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Analysis of Heat Energy on the Drying Process of Paddy Using Fluidized Beds Dryer

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Abstract. The purpose of this study was to determine the amount of heat energy in the paddy drying process using a fluidized bed dryer. The method used in this research was an experimental method using an energy balance. This test was carried out using a fluidized beds dryer, with paddy material, where the paddy was dried at a certain temperature with 3 mass treatments, namely 5, 6 kg, and 7 kg with an air velocity of 21 m/s. The results showed that the total energy that enters the drying chamber for a mass of 5 kg material is 1,022 kJ with a useful energy of 1.339 kJ. The energy that enters the drying chamber for a mass of 6 kg is 1,043 kJ with a useful energy of 2.192 kJ. For a mass of 7 kg of material, the energy that enters the drying chamber is 1,187 kJ with a useful energy of 3.578 kJ.

1. Introduction

Indonesia as an agricultural country has fertile soil and abundant agricultural products; one of the agricultural products is grain. Rice production in Indonesia is one of the top three world grain producers. Handling of grain in Indonesia is often constrained by the problem of drying. The process of drying grain in Indonesia still uses conventional methods, namely by drying directly in the sun, so there are obstacles during the rainy season. In the rainy season, grain drying is less than perfect and requires a longer time when compared to the dry season. Incomplete drying of grain will cause the quality of the grain to decrease, during storage and in the milling process to become rice. One of the solutions to these problems is to provide drying equipment technology. The use of dryers will require additional costs during the drying process, initial investment costs are required and also costs during the tool operation process, but the drying process using a dryer will minimize the risk of yield loss [1].

Basically, drying is reducing the water content in the material to safe moisture content so that microbes can no longer grow in it with the main goal of preventing damage. In the drying process, there are two drying methods, namely natural drying using direct sunlight and mechanically. Sun drying can reduce costs so this process is easily found in traditional societies. However, this drying process has many drawbacks, namely depending on the weather and can reduce product quality. As for the mechanical drying process using drying machines which are widely used on an industrial scale, the advantages are that it is not weather dependent, suitable for large capacities and the process can be controlled.

Drying with a mechanical dryer is by blowing hot air from a heat source into the drying chamber. The more material to be dried as well as the greater the heat energy needed for the drying process. The fluidized bed drying is widely used for the drying of agricultural stuff [2]. Based on the description above, the researchers conducted research on the analysis of the use of heat energy in the grain drying process using a fluidized beds dryer with variations in mass.

2. Materials and Methods

The method used in this study was an experimental method and the data generated from were analyzed using a mass and energy balance approach which is intended to complete a mathematical model [3] and [4]. The energy needed in the drying process is used to heat the material (Q1), to raise the temperature of the water in the material (Q2), and to evaporate the material water (Q3). The amount of heat (heat) used for drying can be calculated using the following formula [3]

$$Q = Q_1 + Q_2 + Q_3 \quad (1)$$

Q = Amount of drying heat (kJ)
Q_1= Sensible heat of material (kJ)
Q_2= Sensible heat of water (kJ)
Q_3= Latent heat of water (kJ)

$$Q_1 = m_k c_p (T_p - T_i) \quad (2)$$

$$m_k = m_t (1 - K_a) \quad (3)$$

m_k	= dry mass of material	(kg)
m_t	= total mass of material	(kg)
c_p	= specific heat of material	(kJ/kg°C)
T_p	= final temperature	(°C)
T_i	= initial temperature	(°C)
Ka	= Water content	(%)

$$Q_2 = m_a c_{pa} (T_p - T_i) \quad (4)$$

$$m_a = m_t . K_a \quad (5)$$

m_a	= mass of water	(kg)
c_{pa}	= specific heat of water	(kJ/kg°C)

$$Q_3 = m_a h_{fg} \quad (6)$$

$$m_a = k_{ai} . m_{ti} - k_{af} . m_{tf} \quad (7)$$

M_a	= mass of water evaporated	(kg)
h_{fg}	= latent heat of evaporation	(kJ/kg)
m_{ai}	= mass of initial water	(kg)
m_{af}	= mass of final water	(kg)
m_t	= mass total	(kg)

To determine the amount of heat given by hot air to the dried material, the following formula is used [3]:

$$q = \rho_u V_u c_{pu} (T_m - T_k)$$

q =	heat enters the drying chamber	(kJ)
ρ_u=	air density	(kg/m^3)
c_{pu}=	specific heat of air	(kJ/kg°C)
T_m=	mean temperature of air in	(°C)

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T_k= mean temperature of air out (°C)

The research method used is an experimental method using a set of fluidized dryers as shown in Figure 1.

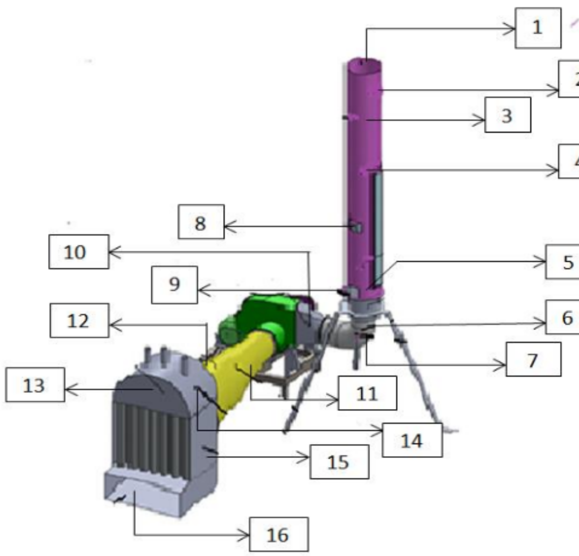

Figure1. Fluidized bed dryer Set-up

1. Outlet Temperature
2. Temperature of the walls of the upper dryer room
3. RH inlet temperature
4. RH temperature of outer outlets
5. The temperature of the drying chamber
6. The temperature of the middle chamber
7. The temperature of the bottom drying chamber
8. Inlet temperature

9-12 Plenum temperature

13. Heat exchanger pipe temperature

14 & 15. Wall temperature 1 & 2

16. Furnace temperature

The stages of the process are similar to Syahrul et al. [3] and [5] were carried out as follows:

1. Weighing grains weighing 5 kg, 6 kg and 7 kg.
2. The stove is heated for ± 5 minutes.
3. Turn on the blower and the constant speed of air at 21 m/s.

4. Observation is done by taking samples every 10 minutes up to 180 minutes.
5. Repeat steps 2 – 4 above for masses of 6 kg and 7 kg.

3. Results and Discussion

The air temperature effect on drying time of paddy using a fluidized bed have been studied in our lab by Syahrul at al. [6]. In this study, Paddy as the grain drying experiments were carried out using fluidized beds dryers with different drying mass variations to analyze the energy production. Grain with a mass variation of 5 kg, 6 kg, and 7 kg were each dried by inserting it through a funnel into the drying chamber. Air from the blower that passes through the heater is blown into the drying chamber through the plenum chamber. Grain lifted and flew around the drying chamber. Drying was carried out for 180 minutes by taking 18 samples on each different mass variation.

Table 1. Moisture Content of Mass 5 kg, 6 kg and 7 kg.

	Moisture Content (%)		
Time	5 kg	6 kg	7 kg
0	23.04	22.62	24.71
10	19.85	21.55	22.42
20	19.89	21.31	19.57
30	18.13	19.90	19.36
40	17.33	17.09	18.68
50	16.59	16.47	16.22
60	15.89	15.86	16.17
70	15.41	15.55	15.46
80	14.09	14.34	14.85
90	13.95	13.86	14.64
100	13.81	13.27	14.46
110	12.63	12.90	14.32
120	12.56	12.00	14.06
130	12.18	11.63	13.98
140	12.11	11.51	13.90
150	11.95	11.48	13.61
160	11.63	11.10	13.36
170	11.58	10.89	11.30
180	10.81	10.26	10.12

Table. 1. shows that the process of decreasing water content occurs in each mass, namely 5 kg, 6 kg and 7 kg. In this study, it is expected that the maximum water content reduction will reach 14% for the water content of Milled Dry Grain (GKP) in each treatment of material mass. The moisture content of 14% occurred at 86 minutes for a mass of 5 kg. Then the 14% water content occurs at 87 minutes for a mass of 6 kg. As for the mass of 7 kg of material, the moisture content of 14% occurred in the 128th minute. So it

can be concluded that the mass of the dried material greatly affects the decrease in the moisture content of the grain. More comprehensive results can be found in Juwita Sari [5]. The specific energy consumption (SEC) needs to be calculated for each mass of the drying material. Energy and mass balance have to be proposed. Thermodynamic analysis has been performed to assess the performance of the fluidized bed drying [7].

The following data obtained for the drying mass balance are shown in the following table.

Table 2. Mass Equilibrium of Grain Materials

Mass Equilibrium of Grain Materials		
Massa Inlet (kg)	Mass Outlet (kg)	Evaporated Mass (kg)
5	4.23	0.77
6	4.74	1.26
7	4.84	2.16

Table 2 shows the results of mass balance analysis in the grain drying process using a fluidized beds dryer. The results of the analysis are obtained from the results of calculations using the general equation of mass balance, namely: Mass in (input) - Mass out (output) = Mass of lost material (accumulation). This shows the amount of output or mass out and the mass that is evaporated is influenced by the velocity of the air flow.

The following data obtained for the drying energy balance are shown in the following table.

Table 3. Energy Balance.

Massa (kg)	Energy Inlet (kJ)	Energy Use (kJ)	Energy Outlet (kJ)	Energy Loss(kJ)	Velocity Air (m/s)
5	1,022	1.339	941.87	18.75	
6	1,043	2.192	1,040	225.4	21
7	1,187	3.758	1,028	114.95	

Table 3 shows the results of the energy balance analysis in the grain drying process using a fluidized bed. The results of the analysis are obtained from the general equation of the energy balance, namely the incoming energy minus the outgoing energy equals the stored energy. Energy in is equal to the amount of useful energy plus energy lost and energy out. Useful energy is the energy used to heat the material in the drying chamber, and the lost energy is the energy that is lost through the walls of the drying chamber and is not utilized. The energy outlet is the energy out of the drying chamber. In this study, the amount of incoming energy, outgoing energy, useful energy and lost energy is calculated every minute. Table 3 shows the smallest amount of incoming energy and useful energy with an air flow velocity of 21 m/s of 1,022kJ and 1.339 kJ, while the highest intake and useful energy of 1,187kJ and 3.758 kJ. This shows that the incoming energy and useful energy in the drying chamber during the drying process are influenced by differences in the mass of the material being dried. Drying conditions based on energy consumption and drying rate need to be optimized [8].

4. Conclusion

The process of decreasing the water content occurred in each mass, namely 5 kg, 6 kg and 7 kg. The moisture content of 14% occurred at 86, 87 and 128 minutes for the mass of material 5, 6 and 7 kg, respectively. So it can be concluded that the mass of the dried material greatly affects the decrease in the moisture content of the grain. The inlet energy and useful energy in the drying chamber during the drying process are influenced by differences in the mass of the material being dried.

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