

# The effect of mixing ratio variation of sludge and organic solid waste on biodrying process

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**Abstract.** In this study, organic waste was co-biodried with sludge cake to determine which mixing ratio gave the best result. The organic waste was consisted of dried leaves and green leaves, while the sludge cake was obtained from a waste water treatment plant in Bekasi. The experiment was performed on 3 lab-scale reactors with same specifications. After 21 days of experiment, it was found that the reactor with the lowest mixing fraction of sludge (5:1) has the best temperature profile and highest moisture content depletion compared with others. Initial moisture content and initial volatile solid content of this reactor's feedstock was 52.25% and 82.4% respectively. The airflow rate was 10 lpm. After biodrying was done, the final moisture content of the feedstock from Reactor C was 22.0% and the final volatile solid content was 75.9%. The final calorific value after biodrying process was 3179,28kcal/kg.

**Keywords:** co-biodrying, mixing ratio, organic waste, sludge cake

## 1. Introduction

Rapid urbanization followed by the industrial development and construction activities is one of the reasons for solid waste (SW) accumulation [1]. SW accumulation will produce odor and leachate during its collection and transportation [2]. Solid waste accumulation in landfill will lead to overcapacity and difficulty to find new site. Moreover, SW management in Indonesia was still dominated with open dumping system which lacked with methane gas control system [3].

Moreover, sludge from wastewater treatment (domestic and industrial) is continuously produced in large number and becoming one of the environmental problems [4]. High moisture content makes it difficult to process sludge directly [5]. Therefore, waste begins to be used for the recycling of materials and energy production from solid waste. Waste treatment into new energy sources is expected to replace fossil fuels [6].

Biodrying, which is based on a process similar to composting, aims at removing water from biowastes with high water content using the heat generated during the aerobic degradation of organic substances, in addition to forced aeration [4], [7], [8]. The removal of excess moisture content on waste may increase the potential for thermal energy recovery [9]. Moreover, biodrying results can be utilized as RDF (refused derived fuel) which is one of the most excellent sources of renewable energy [10].

When organic solid waste and sludge were mixed, there will be a reduction in the number of microorganisms from the sludge, and enhancement of biodegradable organic matter in the mixture. Therefore co-biodrying of organic solid waste and sludge can increase the profile of temperature and stability of the system by utilizing microorganisms contained in sludge and solid waste that are readily biodegradable and rich in nutrients for microorganisms [2].



## 2. Research Method

### 2.1. Preparation of material

Sample used in this study is artificial organic solid waste and sludge cake. The organic solid waste is yard waste from UPS FTUI, while the sludge cake comes from Waste Water Treatment Plant, PT. Jababeka Infrastructure. The sample was put as much as 17 kg, adjusted to the inner volume of the reactor. The mixing ratio is varied to 3: 1, 4: 1, and 5: 1, for solid waste and sludge respectively. The solid waste itself consists of green and dry waste and the fraction used is 2: 1, for each reactor. The selection of fractions refers to the research that has been done [2] as well as based on preliminary experiments conducted before the study began. The feedstock that has been collected is then homogenized and weighed according to a predetermined fraction. Here is the fraction for each composition on each reactor (Table 1).

**Table 1.** Composition of material used for the study.

Composition	Reactor name		
	Reactor A (kg)	Reactor B (kg)	Reactor C (kg)
Dry yard waste	8.5	9	9.5
Green yard waste	4.25	4.6	4.7
Sludge	4.25	3.4	2.8

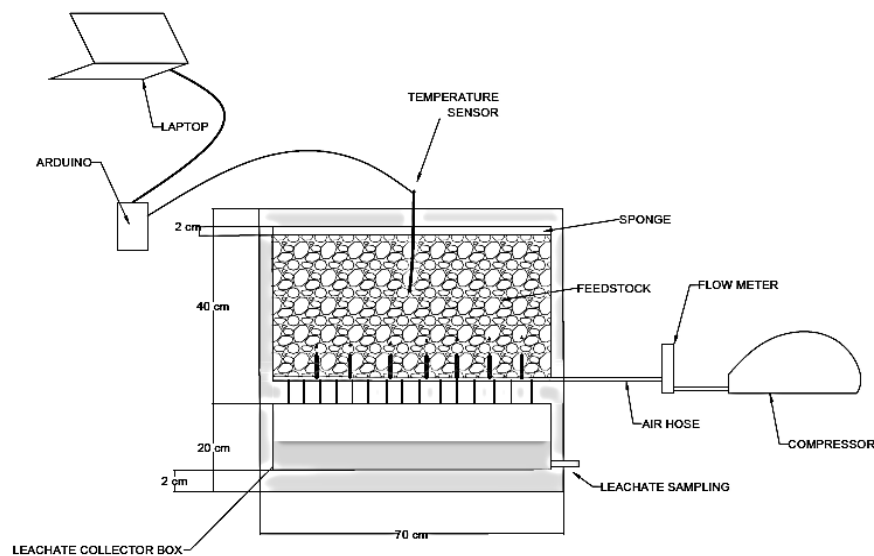
### 2.2. Experimental equipment

The biodrying process was performed on a reactor made of polystyrene foam with volume of 97.5 L (64 cm x 44 cm x 34 cm) with wall thickness of 3 cm. In this study, there were 3 lab-scale reactors, each filled with 17 kg of material mixture. The reactor lid was coated with a 2 cm thick sponge to prevent energy loss and steam condensation.

**Table 2.** Physicochemical properties of the raw materials.

Parameter	Solid waste : Sludge		
	Reactor A (3:1)	Reactor B (4:1)	Reactor C (5:1)
Moisture content (%)	61.81	56.85	54.25
Volatile solid (%)	88.88	83.18	82.37
C/N	9.7	10.9	11.8
FAS (%)	67.81	68.54	72.91

The reactor was connected to the air pump (Multipro Mini Air Compressor) used for aeration, and the pump was equipped with a flowmeter (Wiebrock capacity of 15 lpm) to adjust the airflow. The airflow used in this experiment is 10 lpm (air flow is supplied to the reactor using a hose with diameter of 0.8 mm. Leachate which formed during the process will be channeled into the leachate collector box through the hole provided in the reactor. Temperature sensors were placed in the center of the reactor. Temperatures were recorded using an acquisition data system consist of Arduino and thermocouples. The following were the reactor design used in this study.

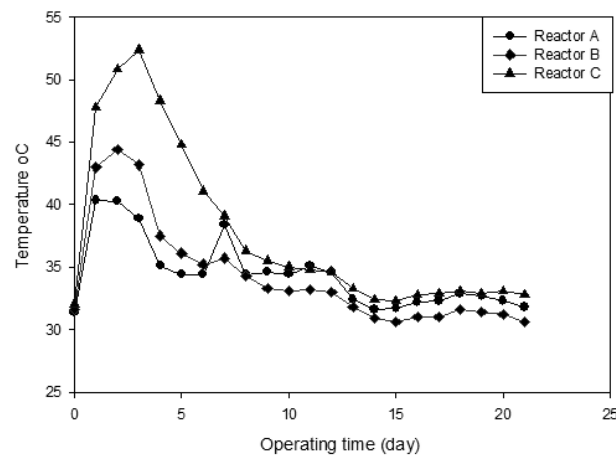


**Figure 1.** Schematic diagram of biodrying reactor.

### 3. Result and Discussion

#### 3.1. Temperature profile on biodrying process

The high temperature with a long duration was the key point to achieve the good biodrying performance [2]. Figure 2 shows the daily temperature profile of co-biodrying process. The initial temperature for each reactor ranges in 30°C. In Reactor A (3:1), the highest temperature reached 38.9°C on the third day. The average temperature in reactor A is 34.4°C. While at Reactor B (4:1), the highest temperature reached 44.4°C on the second day, with average temperature of 36.1°C. In reactor C (5:1) the highest temperature reached 52.4°C on the third day and the average temperature was 37.6°C.



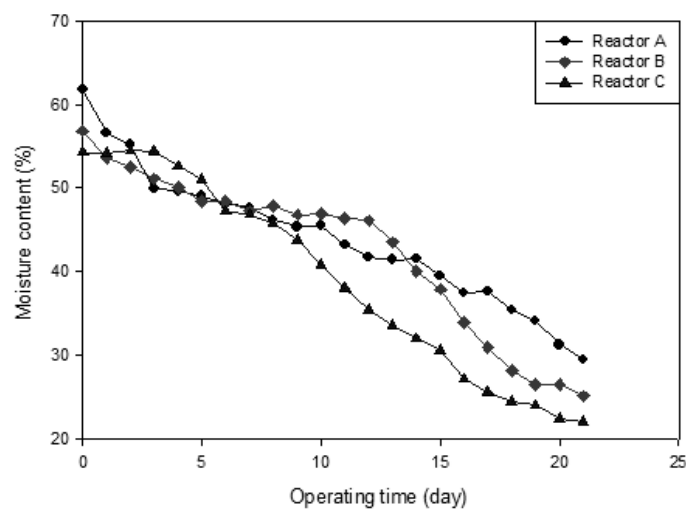
**Figure 2.** Temperature profile during biodrying process.

The rapid increase in temperature is an indication of microbiological degradation of organic matter and heat release from metabolic activity. This phase is called the warming-up phase, where in this experiment occurs on the 1st day until the 4th day. The depletion of temperature in each reactor might be caused by two factors. The first factor is caused by the high temperature formed causing the death of mesophile (15-35°C) microorganisms initially present in the sludge, thus forming a long lag phase for the microorganism enough to start its activity again. Another factor is the lack of biodegradable materials that lead to the death of microorganisms. Based on the temperature range generated in this experiment,

it can be seen that microorganisms that work during the biodrying process are mesophiles (active at 8-48°C) and thermophiles (active at 42-68 °C).

### 3.2. Loss of moisture content

The initial moisture content on reactor A was 61.8%. The moisture content decrease that occurred in reactor A was 32.4% where the final content moisture after process was 29.4%. Whereas in reactor B there was a moisture content decrease of 31.8% where the initial moisture content was 56.9% and the final content moisture was 25.1%. In reactor C, the initial moisture content is 54.3%. After biodrying process was done, the final moisture content was 22.0%, where in this reactor there was a decrease of moisture content of 32.3%.

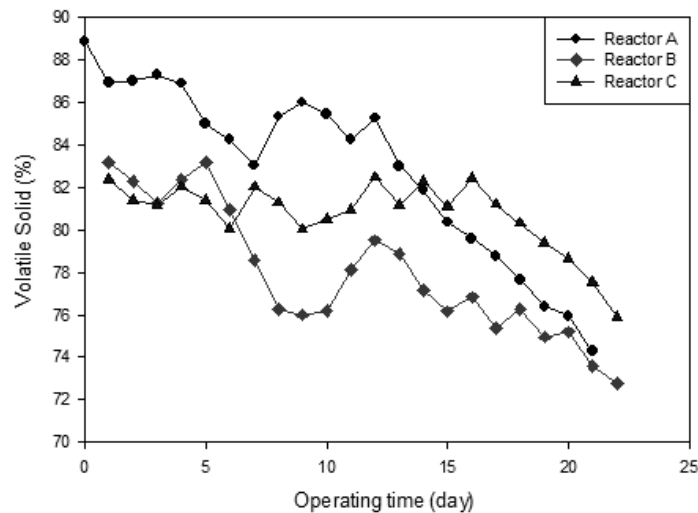


**Figure 3.** Change of moisture content in each feedstock during co-biodrying process.

Figure 3 shows the relationship between decreasing of moisture content and the operating time of the biodrying reactor. The higher the temperature formed during biodrying process, the greater value of the moisture content loss that occurs. High temperatures convert water to steam, increasing the water holding capacity of the air contained in the feedstock [2]. In biodrying process, the loss of water is greater than the addition of water from metabolic process resulting in a dry material [11], [12].

### 3.3. Volatile solid depletion

Volatile solid (VS) determines the number of biodegradable organic matter present in the material [15]. In Reactors A, B and C, the initial solid volatile percentage was 88.8%, 83.2%, and 82.4% respectively. After the biodrying process takes place, the percentage of VS in reactor A became 74.3%. So during the biodrying process there was decrease in VS by 14.6%. In reactor B there was a decrease of VS by 10.4%, where the final percentage of VS was 72.8%. While at reactor C, the final percentage of VS was 75.9%, where there was a decrease of VS by 6.4%.



**Figure 4.** Change of volatile solid content in each feedstock during co-biodrying process.

Based on Figure 4, the larger the sludge fraction added to solid waste, the greater the VS content of the feedstock. In the biodrying process, the less VS is degraded, the better the output is produced. This is because the purpose of the biodrying process is to reduce the biodegradation of VS in order to maintain the heating value of the waste [13], [14]. The decrease of VS in each reactor describes the amount of organic used by microorganisms during the metabolism process.

### 3.4. Calorific value

In the biodrying process, it is expected that the product has an optimal calorific value with low moisture content. The calorific value calculation is performed based on the following equation [15].

$$LCV = HCV / ((100\% / (100\% - \text{moisture content RDF})) \quad (1)$$

Based on the equation (1), we get the caloric value of feedstock for each reactor as follows.

**Table 3.** The calorific value of the feedstock in each reactor before and after biodrying process.

Sample	Before biodrying			After biodrying			$\Delta$ LCV (kcal/kg)
	HCV (kcal/kg)	Moisture (%)	LCV (kcal/kg)	HCV (kcal/kg)	Moisture (%)	LCV (kcal/kg)	
Reactor A	3956	61.81	1510.72	4087	29.40	2885.42	1374.70
Reactor B	4064	56.85	1753.45	4043	25.07	3029.24	1275.79
Reactor C	4164	54.25	1904.89	4076	21.99	3179.28	1274.39

Higher Calorific Value (HCV), is the upper heat value determined when the moisture content value of the material is equal to 0, while LCV (Lower Calorific Value) is the lower heat value determined when H<sub>2</sub>O in the material is on gas phase. LCV is the real calorific value of a material. Based on data obtained, there is an increase in LCV value from feedstock that has been bio-dried. The biodrying process increases the energy content of the material by maximizing the removal of moisture content and maintaining the calorific value (HCV) from organic matter by minimizing biodegradation [10].

## 4. Conclusion

The mixing of organic solid waste and sludge can improve the performance of biodrying process. In this study, Reactor C with mixing ratio of solid waste and sludge of 5:1 gave better results than other reactors.

The final moisture content of the feedstock from Reactor C was 22.0% with final volatile solid content was 75.9%. The final calorific value of the feedstock in Reactor C was 3179.28kcal/kg.

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