Comparison of Recirculation and Non-Recirculation Leachate on Bio-drying of Organic Fraction of MSW

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Abstract. The bio-drying method of the organic fraction of municipal solid waste (OFMSW) can reduce leachate volume but has not completely removed leachate. This study focused on comparing the OFMSW bio-drying process in a batch reactor with recirculation and non-recirculation leachate. The comparison run at 15 days of bio-drying to produce dry waste with a water content fixed at 20%. Each 5 kg of organic waste was placed in two reactors with a volume of 79 L, respectively, with a constant airflow rate of 42 L/minute. Waste weight, temperature, water content, and leachate volume were measured during the bio-drying process. The result indicated that the dynamic waste weight, temperature, and water content showed the similar result. The residence times were 9 days for non-recirculation and 10 days for recirculation to reach 20% water content. During 15 days bio-drying, non-recirculation and recirculation process formed 315 ml and 0 ml of leachate, respectively.

Keywords: Bio-drying, Leachate, Recirculation.

1 Introduction

Indonesia is one of the largest waste-producing countries, which is estimated to produce 66.5 million tonnes of waste in 2025 [1]. The waste composition is dominated by organic waste consisting of food, fruit, vegetable, garden, and other perishable waste, which reaches 60% of the total waste [2]. The increase in the volume of perishable organic waste can cause environmental pollution. The current waste management system in Indonesia is landfilling. This method is ineffective because it causes soil, air, and water pollution [3]. One of the effective methods currently developing for organic waste processing is bio-drying. This method produce dried waste, which can be used as compost, bio-gas, and solid fuel (RDF).

The bio-drying method is a drying technique that uses a heat source resulting from an exothermic reaction of waste biodegradation by aerobic microorganisms, bacteria, and fungi [4]. The bio-drying reactor is a bioconversion reactor that combines mechanical and biological operations [5]. The bio-drying process produces exothermic heat which can be used to evaporate the water content in organic waste with aeration. The aeration is carried out by blowing air using a blower to accelerate metabolism of

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aerobic microorganisms and transporting vapor out of the reactor. Drying organic waste in a natural way conditions takes 30-50 days. Drying time can be accelerated using the bio-drying method, which only takes 14-21 days [6].

The bio-drying of perishable organic waste reduce leachate volume but has not completely removed leachate. The high water content of perishable organic waste causes the heat of biodegradation to be insufficient to evaporate water. In previous research by [7], the bio-drying process produced 1279.5 ml of leachate, while the natural drying produced 1607.5 ml of leachate. Research by [6] concluded that the bio-drying reactor without aeration produced 1569 ml of leachate, while the bio-drying reactor with an aeration using airflow rate of 5 L/m produced 993 ml of leachate. Both results of this study showed that drying waste using the bio-drying process can reduce leachate volume but has not been able to eliminate leachate completely. Some of water formed during the bioconversion process, flows to the bottom of the waste pile in the reactor and cannot be completely evaporated, resulting leachate [8].

Leachate recirculation into a waste pile in a bio-drying reactor can be an alternative method of drying waste without producing leachate. The leachate recirculation can increase the water content in the waste, which is beneficial for the metabolism of microorganisms. Repeated leachate recirculation can remove leachate when the bio-drying process in the batch reactor is complete. The optimal water content for the microorganism growth at aerobic process is 50-70% [9]. A water content of less than 40% causes the bioconversion activity of microorganisms to be low or stopped. On the other hand, if the water content is too high, it fills the waste pores, causing it to become anaerobic process [10].

During the bioconversion process, heat is generated for an exothermic reaction which can raise the temperature of the waste pile [11]. There are two microbiological activities in the organic matter degradation process: mesophilic (ambient - 45 °C) and thermophilic at 45-65 °C [12], [13]. The temperature of the waste pile can be used as an indicator of the progress of the bioconversion process. In this study dynamic waste weight, temperature, water content, leachate volume, and residence time of two processes were compared. The novelty of this research is to develop a method for bio-drying perishable organic waste without forming leachate.

2 Material and Methods

2.1 Sample

The organic waste used in this study was taken from Waste Temporary Shelter called *Tempat Penampungan Sementara (TPS)* Tlogomas, Dinoyo, Malang, and was not pretreated. The waste composition consisted of vegetable scraps, fruit peels, and food scraps. The waste for the research sample was 5 kg, respectively, with an initial water content of approximately 75%. Measurement of water content using a moisture meter T-K 100, which was calibrated using the gravimetric method.

2.2 Equipment

The bio-drying reactor used for running experiments at the Chemistry Department of the State Polytechnic of Malang. The reactors used are two box with respectively dimensions of 63.5 cm long, 50 cm wide, and 25 cm high, which were stacked, as shown in Figure 1. Wire screen boxes were placed inside the reactor to put waste. At the bottom of the screen, baking sheet was put to collect the leachate. The air is flowed using 2 inches diameter blower IDEKU No.5-001, which was placed outside the box. The wire screen box and baking sheet can be attached or removed to take the waste and collected leachate.

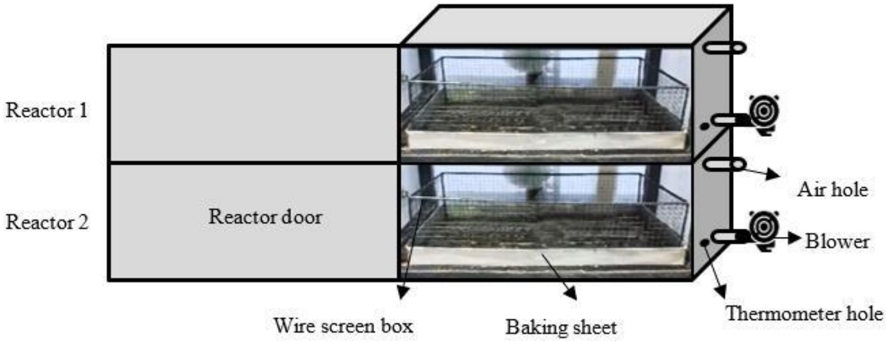

Fig. 1. Bio-drying Reactor

2.3 Bio-drying Experiment

This research was conducted at ambient temperature (25 °C) for 15 days. 5 kg of organic waste was respectively put into two bio-drying reactors, as shown in Figure 1. Air was flowed into the reactor using a blower with an airflow rate of approximately 42 L/minute. Measurement of weight, temperature, water content of waste, and leachate volume inside the reactor were carried out two times a day in the morning and evening. The weight measurement was carried out by removing the wire screen box, then weighing using a digital scale. The leachate was measured by removing the baking sheet, then collecting, and measuring it using a 1000 ml measuring cylinder. Temperature measurement using a thermometer of 100 °C scale and water content measurement using moisture meter TK-100.

3 Result and discussion

This study was conducted on the bio-drying reactor with a leachate recirculation and non-recirculation. Leachate recirculation was carried out by putting back the formed leachate into the reactor, while non-recirculation was carried out by set apart the leachate from the reactor. Dynamic waste weight, temperature, water content, leachate volume for 15 days of bio-drying process. The residence time of two processes were compared to reach the specified water content of 20%.

3.1 Comparison of waste weight reduction

Comparison of waste weight for 15 days of bio-drying in recirculation and non-recirculation processes was obtained from data on daily waste weight measurements. (Figure 2). Experiments were conducted at an ambient temperature of 25 °C, with an airflow rate of approximately 42 L/min during the bio-drying. In the first 6 days, the weight of waste in both processes decreased rapidly due to the evaporation of water and leachate forming. The rate of weight reduction in the first 6 days of the non-recirculation and recirculation was 0.63 kg/day and 0.61 kg/day, respectively. On the 6th to 13th day, the waste weight reduction decreased and stabilized on the 15th day. On the 15th day, the waste weight reduction of the two processes was 82.31% on non-recirculation and 81.57 % on recirculation. In the study by [4], the percentage was lower because the ratio of waste and air was 1 kg: 0.28 L/minute, while in this study, it was 1 kg: 8.4 L/minute. The results of the research by [14] on bio-drying cassava peel showed that the greater the air flow rate, the greater the decreased in sample weight.

Based on the calculation, the average rate of waste weight reduction for 15 days in two processes has almost the same rate. The leachate that is circulated to the waste only sticks to the surface of the waste (unbound water) and does not diffused the pores of the waste tissue (bound water). Unbound water dries faster than bound water. Therefore, the leachate which was recirculated in the waste was quickly dried by the air from the blower.

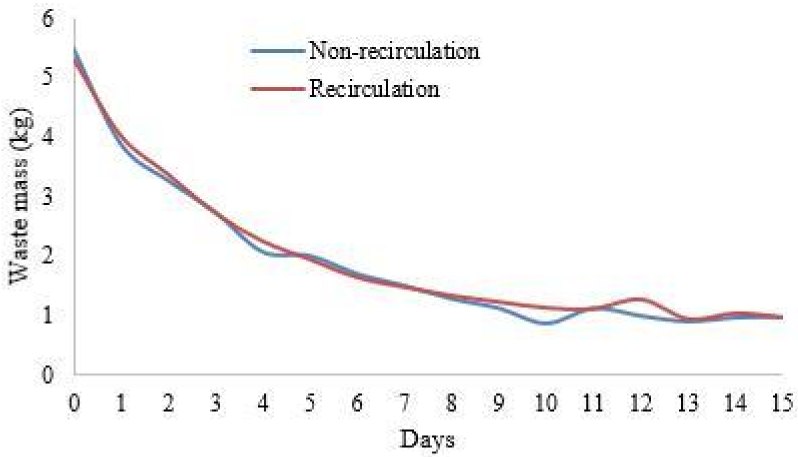

Fig. 2. The waste mass during 15 days of bio-drying, the air flow rate is approximately 42 L/minute

3.2 Comparison of waste temperature for 15 days of bio-drying

Data on waste temperature measurements for 12 days of drying are shown in Figure 3. The dynamics of waste temperature in the bio-drying reactors for the two processes are almost the same, with a minimum of 24 °C and a maximum of 27 °C. The temperature of waste non-recirculation leachate tends to rise until the 8th day it reaches 27 °C and then drops until it stabilizes at 25 °C. The temperature of process waste with leachate recirculation from day one to day three decreases until it reaches 23 °C due to the addition of 315 ml of leachate. This addition causes the temperature of the waste to decrease and then rise again on day 4. During the drying process, there is a temperature fluctuation of 1 °C. The increase in temperature during the 15-day drying process is only 3 °C from the air temperature blown by the blower, which is 25°C. Study conducted by [4] examined the bio-drying of mixed organic and inorganic waste at temperatures of 30 °C, 40 °C and 50 °C providing data on temperature increases until they reached 10 °C respectively. This difference is due to the temperature conditions of the study and the ratio of waste to different aeration air velocities. The temperature dynamic data from the research by [15] concluded that the highest temperature is at the bottom, followed by the middle and top of the garbage pile. This data shows that the temperature is affected by the height of the waste pile in the reactor. In this study, the height of the waste pile in the bio-drying reactor was 5 cm, weighing 5 kg of wet waste. This condition causes the highest temperature of 27 °C due to waste piles relatively low.

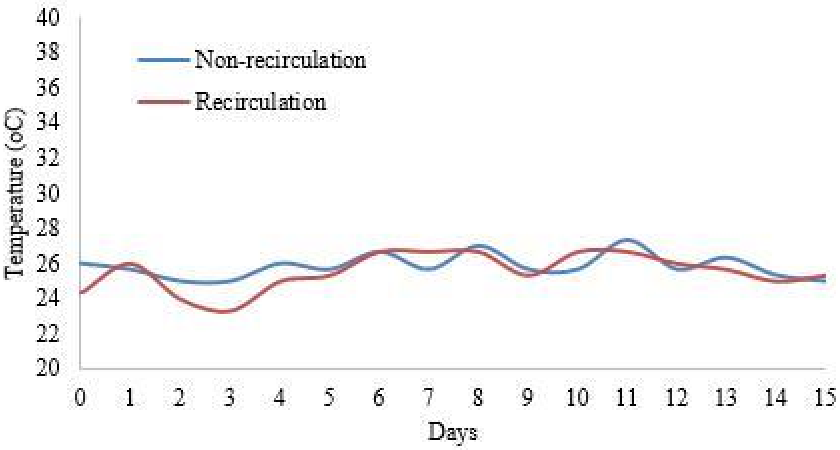

Fig. 3. The waste temperature during 15 days of bio-drying, the air flow rate is approximately 42 L/minute

The low increase in waste temperature was compared to the study by [4] was due to the too-large aeration air flow rate. In this study, the ratio of waste and air flow rate was 1:8, while in research by[4], the ratio was 3:1. Process temperature, the ratio of dry waste to aerated airflow rate, affects drying rate. At high aeration rates, it will cause heat loss, which can reduce microbial activity [4]. There are two microbiological activities in the organic matter degradation process, namely mesophilic (ambient temperature - 45 °C) and thermophilic in the range of 45-65 °C [12].

The drying process was dominantly controlled by convection air heat from hot air which coming out of the blower. In testing the performance of the blower, which was turned on for 24 hours, the air temperature that came out was stable at 25 °C. When the air was supplied to the pile of waste, there was an increase in the temperature of the waste, either due to heat air from the blower or possibly mesophilic microbial activity. The temperature dynamics in the two processes are almost the same at a minimum of 24 °C and a maximum of 27°C, so the leachate recirculation did not affect the drying rate.

3.3 Comparison of waste water content

A comparison of the dynamic waste water content during the 15 bio-drying non-recirculation and recirculation leachate is shown in Figure 4. The experiment was conducted at an ambient temperature of 25 °C, with an airflow of approximately 42 L/minute during bio-drying. The water content of non-circulating process waste decreased from an initial value of 77.7% to 10.7% on the 15th day. The water content of process waste with recirculation decreases from an initial value of 76.1% to 9.9% on the 15th day. Second day, on non-recirculation and recirculation, leachate was formed respectively 315 ml and 300 ml. In the process non-recirculation, the leachate is removed from the reactor, while in the process recirculation, the leachate is returned to the reactor. From the first day until the third day, evaporation was still low. The highest evaporation was during days 4 to 13. On the 14th to 15th day, the evaporation of water vapor was constant because the water content is stable at 9.9 – 10.2%.

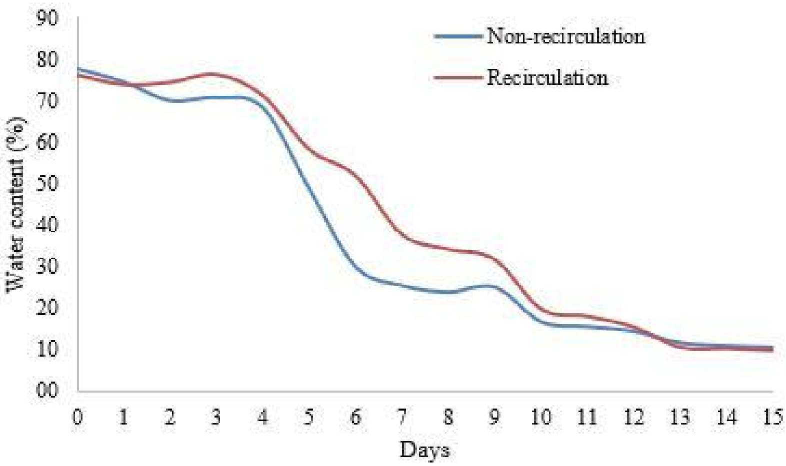

Fig. 4. The water content of the waste during 15 days of bio-drying, the air flow rate is approximately 42 L/minute

Evaporation occurred at a temperature of 24-27 °C, which is lower than the results of previous studies [14], [4]. On both studies, the water evaporation process was due to heat generated by decomposition by thermophilic bacteria. In contrast to the two studies, in this study, water evaporation was due to the heat of convection due to the high-water flow rate (approximately 42 L/h). Bio-drying time to obtain waste with a water content of 20% was 9 and 10 days, respectively, for non-recirculation and recirculation. The drying time of the two processes was almost the same, leachate recirculation has no effect on the residence time of bio-drying.

3.4 Leachate volume comparison

Leachate was formed due to the release of bound water from waste due to gravity [14]. A separate study by [6] concluded that the volume of leachate formed in the bio-drying process was influenced by air flow rate. The greater the air flow rate, the lower the leachate volume. In this study, the highest volume of leachate formed was 386 ml on a waste and air ratio 1:8.

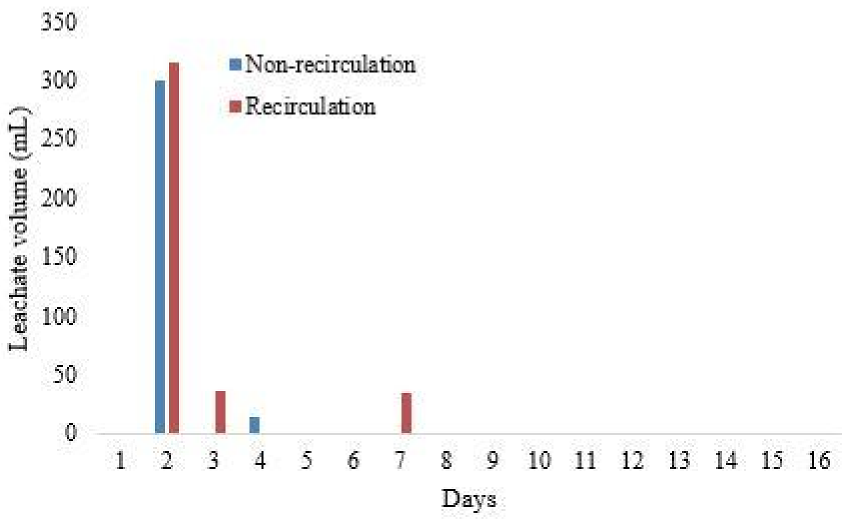

Fig. 5. The leachate volume during 15 days of bio-drying, the air flow rate is approximately 42 L/minute

A comparison of the leachate volume formed during the 15 days bio-drying on non-recirculation (reactor 1) and recirculation (reactor 2) is shown in Figure 4. In both reactors, most leachate was formed in the first two days of bio-drying, respectively, 300 ml and 315 ml. In reactor 1, leachate was separated from the reactor, while in reactor 2, it was collected and recirculated into reactor 2. Day 3 on the reactor 2 process 36 ml of leachate was formed again, because some of the recirculated leachate flows from waste, due the gravity, which was then recirculated to reactor 2. On the

4th day, 15 ml of leachate was formed in reactor 1 and separated. Reactor 1, on days 5 to 15 and reactor 2 on days 5 to 6, no leachate is formed. On the 7th day of reactor 2, 35 ml of leachate was formed, and on the 8th to 15th day, no leachate was formed. At the end of the bio-drying process, reactor 1 produced 315 ml of leachate, while reactor 2 did not produce leachate. The bio-drying process with leachate recirculation is advantageous because no leachate is produced at the end of the process.

4 Conclusion and Recommendation

In the 15 days study, bio-drying processes with recirculation did not produce leachate, while non-recirculation produced 315 ml of leachate. The residence time to achieve 20% water content in both process was respectively 9 days on non-recirculation and 10 days, on recirculation. The bio-drying process that produces leachate requires additional equipment for leachate treatment. Further research is needed as a basis to the feasibility study on selecting the two processes. Each process has advantages and disadvantages. A process non-recirculation requires additional equipment for leachate treatment, while a process with recirculation requires higher operational costs because the residence time is longer. The weakness is that the waste temperature inside the bio-drying reactor is low, approximately 24-27 °C, at an ambient temperature experiment of 25 °C. Further research is needed on bio-drying with leachate recirculation at lower ratio of waste and air flowrate, to increase the bio-drying temperature.

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