Addition of Solid Recovered Fuel (SRF) to the Bio-drying Process and the Effects of Variation in Air Discharge on Temperature Parameters and Urban Waste Water Content

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Abstract. Bio-drying is a technology used to reduce water content in waste using microorganisms that naturally increase the temperature in the decomposition process. With this process, the water content can drop more within a month. Bio-drying produces a product in the form of Solid Recovered Fuel (SRF) which is produced from partially degraded waste. To obtain a waste that is not fully stabilized and maintains a high biomass content, degradation of organic compounds is carried out partially. During the bio drying process, temperature affects the degradation process. Temperature affects the bio drying, which will also affect the bio drying product that is indicated by the value of water content. Therefore, in this study, the change of process parameters will be explained, which is in the form of temperature and water content, that is caused by the difference in the air discharge entering the reactor (0, 2, 4, and 6 l/m) with the initial water content of 60%-65%. After 30 days, the optimum airflow is 4 l/m with a decrease in water content of 58.29%; on the last day of the bio drying process (30th day).

1. Introduction

Waste production in Indonesia has increased every year [1]. From the data of the Ministry of Environment and Forestry, it is noted that the total waste in 2017 was 65.8 million tons, and the total waste in 2018 was 65.752 million tons. This number is estimated to increase by an average of one ton per year. However, proper management efforts cannot yet be made because of the high investment required.

One alternative to reduce waste volume is by waste to energy (WTE) technology with an effectiveness of 90% [2]. Waste that can be converted into energy depends on the density, composition, and relative percentage of water content [3]. However, most of the waste in Indonesia is a wet waste with a lower calorific value, which makes it difficult to be burned [4]. Utilization of waste by increasing the calorific value of waste in the bio drying process is one of the excellent and effective solutions for reducing the level of municipal solid waste (MSW) in these conditions [5].

Bio-drying is the decomposition of partial organic substances by utilizing the heat generated by microorganisms that are helped by aeration [6]. The bio drying process only partially stabilizes waste.
This causes the content of organic substances, such as C-organic and N-total, not degraded as a whole so that these organic substances can be utilized [7]. The purpose of this study is to determine changes in the process parameters before and after the bio drying process due to differences in air discharge. Bio-drying process is carried out on types of urban waste with the composition of paper, food scraps, plastics, and leaves given different air discharge [8].

Figure 1. Biodrying Reactor Design, (a) Plan of Biodrying Reactor; (b) Pieces A-A of the Biodrying Reactor; (c) Pieces of B-B Biodrying Reactors

2. Methodology

Temperature and water content are the parameters of the sample that will be examined in this study [9]. Four acrylic reactors were used with a volume of 42 L as shown in Figure 1 with the air discharge of 0 l/m, 2 l/m, 4 l/m, and 6 l/m, respectively. Waste composition in each reactor consists of a mixture of urban waste by 70% and Solid Recovered Fuel (SRF) by 30% [10]. Urban waste used consists of leaf litter, plastic waste, paper waste and food scraps with a ratio of 64: 19: 15: 2 [11]. About ¾ of the acrylic reactor is filled with waste with the composition already described [12]. Samples from this study were taken by taking a sample at the midpoint of the height of the waste with the amount in accordance with needs for 30 days adjusting the duration of the study. During the research, the parameters of temperature and water content were tested every day. Temperature measurement is done by plugging a thermometer into the centre of the waste in the reactor to measure the temperature of the waste produced during the process.

As for the water content test, the empty watch glass that has been heated in the 105°C oven, is cooled in a desiccator for ± 10 minutes, then the mass is weighed and recorded as a gram. The sample of waste to be tested is weighed at one gram, put in a watch glass whose mass is known and weighed again and recorded as b gram. The b gram watch glass is heated in the 105°C oven for 2 hours then cooled in a desiccator ± 10 minutes, and then the mass is weighed and recorded as a c gram. Wastewater content is calculated by the formula $\% = \frac{b - c}{b - a} \times 100\%$. 

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3. Results

3.1 Production Process of Solid Recovered Fuel (SRF)

Biodrying produces Solid Recovered Fuel (SRF). This process is carried out using a reactor with a volume of 120 L, which is given an air discharge of 2 l/min. This process is carried out for 15 days. Waste that is used in this process has a composition of leaf litter: paper: plastic: food waste of 64: 19: 15: 2. Waste to be processed as initial moisture content of 64.39%. After going through the process for 15 days, the final water content obtained for the processed waste in the form of SRF was 35.93%. While the highest temperature achieved in this treatment is 44 °C and the final temperature is 29 °C.

3.2 Temperature

The initial temperatures of Reactor V, Reactor W, Reactor X and Reactor Y, respectively, were 31°C, 31°C, 32°C, and 32°C. This indicates that the initial conditions in each reactor are in the mesophilic phase. The mesophilic phase is the initial phase of the bio drying process that there are 3 (three) stages in the bio drying process, namely mesophilic, thermophilic, and curing phase. The temperature of each reactor rose dramatically on the first day [8]. With the addition of Solid Recovered Fuel (SRF), the activity of microorganisms can be accelerated. The addition of bio drying product (SRF) ingredients can shorten the lag phase of microbes.

On day 1, the peak temperatures obtained at Reactor V, Reactor W, Reactor X and Reactor Y were 37°C, 39°C, 41°C, and 39°C respectively, with the highest peak temperature obtained at Reactor X with a peak temperature reached 41°C which gets aeration with a discharge of 4 l/min. In addition to the peak temperature, the increase in temperature of each reactor can also be determined. The highest increase was obtained in Reactor X with an increase of 9°C and the lowest increase in Reactor V with an increase of 6°C. Tom (2016) states that the highest temperature obtained by bio drying waste with a height of 30 cm-60 cm is 41.2°C to 56.5°C and with an increase in average temperature to a peak temperature of 1.67°C/hour [7]. In addition, degradation of organic matter will take place more optimally in the mesophilic phase (35°C-40°C) or the moderate thermophilic phase (40°C-45°C) than the thermophilic phase (55°C-70°C). This is because only thermophilic microbes can survive if the ambient temperature is too high [14].

After experiencing a drastic increase, the temperature at each reactor will decrease periodically on the 2nd day to the 5th day with a temperature of 35°C, which indicates that the bio drying process has re-entered the mesophilic phase. On the 6th day, the temperature of each reactor increased. However, the increase that occurred was not significant. This increase occurred following the ambient or environmental temperatures, which almost reached 36°C.

Temperature fluctuations in each reactor occur on the 7th day until the end of the bio drying process. However, the fluctuations that occur are not so abundant around the temperature of 29°C-34°C. The temperature is almost the same as the ambient temperature. The temperature in the bio drying process will increase in the first two days, then decrease slowly to near ambient temperature. Fluctuations that occur during the bio drying process are shown in Figure 2.
3.3 Moisture Content

During the 30 days of the process, the water content data from each reactor were collected according to the specified day. The average water content on the 30th day was 39% with a decrease of 41.92%.

It appears that there is a fluctuation in water content in each reactor until the 30th day. Reactor V, Reactor W, Reactor X and Reactor Y have an initial water content of 69%, 67%, 65%, and 66%, respectively. Original water content must be high enough to support the metabolic activities of microorganisms [15].

During the first five days, the water content tends to decrease. A decrease of 10%, 8%, 7%, and 7% for each Reactor V, W, X, and Y. In the first two days, the water content will decrease in the form of leachate. The emergence of leachate is seen in Reactor V. However, in other reactors, leachate does not form until the 30th day. This shows that the water content in the W, X and Y reactors during the first five days is reduced in the form of water vapour.

On the 6th day until the 10th day, there was a slight increase in water content that was not too high. The highest increase occurred in Reactor W, where the water content rose to 64%. This increase is due to the condensation of water vapour that occurs at the top of the reactor and then falls back into the waste [16]. Condensation occurs because the capacity of the air inside the reactor to carry water vapour has reached its limit so that the air becomes saturated and water vapour returns to water [17].

After the 10th day, the water content in each reactor decreased significantly. The most significant decrease occurred in Reactor Y, which has a moisture content of 42%. Then the water content will slowly rise until the 13th day and drop significantly again on the 15th day. The decrease on that day was the highest decrease which ranged from 30%-40%. During the 7-15 day, the bio drying process will reduce water content by 25%-30%.

Starting from the 16th day until the 30th day, the water content will experience fluctuations that are not too large. At this stage, the bio drying process enters the cooling phase [18]. In this phase, evaporation only occurs due to aeration [19]. With the aeration, the rate of evaporation of water is still more significant than the rate of formation so that evaporation is still possible even though the activity
of microorganisms begins to decrease [20]. The most significant decrease in water content is shown in Reactor X, which achieved a decrease in water content for about 58.29% and has a final water content of 27.29%. The reduced activity of these microorganisms is also characterized by temperatures approaching room temperature.

3.4 Statistical Analysis

3.4.1 Temperature

Linear regression test was performed to determine the effect of variations in air discharge during temperature. The results of the test are presented in Table 1.

**Table 1. Results of Statistical Analysis of the Effect of Air Discharge on Temperature**

| Model Summary |
|----------------|
| Model | R   | R Square | Adjusted R Square | Std. The error of the Estimate |
|-------|-----|----------|-------------------|------------------------------|
| 1     | 203a | .041     | -.003             | 2.53954                      |

a. Predictors: (Constant), Air discharge
b. Dependent Variable: Temperature

**ANOVA**

| Model | Sum of Squares | Df | Mean Square | F | Sig. |
|-------|----------------|----|-------------|---|------|
| 1     | Regression     | 6.075 | 1 | 6.075 | .942 | .342b |
| Residual | 141.883 | 22 | 6.449 |   |      |
| Total | 147.958 | 23 |   |   |      |

a. Dependent Variable: Temperature
b. Predictors: (Constant), Air discharge

After the regression test was performed, a sig value of 0.342 was obtained, as shown in Table 1. This sig value is greater than 0.05 (0.342> 0.05). From the value of sig, it can be concluded that there is no significant effect of air discharge on temperature parameters. In addition, this test obtained an $R^2$ value of 0.041, which indicates that the interplay between variables was not too strong.

3.4.2 Moisture Content

Linear regression test was performed to determine the effect of variations in air discharge over the water content. The results of the test are presented in Table 2.

**Table 2. Results of Statistical Analysis of the Effect of Air Discharge on Water Content**

| Model Summary |
|----------------|
| Model | R   | R Square | Adjusted R Square | Std. The error of the Estimate |
|-------|-----|----------|-------------------|------------------------------|
| 1     | .533a | .284     | .233              | 7.82224                      |

a. Predictors: (Constant), Air discharge
b. Dependent Variable: Moisture content
ANOVA

| Model   | Sum of Squares | Df | Mean Square | F    | Sig.  |
|---------|----------------|----|-------------|------|-------|
| Regression | 340.313     | 1  | 340.313     | 5.562 | .033b |
| Residual   | 856.625     | 14 | 61.188      |      |       |
| Total      | 1196.938    | 15 |             |      |       |

a. Dependent Variable: Moisture content
b. Predictors: (Constant), Air discharge

After the regression test was performed, sig values were obtained for about 0.033, as shown in Table 2. This sig value is more significant than 0.05 (0.033 < 0.05). From this sig value, it can be concluded that there is a significant influence of air discharge on temperature parameters. In addition, this test obtained an R² value of 0.284, which indicates that the interplay between variables was quite strong.

3.5 Scoring

In order to find out the optimum air discharge, descriptive statistical analysis can be applied. This descriptive analysis is done by scoring or weighting between parameters. Scoring/weighting is done by giving values to each parameter, in the form of temperature and water content which is affected by differences in air discharge. The value of the scoring results is a value that can be used to determine the optimum air discharge. Optimum air discharge is the air discharge which gets the highest value. Scoring is done based on the results of the analysis of each parameter.

With the scoring results based on Table 3, Reactor X with an air discharge of 4 l/min shows the highest score with a score of 4 points. While the lowest score is Reactor V with the air discharge of 0 l/min, which gets a score of 1 point, this shows that the optimum air discharge for the bio drying process is in Reactor X with a discharge of 4 l/min.

Table 3. Scoring Results Range of Biodrying Process Scores with additions of Solid Recovered Fuel

| Air discharge | Temperature | Moisture content |
|---------------|-------------|------------------|
| 0             | 1           | 1                |
| 2             | 2           | 1                |
| 4             | 4           | 4                |
| 6             | 3           | 2                |

4. Conclusions

Based on the results of the scoring, the optimal air discharge obtained was 4 l/min (Reactor X) with the highest temperature of 41°C and a decrease in water content of 58.29%. After statistical analysis, it was found that variations in air discharge only had a significant effect on water content parameters with a significance value of 0.033 (sig. < 0.05) and with an R² of 0.284. Extended investigations may also show whether the results hold true for distributions of the dependent and explanatory variables other than the ones explored here. Finally, more research needs to be carried out on more parameters. A particular focus on random coefficients appears to be desirable.
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