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Suan Sunandha Science and Technology Journal

DEVELOPMENT OF AUTOMATIC CONTROL SYSTEM FOR SOLAR DRYING CABINET

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Received: *22 August 2021* / **Revised:** *7 October 2021* / **Accepted:** *16 December 2021*

Abstract

This paper presents the design of thin layer direct mode solar drying cabinet with moisture and temperature automatic control system. Two motors with Arduino™ microcontroller were used to control the air inlet and outlet of solar drying cabinet. The speed of two fans was controlled by thermometer and relative humidity sensors. The electric power of motors and controller were supplied by PV-cell with battery for low light and night time drying. The temperature from inlet reached around 36.1ºC to 46.6ºC, the relative humidity reduced from 55%RH to 21%RH in the cabinet. The Chinda Chili was used as a demonstration drying product to compare automatic solar drying cabinet with normal sun drying. Automatic solar drying cabinet could reach the moisture ratio to 0.3 in 7 hours which showed 2 times of Moisture ratio compared with normal sun dryer.

Keywords: Solar dryer, Automatic control system, Drying cabinet, Temperature control

1. Introduction

Nowadays, the energy from fossil emitted carbon dioxide which caused the global warming problem. Renewable energy should be concerned with reducing greenhouse gas and ultimately reduce production cost in many industries. Thailand, which is located in the tropical area, has high solar radiation intensity (higher than 15 MJ/m2) that can give Thailand high, clean and free energy (Janjai, 2017). In the agriculture sector, drying agricultural products, such as crops, fruits and leaves after harvesting, is very popular for extending the product life and also improving the product taste. Normally, farmers dry agriculture products with open air condition which could not prevent insects and uncertain weather, such as cloudy, rain, too high ultraviolet radiation and too high of heat. Many researchers have studied the condition of drying by controlling temperature and humidity. (Phitakwinai, Thepa & Nilnont, 2019). studied the thin layer of coffee bean and showed the predicted model in drying condition.

The indirect mode solar drying with the help of heat collector and forced convection of heat (Ouaabou et al., 2018) showed the appropriate heat between 60ºC to 80ºC for drying the moroccan sweet cherries. The direct mode solar dryer which allowed solar radiation incident on product through transparent material such as polycarbonate reduced heat loss (Nabnean & Nimnuan, 2020). Therefore, this could be applied to many agricultural products for Banana (Nabnean et al., 2020). Some researchers aimed to scale up the drying capacity. The new model by (Nabnean et al., 2016) could reach 100 kilogram of tomato cherry that showed the efficiency of a drying cabinet with temperature around 30ºC to 65ºC. However, the wide range of temperature during the solar drying is one of the obstacles to control the drying product quality, therefore our research team aims to control the drying conditions such as temperature and relative humidity, with the help of drying through the automation control system.

The objective of this study was to develop the automation drying cabinet, by Arduino™ microcontroller, as a pilot drying system with direct mode cabinet to control temperature and relative humidity in the chamber and preserve agricultural products with low cost and provide a feasible system for the local community.

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2. Materials and Methods

2.1 Drying cabinet fabrication

The solar drying cabinet in this study was a direct mode solar drying according to the ease of air flow controlling and there is no heat collector needed. The body of the cabinet was built with aluminium due to the light weight. The cabinet size is 40 cm. ×60 cm. and the height of trapezoid shape were 20 cm. and 22.3 cm. respectively. The cabinet was painted inside with black color for the better absorption of solar radiation. Two motors in the opposite side are for controlling the inlet and outlet air which were powered by 20 watts of PV-cell with a solar charger attached to the cabinet. The top of the cabinet was covered with Polycarbonate sheet for the light weight and safety.

Figure 1. Inside of the automatic solar drying cabinet

Figure 2. The automatic solar cabinet drying

2.2 Automation system

Arduino nano was the microcontroller used in this study. The microcontroller was powered from a solar charger which reduced the voltage from 12V to 5V. This controller collected temperature and humidity data from 3 Arduino DHTT11 sensors on the condition that if the temperature and humidity of the mid sensors that collected data from the middle of the cabinet were over the setting limit, the motors were driven with higher speed which were controlled by the motor drive board. All 3 data from sensors saved in the SD card module (Figure 3.).

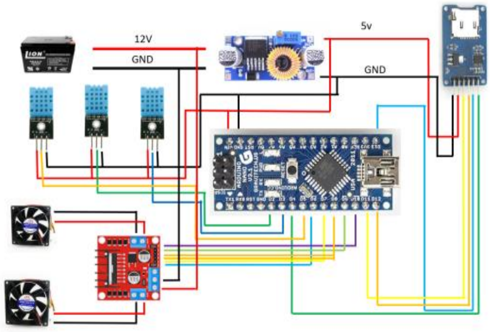

Figure 3. Showed the schematic of automation system for solar cabinet drying

The programming flow chart (Figure 4.) showed a processing diagram; by collecting data from 3 sensors and saved in storage SD card. At the same time, the data from the sensors inside (mid sensor) the cabinet were used as the condition of the controlling 2 steps motors speeds of DC fan motors to control air inlet and outlet inside automatic solar cabinet dryer. In this study, the temperature and relative humidity were set at 60 ^{o}C and 20% respectively as a setting limit. If the temperature and relative humidity reached over the setting limit, the motors speeds of DC fans were raised to higher fans speeds. On the other hand, at the lower setting limit the fans were still at the low speed to keep the heat inside the cabinet and saved the electric power.

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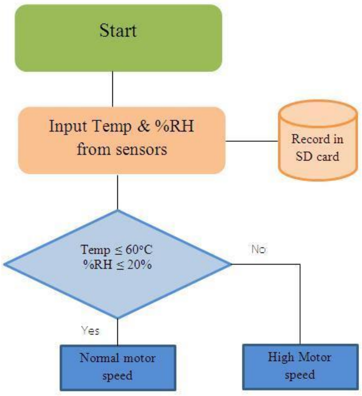

Figure 4. the flow chart of automation programming for solar cabinet drying.

3. Results and Discussion

3.1 Temperature and relative humidity

In this study, we ran the empty solar cabinet dryer to investigate the controlling of temperature and relative humidity from an automation system where we programmed to switch the fan speed if the temperature and relative humidity were getting higher than 60ºC and 20% respectively. The investigation dates were April 23rd 2021 (day1) and April 24th 2021 (day2) for the real weather situations for solar cabinet drying testing. Firstly, the air inlet on day1 showed that the temperature was from 32.4ºC to 36.1ºC and the relative humidity was from 68% to 53% (Figure 5.). When the air moved in the cabinet, the temperature rose to 45.4ºC - 46.6ºC and the relative humidity dramatically dropped to 21% - 25% which showed that the automation system could control the temperature and humidity quite close to the programmed condition although the relative humidity was slightly overshoot. For more precision this automation programming needed to be more complex.

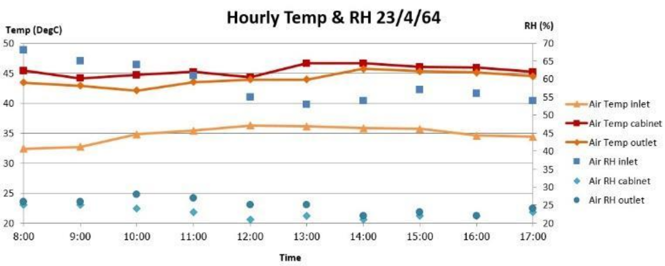

Figure 5. Temperature and relative humidity on 23rd April 2021.

For day2, the automation solar drying cabinet could run as well as day1 due to the clear and partly cloudy sky from 8:00 to 14:00 which could absorb the radiation as normally. The low solar radiation (Figure 6.) and high humidity occurred after 14:00 because of the rain which showed the uncontrollable temperature and relative humidity in this drying cabinet. This situation showed that we need moisture control apparatus and heat assistance for unusual situations.

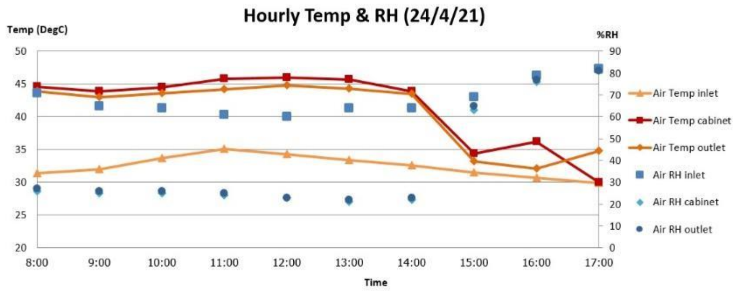

Figure 6. Temperature and relative humidity on 24th April 2021.

3.2 Product drying testing

Chinda chili was carried out as a testing product for this automatic solar drying cabinet. The test was done by drying the Chinda chili in an automatic drying cabinet in comparison to natural sun drying on the same day. The data of drying was interpreted in moisture content and moisture ratio respectively. For the moisture content we calculated in dry basis which was defined as:

$$MC = \frac{M_t - M_d}{M_d} \times 100\% \qquad (1)$$

Where *MC*: moisture content of the product in dry basis; M_t: mass of the product at any time; M_d: dried mass product. From the *MC* we could plot the graph of moisture content versus the time as seen in Fig 7. The moisture contents from both normal sun drying and automatic solar drying cabinet were decreased at the similar rate as the early hour, then the *MC* of normal sun drying was constant at 14:00 and the moisture content of automatic solar dryer cabinet was at the constant at 15:00.

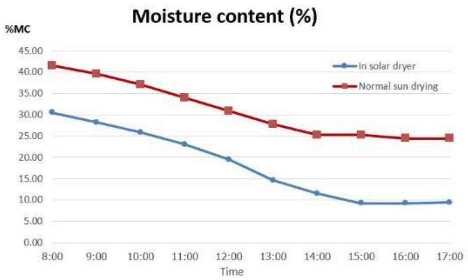

Figure 7. Moisture content of Chinda chili drying with automatic solar dryer cabinet and normal sun drying.

To compare the drying rate of normal sun drying and automatic solar drying cabinet, we needed to carried out by Moisture ratio (MR) as:

$$MR = \frac{MC_t}{MC_o} \qquad (2)$$

Where *MR*: Moisture ratio; MC_t: moisture content at any time; MC_o: Moisture content at initial. The *MR* decreasing rate of automatic solar cabinet dryer was more than normal sun drying at the early of the day and the *MR* of normal sun drying was constant at 14:00 earlier than automatic solar dryer for 1 hour which showed the moisture rate at 0.6 and 0.3 respectively (Fig 8.). This result showed that the final *MR* was different 2 times which showed that the automatic solar dryer cabinet could dry the product (Chinda chili) more than normal sun drying on the same day. Not only could the drier reach for the automatic solar cabinet dryer but also prevented the product from desirable outcome, for example, insects and uncontrollable weather conditions.

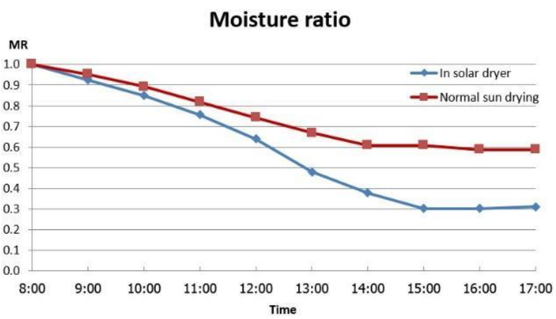

Figure 8. Moisture ratio of Chinda chili drying with automatic solar dryer cabinet and normal sun drying.

4. Conclusions

The automatic solar dryer cabinet could control the conditions of temperature and relative humidity. For normal weather and rainy or low solar radiation situation; the automatic solar dryer cabinet could not control both temperature and relative humidity from programmed conditions which showed that the system needed to improve moisture and temperature control. Chinda chili demonstrated the drying of the automatic solar dryer cabinet in comparison with normal sun drying; this showed the 2 times decrease of moisture ratio of the normal sun drying.

5. Acknowledgement

This research was funded by Dhonburi Rajabhat research and development institute. Thanks to the Food innovation research center, Dhonburi Rajabhat University and faculty of education Dhonburi Rajabhat University for their support.

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