Effect of Airflow on Bio-drying process in Municipal Solid Waste for Biomass Storage

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ABSTRACT

This paper proposes an effect of airflow on bio-drying process of municipal solid waste (MSW). Properties of MSW are considered as the moisture content and optimal airflow for bio-drying process. The organic MSW is an alternative way to recycle and transform the organic solid waste into energy. The objective is to determine the bio-drying properties in forms of air-flow rate for the organic MSW in order to decrease the humidity and to determine the optimal air flow rate for bio-drying that can be brought to reduce the humidity before storing in the warehouse. This paper presents an air-flow model of organic MSW for bio-drying that is suitable for the amount of organic solid waste decreased the humidity of the organic waste. Organic MSW is the household food waste for turning the food waste to energy in forms of biomass. 200-Litre Plastic barrel drum is used for experimental model with the different weight of MSW mass between 5 to 50 kg in the closed system. Experiments are performed at the air-flow volume and the different weight of organic solid waste. Empirical results show that the air-flow rate is proportional to the air inlet volume, which if the mass of organic solid waste increases, temperature and humidity will increase. It found that 30 kg of organic solid waste mass and 60% volume of plastic barrel drum with the air-flow rate of 24.39 m^3/kg/hr or 430.67 CFM per 30 kg of MSW mass can achieve the lowest humidity at 11.8%.

Keywords: *Organic Municipal Solid Waste; Biodry; Air Flow rate; Biomass storage*

1. INTRODUCTION

This paper is an extension of work originally presented in the Conference on Application Research and Development (ECTI-CARD) [1], which has been presented the study of bio-drying process on municipal solid waste properties. Recently, the community is expanding rapidly both in terms of population, housing as well as the increase of the population in urban areas, which is causing the number of solid waste to increase dramatically.

Municipal solid waste (MSW) is known as trash or waste collected from the residential, industrial, commercial and construction waste, which consists mainly of paper, cloth material, yard waste including leaves and branches, food wastes, plastics, a piece of leather, rubber, metals, glass, ceramic, and miscellaneous other materials [2]. Consequently, the waste management will become an important future issue arising in the main cities and metropolitan areas [3]. Therefore, there are many methods to recycle solid waste to a fuel for sustainable alternative energy [4].

In [5] – [6], the pyrolysis procedure is a heat treatment process that causes the anaerobic thermal decomposition of materials using the microwave to reduce the moisture content of the material, where the microwave is a form of high frequency radio signal operating at 2.4 GHz. Food waste collected from communities in China and Spain found that waste samples with different moisture content were taken the different pyrolysis processes time in the range of 70-88% by volume. It is found that the waste samples with different moisture content has consumed more energy in the pyrolysis process.

Bio-drying is a drying process that uses the decomposition of aerobic microorganisms such as bacteria and fungi, which consists of the reducing moisture content in order to obtain a useful output product, such as a biomass fuel [7]. The biomass content of processed waste contains carbon, nitrogen and other substances. From thermal decomposition, carbon dioxide (CO_2) and water (H_2O) are generated by heat in the decomposition process that can help to reduce indirectly the moisture content of the waste [8].

There are many works concerned the MSW with bio-drying process [9] – [13]. Bio-drying process has been selected for treatment of municipal solid waste with high moisture content in terms of sustainable technology [9]. In [10], the authors have presented the dynamics of organic substances during co-bio-drying of sewage sludge and kitchen waste from residential areas. In [11], performance of bio-drying process has been tested in the temperature profile of solid waste. Performance of MSW under the conditions of Greenhouse and non-greenhouse in the reactor have been presented in [12]. Evaluation of the bio-drying process using rotating drum for bio-drying rotary drum of MSW has been proposed in [13].

In this paper, the objective is to determine the bio-drying or air-drying properties of organic waste from municipal solid waste (MSW) as the pre-treatment biomass storage. We aim to determine the optimum air-flow rate for air-drying process to reduce the moisture content of MSW before storing in the warehouse that is suitable for the amount of MSW that decreases the humidity in the organic waste.

2. MUNICIPAL SOLID WASTE

Solid waste is the multi-component materials, or Heterogeneous materials which have a variety of chemical properties. The main sources of solid waste come from residential, industrial and commercial waste [14-15]. Solid waste consists of an organic waste and an inorganic waste and physical composition of solid waste in forms of food waste and non-combustible waste.

Table 1 *Percentage of composition of different fraction in municipal solid waste (MSW) [16]*

Type of samples	Composition of MSW	% composition of MSW (in approx..)
1	Paper	7-10
2	Plastic	0.87-0.96
3	Metal	0.4-0.8
4	Glass	0.39-0.86
5	Organic materials	35.4-43.7

Table 2 *Analysis of MSW properties [16]*

Sample	Moisture content (wt %)*	Volatile content (wt %)	Ash content (wt %)	Carbon content (wt %)
MSW	4.64	**77.94**	**5.32**	**16.73**

*****Percentage by weight (wt %)

Table 3 *Average percentage of basic characteristics of food waste as MSW [17]*

Category	**%Carbon (C)**	**%Hydrogen (H)**	**%Nitrogen (N)**
MSW	50.5	7.1	2.1
	%Sulfur (S)	**%Oxygen (O)**	**Higher Heating Value (HHV) MJ kg^{-1}**
	0.2	**40.1**	**14.7**

***MJ kg^{-1}** = Mega Joules per kilogram

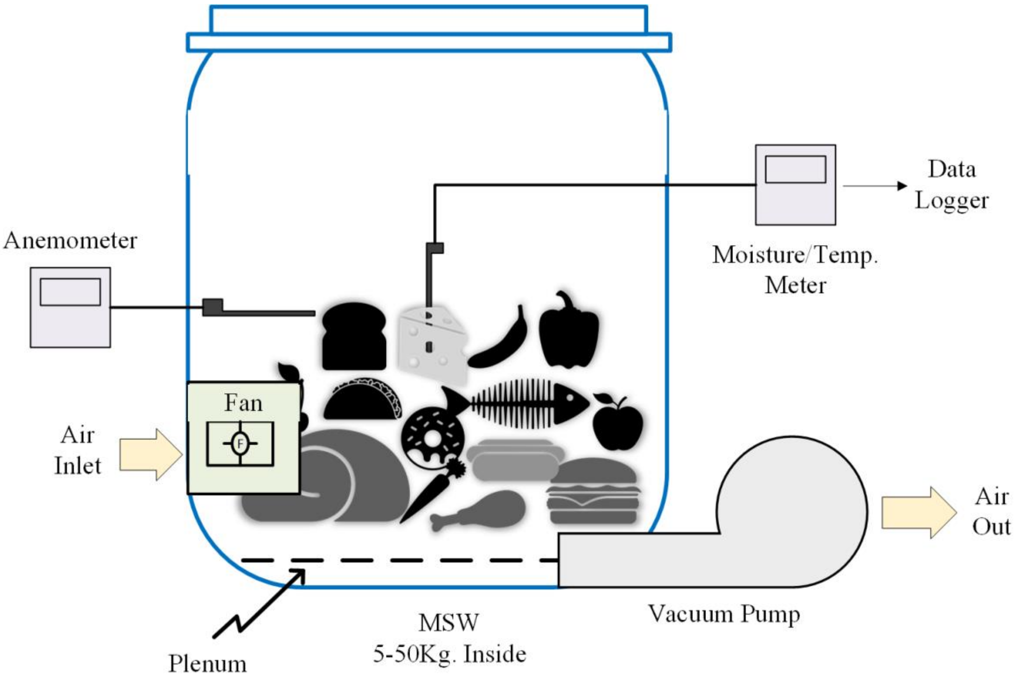

Fig. 1 *Proposed air-flow model of MSW in closed system*

An organic waste includes with the food waste as fruit and vegetable from household in natural products. An inorganic waste is in forms of plastics, foam, textiles, metal and non-metal parts, batteries and various glass shards [14]. Table 1 shows the percentage of composition of different fraction in MSW. It is seen that the organic materials are the main composition of MSW at 35.4-43.7 % approximately. In Table 2, the analysis of MSW properties consists of the moisture contents of 4.64 wt% and the carbon content of 16.73 wt%, which is suitable for biomass fuel.

According to the thermal characteristics, the higher heating value (HHV) is an important parameter for turning waste to energy plants [17]. Table 3 depicts the average percentage of basic characteristics of food waste as carbon (C), hydrogen (H), nitrogen (N), sulfur (S), oxygen (O_2) and higher heating value (HHV) which is interested in the biomass energy. As stated in [18], the authors have tested and confirmed that MSW is a sufficient energy resource for fuel. It is supported that MSW should be an alternative energy for future.

3. PROPOSED AIR-FLOW MODEL OF MSW

In this section, a model for the determination of optimal air flow rate for bio-drying process is proposed with the aim of optimal air-flow rate that can decrease the moisture content and temperature. Organic MSW is the household food waste for turning the food waste to energy in forms of biomass.

Fig. 2 *Installation outside 200-Litre plastic barrel drums*

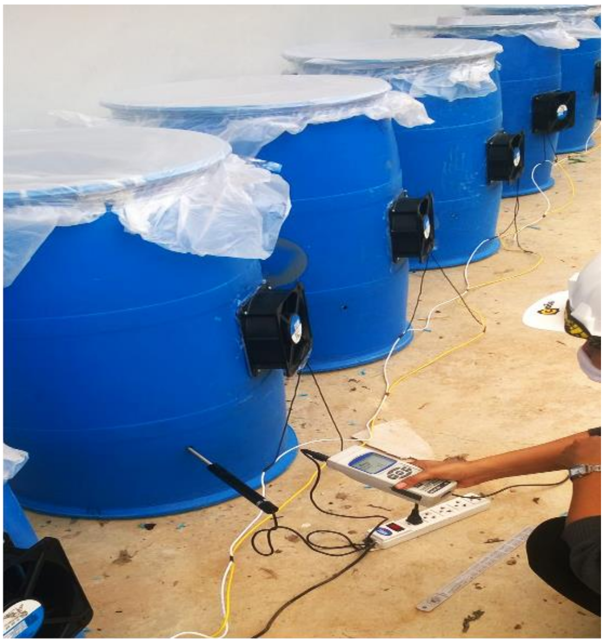

Fig. 3 *How to measure the characteristics of MSW outside the experimental plastic drum*

Table 3 *MSW volume and mass inside for each drum*

No. of drum	% MSW volume	MSW mass (kg)
1	10%	5
2	20%	10
3	30%	15
4	40%	20
5	50%	25
6	60%	30
7	70%	35
8	80%	40
9	90%	45
10	100%	50

3.1 AIR-FLOW MODEL OF MSW

The design of an air-flow model of MSW is presented in closed system shown in Fig. 1. Chamber is designed with a fan installed for air inlet from outside and a plenum placed on the bottom to flow out the air. A mass of MSW mass is placed on a plenum in the range of 5 to 50 kg per chamber. A vacuum pump is installed in air outlet. An anemometer and a moisture-temperature meter are used to measure the characteristic values of MSW stored inside the data logger.

3.2 EXPERIMENT INSTALLATION

The purpose of experiment installation is used the available commercial materials. 200-Litre plastic barrel drum is modified a proposed air-flow model of MSW in closed system shown in Fig. 2. A expanded metal square mesh is inside the drum on the brick block that MSW mass is placed on the mesh. There are 10-plastic barrel drums used for experiment with different MSW mass in the same size of drum. 4.5" 220VAC/0.14A fan is used as an air supply unit mounted on the side at the center of drum.

By assuming that the air is flown directly to MSW mass, a 5" circular hole is for ventilation and a plastic sheet is covered the drum as the closed system. The ventilation is used the principle of simple mechanical ventilation system extracts the air from the ventilated space with fan. All drums are placed to avoid the sun outside the building in the ventilated area as shown in Fig. 2.

3.3 EXPERIMENTAL SETUP

The experiments are determined the proportion of plastic barrel drum with a 200-Litre volume per the amount of MSW in the range of 5 to 50 kg used in Table 3. There are 10 drums installed a 220VAC/0.14A fan for each drum operating for 7 days, 24 hours a day. Fan is mounted at the center of drum. The airflow, temperature and humidity of MSW are measured in each drum every day at 9:00am in the morning. An anemometer and external temperature-humidity instruments are used and measured the MSW placed on the mesh in Fig. 3. The organic solid waste of MSW is selected from household waste such as fruit and vegetable.

4. EXPERIMENTAL RESULTS

The experimental results of temperature of MSW for each drum are on Day#1, Day#3, Day#5 and Day#7 compared with the temperature integration (TI) as shown in in Fig. 4. The average air-flow volume used in each experimental drum as shown in Fig. 5 and Fig. 6. The average percentage of moisture content and temperature of MSW are measured of experiment of each drum. It is noted that a fan of drum#10 is clearly malfunctioning.

4.1 TEMPERATURE DIFFERENCE

Temperature is an important parameter in bio-drying process that affects the bio-degradation and evaporation of water in MSW. The daily temperature change during the experiment can indicate the drying behavior in the system. The temperature difference in operating conditions can result in the heating moist of MSW and should affect the waste concerned with the ambient temperature inside the drum.

Table 4 *Percentage of average moisture content of MSW on Day#1 and Day#7 for each drum*

No. of drum	% Moisture Day#1	% Moisture Day#7	% Moisture reduced
1	30.45	27.90	2.55
2	38.95	28.30	10.65
3	38.35	27.60	10.75
4	34.80	28.80	6.00
5	37.45	28.50	8.95
6	41.70	29.90	11.8
7	41.65	34.20	7.45
8	32.50	32.40	0.10
9	39.40	35.80	3.60
10*	46.50	60.10	-13.60

***A fan is clearly malfunctioning.**

Table 5 *Average temperature content (Temp; °C) on Day#1 and Day#7 and temperature integration (TI) for each drum*

No. of drum	Temp. °C Day#1	Temp. °C Day#7	Temp. °C reduced	Temp. Int. (TI) °C
1	34.3	31.4	2.9	101.7
2	35.2	33.6	1.6	62.4
3	37.9	34.6	3.3	69
4	36.1	33.4	2.7	58.8
5	35.2	33.7	1.9	61.4
6	35.9	33.3	2.9	61.8
7	34.8	33.6	1.2	56.2
8	35.5	32.2	3.3	55.8
9	35.1	35.1	3.5	72.2
10*	35.8	-	-	-

***A fan is clearly malfunctioning.**

To distinguish the temperature differences between ten treatments, the temperature integration (TI) indicates the accumulated daily differences between the average temperature of MSW and the ambient temperature.

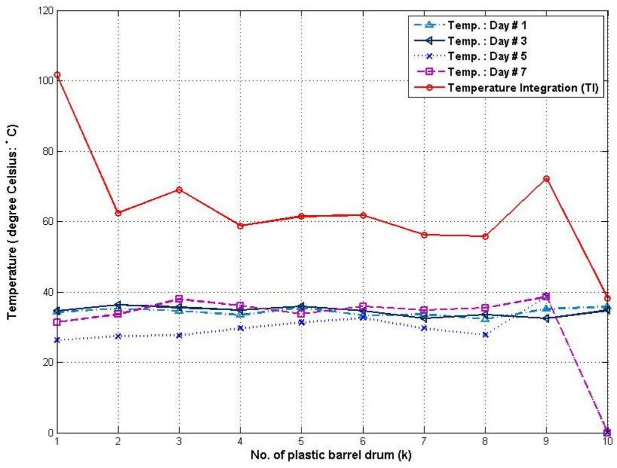

Fig. 4 *Temperature of MSW on Day#1, Day#3, Day#5 and Day#7 and TI for each drum*

Temperature integration (TI_k) at drum k in unit of degree Celsius (°C) is calculated as [12]

$$TI_k = \sum_{i=1}^{n} \left(T_{w_i} - T_{A_i}\right) \; ; \quad (1)$$

where T_{w_i} and T_{A_i} denote the average temperature of MSW and the ambient temperature on the experimental day i, respectively.

Table 4 shows that the average moisture of drum#2 with 10 kg MSW and drum#3 with 15 kg MSW are similarly at 10.65% and 10.75%, respectively. Meanwhile, Table 5 depicts that the temperature of drum#2 with 10 kg MSW and drum#3 with 15 kg MSW are similarly decreased at 1.6°C and 3.3°C, respectively. Temperature Integration (TI) of each drum is shown in Table 5. Fig. 4 shows the temperature in unit of degree Celsius of MSW on Day#1, Day#3, Day#5 and Day#7 and temperature integration for each drum.

Average Air Flow Rate (Avg AFR) per MSW mass in each drum for various units as cubic foot per minute (CFM; ft^3/min), cubic meter per minute (CMM; m^3/min), cubic meter per hour (m^3/hr) and cubic meter per kilogram per hour (m^3/kg/hr) are shown in Table 6. Fig. 5 and Fig. 6 show the air-flow rate of each drum in unit of cubic foot per minute (CFM; ft^3/min) and cubic foot per minute (CFM; ft^3/min), respectively.

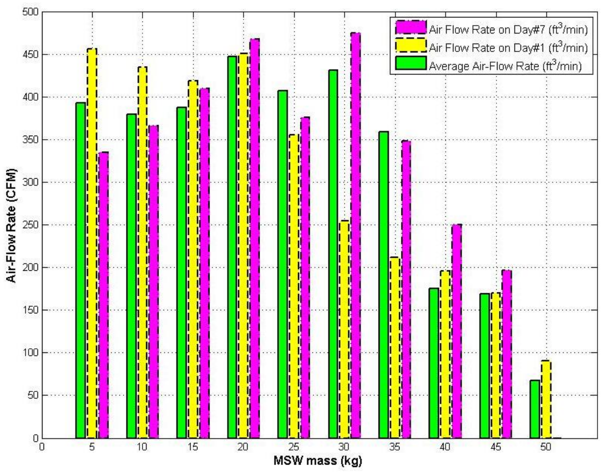

Fig. 5 *Air Flow Rate of each drum in unit of cubic foot per minute (CFM ; ft^3/min)*

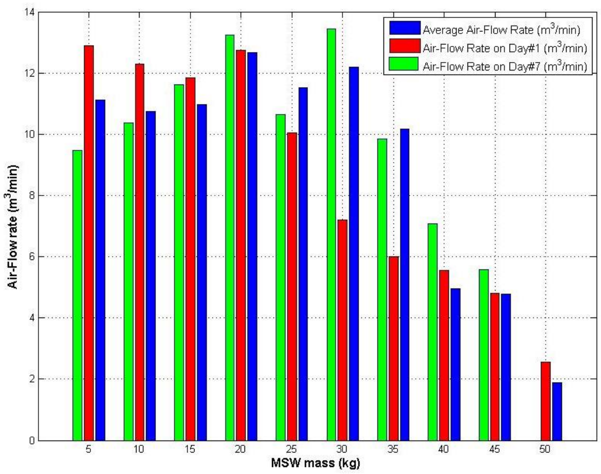

Fig. 6 *Air Flow Rate of each drum in unit of cubic meter per minute (CMM ; m^3/min)*

Table 6 *Average Air Flow Rate (Avg AFR) per MSW mass in each drum for various units*

No. of drum	MSW (kg)	Avg AFR (CFM)	Avg AFR (CMM)	Avg AFR (m3/hr)	Avg AFR per hr (m3/kg/hr)
1	5	392.71	11.12	667.22	133.44
2	10	379.53	10.75	644.83	64.48
3	15	387.35	10.97	658.11	43.87
4	20	446.95	12.66	759.38	37.97
5	25	406.98	11.52	691.46	27.66
6	30	430.67	12.20	731.71	24.39
7	35	358.90	10.16	609.77	17.42
8	40	174.75	4.95	296.90	7.42
9	45	168.59	4.77	286.43	6.37
10	50	66.88	1.89	113.63	2.27

6. CONCLUSION

This paper has presented an effect of air-flow on bio-drying model in municipal solid waste (MSW) that can reduce the moisture content for storage. It was found that the air-flow speed is directly proportional to the air-flow volume when the speed is higher. While, the amount of MSW mass increases, temperature and humidity content is higher. The experiments focus on the reduction of moisture and temperature, in different amounts of MSW contained in barrels.

Experiments are performed at the air-flow volume and the different weight of organic solid waste. Empirical results show that MSW mass and air-flow volume are considered. It is found that the air-flow rate for MSW mass on the sixth drum is suitable compared with the other drums. Model of the sixth drum consists of 30 kg mass with 60% of drum volume that is used an average air-flow volume of 430.67 CFM or 12.20 CMM per 30 kg of MSW mass, or 24.39 m3/kg/hr. The percentage of moisture and temperature reduced are of 11.8 % and 2.9%, respectively.

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