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Significance of Biodrying Reactor Design to Organic Waste Treatment as Energy Source: A Case of Banana Peel Waste

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ABSTRACT : *Banana peel waste is one of typical organic waste that causes various environmental issues and social problems faced by developing nations. Waste-to-energy technology is one of promising solution to reduce the bulk volume of waste in addition to the refuse derived fuel production applications. However, due to high moisture content of banana skin waste, direct application of either thermal or thermo-chemical waste-to-energy technologies is challenging. Therefore, a proper technology handling is required to tackle the issue. In this scenario, biodrying is found effectively reduce the high moisture content of waste as well as increase its energy value. Biodrying is a convective evaporation process, which utilizes the biological heat developed from the aerobic reactions of organic components. The study investigated the treatment of banana peel waste with high moisture content using two different biodrying reactors design. The research work was performed in three set of experiments: a) open reactor without leachate feed, b) open reactor with leachate feed, and c) closed reactor without leachate feed. The aeration used in the tests was also varied at three different flow rate, 0.7liter/min, 1.5liter/min and 3 liter/min with aiming to compare and evaluate the effects of aeration flow on final moisture content and heating value of dried waste as well as temperature of process and volume of generated leachate in each reactor design.*
KEYWORDS *biodrying, banana peel waste, waste-to- energy, aeration flow, dryer design.*

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I. INTRODUCTION

The rising trend of energy consumption has become a common issue along with a growing world population and economy growth. In Indonesia, energy consumption in transportation, industrial and household sectors were increasing with annual rate of 5,4% [1], while the diminishing national energy reserves has create another concern of energy crises for the future since new source of energy was nowhere to be found. Banana, a tropical fruit, is widely cultivated over 130 worldwide [2]. Higher production of this fruit has made the banana to be commonly found in any modern and traditional market. Banana can be consumed in the fresh form and 80% of ripe banana is processed and is ingredient in many types of food such as baby food, banana streamed pastry, deep fried banana, sun-dried banana, sweet banana crisp, and banana stirs [2]. In general, banana peel was abandoned as a solid waste. Consequently, a significant amount of banana peels waste is rising annually. When the peel was decomposed, it produces noxious gases such as hydrogen sulphide and ammonia. In this scenario, switching the peel waste as renewable energy sources will definitely solve the problem in the sustainable way. This peel waste shows a great potential as a lead material for alternative energy resource. However, potentiality of banana peel utilization largely depends on the favorable drying condition of the material before it can be used for further processing. Therefore, it is necessary to identify the suitable drying conditions for banana peel.

Biodrying is one of the mechanical-biological bioconversion alternatives to process solid waste. In its practice, biodrying reactor would process small-sized trash with high water content and produce dry waste output or Refuse Derived Fuel (RDF) that would be mechanically processed further. Heat produced from the aerobic decomposition of organic matters combined with airflow would dry out the trash [3]. As outlined in [4], biodrying has raised the calorific value of organic solid waste. The study used the various aeration flow to find the best operation condition to dry the waste. However, the study did not investigate the effect of adding leachate as feed in the initial raw material and the heating value of final product was also not identified.

Therefore, in this work, the study investigated the effect of aeration flow and leachate feed toward water content and calorific value of dried peels product as well as temperature of process and number of discharged leachate in both open and closed biodrying reactor.

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II. MATERIALS AND METHODS

2.1 Banana peel

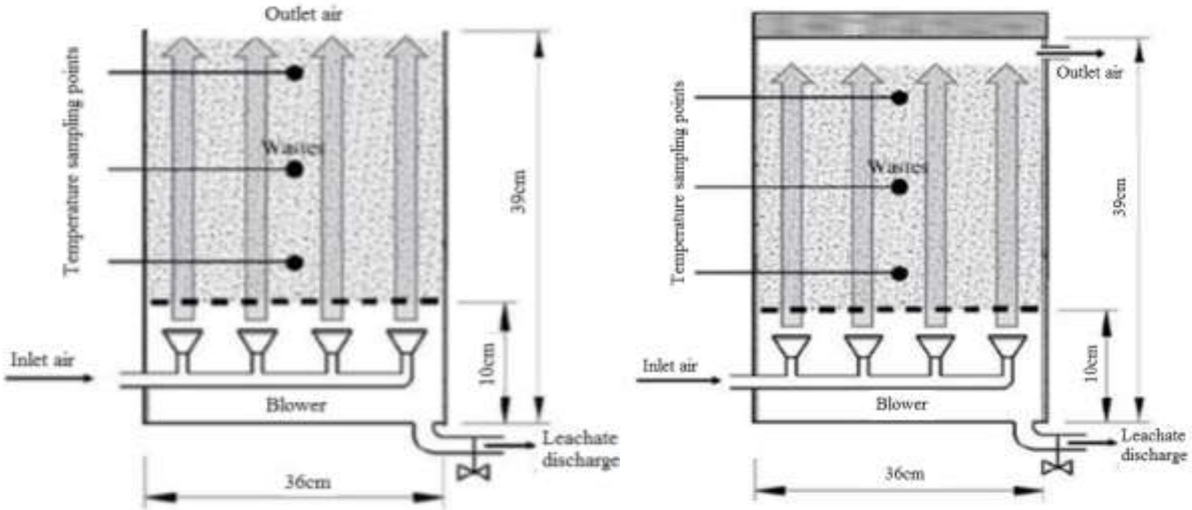
Fresh banana peels were collected from a local home industry of banana chips located in Lumajang Regency, East Java, Indonesia. The peels was initially chopped into small pieces of 2-5cm and then the initial moisture content and energy value were analyzed (Table 1) before used. The amount of peels waste used in each one-batch experiment was 1kg.

Table 1. Initial moisture content and heating value of banana peels

Parameter	Value
Initial moisture content (%)	89,75
Heating value (Cal/gr)	163.76

2.2 Experimental apparatus

The schematic representation of the reactors used in the experiments is shown in Fig. 1. The reactors were designed at laboratory scale with capacity of 1kg. It consists of a vertical cylindrical shell with a height of 39cm and a diameter of 36cm. The reactors consist of 3 points of temperature product sampling. The process airflow in test was varied at 0.7liter/min, 1.5liter/min and 3liter/min throughout the experiment period for 3 sets experiment design: a) open reactor without leachate feed, b) open reactor with leachate feed, and c) closed reactor without leachate feed.



(a) Open reactor (b) Closed reactor

Fig.1. Biodrying reactors design

2.3 Drying procedure

After the dryer reached steady state conditions (i.e. when desired set up operation was reached) the chopped banana peels were distributed onto the reactor. Temperature change and volume of generated leachate were recorded every day during drying process test. The drying experiment was carried out until the leachate was no longer reformed or until the moisture content of the sample reached to the equilibrium moisture content about 13-15% (wb). The drying was continued until weight became constant and experiments were conducted in duplicates. The moisture content and heating value of final dried product were determined after the drying process.

2.4 Data analysis

Analysis and data collection was carried out every day until the drying process finished. The heating value was identified using bomb calorimeter before and after process. Whilst, analysis of water content was determined using gravimetric method. The determination of the water content is defined with the following equation:

$$\text{Water content (\%)} = \frac{(w1 - w2)}{w1} \times 100\% \quad (1)$$

Where:

W1 - Wet waste mass
W2 - Dry waste mass

III. RESULTS AND DISCUSSION

3.1 Temperature of biodrying process

Temperature profiles for different drying treatments are illustrated in Fig. 2. Initial drying process was about 22^{o}C. Temperature of banana peels waste was different due to aeration flow changes. In general, the temperature profiles for all treatments condition were relatively similar. Under the treatment of without using leachate in the initial raw material, the temperature rapidly increased to a maximum of 35^{o}C and 45^{o}C in open reactor and closed reactor respectively, and dropped sharply to around 25^{o}C after 8th day and finally to about 22^{o}C after two weeks. Similarly, under condition of leachate fed in the initial peels waste and using open reactor, the temperature also reached a peak of around 36^{o}C in the first five days and dropped to between 25^{o}C to 29^{o}C after 8th day and eventually to about 22^{o}C during the last day of two weeks drying process. This trend resembles to an earlier three-stage composting cycle reported in [5]. Furthermore, large temperature differences in airflow of 0,7L/min, 1,5L/min, and 3L/min was due to high microbial activity. All results reaffirm the study [6] that the lower aeration flow, the higher temperature of drying process.

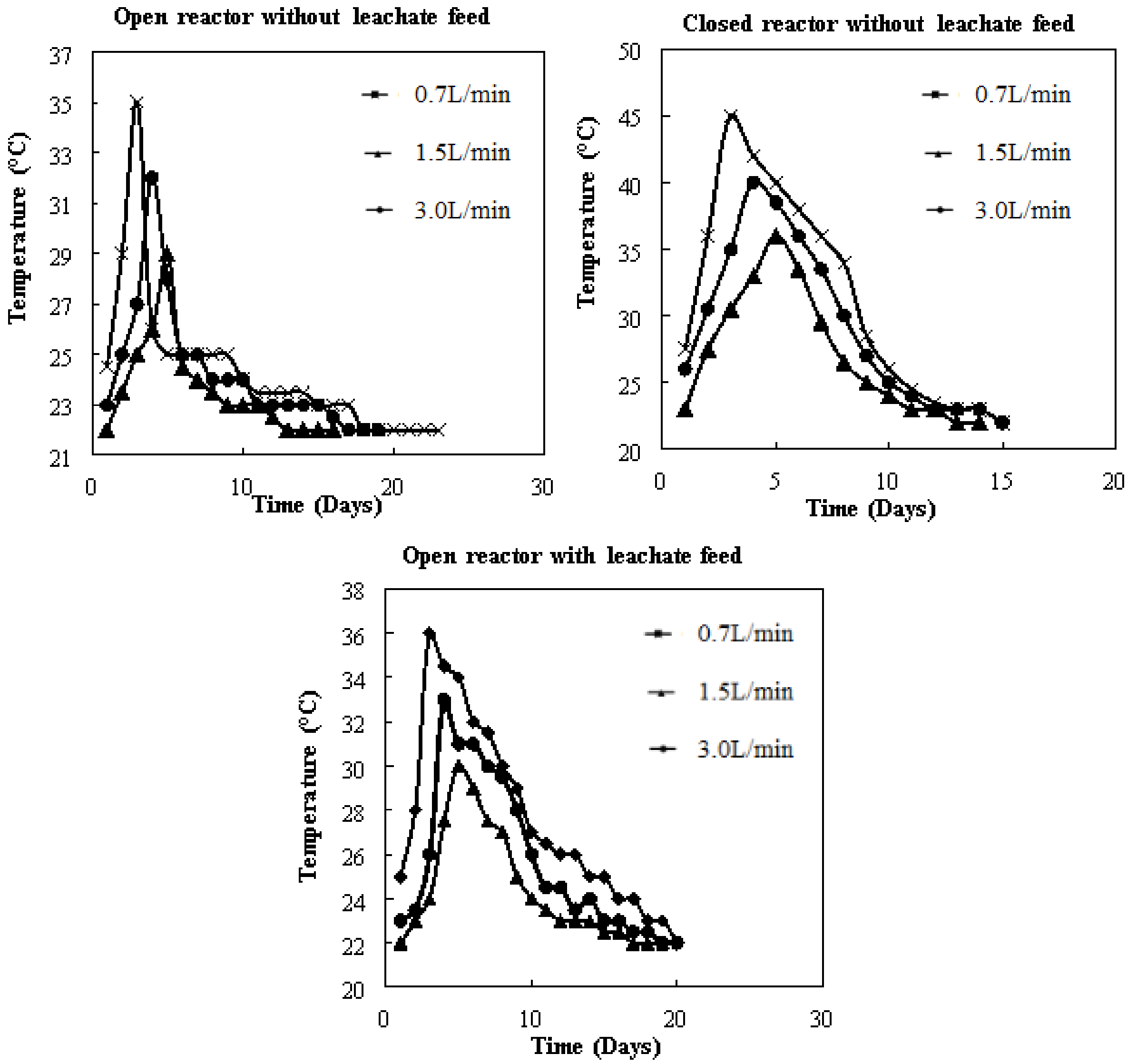


Fig. 2. The effect of aeration flow toward process temperature

Nevertheless, it is interesting to note that the peak temperature under closed reactor was the highest compare to other treatments. The temperature changes also declined gradually and slower compared to open reactor. This profile confirms that reactor lid can act as insulator that able to reduce heat loss in the reactor [7].

Moreover, the using of leachate fed in the initial waste of this reactor also increased the microbial activity and subsequently raised the process temperature.

3.2 Volume of generated leachate

Generally, as presented in Fig. 3 volume of leachate generated during the drying had enlarged at the first 3 to 4 days of process and decreased in further days. Three reactors have different peak of leachate production. In the treatment of without using leachate in the initial waste, the discharged leachate produced in open reactor reached a peak of about 110ml and diminished rapidly to around 30ml after 6th day and finally no longer or small amount of leachate generated after 13th - 20th day. Similarly, with the same treatment by using closed reactor the volume of generated leachate reached slightly lower at a maximum of 105ml at the first 4 days and dropped in the remaining days until two weeks of drying process.

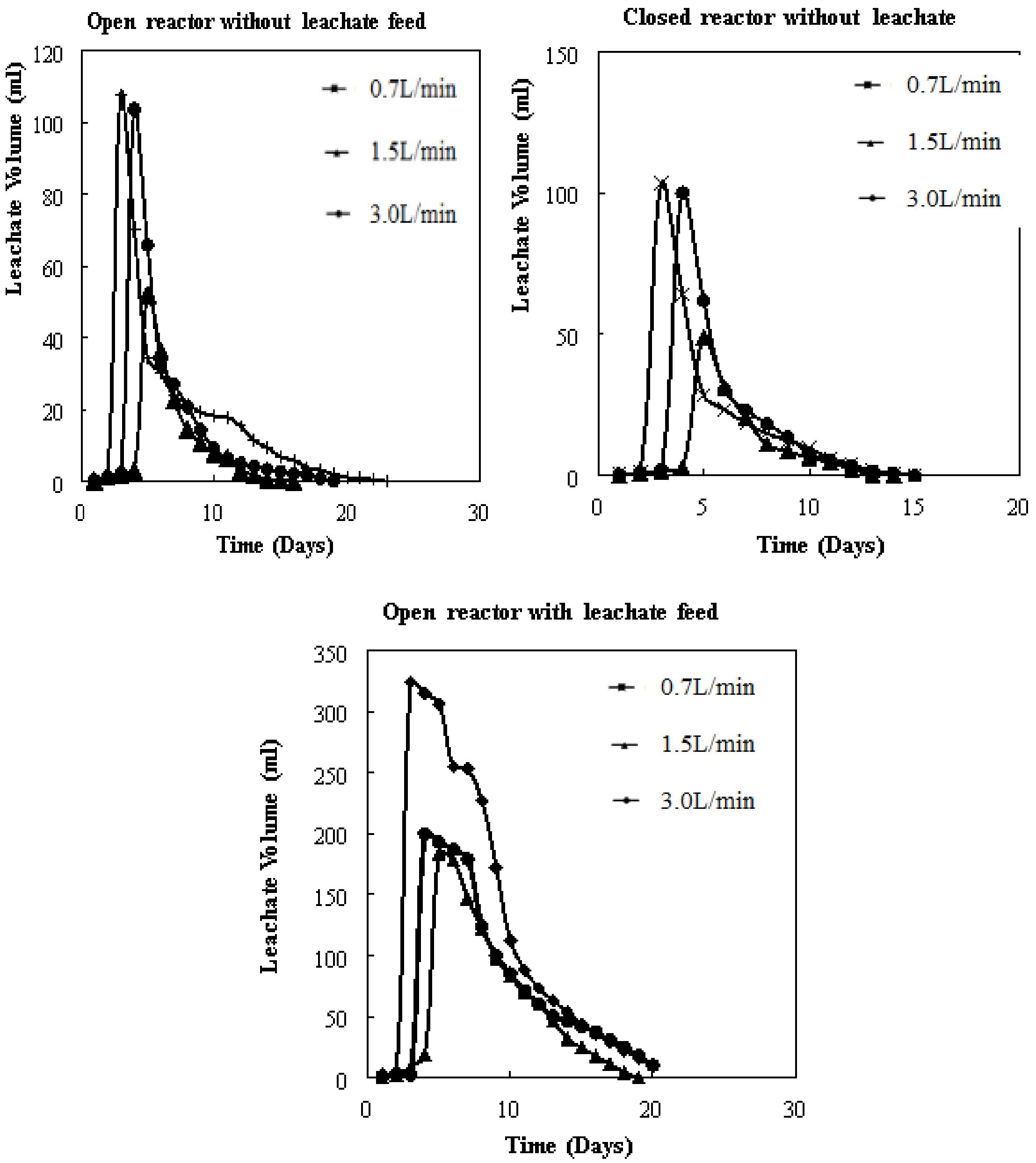


Figure 3. The effect of aeration flow toward volume of leachate

In contrast, it is found different performance in open reactor under the treatment of leachate fed in the initial raw material. The number of leachate produced during first 3 days of drying touched a peak of about three times of the other test, it accounted to about 330ml and then declined gradually in the further days. This profile confirm that the reactor lid affects the number of generated leachate. This trend resembles with the temperature profile, where the reactor lid reduced the heat loss and caused the temperature of process remained high at the certain time, and finally caused the temperature decreased slowly. Moreover, the effect of lower aeration flow was also found highly significant to leachate production as compared to higher flow rate. The higher temperature of process, the higher microorganism activity, and resulted in big volume of leachate production.

3.3 Moisture content and heating value

The identified final moisture content and heating value of obtained biodrying product is presented in Table 2. It can be seen in all three sets experiment design that the effect of aeration flow toward moisture reduction and calorific value profile in this research work are contrary to the temperature and leachate profile. As mentioned in point 3.1 and 3.2 that the temperature and leachate profile were higher at the lower aeration flow. However, in this case the higher aeration flow the better final product obtained i.e. low final moisture content and high calorific value. This might be due to high water content in its raw material has made the heat of biodegradation was not enough to evaporate the water, since initial water content in biodrying should be in the range of 55% and 70% [8]. Therefore, with large amount of aeration flow, organic matter would be able to evaporate better and cannot relying only due to heat of biodegradation.

Among the experiment tests, the using of open reactor and leachate fed in initial waste gave the best moisture content and heating value, which accounted to about 12.53% and 4588.18Cal/gr respectively at the highest aeration flow of 3L/min. Moreover, the using of lower aeration flow in this reactor still has better results compared to the both open reactor and closed reactor without leachate as feed in the raw material. Therefore, the idea of adding leachate in the initial waste contribute to the better results of obtained final product.

Table 2. Mean value of water content and heating value of biodrying product in each reactor

Type of Reactor	Aeration Flow (L/min)	Water Content (%)	Heating Value (Cal/gr)
Open Reactor without Leachate Feed	0.7	42.82	1321.60
	1,5	32,82	1868,63
	3	23.62	2031.57
Closed Reactor without Leachate Feed	0.7	23.1	2041.88
	1,5	19,44	2319,83
	3	16.31	2423.98
Open Reactor with Leachate Feed	0.7	22.10	2241.22
	1,5	17,84	3243,93
	3	12.53	4588.18

IV. CONCLUSION

Biodrying of banana peels waste was investigated in three sets of experiment design under various aeration flow in each test: a) open reactor without leachate feed, b) open reactor with leachate feed, and c) closed reactor without leachate feed. The study purposes to analyses and identified the best suitable treatment for drying of banana peels waste. The results show that the using of open reactor and adding leachate as feed in the initial raw material waste. Moreover, even though the higher aeration flow resulted in bad temperature and leachate production profile, the authors recommend using the higher flow rate instead of lower aeration since it gives the better result of final dried product i.e. low moisture content and high calorific value. Therefore, the utilization of banana peels waste using biodrying process will not only reduce and solve environmental issue but also can be a potential source of renewable energy. For future research point of view, the investigation of secondary impact and feasibility study in real practice of this technology need to be investigated to avoid another ecological issues and social problem.

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