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Drying Characteristics of Cayenne Pepper (*Capsicum frutescens* L.) Using a Rotary Rack Hybrid Dryer with Blanching Pretreatment Application

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ABSTRACT

Proper post-harvest handling is very necessary to maintain product quality and extend the shelf life. One way to extend the shelf life of agricultural products, including cayenne pepper (Capsicum frutescens L.), is by drying techniques. Blanching pretreatment before drying can maintain the condition of the dried product so that it can maintain the final product quality. The aim of this research was to analyze the water content, water content ratio (MR), drying rate, drying constant of cayenne pepper using a rotary rack type of hybrid dryer. The use of rotary racks type hybrid dryer is a cheaper drying alternative and the use of rotary racks is able to standardize the water content in the cayenne pepper drying process. The research was carried out with two treatments, namely with and without blanching process at a temperature of 90°C for 5 min. The second factor was drying temperatures were are 43-47°C, 48-52°C and 53-57°C until the cayenne pepper reach the water content according to the reference, namely in the range of 5-8%. From the research results, it was obtained that the lowest water content of cayenne pepper was given pretreatment blanching at a temperature of 53-57°C, namely 6.43% with a drying time of up to 14 h. The drying rate of blanched cayenne pepper was higher than that of unblanched cayenne pepper.

1. INTRODUCTION

Cayenne pepper is one of the most needed agricultural products in daily life, both in fulfilling daily needs in households, restaurants, stalls, and hotels. The high use of cayenne pepper is one of the causes of the fluctuating price of cayenne pepper in Indonesia in addition to being influenced by weather conditions. Nauly (2017), explained that the high demand for cayenne pepper with minimal supply conditions greatly affected the price of cayenne pepper which caused a price increase. Land competition in chili cultivation can also affect the availability of cayenne pepper. The price of cayenne pepper can decrease when the availability of cayenne pepper is abundant (Fadhilatunnur *et al*., 2022).

The abundant amount of cayenne pepper that is not balanced with the amount of demand needs to be considered, especially related to storage. Improper handling can cause damage to cayenne pepper. One of the factors causing damage to cayenne pepper is the water content in cayenne pepper is quite high (Ramdani *et al*., 2018). When harvesting, the moisture content of cayenne pepper can reach 83% (Anoraga *et al*., 2018). Proper post-harvest handling is very necessary to protect the product and ensure that the product can be stored for a long time. One way that can be done is to maintain the waiting time for agricultural products before further processing, including cayenne pepper, is by inhibiting the development of microorganisms which can be done with drying techniques. The drying method is a method used to release the water contained in the material using heat treatment. Dried cayenne pepper can be a ready-to-use product and can be processed into new products such as powdered cayenne pepper and chili sauce (Khathir *et al*., 2022).

Drying food materials aims to reduce the percentage of water content in the materials (Khaerunnisya & Rahmawati, 2019). The method of drying materials can be done in two ways, namely traditional drying using solar thermal energy and modern drying methods using drying tools or machines. Natural drying is carried out by placing the material to be dried in direct sunlight (Yosika *et al*., 2020). In terms of time, artificial drying is relatively faster compared to natural drying because with artificial drying the drying temperature can be adjusted, so it is not affected by weather conditions (Effendy, 2016). The use of high temperatures in the drying process of the product can speed up the drying process but may cause damage to the product. Uncontrolled drying temperatures can affect the final product, including changes in the taste of the product, shrinkage and degradation of nutritional compounds such as bioactive compounds (Gonçalves *et al*., 2023).

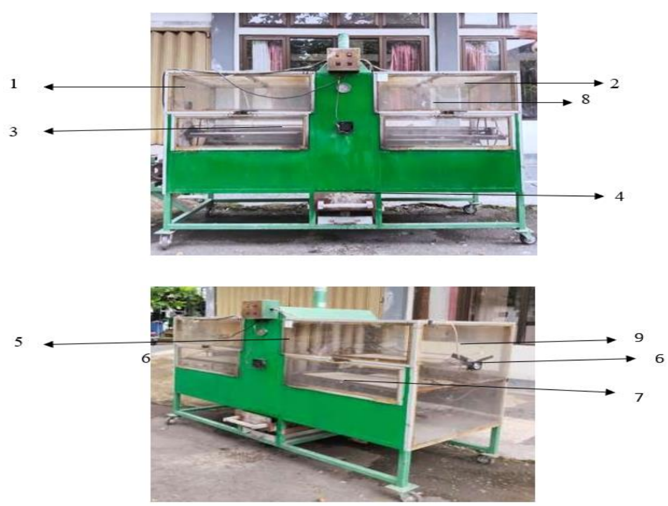
The drying process of agricultural products can affect the final quality of the product, such as it can affect the color change of the product. Pre-drying treatments such as the application of blanching treatment can maintain the color of the dried product so that the final quality of the product can be maintained. Blanching is a heating process for a short time at a temperature of 100°C using water, steam, or with a microwave with the aim of activating enzymes (Saputri *et al*., 2022). The application of blanching techniques in drying can inactivate the work of enzymes, increase drying effectiveness (Muhandri *et al*., 2017). In addition, the inactivation of enzymes due to the blanching treatment makes the texture of the materials, flavor and nutritional content consistent (Widyasanti *et al*., 2018).

In this study, the drying of cayenne pepper was carried out by applying a pre-drying treatment in the form of a blanching technique. Drying cayenne pepper is carried out using a rotating rack-type hybrid dryer. According to Bilang *et al*. (2018), that good dried cayenne pepper is produced with a moisture content level of 5-8%. Another study obtained a water content value of 8.01% (%wb) of cayenne pepper (Samreen *et al*., 2017). This study aims to determine the length of drying cayenne pepper due to the pretreatment process with various drying temperatures. By knowing the right temperature and pretreatment, the quality of cayenne pepper such as color, texture, and taste can be maintained better.

2. RESEARCH MATERIALS AND METHODS

2.1. Research Tools and Materials

Supporting tools used include rotary rack-type hybrid dryer depicted in Figure 1, drying ovens, digital thermometers, thermocouples, digital scales, baking sheets, digital anemometers, cameras, wet and dry ball thermometers, stopwatches, lux meters, and hygrometers. The material used in this study is Juwita F1 variety of cayenne pepper which is a hybrid variety of cayenne pepper and coconut shell biomass. The characteristics of the cayenne pepper used are cayenne peppers that have a color range from orange to fresh red with relatively uniform physical characteristics.



Mark:
1. Left drying chamber
2. Right drying room
3. Inlet
4. Biomass stove
5. Heat exchanger
6. Exhaust fan / outlet
7. Drying rack
8. Digital thermometer
9. Digital thermometer

Figure 1. Rotary rack-type hybrid dryer used for drying cayenne pepper

2.2. Research Methods

The test was carried out using a rotary rack type hybrid dryer that has 8 racks in the dryer room. The study was carried out with two treatments, namely by a process without pretreatment blanching and by a pretreatment blanching process at a temperature of 90°C for 5 minutes. The material used in this study is whole cayenne pepper which is dried with temperature variations of 43-47°C, 48-52°C and 53-57°C until the cayenne pepper reaches the moisture content of 5-8%. Drying is carried out alternately at each drying temperature treatment with a mass of cayenne pepper of 100 grams of chili per rack. The range of values decreased or increased from the temperature of the drying room by 2°C each due to the difficulty of maintaining the stability of the temperature of the drying room. The temperature setting of the drying room is carried out by paying attention to the temperature of the drying room. If there is an increase in the temperature, a reduction in biomass is carried out in the furnace, whereas if there is a decrease in the temperature, the mass of biomass material in the furnace is added to maintain the stability of the temperature in each temperature treatment in the drying room.

2.3. Research Parameters

Important drying parameters included temperature and relative humidity (RH) at drying room. The temperature was measured using digital thermometer, and the RH was calculated wet and dry bulb temperature measured using a glass thermometer with help of a psychometric chart. While, for environmental RH it is measured with a hygrometer. Other parameters involved moisture content progress of the cayenne pepper that is required to calculate moisture ratio and drying rate.

2.3.1. Moisture Content

The moisture content of the material during the drying process was calculated according Equation (1) and (2) for wet and dry basis, respectively.

$$Ka_{wb} = \frac{W_b - W_d}{W_b} \times 100 \tag{1}$$

$$Ka_{wb} = \frac{W_b - W_d}{W_d} \times 100 \tag{1}$$

where Ka_{wb} is wet basis moisture content (%wb), Ka_{db} is dry base moisture content (%db), W_d is dry mass of material (g), and W_w is total mass of sample (g).

2.3.2. Moisture Content Ratio (MR)

The water content ratio was calculated according to Taheri-Garavand *et al*. (2011) through Equation (3):

$$MR = \frac{M_t - M_e}{M_0 - M_e} \tag{3}$$

where MR is moisture content ratio, M_t is moisture content at time t (%), M_o is initial moisture content of the material (%), M_e is moisture content obtained after constant material weight (%). The unit values of M_t, M_o and M_e are the percentage of dry base moisture content (%db)

2.3.3. Drying Rate

Evaporation rate is the amount of water lost from dry food in unit time per unit drying surface. These changes in conditions are shown in the graph of drying rate against time (Hariyadi, 2018). Factors that affect the drying rate include the shape, dimensions and placement of materials when drying, temperature, humidity, and the speed of the drying airflow. The drying rate begins with a fixed drying rate which is the time of water transition on the surface of the material due to the similarity of water vapor pressure between the surface of the material and the drying air until the free water content on the surface of the material is exhausted. Then it is continued with a decreasing drying rate until the balance moisture content is reached (Abustang & Sushanti, 2022). The equation used refers to the following:

$$M = \frac{m_0 - m_f}{\Delta t} \tag{4}$$

where M is material drying rate (g/h), m_o is initial mass (g), m_f is final mass (g), and Δt is drying interval (h).

2.3.4. Drying Constant (k)

The drying rate constant can be determined in several ways, namely by using the empirical method and the graph method of calculating the value of the drying constant (k) using the graph method by plotting the points in relation between the drying temperature (Y-axis) and Ln MR (X-axis) using Microsoft Excel. The equation used is the following Equation (5):

$$MR = \exp(-kt) \tag{5}$$

3. RESULTS AND DISCUSSION

3.1. Drying Room Temperature (°C)

The rotary rack type hybrid dryer consumes energy in the dryer derived from solar and electric irradiation. Electrical energy, in addition to being used for additional heating, is also used for driving power to rotate the drying rack and blower fan. Solar energy and electrical energy are the main sources of thermal energy. Figure 1-3 explain the fluctuations in sunlight and the temperature of the drying room.

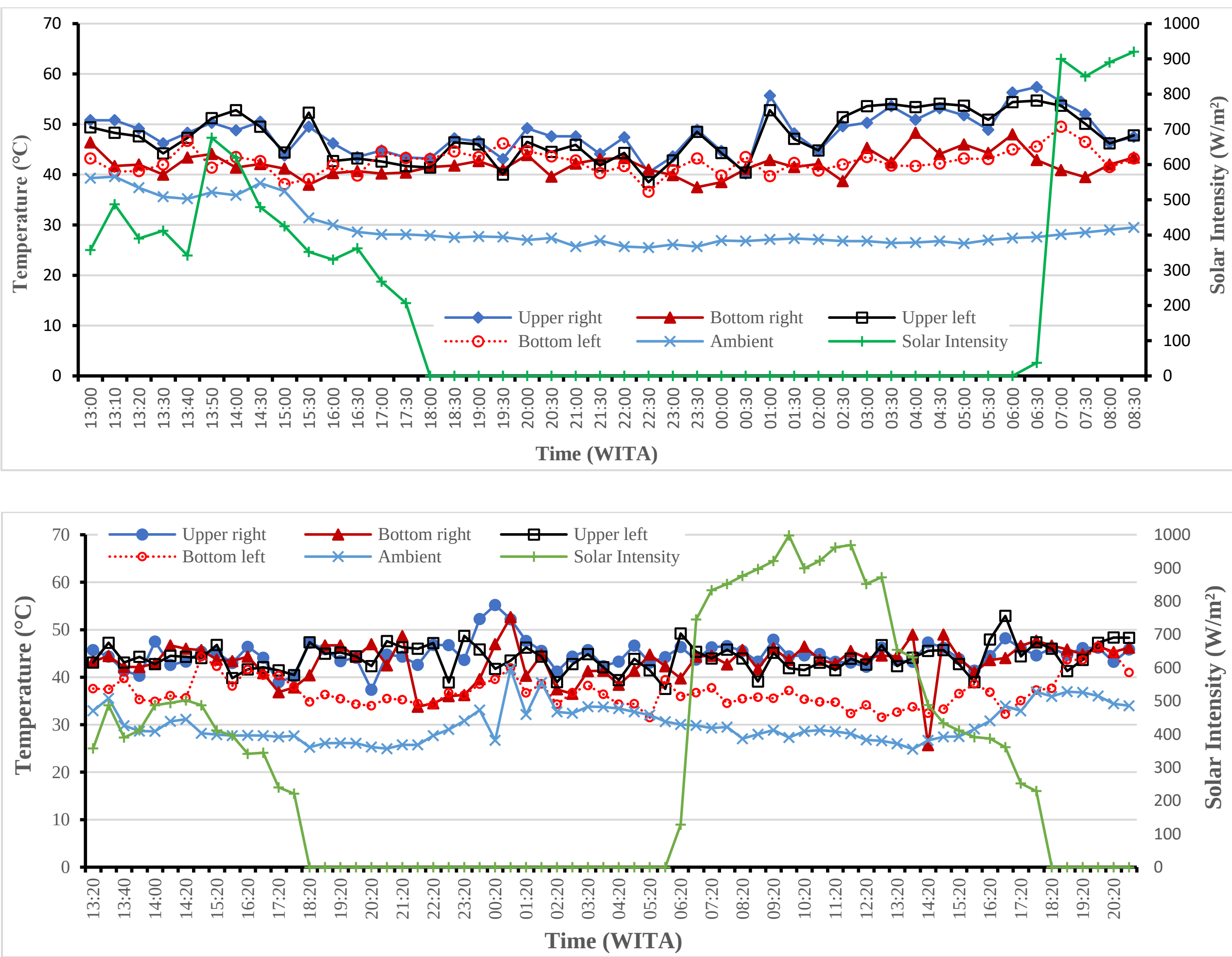


Figure 1. Temperature of drying room and ambient air during drying of peppers for temperature setting 43-47°C: with blanching treatment (top), and without blanching treatment (bottom)

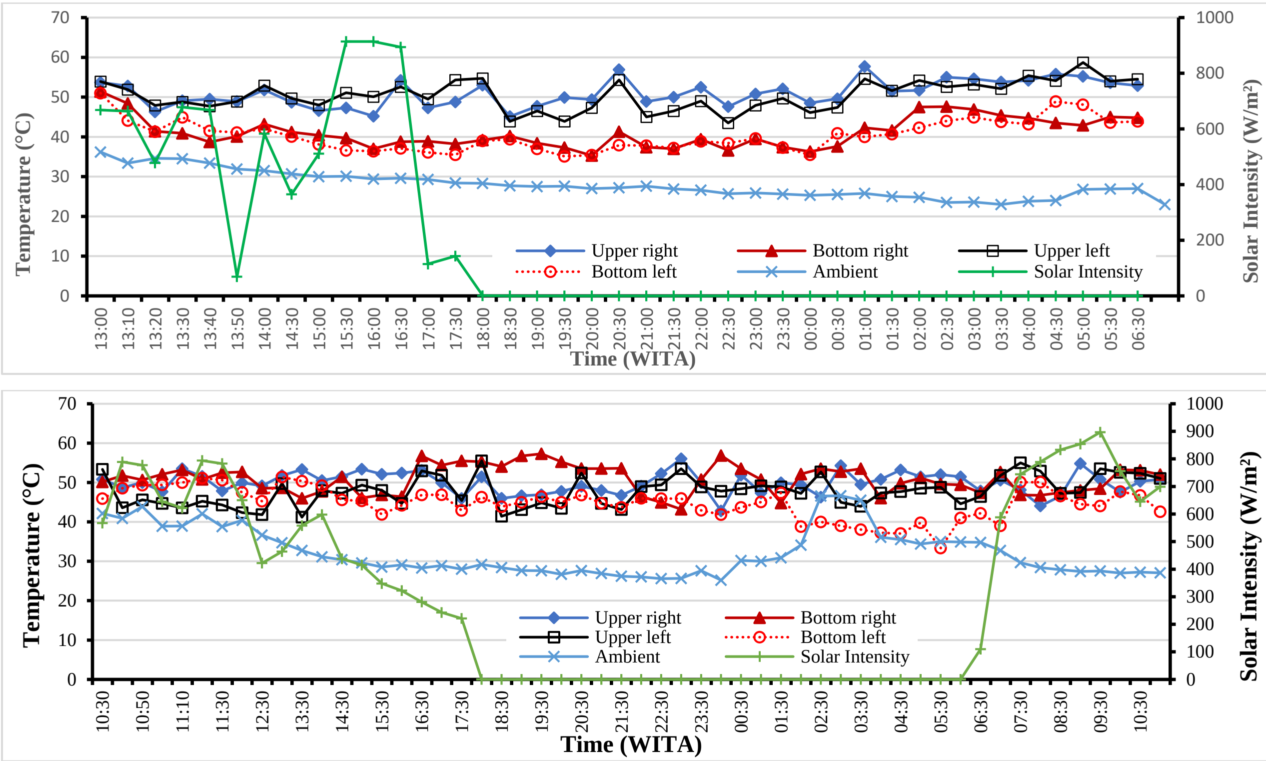


Figure 2. Temperature of drying room and ambient air during drying of un-blanched peppers for temperature setting 48-52°C: with blanching treatment (top), and without blanching treatment (bottom)

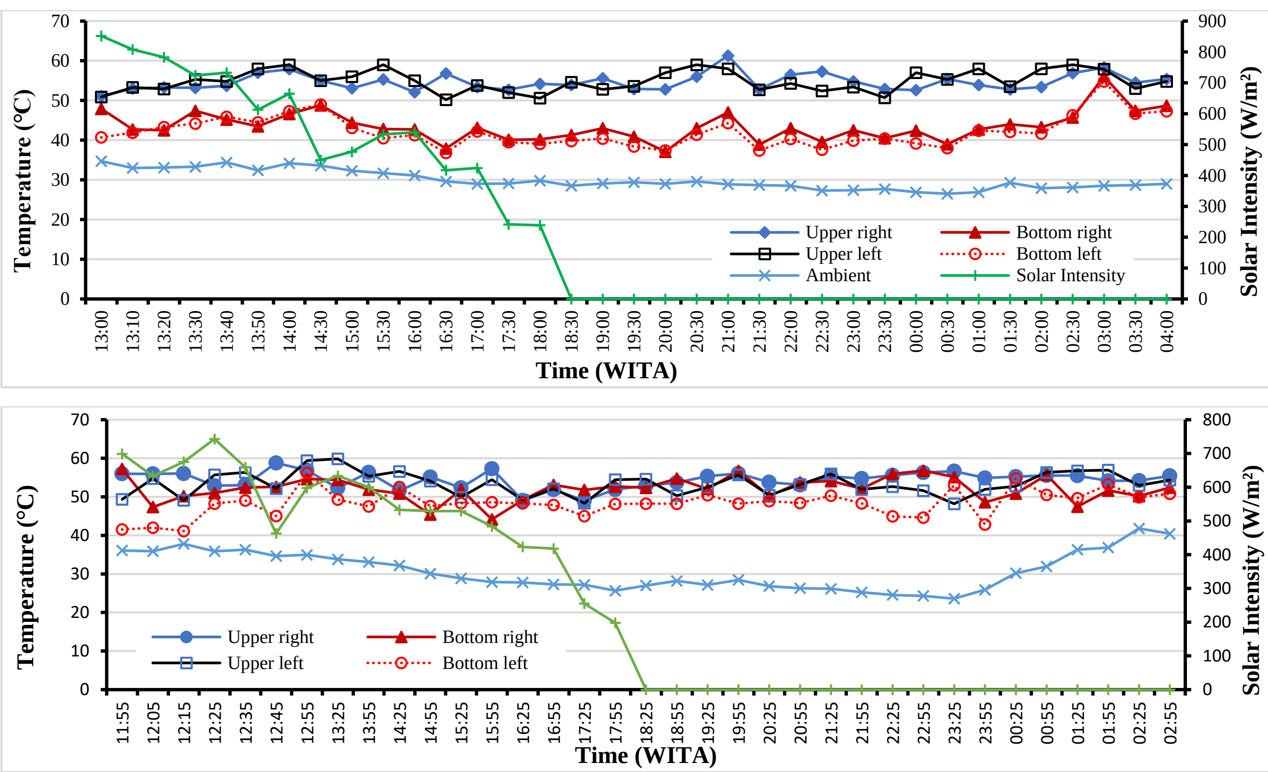


Figure 3. Temperature of drying room and ambient air during drying of un-blanched peppers for temperature setting 53-57°C: with blanching treatment (top), and without blanching treatment (bottom)

Based on the temperature graph in High temperatures in the drying room can accelerate the reduction of water content in the material. The high and low intensity of sunlight will have an impact on the temperature conditions in the drying room, which will ultimately affect the decrease in the moisture content of the material being dried (Irfan *et al*., 2021). The greater the light intensity, the higher the heat transfer to the living space. Sunlight intensity affects the amount of air pressure which will affect the ability to transport moisture from the material to the environment. According to Sari & Lestari (2016), The lower air pressure, the higher the air's ability to lift water from the material during drying, resulting in an increasing amount of water vapor that can be contained and released from the material. A well-run airflow will speed up the drying process. The higher the dryer temperature, the greater the energy produced to dry the material, while the lower the dryer temperature, the less energy available to dry the material (Tobing *et al*., 2019).

3.2. Relative Humidity (RH)

In the drying process, air humidity conditions have a great influence. The air in the drying room is also affected by the ambient air so that it can result in changes in temperature and humidity in the drying room. From the research results, a graph of the relationship between the relative humidity of the drying room and the length of drying time can be seen in Figure 4-6. Relative humidity is greatly affected by the temperature in the drying process. Based on the graph in Figure 4-6, it shows that there is an increase and decrease in the RH value in the drying room. This is caused by the temperature in the drying room also increasing and decreasing during the drying process due to temperature control which is difficult to control. The drying process of a material can take place quickly when there is a partial pressure difference in water between the surface of the dried material and its environment, which in this case is indicated as the relative humidity of the surrounding air (Putra & Kuncoro, 2021).

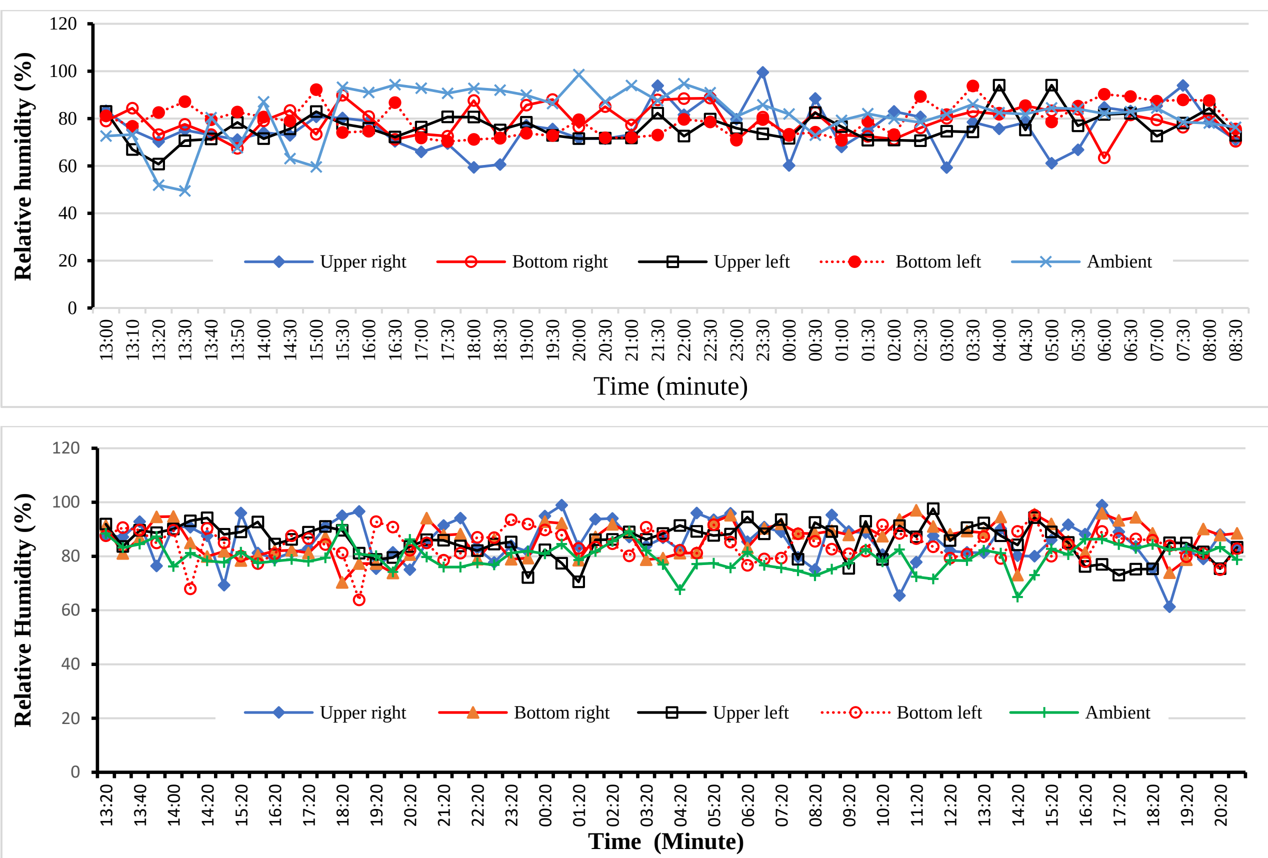


Figure 4. Relative humidity (RH) during drying of cayenne pepper at temperature setting of 43-47°C: without blanching treatment (top), and with blanching treatment (bottom)

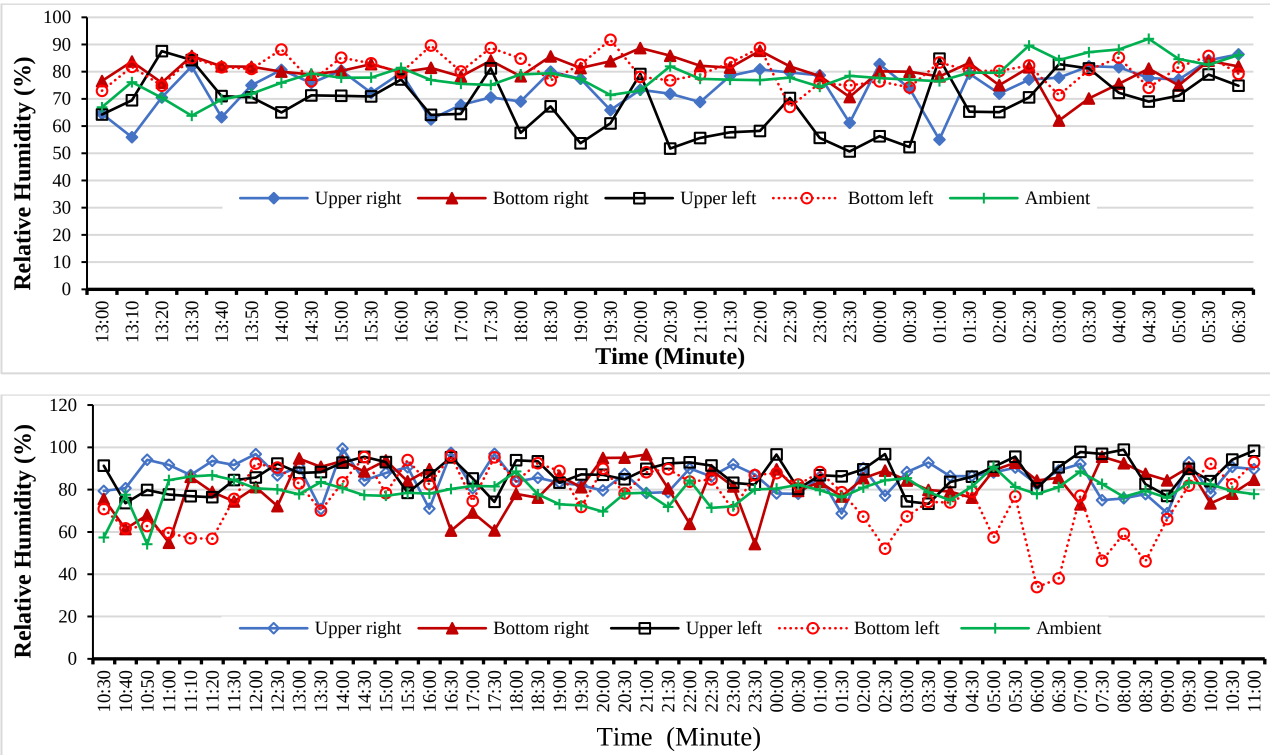


Figure 5. Relative humidity (RH) during drying of cayenne pepper at temperature setting of 48-52°C: with blanching treatment (top), and without blanching treatment (bottom).

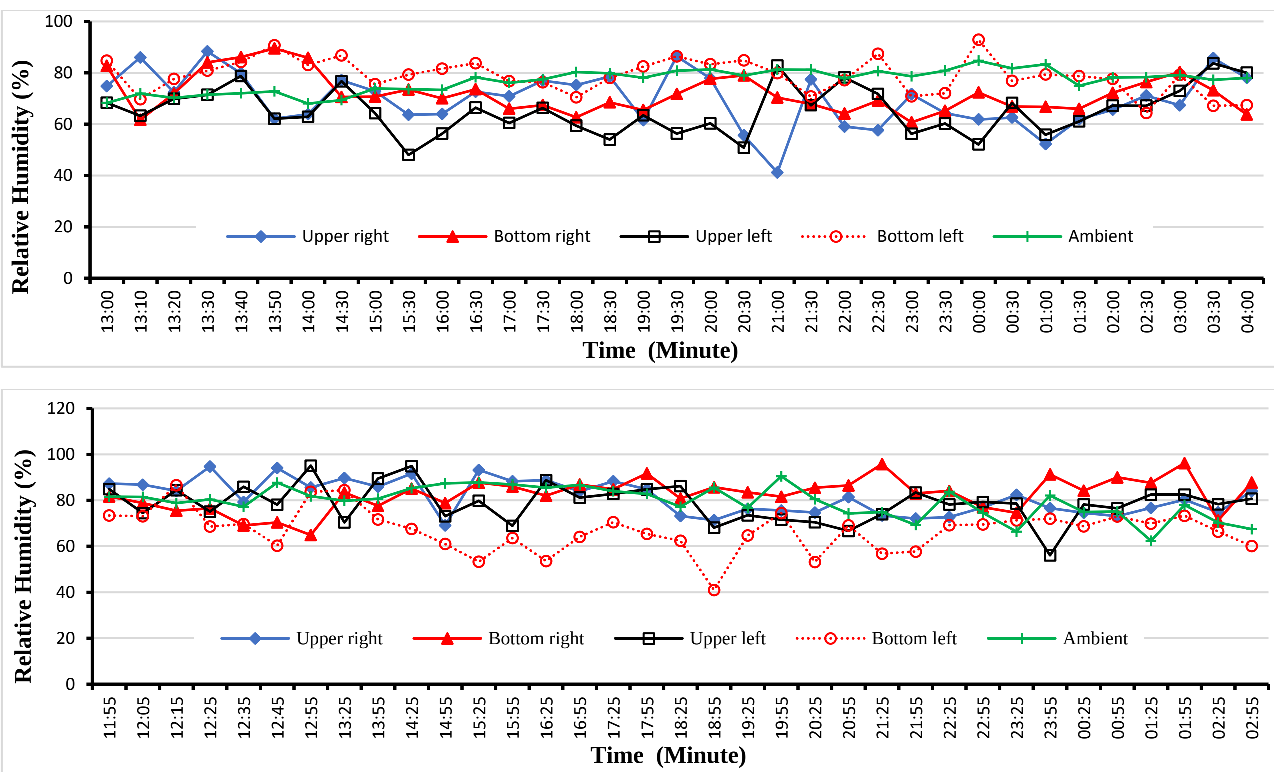


Figure 6. Relative Humidity (RH) during drying of cayenne pepper at temperature setting 53-57°C: with blanching treatment (top), and without blanching treatment (bottom).

3.3. Moisture Content (%)

The water contained in the material is one of the factors that affect the drying process. The temperature in the drying room can affect changes in the moisture content of the material, the higher the drying temperature, the shorter the drying process will take and conversely, the lower the drying temperature, the longer the drying process will take. The reduction in the water content of the material is related to the loss of mass of the material. The water content lost from the material due to the evaporation process can be seen from the amount of mass loss of the material. A graph of changes in water content versus time during the drying process is obtained which is presented in Figure 7.

Based on Figures 7, explains that during the drying process, the moisture content continues to decrease. High drying temperatures cause a rapid decrease in the rate of water content in the material. In Figures 6, it can be seen that the variation in drying temperature and treatment with blanching and without blanching affects the process of reducing the moisture content in cayenne pepper At temperatures of 43-47°C, 48-52°C, and 53-57°C with treatment without blanching, the initial water content was respectively 74.22%, 74.32%, and 75.57% and the final water content respectively is 6.92%, 7.04 %, 6.94%, while the blanching treatment obtained an initial water content of 74.96%, 76.74%, 75.57% and the final water content respectively is 7.67%, 6.37 %, 6.43 %. To achieve the final water content, from two treatments, namely without blanching pretreatment and with blanching pretreatment, the drying time required is different. At temperatures of 43-47°C, 48-52°C, and 53-57°C with treatment without blanching, the time to reach the final water content was 30 h, 24 h, and 14 h, respectively. Meanwhile, for treatment with blanching pretreatment, the time needed to reach the final water content is 19.5 h, 17 h and 15 h, respectively. In the drying process, the moisture content of the material initially decreases very quickly and the longer the drying time causes the decrease in the moisture content slowly. The hot air in the drying chamber also causes the temperature of the pan and the material to rise, resulting in the increase of water vapor pressure. This eventually slows down the mass transfer from the material to the drying air in the form of vapor.

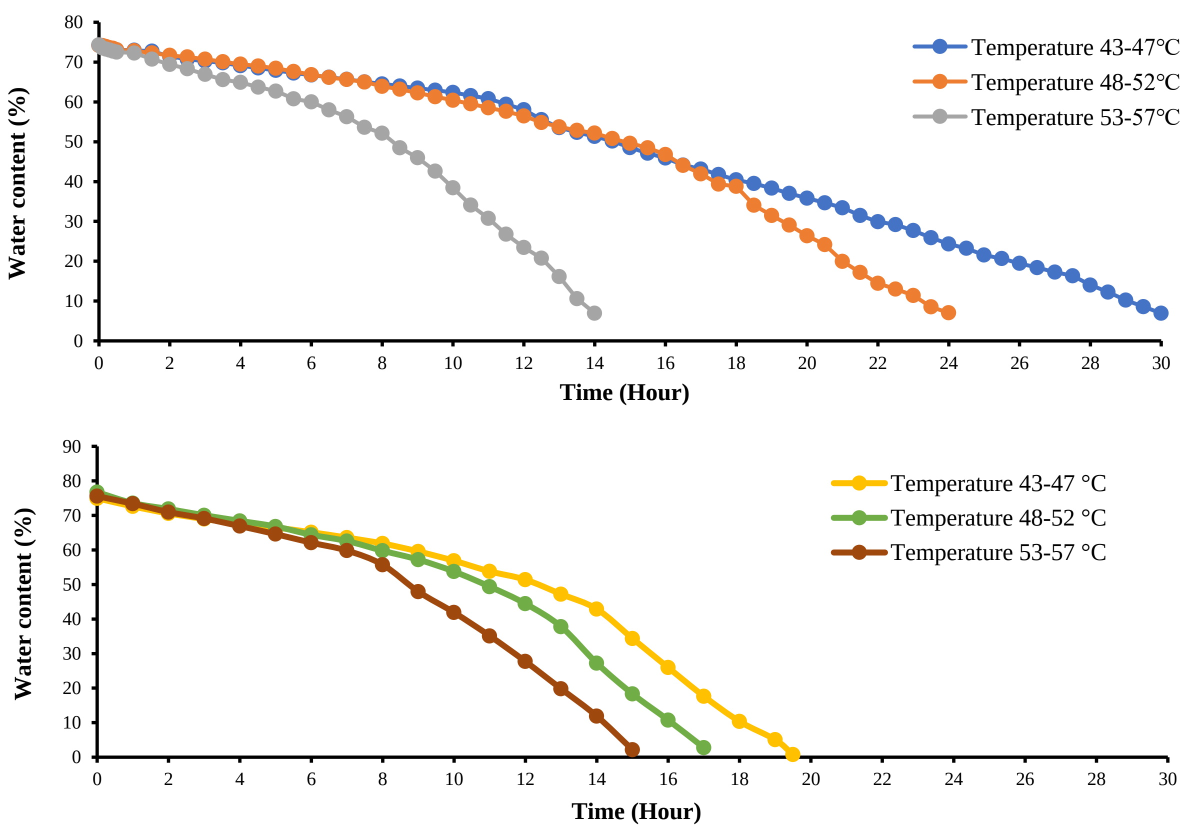


Figure 7. Changes in moisture content of cayenne pepper during drying in different drying room temperature settings: without blanching (top), and with blanching pretreatment (bottom)

Cayenne pepper that is given pretreatment blanching at the beginning before the drying process is faster in reducing the amount of water contained in the material so that the drying time is shorter. Kamsiati *et al.* (2020), stated that the drying time of the material in the blanching treatment is faster because when the material is blanching, the cell membrane will break which results in the tissue structure of the material becoming softer. The condition of the material with a soft texture can stimulate the water contained in the material to leave the material in the drying chamber. This proves that the blanching method is effective for speeding up drying (Irfan *et al*., 2021).

3.4. Moisture Content Ratio (MR)

The MR value is a comparison of the water content contained in a material at each drying time with the total initial water content in the material before the drying process. The balanced water content obtained in pretreatment blanching at 43-47°C, 48-52°C, and 53-57°C was 5.94%, 4.46%, and 3.18%, respectively. Meanwhile, the balanced water content obtained in pretreatment without blanching at temperatures of 43-47°C, temperatures of 48-52°C, and 53-57°C were respectively 2.14%, 2.22%, and 2.04%. MR is used to determine the decrease in moisture content during the drying process. The Ln MR curve of cayenne pepper drying using a rotary rack type hybrid dryer is presented in the following Figure 8.

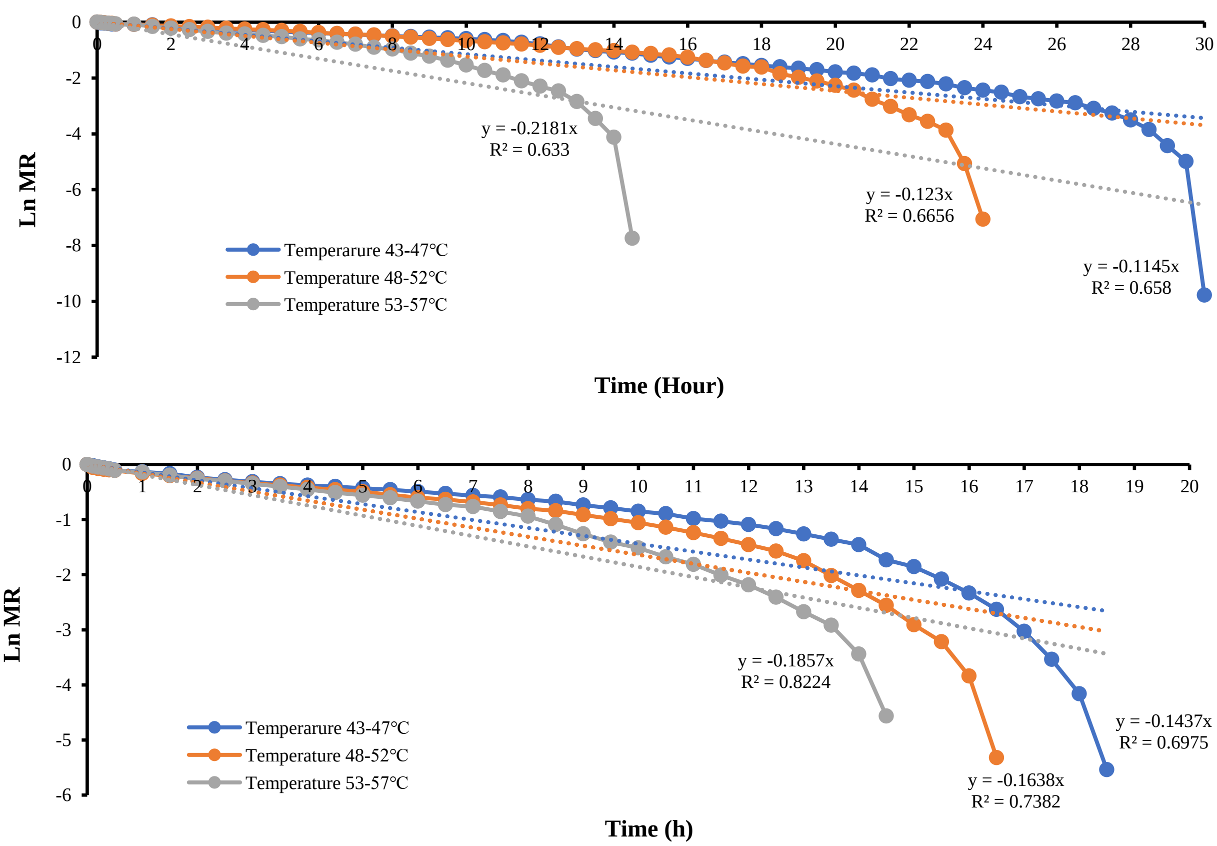


Figure 8. Relationship of Ln MR and time at various drying room temperature settings: without blanching pretreatment (top), and with blanching pretreatment (bottom)

The decrease in MR value occurs in line with the decrease in the amount of water in the material during drying. The higher drying temperature will accelerate the decrease of water in the material until it reaches a constant point. This occurs in the drying temperature range of 53-57°C in the drying of cayenne pepper. The moisture ratio in the blanching treatment decreases faster. This is in line with the faster decrease in the moisture content of cayenne pepper and requires a shorter time in the treatment of cayenne pepper that is given blanching treatment. Higher drying temperatures will make the moisture ratio decrease faster and increase the drying rate (Hasibuan *et al*., 2023). This is because the use of higher drying temperatures will evaporate more water than at lower temperatures (Hasibuan & Gusman, 2018). Based on the graph in Figure 15-16, the Ln MR equation is obtained which can be seen in Table 1.

Table 1. Ln MR equation of cayenne pepper drying with temperature variation and blanching pretreatment

Treatment	Drying room temperature (°C)	Mass of material (g)	Ln MR Equation	R^2
Blanching	43-47	100	Ln MR = -0.1437x	0.8341
	48-52	100	Ln MR = -0.1638x	0.8620
	53-57	100	Ln MR = -0.1857x	0.9108
No Blanching	**43-47**	100	Ln MR = -0.1145x	0.8177
	48-52	100	Ln MR = -0.1230x	0.8102
	53-57	100	Ln MR = -0.2181x	0.7756

3.5. Drying Constant (*k*)

The drying constant is a value that expresses the level of speed at which water is to diffuse out of the material. To determine the drying constant value, the equation obtained from the Ln MR equation obtained in the graph in Figures 13-14 and which has been explained in Table 1 is used. Safrina *et al.* (2023), stated that the value of k is the slope value of the line equation $y = bx$, where the value of b is the drying rate constant value. The k value is obtained by plotting the average value of Ln MR against temperature. Based on the Ln MR value, the drying constant value obtained using the rotating rack type hybrid dryer for cayenne pepper is presented in Figure 9.

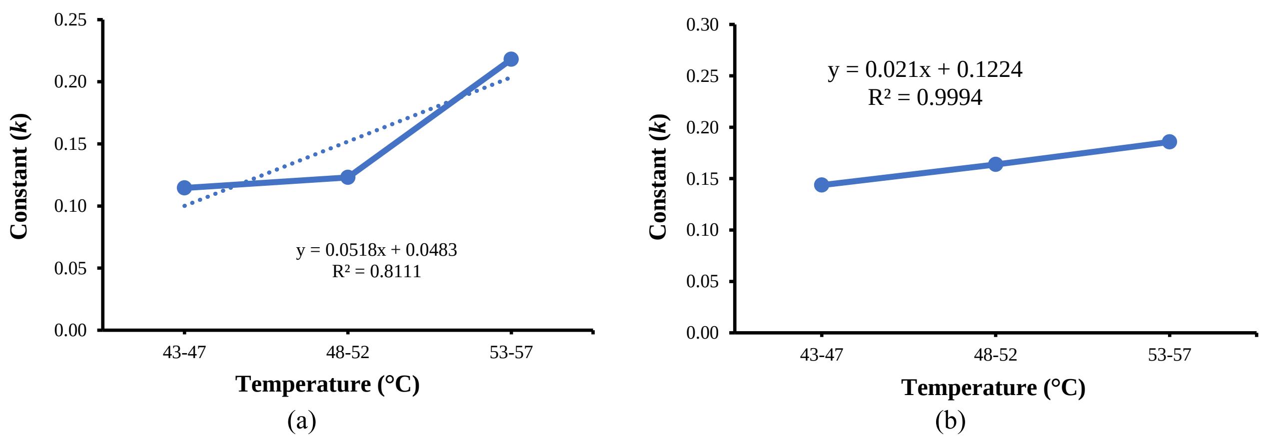


Figure 9. Relationship of constant value (k) to temperature setting in drying room: (a) without pretreatment blanching, and (b) with pretreatment blanching

Based on Figure 9*a* in the treatment without pretreatment blanching, a linear equation is obtained that describes the value of $k = 0.0518T + 0.0483$, so that the general equation of the ratio of moisture content of drying cayenne pepper without blanching pretreatment is MR = exp $(-0.0518T + 0.0483) \times t$. Meanwhile, in Figure 9*b*, a linear equation is obtained that describes the value of $k = 0.021T + 0.1224$, so that the general equation of the moisture content ratio of dried cayenne pepper with blanching pretreatment is MR = exp $(-0.021T + 0.1224) \times t$. The constant value obtained in the blanching treatment is greater than the constant value in the non-blanching treatment, this shows that the ability of water to diffuse out of the material is increasing due to the influence of high temperatures, the humidity in the drying room is quite low so that water evaporation is fast. When viewed from the drying temperature treatment used, the smallest constant value was obtained at a temperature treatment of 43-47°C and the highest constant value was obtained at a temperature treatment of 53-57°C both in cayenne pepper that was given pretreatment blanching and without pretreatment blanching. The small constant value explains that the ability of water to diffuse out of the material is also less due to the influence of low temperature, the humidity of the air in the drying room is high enough so that the evaporation of water becomes slow. This is in line with research conducted by Tanggasari & Jatnika (2023), which states that drying temperature is one of the factors that greatly influences the value of the drying rate constant (k), where increasing the drying temperature can increase the value of the drying rate constant. It can be concluded that the higher the drying temperature, the higher the rate of water diffusion out of the material.

3.6. Drying Rate

The drying rate describes how fast or slow a drying process takes place. The relationship between the drying rate and the length of drying time of cayenne pepper is plotted in the following graph in Figure 19. Based on Figures 19 and 20, it explains the occurrence of a fairly high drying rate. It can be seen that the drying temperature greatly affects the drying rate of the material. If the temperature used to dry the material is high, then the drying rate will be faster so that it will affect the length of time needed, namely the time required in the drying process will be shorter. On the other hand, if the temperature used to dry the material is low, then the drying rate will be slower so that it will affect the length of time it takes to dry the material, i.e. the time required in the drying process is longer. In this case, the drying rate is also affected by the pretreatment given to the cayenne pepper material before drying. Cayenne pepper with blanching treatment has a fast drying rate compared to cayenne pepper without blanching pretreatment. This is in line with Owusu-Kwarteng *et al*. (2017), which said that the drying rate of red cayenne pepper that have gone through the pretreatment process blanching higher compared to the drying rate of cayenne pepper without pretreatmnet blanching. This is caused by the condition of the cayenne pepper when it is in the blanching causing the cell membrane to break and make the tissue structure softer so that this condition can accelerate the process of water escaping during the drying process.

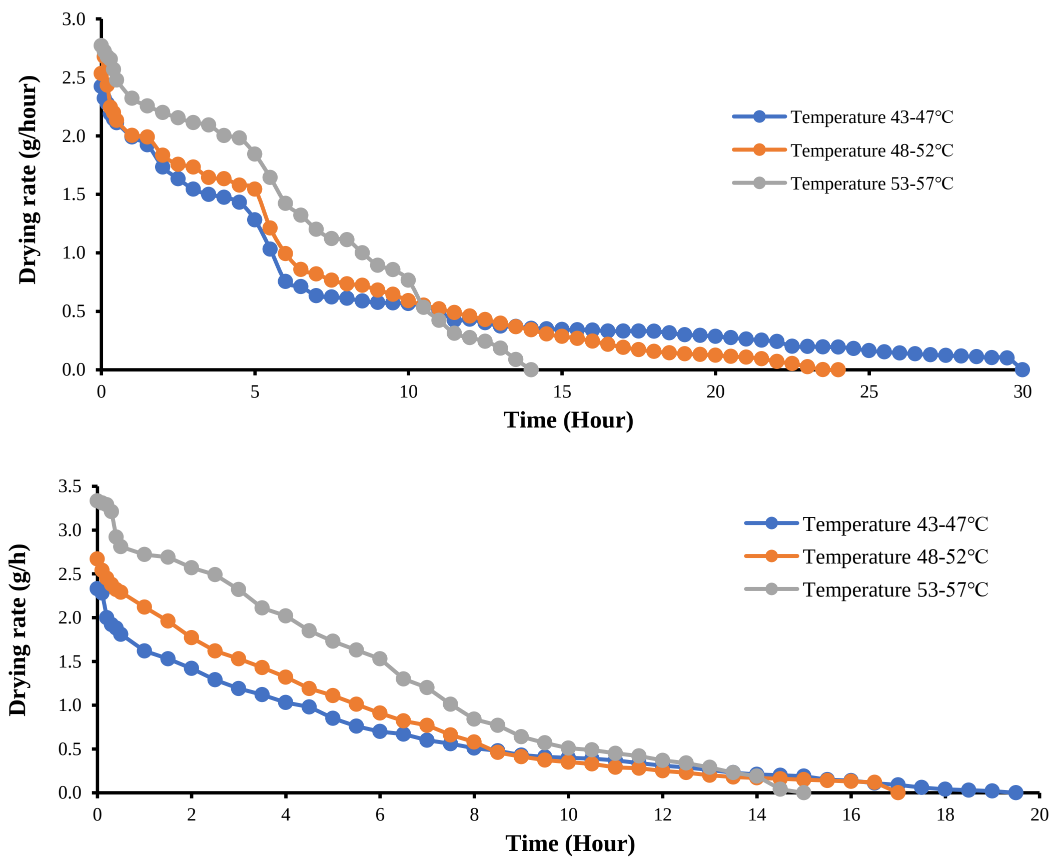


Figure 10. Relationship between drying rate and time at various temperature setting in drying room: without blanching pretreatments (top), and with blanching pretreatments (bottom)

4. CONCLUSION

Cayenne pepper that is given pretreatment blanching at the beginning before the drying process is faster in reducing the moisture content of the material so that the drying time is shorter. The higher the temperature used in drying cayenne pepper and with the addition of pretreatment blanching, the shorter the drying process of cayenne pepper. The best treatment was obtained at a drying temperature of 53-57°C with pretreatment blanching, where in this condition the lowest water content of cayenne pepper was obtained, namely 6.43% with a drying time of 14 h. The drying rate of cayenne pepper that had gone through the pretreatment blanching process was higher than the drying rate of cayenne pepper without pretreatment blanching. The equation of the drying rate constant for the treatment without pretreatment blanching is $k = 0.0518T + 0.0483$, so that the general equation of the ratio of water content of cayenne pepper drying without pretreatment is $MR = \exp(-0.0518T + 0.0483) \times t$. The equation of the drying rate constant for the treatment with pretreatment blanching is $k = 0.021T + 0.1224$, so that the general equation of the ratio of water content of cayenne pepper drying with pretreatment is $MR = \exp(-0.021T + 0.1224) \times t$.

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