The efficiency of effective microorganism (EM) as catalyst in food waste composting using black soldier fly larvae

Irfana Kabir Ahmad[1*], *Noor Ezlin Ahmad* Basri[1], *Nurul 'Ain Abdul* Jalil[2] and N*ur Fardilla* Amrul[1]

[1]Department of Civil Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, Bangi 43600, Malaysia
[2]Department of Earth Science and Environment, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, Bangi 43600, Malaysia

Abstract. Composting is sustainable alternative method which can be utilized to recycle organic wastes. In this research, black soldier fly (BSF) larvae and effective microorganisms (EM) were used together to compost organic waste. This study seeks to investigate the effectiveness of composting food waste using EM together with BSF larvae and to determine whether the growth of BSF larvae is affected by the presence of EM. 5 g of BSF larvae and 300 g of food wastes were put in four different containers with different concentration of EM (0-25%). The larvae were weighed throughout the 13-day experiment, and the changes in food waste volume were recorded to calculate the percentage of frass. Results showed that BSF larvae in the container which has the highest EM concentration (25% EM) produced the highest percentage of compost (89%). Meanwhile, there is a slight difference in the weight of larvae in all samples, where the weight ranges from 5.6 g to 6.5 g. In conclusion, the presence of EM can assist BSF larvae in accelerating the rate of food waste composting.

1 Introduction

Proper management of municipal solid wastes is a challenging task in most developing countries. The increasing generation of solid wastes is the most significant environmental problem in Malaysia. The Malaysian population is growing, which has led to the increased generation of solid wastes [1-2]. Malaysia adopts a number of waste management systems. The most preferred method is landfilling [3-4] and most of the landfills are open-dumping areas since it incurs the lowest cost; it is a commonly used method to treat solid wastes containing a high percentage of organic components [5]. This method has had adverse environmental impacts, such as contamination of surface and groundwater by the leachates produced in the decomposition of organic materials present in food wastes [6-7] as well as the production of toxic elements such as aromatic compounds, halogenated compound,

* Corresponding author: irfana@ukm.edu.my

phenols, pesticides, heavy metals and ammonium. These pollutants have a harmful effect on the survival of aquatic organisms, ecology, and food chains, which eventually leads to health problems [8]. Other impacts of landfilling are air pollution caused by the burning of wastes; soil contamination; the spread of diseases by vectors such as birds, insects and rodents; odour in landfills; and uncontrolled methane production due to the decomposition of organic wastes. It is estimated that over 97 % of food wastes are buried in landfills in the United State [9]. Composting is one of the alternatives for the proper management of food wastes. In Malaysia, this technique has a promising potential to reduce the amount of food wastes being dumped in landfills. It is also a sustainable method for producing bio-fertilizers. Composting method has been improved over time by using black soldier fly larvae (BSFL), *Hemertia illucens,* as an agent to compost food waste in a shorter period of time. The nutritious larvae can then be used as feed stock for farm animals, for instance as chicken feed. However, one of the issues in composting food waste is the emission of unpleasant odours because of the formation of trace volatilization of kitchen wastes during the decomposition process. The unpleasant odour is much stronger when the compost is acidic compared to when it is neutral or alkaline [10–12]. The odour has a significant effect on human health because hydrogen sulphide (H_2S) is a highly toxic gas. It leads to death if the concentration reaches 200 ppm [13]. The current composting methods are tumbler composting, vermicomposting and effective microorganism (EM) composting. Tumbler composting is a fully sealed container which can be rotated to mix the compost materials. The sealed container also helps to contain the heat generated during the composting process, thereby speeding up the process of converting the waste into compost. It was invented to make composting process simpler and faster. However, it is more expensive than compost bins and was designed for a maximum capacity of 9.5 ft^3. Vermicomposting is a process in which worms are used to convert organic material wastes into a humus-like material known as vermin-compost [4]. EM composting is a system generally used for composting with effective microorganism [14].

Effective microorganisms (EM) is commercially available. EM are a type of microbial inoculant developed by Teruo Higa (1991) [15]. The use of EM in compost production has been proven to accelerate composting process, reduce odour emission, and produce compost with higher nutrient content [16-19]. Some studies have demonstrated that EM does not necessarily ensure a good composting [20]. This indicates that the use of EM is only effective for certain types of wastes. EM may be useful for decomposing with microorganisms that are compatible with the characteristic of the waste to be composted. Compost materials produced in the presence of EM is able to produce bio-fertilizers that promote plant growth. Additionally EM has the ability to ensure the growth and establishment of other beneficial microorganism. The aim of this study is to determine the growth of BSF larvae in the presence of EM in the composting of food wastes. Furthermore, this experiment seeks to determine the effect of using EM as a catalyst on the rate of composting by BSF larvae.

2 Materials and method

In this experiment, BSF larvae (*H. illucens*) were used as an agent to decompose food wastes. The three to five day old larvae were supplied by a farm in Selangor. Effective microorganism (EM) was added together with the BSF larvae to establish its effectiveness in composting food wastes. The EM was supplied by a local company. The food wastes were collected from the cafeteria at the Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia (UKM), Bangi. The food wastes were grounded. The experiment was conducted in a batch of four containers labelled S1, S2, S3 and S4. Each container was filled with 500 g food waste, 5 g BSF larvae, and different concentrations of

EM of 0%, 5%, 15%, and 25%, respectively. Figure 1 (a) shows the material used in the experiment, i.e. BSFL, EM and food waste, and Figure 1 (b) presents a schematic diagram for the entire experimental design. The experiment was carried out for 13 days. 30 larvae were collected randomly every three days and weighed to monitor the mass of the larvae. The volume of food waste was also recorded every three days to determine the percentage of compost production, which was calculated using equation 1.

$$\text{Percentage of frass} = \frac{\text{Initial volume of food waste} - \text{Final volume of food waste}}{\text{Total volume of food waste}} \tag{1}$$

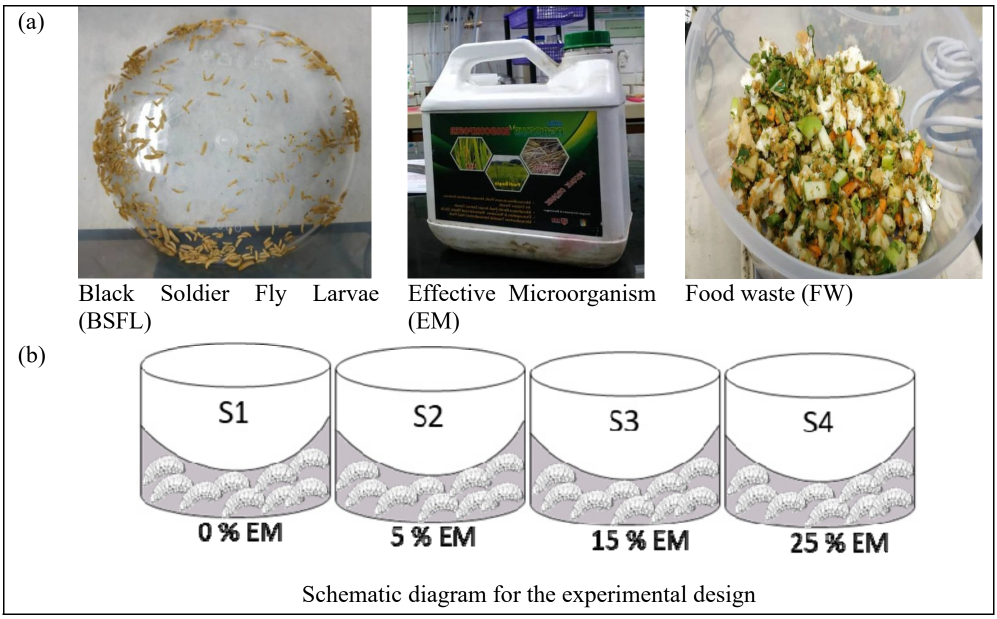

Fig. 1. (a) Materials used in the experiment, and (b) Schematic diagram for the experimental design for samples S1, S2, S3 and S4.

3 Results

3.1 Larval weight

Larval growth was determined by weighing 30 larvae from each sample (S1, S2, S3 and S4) every three days for 13 days. Figure 2 shows larval weight (g) over a period of 13 days. The figure shows a uniform increase in the weight of the larvae in S1, S2 and S4 until day 10, and the weight began to decrease at day 13 as larvae had molted into prepupae and pupae [21]. Based on observation, there were almost 90% of larvae in S1, S2 and S4 had turned into prepupae and pupae at day 13. However, 60% of larvae in S3 are still not molted into prepupae and pupae yet that may due to smaller larvae size from early stage, thus extend their development time. Therefore, larval weight in S2 still uniformly increased until day 13. In this experiment, the larvae in S1 has the highest weight of 6.5 g while larvae in S4 has the lowest weight of 5.6 g at the end of the experiment. Overall, the presence of EM has an effect on larval weight, with the higher percentage of EM resulting in lower larval weight in this study. Despite this, the presence of EM increases the rate of composting, which will be discussed in section 3.2.

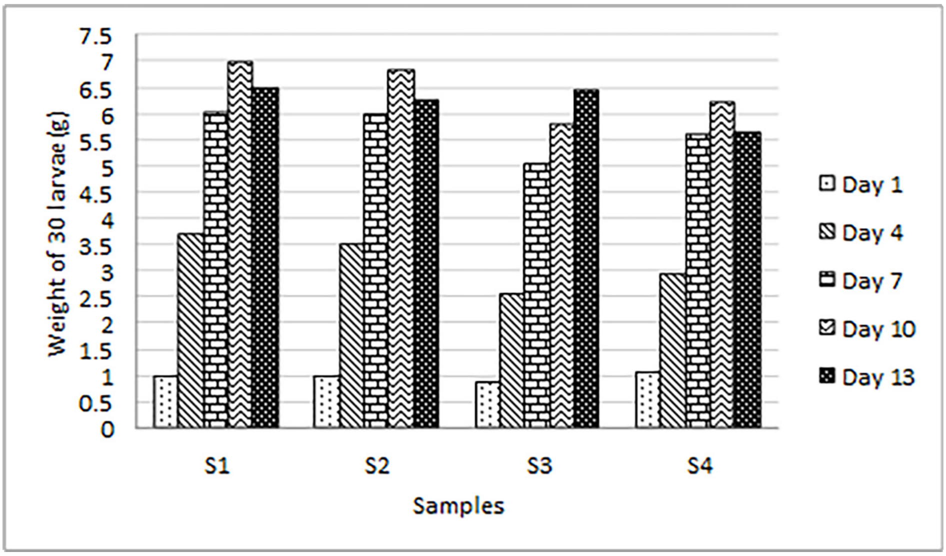

Fig. 2. Larval weight over a period of 13 days from each samples.

3.2 Frass production

The food wastes in each container were weighed every three days to determine the rate of composting based on the percentageof frass produced. Figure 3 shows the percentage of frass produced by BSF larvae over a period of 13 days from each samples. The figure shows that the percentage of frass produced increased uniformly from day 1 to day 13. The amount of frass continued to increase even though the weight of larvae for samples S1, S2, and S4 has decreased on day 13 due to larvae molting to prepupe and pupae [21]. At the end of the experiment, the percentage of frass produced are 80%, 84%, 75% and 89% for samples S1, S2, S3 and S4, respectively. S1 produced the lowest percentage of frass, 80% in comparison to S2 and S4 which produced 84% and 89% frass, respectively. It can be concluded that EM can increase the rate of composting as EM consists of fermenting fungi and lactic acid bacteria that can help to accelerate decomposition of organic matter process [10]. It is also proven by previous studies that showed EM can accelerate the degradation of organic wastes [16]. This experiment hypothesized that the higher concentrations of EM will increase the rate of composting. However, the percentage of frass produced in S3 is much lower (75%) than S1 (80%). Exceptionally, sample S3 has the lowest rate of composting that could be due to the fact that smaller larvae in S3 compost at a slower rate than larger larvae in other samples. In conclusion, the presence of EM can assist BSF larvae in accelerating the rate of food waste composting, which the rate of composting in S2 and S4 is higher than S1. Furthermore, the previous study solely used EM for composting food waste, which takes approximately 28 days to settle [20], whereas composting using BSF larvae and EM takes only 13 days. Also as reason, the combination of BSFL and EM is more effective on the rate of decomposition than EM alone.

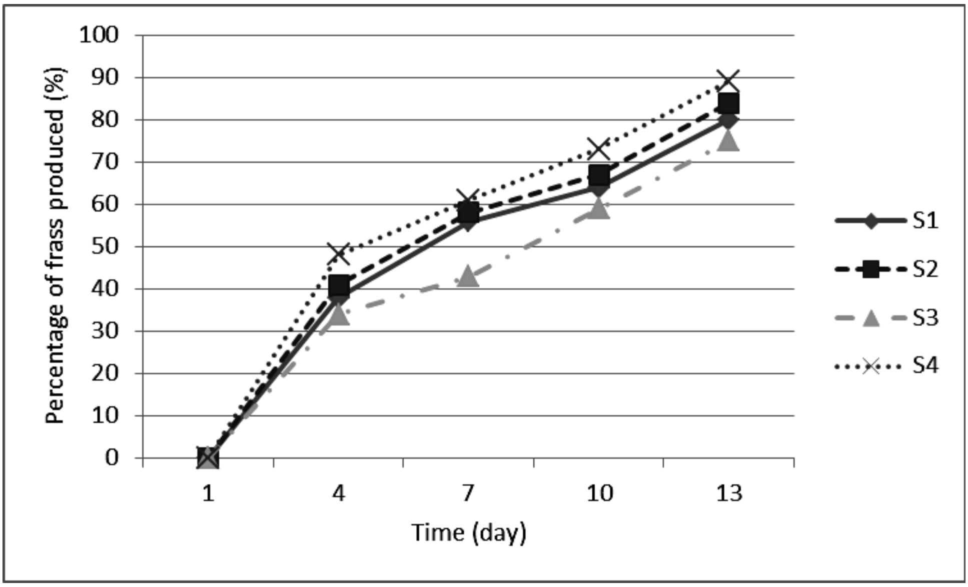

Fig. 3. Percentage of frass produced by BSF larvae over a period of 13 days from each samples.

4 Conclusion

In Malaysia, BSF larvae have been widely used as an alternative method for managing food wastes or organic wastes. Previous studies have proven that effective microorganism (EM) is beneficial in accelerating the decomposition of food wastes. However, despite the apparent benefits of using EM in the decomposition process, not much information is available about the effect of using EM and BSF larvae to decompose food wastes. This experiment has found that, at the end of the experiment, the weight of the BSFL are 6.5 g, 6.2 g, 6.4 g and 5.6 g for samples S1, S2, S3 and S4, respectively. The percentages of compost produced by samples S1, S2, S3 and S4 are 80%, 84%, 75% and 89%, respectively. Hence, it can be concluded that the use of EM in a certain amount does affect larval growth. Instead, use of EM with BSF larvae was able to increase the rate of decomposition. Based on this study, since the difference of larval weight from 5.6 g to 6.5 g is not concerning, the optimum concentration of EM added in BSF larvae composting is 25%.

The authors would like to acknowledge the Ministry of Education Malaysia for the financial assistance under LRGS MRUN/F2/01/2019/3. The authors would also like to show their gratitude to Syarifah Nur Nabila and Jamilah Ahmad for the assistance with the laboratory works and data analyses.

References

1. M. O. Saeed, M. N. Hassan, M. A. Mujeebu, Waste Manag. **29**, 2209–2213 (2009)
2. A. B. M. Dawda Badgie, M. A. Abu Samah, L. Abd Manaf, Assess. Munic. Solid Waste Compos. MalaysiaManagement, Pract. Challeges **21**, 537–547 (2011)
3. M. A. Abas, S. T. Wee, Int. J. Conceptions Manag. Soc. Sci. **2**,12–17 (2014)
4. N. I. Abdul Rahman, M. A. Khoiry, S. Rahim, N. E. Ahmad Basri, Int. J. Disaster Recover. Bus. Contin. **11**, 2230–2242 (2020)
5. U. N. Ngoc, H. Schnitzer, Waste Manag. **29**, 1982–1995 (2009)

6. S. K. Behera, J. M. Park, K. H. Kim, H. S. Park, Waste Manag. **30**, 1502–1508 (2010)
7. B. P. Naveen, J. Sumalatha, R. K. Malik, Int. J. Geo-Engineering, **9** (2018)
8. S. Mukherjee, S. Mukhopadhyay, M. A. Hashim, B. Sen Gupta, Crit. Rev. Environ. Sci. Technol. **45**, 472–590 (2015)
9. J. W. Levis, M. A. Barlaz, N. J. Themelis, P. Ulloa, Waste Manag. **30**, 1486–1494 (2010)
10. S. Aminah, A. Muttalib, S. Norkhadijah, S. Ismail, S. M. Praveena, Asia Pacific Environ. Occup. Heal. J. **2**, 37–47 (2016)
11. W. H. Chen, J. H. Lin, Y. C. Lin, Aerosol Air Qual. Res. **12**, 1386–1397 (2012)
12. C. Sundberg, D. Yu, I. Franke-Whittle, S. Kauppi, S. Smårs, H. Insam, M. Romantschuk, H. Jönsson, Waste Manag. **33**, 204–211 (2013)
13. Y. Du, H. Feng, K. Zhang, L. F. Hu, C. R. Fang, D. S. Shen, Y. Y. Long, J. Hazard. Mater. **272**, 36–41 (2014)
14. J. Mayer, S. Scheid, F. Widmer, A. Fließbach, H. R. Oberholzer, Appl. Soil Ecol. **46**, 230–239 (2010)
15. T. Higa, G. N. Wididana, Proc. First Int. Conf. Kyusei Nat. Farming, 118–124 (1991)
16. C. W. Leow, Y. Van Fan, L. S. Chua, I. I. Muhamad, J. J. Klemes, C. T. Lee, Chem. Eng. Trans. **63**, 85–90 (2018)
17. M. Rastogi, M. Nandal, B. Khosla, Heliyon **6** (2020)
18. G. Anusha, K. Maruthi Venkatesh, M. Aravind, S. Ramakrishnan, *Microbial Composting,* in Proceeding of the International Conference on Chemical, Mechanical and Environmental Sciences, 25-26 March 2021, Coimbatore, India (2021)
19. P. S. Lew, N. N. L. Nik Ibrahim, S. Kamarudin, N. M. Thamrin, M. F. Misnan, Sensors **21**, 1–15 (2021)
20. J. Nair, K. Okamitsu, Waste Manag. **30**, 977–982 (2010)
21. B. Georgescu, D. Struti, T. Păpuc, D. Ladosi, A. Boaru, Eur. J. Entomol. **117**, 216–225 (2020)