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Submission date: 08-Feb-2022 11:38AM (UTC+0700)

Submission ID: 1757476497

File name: Performance_of_Biodrying_Process_based_on_Temperat.pdf (1.4M)

Word count: 2904

Character count: 15061

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To cite this article: B Zaman *et al* 2020 *J. Phys.: Conf. Ser.* **1625** 012040

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Performance of Biodrying Process based on Temperature Profile and Cumulation

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Abstract. The biodrying process of solid waste is an approach to the use of biomass energy, where solid waste is dried using the heat generated from aerobic degradation of organic matter. Temperature profile and cumulation of the solid waste biodrying process are the success factors in drying solid waste. The reactor used is made of plywood with dimensions of (30 x 30 x 100) cm equipped with a heat sink using Thermoshield Universal to minimize heat loss. Aeration discharge at the biodrying process reactor is 0.023 m³/kg/h. The results showed a maximum temperature of 61°C produced from the bottom layer of the biodrying reactor (addition of 6 l / min air flow) on the first day at 10:00 pm. Cumulation temperature in the bottom layer of the biodrying reactor for 21 days of research reached 186.9°C. This value is a source of heat generated from the decomposition of waste under aerobic conditions. Based on the three layers, it can be concluded that the bottom layer produces higher temperature cumulation than the top or middle layer. This research can be a reference for determining temperature monitoring points and knowing Temperature cumulation generated from the waste decomposition process using biodrying technology.

Keywords: biodrying, performance, temperature, municipal solid waste

1. Introduction

An effective municipal solid waste drying process is a significant obstacle to the conversion of MSW into biomass energy. Besides that, heterogeneous composition and high water content [1]. The biodrying process of solid waste is an approach to the use of biomass energy, where solid waste is dried using the heat generated from aerobic degradation of organic matter. Biodrying, is one of the solutions to the conversion of MSW into biomass energy. Solid waste will undergo mechanical-biological bioconversion [2]. The heat generated from the aerobic decomposition process of organic compounds combined with excess air functions to dry solid waste [3]. Solid waste that has dried can be considered as Refuse Derived Fuel (RDF). It can be produced from various types of waste, such as urban waste, industrial waste, or commercial waste [4]. RDF can be used as a substitute for coal [2].

According to Navaee-ardeh, Bertrand, & Stuart, [5] the temperature of the matrix in the biodrying reactor becomes a reference to describe the complexity that occurs in the biodrying reactor. According to Jalil et al., [6] Mesophilic temperatures, between 35°C and 40°C, or moderately thermophilic temperatures of 40°C to 45°C are more applicable for biodrying than the thermophilic temperatures of 55°C to 70°C. But in reality reactor temperature profiles are quite dynamic and challenging to control. In addition, temperature is a factor that greatly influences the process of decomposition of solid waste [7].



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The choice of temperature measurement points becomes biased when the reactor layers (the top, middle, and bottom layers) produce different temperatures. In addition, accumulation temperature must be known to analyze the decomposition process that occurs. The amount of temperature generated from the process of biodrying and composting is generally interesting to study. So this research analyzes the evolution temperature and cumulation temperature using the biodrying process of solid waste, where MSW is dried using the heat generated from aerobic degradation of organic matter.

2. Method

In this study, MSW came from TPA Putri Cempo, Surakarta City, Central Java, Indonesia. MSW is sorted by the type and the calculated percentage (w/w). The composition is from food waste, leaf waste, paper waste, and plastic waste. The portion of each component refers to the KLHK data (2018), which is 56.75% of food waste, leaf litter by 5.20%, paper waste 12.26%, and plastic waste 13.39%. The waste is chopped 2-3 cm in size, and then put the waste into each control and biodrying reactor. The optimum water content at the beginning of the aerobic system process is 50-75% [8]–[10]. The reactor used is made of triplex material with dimensions of (30 x 30 x 100) cm equipped with heat absorbers using Thermoshield Universal to minimize heat loss (Figure 1). The bottom of the reactor is equipped with a stainless still pipe (\varnothing 3 mm) to ensure uniform air distribution. Aeration discharge in the biodrying process reactor is 0.023 m³/kg/h using an aquarium pump (Resun LP-100). Discharge values refer to research [11]. Each reactor has a sampling hole with a diameter of 7 cm at a height of 0.2 cm, 30 cm, and 60 cm from the bottom of the reactor. This hole is tightly closed when not in use. Measurement of temperature parameters is measured every day for 21 days at 06.00 am; 02.00 pm; and 10:00 pm. Temperature probes are placed at the top, middle, and bottom of the reactor's control and biodrying reactors.

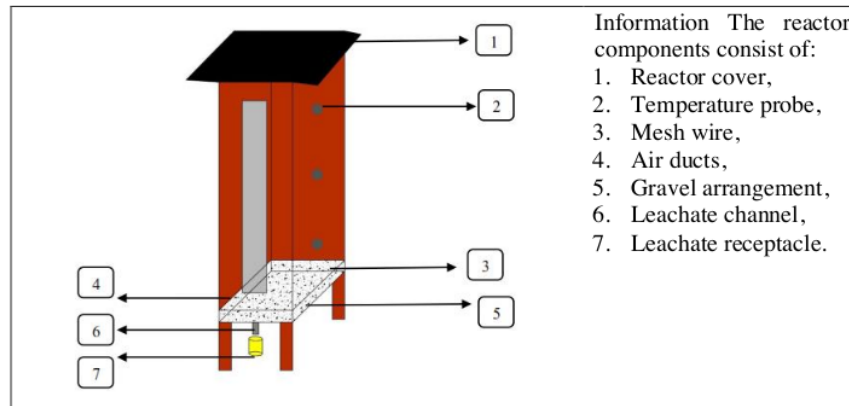


Figure 1. Biodrying reactor made from triplex material with dimensions (30 x 30 x 100) cm. That's equipped heat absorbers using Universal Thermo shield to minimize heat loss.

3. Result and Discussion

3.1. Temperature evolution on Top Layer

The temperature was a crucial factor affecting water evaporation and organic degradation [12]. Figure 2 to Figure 3 is the temperature evolution (average temperature of the top, middle, and bottom of the matrix) on the reactor control and biodrying. Figure 2 is the evolution temperature in the top layer of the control reactor and biodrying. The average ambient air temperature at 06.00 am, 02.00 pm, and 10:00 pm are range from 24-30°C for 21 days of research. The maximum temperature reaches 49°C generated by the biodrying reactor at 02.00 pm. It means that solid waste has undergone a decomposition process for 8 hours (06.00 am to 02.00 pm). This value is a source of heat generated from waste decomposition under aerobic conditions [13]. The temperature of the control reactor is 46°C. The difference between

the control reactor and biodrying is 3° C. Overall the temperature of the solid waste in the top layer undergoes a clear 3-step profile, namely the thermophilic stage (45-55° C), the moderate stage (40-45° C), the cooling stage (less than 30° C). On day four the heat is beginning to decline, which indicates slowed integration [14].

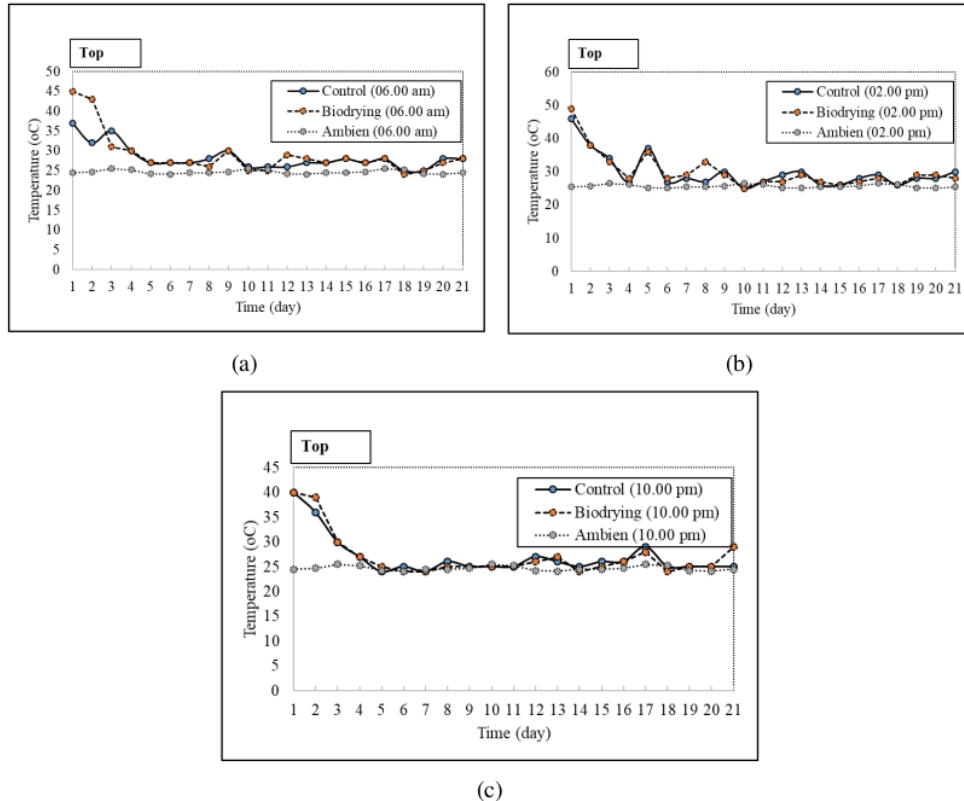


Figure 2. Temperature evolution at the top of the reactor control and biodrying at (a) 06.00 am; (b) 02.00 pm; (c) 10.00 pm.

3.2. Temperature evolution on Middle Layer

The results of evolution temperature measurements in the middle layer of the reactor control and biodrying are shown in Figure 2. The maximum temperature reaches 50°C generated by the biodrying reactor at 02.00 pm. It means that solid waste has undergone a decomposition process for 8 hours (06.00 am-02.00 pm). This value is greater than the top layer, with a difference of 1°C. The temperature of the solid waste in the control reactor was 46°C. Overall the temperature of solid waste in the middle layer decreased from day 4, which indicates the degradation process is slowing down [14].

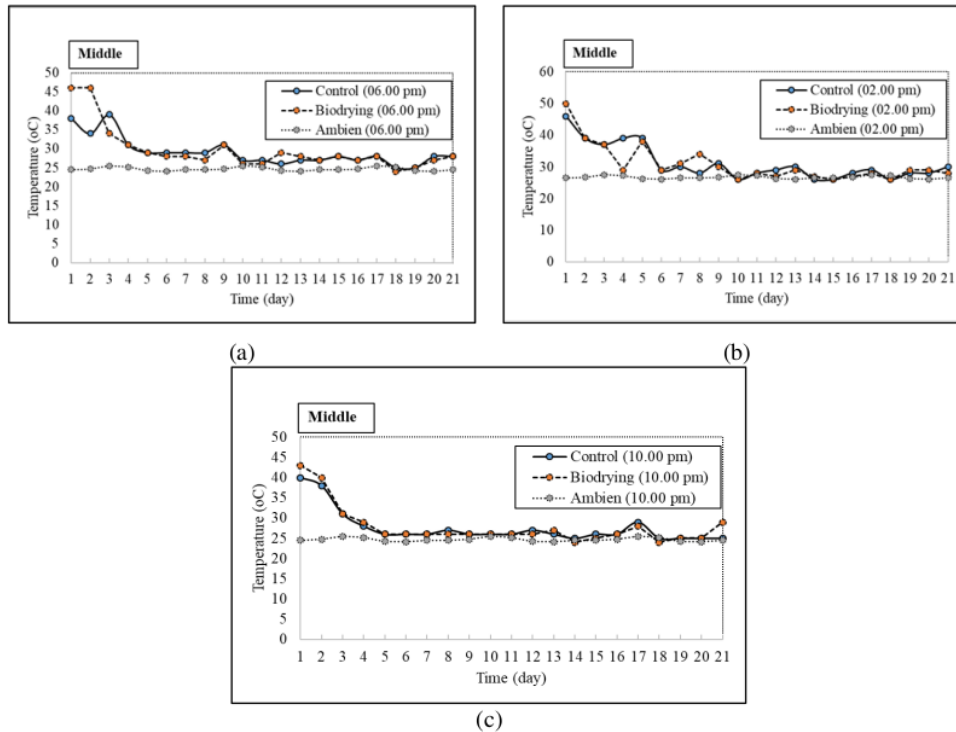


Figure 3. Temperature evolution at the middle of the reactor control and biodrying at (a) 06.00 am; (b) 02.00 pm; (c) 10.00 pm.

3.3. Temperature evolution on Bottom Layer

The results of the temperature evolution measurements at the bottom layer of the control reactor and biodrying are shown in Figure 4. The maximum temperature reaches 61°C generated by the biodrying reactor (addition of airflow 6 l/min) on the first day at 10:00 pm. It means that solid waste has undergone a decomposition process for 16 hours (06.00 am-10.00 pm). This result is in line with research by Rada & Ragazzi [2] and Sadaka et al., [10] which states that the maximum self-heating of the matrix occurs within the first 24 hours (i.e. higher temperature). It's showing an intense microbial activity, which is an indication that the initial period of the bio-drying process is crucial. The temperature of the reactor in the bottom layer is greater than the middle layer, with a difference of 11°C and a longer duration of the decomposition process. The temperature of the solid waste in the control reactor was 41°C at the same hour. In this layer, it is clear the difference in waste temperature in the control reactor and biodrying with a difference of 20°C.

Based on the results of evolutionary temperature measurements in the top, middle, and bottom layers of the reactor, it can be concluded that the temperature of the top layer produces the lowest temperature compared to the middle and the bottom layers. It means that decomposition in the top layer is slower than the middle and bottom layers. The basic principle of biodrying is to achieve the lowest possible level of degradation of organic matter and the removal of the highest possible moisture content [15]. According to Jalil et al., [6] mesophilic temperatures are between 35°C and 40°C or moderately thermophilic 40°C to 45°C are more applicable for biodrying than the thermophilic temperatures 55°C to 70°C. The rate of degradation can be supported by measuring carbon content. For energy preservation purposes during biodrying, the process should favour minimum carbon losses [5], [16].

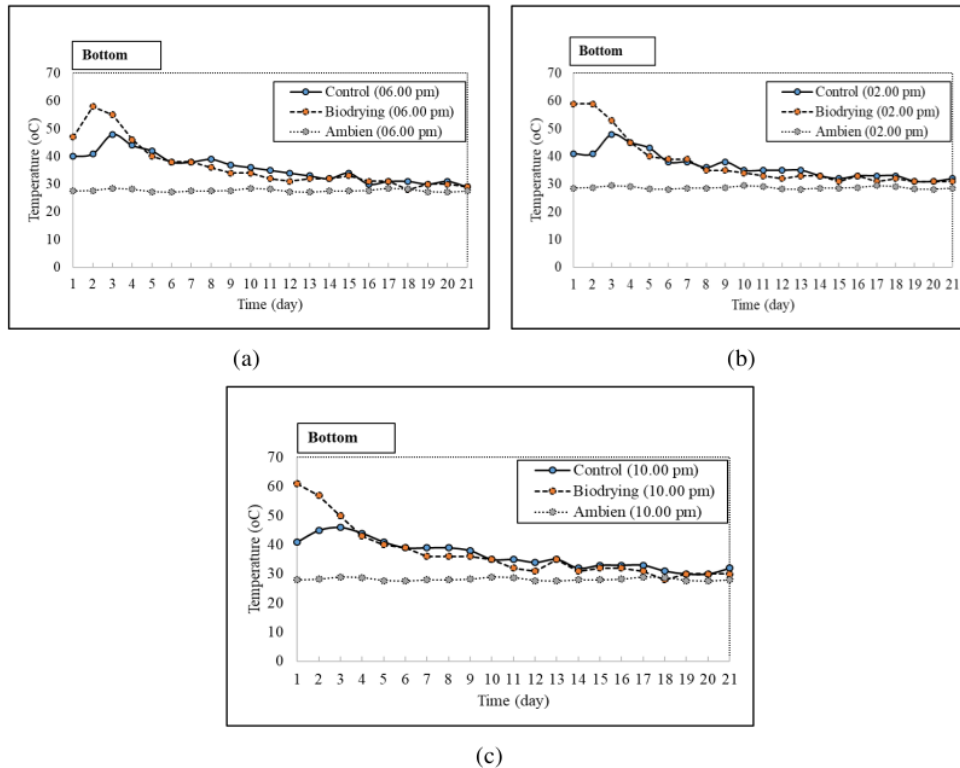


Figure 4. Temperature evolution at the middle of the reactor control and biodrying at (a) 06.00 am; (b) 02.00 pm; (c) 10.00 pm.

3.4. Temperature Cumulation on Top Layer

To indicate the temperature differences between the control reactor and biodrying clearly, an index, temperature cumulation (TC, °Cd), was defined as the sum of temperature differences between the matrix and the ambient environment based on equation (1).

$$TC = \sum_{i=1}^n (T_m - T_a) \cdot \Delta t \quad (1)$$

Where T_{mi} and T_{ai} are the matrix temperature and the ambient temperature at day one, respectively; Δt is the time element (1d) [12]. Figure 5 to Figure 7 is the cumulation temperature of the top, middle, and bottom of the matrix on the reactor control and biodrying. In the top layer of the reactor, the cumulation temperature for 21 days of research reached 91.9 °C produced by the biodrying reactor. Whereas the control reactor was 87 °C. The difference between the two reactors is 5°C. Figure 5 is temperature cumulation of the top of the matrix on reactor control and biodrying.

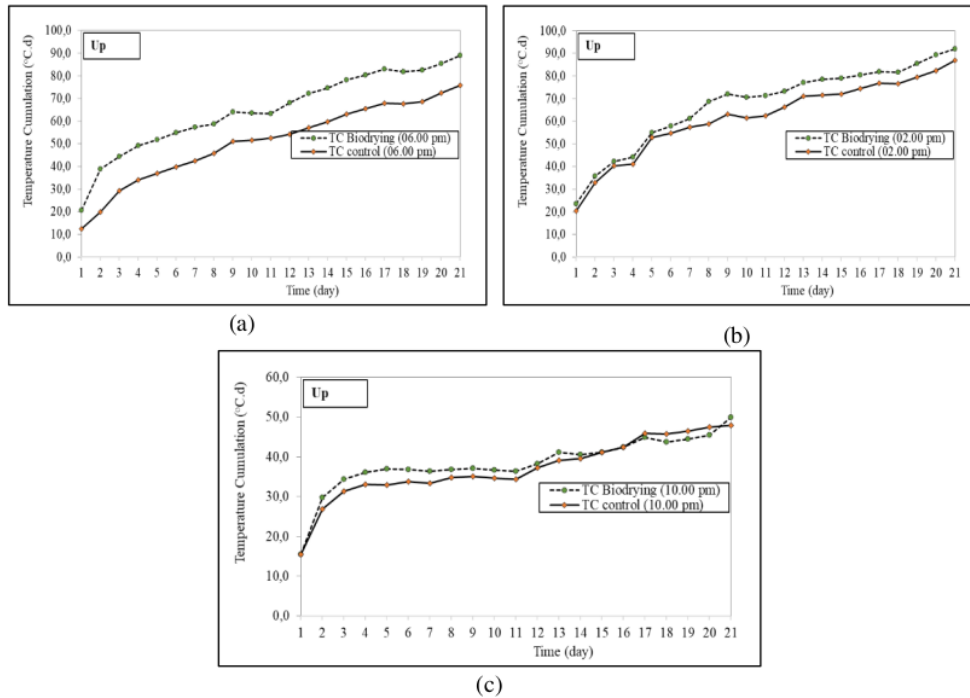


Figure 5. Temperature cumulation of the top of the matrix on reactor control and biodrying at (a) 06.00 am; (b) 02.00 pm; (c) 10.00 pm.

3.5. Temperature Cumulation on Middle Layer

In the middle layer of the reactor, the cumulation temperature for 21 days of research reached 104.9°C generated by the biodrying reactor. Whereas the control reactor was 93.9 °C. The difference between the two reactors is 11°C. Figure 6 is temperature cumulation of the middle of the matrix on reactor control and biodrying.

3.6. Temperature Cumulation on Bottom Layer

In the bottom layer of the reactor, the cumulation temperature for 21 days of research reached 186.9°C generated by the boidrying reactor. While the control reactor is 163.9°C. The difference between the two reactors is 23°C. Figure 7 is temperature cumulation of the bottom of the matrix on reactor control and biodrying.

Based on the three layers, it can be concluded that the bottom layer produces higher temperature cumulation compared to the top or middle layer. This research can be a reference for determining the temperature monitoring point in the biodrying reactor and knowing the amount of temperature generated from the waste decomposition process using biodrying technology.

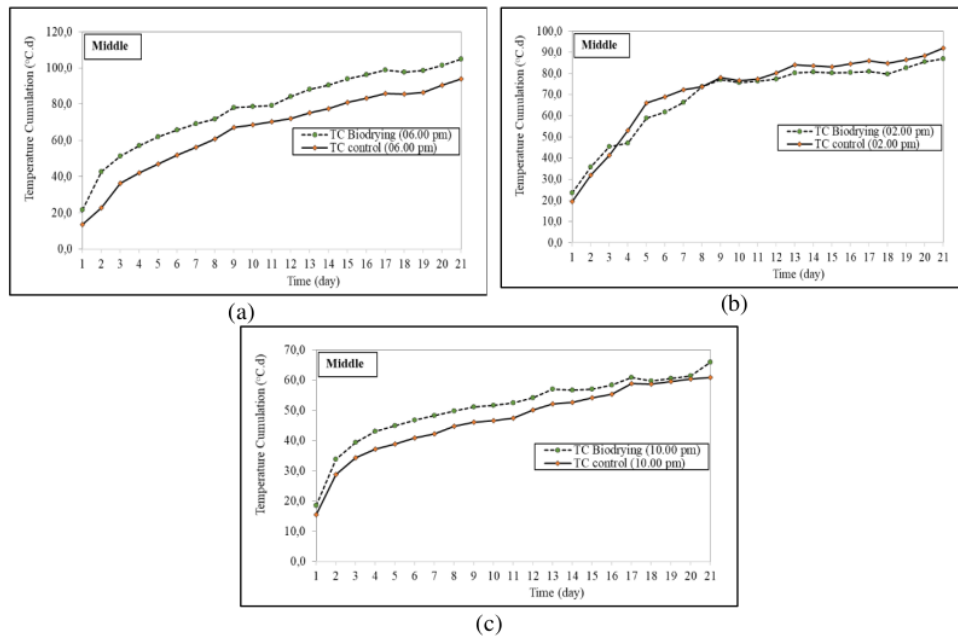


Figure 6. Temperature cumulation of the middle of the matrix on reactor control and biodrying at (a) 06.00 am; (b) 02.00 pm; (c) 10.00 pm.

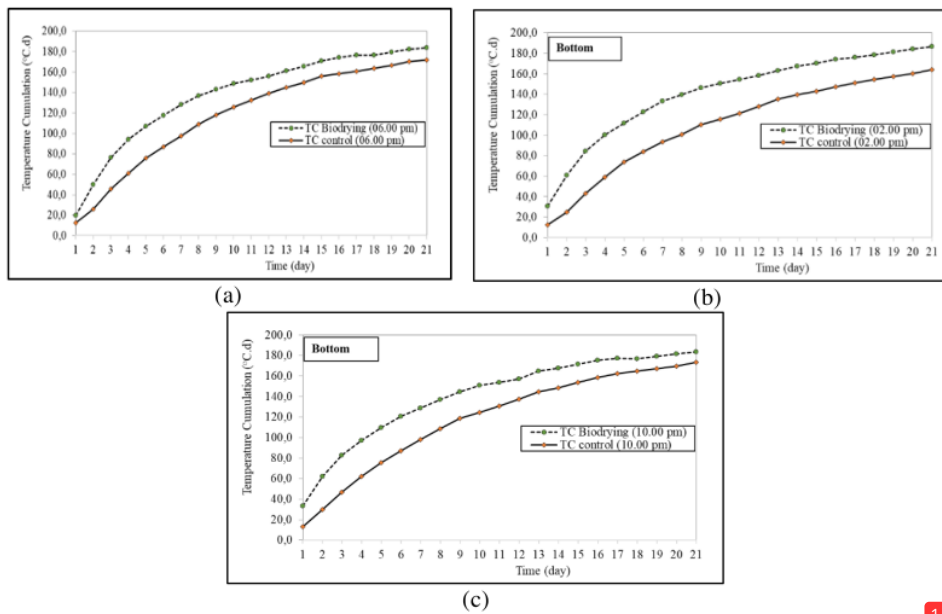


Figure 7. Temperature cumulation of the bottom of the matrix on reactor control and biodrying at (a) 06.00 am; (b) 02.00 pm; (c) 10.00 pm..

4. Conclusions

The highest temperature of solid waste reaches 61°C generated by the biodrying reactor on the first day at 10:00 pm. In this layer, it is very noticeable that the difference in waste temperature in the control reactor and biodrying have differences 20°C. Cumulation temperature in the bottom layer of the biodrying reactor for 21 days of research reached 186.9°C. Based on the three layers, it can be concluded that the bottom layer produces higher temperature cumulation than the top or middle layer. This research can be a reference to determine the temperature monitoring point and determine the amount of temperature generated from the waste decomposition process using biodrying technology.

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Acknowledgment

Thank you to DRPM DIKTI for funding this research through PTUPT grant for financing year 2019.

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