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COMPARATIVE STUDY OF WASTE MOISTURE CONTENT DRYING METHOD BETWEEN HOT AIR BLOWING METHOD AND BOILING METHOD IN A HEATED ROOM

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ABSTRACT

This waste problem can be used as new and renewable energy in the form of Refuse Derived Fuel (RDF) fuel. Due to its relation to energy, the calorific value of garbage becomes an important parameter. Water content is one of the important parameters that determine the calorific value. If the moisture content of the waste is high, then the energy needed for drying and destruction through combustion is also high, so a process of reducing the water content in the waste is needed. The drying mechanism is the most important part of the drying technique because by knowing the drying mechanism, it can be estimated the amount of energy and the need for the optimum air mass for drying. This study is to evaluate the needs of air masses, the amount of drying energy needed, then a comparison of drying calculations using the Relative Humidity dryer method through air media is heated by drying using the evaporation method through boiling by heating the walls of the drying room. The energy required in the Relative Humidity dryer method through a heated air medium is not only to heat the moisture content until it can evaporate but energy is also needed to heat the air from the initial temperature of heating the dryer air to the temperature out of the dryer. In addition, the amount of air needed to carry water vapor is very large. Based on the results of the discussion and calculations of each drying method to reduce the mass of water content in wet waste that has been carried out, it can be concluded that the drying method by evaporating the moisture content by heating the drying chamber is more efficient because it requires less energy than the method of blowing heated air.

Keywords*: Moisture Content; Drying; RDF*

1. INTRODUCTION

Depok City produces 1,321 tons of waste per day. However, only about 600 tons can be transported or served by the Depok City [1]. Cipayung Landfill (TPA) is one of the landfills in the city of Depok. The land owned by the Cipayung landfill has exceeded the capacity of the capacity. Even last year, waste at the Cipayung landfill had a landslide and the waste entered the Pesanggrahan River stream[2].

This waste problem can be used as new and renewable energy (EBT) in the form of *a waste to energy* (WET) concept. The concept *of waste to energy* (WET) is to utilize the energy contained in combustible solid waste in the form of *Refuse Derived Fuel* (RDF) fuel [3]. RDF is the result of the process of separating solid waste between flammable and non-combustible waste fractions such as materials made of metal or made of glass[4]. Due to its relation to energy, the calorific value of garbage becomes an important parameter.

Waste has an energy value varying between the calorific value of waste varying between 1000 - 2000 Kcal / kg and water content between 50 - 70 %[5]. Water content is one of the important parameters that determine the calorific value. A decrease in water content will increase the calorific value (Solikin & Batutah, 2019). If the water content of the waste is high, then the energy needed for drying and destruction through combustion is also high (Rosyadi et al., 2017), then a process of reducing the water content in the waste is needed.

Drying is the process of removing the water content on the surface of the material by the drying medium which is usually in the form of heat (Hatta et al., 2019). Drying occurs due to the process of evaporation of water into the environment because the energy in the environment is greater than the energy in the water, so that the energy in the environment will be absorbed by the

water. The absorption of this energy causes water molecules on the surface to move to break away from the pull of water molecules underneath, resulting in evaporation (Purwanti et al., 2018). The greater the temperature of the energy source, the faster evaporation occurs[9]. Then an energy source is needed to improve the process of removing the water content in the garbage. Boiler exhaust heat has a fairly high energy potential that can be reused for various processes (Solikin & Batutah, 2019).

Boiler is one of the components of steam turbines / steam power plants (PLTU) to evaporate filler water so as to produce *superheated steam* which will be used for turbine expansion to be able to produce electrical energy through electric generators[10]. The exhaust gas temperature of the boiler is still high enough to be utilized for several processes [11]. Utilization of boiler exhaust heat as a heat source can be used for the process of reducing water content in garbage to a certain extent[4].

The mechanism of drying water content can be done by the method of evaporation of moisture content through boiling by heating the environmental space[12], or using the method of reducing relative humidity usually using air media that is hot. Hot air is drained so that it comes into contact with the product to be dried. Hot air results in evaporation of water, then the hot air that flows will carry moisture from the dried product[13]. The drying mechanism is the most important part of the drying technique because by knowing the drying mechanism, it can be estimated the amount of energy and the need for the optimum air mass for drying.

Several studies have been conducted for drying utilizing the residual heat of the exhaust gases to lower the moisture content. [4] drying *bagasse with a* moisture content of around 49-52% as boiler fuel. The drying of bagasse through the use of exhaust gas in the boiler chimney can reduce the moisture content of bagasse by up to 35.1% from a moisture content of 51.2% to 16.1% with an evaporation rate of 1.476 kg /s. The heat required for bagasse drying is 5237.66 kJ/s. Bagasse had an initial burn value of 1771.6 kcal/kg and after drying it became 3456.4 kcal/kg, resulting in an increase in its combustion calorific value of 1684.8 kcal/kg.

[14] examines the mechanism of heat and mass transfer in the grain drying process using hot air as a heat conducting medium. The study sample was wet grain with an initial moisture content of 20.5% dried using a tub-shaped dryer (Batch dryer). The test used two variables, namely variable A is the temperature with 3 levels of 40 °C, 50 °C and 60 °C and variable B is the thickness of the pile with 3 levels of 5, 10, and 15 cm. The results of the study showed that the temperature treatment of 60ºC with a stack thickness of 5 cm resulted in an average decrease in the final grain content of 12.7%. The greater the thermal energy carried by the air, the greater the heat transfer rate, the higher the temperature and the length of the drying time, the greater the amount of liquid mass evaporated from the grain surface.

This study is to evaluate the needs of air masses, the amount of drying energy needed, then a comparison of drying calculations using the *Relative Humidity* method through the heated air medium and drying using the evaporation method through boiling by heating the walls of the drying chamber utilizing the exhaust heat energy from the boiler.

2. RESEARCH METHODOLOGY

In this study, wet waste drying will be carried out by comparing the waste drying method between the heated air media drying method and the drying room wall heating method. The weight of the initial wet waste (MA) will be assumed to be 100 kg with a percentage of the initial water content (MCA) of 80% and the target final product content (MCT) of 10%. From the data will be determined the mass of the evaporated water content.

The relative humidity method drying system utilizes a heated air medium, then the hot air is exhaled on the garbage to be dried so that it will bring moisture from the wet waste. The heat source for heating the air will take advantage of the residual heat of the discharge from the boiler.

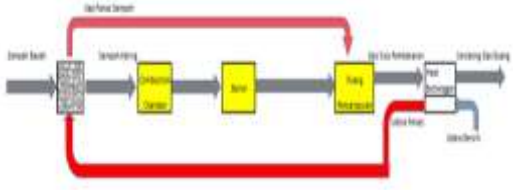


Figure 1. Scheme of Dryer System Method A

The mechanism of drying relatively humidity by the method of heated air occurs due to the difference in water vapor pressure and temperature between the product and the air blown. So that the moisture content contained in the garbage product will evaporate and will be carried by the blown air. The air that comes out after the drying process consists of hot air and moisture. To make it easier to determine the value of the psychrometric property, it is now facilitated by the existence of the property value calculation software. One of them can use the Psychrometric Calculations software from The Sugar Engineers. For the calculation of the property values of dry-bulb temperature, wet-bulb temperature, Relative humidity, Enthalpy, Humidity Ratio, and Specific Volume on drying water content with this heated air blowing method using the Psychrometric Calculations software from The Sugar Engineers.

The drying system of the evaporation method through boiling will evaporate the water content on the surface of the garbage. Evaporation of water content occurs due to the process of thermal displacement from the walls of the drying chamber heated by steam media. To find out the enthalpy value in the steam temperature range, you can use the Steam Table to present the relationship between the thermodynamic properties of steam. Currently, software is available to determine thermodynamic properties with inputs based on pressure or temperature properties of steam or steam. In this study, we will use "X Steam Tables" by Magnus Holmgren in the form of Excel Macro software to determine the value of the thermodynamic property of steam. The software refers to the Industrial Formulation standard IAPWS-IF97.

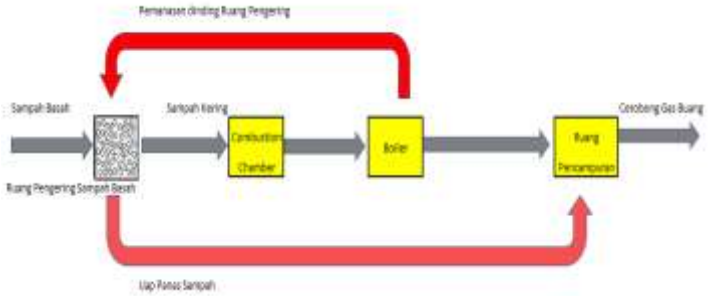


Figure 2 Scheme of Dryer System Method B

The thermal transfer from the hot wall in the drying chamber to the wet garbage will increase the pressure and temperature increase of the wet waste. So that there is a transfer of water mass from garbage to the environment in the form of water vapor and drying occurs on the surface of the garbage

In this study, wet waste drying will be carried out by comparing the waste drying method between the heated air media drying method and the drying room wall heating method. The weight of the initial wet waste (MA) will be assumed to be 100 kg with a percentage of the initial water content (MCA) of 80% and the target final product content (MCT) of 10%. From the data will be determined the mass of the evaporated water content.

$$MC_{w.b} = \frac{W_a}{W_b} \times 100\%$$

$$80\ \% = \frac{Wa}{100\ kg} \times 100\%$$

$$Wa = 80\ kg$$

Then the total dry commodity (KKT) amounted to 20 kg. Because the final wet content target is 10%, the product mass is:

$$Mass\ Products\ (MP) = \frac{(KKT)}{(100\% - (MCT)}$$

$$= \frac{20\ kg}{(100\ \% - 10\ \%)}$$

$$= 22.22\ kg$$

The mass consists of the total dry mass + the final water mass of the product, then the final water content mass (MAP) :

$$(MAP) = (MP) - (KKT)$$
$$= 22.22222222\ kg - 20\ kg$$
$$= 2.22\ kg$$

So, The mass of water that needs to be evaporated (MAU) is as large as

$$(MAU) = (MAA) - (MAP)$$
$$= 80\ kg - 2.22\ kg$$
$$= 77.78\ kg$$

3. RESULT AND DISCUSSION

3.1 Drying Method Hot Air Blowing

Calculation of drying moisture content on garbage drying method of heated air media using Psychrometric Calculations with parameters in the city of Depok. These parameters include: Altitude 77 meters from sea level, Relative Humidity air 60%, and outside air temperature 30^{O}C. From these parameters, it is known that the humidity ratio is 0.0162 kg of water / kg of dry air, enthalpy of 71.55 kJ / kg of dry air, and a specific volume of air of 0.89 m3 / kg using Psychrometric Calculations software. The data is shown in the following figure.

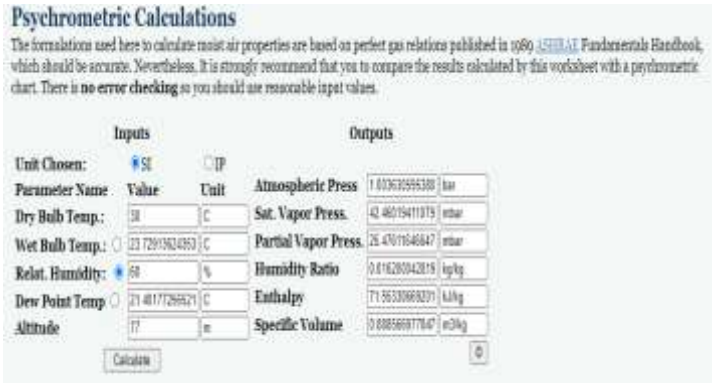


Figure 3. Calculation Results of *Psychrometric Calculations* software with Input Altitude Parameters of 77 m, Relative Humidity of air 60%, and outside air temperature of 30^{o}C

The calculation will be done with different temperature variables and presented in the following Table.

Table 1. Heated Air Propertis Data

Heated air temperature (^{o}C)	**Rh heated air (%)**	**MC (kg of water/kg of air)**	Hot air enthalpy h (kJ/kg)
80	5.38%	0.0162	123.29
85	4.40%	0.0162	128.44
90	3.63%	0.0162	133.63
95	3.01%	0.0162	138.79
100	2.51%	0.0162	143.95
105	2.11%	0.0162	149.14
110	1.78%	0.0162	154.30
115	1.51%	0.0162	159.47
120	1.28%	0.0162	164.66
125	1.10%	0.0162	169.81

The compressed and heated air will be used as a drying medium for moisture content in the garbage. During the drying process, it is assumed that the temperature of the air output that has been used as a dryer becomes 40 ºC. Water protection in the garbage will evaporate and be carried away by hot air or drying media, so that the humidity in the hot air after the drying process will increase.

The data from the calculation of the process of drying the moisture content in the garbage is displayed in the following table:

Table 2. Energy Requirements and Air Masses Needed dryer

Heated air temperature (ºC)	Drying capability DMC (kg water/ kg air)	Dryer Air Requirements MU (m3)	Total Dryer Energy Requirement Q (kWatt)
80	0.016075061	4552,49	69.50
85	0. 018084414	4059,18	67.95
90	0.020094153	3664,51	66.74
95	0.022103404	3341,62	65.72
100	0.024112591	3072,55	64.86
105	0.026122286	2844,86	64.16
110	0.028132006	2649,66	63.54
115	0.030140985	2480,57	63.01
120	0.032150987	2332,56	62.56
125	0.034159782	2198,80	62.14

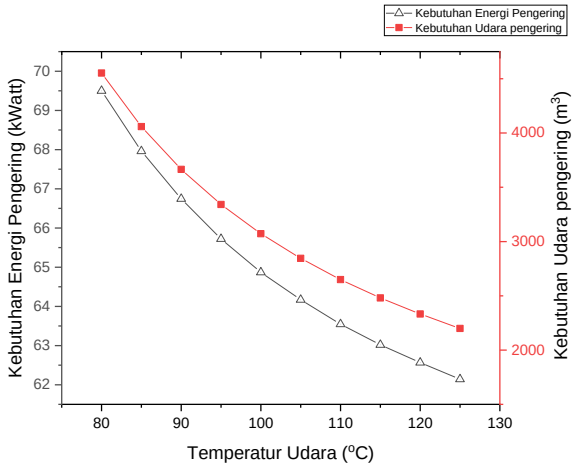


Figure 4. Dryer Energy Requirements Graph

The graph of dryer energy needs with the relative humidity method in the picture above shows that the greater the heating temperature to heat the dryer air, the dryer energy needed to dry the moisture content in wet garbage is lower

3.2 Drying Method Boiling in a Heated Room

The temperature of the drying room heating media is first assumed to be 30 ºC. Then the drying room heating media is heated through a steam medium with a range of variable temperatures of 100 ºC – 200 ºC. Calculation of the properties of steam saturation using Excel Macro software to find the energy value of each variable. The energy required to heat the heating medium is known from the change in the enthalpy of the heating medium

In table 3, the following table is presented the value of the vapor property at a pressure of 1 bar absolute to heat the heating medium with a variable temperature range of 100 ºC – 200 ºC.

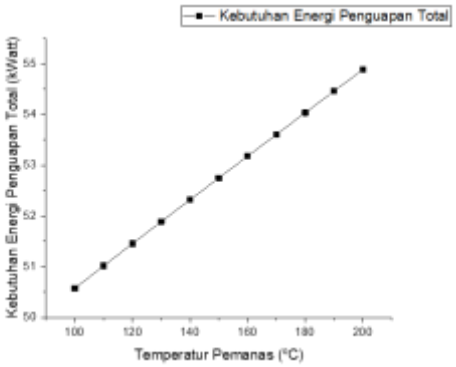
Table 3. Energy Properties of Heating Media

Heating Temperature (saturated) (ºC)	Pre Heating Media Enthalpy h1 (kJ/kg)	Heating Media Enthalpy h2 (kJ/kg)	Energy Needs heating heating media h2-h1
100	125.83	2675.76	2549,93
110	125.83	2696.32	2570,48
120	125.83	2716.60	2590,77
130	125.83	2736.71	2610,88
140	125.83	2756.69	2630,86
150	125.83	2776.59	2650,75
160	125.83	2796.42	2670,58
170	125.83	2816.20	2690,37
180	125.83	2835.97	2710,13
190	125.83	2855.72	2729,88
200	123.83	2875.47	2749,64

Through the energy to heat the drying chamber, energy needs are obtained to boil the moisture content to be evaporated. The total evaporation energy requirement will be presented in the following table

Table 4. Total evaporation energy needs

Heating Temperature (saturated) (ºC)	Total Evaporation Energy Needs (kJ)	Total Evaporation Energy Needs (kWatt)
100	182060,4195	50,57
110	183659,0597	51,01
120	185236,8774	51,45
130	186800,9149	51,88
140	188355,1415	52,32
150	189902,3211	52,75
160	191444,5664	53,17
170	192983,5528	53,60
180	194520,6296	54,03
190	196056,8933	54,46
200	197593,2405	54,88



4. CONCLUSION

The energy required in the Relative Humidity dryer method through a heated air medium is not only to heat the moisture content until it can evaporate but energy is also needed to heat the air from the initial temperature of heating the dryer air to the temperature out of the dryer. In addition, the amount of air needed to carry water vapor is very large. Based on the results of the discussion and calculations of each drying method to reduce the mass of water content in wet waste that has been carried out, it can be concluded that the drying method by evaporating the moisture content by heating the drying chamber is more efficient because it requires less energy than the method of blowing heated air.

Based on the results of the discussion and calculations of each drying method to reduce the mass of water content in wet waste that has been carried out, it can be concluded that the drying method by evaporating the moisture content by heating the drying chamber is more efficient because it requires less energy than the method of blowing heated air.

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