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Drying Kinetics of *Curcuma xanthorrhiza* Roxb.

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Abstract

Curcuma xanthorrhiza Roxb. (giant curcuma) is one of herbal plants which is easily found in tropical region such as in Indonesia and has been widely used for medical purposes. This plant has been intensively used as the main ingredients of traditional medicines due to its potent healing power. Giant curcuma is generally dried using a conventional way under the sun prior to use. This method was less controlled, thus leading to poorer quality of products. Drying in a controlled batch dryer could improve product quality in overall. This experiment aimed to study the drying kinetics of giant curcuma using a laboratory designed batch dryer. Drying temperatures were varied between 40°C to 60°C. Samples were also dried in the oven at corresponding temperatures as the control. The drying was conducted until approximately 11 % dry basis moisture content inside the samples was achieved. In general, the drying time of giant curcuma were shorter when the temperatures were increased. This was also confirmed by Page's Model whereby drying rate constants increased four times both in the batch dryer as well as in the oven when the drying temperatures were increased from 40°C to 60°C.

Keywords: batch dryer; drying rate; diant curcuma; Page's Model.

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1. Main text

Herbs have been used by Indonesian for a long time ago as a medical alternative, for disease prevention, healing, rehabilitation, and for promoting health [1] since herbs contain biological active compounds and antioxidants so that they can as be used medicines with low side effects. Herbs used as medicines could be in the forms of rhizomes or leaves. The moisture contents of herbs used for medicinal purpose may not exceed 10 % water in wet basis or approximately 11 % dry basis [2].

Giant curcuma (*Curcuma xanthorrhiza* Roxb.) which is also known as Java Ginger or Javanese Ginger [3], has been intensively used as traditional medicines. This herb is easily found in Indonesia and has been one of important herbs because of its bioactive compound.

For medicinal purposes, giant curcuma must be properly dried for the initial use to reduce its bulky volume and increase the shelf-life. There are several common techniques for drying herbs in a more controlled way, such as drying using hot air and oven is mostly used to dry herbs. Both techniques are quite simple and not expensive. In this experiment, a self-designed batch dryer with varying hot air temperatures was used for drying the giant curcuma. A blower was used for the hot air circulation. The drying characteristics of the samples dried in batch dryer were compared with those dried in the oven. Furthermore, the drying kinetics of biological materials is essential for the design, optimization, and control of the drying process [4]. Therefore, the drying kinetics using Page's model was also studied.

2. Materials and methods

2.1. Raw materials

Giant curcuma (*Curcuma xanthorrhiza)* which is usually known as 'temulawak' was purchased from Jagir Local Market, Surabaya, Indonesia. At first, dust and dirt were manually removed out from the giant curcuma. Afterwards, it was horizontally sliced with the thickness of about 3 mm. Slices were collected and weighed using a balance (Mettler, Toledo) which had accuracy up to 0.1 mg prior to drying.

2.2. Instruments

Drying was conducted in the self-designed batch dryer and also in the oven (MMM Medcanter, Germany). The self-designed batch dryer was depicted in Fig. 1. It was equipped with a blower which has 500 VA capacity and regulator type 242,5M fabricated by Matsunaga MFG, co., LTD, Japan used to control the speed of hot air.

2.3. Drying process

The drying temperatures were set at 40°C; 50°C; 60°C both in the batch dryer and oven. During the experiments, RH (relative humidity) of the air was fluctuated between 30 % to 70 %. The hot air flow rate was set at 2.1 $m \cdot s^{-1}$ during the experiments using the batch dryer. Two slices of giant curcuma were put into the sample holder and placed in the dryer once the temperature inside the dryer was already steady. Samples were continuously weighed after a certain time until reaching a constant weight.

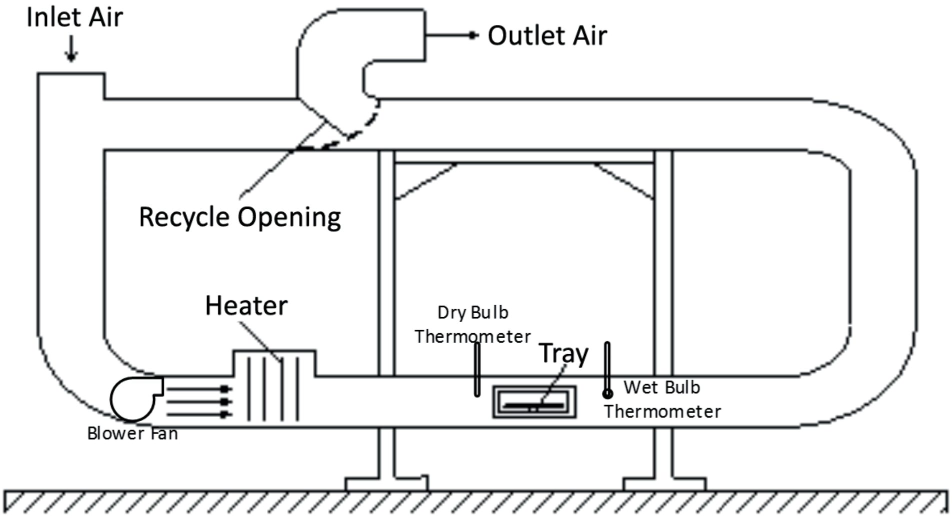

Figure 1: Self-designed batch dryer.

2.4. Data processing

Results were presented as drying characteristic curves whereby free moisture contents (X) were plotted versus the drying time [5]. Free moisture content was obtained from the subtraction of equilibrium moisture content (X*) from moisture content at certain time (X_t). The calculation of X_t and X could be seen in Equation (1) and Equation (2), respectively.

$$X_t = \frac{W_t - W_d}{W_d} \tag{1}$$

where X_t = moisture content at certain time (kg H_2O/kg dry weight); W_t = sample weight at certain time (kg); W_d = sample dry weight (kg) obtained from drying up the sample at 120°C for about 2 hours until the weight was constant.

$$X = X_t - X* \tag{2}$$

where X = free moisture content (kg H_2O/kg dry weight); X_t = moisture content at certain time (kg H_2O/kg dry weight); X* = equilibrium moisture content (kg H_2O/kg dry weight).

Furthermore, drying rate (R_c) was plotted against free moisture content (X) in order to study the constant rate zone and falling rate zone [5].

$$R_c = -L_s \frac{dX}{dt} \tag{3}$$

where R_c = drying rate (kg H_2O/min); Ls= sample dry weight (kg); dX/dt = rate of free moisture changes per time (kg H_2O/(kg dry weight.min)). The slope of Eq. (4) and Eq. (6) was determined yielding Eq. (5) and Eq. (7) for calculating dX/dt for constant rate

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zone and falling rate zone, respectively. The data was processed using Microsoft Excel 2013 and Curve Expert Professional 2.3.0.

$$X = at + b \tag{4}$$

$$\frac{dX}{dt} = a \tag{5}$$

$$X_t = a \times \ln t + b \tag{6}$$

$$\frac{dX}{dt} = \frac{a}{t} \tag{7}$$

The loss of moisture content in wet basis could be calculated using Eq. (8).

$$Loss = 100\% - \frac{W_t - W_d}{W_i} \tag{8}$$

where W_t = giant curcuma weight in certain time (kg); W_d = dry solid weight (kg); and W_i = initial weight of giant curcuma (kg).

2.5. Mathematical modeling

According to the study of Ademiluyi et al. [6] and Tarigan et al. [7] drying kinetics were mathematically modeled using Page's Model of which equation is

$$MR = e^{-k.t^n} \tag{9}$$

where MR is ratio between free moisture content at certain time and initial free moisture content; k is drying rate constant in $hour^{-1}$, n is dimensionless constant from Page's Model, and t is drying time in hour.

3. Results and discussion

From the experiment, it was obvious that the drying time was getting shorter as the temperature was increasing both in the oven as well as in the batch dryer as can be seen in Fig. 2. The slopes were getting steeper as the increased temperatures indicating the higher drying rate with the increase of temperature. Similar findings have been reported by Jabeen et al. [8].

In general, drying process were occurred in two periods, i.e. constant rate period and falling rate period as could be more clearly seen in Fig. 3. In the constant-rate drying period, the surface of the solid was initially very wet and a continuous film of water existed on the drying surface [5]. This period continued as long as the water diffusion rate inside the pores to the surface was equal to the evaporation rate of water from

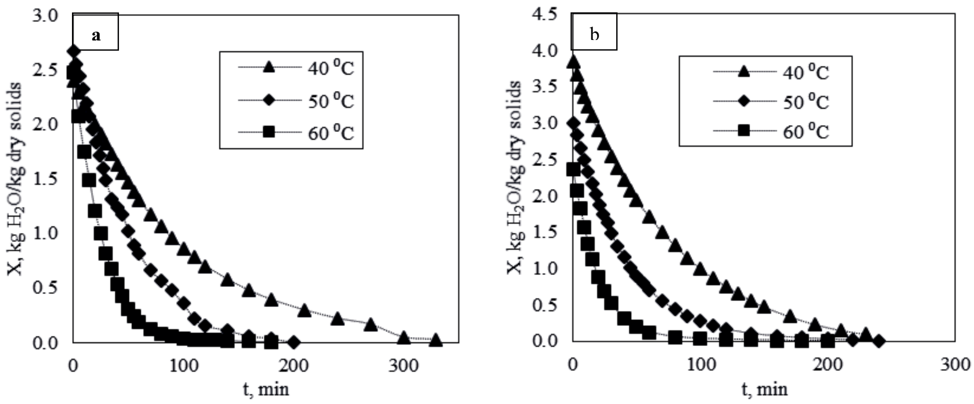

Figure 2: Free moisture content versus time at varying temperatures. (a) oven; (b) batch dryer.

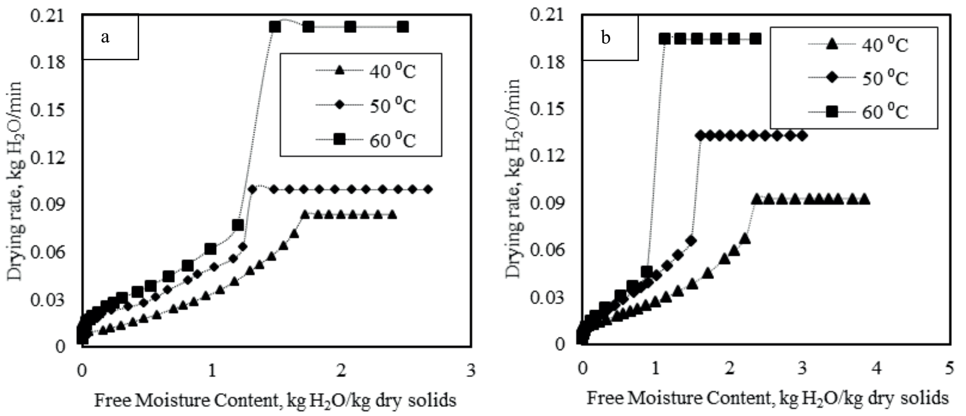

Figure 3: Rate of drying curve as rate versus free moisture content at varying temperatures. (a) oven; (b) batch dryer.

the surface to the air. The falling rate period just began when the entire surface was no longer wetted and the wetted area was continually decreasing until the surface was completely dry. It was also obvious from Fig. 3 that the constant drying rate (Rc) were higher as temperatures increased.

The increase of drying rate with the increase of temperature was also confirmed by empiric constant k derived from fitting the experimental data with Page's model (Fig. 4 and Table 1). The constant k which was related to drying rate was increased ~4 times when the temperature was increased from 40°C to 60°C both in the oven as well as in the batch dryer as could be seen in Table 1.

It was also clearly seen that drying kinetics in the batch dryer was faster than those in the oven. The value of k derived from drying process in the oven was about 25 % lower than the corresponding k obtained from the drying process conducted in the batch dryer. This was plausible since the convective heat transfer in the batch dryer was more improved due to the continuous hot air flowing throughout the sample, thus

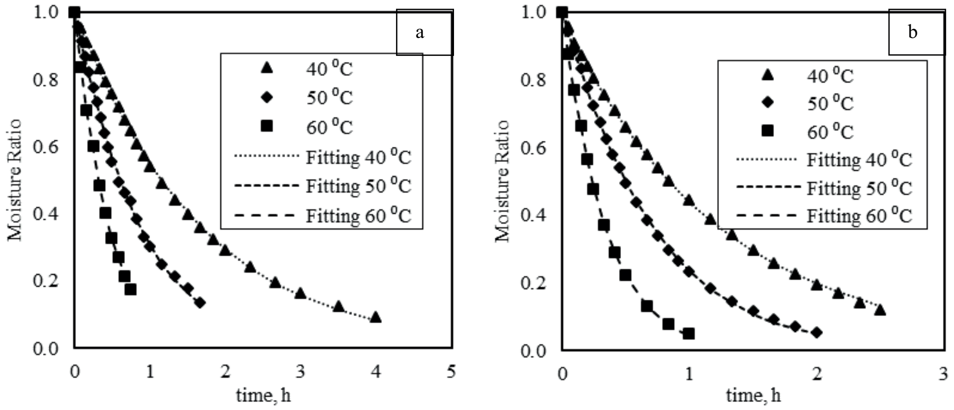

Figure 4: Fitting of experimental drying data using Page's Model. (a) oven; (b) batch dryer.

Dryer	Temperatures (°C)	Page's Model Parameter		
		k	n	r^2
Batch dryer	40	0.821	0.981	0.999 8
	50	1.442	1.064	0.999 8
	60	3.113	1.056	0.999 9
Oven	40	0.594	1.036	0.999 7
	50	1.174	1.072	0.999 2
	60	2.338	1.070	0.999 6

Table 1: Parameter of drying kinetic from Page's model.

enhancing the water vapor mass transfer from the sample to the hot air in contrast to the less dynamic air flow in the oven.

Finally, the total loss of moisture (wet basis) inside giant curcuma during drying process was shown in Table 2. In overall, all drying temperature could remove out more than 99 % moisture (wet basis) although the moisture loss was increased when drying temperature was increased. The final moisture content was lower when giant curcuma was dried at higher temperature. The moisture loss during drying in the batch dryer

Time (h)	Oven			Batch dryer		
	40 °C	50 °C	60 °C	40 °C	50 °C	60 °C
0	-	-	-	-	-	-
1	62.64	78.15	94.74	66.04	82.90	96.44
2	79.83	95.81	99.37	85.01	95.94	99.27
3	88.71	98.93	99.83	93.31	98.87	99.85
4	93.68	-	99.94	99.04	99.83	99.99
5	98.61	-	-	-	-	-
6	99.40	-	-	-	-	-
Dry basis, last moisture content	2.07	3.96	0.22	0.96	0.17	0.012

Table 2: Loss of Moisture during Drying (% wet basis).

especially within the first hour was higher in comparison to that in the oven. This was indicated by the much lower final moisture content dry basis of giant curcuma dried in the batch dryer. The color of the samples dried in the batch dryer was almost similar to that dried in the oven. However, the higher the temperature the less preserved the color of the giant curcuma was which might be related to the loss of the activity of their bioactive compounds. This experiment showed that the superior drying process conducted in the self-designed batch dryer in comparison to drying process conducted in the oven.

4. Conclusion

The drying process carried out in the self-designed batch dryer was more effective compared to that in the oven. It turned out that drying time required to dry the sample in the batch dryer was shorter due to its higher drying rates. The higher the temperature, the higher the drying rate and the shorter the time required to achieved the constant moisture content. The drying rate constants derived from fitting the experimental data with Page's model were four times higher when the drying temperatures were increased from 40°C to 60°C both in the batch dryer as well as in the oven.

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