Drying kinetics and characteristics of dried gambir leaves using solar heating and silica gel dessicant

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Abstract. A drying combination of solar heating and silica gel dessicant has been applied to dry gambir leaves. The solar energy is captured by a collector to heat the air and the hot air is used to dry gambir leaves in a drying chamber. An exhaust fan in drying chamber assists to draw water molecules from gambir leaves accelerated by silica gel dessicant. This study has investigated the drying kinetics and drying characteristics of gambir leaves drying. In drying operation the air velocity is tuned by a PWM (pulse width modulation) controller to adjust minimum and maximum level, which is based on the rotation speed of the exhaust fan. The results show that the air velocity influenced the drying kinetics and drying characteristics of gambir leaves using solar-dessicant drying at 40 cm distance between exhaust fan and silica gel dessicant.

1. Introduction

A gambir leaf (Uncaria gambir Roxb.) is a plant that lives in Indonesia and have small comodity with high economic, and the origin of gambir plants is known with certainty, but allegedly from Southeast Asia. Uncaria gambir is known as safed katha belongs to family Rubiceae, a native Southeast Asian herbal plant, which contains tannins namely, catechutannic acid, acacia catechin, catechu red, catechin, epicatechin & flavonoids–quercetin and quercitrin. In Indonesia, gambir is found growing wild in the forest of Sumatera, Borneo and The Malay Peninsula [1-3].

The shape of gambir plants height is 1.5 to 2 m, the branch colour is light brown to dark brown, branching many angles of 30°-50° from the main trunk. For the gambir leaves, the leaves shape is ovalis, and have young green colour, green brown, and green, with a length 5 cm to 8 cm [1].

Drying is commonly described as the operation thermally removing water content to yield of a product [4]. Drying with sun light method is a conventional method that is still used in many developing countries. Due to low cost, this method still used. However, this method has shortage like contamination of aves, flea, microorganism, dust particle and so on. This method takes long drying time and yields uniform dried material [5].

Generally, the drying process of gambir leaves is still using conventional drying, and the resulting of dried material is not uniform and not hygienic. Therefore, this study applies a drying combination of solar heating and silica gel dessicant. The air velocity in terms of PWM, drying rate, and moisture content related to drying time to study the drying kinetics and drying characteristics have been investigated in this work. The drying method follows the previous work used for drying rosella using solar-dessicant dryer (SDD).
2. Materials and Method

2.1 Materials
Gambir leaves were obtained from Sidikalang farm, silica gel from Rudang jaya and PWM controller was made by Electrical Engineering students from Universitas Sumatera Utara, Medan, Indonesia.

2.2 Preparation of solar-dessicant dryer (SDD)
Solar energy is captured by a collector to heat the air in the collector and the hot air is used to dry the gambir leaves put on the surface of silica gel dessicant. The air velocity can be adjusted by tuning the exhaust fan in drying chamber to minimum or maximum level.

![Figure 1. (a) Solar-Dessicant Dryer Front View (b) Solar-Dessicant Dryer Side View](image1)

![Figure 2. (a) Gambir Leaves before dried and (b) Gambir Leaves after dried](image2)
2.3 Drying

150g of gambir leaves was dried using solar-dessicant dryer (SDD) with a distance of 40 cm between the silica gel dessicant and the exhaust fan. The weight ratio of gambir leaves and silica gel dessicant was made 1:1. The exhaust fan is tuned with a PWM controller (minimum or maximum speed of exhaust fan). Drying started from 10.00 AM to sunset.

2.3.1 Moisture Content.
The moisture content of gambir leaves has been investigated by the standard of SNI 01-3391-1994 with 10g of gambir leaves. Gambir leaves were put in an oven for 24h. The moisture content is calculated as follows [6]:

\[ Mc = \frac{w - wd}{wd} \times 100\% \] (1)

where:
- \( w \) = wet weight (gram)
- \( wd \) = dry weight (gram)

Using this formula, the initial moisture content and moisture content after dried of gambir leaves with SSD method can be determined.

3. Results and discussion

3.1 Initial Moisture content

The average initial moisture content of three replications of 10g gambir leaves put in an oven for 24h is found to be 69-70%.

3.2 Drying kinetics in terms of moisture content

Figure 3 shows the reduction of water content in the drying process of gambir leaves as the drying time getting longer with respect to different speed of exhaust fan (minimum and maximum).

![Figure 3](image_url)

**Figure 3.** The graph of drying kinetics in terms of moisture content with respect to minimum and maximum speed of exhaust fan.

In Figure 3, it is shown that the graph of drying kinetics in terms of moisture content of gambir leaves dried. At \( t = 0 \), the moisture contents of PWM minimum and PWM maximum were found to be 70% and 66%, respectively. In the drying process, the moisture content of PWM minimum decreased much slower than that of PWM maximum [5]. At the end of this investigation (\( t = 300 \) min), the moisture contents of PWM minimum and PWM maximum were found to be 10% and 3%, respectively.

3.3 Drying kinetics in terms of drying rate
Figure 4 shows the decreasing of drying rate in the drying process of *gambir* leaves as the drying time getting longer with respect to different speed of exhaust fan (minimum and maximum), which is referred to PWM minimum and PWM maximum.

![Figure 4](image-url)

**Figure 4.** Drying kinetics in terms of drying rate of *gambir* leaves drying at 40 cm distance between exhaust fan and silica gel dessicant.

At Figure 4 when \( t = 0 \), based on both graphs of drying kinetics, both PWM minimum and PWM maximum show zero drying rate. Moreover, when \( t = 60 \) min, the drying rate of PWM minimum is found to be \( 0.04 \) g/m\(^2\).min, however, the drying rate of PWM maximum is \( 0.20 \) g/m\(^2\).min, and after \( t = 120 \) min, both drying rates decreased with increasing drying time. With respect to the drying rate of PWM minimum, it is fluctuated from \( t = 60 \) min to \( t = 240 \) min. This phenomenon is related to slow heat transfer giving time of phase change from free water liquid to free water vapor and therefore, it shows unstable drying rate. Furthermore, at \( t = 180 \) min, the graph of drying rate of PWM minimum increased again from \( 0.04 \) g/m\(^2\).min\( (t = 120 \) min) to \( 0.02 \) g/m\(^2\).min\( (t = 180 \) min) and after that it continuously decreased.

3.4 **Drying characteristics of *gambir* leaves**

Figure 5 shows the drying characteristics of *gambir* leaves drying. This investigation found two drying periods, i.e. the increasing drying period and the decreasing drying period.

![Figure 5](image-url)

**Figure 5.** Drying characteristics of *gambir* leaves at 40 cm distance between exhaust fan and silica gel dessicant.

Figure 5 reveals that the drying characteristic of PWM maximum shows two periods of drying rate, i.e. the increasing and decreasing drying rates, however, the drying characteristics of PWM
minimum shows three periods of drying rate, i.e. the increasing, constant, and decreasing drying rates. With respect to the drying rate of PWM maximum, the faster speed of exhaust fan caused faster heat transfer and therefore, all free water molecules on the surface of gambir leaves released and directly changed from liquid to vapor. On the other hand, with respect to the drying rate of PWM minimum, the slower speed of exhaust fan caused slower heat transfer and therefore, only part of free water molecules on the surface of gambir leaves changed to water vapor, thus, it shows a fluctuated drying rate referred to a period of constant drying rate. The period of increasing drying rate is related to the release of free water molecules on the surface of a material due to heat transfer, while the period of constant drying rate is related to phase change of water liquid to water vapor indicated that the heat transfer is used for phase change in this period, and the period of decreasing drying rate is associated to releasing of bound water in the capillary system of material subsurface. With respect to the PWM maximum, it can be elucidated that the faster heat transfer causing faster drying process in relation to flammable organic properties of gambir leaves.

4. Conclusion
The study shows that air velocity due to rotation of exhaust fan in terms of PWM level affected the drying kinetics and drying characteristics of gambir leaves drying. This study found that the PWM minimum yielded three periods of drying rate related to part of free water released from material surface changed to water vapor due to slower heat transfer in the first period of drying rate, however, the PWM maximum showed two periods of drying rate related to all free water changed to water vapor due to faster heat transfer in the first period of drying rate.

5. Acknowledgment
The authors gratefully acknowledge that the present research is supported by the University of Sumatera Utara, Medan, Indonesia through Non-PNBP fund under talent research contract 2017.

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