Study on Experimental of continuous solar dryer with dessicant CaCl₂ thermal storage

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Abstract. These studies relate to Red chili dryers sourced from solar energy, the main objective of these experiments to analyses the effectiveness of desiccant CaCl₂ at nighttime, so that they can be received by the community. The parameters that are used in this experiment are, Temperature and Relative humidity, temperature and humidity can be maintained. The initial weight of 0.61 kg in drying chamber 1 and 0.60 kg drying chamber 2, then placed in a different drying chamber, and the final result where a 0.61 kg with desiccant and 0.64 kg without desiccant. The result of these experiment with desiccant CaCl₂ the weight can be maintained with constantly and drying chamber without dessicant can be reached 0.05 kg.

1. Introduction

The sun is the largest available carbon-free energy resource for human being. Many investigations have been conducted to learn how to harvest and apply solar energy as a primary source of energy [1]. The constant of radiation can be received by the earth is 1350 w/m² [2]. Indonesia is located in the tropical climate zone with average temperature with 33-35°C [3] and Relative humidity is in a range of 40-60%.

To take advantage of these potential, one of them is on drying, especially on agricultural products. In agricultural products in the form of granules such as peanuts, Red chili, chili and others the drying process plays an important role in its preservation. Solar dryers represent an alternative technique to traditional sun drying of agricultural products with moisture contents [4]. Most of the works on solar drying application have been directed to low temperature drying system since is, for many biological products, a maximum permissible temperature which should not be exceeded in order to maintain the quality characteristics of the products under drying [5].

The drying process aims to reduce the water content to certain limits, so as not to cause damage due to metabolic activities by microorganisms. Drying helps in reducing the moisture content to a level below which deterioration does not occur and the product can be stored for a definite period [6].

Drying can be done using a dryer or by conventional means. However, the conventional method has many disadvantages because it produces low quality products, prone to contamination with impurities, requires a long drying time, according to weather requirements, and requires extensive land [7].

These problems can be overcome by using a dryer. Dryers must have the ability to dry products that are safe and of good quality [8]. Therefore, the feasibility of solar energy can be added by using solar energy technology, one of which is by using a flat plate collector dryer, these tool can increase the temperature of 40-60°C during the daytime, to overcome the decrease in quality due to the drying process by using a high temperature, it is necessary to do a low temperature drying process, low temperature
drying can be done through the absorption process, drying absorption is a drying process where the water in the material is absorbed by a suction material called desiccant, the desiccant used in this work is calcium chloride (CaCl2), desiccant is a chemical compound that has the ability to absorb water, and can be used as a dryer or retain moisture if stored together with crops. And this work red chili as ingredients to be dried, red chili is a typical Indonesian food commodity, besides that chili is considered as an appetite enhancer, red chili also contains vitamins, and can be used as medicine.

The main purpose of this paper is to get the best drying data from different drying methods, which is to compare drying with open sun drying method, with using solar collector, and solar collector addition desiccant calcium chloride (CaCl2).

2. Solution Method

2.1. Sample Preperation

Sample of chili (*Capsicum annuum* L.) were obtained from local market in the Karo Regency, a total 2 kg of red chili and divided two consists methods: 1 kg with solar collector, and 1 kg solar collector with addition desiccant CaCl2 at night. The Average moisture content was 76%.

2.2. Method

The solar drying system was installed in the Sustainable Research Centre of Energy, Universitas Sumatera Utara. The Solar drying with collectors has two dryers and 1 rack with open sun drying, the dimension solar drying with collector it consists of three main components: the box dryer with dimension 50 cm x 50 cm x 70 cm, plate absorber 100 cm x 150 cm with the other side have angle of 30°. A chimney-dependent solar dryer combined with an inclined roof drying chamber was designed by [8] in order to improve ventilation in the solar dryer, the addition of a chimney was believed to improved the ventilation in the dryer and also the drying rate of the crop although this assumption was proven wrong from the sensitivity analysis of buoyancy effect [9].

The basic function of a solar dryer is to rise the vapor pressure of moisture found inside the product and increase moisture carrying capacity of the drying air by decreasing its relative humidity [10]. During solar drying, warm air captures moisture from the dried product [11]. Drying system efficiency takes into account the weight of moisture evaporated from the product and the energy input to the drying system during the drying time. However, the efficiency of a dryer is often reported individually as collector efficiency, pick-up efficiency, and drying efficiency. Collector efficiency is a common measure of collector performance generally ranging between 40 to 60% for flat plate collectors [12].

As a note, drying is a simultaneous heat and mass transfer process and is followed by evaporation. The drying process can be driven by temperature difference and/or concentration difference. A lower vapor concentration of drying air above the surface can provide drying process, even though the temperature of the object is relatively low.
The solar dryer was operated in the daytime, the Red chili is dried inside the drying chamber by using hot air resulted by the solar collector. The parameters of these work are temperatures, mass of the Red chili, relative humidity, wind velocity, and solar radiation were recorded every minute. Thermocouples of J type with an accuracy of 0.4% were used to measure temperatures. An Agilent 3497A data acquisition system with a 20 Channel multiplexer was used to record measurements. To measure the humidity inside the drying chamber, 2 USB Temperature Humidity Logger were used. The mass of measured using a load cell weight system data logger with an accuracy of 0.01 kg. A HOBO micro station data logger was used to measure the weather conditions. They are ambient temperature, RH, solar radiation, and windvelocity. During the drying process, the temperature and Relative humidity can be calculated as follows:

The specific energy consumption (SEC) is defined as total energy received during divided by amount of water evaporated from the object:

$$SEC = \frac{Q_{net}}{m_{eva}}$$  \hspace{1cm} (1)

Where $Q_{net}$ [kJ] and $m_{eva}$ [kg water] are total energy received and mass of water evaporated from the red chili.

The energy received by solar collectors comes from solar radiation:

$$Q_r = F'' (IAta) - Q_i$$  \hspace{1cm} (2)

Where $F''$ is the factor efficiency of the collector that is assumed 0.9 and $I$, $A$, $t$, $a$, solar intensity [W/m2], solar collector area [m2], transmittance, and absorption coefficient, respectively.

Drying process of red chili can be analysed by following equation:
\[ MC = \frac{W_t - W_r}{W_t} \quad (3) \]

The thermo–chemical energy released by desiccant \( Q_d \) during the off-sunshine can be calculated by using the following equation:

\[ Q_d = m \Delta H_r \quad (4) \]

Where \( m \) [kg] is mass of the desiccant and \( \Delta H_r \) [kJ/kg] is enthalpy difference of the desiccant before and after-sunshine. The specific energy consumption can be calculated by using the following equation:

\[ SEC = \frac{Q_t - Q_d}{m_{eva}} \quad (5) \]

3. Results and Discussion
These drying had been carried out during 05 October 2019 in Medan city, this drying uses Red chili as commodities with duration is carried out for one day with drying time at 8.00 am-18.00 pm and the night time at 19.00 pm – 6.30 am. And the drying process is terminated if equilibrium is reached. The results for each group are presented in the section below.

3.1 Temperature and Humidity in drying chamber at day time
In these parts will be show temperature and humidity (RH) with solar radiation:

![Figure 2](image1.png)

This Fig. 2 Showed of the temperature and Humidity at drying chamber, drying chamber temperature range was 29.5 to 67.10 °C and Relative humidity of drying chamber was around 11.20 to 80.30% RH with the highest temperature the low humidity is at the time 14.00, and the range of intensity radiation was 18.1 to 629 W/m² with the highest intensity is at the time 12.55.

3.2 Temperature and humidity in drying chamber at night time
In these parts will be show temperature and humidity (RH) in drying chamber at night time:
Figure 3. Chamber of Temperature and humidity in drying chamber at night time

These research on the first night was conducted on August 5, 2019, the data obtained as follows, on the collector with the addition of temperature desiccations varied between 25.70-31.20 °C with an average temperature of 28.52 °C and Humidity (RH) between 49.30-67.50% with an average of 58.58%, while collectors without desiccation between 24.30-29.00 °C with an average temperature of 26.04°C and Humidity (RH) between 61.80-79.20% with an average of 72.20%.

In the above data it can be seen that the temperature in the drying chamber is higher compared to without desiccation and the humidity in the drying chamber is relatively low, this is caused by the desiccation of CaCl2 which is a hydrate salt whose nature has a partial pressure of water vapor which is lower than environmental air so that the vapor water moves from air to desiccation.

3.3 Comparisson between mass with desiccant
In these part will be show comparison between mass of Red chili, as shown below:

Figure 4. Comparisson between mass with desiccant CaCl2 (a), without dessicant (b)
This Fig. 3 showed of the mass Red chili with desiccant CaCl2 (a) and without desiccant (b), drying is continued at night with an initial weight of 0.61 kg in drying chamber 1 and 0.60 kg drying chamber 2.
then placed in a different drying chamber, where a 0.61 kg is placed with desiccant and 0.60 kg without desiccant, from the graph shows the temperature with desiccant was 25.60 to 31.00 °C with Relative humidity 49.80 to 68.80 % RH and without desiccant was 24.30 to 28.80 °C with Relative humidity was 61.40 to 89.30 %RH, and the final weight with desiccant can be maintained 0.61 kg and without desiccant 0.64 kg.

4. Conclusions
The conclusions obtained from the Red chili dryer are as follows:
This experimental research of red chili has been shown above and drying processes with desiccant CaCl2 can be maintained, but the drying chamber without desiccant increased 0.05 kg. The main conclusion here is that solar dryer with desiccant thermal energy storage makes drying using solar energy more effective in terms of drying time and specific energy consumption.

5. References
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Acknowledgment
Thank you to the authors express their gratitude to Telenta Research of universitas Sumatera Utara under grant 4167/UN5.1. R/PPM/2019.