The Effect of Air Temperature on Drying Rate of Red Cayenne Pepper

M Yusuf Syafza*, Yura Amalia Diamantini, Mohamad Djaeni

Department of Chemical Engineering, Diponegoro University
Prof. H. Soedarto, SH Street, Tembalang, Semarang, 50275, Indonesia

*Corresponding author: myusufsyafza@students.undip.ac.id

Abstract. The red cayenne pepper (red chili), an agriculture crop, is useful for food seasoning. The fresh red pepper popular as red chili contains around 73-75% water. With high water content, the pepper cannot be stored for a long time due to the microorganism and enzymatic activities. The drying is a good option to remove its water content in which improves the storage life. The research studies the effect of drying temperature on the drying rate of the red pepper. Here, the red pepper was put in a tray dryer to be contacted with air at various temperatures ranging from 40°C – 70°C for 180 minutes. As a response, the moisture content in the red pepper was observed and the drying rate, as well as thermal efficiency, were calculated. Research showed that the higher air temperature accelerated the rate of water removal. At operational temperature 70°C, thermal efficiency was the highest. Besides, the moisture content in the pepper was also below 15% in which was favorable for dry pepper storing.

Keywords: Red cayenne pepper, drying, thermal efficiency, tray dryer

1. Introduction

Red cayenne pepper is very useful for meeting various needs, both those related to household needs, as well as other needs such as medicine, commercial food and beverages, and as an additive in the chemical industry. The need for red cayenne pepper tends to increase every year but difficult to maintain its freshness quality especially when it is humid. This perishability is influenced by the high water content of 73.51% [1]. It is causing the activity of enzymes and microorganisms that can damage the quality of red cayenne pepper. Drying is used as an alternative solution to overcome post-harvest problems so that chilies can be stored longer so that sales can be adjusted to market needs. Several methods of drying red cayenne pepper that has been done previously are using direct sunlight and a convective tray dryer. However, there are several drawbacks to drying using direct sunlight, which is weather dependency. Chili drying tray can be done using a convective tray dryer. The advantages of using the dryer are that the airflow rate and drying temperature can be controlled resulting in controlled product quality.

Drying is the process of transferring heat and water vapor simultaneously, which requires energy to evaporate the water content from the surface of the material [2]. The purpose of the drying process of agricultural commodities is to preserve the product, prolong durability, reduce packaging costs, reduce transportation weight, improve the taste of ingredients, and maintain the nutritional content [3]. The factors affecting drying consist of the quality of the air as a drying medium involving temperature,
velocity, and relative humidity. The product characteristic such as heat sensitivity, moisture sorption isotherm, and material size.

2. Materials and Methods
In this experiment, drying was carried out using a convective tray dryer with a heater, blower, and control system for the temperature and flow rate of airflow (see figure 1). Drying was carried out at 40°C, 50°C, 60°C, and 70°C for 180 minutes with the air velocity of 1.6 m/s. The weight of chili was 50 grams sorted according to color and size. Ambient air condition was relative humidity (RH) ranging 70-77% and temperature around 30°C. At initial, red cayenne pepper (red chili) was sorted by color and size. The chili was then separated and weighed as much as 50 grams. The chilies were then arranged on a baking sheet and put into the tray dryer at the bottom tray position. Every 30 minutes, the moisture content, the inlet and outlet temperatures as well as the relative humidity of air in the dryer were measured.

![Figure 1. Schematic overview of tray dryer, (1) tray chamber (2) trays (3) air exhaust (4) power (5) temperature control (6) air flowrate control (7) adsorben chamber (8) blower](image)

2.1. Estimating Moisture Content
The moisture content can be estimated on a dry basis as follow:

\[ X_n = \frac{W_n - W_{n-30}}{W_n} \times 100\% \]

Here, \( X_n \) was moisture content (%), \( W_n \) was the mass of red chilies at \( t=n \) (g), and \( W_{n-30} \) was the mass of red cayenne pepper at \( t=n-30 \) (g).

2.2. Estimating Drying Rate
The drying rate can be estimated using the following formula:

\[ N_n = \frac{W_{n-30} - W_n}{\Delta t} \]

Here, \( N_n \) was the drying rate (g/minutes), \( W_n \) was the mass of red cayenne pepper at \( t=n \) (g), \( W_{n-30} \) was the mass of red cayenne pepper at \( t=n-30 \) (g), and \( \Delta t \) was drying time (30 minutes).

2.3. Estimating Thermal Efficiency
The thermal efficiency can be estimated based on inlet and outlet temperature of air temperature at the dryer, as follow:

\[
\eta = \left(1 - \frac{T_{\text{out}} - T_a}{T_{\text{in}} - T_a}\right) \times 100\%
\]

Here, \(\eta\) was the thermal efficiency (%), \(T_{\text{in}}\) was the inlet temperature (K), \(T_{\text{out}}\) was the outlet temperature (K), and \(T_a\) was the ambient temperature (K).

3. Result and Discussion

3.1 The Effect of Temperature on Moisture Content

In this experiment, the drying process was carried out using a tray dryer with temperature conditions of 40°C, 50°C, 60°C, and 70°C for 180 minutes with an air velocity of 1.6 m/s. As a response, the moisture content versus time was observed and plotted in a graph as illustrated in Figure 2.

![Figure 2](image_url)

**Figure 2.** The response of moisture content red cayenne pepper versus time at different operational temperature

The experimental results showed that the temperature of the drying air affected the moisture content in red cayenne pepper. From the experimental results, it was found that increasing the temperature caused a decrease in moisture content. The moisture content values contained in the dried red cayenne pepper at temperatures of 40°C, 50°C, 60°C, and 70°C for 180 minutes were 72.9%, 69.5%, 57.9%, and 14.4%, respectively. The maximum moisture content for dry red chilies was 8% [4]. The drying process depends on air temperature, relative humidity, and velocity. The moisture concentration difference in air and product is the driving force for drying. So, the water diffuses from inside the material to the air [5]. This was following the results of the experiment on grain drying conducted by [6] where the higher temperature of the drying air resulted in lower relative humidity so that the mass and heat transfer between the material and the air was enhanced. This can be reinforced by previous research which states that an increase in mass transfer activity occurred during the drying process which caused the moisture content in the material to continue to decrease [7].

3.2 The Effect of Temperature on Drying rate

Based on the experimental results, the drying air temperature also affected the drying rate. As a response, the drying rate versus time with different temperatures was observed and plotted in a graph as illustrated in Figure 3.
Based on the experimental results in Figure 4, it was found that an increase in the drying air temperature increased the drying rate. However, after a certain time where the moisture content in chili became low, the drying rate decreased. The decrease in drying rate occurs as a driving force is limited. At the initial time, the drying rate was very high because of a lot of free moisture content on the product surface. This condition was easily removed. After a certain time, the availability of free moisture was close to zero, and the air initiated to evaporate bounded moisture in which required more heat [8]. The drying rate also decreases because, over time, the air on the surface of the evaporated and remaining material is on the inside of the material which requires more time to diffuse to the surface before evaporating, causing a decrease in the drying rate [9].

According to [10] in the drying process, it is known that the drying rate is constant and the drying rate decreases. A constant drying rate occurs in the free water layer on the surface of the material. This drying rate occurs very quickly during the drying process, the rate of evaporation of water at this stage can be equalized to the rate of evaporation of free water. After the material water decreases, the water vapor pressure of the material will decrease until there is a balance with the surrounding air. The drying process cannot occur at one time. Thus, a tempering time is required in drying which causes the drying rate to decrease.

3.3 The Effect of Temperature on Thermal Efficiency
Thermal efficiency was calculated based on the amount of heat used to heat the material and to evaporate the moisture content compared to the total heat. The parameter used to calculate heat efficiency was the temperature difference in and out of the tray dryer. As a response, the thermal efficiency versus time with different temperatures was observed and plotted in a graph as illustrated in Figure 3.

**Figure 3.** The response of drying rate red cayenne pepper versus time at different operational temperature
Based on the experimental results, the average thermal efficiency of drying red cayenne pepper (red chili) at temperatures of 40°C, 50°C, 60°C, and 70°C for 180 minutes was, 34.2%, 47.59%, 54.69%, and 57.76%, respectively. This meant that the higher the temperature used, the average thermal efficiency of the red cayenne pepper drying process increased. The heat carried by the drying air can evaporate the water molecules contained on the surface and inside of the material because the humidity around the material decreased which caused an increase in water vapor pressure in the material resulting in a mass transfer of water from the material to the air [11]. This was following the results of research conducted by [12] where the decrease in water content was greater when drying using high temperatures. If the temperature of the drying air was high, the water content in the air (relative humidity) was less so that the difference in water content between the air and the material was greater. Therefore more water was evaporated from the material and the thermal efficiency of drying was greater.

During the drying process, the thermal efficiency changed. At a temperature of 40°C, the efficiency increased during the drying time. Perhaps, it was due to the slow water evaporation or the part of sensible heat from the air that was used to heat the product. At 50°C, the thermal efficiency tended to be similar to that of 40°C drying temperature. Upper 50°C, the evaporation rate of water was faster. Then, at the initial time, the thermal efficiency was higher. After free moisture content was limited, the evaporation of moisture became lower in which reduced thermal efficiency. In the drying process, there was a decrease in the drying rate caused by changes in the water content gradient between the air and the material [13]. Therefore there was a decrease in thermal efficiency at drying with temperature 60°C and 70°C.

4. Conclusion

In drying red cayenne pepper (red chili) using a tray dryer, temperature affected the moisture content removal, drying rate, and thermal efficiency, significantly. The higher operational temperature, the water removal became faster in which enhanced thermal efficiency. Here, the drying temperature of 70°C was favorable in which resulted in the fastest drying rate and highest thermal efficiency. In this condition, the moisture content in red cayenne pepper was below 15% in which was good for storage.

References

[1] Ikhsani, Atika Y and Wahono, H.S. *The Effect of Proportion of Pumpkin Paste and Hot Chili with Concentration of Extract Roselle on Physicochemical and Organoleptic of Hot Pumpkin*
Sauce. Department of Agricultural Product Technology, FTP University of Brawijaya, 3, 1-12.

[2] Aninditya, Dea N et al 2014. DRYER Clothes Using The Working System Heater. Faculty of Engineering Sepuluh Nopember Institute of Technology. (N.D.), 1–3.

[3] Subarjo et al. 2015. Modification Of Solar Dryer Equipment With Automatic Ventilator. Department of Agricultural Technology, Lampung State Polytechnic, 3, 1-3.

[4] Rukmana R 2002. Chili Farming Business. Yogyakarta (ID): Kanisius.

[5] Ikhsan, Muhammad et al 2016. The Effect Of Drying Temperature Variation On The Quality Of Lele Fish Jerky Dumbo (Clarias Gariepinus). Agricultural Technology Education Study Program, 2, 1-9.

[6] Widjanarko, Affian et al 2012. The use of synthetic zeolite in grain drying using indirect contact fluidization process. Department of Chemical Engineering, Faculty of Engineering, Diponegoro University, 1, 1-8.

[7] Agarry S.E. et al 2013. Thin Layer Drying Kinetics of Pineapple: Effect of Blanching Temperature–Time Combination. Nigerian Journal of Basic and Applied Science, 21, 1-10.

[8] Ummah, Narjisul et al 2016. Determinate drying Rate Constant of Shallot (Allium Ascalonicum L) Slice using Tunnel Dehydrator. Faculty of Agricultural Technology, Bogor Agricultural Institute, 33, 1-8.

[9] Prasetyo, Dwi J et al 2018. Drying Characteristics of Ulva sp. and Sargassum sp. Seaweeds. Research Institute for Natural Material Technology, Indonesian Institute of Sciences, 13, 1-12.

[10] Hadi, Syafrul 2015. Drying Kapulaga Using Dryer Glass House Effect With Biomass Waiting Assistance. Department of Mechanical Engineering, Faculty of Industrial Technology, Padang Institute of Technology, 5, 1-10.

[11] Dwika, Ruben T. et al 2012. Effect of temperature and air flow rate on carrageenan drying using spray dryer technology. Department of Chemical Engineering, Faculty of engineering, 1, 1-7.

[12] Rizky et al. 2013. Use of fluidized bed drying technology to improve drying efficiency of tapioca starch. Department of Chemical Engineering, Faculty of Engineering, Diponegoro University, 2, 1-6.

[13] Yuariski, Oki et al. 2012. Rosella flower (Hibiscus Sabdariffa) drying using a recirculating air rack dryer. Department of Chemical Engineering, Faculty of Engineering, 1, 1-6.