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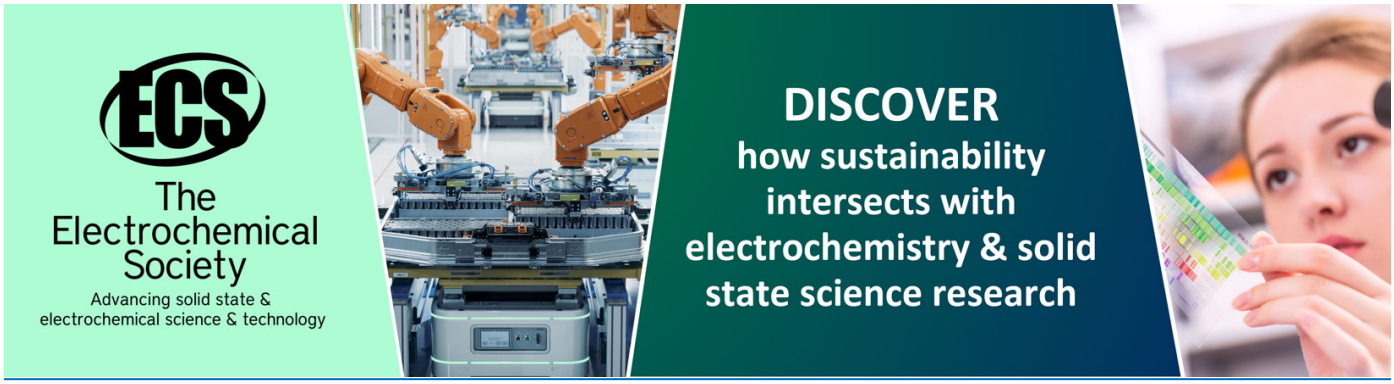

The development of five - level trays type biodryer reactor for processing of organic waste and vinasse mixture into solid recovered fuel

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Abstract. At Malang city, municipal solid waste (MSW) composition is mostly an organic waste that can utilize for Solid Recovered Fuel (SRF). Vinasse is a side product of the bioethanol industry, that mixed with MSW and dried by biodrying technique for solid fuel. The purpose of this research is to evaluate SRF characteristics of organic waste and vinasse mixture generate from biodrying. Research performed by drying the mixture of organic waste and vinasse at (0, 10, 20, 30, 40%) b/b ratio using biodrying reactor with five-level trays. This mixture inserted into the reactor tray, aerated at aeration flow rate 2 L/min from the compressor for nine days. The resulting SRF performed then characterized its moisture content, burning rate, and calorific value. The results showed that the biodryer reactor was successfully made with dimensions of 165 x 50 x 70 cm, consisting of five-level tray with a size of each level tray biodryer of 60 x 45 x 5 cm. The best SFR which has the highest heating value obtained from organic waste with vinasse 10%. It has a moisture content of 11.56%, the burning rate of 0.0135 g/sec, and calorific value of 3912.56 cal/g.

1. Introduction

MSW composition of cities in Indonesia is mostly organic waste (80%) [1]. The increasing amount of solid waste can cause environmental pollution problems. As a description in the year of 2012, Malang City generates MSW of 480 tons, while the current has risen to 600 tons every day [2]. Solid waste management mostly by piled on open land and only a small part (2%) used as compost. The open process of organic waste decomposition can contaminate the environment, producing gases (H_2S and CH_4) that cause a foul odour. It also produces leachate, which causes groundwater and surface water pollution [3].

The current organic waste technology consists of sanitary landfill, incineration, garbage briquette, bio-charcoal, biodrying, digestor anaerobic, and livestock feed pellets [3–5]. At Malang, utilization of organic solid waste processing products is mostly for compost. However, because the use of compost is still in small quantities, it is still required other MSW waste processing technology to maximize the amount of waste processed. One alternative method of processing waste environmentally friendly is biodrying because it can imposition the occurrence of leachate in organic waste. The biodrying product is stable dry garbage, and its can be used as solid fuel or SRF. The SRF already used in industrial areas, including power plants as co-firing fuel [6]. The prospective environmental benefits of using SRF as a fuel are enhanced carbon emissions [7], and decrease air pollutants owing to their low sulphur and nitrogen contents [8]. Biodrying (biological drying) is a biological and physical drying technique in the

processing of garbage in bioreactors. The process of organic material decomposition using microorganisms is an exothermic biochemical reaction that can raise the temperature of the material [4]. The biodrying method relies on the heat of the biological activity of microorganisms and supports aeration to reduce the moisture content from organic waste [5,9]. The method can reduce water content by 40% to less than 20% [10].

Vinasse, wastewater generated by the bioethanol industry, is made of molasses [11]. Vinasse such as organic waste can pollute the environment so it should be processed first before it is discarded or utilized. Vinasse contains more than 90% of the water, and the rest are dried ingredients containing dead yeast, unfermented carbohydrates, unconverted sugars and various inorganic compounds [12]. Vinasse still contains many microorganisms that can utilize as a bioactivator for the fermentation process [13]. Also, the net calorific value (NCV) Vinasse is still relatively high 7800 J/g so it can apply as fuel [14]. The addition, vinasse in an organic waste can accelerate the fermentation process that impacts the garbage pile temperature, thereby accelerating the evaporation of water. Similarly, the garbage pile can utilize as a bulking agent for drying vinasse. The Bulking agent serves to increase porosity to increase aeration efficiency [15].

Waste processing products are biodrying called SRF with biodrying moisture content less to 20%. The effectiveness of the biodrying process application depends on the equipment, operation and control condition of the process operation and the initial conditioning of the dried material [4]. Preliminary conducted research showing that the waste of food leftovers when dried has a heating value of about 3400 kcal/kg, which is sufficient when used as fuel [2]. The calorific value on fuel is affected by moisture content. In the complete combustion process, the moisture content should be lowered to about 10% so that the calorific value reaches approximately 11600 J/g. The condition achieves by proper drying method [4].

The tray-type biodryer reactor builds from a rectangular-shaped reactor that stands upright. On the inside, five pieces of trays installed serially. This form of design is advantageous as it can use for dry out the garbage mixture and the laid-down vinasse to facilitate the arrangement of aeration airflow with contact material. The purpose of this research is to create biodrying reactor with a five-level tray reactor and evaluate the characteristics of moisture content, calorific value and burning rate from SRF generated from organic waste processing biodrying with a variation of the ratio of vinasse as substrate processing organic waste.

2. Material and methods

2.1. Materials

Organic waste consists of a mixture of leftover vegetables and food then added vinasse by (0, 10, 20, 30, 40%) b/b ratio. Two kg mixture of organic garbage and vinasse, is filled in each tray than dried for nine days using reactor biodrying with aeration flow rate 2L/min. The drying result using five-level biodrying reactor SRF, were analyzed for moisture, burning rate and the calorific value.

2.2. Apparatus

Biodrying Reactor consisting of five-level tray biodryer, bomb calorimeter merk PAAR 1241 EF, oven, and analytical balance.

2.3. Solid recovered fuel analysis procedure

2.3.1. Moisture content analysis

Moisture content determined using gravimetry method. Water content analyzed by weighing 1 g of samples in the porcelain cup then heated in an oven with a temperature of 110°C to a constant weight. Moisture content determined by the formula:

Moisture content (%) = $\frac{m2}{m1} \times 100$; with m1 = mass of samples (g); m2 = mass of samples after heated

2.3.2. Analysis of burning rate

Burning rate (g/sec) reported in the form of an SRF mass burned/combustion time. A total of 10 g of SRF weighed, then burned. The burning time and the remaining mass of combustion recorded. The burned SRF mass calculated based on the initial mass minus combustion mass. Besides, the flame burning colour observed.

2.3.3. Analysis of the calorific value

A total of 1 g of SRF weighed in order to get an accepted temperature rise of 2 litres of water in the oxygen bomb jacket (30-40 atm) for calorimetry measurements at the ambient temperature of 25°C.

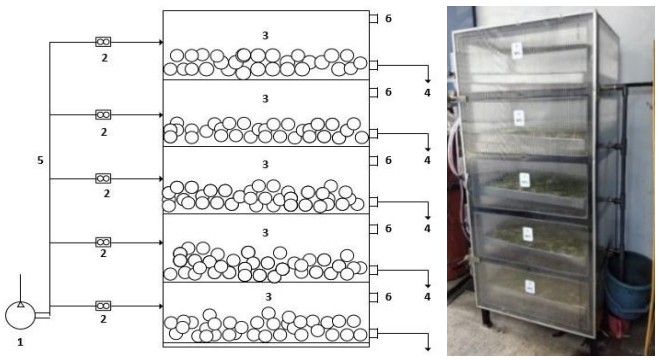
3. Results and discussion

Biodrying is a drying technique assist with aeration that relies on the biological activity of microorganisms to reduce moisture content in organic waste, aims to eliminate as much water content in a short time compared to drying naturally. Organic takes a relatively long time in the process of achieving a dry condition of natural about 30-50 days with regular composting [10]. The biodrying process lasts between two to three weeks [9]. This research, the duration of the proses biodrying was faster for nine days with the addition of vinasse because, on vinasse, may contain microorganisms that can act as a bioactivator [14].

Bioactivator assists the fermentation process of organic waste that can increase the temperature of organic waste due to decomposition of simple organic compounds such as amino acids, glucose and organic acids that produce heat because of its exothermic reaction. A mixture of organic waste and vinasse can be dried successful by biodrying method in tray type reactor. The reactor can be used to dry organic waste and vinasse simultaneously. Vinasse can serve as a bioactivator and organic waste as a bulking agent while the bioreactor type tray increases the effectiveness of aeration. The combination of the fermentation process and the presence of aeration airflow caused the garbage drying process.

3.1. Specification of biodryer reactor

The Biodryer Reactor was successfully made with dimensions of 165 x 50 x 70 cm consisting of five trays with a size of each tray of 60 x 45 x 5 cm (Figure 1 B). The Biodyer reactor is connected with the compressor to supply aeration air. The Biodryer reactor is equipped with a flow meter to regulate air flow rate, inlet air tube, outlet air tube, leachate output pipe, five-level iron frame, and five biodryer reactor Racks (Figure 1 A).



A **B**

Figure 1. Biodryer reactor: **a**. biodryer reactor design scheme (1. Compressor, 2. Flowmeter, 3. Mix organic waste and vinasse, 4. leachate output pipe, 5. inlet air tube, 6. outlet air tube); **b**. Biodryer reactor with consisting of five-level tray Biodryer.

3.2. Moisture content

In this study, the biodrying process for nine days of organic waste with the addition of vinasse produces solid recovered fuel (SRF) with a moisture content of between 9.80 to 36.44% as shown in Figure 2.

This is appropriate because of the biodrying method capable of lowering the moisture content between 40 to ≤ 20% [11]. The higher addition of vinasse used in biodrying, the higher the moisture content of SRF. The most optimal addition of vinasse is at a ratio of 10%. But the moisture content in the SFR (11.65%) higher than that without the addition of vinasse (9.80%). This is because vinasse is a liquid waste that has high water content [12].

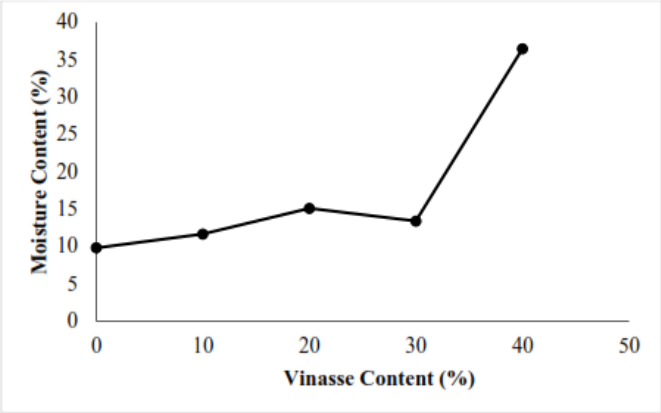


Figure 2. Moisture content of SRF with various vinasse content in biodrying process.

3.3. Burning rate

The rate of combustion is a measure of the energy released by combustion of fuel per unit time per area expressed in kilowatts per square meter [16]. In this study, the burning rate was determined by dividing the SRF burned mass and combustion time and is expressed in mass / time. The burning on SRF shown in figure 3.

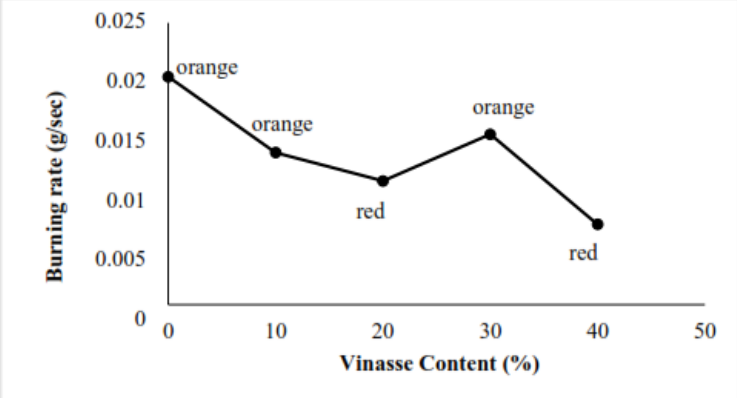


Figure 3. Burning rate of SRF with various vinasse content in biodrying process.

Generated SRF has a value of burning rate between 0. 0071 to 0. 0202 g/sec. The smallest burning rate value is in SRF generated from vinasse 40% with a red flame colour. The largest burning rate value is in SRF without vinasse addition. SRF generates from vinasse 10% has an orange coloured flame having a burning rate value slightly smaller (0.0135 g/sec) than the SRF without the addition of a vinasse (0.0202 g/sec) with an orange flame. The greater the burning rate, the greater the energy released during combustion, as well as the greater the caloric value of SRF.

3.4. Calorific value

Calorific value is the most important parameter to the fuel. Calorific value on SRF resulted from organic waste processing in the biodrying method with variations in the addition of the vinasse ratio shown in figure 4.

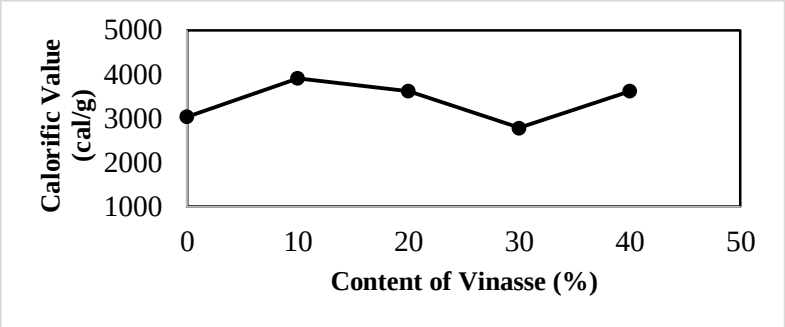


Figure 4. The calorific value of SRF with various vinasse content in biodrying process.

SRF generated has the calorific value between 2783. 43 to 3912. 56 cal/g. The largest calorific value is on SRF generate from vinasse 10%, and the smallest calorific value is on SRF generate from vinasse 30%. The vinasse addition can increase SRF caloric value, due its high caloric value (10-15 MJ / kg on a dry basis) [17]. However the greater the ratio of vinasse increases water content of organic waste, which can reduce the caloric value of the SRF. Thus, the optimum vinasse ratio in organic waste processing biodrying is 10% with SRF calorific value of 3912.56 cal/g or 16.37 MJ/Kg. The calorific value derived from bituminous coal is 26-28 MJ/Kg [18,19], and SRF class 3 calorific value based on the European Committee for Standardization, 2011 is > 15 KJ/Kg, indicate that the generated SRF is very potential to be used as a solid fuel.

4. Conclusion

The Biodryer Reactor was successfully made with five-level tray biodryer. SRF resulting from the processing of organic waste in biodrying method with variations added to the ratio of vinasse. The best SRF which has the highest heating value obtained from organic waste with vinasse 10%. It has a moisture content of 11.56%, the burning rate of 0.0135 g/sec, and heating value of 3912.56 cal/gram.

Acknowledgments

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