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HEAT EFFICIENCY IMPROVEMENT AND COLOR EVALUATION OF RED CHILI PEPPER *(Capsicum frutescens)* DRYING WITH AIR DEHUMIDIFICATION USING SILICA GEL

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ABSTRACT

Fresh red chili pepper *(Capsicum frutescens)* can be dried to a moisture content below 15% for prolonged storage life for a wider range of applications such as in the medicinal, food, and chemical industries. Currently, red chili pepper drying is conducted with direct solar heat that is very dependent on weather conditions. Meanwhile, common convective drying with fossil fuel is inefficient in heat usage and operated at high-temperature air which could potentially lower the product quality. Convective drying with air dehumidification works at low-medium temperatures that are conducive for red chili pepper drying. This research aimed to determine the effect of dehumidification with silica gel on heat efficiency and its impact on the red chili pepper's quality of color. Drying was conducted at temperatures in the range of 40-70℃ with silica gel as an air dehumidifier. The moisture content and colour of red chili pepper were observed. Results showed that red chili drying with silica gel at a temperature below 60°C can improve the heat efficiency as well as the red chili color retention.

Keywords: red chili pepper, dehumidification, drying, efficiency, silica gel.

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INTRODUCTION

Globally, red chili pepper *(Capsicum frutescens)* is a chili variety that is frequently used in cuisine. It adds depth and richness to a wide range of meals and is renowned for its vivid red color and complexity. It is typically consumed fresh with snacks as chili sauce or used as a spice in cooking. Typically, there are two varieties of chili namely the large chili and small chili. Large chili, also known as sweet chili or chili peppers, are frequently used as a culinary decoration because of their large size and mild flavor. Hot and small chilies are widely consumed in Indonesia and are known as red chili peppers [1].

In Indonesia, red chili pepper production increased annually. In 2016, cayenne pepper production reached 915,997 tons and increased to 1,386,447 tons in 2021 [2]. As the population grows and new industries that use chili as a raw ingredient develop, the demand for chili keeps rising annually. Because of its high economic value and broad market, it is important to preserve red chili pepper quality [3]. Moreover, the freshness of chilies is influenced by their high moisture content, which is about 75%, in the red chili pepper [4]. Therefore, efficient drying technology is required to preserve the red chili pepper's quality for long duration storage.

Several drying methods have been studied to process red chili peppers and open sun drying is the ordinary method to dry the red chili peppers. However, it is highly dependent on weather fluctuation and often results in production losses and quality degradation [5]. Other methods use hot air as the drying medium to increase the drying rate as well as to shorten the time for drying. This exposure to high temperature conditions reduces the quality of the product chemically and physically [6]. As an alternative, a fast-drying process can be achieved by lowering the air's relative humidity using dehumidification which could further retain the product quality due to the low-temperature condition.

In this experiment, red chili pepper drying was conducted under low temperatures and humidity using a tray dryer with air dehumidification. This research aimed to determine the effect of dehumidification with silica gel on heat efficiency and its impact on the red chili pepper's quality of color.

MATERIALS AND METHODS

Materials

Red chili pepper *(Capsicum frutescens)* was purchased from a traditional market in Semarang, Indonesia. The initial moisture content of the red chili pepper was 77.05 % wet basis (or 3.36 g water per g dry solid in dry basis) and it was determined by the gravimetric method [7].

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Drying Process

A modified tray dryer was used in this experiment (Figure-1). This dryer was equipped with a dehumidification system to reduce the air's relative humidity. The ambient air with a velocity of 1.6 m/s, relative humidity of 75 ± 2.82 %, and temperature of around 29 ± 1.41 °C passed through the dehumidification chamber containing silica gel as the moisture adsorbent. After that, the dried air was heated up to a temperature of 40 °C for subsequent drying. About 250 grams of red chili pepper with uniform size (2.85 ± 0.13 cm) and color (red) was placed in a tray and dried using the heated air. The moisture content and air temperatures (inlet and outlet) were observed by gravimetric method every 30 minutes. The moisture observation took place for 180 minutes. Then, the procedures were conducted at different air temperatures (50, 60, and 70°C). In comparison, the drying process was conducted without silica gel as the adsorbent.

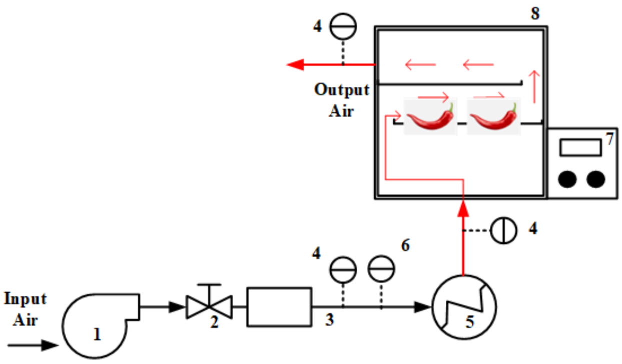

Figure-1. Schematic overview of modified tray dryer :1. Blower; 2. Valve; 3. Adsorbent chamber; 4. T-V meter; 5. Heater; 6. T-RH meter; 7. Thermo-controller; 8. Tray chamber.

Kinetics Modelling of Red Chili Pepper Drying

The moisture content from experiment was converted into moisture ratio as expressed in Equation 1. The data was then used to validate the kinetic model constant of red chili pepper drying based on the Newton Model (Equation 2). This model was used since the red chili pepper can be assumed as thin layer with a uniform distribution of temperatures [8].

$$MR = \frac{(M_t)}{(M_o)} \quad (1)$$

$$MR = exp\ (-kt) \quad (2)$$

Where M_t *and* M_o are the moisture content t and 0 time (minutes). The moisture content in dry basis, g water per g dry solid.

Heat Efficiency Analysis

The evaluation of heat efficiency was obtained as the ratio of the heat for evaporation (Q_{evap}) and the sensible heat $Q_{sensible}$ [9], [10]expressed in kJ as follows:

$$\eta = \frac{Q_{evap}}{Q_{sensible}} \times 100\% \quad (3)$$

where the Q_{evap} was calculated using Equation 4.

$$Q_{evap} = W_d(M_o - M_t)\lambda \quad (4)$$

Where, W_d is the red chili pepper dry mass (kg) and λ is the heat of vaporization of water (2,350 kJ/kg water). The sensible heat is calculated using Equation 5.

$$Q_{sensible} = FC_p(\Delta T\ )t_d \quad (5)$$

Specific Heat Consumption, SEC (in kJ.kg^{-1}), was calculated as follows [11]:

$$SEC = \frac{A \times v \times \rho \times C \times \Delta T \times t}{W} \quad (6)$$

where A is the tray area (m2), v is the velocity of hot air (m/s), ρ is the density of hot air (kg/m^3), C is the air – specific heat (kJ/kg°C), ΔT is the temperature difference (°C), and W is the mass of moisture removed (kg).

Color Evaluation

The color of the red chili pepper during the drying process was observed. The observation using a Chroma Meter (CR-300, Minolta Co., Ltd., Japan) . After that, the total color difference was calculated using Equation 7 [12].

$$\Delta E = \sqrt{(L^* - L_0^*)^2 + (a^* - a_0^*)^2 + (b^* - b_0^*)^2} \quad (7)$$

Where ΔE is the total color difference, L^*, a^*, and b^* are the measured values of fresh, red chili pepper, and L_0^*, a_0^*, and b_0^* are the measured values of dried red chili pepper.

RESULTS AND DISCUSSIONS

The Effects of Temperature and Dehumidification Using Silica Gel on Moisture Ratio

Figure-2 showed the moisture ratio data of red chili peppers with and without dehumidification using silica gel at various drying temperatures (40-70 °C). Results showed that the addition of air dehumidification and drying temperature affected the moisture ratio. The drying conditions such as air temperature, relative humidity, and velocity correlated with the rate of the drying process [13], [14]. The heat transfer between the drying air and the red chili pepper become higher in elevated temperature condition. Therefore, the rate of moisture evaporation becomes higher [15].

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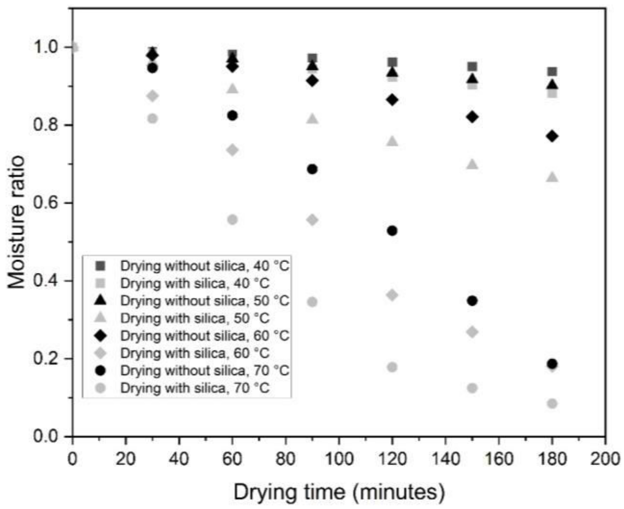

Figure-2. The response of moisture ratio in red chili pepper drying at different operational temperatures.

Figure-2 shows that at various drying temperatures studied, the dehumidification using silica gel significantly reduced the moisture ratio up to 1.06-4.28 times. Dehumidification using silica gel can speed up the moisture evaporation rate in red chili pepper drying by lowering [15,17]. In comparison to other chili drying, dehumidification using silica gel drying was higher than the ordinary tray dryer [18], sun drying [4], and solar tunnel drying [19].

The Heat Efficiency and Specific Heat Consumption

The moisture content in red chili pepper was removed by the introduction of heat. In this study, the heat efficiency and specific heat consumption were also observed and were depicted in Figures 3 and 4. Based on Figure-3, the addition of an air dehumidification system and drying temperature affected the average heat efficiency. In the red chili drying using silica gel as the air dehumidified and using higher temperature, the average heat efficiency increased. The use of silica gel and higher temperatures can lower the air's relative humidity, enhance the driving force for drying, shorten the drying time, and the heat can be used more efficiently [20]. This dryer was higher than other chili drying in terms of heat efficiency, such as open and solar dryers [21], two-stage solar tunnel [22], and stand-alone solar photovoltaic thermal dryers [23].

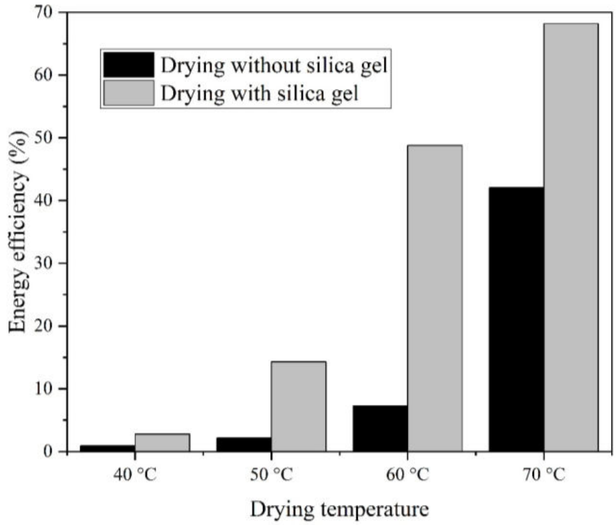

Figure-3. The response of heat efficiency of red chili pepper drying at different operational temperatures.

The addition of an air dehumidification system and different drying temperatures resulted in different specific heat consumption. At a temperature of 40 and 50°C, the specific heat consumption of red chili pepper drying without air dehumidification using silica gel was higher. Perhaps, in these lower drying temperatures, the sensible heat of air was just used to increase the temperature of the product and the water evaporation rate was lower. So, the specific heat consumption was higher.

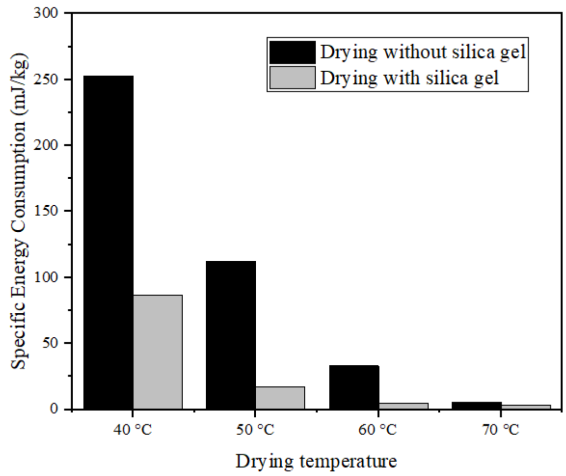

Figure-4. The response of specific heat consumption of red chili pepper drying at different operational temperatures.

At higher drying temperatures (upper 50 °C), the heat successfully removes the free moisture in red chili pepper. The drying rate becomes slower lowering the specific heat consumption. When the driving force for the drying is lower, the drying rate is reduced [24,25]. Therefore, it reduced the specific heat consumption, especially at drying temperatures of 60 and 70 °C. The specific heat consumption of this work was comparable with other drying methods such as such as solar dryers [26] and infrared rotary dryers [27].

Color Evaluation

The total color difference values of the red chili pepper indicate the overall color change of dried red chili pepper to fresh red chili pepper and the value is depicted in Figure-5. Drying at 40°C and 50°C did not significantly affect the color of red chili pepper. At 50°C, there was a significant change in color as seen from the larger total color difference values. The most significant color change occurred in drying with the introduction of silica gel as an air dehumidifier, where at 70°C the ΔE value was 55.77. The addition of silica gel increased the air temperature due to the adsorption heat [10]. With increasing drying temperature, the color of red chili pepper was also affected. Carotenoid substances (yellow, orange, and red) as the pigments in red chili pepper are heat-sensitive so the high temperature can cause an increase in color changes in red chili pepper due to carotenoid degradation. The decrease in carotenoid during chili drying was also studied by a solar dryer and showed a reduction a* (redness) and b* (yellowness) values after drying [4].

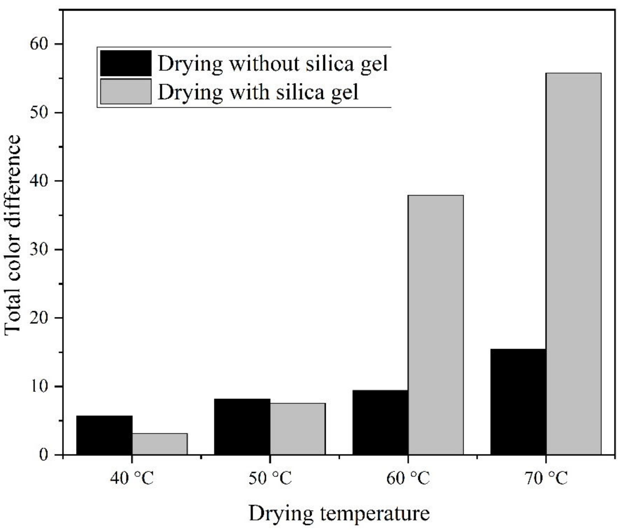

Figure-5. The response of total color difference of red chili pepper at different operational temperature**.**

CONCLUSIONS

Dried red chili pepper drying was successfully conducted with the addition of silica gel as the adsorbent at various drying temperatures (40-70°C). The results showed that by using silica gel, the drying rate of red chili pepper could be increased, and the specific heat consumption could be reduced. In this case, the increase in drying temperature could also improve the heat efficiency, but the color of the red chili pepper degraded. Here, at drying temperatures of 40°C and 50°C, the change in red chili peppers was not significant. At temperatures higher than 50°C, the color changed significantly due to carotenoid degradation.

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