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Effect of mass variation of material on continuous vertical type drying machines against drying time

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ABSTRACT

Post-harvest handling of grain before being ground or stored for a long time is drying or reducing water content. To dry the grain is more effective by using a mechanical dryer. In this study, grain drying was carried out using a continuous vertical dryer by varying the grain mass to determine the effect of grain mass variation on the grain drying time. Mass variations observed were 10 kg, 20 kg, 30 kg, 40 kg, 50 kg, 60 kg, with an air temperature of 50°C and an air velocity of 7 m/s. The result showed that the more grain mass the lower the drying rate. However, the drying time was longer, and the efficiency was higher. At the 10 kg, the fastest drying time was 75 minutes. Whereas at the 60 kg, the maximum drying time was 150 minutes. The highest efficiency of 8.78, occured at a mass of 60 kg and the lowest efficiencywas 1.6% occured at a mass of 10 kg.

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1. INTRODUCTION

Indonesia is an agricultural country that is rich in agricultural products. One of them is rice and even Indonesia third ranks with a total production of 70.8 million tons/year. Agricultural products, after harvest, still have high water content. Therefore, one of the methods used by farmers in handling the harvest is by drying. Drying aims to reduce the water content stored in the material, grain milling entrepreneurs and farmers in Indonesia currently carry out the process of drying by utilizing sun rays. This method, however, is still classified as very conventional and inefficient. Damaged agricultural products can be caused by two factors, namely internal and external factors. The damage results in a decrease in quality. The quality of the yields decreases the selling price. One important point set by the Government is that the maximum water content permitted in grain seeds is 14%. The harvested grain generally has a fairly high water content of around 20-23% wet based on the dry season and the rainy season around 24-27% (Yahya, 2015).

Rusli et al., (2018) said that in Indonesia still there is a lot of traditional drying ways. People dry the rice on top of dry cement, stone, or soil. The advantages of this method are low drying costs, no need special handling, the drying uniformity. While the disadvantages of the method are very dependent on the weather, longer drying time and require a large area, as well as high losses.

Uncertain weather conditions especially during the rainy season result in not optimal drying processes, and also the products damage due to the humid air. The process of drying with sun rays is also unhygienic because it is placed in an open place. The open place causes canary seeds to be contaminated. Besides, in the rainy season drying takes place slowly. This imperfect drying can even cause the products to have mushroomed and then rot so that the selling price drops dramatically. As human thought develops, drying arises using mechanical devices or artificial drying that uses additional heat to overcome the shortcomings of drying by the natural drying process. This mechanical drying requires energy to heat the material, evaporate the water, and flow the air. The mechanical dryers are available in various types. A conventional vertical type dryer was ever examined by Risnawati et al., (2017). Graciafernandy et al., (2012) stated that a continuous vertical type machine could reduce the water content of grain. At a drying air temperature of 60°C, the product could dry quickly. The increase in the temperature of the drying air could speed up the drying time. The faster the decrease in water content in the material, the shorter the drying time. Based on the above situations, this study tries to investigate the effect of the grain mass on the drying time.

2. Mathematical analysis

Drying is a process of removing the water content of a material. In the drying process, it is necessary to have dry air-fluid that can absorb water in the material. Efforts that can be done to make the air dry is to warm up the air before crossing the material. Hot and dry air conditions can absorb water in the material in a shorter time. The effort made to obtain hot and dry air is used in combination of two different energy sources as performed by Suriadi and Murti (2011).

In the drying process, water from the wet material is evaporated with media such as hot gas or hot air. The heat carried by the hot air heats the surface of the wet material, so that the material temperature rises, and the water is evaporated. The higher air temperature causes faster drying process as reported in Widjanarko et al. (2012). According to Taufiq (2004), material moisture content indicated the amount of the water content of materials. The determination of water content in the dry basis can be determined by the following equation:

$$K_a = \frac{m_t - m_k}{m_t} x100\% \tag{1}$$

K_a is the water content (%), m_t is the total mass (kg), and m_k is the dry mass (kg). Drying efficiency is the result of a comparison of the use of actual heat in drying to theoretically heat required as explained in Fathurrahman (2017). It can be obtained as follows.

1. total heat.

$$Q_{use} = Q_1 + Q_2 \tag{2}$$

Q_{use} is the total amount of heat energy used for drying materials (J), Q_1 represents the amount of heat energy to heat the material (J), Q_2 is the heat to evaporate the water contained in the material (J).

2. Q_1 is obtained from equation (3), which is written as:

$$Q_1 = m_t c_p \left(T_f - T_i\right) \tag{3}$$

c_p is the grain heat specifik, it is assumed to be 1.51 kJ/kg°C, T_f is the final grain temperature (°C), and T_i is the initial grain temperature (°C).

3. Q_2 is estimated using equation (4), which is expressed as:

$$Q_2 = m_u h_{fg} \tag{4}$$

m_u is evaporated water mass (kg), and h_{fg} is heat of evaporation (J/kg).

4. Volumetric rate entering the drying chamber

$$\dot{\forall} = vA \tag{5}$$

$\dot{\forall}$ is the volumetric rate (m³/s), *A* is the cross-sectional area (m²), and

$$A = s^2 \tag{6}$$

s is the side length of the dring chamber (m).

5. The volume of air entering the drying chamber can be calculated using the following formula:

$$V_u = \dot{\forall}\Delta t \tag{7}$$

V_u is the air volume inside the drying chamber (m^3), and Δt is the drying time (s).

6. To determine the amount of heat given by the hot air to the material, the following formula is used:

$$Q_{in} = \rho_u V_u c_{pu} \left(T_m - T_k\right) \tag{8}$$

Q_{in} is air heat energy (J). ρ_u is the air density (kg/m^3), c_{pu} is the air specific heat (J/kg°C), T_m is average temperature of air (°C) at the entrance, T_k is the average temperature of air (°C) at the outlet.

7. The drying rate in the process can be calculated by the equation:

$$\dot{m} = m_u / \Delta t \tag{9}$$

$\dot{m}$ is drying rate (kg/s).

8. Thermal drying efficiency
The efficiency of thermal drying can be calculated using the following formula:

$$\eta_{th} = \frac{Q_{use}}{Q_{in}} \text{ x100\%} \tag{10}$$

η_{th} is thermal drying efficiency (%)

3. research method

The method used in this tsudy is experimental works. The study was conducted at the Mechanical Engineering Student Association Workshop, Mataram University. The tools used in the study were 1. Vertical continuous dryer, 2. Scales, 3. Moisture meter, 4. Wet ball thermometer, 5. Thermocouple, 6. Digital Scales, 7. Stopwatch, 8. Data logger, 9. Anemometer, 10. Digital thermometer. The dependent variables investigated were drying air temperature, drying rate, while the independent variables tested were mass variations: 10 kg, 20 kg, 30 kg, 40 kg, 50 kg, and 60 kg. The experimental appartus is described in figure 1.

A standard moisture content of 20% with an uncertainty of ± 0.5% was used as the initial water content of the material. If the water content of the material did not meet the standards in the test and it was higher then 20%, then a treatment should be carried out such as drying, if the water content was less than 20%, the the material was soaked with water. Grain containing 20% water was then weighed using a scale to obtain a mass of grain 10 kg, 20 kg, 30 kg, 40 kg, 50 kg, and 60 kg. Then air with a costant temperature of 50ºC was flowed in to the chamber. The data were obtained at every 15 minutes until the material got the water conten of about 14%. The air velocity emplyed was 7 m/s with

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an uncertainty of 0.1 m/s. All temperatures were measured using calibrated K-type thermocouples with an uncertainty of ± 0.5°C, and the uncertainty of the mass measurement was ± 0,1 kg.

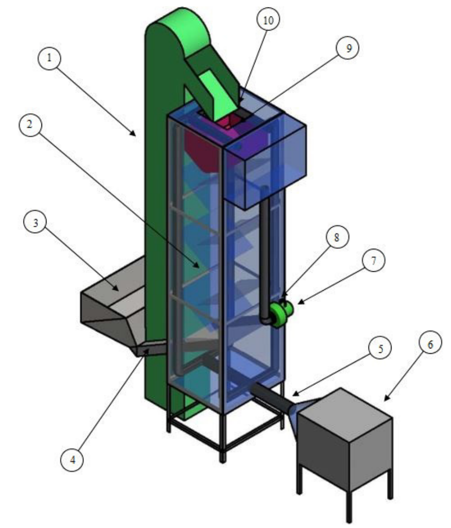

Figure 1. Design of a continuous vertical dryer. 1. Elevator bucket, 2. Drying chamber, 3. Material container, 4. Drain out material that has been dried, 5. The air inlet pipe is from the stove, 6. Stove / heater, 7. Blower, 8. Air dryer inlet, 9. Drying air outlet, 10. Material inlet from bucket elevator.

The placement of the thermocouple points is shown in figure 2.

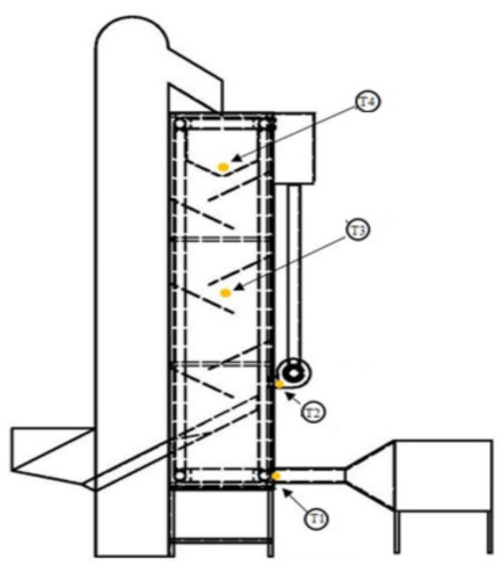

Figure 2. Thermocouple placement, T1: Air inlet to blower, T2: Air inlet to the drying chamber, T3: drying chamber, and T4: Air outlet.

4. Results and discussion

After conducting research of effect of mass variations on drying time at a vertical dryer, the results obtained vary according to the mass variations. Increasing the mass levels the drying time. This was because the larger mass, the larger water in the material as the water in the material was

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directly proportional to the material mass. Therefore, the more mass of material, the more time needed for the drying process. The more mass of material, the more water content needs to be evaporated. Table 1 shows experimental results with mass variations of 10 kg, 20 kg, 30 kg, 40 kg, 50 kg, and 60 kg at the constant air temperature of 50ºC and air velocity of 7 m/s. Tables 1 and 2 indicate that increasing the mass elevate the drying time ∆t, and also incrasing the mass raises efficiency.

Table 1. Data obtained in the experiments.

V (m/s)	T_m(ºC)	m(kg)	T_1 (ºC)	T_2(ºC)	T_3(ºC)	T_4 (ºC)	T_i (ºC)	T_f (ºC)	Ka initial (%)	Ka final (%)	∆t (s)
		10	170.07	50.11	48.65	40.09	30.25	39.65	19.90	13.82	4500
		20	143.62	50.18	44.92	41.52	30.20	39.95	19.97	13.90	5400
		30	164.28	50.27	47.08	42.69	29.90	40.70	20.35	13.85	6300
7	50	40	191.87	50.29	46.77	43.56	29.25	38.70	20.18	13.85	7200
		50	184.69	50.62	49.70	44.27	30.20	39.85	20.37	13.85	8100
		60	171.88	50.78	47.82	44.90	30.94	40.75	20.43	13.80	9000

Table 2. Calculation results of drying efficiency for each variation.

m(kg)	T_m (ºC)	Q_{use} (kJ)	Q_{in} (kJ)	Q_{loss} (kJ)	P (kWh)	ṁ (kg/s)	η (%)
10	50.11	1998.33	125260.96	123262.63	1.688	0.0001351	1.60
20	50.18	3995.23	129882.15	125886.92	1.725	0.0002248	3.10
30	50.27	6313.96	132584.88	126270.92	1.838	0.0003095	4.76
40	50.29	8182.21	134542.58	126360.37	2.250	0.0003617	6.08
50	50.62	10528.75	142653.37	132124.62	2.438	0.0004025	7.38
60	50.78	12890.13	146876.89	133985.76	2.475	0.0004420	8.78

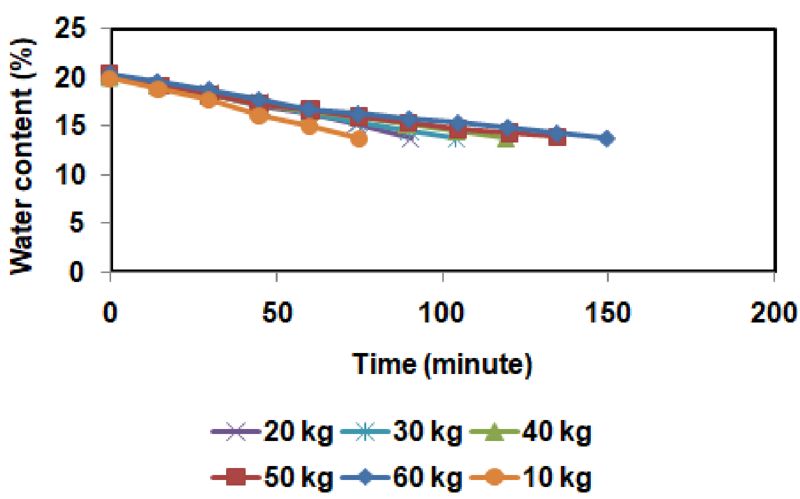

Figure 3. Relationship of drying time with water content at air temperature of 50°C and several masses.

Figure 3 shows that water content decreases with time at all tested masses. The fastest drying time was 75 minutes that was obtained at the mass of 10 kg. The water content achieved for 75 minute was 13.82%. Meanwhile at 20 kg, the drying time was 90 minutes, and at 30 kg, it needed 105 minute and so on. The drying time increases with the increasing in the material mass. Therfore, it can be conlcuded that the mass of the material influences the drying time. The more mass of materials,

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the longer the drying time. This was because of the more water content that should be evaporated. However, the trends of the water content were also found by Maranggana and Sukmawaty (2010), Mustafa (2011), Suherman et al., (2012), Dwika et al. (2012), Syahrul et al. (2016),

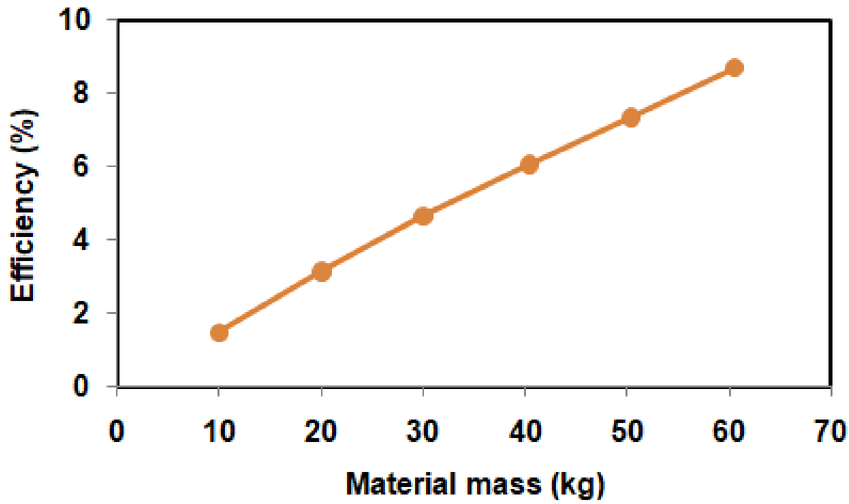

Figure 4. Efficiency of drying at masses of 10 kg, 20 kg, 30 kg, 40 kg, 50 kg, and 60 kg, and at a temperature of 50ºC.

Drying efficiency is a value that shows how the work success rate of a machine in drying. Figure 4 demonstartes that the efficiency increases with the material mass. The highest efficiency was obtained at a mass of 60 kg, and the lowest efficiency was achieved at the material mass of 10 kg. This was due to the increase in the Q_{use}. Q_{use} increased with the mass, while Q_{in} was constant, consequently, owing to equation (10), the efficiency increased with the mass.

5. Conclusions

Experiments to obtain the effect of material mass on the drying time at a vertical dryer was conducted. Based on the experimental data and discussion some conluding remark are: the mass of the material affects the drying time, the more mass the longer the drying time. The fastest drying time at a temperature of 50°C and a constant air velocty of 7 m/s is at a mass 10 kg. The longer darying time occurs at 60 kg. The drying efficiency in this study is directly proportional to the material mass. The more mass, the higher the drying efficiency, and vice versa. The highest drying efficiency is 8.78% at 60 kg, a temperature of 50°C and a constant air velocity of 7 m/s. The lowest efficency is 1.6% at 10 kg.

Nomenclature

A : Cross-sectional area (m²)
c_p : Specific heat (J/kg K)
c_{pu} : Air specific heat (J/kg K)
K_a : Water content (%)
$\dot{m}$: Drying rate (kg/s)
m_k : Dry mass (kg)
m_t : Total mass (kg)
m_u : Evaporated water mass (kg)
Q_{in} : Air heat energy (J)
Q_{use} : Total amount of heat energy used for drying (J)
Q_1 : Amount of heat energy to heat the material (J)
Q_2 : Heat energy for evaporation (J)
s : Side length of the chamber (m)
T_f : Final temperature (°C)
T_i : Initial temperature (°C)

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T_k	:	Average air temperature at the outlet (°C)
T_m	:	Average air temperature at the entrance (°C)
Δt	:	Drying time (s)
$\dot{\forall}$	:	Volumetric rate (m³/s)
V_u	:	Air volume in the chamber (m³)
ρ_u	:	Air density (kg/m³)
η_{th}	:	Drying efficiency (%)

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