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Drying Characteristics of *Curcuma longa* Using Solar Dryer

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ABSTRACT

Curcuma longa (turmeric) is a rhizomatous herbaceous perennial plant which is widely cultivated in tropical regions, such as Indonesia. It has been intensively used for medical purposes as an ingredient of traditional medicine for a long time. In order to extend its shelf-life, turmeric is generally dried under the sun prior to use. This method generally takes a longer time and is less controlled, thus yielding less qualified products. This experiment was carried out using a manually designed solar dryer for improving the drying process of turmeric. The drying process using solar dryer is shorter and also protects the samples from dirt, insects, as well as direct contact with UV radiation which may deteriorate its bio-active compounds. The drying was done until moisture of about 10% content was achieved. In general, it took about 450 minutes in the solar dyer in comparison to that of 480 minutes using sun drying to reach the equilibrium moisture content. This was caused by a higher temperature profile distributed inside the solar dryer accelerating the drying process. The use of solar dryer has the potential to be further developed to replace the conventional sun drying method of herbs.

Keywords: Curcuma longa, drying process, solar dryer, sun drying, turmeric

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INTRODUCTION

Curcuma longa (turmeric) is known as *kunyit* by Indonesians. This herb is very popular in Indonesia because of its benefits. Turmeric has been used as a spice for traditional Indonesian cuisines, as a traditional drink and the most popular as the main ingredient for traditional medicines because of its high antioxidant contents. Turmeric has also been reported to

have a role in preventing diseases such as cancer due to its powerful antioxidant properties and anti-carcinogenic action. It is also said to prevent cardiovascular diseases (Prathapan, Lukhman, Arumughan, Sundaresan, & Raghu, 2009).

Herbs including turmeric must be initially well-dried before being used as the ingredients of traditional medicines. This helps reduce the moisture content, thus also functions as a disinfection, microbial decontamination and long-term preservation in order to prolong its shelf-life (Schweiggert, Carle, & Schieber, 2007). In Indonesia, herbs are simply dried under the sun immediately after they are harvested. The direct contact of sunlight could destroy the bioactive compounds retained in the samples. Besides that, the drying process is uneasy to maintain since temperature and humidity tend to fluctuate. Furthermore, there has been a greater risk for being contaminated due to insects, birds, or other animals, and dust (Weiss & Buchiner, 2001). Solar dryer has become one of the drying alternatives harnessing the sun energy but in a more controlled way and could eliminate the contaminants. Heat from the sun is collected and transferred indirectly to the herbs, thus preventing the deterioration of their bioactive compounds and improving the overall product quality. Solar dryer has been categorised into 2 types - either active or passive, depending on the presence of fan / blower facilitating the air flow inside the solar dryer.

The main purpose of this work is to study the drying characteristics of turmeric using a passive type solar dryer. The solar dryer was self-designed by Suyanto and Antoro (2016) and had been continually modified to improve its performance for drying herbs in a more efficient and controlled way.

MATERIALS AND METHODS

Turmeric (*Curcuma longa*) was purchased from Jagir Local Market, Surabaya, Indonesia. The turmeric was separated from dust and dirt. It was then sliced horizontally with a thickness of about 3 mm and weighed about 7 grams as a sample using a balance (Mettler, Toledo) before being dried. It was dried under the sun and in the solar dryer until reaching a constant weight and the final moisture content was below 10% (Ministry of Health Republic of Indonesia [KEMKES], 1994).

The solar dryer was self-designed using aluminum for the body, plywood board for the door, glass for the heat collector, and black painted aluminum for absorbing heat from the sunlight. There were four trays arranged vertically as sample containers. The details of the solar dryer design are shown in Figure 1.

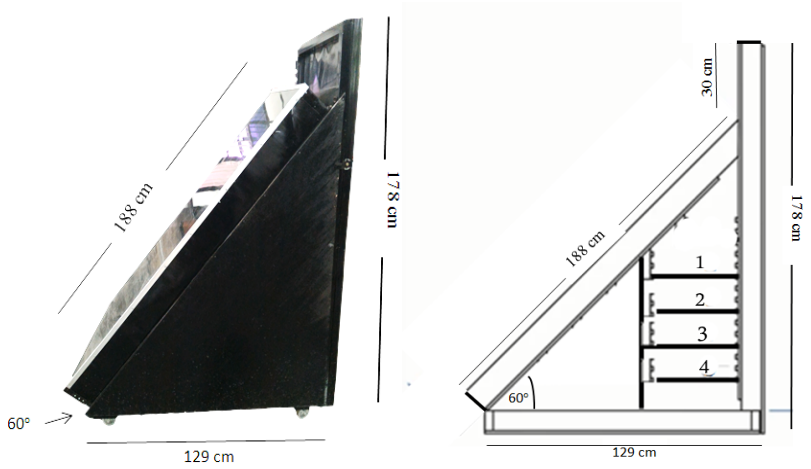

Figure 1. Self-designed solar dryer

Approximately 2 kg turmeric samples were distributed on all trays (tray 1, 2, 3, 4). There was a boundary circle area in the middle of each tray containing of three to four slices for samplings. The temperature of each tray was recorded using thermocouple every five minutes and the sample was weighed every 30 minutes. All trays were rotated downwards every two hours (Figure 2) in order to equalise heat distribution absorbed in each tray since the first tray generally received maximum sun radiation. The solar dryer was moved from time to time following the sun direction.

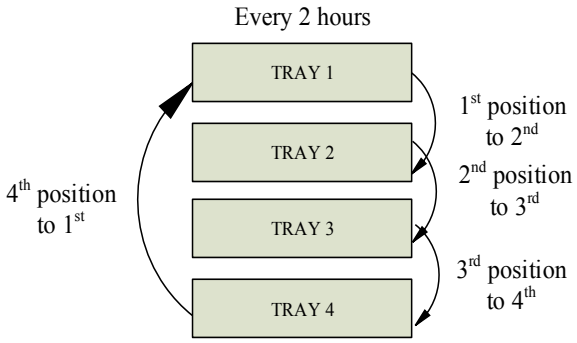

Figure 2. The sequence of tray rotation

The sampling process was conducted in two days. On the first day, sampling was conducted from 9.00 a.m. until 3.00 p.m. The data was simply continued by the sampling taken on the following day starting from 9.00 a.m. until it reached equilibrium weight. Sun drying was also conducted for the comparison of the drying process conducted in the solar dryer. The turmeric

slices were evenly distributed on a tray and placed under the sun until the drying process was completed. During the samplings, two slices of turmeric samples in the middle of the tray were weighed every 30 minutes. The air temperatures, both dry bulb and wet bulb temperatures were measured using alcohol thermometers and the corresponding RHs were calculated using the psychrometric chart.

Results were presented as drying curves whereby free moisture content (X) was monitored versus the drying time (Geankoplis, 2003). Free moisture content was obtained by deducting the equilibrium moisture content (X^*) from the moisture content at certain time (X_t). The calculation of X_t and X can be seen in equation (1) and (2).

$$X_t = \frac{W_t - W_d}{W_d} \quad [1]$$

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 after sample was dried at 120°C for about two hours.

$$X = X_t - X^* \quad [2]$$

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). The drying rates were also analysed using equation (3) (Geankoplis, 2003).

$$R = R_c.A = -L_s \frac{dX}{dt} \quad [3]$$

where R_c= constant drying rate (kg H_2O/ minutes), Ls= sample dry weight (kg), dX/dt= rate of free moisture changes per time (kg H_2O/ (kg dry weight. minutes)). The data was processed using Microsoft Excel 2013 and Curve Expert Professional 2.3.0.

RESULTS AND DISCUSSION

Sun Drying

Drying process under the sun was dependent on the ambient air temperatures and RH. The temperatures and RH profiles during the experiment are presented in Figure 3. Dry air temperatures ranged from 35°C to 41°C with mean temperature of about 38.5°C, and RHs were in the range of about 51% to 65%.

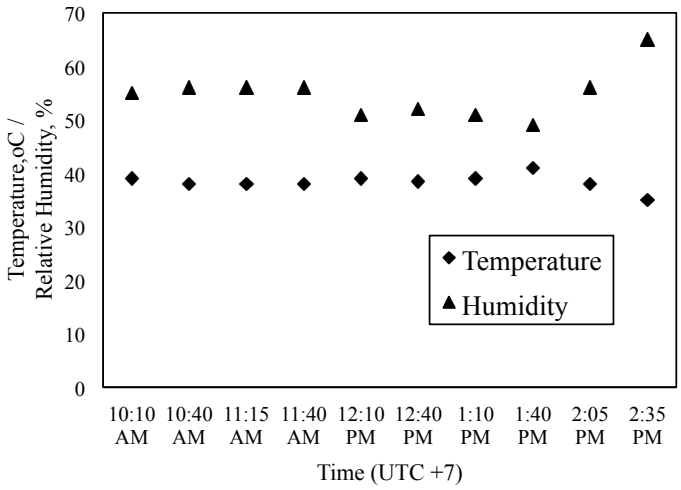

Figure 3. Temperature and relative humidity profiles during sun drying

The drying characteristics of turmeric using sun drying mode can be seen in Figure 4. The free moisture contents continuously decreased until it became constant. Drying began with the constant rate (from 0 minutes until 150 minutes) followed by the falling rate (from 150 minutes until it reached constant moisture content). Drying of turmeric under the sun took about eight hours (480 minutes) to reach the required moisture content of 10% or free moisture content of about 11.1%, according to Indonesian government regulations.

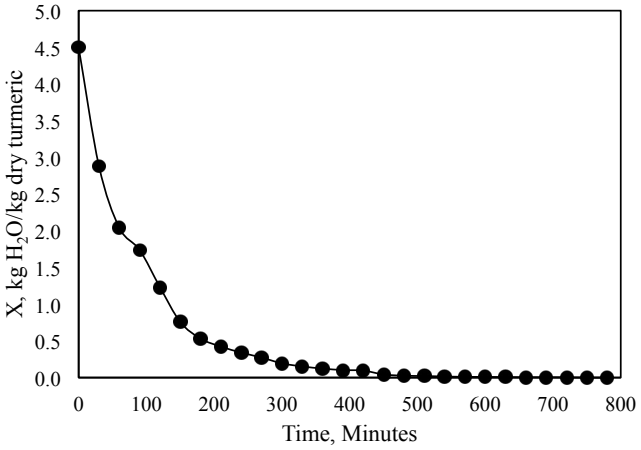

Figure 4. Free moisture content versus time during sun drying

Solar Drying

During the experiment using the solar dryer, the measured temperatures on each tray fluctuated depending on heat intensity. The highest temperature achieved during drying was about 55°C and occurred between 12:24 p.m. to 1.00 p.m. The temperature profiles on each tray inside the solar dryer are shown in Figure 5.

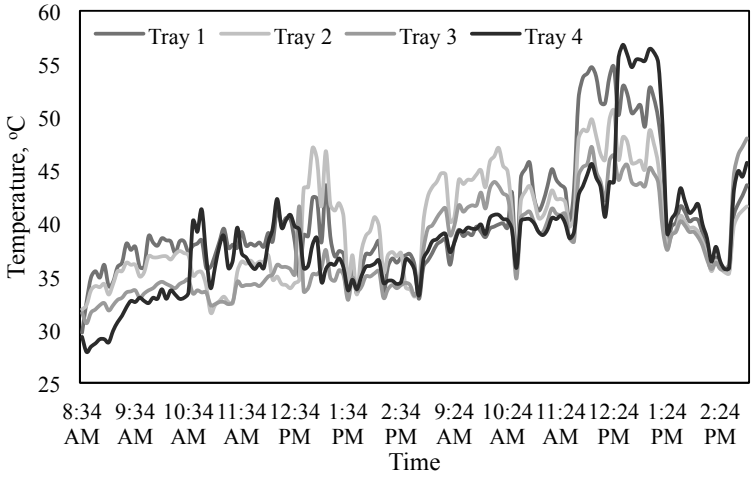

Figure 5. Temperature profiles on each tray inside the solar dryer

The trays which were placed on the top received the highest heat radiation from the sun than the others, thus would reach the highest temperature leading to sample overheating compared to the samples placed on the lower trays. Therefore, trays were rotated during the experiment as shown in Figure 2, so that the temperatures were more evenly distributed amongst the trays. It was evident that the temperature profiles in all trays did not differ very much. The average temperature on each tray was about 37°C to 40°C and the average was about 39°C, which was slightly higher than the average air temperature during sun drying. The temperature inside the solar dryer generally was higher compared to the ambient temperature during sun drying (Weiss & Buchiner, 2001). This was due to heat accumulation in the sunlight collector which was then transferred to the air drying up the samples.

The turmeric drying characteristics in each tray can be seen in Figure 6. Free water content of the turmeric decreased over time until it became constant. Furthermore, after 360 minutes, the free water content of turmeric dried in all four trays approached zero, even though the initial water contents were different and all reached the equilibrium water contents after about 450 minutes of drying. This indicates that homogeneous heat transferred on each rotated tray. Borah, Hazarika and Khayer (2015) previously also dried turmeric using a passive solar dryer. It took about 11 hours to dry the samples until reaching the constant weight. This indicates comparable performance of this self-designed solar drying with other existing passive solar dryers.

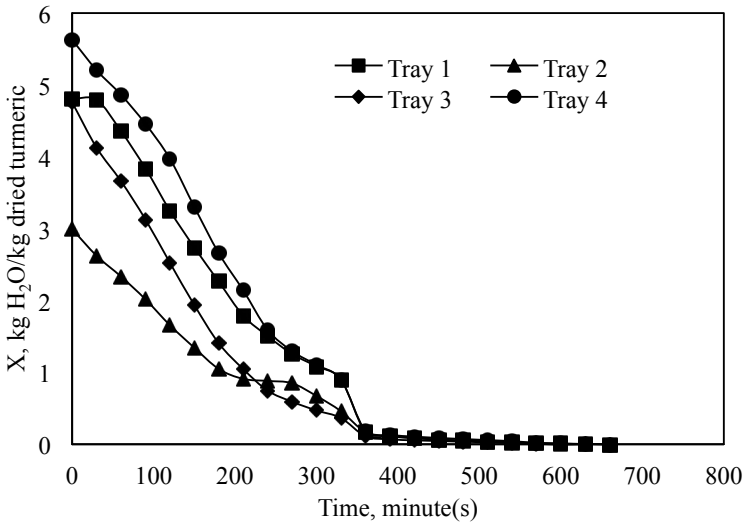

Figure 6. Free moisture content versus time during solar drying

Drying of turmeric at constant rates was indicated by the abrupt linear decrease at the beginning of the drying process. The slope corresponded with the constant drying rate. The steeper the slope the faster the rate of drying was. The differences in these constant drying rates could be due to unsteady temperature profiles (Figure 5) during the rotation of the trays. The calculated constant drying rates of turmeric dried in both solar dryer as well as under the sun are shown in Table 1.

Table 1
Constant drying rate of turmeric

Drying	Tray	Constant drying rate (R_c) [kg H_2O/minutes]
Solar Drying	1	0.01869
	2	0.01863
	3	0.01749
	4	0.01988
Sun Drying	-	0.02442

The constant drying rate of turmeric dried under the sun was a little higher than that dried in the solar dryer. This could be due to more dynamic air flow during sun drying accelerating the drying process during the first period. However, it took 480 minutes for drying turmeric under the sun compared to the time required in the solar dryer of about 450 minutes, until reaching the equilibrium moisture content. This was plausible that the falling rate of turmeric in solar dryer was higher than that of sun drying. Falling rate occurred after the constant rate when rate of water diffusion from the sample surfaced to the air and was higher than the rate of water diffusion from the pores inside the samples to the surface. During the overall drying process,

the average temperatures in the solar drying were slightly higher than the air temperature during sun drying. This would then increase the water mass transfer to the air due to the increase gradient between the saturated vapor pressure inside the sample and partial vapor pressure in the air (Geankoplis, 2003). The colours of the samples dried inside the solar dryer were more preserved compared to those dried under the sun based on the visual observation (Figure 7). This result shows the potential use of the solar dryer for drying herbs in order to prolong their shelf life as well as to ensure their quality. To be able to be used in an active mode, the modification of solar dryer should be further developed in order to improve its performance.

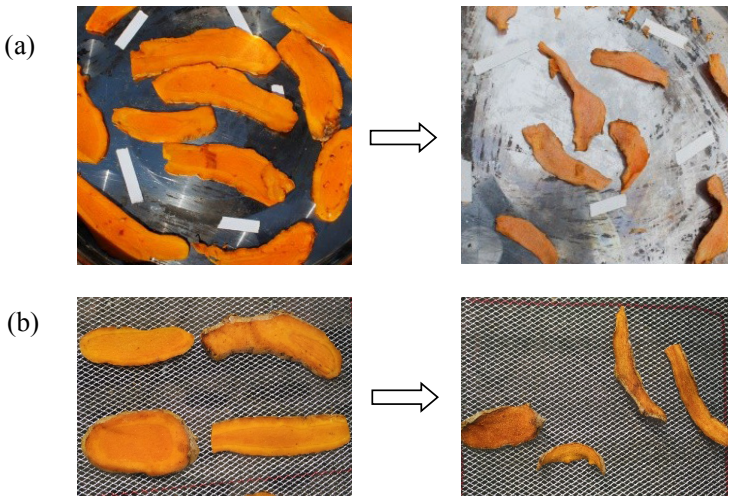

Figure 7. (a) Turmeric (*Curcuma longa*) before and after being dried under direct sun; (b) Turmeric (*Curcuma longa*) before and after being dried in the Self-designed solar dryer

CONCLUSION

Drying of turmeric (*Curcuma longa*) was conducted in a manually designed solar dryer which consisted of four trays. The drying process in all trays was quite similar and the average temperatures on the trays were about 40°C to 41°C. Overall, the drying process of turmeric using the solar dyer was better in comparison to that under the sun in terms of drying time and sample quality. It took about 450 minutes in the solar dryer compared to 480 minutes under the sun for the samples to reach the equilibrium moisture content. The colour of turmeric was better preserved in the solar dryer since the UV radiation did not directly impinge on the samples. Thus, solar dryers should be widely developed and used for producing improved quality of herbs.

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