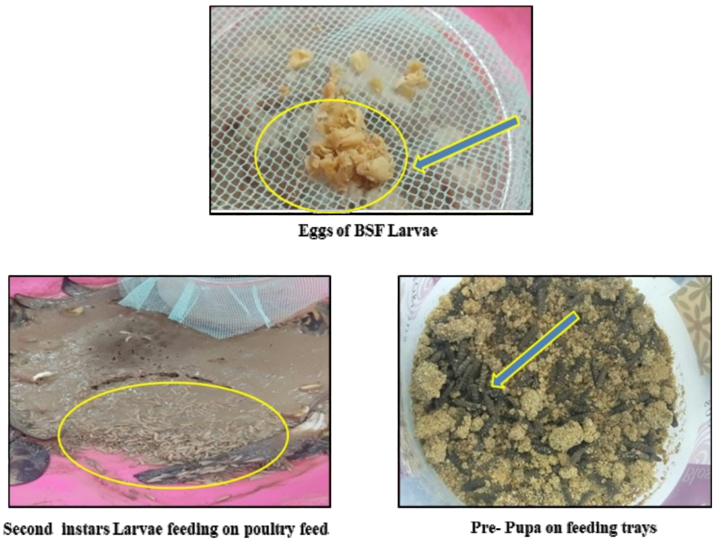

Figure 2. Rearing of BSF larvae in constructed chamber

Figure 3. Stepwise Method for Preparation of BSF Compost

Figure 4. Treatment wise Final compost

Table 1: Pooled mean effect of larvae perform following parameter

TR	TR (Larvae/20kg KW)	Feed added (kg)	Feed consumed (kg)	Substrate reduction (%)	Feed conversion rate (FCR) %	Bioconversion rate (%)	Pre pupa wt (gm)	Substrate obtained (kg)	Final substrate obtained(g)	Survival Rate %
T1	500	20	17.41	76.13	18.27	1.42	118.92	2.20	169.00	90.92
T2	1000	20	18.05	79.34	14.12	2.77	161.82	2.18	197.33	89.57
T3	1500	20	18.40	76.13	15.00	2.99	218.85	2.13	285.67	86.52
T4	2000	20	18.57	87.95	13.55	5.13	508.67	2.06	192.33	85.80
T5	2500	20	18.03	86.03	14.53	3.27	529.22	2.00	352.00	83.76
T6	3000	20	18.52	85.02	15.97	5.13	444.92	1.86	632.33	73.93
T7	3500	20	18.34	84.06	16.26	3.69	649.10	1.96	452.33	73.68
T8	4000	20	18.49	84.32	13.79	6.37	926.85	1.58	420.00	74.49
T9	4500	20	18.53	84.37	13.58	5.83	707.22	1.26	467.33	76.55
T10	5000	20	18.57	86.87	12.13	11.88	1162.96	1.84	472.67	68.55
SE (m ±)	SE (m ±)		0.10	6.693	1.58	1.6	111.72	0.250		4.50
CD at 5 %	CD at 5 %		0.32	NS	18.27	5.03	331.90	NS		13.36

Table 2: Pooled mean effect of larvae on compost parameter

TR	TR (Larvae/20kg KW)	PH	EC	Total N %	Total p %	Total K %	Carbon content%	C/N Ratio
T1	500	8.82 ±0.01	3.48 ±0.24	1.35± 0.10	0.65± 0.03	1.32 ±0.02	29.56 ± 0.2	23.85
T2	1000	7.26 ±0.03	3.19 ±0.49	1.36 ± 0.02	0.64 ± 0.02	1.36 ± 0.02	27.21 ± 1.15	20.04
T3	1500	7.02 ±0.08	3.29 ±0.06	1.44 ±0.02	0.71 ± 0.00	1.39 ± 0.00	25.56 ± 0.55	17.81
T4	2000	6.82 ±0.05	3.51 ±0.17	1.56 ± 0.00	0.76 ± 0.01	1.41 ± 0.00	25.14 ± 0.59	16.12
T5	2500	6.71 ±0.09	3.56 ±0.27	1.62 ± 0.03	0.78 ± 0.00	1.40 ± 0.00	25.04 ± 0.01	15.50
T6	3000	6.65 ±0.11	3.67 ± 0.49	1.60 ± 0.02	0.79 ± 0.02	1.45 ± 0.00	24.89 ± 0.35	15.53
T7	3500	6.59 ±0.06	3.83 ±0.08	1.61 ± 0.93	0.79 ± 0.00	1.48 ± 0.01	24.27± 0.47	15.04
T8	4000	6.55 ±0.05	3.76 ±0.47	1.63 ± 0.01	0.79 ± 0.02	1.46 ± 0.00	24.02 ± 0.62	14.73
T9	4500	6.58 ±0.06	3.78 ±0.51	1.60 ± 0.02	0.80 ± 0.00	1.47 ± 0.00	24.12 ± 0.59	15.06
T10	5000	6.60 ±0.04	4.48 ±1.33	1.62 ± 0.02	0.78 ± 0.02	1.49 ± 0.01	24.47 ± 0.62	15.08

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