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Research Paper

Study on occurrence of black soldier fly larvae in composting of kitchen waste

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Abstract

Composting technology has emerged as a brilliant solution for managing the accelerated pace of waste generation. It proves to be an environment friendly and sustainable approach of converting the waste into a nutrient rich by product called as compost/manure. This process is accomplished by the combination /interaction of various physical, biological and chemical parameters. The biological parameters involve interaction of various micro and macro organisms. Several investigations on occurrence and role of microorganisms during composting have been done, but little on the occurrence a role of macro-organisms in the process of waste to energy transformation. Macro-organisms include several arthropods, particularly insects that play a pivotal role in the process of waste management. The macro-organisms enhance the composting by feeding upon decomposing organic matter, and converting it into cured compost. Among these insects soldier fly *Hermetia illucens* (Diptera: Stratiomyidae) was observed during the study. The larvae of black soldier fly (BSF) have been used in manure management and as a protein feed in western countries, but not much light has been shed on their role in waste management in India. The present paper investigates the occurrence, problems and benefits of BSF larvae during the composting of kitchen waste.

Keywords: Black soldier fly, Composting, *Hermetia illucens,* macrorganisms, waste management.

Introduction

Rapid industrialization and urbanization has accelerated the pace of waste generation. Improper waste management practices such as incineration and land fillings create environmental pollution. Therefore there is a need to adopt an environment friendly technique to manage the waste generated. Many technologies have been developed for waste management, in which the most practiced one is composting technology. Composting is the process of converting the waste into useful product such as humus or manure which can be further used for plant nutrient and disease management. It involves the amalgamation of various physical, chemical and biological parameters. Biological parameters involves both the micro and macro organisms that take part at different stages and play a pivotal role in degradation of the waste, converting it into a useful end product. Many investigations have been done on the microorganisms, and a little on the macro organisms involved in the process[1]. One such macro organism found during composting process is the black soldier fly (*Hermetia illucens*).

Black soldier fly (BSF) (Linnaeus, 1758), is a tropical fly, that was first seen in 1930 in Hilo sugar company in Hawaain islands. It is native to America, stretching from the southern tip of Argentina to Boston and Seattle and was also spread to Europe, India, Asia and Australia during World War II [2]. Members involved in Stratiomyidae family generally appear in different colors ranging from yellow, green, black or blue, to some even having a metallic appearance. Some members also mimic other flying insects, such as bees and wasps. Gujarathi and Pejaver (2013) have brilliantly described the physiology of Black soldier fly. The adult flies are without bristles and have wasp like appearance.

Their scutellum is often conspicuously developed with two translucent "windows" located on the first abdominal segment. They have particular vein system, with all the wing veins crowded near the costa with more pigmentation than the ones behind, while vein C, not surrounding the wing. The adult's possess elongated antennae with three segments. White coloration appears near the end of each leg. The most important benefit of this fly with respect to its proposed use for composting of organic waste matter is that the adult flies are not attracted to human habitation or foods and therefore it is not considered as a pest [3]. Black soldier flies lay their eggs in moist organic material during natural breeding whereas in urbanized areas they lay their eggs in dumpsters or compost [4]. Various organic matter such as kitchen waste, food waste (animal and vegetable origin) and fresh manure have been found to be the habitat of larvae of black soldier flies[5]. The harvested pupae and pre pupae have been found to be consumed by dogs, poultry, pigs, fish and even turtles.

Figure 1: Larvae of black soldier fly

Soldier fly adults (females) mate once with one ovipositon event in their lifetime and produce 320- 639 eggs. They lay eggs in dry cervices near a moist waste (food) source nearly 2 days after copulation, once with suitable partners, near a secluded bush or tree[6]. After the eggs, the hatched neonate larvae quickly make their way to the resource[7]. These neonate larvae feed on the moist decomposing organic matter until their post feeding stage after which they leave their resource and search a place to pupate and complete metamorphosis. This life history was observed in confined animal feeding operations in the southeastern United States[8]. The development of larvae directly depends on the food quality available to them[6]. Similar to this hypothesis on black soldier fly , Chippindale et al. 1993 also determined that the food quality was directly related to the number of egg produced, and inversely to the adult longevity for *Drosophila melanogaster* Meigen (Diptera: Drosophilidae).

Apart from various other important benefits, (Figure 2), these maggots (BSF larvae) play a pivotal role in composting of organic waste. While occupying the manure, they play an important role of aeration (by regular turning/ crawling) and reduction in moisture and odor. This comes from their property of modifying the micro flora of the compost, reducing the harmful bacteria such as of E. coli 0157:H7 and Salmonella enteric[10] through production of bacteriostatic, bactericidal, and/or fungicidal compounds[10]. Western countries are employing this technique to reduce animal manure in commercial swine and poultry facilities [2], but in india this technique for waste management is not much common. In low and middle income countries black soldier fly constitutes a potential benefit by valorization of municipal organic waste through its larval feeding activity[11]. Larvae of BSF were found in poultry house in Punjab (India) in 2007[12].

These maggots are not being employed for composting of kitchen waste in India. In the present study, these maggots appeared during composting process, when the season was humid, with temperature and relative humidity around 28-30°C and 70% respectively.

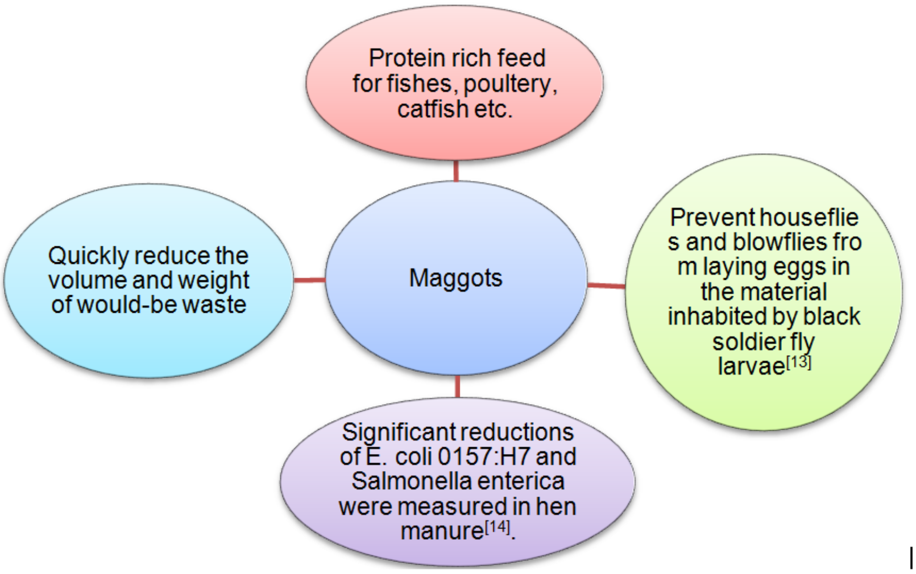

Figure 2: Benefits of black soldier fly larvae

It has been reported that these maggots can survive in a wide range of temperature ranging from 28-36 degrees[15]. The larvae of the black soldier fly are voracious consumer of decaying organic matter including kitchen waste, spoiled feed, and manure[5].The present paper therefore, investigates the occurrence, problems and benefits of maggots (BSF larvae) during composting of kitchen waste.

Materials and Methods

Experimental set up

Kitchen waste and cow dung (3:1) were mixed together in an earthen pot having a capacity of 4 Kg with a hole at the bottom. The waste comprised of food waste and vegetable peelings disposed off from hostels in the campus. The experiment was performed in three replicates. The oviposting black soldier fly came from the natural surroundings. The pots were covered by wire meshes to prevent any invasion from animals. The pots were incubated in natural environmental conditions. The experiment was performed till 60 days after which the whole waste was converted into manure. Samples were withdrawn / collected at regular intervals (10 days) for analysis. The initial moisture content of the feedstock was 79%. Black soldier flies were observed on the upper strata of the pot, while their larvae were found buried in the middle and the lower layers of the compost. These were not isolated from the compost, in order to observe their role in composting process. After pre decomposition (15-20 days), the substrate was also fed upon with 10 earthworms (*Eisenia fetida*) to investigate their interaction with the larvae.

Analytical methods

Parameters viz. moisture content, electrical conductivity, pH, TOC and TKN content were investigated during the study. Approximately 100 gram of sample was withdrawn at regular intervals (10 days). The samples were withdrawn after mixing the whole substrate. Fresh samples were used for determining moisture content by moisture analyzer. Electrical conductivity and pH were analysed in a 1:10 and 1:5 water soluble extract by conductivity meter and pH meter respectively. TOC and TKN were determined by CHNS analyzer.

Seed germination and root length test was carried out on water extracts by mechanically shaking the fresh samples for 1 h at solid: double distilled water ratio of 1:10 (w/v, dry weight basis). About 10.0 mL of each extract was pipette into a sterilized plastic petri dish (9cm) lined with a Whatman #2 filter. Ten pea seeds (*Pisum sativum*) were evenly placed on the filter paper and incubated at 25^{0}C in the dark for 48 h. Triplicates were analyzed for samples from composting mixture. Germination index in the compost sample extract was calculated by counting the number of germinated seeds and measuring the length of roots. The responses were calculated by germination index (GI) that was determined according to the following formula [16]:

$$\text{Germination Index} = \frac{\text{Seed germination \%} \times \text{mean root length of treatment}}{\text{1Seed germination \%} \times \text{mean root length of control}} \times 100$$

Results and discussion

During the present study, the adult flies hovered upon the strata while the larvae were found voraciously eating the remaining matter in the compost. The blackish gray and the white larvae consumed almost every bit of the organic matter present in the waste, reducing the volume of the compost to 50 % of the initial substrate.

pH

The pH change during composting of kitchen waste is shown in table 1. During initial phases of composting, ammonia releases due to ammonification and mineralization of organic nitrogen which resulted in increase in pH values from initial 6.61 to 7.60 in 10 days [17]. After that, the pH gradually decreased creating acidic conditions with a pH of 6.61 till day 40. After day 40, the pH values shifted to neutral values and stabilized in values of 7.03 for the composting mixture. This might be due to the volatilization of ammonia, the H+- released from microbial nitrification, the decomposition of OM and production of organic and inorganic acids and release of carbon dioxide during the composting process [17].

Electrical conductivity

Electrical Conductivity(EC) reflects the degree of salinity in the composting product, which indicates its possible phytotoxic /phyto-inhibitory effects (e. g. low germination rate, withering) on the growth of plants[18] EC for composting mixture of initial 4.40mS/cm increased to 4.63 mS/cm on day 20, followed by a gradual decrease till the end of composting process (table 1). The initial EC increase could be caused by the release of mineral salts such as phosphates and ammonium ions through the decomposition of organic substances[19]. As the composting process progressed, a decrease in the EC was observed. This could be probably due to volatilization of ammonia and the precipitation of mineral salts in the later phase of composting[20]. Consumption of nutrients by the larvae could also be a probable reason for decrease in EC in later phases of composting. After 60 days of composting, the EC contents of the composting mixture did not exceed the limit value of 3000 mS /cm suggested by [21] for stable composts.

Moisture

The moisture content during composting was monitored, and the changes are shown in Table 1. In the 60-day composting process, the total moisture content dropped from 79%to 50%. Since the optimal moisture content in composting is 50.0 to 60.0%, a moisture content of over 65.0% can cause oxygen depletion [22,23]

Total kjeldahl nitrogen and Total organic carbon

Nitrogen content decreased during the course of composting process (Table 1). The decrease in nitrogen could be due to volatization of nitrogen in form of ammonia. A similar decline in total nitrogen was observed during the later stages of composting. The probable reason could be the consumption of nitrogen by larvae of BSF. Sheppard et al. 1998 also observed a 24% reduction in total nitrogen concentration (62% reduction of N mass) in manure managed by BSF larvae. This decrease is contradictory to the studies that state that the nitrogen (nitrates and nitrites) content increases, due to the presence of nitrifying bacteria in the later phases of composting[25]. During a study it has been observed that black soldier fly larvae reduces the concentrations of nutrients of fresh manure, generally, from 40 to 55% .This reduction does not take into account the 56% reduction in manure mass[5]. Total organic carbon reflects the mineralization of the organic matter. The carbon content decreased from an initial value of 30.98% to 12.56 %, due to loss of the organic carbon in form of CO_2 (Table 1). The loss of dry mass (organic carbon) in terms of CO_2 as well as water loss by evaporation during mineralization of organic matter was also reported by Viel et al. 1987.

Compost maturity

Germination index (GI), is a measure of phytotoxicity, and is being considered as an indirect method to evaluate the maturity of compost [27]. However, it is difficult to apply these parameters across a wide range of composts prepared from different organic wastes [28-30]. In the present study, seeds showed 90% germination, but there were differences in the root lengths of the seeds in compost extract and control. The Germination Index values in composting mixture were found to be 77%. Zucconi, et al 1981 reported that a GI value of more than 80% is an indication of phytotoxic-free and mature compost. Similar suggestions were also reported by Tiquia *et al.* 1998. Maturity of the compost is also expressed in terms of C/N ratio. In the present study, as the decomposition progressed due to losses of carbon mainly as carbon dioxide, the carbon content of the compostable material decreased with time and N content per unit material also decreased, which resulted in the decrease of C/N ratio. The C/N ratio declined to 8.23 from an initial of 20.31(Figure3). This is contradictory to the results of Goyal et al. 2005 which state that there is a decline in TOC but an increase in TKN during the composting period. C/N ratio below 20 is considered as an acceptable limit of mature compost. However, Hirari et al. 1983 stated that the C:N ratio cannot be used as an absolute indicator of compost maturity, since the values for well-composted materials present a great variation in the maturity, possibly due to the characteristics of the waste[32].

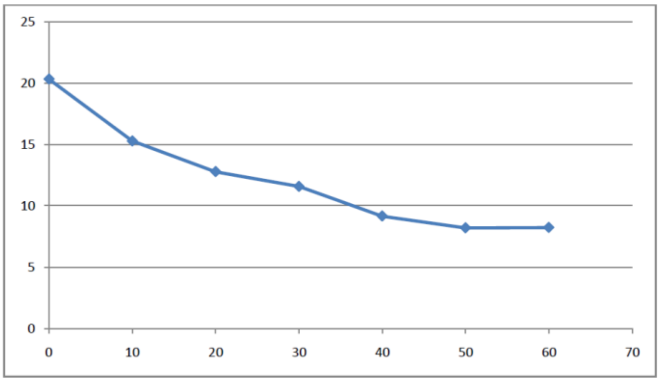

Figure 3: Changes in C: N ratio v/s days of the compost

Interaction with earthworms

Earthworms inoculated after pre decomposition, could not survive in the composting environment. A hypothetical reason could be the acidic environmental and hot temperatures 37.78^{0}C created by the larval laechet and the larvae respectively.

Most attempts to raise large number of larvae with earthworms in the same container, at the same time, were unsuccessful during the present study. Earthworms may survive in grub bins when there are not a large number of larvae present.

Also, the worms could be introduced when the larvae population gets low specially in the cold season. Another apparent reason for reduction in number of earthworms could also be depletion of the nutrients, as the authors are not sure whether the earthworms were attacked by the larvae.

Conclusion

BSF larvae are commonly used in household and animal waste management in western countries since long time [34,11]**.** In India as larvae flourish more in tropical environment than in colder one[34], they may be cultured for different applications such as soybean or fish meal in formulated diets, feed for cockerels[35], pigs[36] and catfish and tilapia[37], suitable replacement for conventional protein and fat sources, feed for chicks as the protein supplement[35]. The present study concludes that although the BSF larvae play role in converting the waste into compost, the compost generated is low in nutrient content. The reason behind it is the consumption of the nutrients from the compost by the larvae. Also the study revealed that the vermicomposting of waste in presence of the larvae is not possible. The larvae have been found to reduce the number of earthworms. As not much attention has been paid on the occurrence of these maggots in the composting process, in depth research is needed in this area to get more information.

Table 1: Changes in EC, pH, TOC, TKN and protein during composting

Days	EC (mS /cm)	pH	TOC (%)	TKN (%)	Moisture content (%)
0	4.40±0.02	6.61±0.06	30.98±0.1	1.689±0.01	79±1.36
10	4.52±0.02	7.60±0.03	25.03±2	1.639±0.01	75±3
20	4.63±0.01	6.86±0.05	20.63±1	1.614±0.001	70±4
30	3.30±0.15	6.71±0.01	18.45±3	1.594±0.02	68±1
40	2.63±0.01	6.61±0.01	14.56±1	1.589±0.01	65±6
50	1.64±0.02	6.86±0.04	12.98±2	1.582±0.03	58±2
60	1.63±0.01	7.03±0.03	12.56±1	1.525±0.01	50±6

References

1. Sagade G.A. and Pejaver M.K., Study of diversity of insect fauna from the household biocompost, Bionano Frontier*,* 3(1), 67-70 **(2009)**

2. Gujarathi G. R. and Pejaver M K., Occurrence of Black Soldier Fly *Hermetia illucens* (Diptera: Stratiomyidae) in Biocompost, J. Research Journal of Recent Sciences, 2(4), 65-66, **(2013)**

3. Furman D. P., Young R. D. and Catts E. P., Hermetia illucens as a factor in the natural control of Musca domestica Linnaeus, J. Econ. Entomol. 52, 917-921 **(1959)**

4. Diclaro II J.W. and Kaufman P.E., Publication # EENY 461 http://edis.ifas.ufl.edu/in830 **(2009)**

5. Newton L., Shepphard C., Watson D.W., Burtle G., Dove R., Using the black soldier fly, hermetia illucens, as a value-added tool for the management of swine manure. Report for mike williams director of the animal and poultry waste management center, north carolina state university, raleigh, nc. agreements between the nc attorney general, smithfield foods, premium standard farms, and frontline farmers **(2005)**

6. Tomberlin J.K., Sheppard D.C. and Joyce J.A., Selected life-history traits of black soldier flies (diptera: stratiomyidae) reared on three artificial diets, Ann. entomol. soc. am., 95(3), 379-386 **(2002)**

7. Booth D.C. and Sheppard D.C., Oviposition of the black soldier fly, *Hermetia illucens* (Diptera: Stratiomyidae): eggs, masses, timing and site characteristics, Environ.Entomol., 13, 421-423 **(1984)**

8. Sheppard D.C., Newton G.L. and Thompson S.A., A value added manure management system using the black soldier fly, Bioresource Tech. 50, 275-279 **(1994)**

9. Chippindale A.K., Leroi A.M., Kim S.B., Rose M.R., Phenotypic plasticity and selection in *Drosophila* life history evolution. I. Nutrition and the cost of reproduction, J. Evol. Biol., 6, 171-193 **(1993)**

10. Erickson M.C., Islam M., Sheppard C., Liao J. and Doyle M.P., Reduction of Escherichia coli O157:H7 and Salmonella enterica serovar Enteritidis in chicken manure by larvae of the black soldier fly, J. Food Protection, 67, 685-690 **(2004)**

11. Diener S., Zurbrug C., and Tockner K., Conversion of organic material by black soldier fly larvae: establishing optimal feeding rates, Waste Manag. Res*.,* 27 (4), 603-610 **(2009)**

12. Ashuma B.M., Kaur P., Rath S. and Juyal P., First report of *Hermatia illucens* larvae in poultry houses of Punjab, Journal of Parasitic Diseases, 31(2), 145-146 **(2007)**

13. Black Soldier Fly: Compiled Research On Best Cultivation Practices. Research Resources, 9, (**2008)**

14. Research Summary: Black Soldier Fly Prepupae - A Compelling Alternative to Fish Meal and Fish Oil, February 14, **(2011)**

15. Tomberlin J.K., Adler P.H. and Myers H.M., Development of the Black Soldier Fly (Diptera: Stratiomyidae) in Relation to Temperature, environ. entomol., 38(3),930- 934 **(2009)**

16. Zucconi F., Pera A., Forte M., De Bertoldi M., Evaluating toxicity of immature compost, Biocycle, 22, 54–57 **(1981)**

17. Wong J.W.C., Mak K.F., Chan N.W., Lam A., Fang M., Zhou L.X., Wu Q.T., Liao X.D., Co-composting of soybean residues and leaves in Hong Kong, Bioresour. Technol., 76, 99–106 (**2001)**

18. Lin C., A negative-pressure aeration system for composting food wastes, Bioresour. Technol., 99, 7651–7656 (**2008)**

19. Fang M., Wong J.W.C., Effects of lime amendment on availability of heavy metals and maturation in sewage sludge composting, Environ. Pollut., 106, 83– 89 **(1999)**

20. Wong J.W.C., Li S.W.Y., Wong M.H., Coal fly ash as a composting material for sewage sludge: effects on microbial activities, Environ. Technol., 16, 527–537 **(1995)**

21. Soumare M., Demeyer A., Tack F.M.G., Chemical characteristics of Malian and Belgian solid waste composts, Bioresour. Technol., 81, 97–101 **(2002)**

22. Gray K.R., Sherman K. and Biddlestone A.J., A Review of Composting − Part 2. The Practical Process. Process Biochemistry, 10, 22-28, **(1971)**

23. Ryckeboer J., Megaert J., Coosemans J., Deprins K. and Swings J., Microbiological aspects of biowaste during composting in monitored compost bin. – J. Appl. Microbiol., 94(1), 127-137 **(2003)**

24. Sheppard D.C., Newton G.L., Thompson S., Davis J., Gascho G., Bramwell K., Using soldier flies as a manure management tool for volume reduction, house fly control and reduction, house fly control and feedstuff production (51-52). (In) Sustainable Agriculture Research and Education, Southern Region, 1998 Annual Report. Gwen Roland, Editor **(1998)**

25. Pare T., Dinel H., Schnitzer M. and Dumontet S., Transformations of carbon and nitrogen during composting of animal manure and shredded paper, Biol Fertil Soils, 26, 173–178**(1998)**

26. Viel M., Sayag D., Andre L., Optimisation of agricultural, industrial waste management through in-vessel composting, In: de Bertoldi, M. (Ed.), Compost: Production, Quality and Use, Elseiver Appl. Sci. Essex., 230–237 **(1987)**

27. Queda C., Vallini A.C., Agnolucci G., Coelho M., Campos C.A., De L. and Sousa R.B., Microbiological and chemical characterization of composts at different levels of maturity, with evaluation of phytotoxicity and enzymatic activities, In: Insam, H., Riddech, N., Krammer, S. (Eds.), Microbiology of Composting, Springer Verlag, Heidelberg, 345–355 **(2002)**

28. Roletto E., Barberis R., Consignlid M., Jodice R., Chemical parameters for evaluation compost maturity, Biocycle March, 46– 48 **(1985)**

29. Saviozsi A., levi-Minzi R., Riffaldi R., Maturity evaluating of organic waste, Biocycle March, 54–58 **(1988)**

30. Benito M., Masaguer A., Moliner A., Arrigo N., Palma R.S., Chemical and microbiological parameters for the characterization of the stabilizing and maturing of pruning waste compost, Biol. Fertil. Soils, 37, 184–189 **(2003)**

31. Tiquia S.M., Tam N.F.Y., Elimination of phytotoxicity during co-composting of spent pig-manure sawdust litter and pig sludge, Bioresour. Technol. 65, 43– 49 **(1998)**

32. Goyal S., Dhull S.K., Kapoor K.K., Chemical and biological changes during composting of different organic wastes and assessment of compost maturity, Bioresource Technology, 96,1584–1591**(2005)**

33. Hirari M., Chanyasak V., Kubota H., A standard measurement for compost maturity, Biocycle., 24, 54–56 **(1983)**

34. Sheppard D.C., Tomberlin J.K., Joyce J.A., Kiser B.C. and Sumner S.M., Rearing methods for the black soldier fly (Diptera: Stratiomyidae), Journal of Medical Entomology, 695-698 **(2002)**

35. Hale O.M., Dried Hermetia illucens larvae (Stratiomyidae) as a feed additive for poultry, J. Ga. Entomol. Soc., 8, 16-20 **(1973)**

36. Newton G.L., Booram C.V., Barker R.W., Hale O.M., Dried *Hermetia illucens* larvae meal as a supplement for swine, J. Anim. Sci., 44, 395-399 **(1977)**

37. Sheppard D.C. and Newton G.L., Valuable by-products of a manure management system using the black soldier fly, Proceedings of the 8th International Symposium, ASAE, St Joseph, MO in Animal, Agricultural and Food Processing Wastes, 35-39 **(2000)**