Sustainable Extraction of Micronutrient of Food Waste by Thermal Treatment under Elevating Temperature

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Abstract. Food waste management by biological treatment is widely used due to the eco-friendly and more attractive than physical and chemical treatment. However, the use of biological treatment takes longer time for the food waste to degrade. To overcome this problem the pretreatment of food waste is proposed. The aim of this study is to determine the characteristic of food waste when subject to pretreatment, to determine the effect of thermal pretreatment on chemical compositions of food waste, and to determine the relationship between the effect of temperature and time on food waste carbon to nitrogen ratio, pH and micronutrient by using statistical analysis. The water bath method was carried out in this experiment. The parameter measured were Carbon to Nitrogen ratio (C:N), pH and micronutrient with the effect of temperature and time. The result of the food waste before treatment and after pretreatment was compare. The laboratory results showed that the chemical composition of the food waste was affected by the thermal pretreatment of water bath method for C:N and pH which in the range 11.18 to 25.94 and 5.32 to 5.72 respectively. The statistical analysis indicates that the interaction effect between retention time and temperature was not significant for pH, Fe, Cu and Mn except for C:N (F=4.394, P= 0.003). Overall, the thermal pretreatment applied on the food waste revealed that temperature below 100 °C did not suitable to use as a pretreatment before the biological treatment, in order to expedite the degradation process. Instead, high temperature which above 100°C and long heating duration are beneficial for the release and reduction of organic compounds.

1. Introduction

Food waste is a discarded or uneaten food which is part of municipal solid waste. Food waste can cause environmental problem due to the high organic content that can lead to odour problem and the growth of the pathogenic organism. To overcome this problem its need an appropriate management in order to reduce the environmental pollution and the risks to human health.

There are several treatment techniques on the food waste such as composting, landfilling and anaerobic digestion. Pretreatment is the most effective treatment in speeding up the degradation process. According to the previous study, in order to enhance the productivity of biological treatment,
Pretreatment is needed to speed up the hydrolysis process [1]. Pretreatment is a chemical breakdown of compound due to the reaction with heat and water. The end product of the food waste pretreatment can be used as a fertilizer and a solid compostable residue, which can be used as a compost and soil conditioner.

There are four different types of thermal pretreatment technique available which is hot air oven, microwave, autoclave and hot water bath [2]. In previous study, thermal pretreatment was used to facilitate the solubilisation of food waste and improve the biodegradability of the substrates [3]. Thus, thermal pretreatment is important in order to expedite the degradation process.

Thermal pretreatment is used to enhance the decomposition of the food waste. The product of this treatment also will be used before composting which is to speed up the time for a compost to become stable and mature.

2 Methodology

2.1. Food Waste Collection
Food waste that used in this study was collected from Baktisiswa Cafeteria at Universiti Sains Malaysia. The organic and inorganic waste was separated from the waste and the method used as recommended by [4]. Only the organic waste was used in this treatment

2.2. Preparation Of Food Waste
First, the food waste that have been collected was dried for 24 hours at 130°C in an oven dried [5,6]. In this study the dry food waste were blended in the heavy duty blender (WARING, Heavy-duty 1.5 HP motor) as shows in Plate 3.1 to homogenize the composition of the food waste. The samples were then stored in air-tight plastic bags for further use

2.3. Thermal pretreatment
The dried food waste sample was placed in a 250ml of conical flask with deionised water at solid to liquid ratio 1:10 [7,8]. The conical flasks were sealed with aluminium foil before being placed in Memmert Hot Water bath (WNB 7) [2]. The temperature of pre-treatment was varied from 60°C to 100°C with 10°C increments for 30min to 60min with 30min increments [9].

2.4. Chemical Characteristics
The chemical characteristics performed for the food waste before and after treatment in this study were pH, C:N and micronutrient (Fe, Cu, Mn).

2.4.1. pH determination
The pH of the food waste before and after treatment was determined by using HACH Sension 3 PH meter as shows in Plate 3.3. First, the pH meter was calibrated by using three pH buffers which 4, 7 and 10. Then, the dried food waste sample were mixed with deionizes water in 1:10 ratio to make a solution. Then, the solutions were stir uniformly for five (5) minute until the solvent dilute. The solutions were measure after one (1) hour by using pH meter (HACH Sension 3). The experimental data was repeated three times in order to ensure the accuracy and reproducibility of data.

2.4.2 Carbon to Nitrogen ratio (C:N)
Determination of carbon to nitrogen ratio was carried out based on the literature study as recommended by Iqbal et al. (2014). The carbon and nitrogen contents of the sample were determined by using Total organic carbon method and Total Khejadal Nitrogen.

2.4.3 Micronutrient content (Fe, Cu, Mn)
Micronutrient content which all Fe, Cu and Mn of the food waste were determined by using Flame Atomic Absorption Spectroscopy (FAAS).
2.5. Data analysis
The collected data from laboratory was calculated and assessed graphically by the use of Microsoft Excel and IBM SPSS. Data were analysed by two-way ANOVA to determine interactions between temperature and time. The strength of relationship between independent variable and dependent variable was analysed by using Correlation analysis. The significance of differences in the average of C:N, pH, and micronutrient element concentration were determined.

3. Results and Discussion

3.1. Effect of thermal pretreatment on chemical characteristics of food waste

3.1.1. Carbon to Nitrogen Ratio
Carbon to nitrogen ratio (C:N) is the ratio between the percentage of carbon to the percentage of nitrogen. Based on the literature the value of C:N was found in the range 15.72 to 24.4. The C:N of the treated food waste in this study was compared to the range as recommended by Malaysia standard of Commercial organic fertilizer. In general, the value of C:N will increase by increasing the temperature and residence time. However, in this study the C:N values shows different pattern.

As shown in Figure 1, the value of C:N was decreases by temperature from untreated (20.56) to 60°C for both 30 and 60 minutes of thermal pretreatment at 11.18 and 12.81. At 70°C of thermal pretreatment for 30 minutes of retention time has lower C:N (11.8) than 60 minutes of retention time (15.92). In the next level of temperature which was 80°C the values of C:N for 30 minutes of treatment was higher (25.94) than C:N for 60 minutes (23.97). For temperature at 90°C, 30 minute and 60 minutes of retention time have the same level of the C:N value which is 10.84 and 10.94 respectively. Then, 60 minutes of retention time at 100°C of thermal pretreatment has higher C:N (7.67) value than 30 minutes (15.23). It was apparent that the carbon and nitrogen content varied greatly when increasing the heating temperature and duration time. The higher the temperature, the higher of C:N became. According to a previous study, temperature below 100°C was described as low temperature thermal pretreatment [10]. Based on the C:N result presented it could be concluded that at the lower temperature under thermal pretreatment, the organic matter in the food waste may not effective in transforming the food waste into small molecules as result a decrease in C:N value except for 80°C of thermal pretreatment for both 30 and 60 minutes of retention time. Decrease in C:N value for both control time and temperature, it due to the incomplete mineralization of organic matter [10], on the other hand, according to [11] reduction in the C:N was due to the degradation of organic matter. However, all of the C:N of the food waste were within the range that suggested by the Malaysia standard of Organic Fertilizer (3.8–42.7) which is in the range 7.67 to 25.94.
3.1.2. pH value

pH value was conducted out to measure the acidity or alkalinity of the food waste, in order to determine whether the treated food waste is suitable for direct application to the soil or compost. Based on the literature study the pH value of the treated food was in the range 5.98 to 8.74 [12]. In general, the pH value of the food waste will decrease by increasing the temperature and residence time. However, in this study the pH values shows different pattern.

As shown in Figure 2, pH value was increase by temperature, from untreated to treated food waste of thermal pretreatment. At 60oC to 90oC of thermal pretreatment for 30 minutes of retention time has higher pH values than 60 minutes of retention time which is in the range of 5.36 to 5.72 and 5.32 to 5.65 respectively. In the next level of of temperature which was 100oC the value of pH for 30 minutes of treatment was lower (5.34) than pH value for 60 minutes of retention time (5.4). The entire sample for untreated and treated was mild acidic in nature. The longer duration of pretreatment was formed to increase the pH except for 100oC of thermal pretreatment for both 30 and 60 minutes of retention time. The decrease in pH was limited compared to pH at higher temperatures which was at 100oC. Higher temperatures (100oC) increased the pH reduction rate because organic acids were continuously released into the liquid phase from the solid phase in the food waste during thermal pretreatment [13, 14].When the treatment temperature increased to 100oC, the decrease in pH became more apparent. These results also suggested that both as the rate and amount of organic acid release increased, in a lower pH value was expected. However, all of the pH values of the food waste was within the range (5.21-5.72) that suggested by the Malaysia standard of Commercial Organic Fertilizer (4.5-9.8).

Figure 1. Carbon to Nitrogen ratio (C:N) for untreated and treated food waste
3.1.3. Micronutrient
Micronutrient is an essential for plant growth and soil in order to balanced crop nutrition. They include copper (Cu), iron (Fe) and manganese (Mn). The result indicates that the amount of micronutrient content in the food waste was really limited due to the composition of the food waste. The thermal pretreatment also does not affect the micronutrient content in the food waste which is may due to the unhomogenized of the food waste during the food was preparation. Thus, the thermal pretreatment by water bath method give a flattuated result to the micronutrient content in the food waste.

3.2 Interaction between duration time and temperature by using statistical analyses

| Interaction                | Parameter | C/N ratio | pH   | Fe    | Cu   | Mn   |
|----------------------------|-----------|-----------|------|-------|------|------|
| Time * Temperatures        | P = 0.003 | P = 0.287 | P = 0.345 | P = 0.120 | P = 0.801 |
| Time                      | P=0.004   | P=0.155   | P=0.970 | P= 0.109 | P= 0.514 |
| Temperature               | p=0.00    | P=0.000   | P= 0.845 | P= 0.801 | P= 0.532 |

4. Conclusions
From the research, we can conclude several conclusions which are;

i. pH of untreated and pretreated food waste was more or less similar which in the range 5.21 to 5.72. The higher C/N ratio (25.94) of the food waste was at 80˚C of thermal pretreatment for 30 minutes of retention time. For micronutrient, it shows that thermal pretreatment does not give much effect on Fe, Cu and Mn.

Figure 2. Carbon to Nitrogen ratio (C:N) for untreated and treated food waste
ii. Interaction effect between retention time and temperature was not significant for pH, Fe, Cu and Mn except for C/N ratio.

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