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Sustainable Vermicomposter Design for Household Usage

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Abstract: Mostly, the food waste that is produced will be disposed of in landfills. Therefore, by applying the concept of food waste recycling, it may be an interesting option for reducing landfill use. In this study, vermicomposting is an alternative method for food waste recycling since it is eco-friendly and cost-effective. In the vermicomposting process, the red worm (*Eisenia fetida*) is used for the decomposition of food waste. The food waste was collected from the household and segregated into two categories which are food waste that is suitable and unsuitable for the worm. The amount of food waste that worms can consume from the household is known and the data was used for the efficiency of the vermicomposting bin. The 3-tier plastic drawer is used as a vermicomposting bin. The maximum volume of food waste that fitter on first and second drawer including the bedding materials was 8.988 kg. Ready-made vermicompost will be used on Brazilian spinach plants with four different treatments, T1, T2, T3, and T4 to access the ability of vermicompost as an organic fertilizer for plant growth. From several parameters, T3 shows an improvement of the plant growth compared to other treatments.

Keywords: Vermicompost, Food Waste, Organic Fertilizer

1. Introduction

Population expansion and the rate of urbanization have increased waste generation. By recycling food waste, it can reduce the costs of waste treatment. Besides, odors and waste from landfills and air pollutants from incineration also can be reduced. Vermicomposting acts as an alternative method for food waste recycling since it is environmentally safe, cost-effective, and hygienic. Vermicomposting or earthworm composting is a good technique for recycling food waste [1].

Vermicomposting is a process that uses earthworms to break down food waste particles into nutrient-rich bio-fertilizers. The processing of the food waste into composting can reduces environmental risk by converting the waste into a safe and more sustainable product that suitable for soil application. Composted materials are now being known as organic fertilizers in sustainable

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agriculture. There has been a substantial increase in research on the effects of compost-like materials on soil properties and plant growth [2]

1.1 Problem Statement

The increasing quantities of municipal solid waste (MSW) in developed and developing countries make it a major challenge to collect, recycle, and dispose of the volume of waste [3]. Landfilling, incineration, recycling, re-use, and source reduction are the current methods for solid waste management. Leachate management is a problematic issue which requires proper management and disposal in the landfill. Greenhouse gas emission related to the decomposition of solid waste in the landfill are also a concern. The land limitation and the importance of managing the waste are strong reasons to move away from landfills and shifts towards a more efficient waste management strategy [4].

Composting offers an alternative solution to handling solid waste. It is easy to conduct and safe to be used as organic fertilizer and soil conditioner [5]. Therefore, in this study, the vermicomposting process was selected for composting the organic waste generated from household as one of the waste management methods. The organic waste was collected from the study area that is located at Ground Level Blok 10, Flat Area Taman Alam Megah, Shah Alam, Selangor.

1.2 Objective of the Study

This study aims to observe the potential of the red worm, *Eisenia fetida* in the sustainability of vermicomposting design for household usage. Therefore, the following objective is identified:

i To characterize and analyze the food waste composition from the household.
ii To determine the efficiency of vermicomposting bin design on waste decomposition using the red worm.
iii To evaluate the effects of vermicompost on the growth of the plant.

2. Materials and Methods

2.1 Food Waste Composition and Characterization

In this process, it consists of three main stages: 1) weighing the waste, 2) recording the data, and 3) analyzing the data. The food waste was separated into 2 categories, particularly, the food waste that is suitable and unsuitable for worms. All the sorted food waste from every category was weighed and the data were recorded in the standard form for analysis. The total weight of food generated at the household was calculated by mathematically using Eq. (1) as follows:

$$T = Sfw + Ufw \quad Eq.1$$

where, *T*= Generated food waste (kg), *Sfw* = Suitable food waste for worm (kg), *Ufw* = Unsuitable food waste for worm (kg) [6]. The weights of the waste compositions were recorded on the classification spreadsheet and illustrated in terms of percentages (see Eq. 2). The percentage composition of each waste category was calculated as follows:

$$Percentage\ composition\ (\%) = \frac{x}{T} \quad Eq.2$$

where, T= Total weight of generated food waste (kg), x= weight of each category of food waste (kg) [6]. The food waste was collected from the household for a certain duration to determine the waste generation rate- the quantity of waste generated per person per day (kg/capita/day). The rate of waste generation (rw) was obtained by measuring the total weight of food waste (kg) collected for a certain period and then using Eq. (3) as follows:

$$rw = \frac{T}{d\ (c)} \quad Eq.3$$

where, T= total food waste generated (kg), rw = rate of waste generation (kg/capita/day), d= number of days, c= number of persons [6]. The total of food waste that is suitable for worms was recorded to use in design the vermicompost bin.

2.2 Design of Vermicomposting Bin

A recycled 3-tier plastic drawer has been chosen with the size of each drawer is 32.00 cm in length, 25.00 cm in width, and 15.00 cm in height. The closer drawer was used to prevent bad smell or odor. There are a few holes that drill at the bottom and the side of the bin to provide airflow for the vermicomposting process. The four wheels are installed on the vermicomposting bin base so that it can be rotated and easy to move.

2.3 Vermicomposting Process

The process of vermicomposting was prepared on the second drawer of the vermicomposting bin (Figure 1). The third drawer at the bottom was used to collect the vermiwash. All bedding materials will be moisture first before it is used in the vermicomposter process. The food waste is cut into smaller pieces. The vermicomposter will be spray with water once or twice a week to control the moisture content. The food waste will be added every day until the drawer achieved its maximum volume of waste. The time taken for the vermicompost process depends on the worm's ability to decompose food waste.

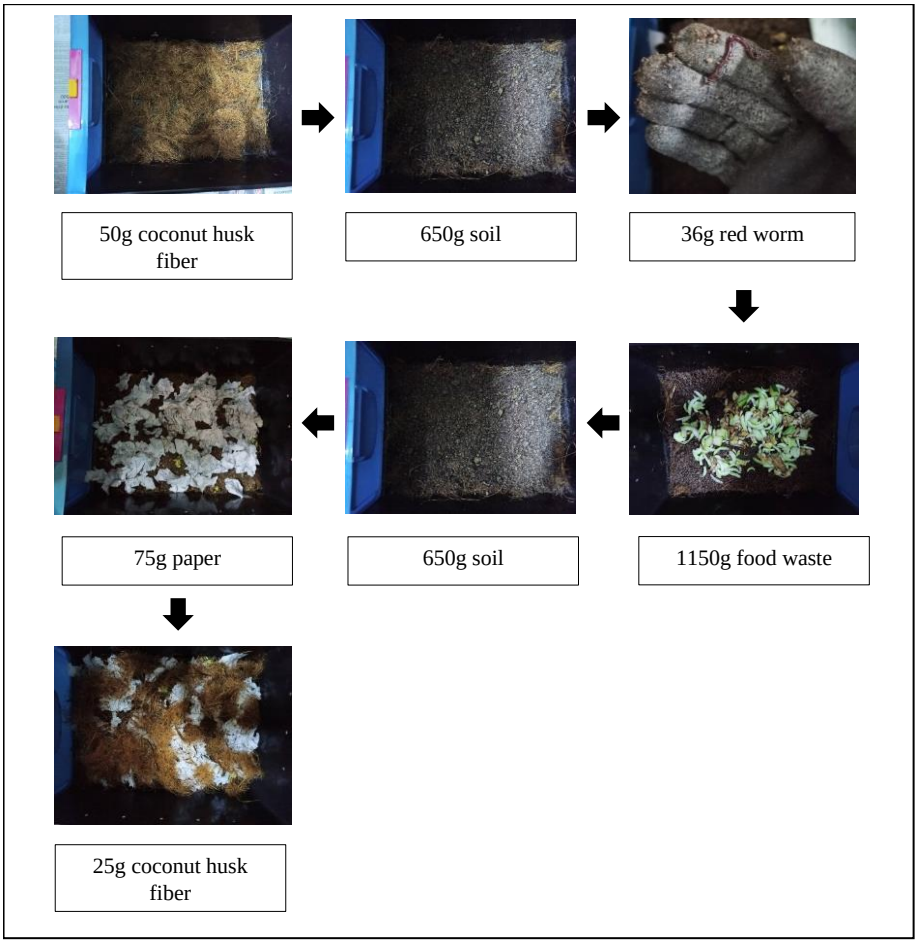

Figure 1: The process of vermicompost

2.4 The Application of Vermicompost on the Plant Growth

The final product from the vermicomposting process was used as organic fertilizer for plant growth. The Brazilian spinach (*Alternanthera sissoo*) was used to observe the effect of vermicomposting on plant growth with different treatment based on Table 1. The height of the plant (cm), number of leaves, number of branches, and length of leaves (cm) are measured in this study.

Table 1: The different treatment of plant growth

Treatment Number	Treatment	Number of saplings
T1	600g soil (Control)	1 sapling
T2	10% vermicompost + 600g soil	1 sapling
T3	20% vermicompost + 600g soil	1 sapling
T4	30% vermicompost + 600g soil	1 sapling

3. Results and Discussion

3.1 Food Waste Characterize and Composition from the Household

The food waste was collected for 14 days because it is the maximum volume of food waste that fits into the second drawer since day 1 vermicompost process takes place. A total of 6.245 kg of food waste was generated over 14 days. The amount of food waste from a household that suitable for worms was 3.025 kg while food waste that is not suitable for worms was 3.221 kg. The percentage composition of food waste that worms can consume is 48.40 %, meanwhile, 51.60 % is food waste that worms cannot consume from the household. Figure 2 shows the fraction pie chart of the percentage composition of the food waste that suitable for worms. The highest food waste produced by the house is vegetable scraps which are 48.00 %. The percentage composition of the food waste that is not suitable for worms is illustrated in figure 3. Starchy foods contributed to the highest percentage composition of food waste which is 35.00 %, followed by meat and bone, citrus fruit, processed foods, and allium vegetable with percentages of 22.00 %, 19.00 %, 16.00 %, and 8.00 % respectively.

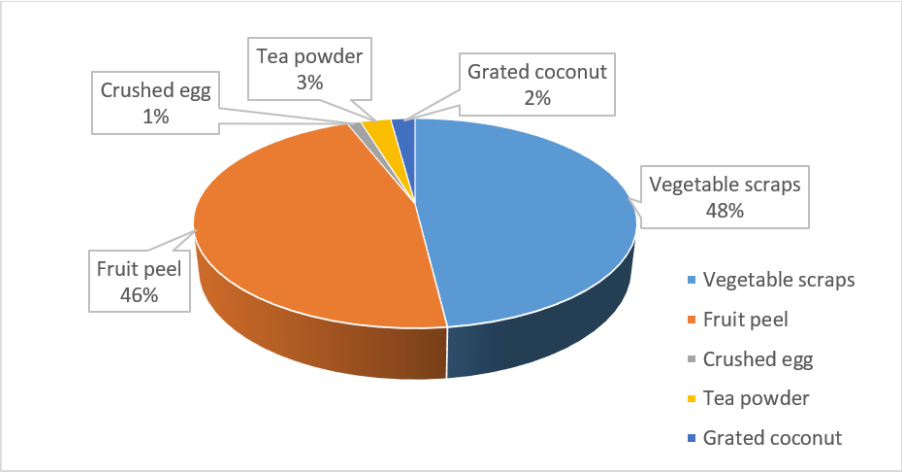

Figure 2: The percentage composition of the food waste that is suitable for worms

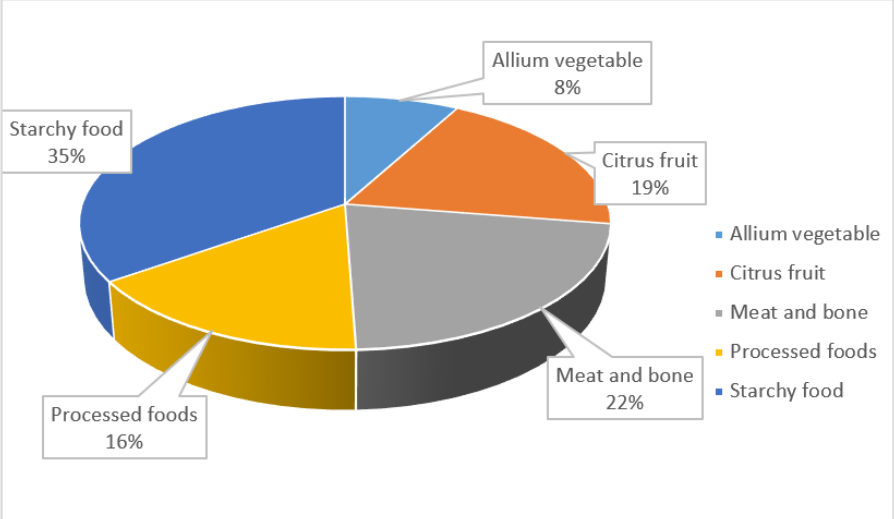

Figure 3: The composition of food waste that is not suitable for worms

3.3 The Efficiency of Vermicomposting Bin Design on Waste Decomposition using the Red Worm

The vermicomposting bin has a size for each drawer 25.00 cm in length, 32.00 cm in width, and 15.00 cm in height with a total storage volume, 12000 cm^3. From the collection of food waste, 3.025 kg are fitted into the second drawer with the bedding material (1.471 kg) that has been mixed with food waste since day 1. It shows that the size drawer can accommodate a total waste of approximately 4.496 kg in each drawer for 14-day food waste collection. The time taken to produce vermicompost from 4.496 kg of total waste in the drawer is 42 days. 36 g of red worms is used for initial weight and 64 g of the final weight of worm. The vermicomposting process takes 42 days because it is the time it takes for the worms to decompose all the food waste in the vermicomposting bin. From the study, the amount of food waste generated from household, approximately 0.216 kg/day.

By using a two-drawer, which is the first and second drawer, approximately 8.988kg of total waste can accommodate in the bin with the food waste collection for 28 days. Approximately, 12.49 kg of food waste will be generated from the household. Therefore, the percentage reduction of food waste from the household by using the vermicomposting process is 48.40 % of the total food waste generated. The efficiency of vermicomposting bin design on waste decomposition using red worm is 72.00 %. It is from the data total generated food waste and the capacity of the vermicomposting bin that can accommodate total waste for 28 days.

Besides, the vermicompost process takes 42 days which is approximately 13.48 kg of total waste will be produced throughout the process of decomposing food waste for 42 days. However, the capacity of the bin can only accommodate 8.988 kg of waste for 28 days. So, there is a balance of 4.49 kg that can not be treated after 28 days using 2 drawers and it needs an additional drawer. Therefore, this design of the vermicomposting bin has a limitation of the capacity of the bin for 42 days. Figure 4 (a) shows the red worm the vermicompost. The vermicompost has a deep blackish brown color and has a slightly moist texture (Figure 4 (b)). The three-dimensional (3D) with the side view of the vermicomposting bin using SketchUp is shown in Figure 5. The first and second drawer is used for the collection of food waste and vermicomposting process. Meanwhile, the third drawer is used as vermiwash to collect the leachate that is produced during the vermicomposting process.

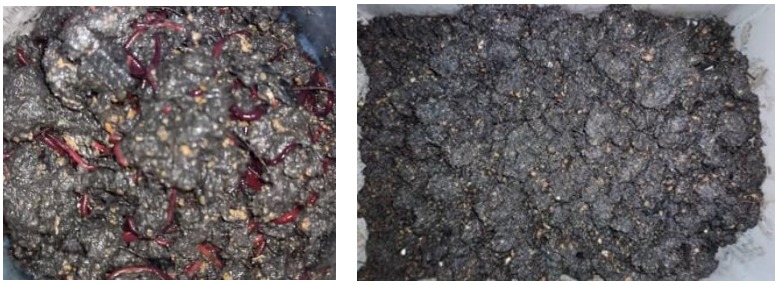

Figure 4: a) The red worm in the vermicompost; b) The vermicompost

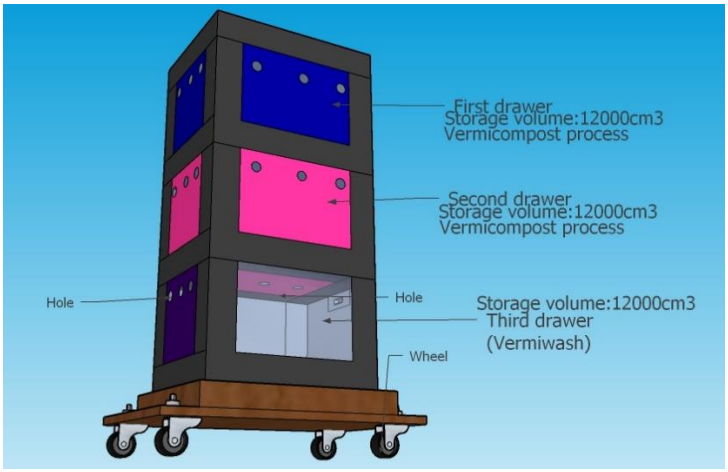

Figure 5: The three-dimensional (3D) with the side view of the vermicomposting bin using SketchUp

3.4 The Effects of Vermicompost on the Growth of the Plant

The mean data for the growth of Brazilian spinach for 30 days from each treatment (T1, T2, T3, and T4) is shown in Table 2. Figure 6 shows the growth of Brazilian spinach for 30 days.

Table 2: The mean data for Brazilian spinach for different parameter and treatments

Treatment	Mean			
	Height of plant (cm)	Number of leaves	Number of branches	Length of leaves (cm)
T1	24.68	13.50	12.50	1.83
T2	25.58	20.17	16.33	2.16
T3	26.18	20.83	18.00	2.20
T4	24.93	14.00	12.33	2.11

Figure 6: The growth of Brazilian spinach for 30 days

3.4.1 The Height of Plant (cm)

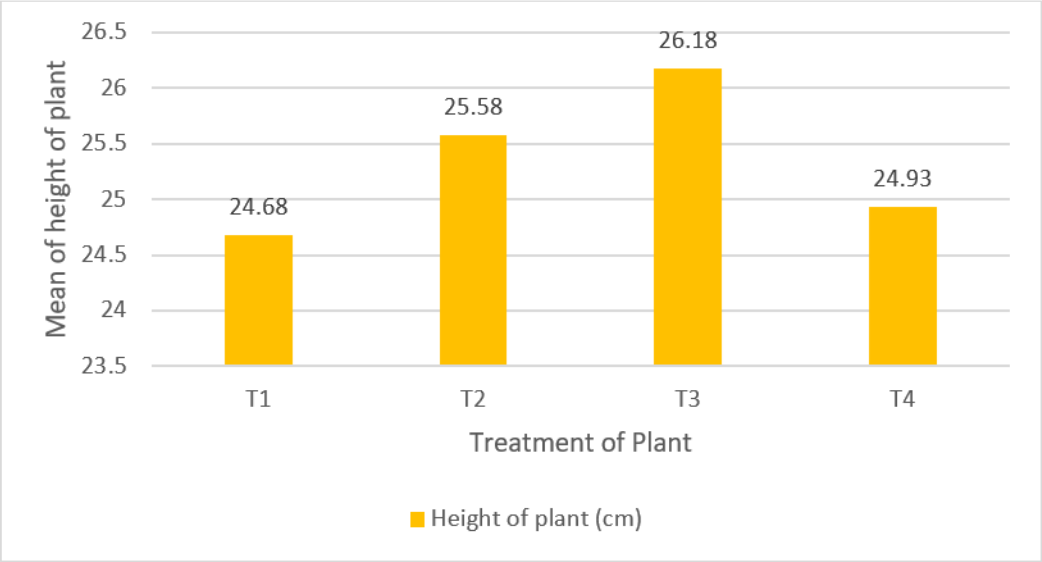

Figure 7: The bar graph mean of the height of the plant (cm)

Refer to Figure 7, treatment 3 (T3) showed the highest height (26.18 cm), compared to the other three treatments which are 24.68 cm for T1, 25.58 cm for T2, and 24.93 cm for T4. The poorest growth in height was shown by controlled treatment, T1. According to [7], plant growth and development is due to the presence in vermicompost of humic acids and micro and macronutrients.

3.4.2 Number of Leaves

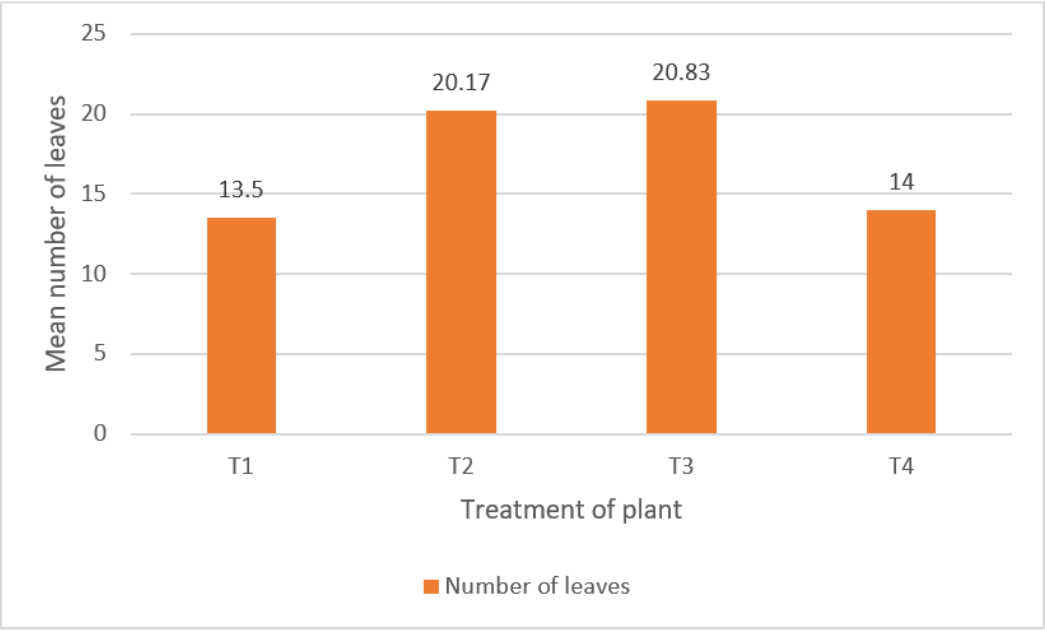

Figure 8: The bar graph mean of the number of leaves

Treatment 3 (T3) showed the highest mean performance of 20.83 leaves in the number of leaves in figure 8. T1 has 13.5 mean number of leaves followed by T2, 20.17 leaves, and 14.00 leaves for T4. The vermicompost affects plant growth and encourages the length and number of leaves. It is indicating the relation between the biological effects of vermicompost and the microbial metabolites that affect plant growth and development [8].

3.4.3 Number of Branches

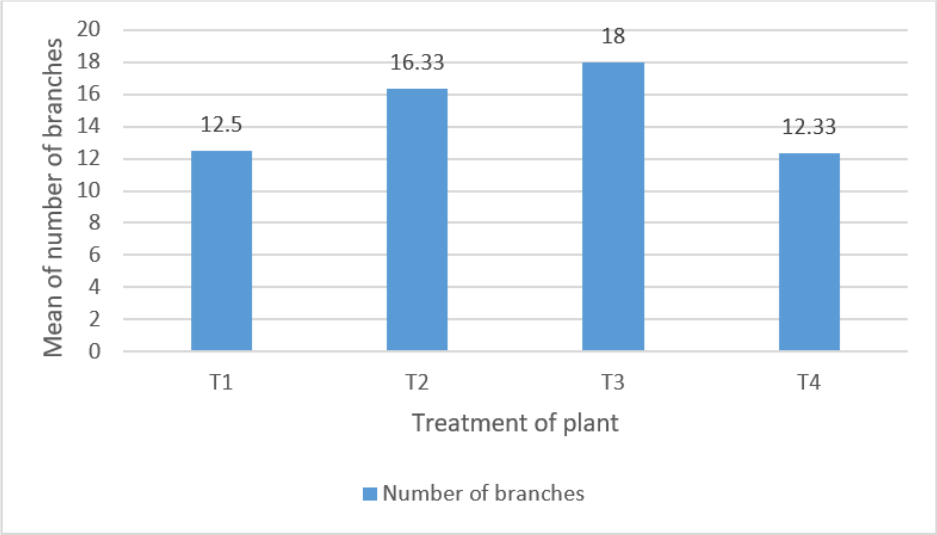

Figure 9: The bar graph mean of the number of branches

Figure 9 shows T3 has the highest mean for the number of branches (18.00 branches). T1, T2, and T4 showed values of 12.50, 16.33, and 12.33 mean values for the number of branches. T4 significantly shows the lowest mean of the number of branches compared to the other treatment. This shows that the high proportion of vermicompost can affect the growth of branches of the plant.

3.4.4 Length of leaves (cm)

Figure 10: The bar graph mean length of leaves

The highest performance of length was shown by T3, which is 2.20 cm compared to the T1, T2, and T4 which is 1.83 cm, 2.16 cm, and 2.11 cm in figure 10. T1 shows the lowest mean length of leaves compared to T2, T3, and T4. The application of vermicompost has been shown to maximize the length of Brazilian spinach leaves. Vermicompost contains many nutrients and acts as a fertilizer that works efficiently.

4. Conclusion

The vermicomposting provide a solution to reduce the use of chemical fertilizers with the use of organic fertilizers that are safer for humans and the environment. It can decrease the quantity of food

waste to landfills that can cause the release of methane gas with the approach of vermicomposting. From this study, the type of food waste that suitable for worm are known and worm can consume as much as 48.40 % composition of food waste from the household. Besides, the vermicomposting bin has a capacity of approximately 8.988 kg of the overall amount of food waste that can fill the first and second drawer. Process decomposition of food waste takes about 42 days. Next, the resulting vermicompost was applied to the plants, T3 shows a positive effect on plant growth compared to T1, T2, and T4. In conclusion, vermicomposting is the easiest way to reduce or recycle municipal solid waste because relative to conventional methods of collection and disposal, it produces fewer emissions and is more beneficial to the environment and economy.

Acknowledgement

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