

Constant rate of paddy rice drying using air dehumidification with zeolite

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Abstract. Drying using air dehumidification with zeolite has the purpose to produce paddy rice with lower moisture content and to enhance the storage life. In this study, the paddy rice was dried from initial moisture content 21% wet basis to 14% wet basis (final moisture content) using fluidized bed dryer and dehumidification with zeolite. This dryer lifted the paddy from the bottom (fluidized state) so the final moisture content was uniform. The paddy was dried in various drying temperatures (40-60°C). The moisture content was observed every 15 minutes for 120 minutes. As the control, paddy was dried without using air dehumidification. Several thin layer model was used to determine the constant rate of the drying and then the drying time can well be predicted. Result showed that Two term model was suitable to determine the constant rate of the drying. The constant rate of the drying was 19% higher in drying using air dehumidification.

Keywords : *constant rate, dehumidification, drying, paddy, zeolite*

1. Introduction

Agriculture, especially paddy (*Oryza sativa* L.) cultivation become a concern for Indonesian Government. The paddy field area in Indonesia at 2015 was 14,116,638 ha and the production was 75,397,841 ton [1]. One of the important quality of paddy is the moisture content. Inadequate drying of postharvest paddy that resulted higher moisture content can lead quality deterioration and development of insects and molds. Paddy must be dried until moisture content 14 % or less (wet basis) to get the storage life around 18 months before milling [2,3].

Paddy has been dried with two methods, using sun dryer and conventional dryer. Sun drying is the conventional drying method that free and using renewable energy resources. But sun drying process easy to contaminated and depends on the weather condition that usually unpredicted [4]. The conventional dryer using fluidized bed dryer gives many advantages: (1) moisture content of the product is uniform because the complete mixing; (2) high drying capacity and high drying rate due to high surface area; (3) Small equipment and lower initial cost [5,6].

Fluidized bed dryer using high drying temperature (85-90 °C) was observed in previous study [6]. In higher drying temperatures, the quality of paddy like head rice yield, amylose content, and gel



consistency decreased. Considering to the quality of paddy and efficient drying process, the drying process that operated in lower drying temperature and high energy efficiency must be done.

Dehumidification of the air for drying through adsorption by adsorbents (silica gel, zeolite) was used to dry the food product: cabbage, eggplant, carrot, butterbur and spinach [7]; onion [8]; carrageenan [9]; seaweed [10]. Zeolite consists of SiO_4 (neutral charge) and AlO_4 (negative charge). The ability to adsorb water comes from the negative charge that links to positive ions. There are two types of zeolite: as an engineered product and as a natural product (clay and stones). The effect of engineered zeolite is very significant at drying temperature below 80°C [4,9].

This work aims to produce the paddy with lower moisture content using air dehumidification by zeolite. The effect of addition zeolite and drying temperature is evaluated. The experimental results are fitted to several thin layer model to describe the drying phenomenon.

2. Materials and Methods

2.1. Paddy drying

Postharvest of paddy rice provided from a local farmer in Tembalang districts, Semarang, Indonesia. Initial moisture content in paddy was 21% (wet basis), analyzed by Grain Moisture Meter, (GMK 303 RS, Gwon) Paddy rice was placed in fluidized bed dryer chamber under drying temperature (40°C - 60°C). The drying process took place for 120 minutes with the superficial velocity of 5.51 ms^{-1} . The moisture content was determined every 15 minutes. In the drying process, the zeolite (zeolite 3A provided by Zeochem, Switzerland) was added as the air dehumidifier. The zeolite was regenerated after each process to avoid the saturated zeolite. As a comparison, the control sample (without the addition of zeolite) was dried.

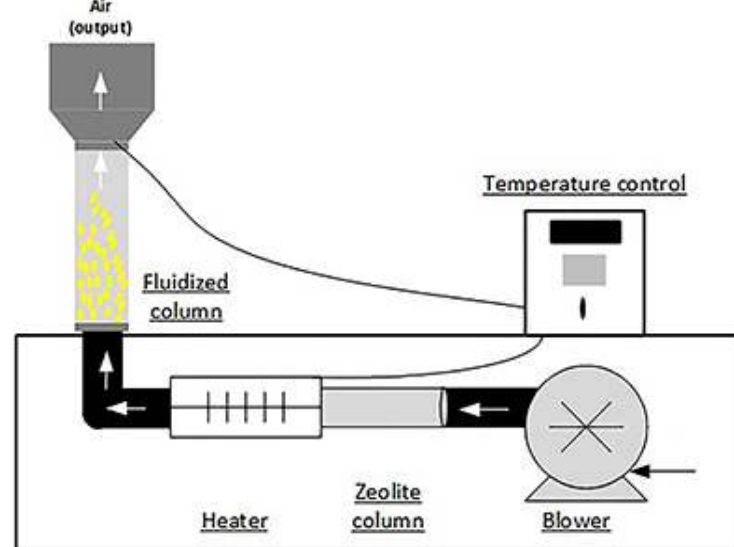


Figure 1. The schematic overview of the fluidized bed drying equipment from Djaeni et al. with modification [4].

2.2. Moisture ratio

The correlation between moisture ratios with time in paddy drying can be represented by Equation 1

$$MR = \frac{(M_t - M_e)}{(M_0 - M_e)} \quad (1)$$

where M_t was the moisture content at time t , M_0 was the initial moisture content, M_e was the equilibrium moisture content of paddy, all of them in dry basis (g g^{-1}). The equilibrium moisture content in paddy was estimated using oswin model as expressed below [11].

$$M = A[a_w/(1 - a_w)]^B \quad (2)$$

where M is the moisture content (kg kg^{-1} , dry based), a_w is the water activity, A and B are constants (dimensionless). The value of A and B can be extended as using quadratic equation (Equation 3 and 4) to get the value in higher temperatures.

$$A = 3 \times 10^{-6}T^2 - 0.0012T + 0.1418 \quad (3)$$

$$B = -0.0001T^2 + 0.0116T + 0.0876 \quad (4)$$

2.3. Model fitting

Moisture ratio of paddy drying was fitted to several thin layer model (Table 1). As an indicator, the coefficient of determination (R^2) and Root Mean Square Deviation (RSMD) were evaluated using POLYMATH Educational 6.0 software. The best model can be judged based on the highest R^2 value and the lowest RSMD value.

Table 1. Thin layer model.

Model	Model equation	References
Newton	$MR = \exp(-kt)$ (5)	O'Callaghan et al. [12]
Handerson-Pabis	$MR = a \exp(-kt)$ (6)	Henderson and Pabis [13]
Page	$MR = \exp(-kt^n)$ (7)	Page [14]
Logaritmic	$MR = a \exp(-kt) + c$ (8)	Yagcioglu et al. [15]
Two term	$MR = a \exp(-kt) + b \exp(-ft)$ (9)	O'Callaghan et al. [16]

3. Results and discussion

3.1. Effect of air dehumidification using zeolite

The initial moisture content of postharvest paddy was 21% (wet basis). The quality deterioration and development of insects and molds happen in paddy storage at higher moisture content. In this case, paddy must be dried until moisture content 14 % (wet basis). At the storage condition with moisture content 14%, the storage life around 18 months before milling [2,3].

Paddy was dried in fluidized bed dryer for 120 minutes. After drying process, all variable resulted the final moisture content range from 9 until 12.7 % (wet basis). The correlation between moisture content and drying time for drying with and without zeolite at drying temperature 40°C was depicted in Figure 2. Lower moisture content was derived from the drying using zeolite as the air dehumidifier.

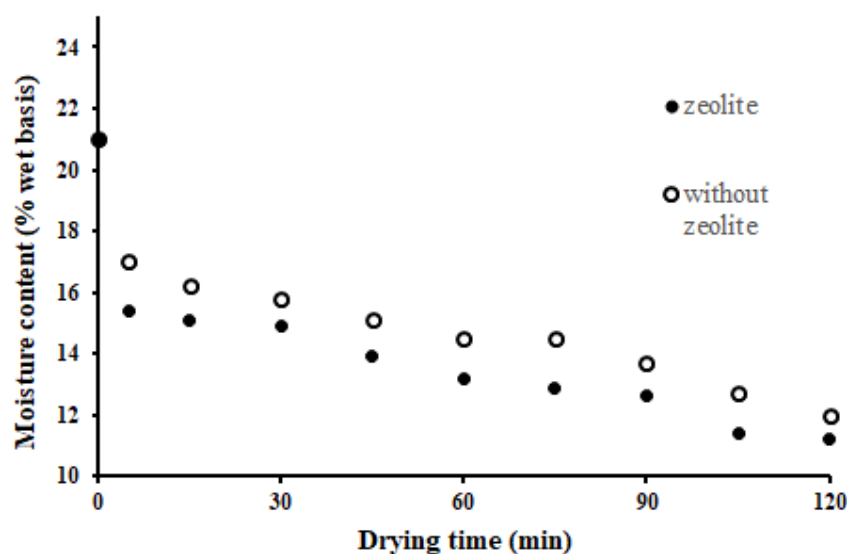


Figure 2. Effect of zeolite on moisture content.

There were two advantages of air dehumidification using zeolite, enhanced the driving force of the drying by the lower air humidity and increased the air drying temperature by release the heat of adsorption [17]. Application of zeolite as the air dehumidifier in the drying process enhanced the dryer efficiency. Energy efficiency of dryer using zeolite for food product was previously studied. The dryer that was operated with zeolite at drying temperature 50-60 °C resulted efficiency until 75% [18]

The constant rate of the drying using zeolite at drying temperature 40 °C was 19 % higher than without zeolite (Henderson-Pabis model), see Table 2. Higher constant rate of the drying resulted lower moisture content. Another study about paddy drying using mixed adsorption drying with zeolite resulted the drying time was 5-10% faster than without zeolite [4]. On the other hand, the dryer operation with zeolite in lower drying temperature give the advantage in order to retain product quality [7], [19].

Table 2. Model constant and statistical analysis on thin layer drying of paddy.

Model	Parameter	T (°C)	Model Constant			R ²	RSMD	
Newton	Zeolit	40 ⁰ C	k:0.0064			0.2524	0.0335	
		50 ⁰ C	k:0.0068			0.2568	0.0348	
		60 ⁰ C	k:0.0086			0.6123	0.0319	
	Without zeolit	40 ⁰ C	k:0.0046			0.3437	0.0258	
		50 ⁰ C	k:0.0055			0.4738	0.0265	
		60 ⁰ C	k:0.0070			0.7844	0.0221	
Handerson-Pabis	Zeolit	40 ⁰ C	k:0.0040	a:0.8401		0.7390	0.0198	
		50 ⁰ C	k:0.0042	a:0.8336		0.7399	0.0206	
		60 ⁰ C	k:0.0062	a:0.8483		0.8493	0.0199	
	Without zeolit	40 ⁰ C	k:0.0030	a:0.8809		0.7680	0.0153	
		50 ⁰ C	k:0.0037	a:0.8755		0.8174	0.0156	
		60 ⁰ C	k:0.0054	a:0.8953		0.9201	0.0135	
Page	Zeolit	40 ⁰ C	k:0.1550	n:0.2651		0.9857	0.0046	
		50 ⁰ C	k:0.1681	n:0.2573		0.9579	0.0083	
		60 ⁰ C	k:0.1223	n:0.3836		0.9478	0.0117	
	Without zeolit	40 ⁰ C	k:0.1044	n:0.2880		0.9424	0.0076	
		50 ⁰ C	k:0.1027	n:0.3274		0.9582	0.0075	
		60 ⁰ C	k:0.0629	n:0.4946		0.9577	0.0098	
Logaritmic	Zeolit	40 ⁰ C	k:0.0773	a:0.3435	c:0.6126	0.8750	0.0137	
		50 ⁰ C	k:0.0407	a:0.3340	c:0.5730	0.8111	0.0176	
		60 ⁰ C	k:0.0183	a:0.4892	c:0.3940	0.8683	0.0186	
	Without zeolit	40 ⁰ C	k:0.0360	a:0.2659	c:0.6695	0.8218	0.0134	
		50 ⁰ C	k:0.0242	a:0.3243	c:0.5939	0.8554	0.0139	
		60 ⁰ C	k:0.0127	a:0.5398	c:0.3759	0.9300	0.0126	
Two term	Zeolit	40 ⁰ C	k:0.0025	a:0.7511	b:0.2489	f:0.4360	0.9956	0.0026
		50 ⁰ C	k:0.0030	a:0.7620	b:0.2378	f:9.0459	0.9917	0.0037
		60 ⁰ C	k:0.0048	a:0.7680	b:0.2320	f:1.3856	0.9844	0.0064
	Without zeolit	40 ⁰ C	k:0.0021	a:0.8252	b:0.1748	f:0.7756	0.9723	0.0053
		50 ⁰ C	k:0.0027	a:0.8138	b:0.1862	f:0.6506	0.9893	0.0038
		60 ⁰ C	k:0.0047	a:0.8513	b:0.1490	f:16.7292	0.9927	0.0041

3.2. Effect of drying temperatures

The drying was done with variation of drying temperature (40-60⁰C). The curve of moisture content versus time was depicted in Figure 3. After the drying process, the final moisture content of paddy dried with zeolite in drying temperature 60⁰C was 9% (wet basis), while in drying temperature 50⁰C was 11.2% (wet basis). The result showed that the higher temperature, higher moisture that was evaporated. The constant rate of the drying using Henderson Pabis model in temperature 60⁰C was 1.6

times higher than in temperature 50°C (see Figure 2). At higher drying temperature, the air bring more sensible heat for evaporation and the relative humidity of air is low. So, the drying rate was higher in higher drying temperature [4,20,21].

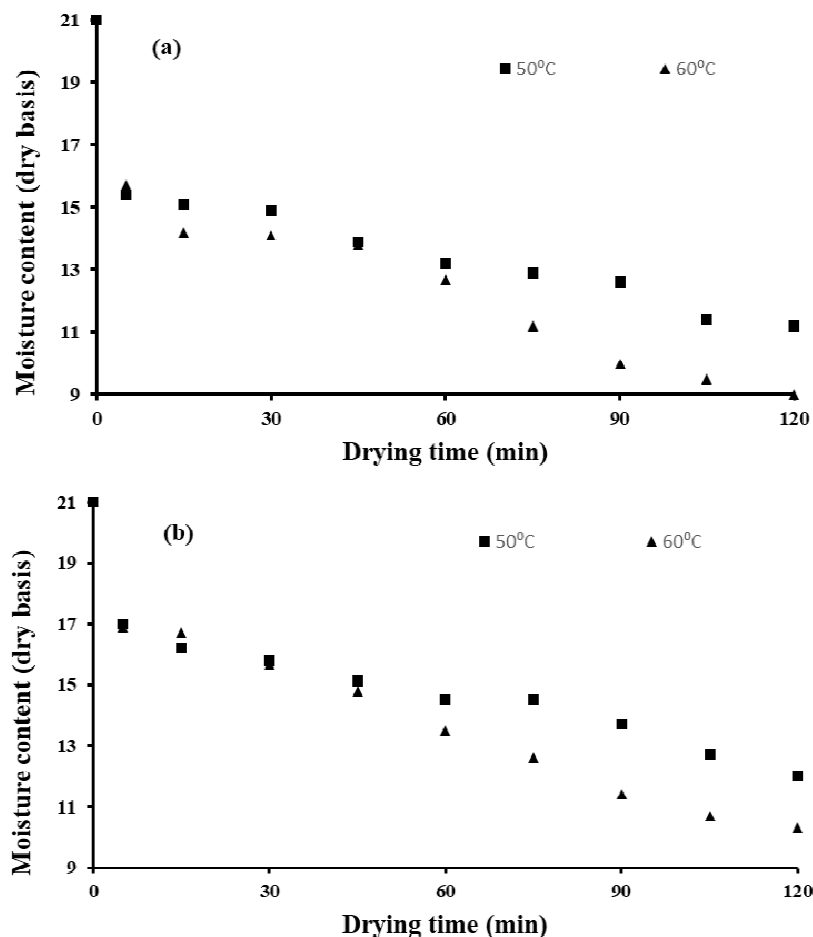


Figure 3. Effect of drying temperature on moisture content (a) zeolite (b) without zeolite.

3.3. Model fitting

The moisture ratio data of paddy drying using zeolite and without zeolite at different temperatures were fitted into several the thin layer drying model. The constant and statistical analysis are listed in Table 2. Two term gave the highest R^2 value range from 0.9723 until 0.9956 and the lowest RSMD value range from 0.0026 until 0.0064. The two term model was selected to describe the drying phenomenon in paddy drying with and without zeolite. Two term model was selected in various food drying: bael pulp drying [22], Channa fish (*Channa lucius*) [23], dika nut (*Irvingia gabonensis*) [24]. Figure 4 demonstrated the experimental curve and calculated curve using Two term model in paddy drying using zeolite in various drying temperature.

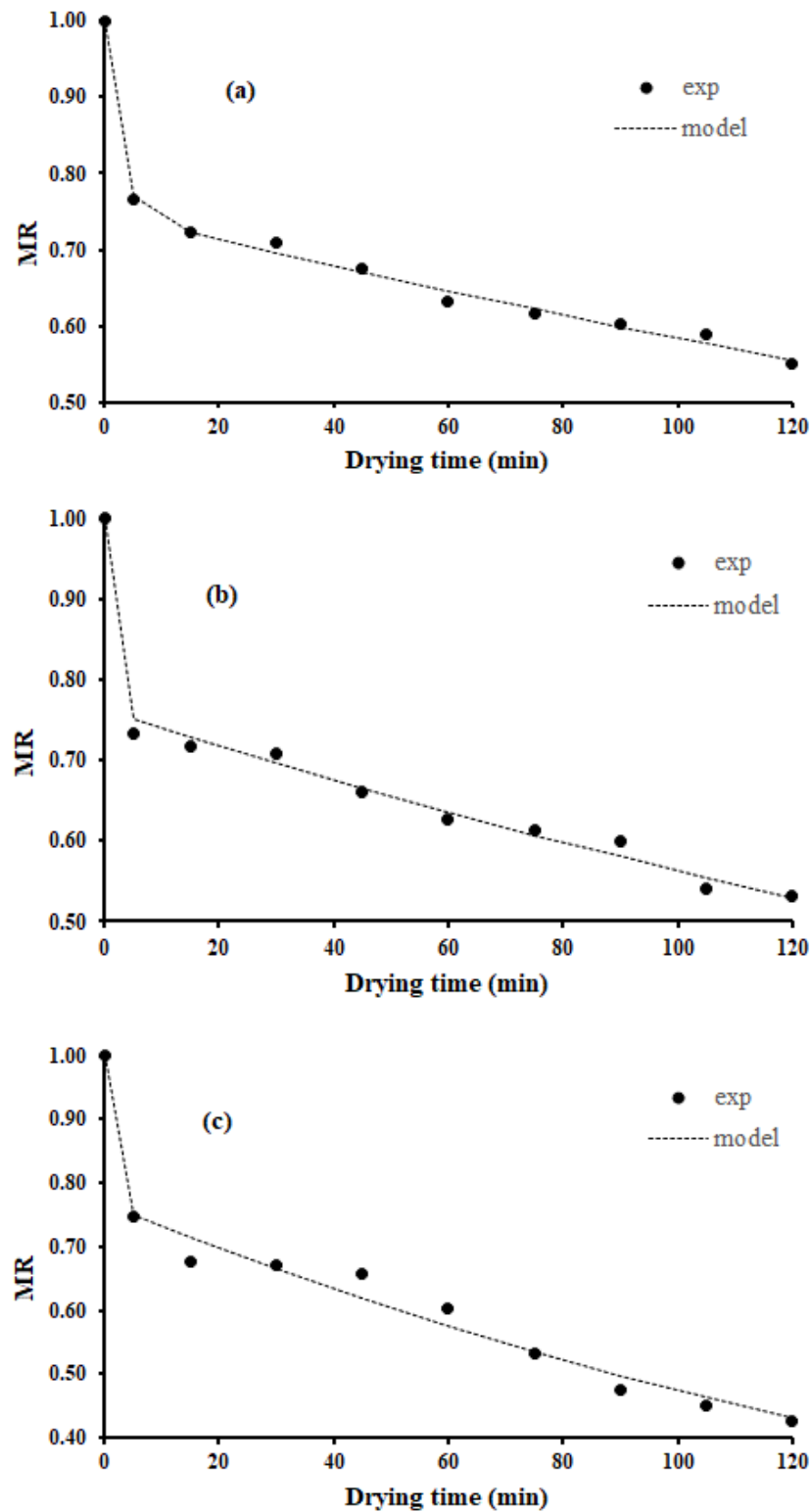


Figure 4. Comparison of experimental and calculated (model) moisture ratio curves of paddy drying using zeolite at various drying temperature (a) 40°C (b) 50°C (c) 60°C.

4. Conclusion

Paddy must be dried until moisture content 14% to avoid the quality deterioration, to avoid development of insects and molds and to enhance the storage life. The paddy drying was done with addition of zeolite under various drying temperature. Zeolite as air dehumidifier performed well. The constant rate of the drying using zeolite at drying temperature 40°C was 19% higher than without zeolite. Zeolite enhanced the driving force of the drying by the lower air humidity and increased the air drying temperature by release the heat of adsorption. The constant rate of the drying in temperature 60°C was 1.6 times higher than in temperature 50°C. The drying rate was higher in higher drying temperature because the air bring more sensible heat for evaporation and the relative humidity of air is low. The two term model was selected to describe the drying phenomenon in paddy drying with and without zeolite with R^2 value range from 0.9723 until 0.9956 and the RSMD value range from 0.0026 until 0.0064

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