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Original Article

The Kinetics of Drying Process of the Mocaf Chips using Automatic dryer

Anwar Ma'ruf[1*], Alwani Hamad[1], Dini Nur Afifah[1], Itmi Hidayat Kurniawan[2], Arif Prashadi Santosa[3], Fajar Bagas Firmansyah[1]

[1]*Chemical Engineering Department of Universitas Muhammadiyah Purwokerto, Purwokerto, Indonesia*
[2]*Electrical Engineering Department of Universitas Muhammadiyah Purwokerto, Purwokerto, Indonesia*
[3]*Agrotechnology Department of Universitas Muhammadiyah Purwokerto, Purwokerto, Indonesia*

**Corresponding Author : anwarump@yahoo.com*

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Abstract *- The critical process during mocaf (modified cassava flour) production is the drying process. Commonly, the drying of mocaf chips using the conventional method by sunlight dyer. The usage of sunlight has a weakness, especially during the rainy season. On the other side, the time-drying process causes the mocaf chips to become oxidated, resulting in a musty odor and a brownish colour, reducing the quality of the final product.The Automatic dryer is one of the alternative methods for the mocaf drying process. The Automatic dryer uses an electric heater element as the heat source. The research aims to develop the mathematical models of drying kinetics and determine the parameters of the drying process of mocaf chips drying process. The result shows that the kinetics model of drying that best fits the data is the second-order kinetic model. The average of the determinant coefficient is 0.822. At the higher temperature, the drying speed constant gets bigger. The activation energy of drying of mocaf drying is 13.49 x 10^{-3} kcal/gmol.*

Keywords *- Mocaf, Mocaf chips, Drying, Drying kinetics, Moisture content.*

1. Introduction

Modified cassava flour (mocaf) is flour obtained from cassava (Manihot esculenta) by the fermentation process of cassava [1]. In contrast to cassava starch, mocaf can be used as a substitute for wheat flour as an ingredient for making noodles or bread. The critical process during mocaf production is the drying process. Commonly, the drying of mocaf chips using the conventional method by sunlight dyer. The usage of solar dryers has a weakness, especially during the rainy season. On the other side, the time-drying process causes the mocaf chips to become oxidated, resulting in a musty odor and a brownish colour, reducing the quality of the final product.

The Automatic dryer is one of the alternative methods for the mocaf drying process. The Automatic dryer uses an electric heater element as the heat source. The parameters to determine the effectiveness of using automatic dyer are the drying time and temperature of the drying room. Although other researchers have widely studied the study of food drying, however, the research that is studying the kinetics of the drying process of the mocaf chips using an automatic dryer has not been studied much yet. Several researchers have conducted the drying process of cassava chips. Pornpraipech et al. [2] studied the kinetics of drying of cassava chips using oven drying. The variables studied were the shape of cassava chips and the temperature of drying. The temperature ranged from 60 – 120 °C. The final moisture content of cassava dried ranged from 10.69 - 1.62%. The shape of cassava chips affects the final moisture content. The circular shape of cassava chips gives the best moisture content. Silayo et al. [3] studied cassava chips using solar drying. The study focuses on the performance on various surfaces and drying bed depths. The drying process took 24 – 48 hours to achieve the constant weight. Simo-Tagne [20] studied the drying of cassavaroots using a solar dryer in natural convection[4]. The result of the study shows that the drying kinetics was affected by the humidity of the air.

Referring to the kinetics of drying theory, there are several models of kinetics of drying [5 - 7]. The kinetics of drying is developed based on thin-layer drying models. The research aims to develop mathematical models of drying kinetics and determine the parameters of the drying process of mocaf chips. The models of drying kinetics in this research are based on real moisture content. The zero-order, first-order, and second-order are studied. Several factors affect the drying process of mocaf, such as air velocity, temperature, size and shape of the material, and air humidity. From the literature, the most factors are temperature and material thickness. This research focuses on the effect of temperature to determine the constant of drying and the energy of activation of the drying process.

2. Materials and Methods

2.1. Materials

Cassava was obtained from the local market at Banyumas Regency. Lactic acid bacteria (Lactobacillus sp.) was obtained from PT Rumah Mocaf Indonesia, Banjarnegara Regency.

2.2. Methods

2.2.1. Mocaf Production

The amount of 3 kg of cassava was peeled and then washed. Clean cassava was then cut into pieces with a thickness of 0.5 cm. The cassava chips were then fermented using lactic acid bacteria for 3 days. After 3 days, the mocaf chips were then pressed to reduce the water content.Mocaf chips were then dried in an automatic dryer. Figure 1 shows the flow diagram of mocaf production.

2.2.2. Drying Process of Mocaf Chips

The amount of 1 kg of mocaf chips was inserted into the automatic dryer. The temperature of the drying room was set at 40 ^{o}C. Every 2 hours, take one piece of mocaf chips to be analyzed for their moisture content. Figure 2 shows the schematic diagram of the automatic dryer.

3. Results and Discussion

3.1. Drying Process

Figure 3 shows the mocaf chips before and after the drying process. Figure 4 shows the moisture content profile of the mocaf chips during the drying process. From the figure, it canbe seen that at the temperature of 40 – 50 ^{o}C, the optimum process of drying is in the 4 first hours, when the decrease of moisture content is relatively high. At the drying temperature of 40 – 50 ^{o}C, the moisture content of mocaf chips decreases to 8.17% and 4.50%, respectively. While at the temperature of 60 – 70 ^{o}C, the optimum of the drying process is in the 2 firsthours. At the drying temperature of 60 – 70 ^{o}C, the moisture content of mocaf chips decreases to 3.38% and 0.42%, respectively.

Compared with the cassava chips drying at the temperature of 60 ^{o}C and 520 min (8.6 hours), the final moisture content of cassava chips is 6.34% and 10.69% for circular and rectangular shapes, respectively [2]. It needs 120 ^{o}C and 170 min (2.8 hours) to achieve a moisture content of 1.62%. Taiwo et al. [8], in the process of cassava drying using a cabinet dryer, reported that it needs 16 hours to achieve a moisture content of 13.9%. Ajala [19], in the process optimization of cassava drying using the tunnel drying process, reported that the optimum moisture content of dried cassava was 10.22% obtained at the temperature of 86 ^{o}C, air velocity of 3.5 m/s, and loading density of 5 kg/m^{2}.

Cassava Cassava chips Fermentation Mocaf chips

Fig. 1 Flow diagram of mocaf production

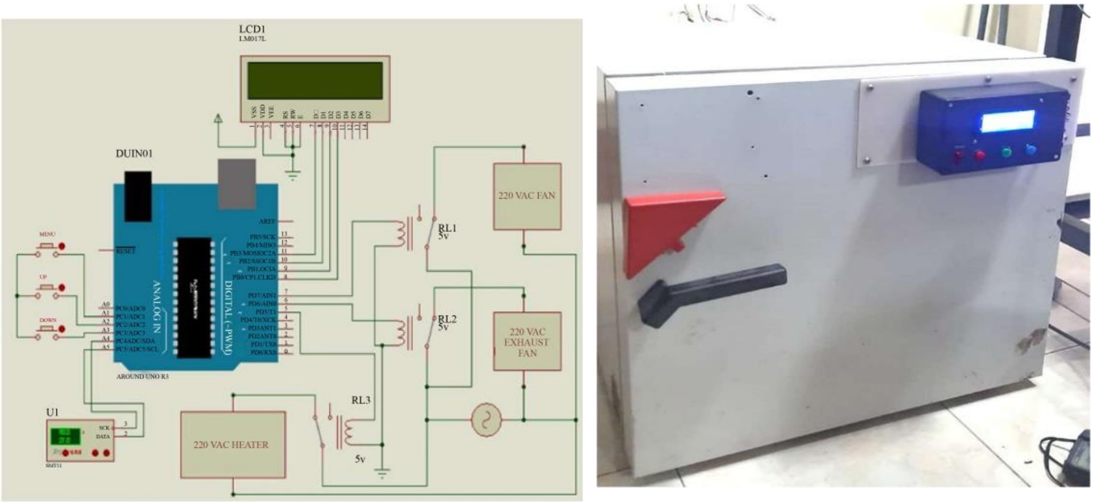

Fig. 2 Schematic diagram of an automatic dryer

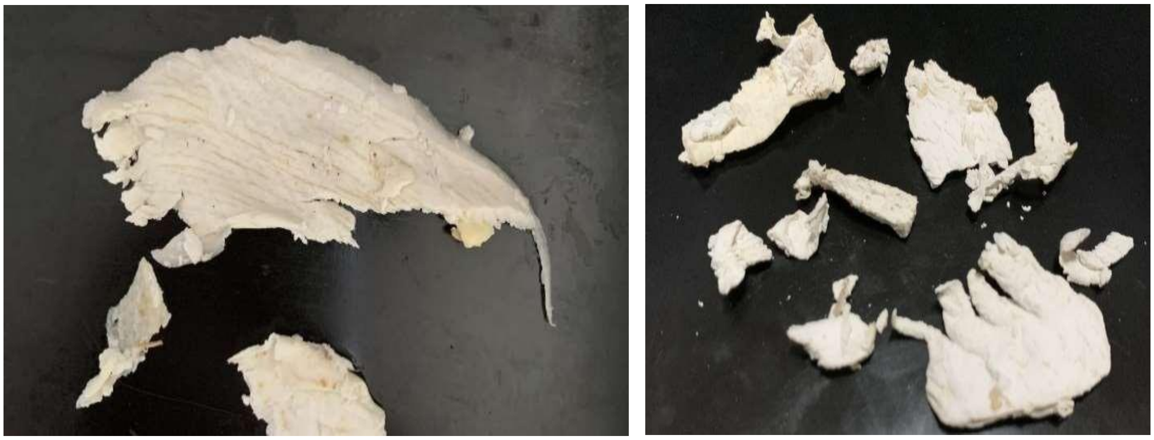

Fig. 3 Mocaf chips: (a) before drying; (b) after drying

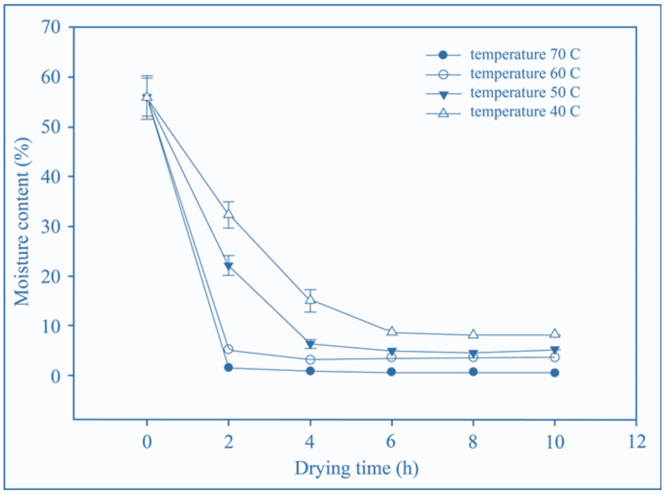

Fig. 4 The profile of moisture content of the mocaf chips during the drying process

Figure 5 shows the profile humidity of the drying room during the drying process. Figure 5 shows that the humidity of the drying room decreases at a higher temperature. The humidity of the drying room reaches 3% at the temperature of 70 ºC. There is a strong relationship between the humidity of the drying temperature with the drying process [10 - 11]. Table 1 shows the temperature process, the humidity of the drying room and the moisture content of mocaf chips.

3.2. Kinetics Models Analysis

The drying process is a process of heat transfer and mass transfer simultaneously. Heat transfer occurs from the air to the surface of the solid material by convection, while water transfer from the solid material to the solid surface is through diffusion and then moves to the air by convection [12]. Referring to the kinetics of drying theory, there are several models of kinetics of drying. The drying kinetics is developed based on thin-layer drying models [6, 9, 12 – 15]. The basic equation for the thin-layer drying model is shown in Equation 1. Equation 1 is also well-known as the Newton model.

Table 1. Temperature, humidity and moisture content of mocaf chips

Temperature (°C)	Humidity (%)	Moisture content (%)
40	32	8.17
50	8	4.5
70	5	3.38
70	3	0.42

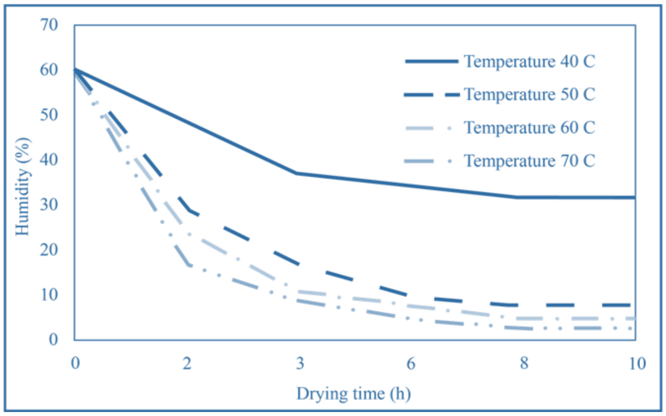

Fig. 5 The humidity of the drying room.

$$\frac{m-m_e}{m_0-m_e} = \exp\left(-kt\right) \tag{1}$$

Where m is the moisture content of mocaf chips at the time (%), m_0 is the initial moisture content (%), and m_e is the final moisture content (%), k is the first constant drying process (h^{-1}), and t is time (h).

3.2.1. Zero Order Kinetics Model

The zero-order kinetics is developed, assuming no effect of the moisture content in the bulk mocaf chips. Equation 2 shows the mathematical model of the zero kinetic models of mocaf drying.

$$\frac{dm}{dt} = k_{d0} \tag{2}$$

Where m is the moisture content of mocaf chips (%), kd_0 is drying constant at zero order (%/h). Equation 2 can be linearized becomes Equation 3.

$$m - m_0 = k_{do}t \tag{3}$$

Table 2 shows the result of data analysis based on the zero-order kinetic model. The analysis of kinetics data gives the average determination coefficient of 0.272. It can be explained that the zero-order kinetics model is not suitable.

Table 2. Data analysis based on a zero-order kinetic model.

Temperature (ºC)	K_{d0}	R^2
40	6.157	0.629
50	6.785	0.371
60	7.109	0.026
70	7.542	0.063
average		0.272

3.2.2. First Order Kinetics Model

The first-order kinetics is developed with the assumption that the effect of the moisture content in the bulk mocaf chips is linear. Equation 4 shows the mathematical model of the first-order kinetic model of mocaf drying.

$$\frac{dm}{dt} = k_{d1}m \tag{4}$$

Where m is the moisture content of mocaf chips (%), kd1 is drying constant at first order (1/h).Equation 4 can be linearized becomes Equation 5.

$$\ln\frac{m}{m_0} = k_{d1}t \tag{5}$$

Equation 5 is similar to the basic equation of thin layer drying models (Equation 1), assuming that m is very small so that it can be negligible. Table 3 shows the result of data analysis based on the first-order kinetic model. The analysis of kinetics data gives the average determination coefficient of 0.515. It can be explained that the first-order kinetics model is not suitable.

Table 3. Data analysis based on the first-order kinetic model.

Temperature (ºC)	K_{d1}	R^2
40	0.237	0.841
50	0.316	0.662
60	0.369	0.212
70	0.625	0.345
average		0.515

3.2.3. Second Order Kinetic Model

The second-order kinetics is developed with the assumption that the effect of the moisture content in the bulk mocaf chips is quadratic. Equation 6 shows the mathematical model of the second-order kinetic model of mocaf drying.

$$\frac{dm}{dt} = k_{d2}m^2 \tag{6}$$

Where m is the moisture content of mocaf chips (%), kd2 is drying constant at second order(1/%^2.h). Equation 6 can be linearized becomes Equation 7.

$$\frac{1}{m} - \frac{1}{m_0} = k_{d2}t \tag{7}$$

Table 4 shows the result of data analysis based on the second-order kinetic model. The analysis of kinetics data gives the average determination coefficient of 0.822. It can be explained that the second-order kinetics model is suitable.

Table 4. Data analysis based on the second-order kinetic model.

Temperature (ºC)	K_{d2}	R^2
40	0.0012	0.906
50	0.0236	0.780
60	0.0369	0.624
70	0.249	0.975
	average	0.822

3.2.4. Energy Activation of Mocaf Drying

The correlation of the drying constant with the temperature can be referred to Arrhenius model [12, 15, 16, 17]. The Arrhenius model can be expressed by Equation 8.

$$Kd = D_0.\exp(-Ea/RT) \tag{8}$$

Where D_0 is constant, Ea is the activation energy of drying cal/gmol, R is the ideal gas constant (cal/gmol.K), and T is the temperature (K). Equation 8 can be linearized becomes Equation 9.

$$\ln kd = \ln D_0 - \frac{Ea}{RT} \tag{9}$$

Fig. 6 shows the plot of 1/T vs k_{d2}. The slope of the equation presented the value of Ea. The result of the calculation, the activation energy of drying is 13.49 x 10^{-3} kcal/gmol. The value of the determinant coefficient of 0.99 shows that the equation is suitable. Rajasekar et al. [18] reported that the drying of chickpeas (*Cicer arietinum*) and black-eyed peas (*Vigna unguiculata*) using a tray dryer with the stream of air at different temperatures showed that the energy activation was 3.841 kcal/gmol and 3.614 kcal/gmol for chickpeas and black-eyed peas respectively.

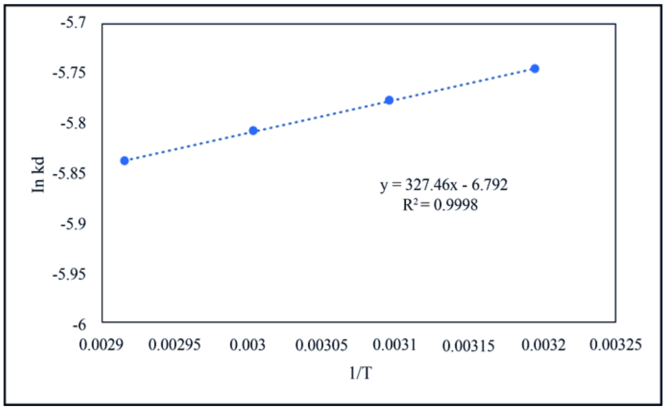

Fig. 6 Arrhenius correlation between 1/T vs ln kd

The energy activation of drying of mocaf chips is very small compared to other drying process of fruits or vegetables. It can be explained that the fermentation process during the mocaf production process can reduce energy activation. The activity of Lactobacillus sp bacteria in the fermentation process, besides breaking the carbon chain in the starch structure in cassava, will also weaken the H_2O bond in the starch structure of mocaf so that the activation energy becomes low.

4. Conclusion

The result shows that the kinetics model of drying that best fits the data is the second-order kinetic model. At the higher temperature, the drying speed constant gets bigger. The activation energy of drying of mocaf drying is 13.49 x 10^{-3} kcal/gmol. The activity of Lactobacillus sp bacteria in the fermentation process, besides breaking the carbon chain in the starch structure in cassava, will also weaken the H_2O bond in the starch structure of mocaf so that the activation energy becomes low.

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