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Comparison of Black Soldier Fly Larvae (BSFL) Growth and Frass Production Fed with Fermented Food Waste, Coconut Dregs and Cow Manure

[1]Noor Ezlin Ahmad Basri, [2]Nur Asyiqin Azman, [3]Irfana Kabir Ahmad, [4]Fatihah Suja, [5]Nurul Ain Abdul Jalil, [6]Muhammad Amir Mohd Partonoor,

[1,2,3,4,6]Department of Civil Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, [5] Department of Earth Science and Environment, Faculty of Science and Technology, Universiti Kebangsaan Malaysia

[1]noorezlin@ukm.edu.my, [2] p103541@siswa.ukm.edu.my, [3]irfana@ukm.edu.my, [4]fati@ukm.edu.my, [5]nurulain@ukm.edu.my, [6] a165367@siswa.ukm.edu.my

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Abstract— Currently, many producers of organic waste streams pay for the treatment or disposal of organic waste. Alternatively, organic waste could be treated using Black Soldier Fly Larvae (BSFL) to produce various beneficial products. BSFL may ingest a wide range of organic materials, including food waste, industrial agricultural products, and animal waste. The goal of this study is to measure the growth of larvae and to examine the texture of the frass produced based on different types of waste such as fermented food waste, coconut dregs and cow manure. For each type of waste, 10,000 BSFL was fed at a rate of 100mg/day. Following the treatment, parameters such as larval weight and length, pH value, temperature, moisture content, odor, and frass texture were collected and analyzed. The duration of this treatment is 32 days. From this study the larvae weighted 0.178g fed with fermented food waste and measured 1.88cm in length. The larvae weighed 0.1g and measured 1.53cm in length when fed with coconut dregs, while the larvae weighed 0.013g and measured 0.7cm in length when fed with cow manure. Frass produced by cow manure was the driest compared to food waste and coconut dregs. This condition may be due to the initial moisture content of cow manure is 62.28% in comparison to fermented food waste (74.69%) and coconut dregs (78.96%). In conclusion, fermented food waste is the most suitable type of waste to be fed to BSFL in comparison to coconut dregs and cow manure, however the frass produced is comparatively wet and greasy that requires further treatment for applications.

Index Terms—Black soldier fly larvae, black soldier fly larvae frass, black soldier fly larvae growth.

I. INTRODUCTION

Organic waste often known as recoverable waste material is being produced at an alarming rate all around the planet. Annual organic waste creation was over 600 million tonnes in the first decades of this century and is expected to reach one billion tons by 2025[3]. Organic waste is mostly produced by living organisms, both plant and animal. Food waste, human waste, sewage, paper waste, manure, green wastes, biodegradable plastic, and slaughterhouse waste are some examples. Global food waste generated was 1.3 billion metric tons per year in 2018 [6]. Organic waste can have severe environmental (air and water pollution) and health consequences for human. Traditional waste disposal methods such as disposal to landfill frequently have significant environmental repercussions [4]. Other inadequate waste management practices also include irresponsible dumping, fouling drains, and open burning.

The utilization of insects to convert organic waste into insect biomass, which can then be used as an animal feed ingredient, is a viable alternative method for organic waste management. Black soldier fly larvae (BSFL) have been proposed as efficient organisms for converting several types of organic waste into insect biomass, including food waste, waste plant tissues, animal offal, and animal manure [8]. It is BSFL personal uniqueness in morphological and physiological traits that allow them to absorb these numerous organic sources [13]. BSFL feed voraciously and reduced weight by at least 50% of the original weight and may produce a residue known as frass, which can be used as compost that contains nutrients suitable for agriculture purposes [12]. Meanwhile, the proximate composition of the larvae, which is about 40% larval protein and 30% larval fat, is directly related to the composition of the substrate provided to the BSFL, specifically the protein and carbohydrate content of the substrate [1]. In a nutshell, BSFL treatment can be utilized as the foundation for a highly promising technology to sustain a circular economy, which is an economic system that produces no waste and consumes less raw materials and energy [5].

In this study, a simple laboratory experiment was conducted to assess the performance of BSFL in converting locally generated organic waste into insect biomass, with all prepupae and residue (frass) were collected at the end of the experiments. Based on their existing treatment in Malaysia and palatability of BSFL, three types of organic waste were chosen: fermented food waste, coconut dregs, and cow manure. Food waste is the largest percentage (45%) of waste produced in Malaysia, while fermented food waste has contain higher protein content (26.16%) than fresh food waste (15.58%) and it is more preferred to be consumed by BSFL. Coconut dregs are basically produced from coconut milk stall, where some quantity of it is collected by chicken farmers, while the rest is dumped to landfill. While current waste management raw cow manure requires to be composted at cow farms before dumped to landfills or they are demanded by some of the farmers for agriculture purposes.

II. METHODOLOGY

A. Experiment Material and Procedure

The experiment were conducted with 10 0000 tails of 5-day-old BSFL to treat different types of organic waste. There were three types of waste treated in this study, namely fermented food waste, coconut dregs and cow manure. Food waste was obtained from a residential area in Seksyen 8, Bandar Baru Bangi, Selangor. The food waste was shredded then gone through a fermentation process for two months in an airtight container. Coconut dregs was obtained from a local coconut milk stall, Bt 12 Enterprise Sdn. Bhd. The cow manure was obtained from local farmer, a supplier for Standard and Industrial Research Institute of Malaysia (SIRIM), which was taken in dry condition. The objective of this study is to compare the growth of larvae and frass texture. For each type of waste, 10 000 BSFL was fed at a rate of 100mg/day during 32 days of experiment. The waste was fed to BSFL in a 50 L container with a lid. The lid had relatively large holes that was covered with a thin piece of cloth to provide air space for the larvae. The containers were labeled, and the three types of waste were added into each of the containers separately, then followed by the BSFL. The plastic containers were then closed with lids throughout the experiment to prevent BSFL from escaping and being eaten by predators. Twenty tails of BSFL were collected and washed out using distilled water before measurement of the length and weight were taken. The substrate and frass were then collected for analysis. The parameters involved were moisture content, temperature, pH value, as well as observations of odor and texture of frass. The moisture content, temperature, and pH value for each waste type fed to the larvae were taken every 4 days to ensure that the moisture content, temperature, and pH value were in optimum condition during BSFL treatment.

B. Experiment Equipment

The weight of larvae was taken using analytical balance with the accuracy of 0.0001g. The instrument used for frass temperature experiments was a temperature gauge. The experimental procedure was to observe temperature changes at three different locations of the stack with a depth of 50% of the original depth and taken every 4 days. The pH value of frass was taken by using 10 grams of frass sample mixed with 100 ml of distilled water at a rate of 1:10. The pH meter was put into a beaker containing distilled water and the sample to record the pH value of frass. The instrument used for frass temperature experiments was a temperature gauge. Moisture content was determined by standard procedure of oven-dried technique at the temperature of 105 °C.

III. RESULTS AND DISCUSSION

A. Substrate Condition

Based on Table I: the pH value of the feedstock media or substrate namely fermented food waste, coconut dregs and cow manure before being fed to BSFL were taken on every 4 days during the experiment. The mean pH value of fermented food waste, coconut dregs and cow manure are 4.01, 3.88 and 8.17 respectively. Two of the media were acidic, namely fermented food waste and coconut dregs with pH of below 7, while the pH of cow manure was alkaline with pH above 7. Coconut dregs reached the lowest pH of 3.88 compared to the other types of media, while fermented food waste reached a pH of 4.01 and the pH of cow manure was 8.17. The mean temperature observed during the experiment for fermented food waste was 28.4 ºC, coconut dregs 28.2 ºC and cow manure 28.3 ºC. During mesophilic phase, BSFL continued to convert the substrate, while greater air circulation during the BSFL composting process had maintained a reasonably consistent temperature of the feedstock media (about 30°C) for optimum waste consumption by BSFL [10]. The mean moisture content of fermented waste, coconut dregs and cow manure are 74.69%, 78.96% and 62.28% respectively.

Table I: Mean pH value, temperature, and moisture content of different substrate

Substrate	Mean pH value	Mean temperature (°C)	Mean moisture content (%)
Fermented food waste	4.01	28.4	74.69
Coconut dregs	3.88	28.2	78.96
Cow manure	8.17	28.3	62.28

B. Growth of BSFL

Fig. I show the condition of BSFL after being fed with three types of organic waste as the feedstock media: fermented food waste, coconut dregs and cow manure. The growth of BSFL was determined by their weight and length as shown in Fig. II and III. Upon feeding the BSFL with fermented food waste, the larvae weighed the heaviest at 0.1780g and measured the longest at 1.88cm. While the larvae weighed 0.1000g and measured 1.53cm in length when fed with coconut dregs, and the weight of BSFL is 0.0130g and 0.70cm in length when fed with cow manure. Previous studies had indicated that BSFL fed with cow manure grew slower and had smaller larvae [9]. Similar result obtained from this study that the larvae fed using cow manure are the smallest and some were dead as the cow manure obtained for this study is in dry and solid condition even though water had been added in the beginning of the experiment in order to ensure suitable moisture content for BSFL growth (moisture content of 62.28%).

Based on this experiment, cow manure in dry and solid condition was considerably unsuitable to be fed to BSFL, while raw cow manure was more suitable because it contains higher protein composition based on previous studies (41.2%) [1]. Meanwhile, BSFL fed with coconut dregs was observed to be smaller than BSFL fed with fermented food waste. This is due to coconut dregs contain relatively lower protein (11.35%) [11] than fermented food waste with protein content of roughly 26.16% [2]. The BSFL fed with fermented food waste showed the heaviest and fastest larval growth. Thus, it has been proven that fermented food waste is more suitable for BSFL consumption in comparison to the other types of feedstock media. The reason for using fermented food waste as the feedstock media in this study was because it had shown higher nutritional composition than fresh food waste based on the previous study conducted. Having low cost and low technical skill, fermentation process was recommended as it could improve nutritional composition of feedstock media by improving the properties of the raw food waste. Raw food waste may pose constraints due to high crude fiber content and low protein. Furthermore, fresh food waste was not easy to be stored, hence it will be more efficient to store the feedstock media in fermented condition and later will be used as the feedstock that can last for over 6 months. Fermented food waste is capable to increase the digestibility of livestock for easy and faster consumption [2].

		
BSFL fed on fermented food waste	BSFL fed on coconut dregs	BSFL fed on cow manure

Fig. I: BSFL condition after fed on different organic waste.

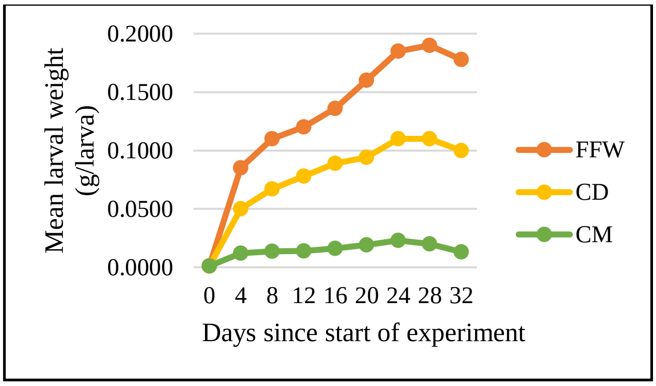

Fig. II: Larval mass gain (g) over time (days) in different wastes

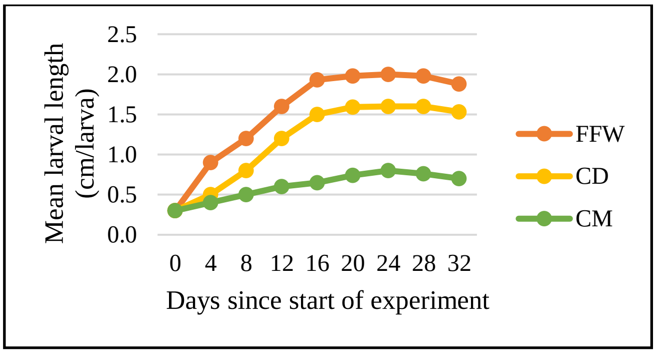

Fig. III: Larval length (cm) over time (days) in different wastes

C. Frass Harvested

From the three types of waste fed to the BSFL as the feedstock media for this study, pH of fermented food waste was relatively low at 4.5. This may be due to uneaten leftovers of the media that were mixed with the frass. This reason was also supported by the foul odour produced during the process when food waste was not consumed by larvae because most of the larvae in fermented food waste had reached the pre-pupae stage earlier than the other feedstock media, thus the rate of decomposition of waste by the BSFL became slower. The pH value of frass taken on the last day of the experiment showed that the pH value had increased to 7.19

for coconut dregs and 4.5 for fermented food waste. The increase in pH for these media was in line with observations made by another researcher's study [12]. An increase in pH also meant that the media was in maturation phase. However, the pH of cow manure decreased from 8.17 to 8.05 but still it was alkaline. This may be due to the cow manure was already stable and there was not enough protein and nutrients for the growth of BSFL. Referring to Table II, the moisture content decreased from 74.69% to 74.1% for fermented food waste and 62.28% to 60.5% for cow manure, respectively. On the other hand, the moisture content of coconut dregs increased from 78.96% to 85.5%. Cow manure reached moisture content of 60.5%, which was the lowest among all types of waste in this study.

Based on the data obtained, moisture content influences the growth of BSFL. BSFL require a moisture content between 60% to 85% to decompose the media optimally [7]. This is shown in Fig. II and III where the growth of BSFL in cow manure was the lowest followed by BSFL in coconut dregs and fermented food waste. This was due to the moisture content of cow manure was the lowest followed by coconut dregs and fermented food waste. It can be observed that all types of frasses produced after the treatment process completed showed temperatures in the range of 27.0 °C to 31 °C. Cow manure experienced a decrease in the mean temperature with the initial feedstock media temperature at 28.3 ° C before being fed to the larvae and the temperature of the frass produced was at 27.0 °C. The initial temperature of fermented food waste was 28.4 °C before being fed to BSFL then later had increased to 30.1 °C. The temperature of coconut dregs was 28.2 °C before being fed to BSFL and the frass produced had a temperature of 14.5 °C. Frass harvested from all treatment process in this study produced foul and smelly odour at the end of the experiment. This may happen because of the high moisture content of the frass produced. The texture of frass harvested from fermented food waste was the most slurry (85.5% in moisture content) in comparison to coconut dregs. This was due to the presence of oil and grease produced from the fermentation of food waste. The frass obtained from cow manure was the driest as shown in Fig. IV, due to low moisture content of substrate at the beginning of experiment.

Table II: Mean pH value, mean temperature, mean moisture content, odour and texture of different frass

Frass	**Mean pH value**	**Mean temperature (ºC)**	**Mean moisture content (%)**	**Odor**	**Texture**
Fermented food waste	7.19	30.1	74.10	foul odour	wet and slurry
Coconut dregs	4.50	14.5	85.50	foul odour	wet
Cow manure	8.05	27.0	60.50	foul odour	semi-dry

		
Frass from treatment of fermented food waste	Frass from treatment of coconut dregs	Frass from treatment of cow manure

Fig. IV: Frass harvested from different organic waste.

D. Effectiveness of BSFL treatment

Frass weight indicates the effectiveness of composting treatment using different types of waste fed to the BSFL. Fig. V shows the waste reduction index of fermented food waste, coconut dregs and cow manure after the BSFL treatment. Fermented food waste present highest waste reduction index (1.56), followed by coconut dregs (0.89) and cow manure (0.39). From this study, cow manure was dry and solid condition was considered unsuitable for BSFL treatment due to less moisture and nutrient contents to be ingested by the BSFL. The frass produced by cow manure was the driest in comparison to the other types of waste. This may be due to the moisture content of the waste before treatment is the least which is only 62.28% as compared to fermented food waste (74.69%) and coconut dregs (78.96%). As for the fermented food waste, it can be clearly seen that the frass produced was greasy and wet. This may be due to the food waste not being consumed by the BSFL and may also resulted from the fermentation process before the BSFL treatment was carried out. The frass from fermented food waste was the only frass produced greasy in texture as compared to the other waste types. Additionally, frass produced from fermented food waste and coconut dregs gave off foul odor. The frass produced from coconut dregs was light in color while the frass produced from fermented food waste and cow manure was darker color. Therefore, from the observations and results of this studies concludes that all frass produced from the study is recommended to be treated further before applications.

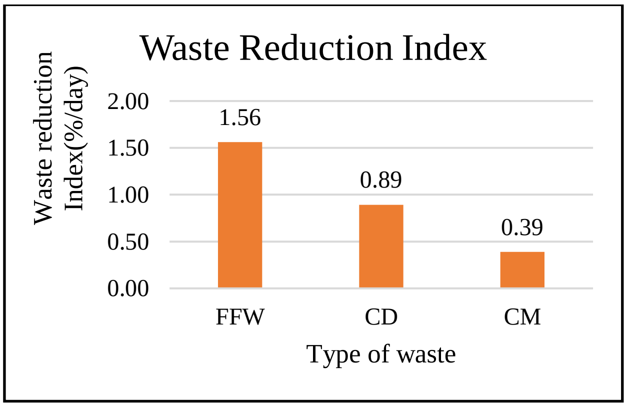

Fig. V: Waste reduction index of different type of waste

CONCLUSION

The foremost advantages of treating organic waste using BSFL treatment method is its ability to convert various types of organic waste into high quality biomass and frass for applications in livestock farming and agriculture sectors. From this study, fermented food waste had shown the fastest BSFL growth followed by coconut dregs and cow manure. This study had proven that moisture content influences the growth of BSFL. The moisture content had decreased from 74.69% to 74.1% for fermented food waste, 78.96% to 85.5% for coconut dregs and 62.28% to 60.5% for cow manure, respectively. BSFL require a moisture content between 60% to 85% to decompose the feedstock media optimally. The pH of coconut dregs showed the most stable value of 7 in comparison to fermented food waste with a pH value of 4.5 and cow manure with a pH value of 8.05. Significant changes in pH were only seen in coconut dregs where the initial pH value was 3.88 then increased to 7.19 after 14 days. For fermented food waste, the pH increased from 4.01 to 4.5 while the pH value of cow manure had decreased from 8.17 to 8.05. The effectiveness of organic waste treatment using BSFL treatment method for various types of organic waste is indicated by waste reduction index calculated using the frass weight. Fermented food waste showed highest waste reduction index (1.56), followed by coconut dregs (0.89) and cow manure (0.39). From observation, the frass produced from fermented food waste was greasy and wet. On the other hand, the frass produced from cow manure was the driest in comparison to the other types of waste. This may be due to the moisture content of the waste before treatment was the least which was only 62.28% for cow manure as compared to fermented food waste (74.69%) and coconut dregs (78.96%). Finally, frass produced from fermented food waste and coconut dregs gave off foul odor and had changed from light to a darker color, but no changes was observed in cow manure. Therefore, the frass produced from this study is recommended to be treated further due to their immature compost product characteristics.

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