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Composting Fruit and Vegetable Waste Using Black Soldier Fly Larvae

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ABSTRACT

In recent years, the amount of solid waste generated has been increasing, and larger land space is needed for the disposal of the generated waste. One of the ways to deal with the limited landfill space is by composting organic waste using black soldier fly larvae. This study aims to determine the percentage of BSFL growth and to assess the effectiveness of using BSFL in composting fruits, boiled vegetables, and raw vegetables. The waste used in this study was collected from the college cafeteria and sorted into three waste categories, and 100g of each waste category was placed in different containers. Two different sets of experiments were carried out using an initial weight of 2g and 4g of BSFL. Within 17-days experiment, the weight of BSFL and composted waste were measured every three or four days, also an additional 100g of new waste was added to the containers until the amount of waste reached a total of 500g. The BSFL fed with the fruit waste has the highest growth percentage of 1700% relative to their initial weight of 2g. The BSFL with a higher initial density of 4g showed a lower percentage growth of 1200%. Fruit waste showed the highest percentage of weight reduction of 57%. This study has proven that fruit waste is a more suitable medium for larval growth compared to vegetable waste. The use of BSFL in organic waste composting is an effective method for reducing the amount of wastes disposed of in landfills.

Keywords: Black soldier fly larvae; composting; waste reduction; organic waste management

INTRODUCTION

The demand for a better standard of living as the population of a country increases has resulted in the generation of a higher amount of solid waste. The world population is expected to increase rapidly, and this will exacerbate the problem of solid waste generation. With each person generating about 0.74 kg of waste per day, the global waste generation is expected to increase from 2 billion tonnes in 2016 to 3.4 billion tonnes in 2050 (Kaza et al. 2018). A study by Jabatan Pengurusan Sisa Pepejal Negara (JPSPN) (2012) has shown that municipal waste consists of 45% of food waste, 24% plastic products, 7% paper, 6% metal, 3% glass, and 15% of other types of waste. The statistics from Solid Waste Corporation of Malaysia (SWCorp) showed that 15,000 tonnes of food are wasted daily, including 3,000 tonnes of foods that are still fit for consumption and should not have been discarded (Darshan 2016). The research by the Malaysian Agricultural Research and Development Institute found that between 20 to 50% of the 15,000 tonnes of food waste generated daily by Malaysians are fruit and vegetable waste (Ram 2016).

TABLE 1. Solid waste disposal sites in Malaysia

State	Operating Landfill	Closed Landfill
Johor	13	24
Kedah	7	8
Kelantan	11	8
Melaka	1	7
Negeri Sembilan	6	14
Pahang	14	18
Perak	17	13
Perlis	1	1
Pulau Pinang	2	1
Sabah	19	2
Sarawak	49	14
Selangor	8	14
Terengganu	9	11
Wilayah Persekutuan	1	10
Total	158	145
	303	

Source: JPSPN 2016

Table 1 shows the solid waste disposal sites in Malaysia in 2016. There were 303 landfills in Malaysia, including 158 landfills that are still operating. Only 14 of the landfill sites are sanitary landfills that safely decompose waste and prevent the hazard from the accumulation of waste that releases gases and leachate into the environment (JPSPN 2016). A total of 145 landfills have reached their capacity and have been closed. Based on Table 1, Sarawak has the highest number of landfill sites (63), because of the vast land area of the state (Johari et al. 2014). Given that most l=andfills have almost reached their capacity, more landfill spaces are needed for the disposal of solid waste. The lack of landfill sites has resulted in illegal dumping sites. A large amount of solid waste is dumped next to rivers, produced leachate and this has caused environmental problems. The decomposition of organic waste releases methane and carbon dioxide, which contribute to climate change (Cogut 2016). The unhygienic condition at landfill sites encourages the breeding of vermin, flies, and rodent vectors that can spread diseases such as cholera and malaria in the community (Chowdhury et al. 2017). Besides, JPSPN (2013) estimated that the cost of constructing and operating a landfill site in Malaysia is RM 30 million or about RM 28.80 – RM 49.00 per tonne of solid waste. The high cost of managing organic wastes means that there is a need to avoid sending the waste to landfill sites (Ayeleru 2016). Given the urgency to deal with these problems, researchers are trying to discover processes and technologies to deal with the problems in solid waste management. The primary aim of waste management is to reduce the amount of waste generated, to reduce the disposal cost as well as the impacts on the environment and human health (Agamuthu et al. 2009).

Composting is a more efficient method of waste management than landfilling as it manages solid waste more efficiently while reducing pollution. In Malaysia, the composting of food waste is an effective solution for landfills that have reached their capacity (Kadir 2016). Composting is an effective method for treating organic waste under certain conditions. The performance of composting can be improved through the conversion of organic refuse using Saprophages (CORS) system by feeding organic waste to organisms (saprophages) that specialize in decomposing decaying matter. The well-known application of CORS is vermicomposting, where organic waste is converted into nutrient-rich humus by worms and microorganisms (Diener et al. 2009).

The larvae of Hermetia illucens, also known as the black soldier fly (BSF), have been used as organic waste converters. BSF is a common fly of the Stratiomyidae family. It is native to South America but is found throughout the tropical and warm temperate regions (Nyakeri et al. 2017). The life cycle of BSF consists of four developmental stages, egg, larva, pupa, and adult. The life cycle of BSF is influenced by different factors, including population (wild or domesticated) and the environment (temperature, humidity, light intensity, and the quality and quantity of the available food (Domenico et al. 2013). Female BSF produces about 500-900 eggs in her short life span of 5 to 8 days compared to the housefly adults that can live up to 30 days and actively spread diseases while looking for food during their life span. BSF adults are considered non-pathogenic as they do not feed (Diener et al. 2009; Banks et al. 2014). Researchers found that BSF larva can hinder the transmission of house flies and reduce harmful bacteria such as E. coli and Salmonella enterica by secreting harmful bactericidal compounds. Because of this, BSF farming on an industrial scale does not cause the transmission of diseases (Lalander et al. 2015).

BSFL feed voraciously on a wide variety of organic waste such as manure, rice straw, food waste, distillers' grains, fecal sludge, animal offal, and kitchen waste; reduced weight by at least 50%, produce a residue known as frass, which can be used as compost that contains nutrients such as phosphorus (60% to 70%) and nitrogen (30% to 50%). Meanwhile, BSFL is a particularly suitable feed for poultry and fishes as it contains approximately 40% protein and 35% fat in a dry matter (Yu & Matan 2017; Moula 2018). Because of the high nutrient content of the BSFL, they can be used as a basis for a highly promising technology to sustain a circular economy, which is an economic system that does not produce waste and reduce the consumption of raw materials and energy. This study aims to determine the growth rate of BSFL and study the effectiveness of composting fruit and vegetable waste using BSFL.

METHODOLOGY

BLACK SOLDIER FLY LARVA

The experiments were conducted from 22 February 2019 to 11 March 2019 at the Environmental Laboratory 2 in the Department of Civil Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia. The six-day-old BSFL used in the experiment was provided by a supplier from Bangi Golf Resort, Bangi. The larvae were kept in an inert material at room temperature for one day to prevent them from gaining weight before beginning the experiments. The duration of the experiments is about 17 days and ended before the larvae reach the prepupae stage. A discussion was held to determine the most suitable location for the growth of BSFL to ensure that the experiments run smoothly and successfully. The primary concern in the experiments is the growth conditions of BSFL, and the growth of the larvae was recorded every day during the duration of the experiments to ensure that the larvae can decompose the waste.

WASTE COLLECTION

Fruit and vegetable waste are defined as the parts not used during food preparation and are thrown in the refuse bin. The fruit and vegetable waste collected from local traditional markets and cafeterias in UKM are papaya, banana, pineapple, apple, cucumber, vegetable salad, tomato, and cabbage that are disposed of after one or two days. The waste used in this study is divided into three categories, fruits, raw vegetables, and boiled vegetables, to compare the consumption rate by the BSFL and the growth of the BFSL. The waste was separated at the source and placed in different containers. The waste samples were fed to two larvae groups with an initial weight of 2g and 4g.

EXPERIMENT EQUIPMENT

The waste and larvae were weighed using an electronic balance. There are two types of electronic balances in the laboratory. One electronic balance has an accuracy of up to 0.1g and was used to weigh the waste and larvae in each container; the second balance has an accuracy of up to 0.0001g and was used to measure a small mass such as the weight of 10 larvae. Figure 1 shows the electronic balances used in this study.

FIGURE 1. Electronic Balances with 0.0001g and 0.1g accuracy

The container for BSFL composting is around a 3L container with a lid. The lid has large holes that are covered with a thin piece of cloth to provide ventilation for the larvae. The containers were labeled, and the fruit and vegetable waste was added into the containers, followed by the BSFL. The plastic containers were closed with the lid throughout the experiment to prevent the BSFL from escaping and to prevent the BSFL from being eaten by the other animals or insects.

EXPERIMENT PROCEDURE

Three containers were labeled for fruits, raw vegetables, or boiled vegetables. The weight of the empty containers was measured and recorded. Each type of waste in the amount of 100g was added into the plastic containers, followed by 2g of larvae. Every 3 or 4 days, all larvae were taken out of the containers, and the weight of ten random larvae was measured and recorded. The weight of the containers containing residual waste was measured and recorded. The residual waste was also discarded, and 100g of fresh waste was added to each plastic container. The larvae were then returned to the containers. The total waste added to each container was 500g. The duration of the experiment was 17 days where this experiment ended before the larvae reached the prepupae stage. The experiment was repeated by using 4g of larvae to determine the effect of larval density on waste reduction during the decomposition process.

DATA ANALYSIS

In this study, the critical parameters for determining waste reduction efficiency are larval weight and residual weight. The percentage of BSFL growth, G, is given by Equation (1),

$$G = \frac{T-B}{B} \times 100\% \qquad [1]$$

where B was the weight of BSFL at time t, and T was the weight of BSFL after time t.

The waste reduction rate, D, is given by Equation (2),

$$D = \frac{W-R}{W} \times 100\% \qquad [2]$$

where W was the weight of waste used at time t, and R was the residue after time t.

RESULTS AND DISCUSSION

GROWTH OF BSFL

The weight of the larvae was measured every three days, except on the first and last day of the experiment, to determine the growth of BSFL and identify the most suitable rearing substrate. The average initial weight for ten larvae in each container is between 0.080g to 0.090g. Figure 2 shows the rate of BSFL growth for the experiment using 2g of larvae, and Figure 3 shows the rate of BSFL growth for the experiment using 4g of larvae. The figures show there is a small difference in the weight of the larvae on the fourth day, and the difference in larval weight is greater on the seventh day and the following next few days. The daily increase in larvae weight is an indication that the larvae were growing every day.

Figure 2 shows that the larvae fed with fruit waste recorded a 1700% growth, which is significantly higher than the growth of the larvae fed with vegetable waste. The weight of the larvae fed with raw vegetable waste and boiled vegetable waste remained almost unchanged throughout the experiment. At the end of the experiment, the larvae fed with vegetable waste showed an increase of 400-600% of their initial weight. The weight of the larvae fed boiled vegetable waste is slightly higher than the larvae fed raw vegetable waste since boiling vegetable can make the cell walls less rigid, which makes it easier to absorb certain nutrients and digest better (Brookshier 2018). The results for the 17-day experiment indicate that the larvae that fed on fruit waste grow rapidly compared to those fed vegetable waste.

Meneguz et al. (2018) used a mixture of fruit and vegetable wastes and a mixture of fruit waste as rearing substrates in their study. The results showed that the weight of the larvae fed with fruit and vegetable waste is higher than the weight of the larvae fed with fruit waste. The balanced nutrient in the mixture substrates helps the BSFL to utilize the available nutrients to a higher degree (Lalander et al. 2018). In the present study, the fruit waste (papaya, banana, pineapple, and apple) may have a higher nutrient content compared to the vegetable waste (cucumber, salad, tomato, and cabbage), and thus contribute to the higher percentage growth of the larvae. It is proven by Singh & Kumari (2019) that highlighted the comparison of larval nutrient composition based on their feeding sources. Larvae fed on fruit waste had 37.8% of crude protein and 41.7% of fats. Meanwhile, larvae fed on vegetable waste had slightly higher of crude protein (39.9%) but lower fats (37.1%) compared to fruit waste. Besides, vegetables have a high fiber content that cannot be easily digested, thus less favored by larvae (Nyakeri 2017).

Figure 3 shows the percentage of BSFL growth in the experiment using 4g of larvae. The pattern of the graph is almost similar to that in Figure 2. Even though the slope of each line in the graph is identical, it is apparent that the growth of larvae is much slower and that the larvae can grow up to only 1200% of its initial weight. The result indicates that the larvae density affects their growth since the larvae tend to aggregate and compete for food and, as a result, may not get as much food as they need (Parra Paz et al. 2015).

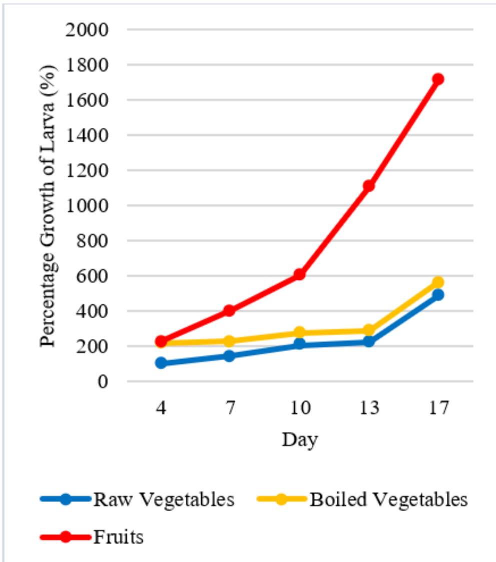

FIGURE 2. Growth percentage of BSFL when using 2g of larva

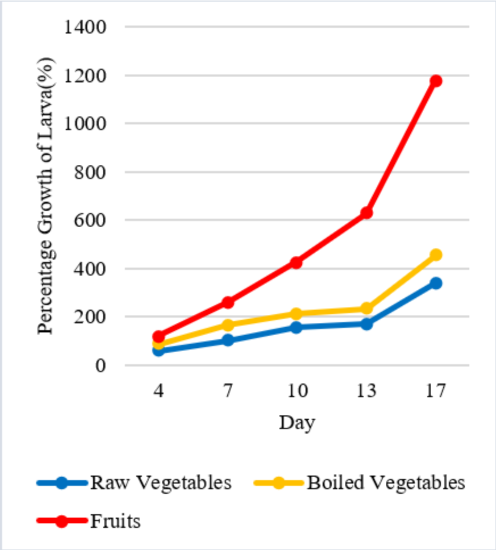

FIGURE 3. Growth percentage of BSFL when using 4g of larva

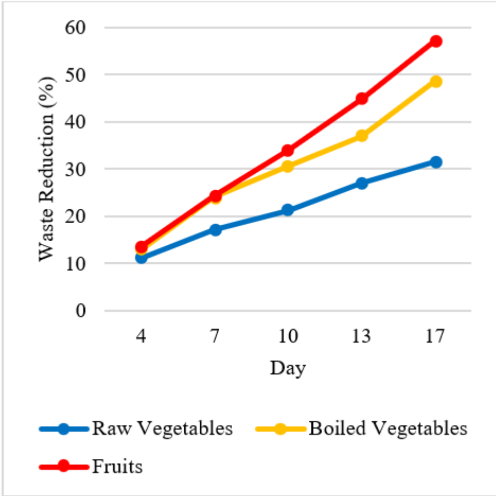

FIGURE 4. Waste reduction when using 2g of larva

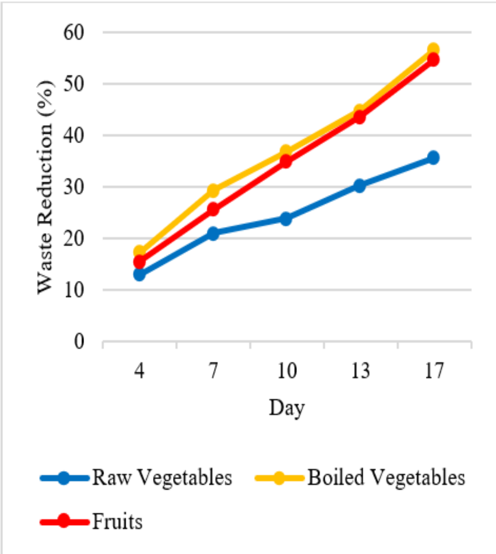

FIGURE 5. Waste reduction when using 4g of larva

EFFECTIVENESS OF BSFL IN COMPOSTING

The residual weight of fruit and vegetable waste indicates the effectiveness of composting using BSFL. A total of 500g of waste was added to each container during the 17-day experiment. Figure 4 shows the waste reduction when using 2g of larvae as the initial weight, and Figure 5 shows the waste reduction when using 4g of larvae. The figures show that the change in the weight of the waste composted by the larvae is almost the same at the start of the experiment until the fourth day and the difference in the compost weight became very apparent after seven days.

Figure 4 shows that the container with fruit waste has the highest waste reduction of 57% (285g) of the total amount of 500g. The waste reduction of boiled and raw vegetable waste is 49% and 32%, respectively. Meanwhile, Figure 5 shows boiled vegetable waste has the highest waste reduction (57%), followed by fruit waste (55%) and raw vegetable waste which has the lowest waste reduction (36%). The waste reduction of boiled vegetables is higher than raw vegetables because thermal treatment by boiling makes vegetables easily digest as the cell walls become less rigid and increase the decomposition rate that caused the higher weight has been reduced (Wieczorek & Jelen 2019; Brookshier 2018). The waste reduction percentages from both figures are not much different. These results are contrast to the results obtained by Parra Paz et al. (2015) that showed a higher waste reduction with a higher number of larvae per gram of substrate. However, this present study concludes that the number of larvae used affects larval growth but has no impact on the waste reduction rate.

CONCLUSION

The composting of organic waste using BSFL is highly recommended in all areas, including residential areas and universities, due to the large amount of organic waste generated daily. The findings of the present study showed that BSFL is suitable to use as an agent for composting because the larvae feed voraciously on rich organic waste, and this has resulted in a significant reduction in the amount of waste. The larvae fed with fruit waste showed the highest percentage of larval growth, followed by the larvae fed with boiled vegetable waste and raw vegetable waste. The waste reduction of fruit waste is the highest compared to vegetable waste that is less digestible and palatable because of higher fiber content (Nyakeri 2017). Besides, this study also shows that the waste reduction by different amount of larvae was not much different. However, the larvae to feed ratio must be taken into account to ensure that the larvae are provided with a sufficient amount of feed to prevent competition that will hinder the larval growth. In this study, full compost was not produced because the substrates were regularly replaced with new waste to avoid the decomposition of waste by other microorganisms and bacteria. This method provides more accurate data because the BSFL decomposed most of the substrates.

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DECLARATION OF COMPETING INTEREST

None

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