Food Waste Quantification and Characterization as a Measure towards Effective Food Waste Management in University

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Abstract. Globally, one-third of the food produced is wasted or underutilized which accounted for about 1.3 billion tonnes of food. If the food waste (FW) is disposed of in the landfill, it decomposes under anaerobic conditions that release methane gas, a harmful greenhouse gas. FW is also referred to as biodegradable materials where it has a higher moisture content that easily breaks down by the microbe and could produce odor problems. Thus, a study on FW generation rate and its characteristics were carried out. Physical and chemical characteristics of the FW which include the density, food waste composition, the generation rate, pH, moisture content, ash content, C/N ratio and the calorific value were determined based on the Malaysian Standard MS 2505:2012. Based on the field and laboratory work analysis, it was observed that the generation rate for the café A and B was between 0.04 kg/cap/day to 0.112 kg/cap/day and 0.01 kg/cap/day to 0.119 kg/cap/day. Meanwhile, the density of the FW was in the range between 0.035 kg/m\textsuperscript{3} to 0.077 kg/m\textsuperscript{3}. Based on the standard method recommendation, 5 compositions were tabulated which include FW, plastic film, plastic rigid, paper and others (aluminum, steel and etc.). Food waste demarcated was further divided into five categories such as rice, noodles, vegetable, shells and meat & bones. Rice and noodles produced the largest amount which was 52.50% and 55.52%. Moisture content and an ash content of the FW was recorded at 71.52% and 25.31% where it was slightly acidic (6.16) in nature. The calorific value for wet and dried FW was 4539.914 kcal/kg and 2091.3 kcal/kg. Based on the result obtained, the suitable method to treat food waste from the cafeteria was proposed.

1. Introduction

Malaysia is one of the countries that have rapid population growth, urbanization, economic levels and rising of community that generates an enormous rate of MSW [1]. The increasing of waste generation per capita can be influenced by the continuous economic growth and development. For example, there are many rural areas have been transformed into industrial areas and provide many job opportunities to rural communities. Thus, the job opportunities intriguing the citizen from another country like Bangladesh, Nepal, Myanmar and many more to migrate in these areas. The rising of population growth and migration of the citizen into this country contributing to increasing of average solid waste generation [2, 3]. The quantity of solid waste generated in Malaysia is exponentially increasing year by year. The solid waste generated was increased as much as 2,900 tons/day from 2001 to 2005. The solid
waste generated was estimated will reach 30,000 tons/day in 2020. For example, a metropolitan city like Kuala Lumpur generates a lot of solid waste because of the population growth. The solid waste generated was estimated to reach 7,713.6 tons/day in the year 2020 [4].

The composition of MSW in Malaysia consists of organic or FW, paper, plastic, glass, metal, textile and so on. But, organic or FW is predominant components in MSW [5, 6]. Besides, there are 15,000 tons of daily FW generated including 3,000 tons of food that can be consumed and should not be discarded in Malaysia.

However, there is a variety of adverse environmental impacts involving FW. Global climate change on FW resulting in unnecessary greenhouse gas emission that compromising water and land. This will cause natural ecosystems becoming lesser than it should [7, 8]. Besides, untreated FW can increase of CO2 emissions. According to the European Commission, the importance of household waste such as FW must be taken care of. Therefore, by divesting FW from municipal solid waste composition, can increase the lifespan of a landfill. Furthermore, landfilling is one of the options for MSW disposal in Malaysia [9].

Until now, there is no documented report on the FW generation rate, characteristics and their potential has been established or available especially in USM. Therefore, there is a need to address these issues so that the result of the proposed study will be useful for future research work. Apart from that, there is urgency for this study to be carried out because, in line of a new implementation of separation at source campaign by the state government, no results have been put available to the stakeholders. Thus, this study will provide some baseline data potential of diverting FW from the waste stream in order to reduce the dependency on landfill.

2. Material and method
2.1 Sampling site
The selected location for this study was the University Sains Malaysia on Penang Island, Malaysia located at coordinates 5.3559 North and 100.3025 East. The study involved 2 cafes at Cafeteria Bakti Permai within the university compound. These cafes located near to student hostel and academic building which was School of Industrial Technology. Both cafes were coded as Café A and B. Café A stands for Kak Ani’s Café and Café B stands for Koay Teow Th’ng’s Café as shown in Figure 1.

2.2 Food Waste Generation Rate
The data collected from the FW generation was chosen to be from food preparation and uneaten food. The calculation of daily FW generation was computed by weighing the FW generated by each café.
every day. The FW collected was fixed at 3 pm and weighed by using a weighing balance. Data obtained were recorded in the datasheet that provided in Appendix A. Next, the density of FW generate was determined by the total volume of FW in the tray multiply with the volume of the tray. The data was recorded into the datasheet in Appendix B. Other than that, the estimation of FW per capita rate per day was determined by the number of eateries recorded from Monday to Friday. The FW generation rate per day was calculated by using the following equation:

\[
\text{Rate} = \frac{\text{Food Waste Weight (kg)}}{\text{Total Eateries}}
\]  

2.3 Sample Processing and Characterization

The dry matter (DM) determination was carried out following a method as recommended by Adhikari [10]. The FW sample was dried at the temperature 105ºC for 24 hours in the oven (Memmert, Germany). After that, the dried sample was cooled by using desiccators. The size of the dried sample was reduced by using a grinder (Waring, USA). Then, the sample was sifted into small size of 0.25 mm by using sieve shaker (Retsch, Germany). DM was used to arbitrate both characteristics which are physical and chemical. The dried sample was placed in a plastic bag and sealed so that it was not exposed to the air.

pH value was measured by soaking 1 part dried sample with 10 part of distilled water for 60 minutes. Then, the pH value was measured by using a HACH Session 3 pH Meter (HACH, USA). The size of the sample is less than 180 µm [11]. Moisture content is the amount of water in the FW which is referred to the percentage of the weight loss during drying. The sample of raw FW was placed in the evaporating dish and weighed by using analytical balance, W1. After that, the sample of raw FW has been dried in the oven about 24 hours at 105ºC. Then, the dried sample was cooled in the desiccators and weighed, W2. The percentage of the moisture content was calculated by using this formula which is taken from the guidelines from United Nation for Education Program published in 2002. C/N ratio of the FW was determined by using CHNS elemental analyzer (Elementar, Italy). The sample size is less than 180 µm.

The calorific value of the FW sample was analyzed based on the method recommended by UNEP. In general, raw FW and dried FW were ground into a small particle (<1mm). The bomb calorimeter (IKA C200) was used to ignite the sample. Nickel wire was used for ignition. Then, the oxygen was filled to the cylinder which accommodates sample with ignition wire. The sample was weighted using combustion bag (0.5 to 0.8 g). The temperature of the equipment should not greater than 25°C for a half-hour. The value of calorific value reading was recorded in unit kcal/kg.

3. Result and Discussion

3.1 Food waste management system

Based on observation, the USM compound did not provide appropriate food waste management. The generation, collection, and transportation of FW were managed by the owners of the cafeterias. All the plates used by the eateries were collected by the representative of each café. The uneaten FW was placed together with the kitchen waste in the primary bucket. As we know, FW is the degradable organic material and need to be thrown after operating time so that the FW would not produce any foul odor. Basically, every university has its own rule about the MSW management including FW that needed to obey by all the owner of cafeterias to prevent any environmental problems such as foul odor. On the other hand, these methods are not efficient and suitable. It is because FW is one of the renewable resources. It can be converted into valuable materials, for instance, the organic fertilizer that can be used for the plant in the university. In this study, the foods waste generation rate and the alternative method for FW management have been studied as shown in Figure 2.
3.2 Food waste generation rate

Figure 3 (a) and (b) represent the total weight of the FW generation rate that from two cafeterias within 15 days based on data shown in Appendix I. The weight of FW generated within 15 days that starting from 6 March 2018 until 23 March 2018 which from Monday to Friday that produced by two cafes in Bakti Permai, USM was totaled up for each collection day. Based on the figures, the generation rate for Café A has ranged between 41.08 g/cap/day to 112.24 g/cap/day. Meanwhile, the generation rate ranging for Cafe B was between 10.79 g/cap/day to 118.79 g/cap/day. From the analyzed figures, it could be observed that the generation rate for Café A was less than Café B. because students and staff more prefer to eat at Café A. Café A stand for Kak Ani’s Café which selling rice and variety of dishes while Café B stand for Koay Teow Th’ng’s Café which is selling several types of combining with soup like koay teow th’ng, noodles, and yong tau fu. So that, more students and staffs choose Café A because the food portion was bigger than Café B. There are no data on the 20th March 2018 (Monday) and 24th March 2018 (Friday) because during that day the weather is not good (raining heavily). According to the bar chart below, we can see that there was an irregular trend of WGR because of the inconsistent number of eateries.
Figure 3. (a) and (b) Daily FW generation rate within 15 days for Café B.

Total weight of the FW generated in both cafes within 15 days was 332.09 kg which equals to 22.14 kg/day. This value showed a small amount of FW was generated in the Main Campus. However, there were only two cafes out of 18 cafes in the Main Campus, USM. In short, if the waste management is not properly managed, the possibility of the environmental problem of improper waste management would be plausible. Fig. 4 shows the trend of total FW generation within 15 days that was generated by two cafes based on five consecutive days. The highest value of FW generated on Tuesday, Thursday and Wednesday which was 25.79 kg, 24.01 kg and 23.67 kg compared to Monday and Friday which was 12.88 kg and 13.66 kg. The differences between the highest and a lower mean value of FW generated was 12.91 kg. It was due to the fact that there was no data recorded on Monday and Friday in the 3rd-week cause of the bad weather (raining). So, it was therefore unsuitable to do sampling because the weather would affect the data collection. Other than that, there were fewer students in the cafeteria on Monday and Friday because some of the students might free from having to attend the lecture on those days. As reported in Table 1, there was no significant between no of eateries and amount of FW where the value was 0.321. It was largely because not all the eateries mark the datasheet provided and the waste produced depends on the eating behavior.
3.3 Food waste composition

Basically, Café A and Café B exerted similar food preparation process with comparable raw material used. The composition studied of FW was carried for 15 days (3 weeks). FW generated from café because of the leftover food and the food preparation activities. All the waste generated like FW, plastic rigid (food container, bottle, and others), plastic film (straw, plastic bag and so on) and paper (tissue and paper) were dumped together in the bucket. After that, the manual segregation process was carried out to obtain the percentage of waste generated. Figs. 4 (a) and (b) show the percentage of MSW generated for Café A and Café B. During segregation process, the MSW was divided into five categories which are FW, mixed paper, plastic film, plastic rigid and others (steel, aluminum, and etc.). It is because the waste composition is one of the factors that contributed to the emission of solid waste treatment.

As reported in Figs. 5 (a) and (b) there was a large amount of FW produced followed by plastic film, mixed paper, and others. The percentage of FW generate in Café A was 89.59% higher than mixed paper, plastic film, plastic rigid and others where 6.94%, 3.02%, 0.35%, and 0.10%. Meanwhile, for Café B the percentage of FW is 63.57% followed by the plastic film is 22.64%, mixed paper is 12.48%, others and plastic rigid where 0.81% and 0.50%. According to Saheri et al. [12], FW has a large percent compared to others in MSW. Thus, this study confirmed to the previous study done by Saheri et al. [12] and FW stood at 89.59% and 63.57% for Café A and Café B. So, we can proof that by doing this study where there was a higher amount of FW generated.
Table 2 shows the percentage of MSW and FW composition in 3 weeks based on five consecutive days for Café A and Café B. Café A generated a higher percentage of rice on Tuesday and Wednesday while a higher percentage of noodles for Café B on Tuesday and Thursday. Other than that, bones and meats waste also generated a large amount on Wednesday and for Café B a large amount of vegetable which is on Thursday. According to this study, FW composition comprised of rice, noodles, bones and meats, vegetable and shells. Rice and noodles was the main dish in Malaysia. So, the higher percentage in FW was rice and noodles followed by bones and meats, vegetable and shell as the side dish. It was predicted that the eating habit of the eateries were found to influence the composition of FW.

**Table 2. Density for Café A and Café B within 15 days.**

| Composition   | Café A          | Café B          |
|---------------|-----------------|-----------------|
| Mixed paper   | 2.78            | 1.85            |
| Plastic Film  | 1.58            | 4.34            |
| Plastic Rigid | 1.64            | 1.45            |
| Others        | 1.24            | 0.35            |
| Rice          | 1.45            | 3.14            |
| Noodles       | 0.14            | 0.06            |
| Bones         | 0.40            | 0.01            |
| Meat          | 0.37            | 0.37            |
| Shell         | 0.37            | 0.37            |
| Vegetable     | 11.08           | 2.32            |

3.4 Chemical characteristics of the FW

The chemical characteristics of FW obtained from the laboratory analysis are shown in Table 3. The value of pH obtained from the FW generated ranging between 6.15 to 6.17 and the average pH value is 6.16. The pH value of the FW generated can be categorized as acidic. Besides, the pH value of the FW generated from the food courts in Universiti Putra Malaysia (UPM) ranging between 4.5 to 5.5 [13]. The pH value is slightly acidic because of the mix of the citrus/ juice and fruits. Other than that, the value of ash content in the FW is 25.31%. Ash content in FW represented the content of mineral. Ash content of foods is important for microbiological stability. According to the UNEP, the ash content for both cafés is higher than the value of ash content for kitchen waste in the UNEP statistics which is 15.37%.

Based on the result obtained in Table 3, the composition for carbon and nitrogen in the FW were 39.98% and 3.87% while the C/N ratio was 10.32%. C/N ratio is calculated to estimate the nutrient deficiency and ammonia inhibition. The combination of organic waste to obtain the desired value for the C/N ratio to obtain higher composting efficiency [14]. C/N ratio is a source of nutrient for compost.
The ratio of C/N ratio per gram is 6:1. The value of C/N ratio obtained is considered as low value. The lower value of C/N ratio can take a longer treatment time.

| Sample       | Food Waste |
|--------------|------------|
| pH           | 6.16       |
| Ash Content  | 25.31%     |
| Carbon (C)   | 39.92%     |
| Nitrogen (N) | 3.87%      |
| C/N Ratio    | 10.32%     |

Table 3. Chemical characteristics of FW.

4. Conclusion
The field and laboratory work had indicated that the generation rate for Café A is 0.04 kg/cap/day to 0.112 kg/cap/day while for Café B is 0.01 kg/cap/day to 0.119 kg/cap/day. The density of the food waste generates is ranged between 0.035 kg/m3 to 0.077 kg/m3 for Café A and Café B within 15 days. The composition of MSW generated from both cafes consists of five categories which were food waste, paper, plastic film, plastic rigid and others (aluminum, steels). Based on the result obtained, the food waste generates a large portion compared to other components of solid waste. The composition study of FW comprises of rice, noodles, bones and meats, shells and vegetables. Rice and bones and meats are a major fraction of FW for Café A while noodles and vegetable is a large fraction of FW for Café B. There was a higher percentage of moisture content of 71.52% and slightly acidic (6.16). The value of ash content is 25.31%. Other than that, there was a higher value of CV for dried sample (4539.914 kcal/kg) compared to the wet sample (2091.3 kcal/kg). Meanwhile, the C/N ratio is 10.32%. Further, composting is a suggested method to treat FW in this study. According to the result obtained, the higher moisture content of the FW is not convenient to used incinerator as a method in treating food waste. Besides, the higher of FW generation rate is one of the factors where landfill is not seemly to be able use in FW management. The analyze shows that the composting method is the best way for treating FW in the cafeterias. However, various issues need to be controlled before executes the composting as FW management.

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