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Original Article

Innovative Hybrid Food Processing Drying Chambers

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Abstract - *This article aims to discuss the drying problem during the low solar energy period by using advanced hybrid drying technology, which uses heat energy from solar radiation and hot water from solar collectors. Another layer of heat-conducting copper pipes is placed under the drying chamber to increase the heat inside the drying cabinet. Cucumber, broccoli, gourami, carrot, and pumpkin are the carefully chosen raw materials for drying. The experimental results show that the temperature of the drying cabinet can increase the heat when exposed to hot water and sunlight. This technique can extend the drying time for at least 10 minutes in conditions with low heat radiation or weak sunlight.*

Keywords - *Hybrid drying, Innovation, Food processing.*

1. Introduction

Solar radiation energy is really significant right now. The sun is a natural means of drying food, but later, solar dryers were created in the previous research. Using a U-shaped copper and aluminium heat exchanger with and without fins, the experiment confirmed the heat efficiency of parabolic rail heating (PTSAH). The findings were from the direct natural heat convection drying of cassava, bananas, and plantains. The indirect solar dryer uses a specialized energy source to heat the sliced potatoes through the joule effect produced by the parallel connection of the welded photovoltaic module. Farmers can use many kinds of drying devices. Comparing the drying effectiveness of different protection machines still presents challenges due to the need for drying based on product characteristics. Utilizing the performance evaluation process can make it simpler. The fundamental capacity notion [1]. A solar dryer increases the capacity to dry air in order to supply additional moisture from the dick pods. It might be simple to use the built-in solar dryer. All of the dick pods may be dried quickly and affordably. It is safe to complete the process of all dick pods in a single day. Because the drying rate is not fixed [2].

The installation system's yearly solar energy percentage rises from 28.9% to 50.5%. Adaption tanks for storing solar hot water and connecting in series with a new compact heating tank are the most expensive installation options, with an annual performance of up to 50.5%. Consequently, tiny tanks with modern insulation have a greater average temperature than large tanks with a lower average temperature. The average temperature in the tank is higher. In addition to reducing heat loss, this will increase solar engagement. An independent conventional heating system with the same storage space generates the annual solar fraction. Storage and reference conditions account for 52 percent of the total. It indicates that the two systems' displays and installation systems are identical. The possibility of a lower investment cost exists as well. A common solar energy source in an area with poor sunlight is a solar collector with a heat pump. The type of refrigerant, for example, affects the SWHS design. Therefore, it might be necessary to search for new refrigerants in the future that can produce better results than those that are now on the market. Aspects are required to assess the system's economic viability. Investigating solar collectors in-depth is necessary to make them the consumers' first option and to fully comprehend the many variations in flow and heat behaviours [4].

The processed food drying cabinet is powered by solar energy using heat pipes heated by solar radiation. The specific energy waste from drying and the quality of the ball goods after drying should be considered. The moisture content falls with increasing time and temperature. Solar drying can be quite successful if the temperature is raised to 50 °C. Processed foods do not work with electrical systems. Electricity can be saved effectively in this manner [5]. Consequently, solar dryers that employ combined heat radiation from solar radiation and thermal water are used.

With the help of this study, you will be able to determine how to dry food when there is little or no sunlight, such as rain, late at night, or no sunlight. The food will dry more quickly than conventional sun dryers if the heat from the hot water tank is transferred to the drying chamber to raise the internal temperature.

2. Research Methodology

2.1. General (Original Model Drying Cabinet)

Farmers formerly frequently employed the sun-drying technique Figure 1. This is because they lower household expenses and costs, such as the cost of not having access to technology.

Fig. 1 Historically, through sun-drying

The conventional approach usually involves drying food products. However, because of the problem of dust and PM 2.5 dust, including flies that carry disease germs, Therefore, a drying system using a solar oven has been developed, as shown in Figure 2.

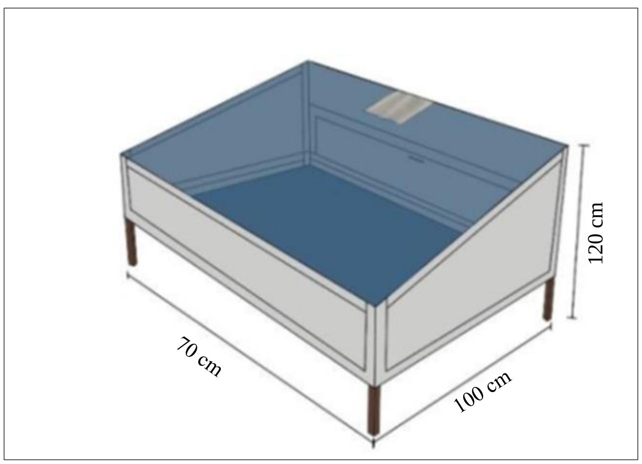


Fig. 2 Original model drying cabinet

2.2. Synthesis (Add to Pulsed Copper Heating Pipes)

However, traditional dryers have many limitations. For example, the temperature dryer chamber is quite low during the sunlight or in the evening. The inability to dry it is, therefore, a concern. Researchers have, therefore, developed a dryer that combines infrared radiation and hot water, increasing the temperature in the oven by 2 minutes. The drying cabinet is heated by convection using hot water stored in the water tank. The heat is radiated by placing pulsed copper heating pipes in the drying chamber, as shown in Figure 3. The new solar drying cabinet and pulsing heat pipes' placement are shown in Figure 4.

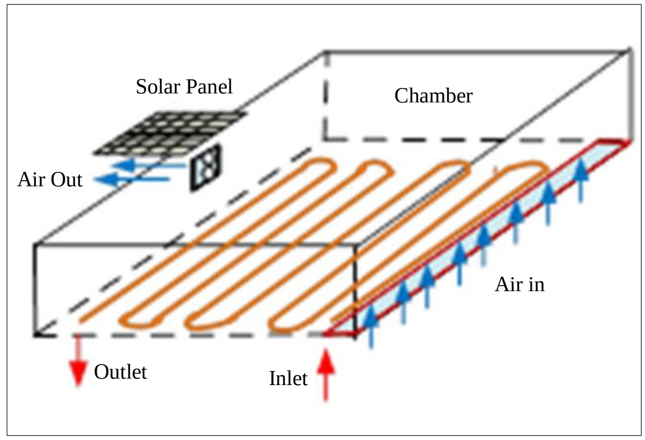


Fig. 3 Placing pulsed copper heating pipes in the drying chamber

Fig. 4 New solar drying cabinet and pulsing heat pipes' placement

Three components made up the dryer designed by the authors of this research: 1) design of a combined heat energy dryer using infrared radiation, 2) design of solar hot water tanks and 3) design of control circuits.

Drying food products is usually the traditional method. However, due to the problem of dust and pm 2.5 dust, there has been a development of drying with solar incubators, as shown in Figure 1. Drying food products is usually the traditional method. However, due to dust and PM 2.5 problems, the solar dryer drying oven was developed. However, the limitation of the conventional solar dryer is that the researcher has developed a drying oven combined with infrared radiation and thermal water, which can be heated up within 2 minutes. The heating method is by convection of hot water stored in the water tank to heat the drying cabinet. That radiates heat with the copper pipe in the solar drying cabinet, as shown in Figure 5. The innovation of a hybrid drying cabinet by adding an additional pulse heating pipe is shown in Figure 6.

2.3. Hybrid Dryer

A combined heat energy dryer or hybrid dryer uses infrared rays and hot water. The old dryer will be replaced by one that will help address the issue of drying during the hours when sunlight is not as strong.

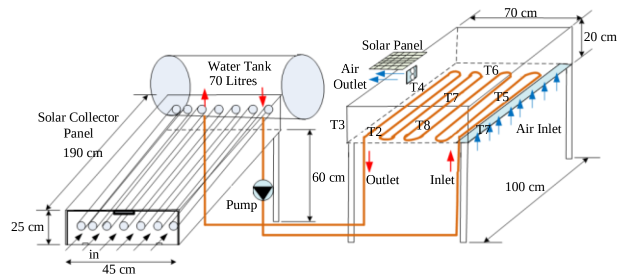


Fig. 5 The layout of the pulsing heat pipes and the design of the hybrid drying system

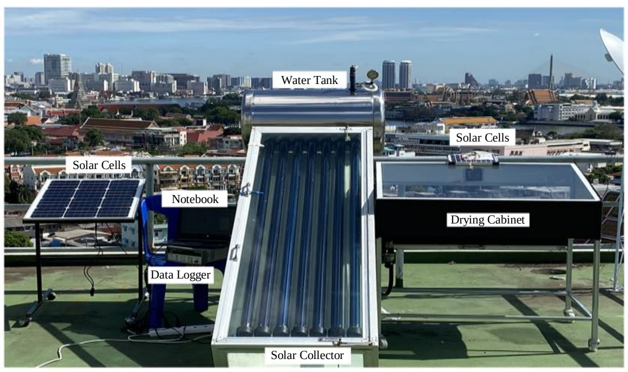


Fig. 6 Innovative hybrid drying system

2.4. Temperature Control Circuit

Selecting the switch to the desired position allows the system to operate manually and automatically. The temperature control circuit design uses heat from the water tank for drying. If the automatic system is chosen, a thermostat will regulate the temperature between 0 and 120 degrees Celsius in a preset setting. The control temperature inside the drying chamber of the combined heat energy infrared radiation dryer was changed to three different levels—50, 60, and 70 °C, respectively. In order to witness the impact of the combined heat energy from infrared radiation.

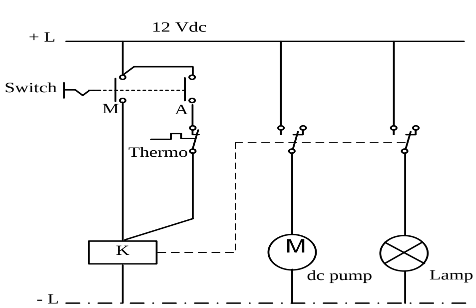


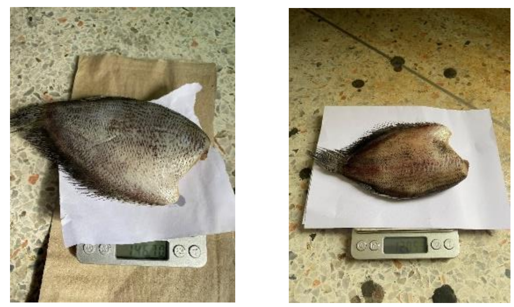
Fig. 7 Combined heat and power drying system control circuit

3. Materials and Methods

The drying rate was determined using the following data from the experiment: temperature, initial and final moisture contents, raw material weights before and after drying, and drying times for gourami, cucumber, broccoli, carrot, and pumpkin.

3.1. Gourami Fish Drying

Calculating the difference between the weight of the Gourami fish before and after drying is the first step in analyzing the yield. Production amount both before and after drying at a regulated temperature of 50 °C. 9.30 am to 4.30 pm is the drying time. Six hours a day is the average drying time.



(a) (b)

Fig. 8(a) Before drying: 146.70g, and (b) After drying: 120.53g.

3.1.1. Standard wet moisture

$$M_w = \frac{m_w - m_d}{m_w} \text{x}100\% = 17.83\%$$

The standard wet moisture content indicates the amount of water present in the fish meat compared to the mass of the fish before drying. 17.83%.

3.1.2. Dry Standard Moisture

$$M_d = \frac{m_w - m_d}{m_d} \text{x}100\% = 21.71\%$$

Dry standard moisture indicates the amount of water present in the fish meat compared to the mass of the fish after drying. 21.71%. The wet standard moisture content and dry standard moisture content from drying the gourami at controlled temperatures of 50, 60 and 70 °C are shown in Table 1.

Table 1. Gourami's typical wet and dry levels of moisture

T (°C)	I_o (W/m^2)	m_w	m_d	M_w	M_d
45.10	523.22	146.70	120.53	17.83	21.71
47.08	531.58	138.19	112.35	18.69	22.99
49.43	348.73	138.87	119.26	14.12	16.44
51.30	552.64	181.00	175.53	3.02	3.12
54.53	496.35	196.14	173.59	11.49	12.99
52.16	538.92	175.56	149.64	14.76	17.32
63.67	841.29	135.51	119.00	12.18	13.87

Figure 9 illustrates how the wet standard moisture and dry standard moisture have changed.

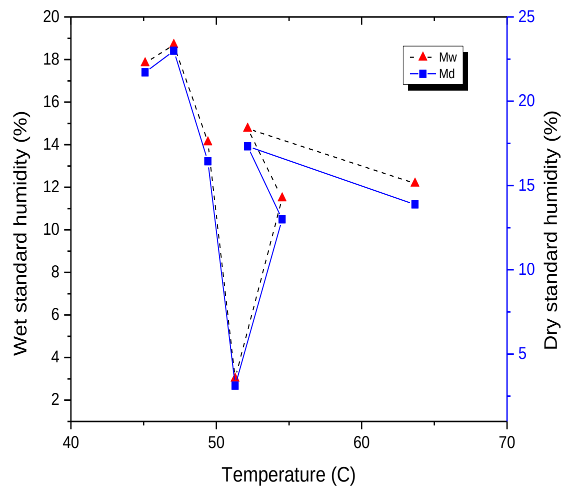
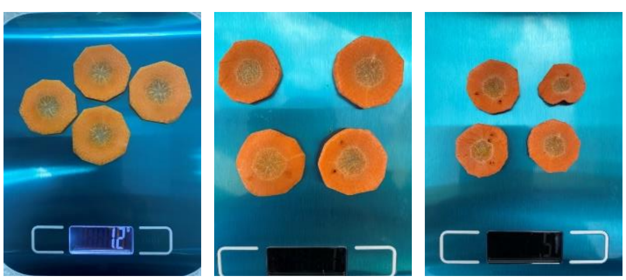


Fig. 9 Wet standard humidity (M_w) and dry standard humidity (M_d)

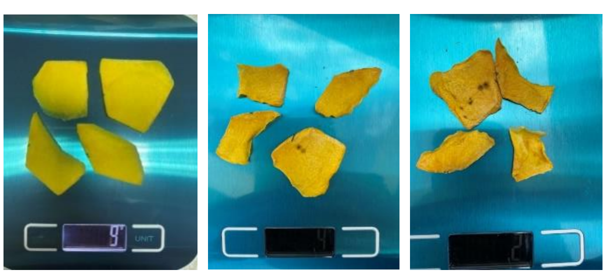
3.2. Drying of Carrot, Pumpkin, Cucumber and Broccoli

The yield analysis after drying is to take the product weight data before drying to see how much it differs from the weight after drying. At the controlled temperature of 60 o C, the yield before and after drying, the drying time from 9.30 a.m. to 4.30 p.m., the average drying time is 6 hours per day. The wet standard moisture content and dry standard moisture content from drying the Carrot, Pumpkin, Cucumber and Broccoli at controlled temperatures of 60 °C are shown in Table 2.



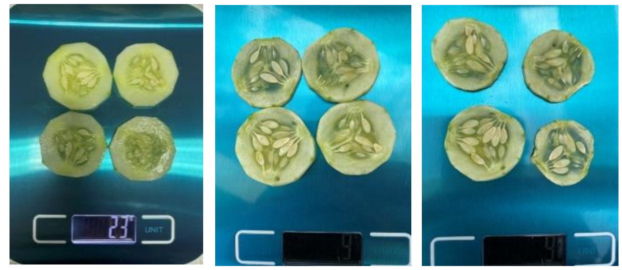
(a) 1 hr ; 12 g (b) 2 hr ; 7 g (c) 3 hr ; 5 g

Fig. 10 The carrot product takes 3.00 hours to dry



(a) 1 hr ; 9 g (b) 2 hr ; 4 g (c) 3 hr ; 2 g

Fig. 11 The pumpkin product takes 3.00 hours to dry



(a) 1 hr ; 23 g (b) 2 hr ; 9 g (c) 3 hr ; 4 g

Fig. 12 The cucumber product takes 3.00 hours to dry

(a) 1 hr ; 9 g (b) 2 hr ; 6 g (c) 3 hr ; 4 g

Fig. 13 The broccoli product takes 3.00 hours to dry

Table 2. Typical wet and dry levels of moisture of raw materials

T (°C)	m_w	m_d	M_w	M_d
60	12	5	58.33	140
60	9	2	77.77	350
60	23	4	82.60	475
60	9	4	55.55	125

3.3. Drying Process Temperatures

The infrared combined heat dryer (SR+W). Maintain a temperature of 50, 60, and 70 °C, respectively. It was found that the drying system with an infrared combined heat energy dryer that the researchers designed can heat higher and has a faster drying time than the conventional drying methods mentioned above.

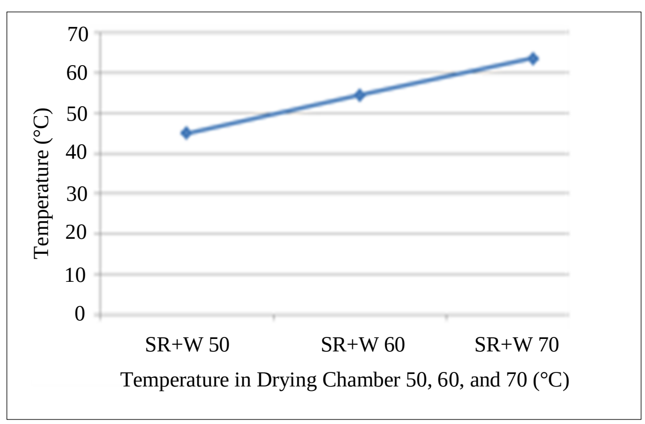


Fig. 14 Temperature (SR+W) in the drying chamber

4. Conclusion

Innovative hybrid food processing drying chambers are heated using infrared and hot water. The sun's energy heats the solar collector, storing the heat in a water tank. A copper pipe system will transfer the thermal water from the tank to the drying room. The quality of the product after drying should be considered.

Operating at an average temperature of 49.43 °C, a mass flow rate of 19.61 kg/s, an average solar energy intensity of 348.73 W/m2, and an enthalpy of 449.21 kJ/kg during the water's phase change from liquid to vapour, the dryer's maximum efficiency is 36.08%. Through the convection of hot water, a hybrid drying oven that combines infrared heat and hot water may enhance the drying chamber's temperature in just two minutes and sustain it for over an hour. The challenge of drying food in warm sunlight or during the rainy season may be effectively addressed by this method.

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