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Drying rate and efficiency energy analysis of paddy drying using dehumidification with zeolite

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Abstract. Paddy must be dried to prolong the storage life and maintain the quality. There was some researches about paddy drying system: bin dryer. The dehumidification process giving advantages in high efficiency energy, but it is taking the heat for regeneration. Based on the literature study, it is hard to find the literature about drying efficiency analysis during the drying of paddy. This research aims to observe the effect of drying temperatures and addition of zeolite in drying system. Paddy grains were dried from initial moisture content 22% (wet basis) under different temperature 40, 50, and 60°C for 90 minutes drying. Zeolite was used as adsorbent to decrease the relative humidity of air dryer. Results showed that use of zeolite lowering the air humidity and increasing driving force for drying. These made the drying rate increased. The higher drying temperature can also increase drying rate. Energy efficiency decrease during the drying process. Also, addition of zeolite in drying process affected the drying efficiency.

Keywords: paddy, drying, temperature, efficiency, zeolite.

1. Introduction

Drying of post-harvest product giving several reasons: easy to handle, preservation and storage, reduction cost for transportation, and maintain the quality of product. Improper drying process lead to product quality degradation [1]. Paddy must be dried to prolong the storage life and maintain the quality [2]

There were some researches about paddy drying system: bin dryer [3], bed dryer [4, 5]. The quality of paddy along the drying process must be maintain. The type of drying system that can operated in lower drying temperature and high energy efficiency is needed. Dehumidification can be option to dried the paddy in lower drying temperature and high efficiency [6]. Dehumidification using zeolite was used in several food product drying: vegetable [7]; seaweed [8]; carrageenan [9]; and vegetable seed [10]

The dehumidification process giving advantages in high efficiency energy, but it is taking the heat for regeneration. Based on the literature study, it is hard to find the literature about drying efficiency analysis during the drying of paddy. This research aims to observe the effect of drying temperatures and addition of zeolite in drying system. Drying rate and energy efficiency during the drying process is evaluated.

2. Materials and Methods

2.1. Materials

In this study, paddy from. local farmer in Tembalang, Semarang was used. Paddy grains were dried from initial moisture content 22% (wet basis) under different temperature 40, 50, and 60˚C. 100 grams of Zeolite 3A (provided by Zeochem, Switzerland) were used as adsorbent in purpose to decrease the relative humidity of air dryer.

2.2 Experimental design

This drying process used fluidized bed dryer from Chemical Engineering UNDIP, Semarang. Paddy grains were fluidized in fluidized column Ambient air with relative humidity 70-80% and temperature between 29-33˚C was heated in the heater completed with PID controller to reach dryer temperature (40˚C with zeolite at first experiment). The air dryer flow was set at 5.51 m.s^{-1} (72% above minimum velocity for fluidization).. It was measured with an Instruments KRISBOW Anemometer KW06-562. Moisture content was observed by grain moisture meter G-Won GMK-303RS every several minutes. 250 grams of paddy were dried until 14% moisture content. The process was repeated for the inlet air dryer temperature 50˚C and 60˚C, as the comparison the paddy was dried without zeolite.

2.3 Drying rate calculation

Initial moisture content, moisture content at *i* time, and interval time datas of all experiment variables were needed to calculate drying rate. The difference moisture content at *i* time with the previous, divided by the difference time resulted drying rate of process, see equation 1 [1].

$$N = \frac{dM}{dt} = \frac{X_2 - X_1}{\Delta t} \tag{1}$$

Where N was drying rate (kg min^{-1}), X_2 was moisture content at *i*, X_1 was moisture content at i_1, and Δt was time difference between *i* and i_1.

2.4 Drying efficiency

The humidity and air temperature were measured by KW0600561, Krisbow®, Indonesia (T-RH sensor) to calculate the energy efficiency during the drying process. Drying efficiency in dehumidification system was estimated using following equations:

$$\text{Drying efficiency} = \frac{Q_{evap}}{Q_T} 100\% \tag{2}$$

$$Q_T = Q_d + Q_{reg} \tag{3}$$

$$Q_{evap} = M_p(q_{w,0} - q_{w,f})\lambda \tag{4}$$

Where Q_{evap} was the total heat to evaporate water from product (kJ) and Q_T was the total heat required the system for drying (kJ), Q_{reg} was heat to regenerate saturated zeolite (kJ), Q_d was the total heat to heating up air for dryer (kJ.h^{-1}), M was the mass of dry product in dryer (kg), q_{w0} was the moisture in product entering dryer (kg water per kg dry product), $q_{w,f}$ was the moisture in product exiting the dryer (kg water per kg dry product), and λ was the latent heat of water evaporation (kJ.kg^{-1})

3. Results and Discussion

3.1 Drying rate

The drying curves in the form of drying rate versus moisture content were depicted in Figure 1. Drying rate reduces with the reduction of moisture content or reduction of drying time. There are two periods of drying rate: (1) constant rate period, the external rate depends on heat and mass transfer of free water in product surface; (2) falling rate period, the internal heat and mass transfer [11]. Paddy drying took place in the falling rate period. Similiar result was reported in several food product: pepper [12]; apple [13]; red chilli [11]. In falling rate period, depends on the rate of water diffusion in the solid [14].

The drying rate in drying with zeolite was higher than without zeolite. The average drying rate of drying with zeolite was 1.13 times higher than without zeolite). Increasing the drying rate can shorten the drying time. Using zeolite as the air dryer adsorbent in drying process giving two advantages: (1)

zeolite lowering the air humidity and increase the driving force for the drying; (2) increase the temperature due to release the heat adsorption [2].

The drying rate curve at different drying temperature can be seen in Figure 2. The average drying rate at drying temperature 60°C was higher than temperature 50°C and 40 °C. In higher drying temperature the drying rate is higher since hot air bring more sensible heat and relative humidity of air is low. In this research, the zeolite was applied in low-medium drying temperature because application of zeolite in higher drying temperature (80°C or higher) give not significant impact [11, 15].
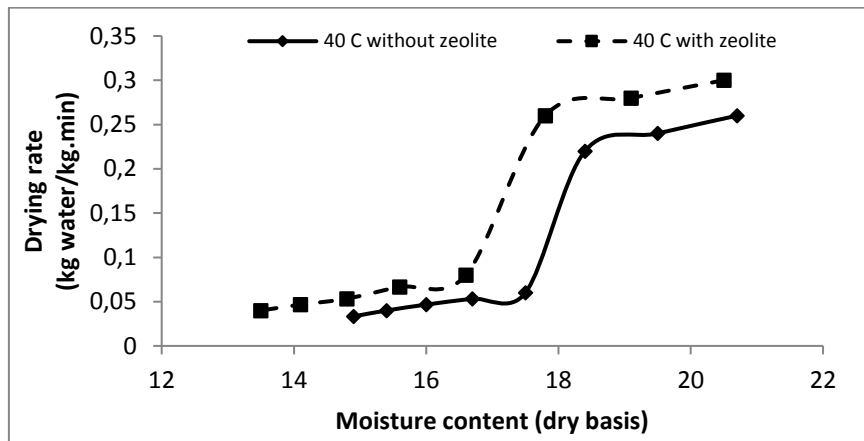

Figure 1. Comparison of drying rate curves in paddy drying with zeolite and without zeolite
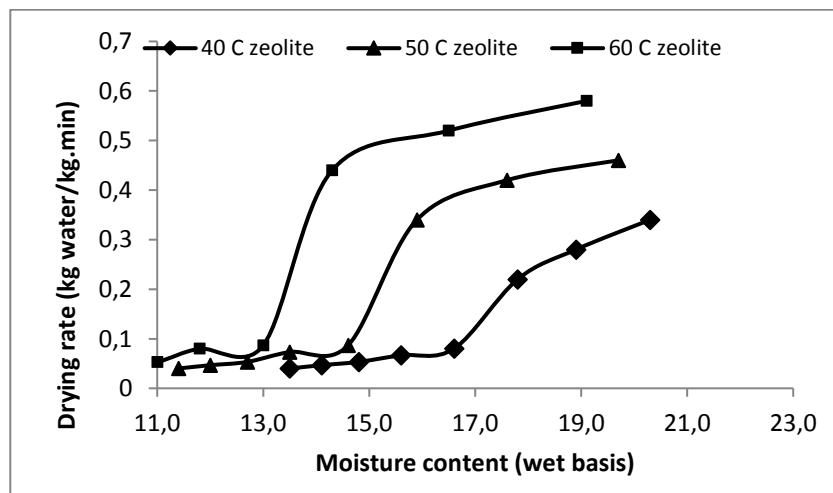

Figure 2. Comparison of drying rate curves in paddy drying at different drying temperature

3.2 Drying efficiency

The variation of energy efficiency with drying time in drying with zeolite and without zeolite were listed in Table 1. In initial time of drying, the energy efficiency was very high. It is indicated that energy from dryer that was absorbed by the product is high. During the drying process, moisture content reduce, the energy that is absorbed by the product decreased. Energy efficiency decrease during the drying process [11, 16].

Table 1. Drying efficiency of paddy without and with zeolite at different drying temperature

Temperature (^{0}C)	Drying time (min)	Energy efficiency (%)	
		Without zeolite	With zeolite
40	5	89,33	98,92
	10	82,46	92,33
	15	75,59	85,74
	30	61,85	79,14
	45	54,98	65,95
	60	48,10	52,76
	75	41,23	46,17
	90	34,36	39,57
50	5	81,57	87,27
	10	66,03	79,68
	15	58,26	64,50
	30	38,84	49,32
	45	31,07	41,74
	60	27,19	30,35
	75	27,19	26,60
	90	19,42	22,76
60	5	73,09	77,23
	10	62,27	69,24
	15	51,44	58,59
	30	29,78	34,62
	45	24,36	31,96
	60	21,66	21,30
	75	18,95	18,64
	90	16,24	18,64

Energy efficiency was decrease with increasing drying temperature. Similar result was reported in drying process [14]. Addition of zeolite in drying process affected the drying efficiency. Dehumidification dryer needs an extra energy in regeneration system. Although the dehumidification using extra energy, the efficiency of drying using zeolite is still higher and comparable with drying without zeolite. The advantage of drying with zeolite is increasing the temperature from heat release of adsorption [15].

Table 2. Average drying efficiency of paddy at different drying temperature

Variable	Temperature (^{0}C)	Average energy efficiency (%)
Without zeolite	40	60,99
	50	43,70
	60	37,22
With zeolite	40	70,07
	50	50,27
	60	41,28

The average energy efficiency in paddy drying was listed in Table 2. The average energy efficiency value range from 35.19% to 57.85%. The energy efficiency was comparable with previous study about grain drying. At drying temperature 50˚C, drying grain with capacity 0.3 kg resulted energy efficiency around 24.3% [9].

4. Conclusions

Results showed that use of zeolite lowering the air humidity and increasing driving force for drying. These made the drying rate increased. The higher drying temperature can also increase drying rate. During the drying process, moisture content reduce, the energy that is absorbed by the product decreased. Energy efficiency decrease during the drying process. Also, addition of zeolite in drying process affected the drying efficiency.

Acknowledgement

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