wjert, 2022, Vol. 8, Issue 3, 47-61. **Review Article** **ISSN 2454-695X**

World Journal of Engineering Research and Technology

WJERT

www.wjert.org **SJIF Impact Factor: 5.924**

ELECTRIC-SOLAR ENERGY HYBRID DRYER FOR SA KAEO PROVINCE

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Article Received on 10/12/2021 **Article Revised on 30/01/2022** **Article Accepted on 20/02/2022**

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ABSTRACT

This research aims to study the drying process by using solar sensor, electric circuit controlled combined with stationery solar dryer. The design started with a flat plate receiver and built a cabinet with a 100 cm width, a 198 cm length, and 40.5 cm height, and has a tilted mirror at an angle of 45°. Solar panels were installed as well as an electric charger, and a small 12-volt battery. There are two 12-volt DC electric fans, which deliver hot air through two aluminum tubes and the 8-tray hot-air incubator. A solar sensor was installed to adjust the working mode between the sunlight and the electric coil. Herbs in Sa Kaeo province of Thailand were selected for the test, such as Plai, Ma Kra Tueap Rong, and Do-Mai Roo Lom. Installed temperature and relative humidity instruments inside and outside the drying cabinet. The experiment was conducted from 9:00 a.m. to 5:00 p.m. (September-October). The experiment was conducted with a total duration of 24 hours per drying time, 14 kg per time. The average initial weight of the sample product was 48 g, the average final weight was 24 g, for wet standard moisture products. The initial wet standard was 80.5%, the final wet standard humidity in the product was reduced to 31%. The maximum temperature inside the cabinet was 61 °C. The flat plate collector's maximum efficiency was 18%.

KEYWORDS: Herb Hybrid Dryr; Solar Sensor; Electric Circuit Controlled; Solar Energy; Wet Standard Humidity.

INTRODUCTION

In this work, drying herb processing is the use of solar energy by heating the dried products by evaporating water in the product. The thermal efficiency of the drying equipment depends mainly on the intensity of solar energy. The advantage of using the hybrid dryer is; it can be used without causing any environmental impact. Reduce the problem of contamination from dust, insects, and products with better quality. It also reduces drying time as well. It also contributes to the reduction of energy consumption for electric or fossil fuel drying applications. From traditional drying in the community, it found that natural drying would result in a relatively low production capacity of dried herbs. Many researchers have worked to solve the problem on drying period. The community has a need to support professional groups that make dried herbs. By using high-efficiency dryers to increase productivity by strengthening the community to be more self-reliant in terms of creating jobs and generating income by designing to move certainly. This equipment can be used in all areas save drying time and to preserve product quality in terms of color, smell and taste of herbs. This research aims to design and build an oven using solar thermal energy combined with electric heat in an automatic temperature-controlled hot air dryer to test and analyze the efficiency of the built drying oven as well as evaluate the economic value of the dried product. Such many researchers have studied herbal drying cabinets with automatic temperature control systems. Chakrin Rojanaburanon and colleagues.[1] designed and built herbal incubator that automatically tracks the sun. To help facilitate and reduce the drying time of medicinal plants in accordance with the daily weather conditions by relying on electronic circuits for controlling the operation. It uses two phototransistors to detect the position of the sun and uses a microcontroller to process them for controlling the rotation of the electric motor. Santi Wangnirvanto and colleagues.[2] designed and built a drying cabinet for bananas using solar energy. The weight change of the material inside the drying cabinet is also displayed. The heating coil and fan drive the air are optional accessories. Use a computer as a processor aimed at controlling fuzzy logic system to control the temperature inside the drying cabinet and display the weight change of the material during drying. The result showed that it can reduce the drying time of bananas by 3-4 times compared to normal sun drying. Thiraphong Borirak.[3] studied stationary solar dryer using a cabinet in the size of 45 cm width, 108 cm length and 38.5 cm height, with a mirror tilted at an angle of 45°, using cultivated bananas as product. The drying time was 8 hours per day, it was able to dry 144 bananas at a time, the starting weight of the average sample product of 46.93. g. The average final weight of 23.41 g.

The initial wet standard humidity in the product was 79.18%, the final wet standard humidity in the product was reduced to 29.3%. The mean temperature inside the cabinet was 48.47 °C. Thaksin Wangsing and his team.[4] have built a smart solar incubator with the connect of the internet of the things technology system. Arduino, a sensor-based control system was used to design and build a smart solar oven with the connected technology system. This work studied and developed a solar dryer for drying chili, Banana, and mango. Connectivity Technology by controlling and taking care of turning on and off the cooling fan with an automatic system to be a role model for farmers. Sakda Deesang et al.[5] created 2 in 1 smart drying machine. Use the KidBright program with the condition 1) If the temperature is less than or equal to 60 degrees, the lamp will work, but if the temperature is more than 61 degrees, the lamp will not work. 2) If the temperature is less than 60 degrees, the fan will not work, but if the temperature is greater than or equal to 60 degrees and humidity is greater than 15, the fan will work. 3) Check the temperature and humidity in the air through the App Kid Bright, which is dried using a smart 2 in 1 dryer faster than traditional drying from 5 days to 2 days and can work according to the specified conditions to get quality products sanitary. B.M.A.Amer et al.[6] conducted “Design and performance evaluation of a new hybrid solar dryer for banana”. A hybrid solar dryer was designed and constructed using direct solar energy and a heat exchanger. The dryer consists of a solar collector, reflector, heat exchanger cum heat storage unit and drying chamber. The color, aroma and texture of the solar dried products were better than the sun drying products.

Baher M.A.Amerab Klaus Gottschalkc M.A.Hossain.[7] studied integrated hybrid solar drying system and its drying kinetics of chamomile. A united solar arrangement was studied and operated for drying chamomile throughout the summer season 2013 in Germany. The system consisted of collector, heat exchanger, reflector, main drying chamber below collector, additional drying chamber and supplementary electric heaters immersed in a water tank. It could also storing of solar energy into water through the time of sunshine and salvage this energy at gray climate or off sunshine time to increase the temperature of drying air in the system. The capacity of the main drying chamber ranged 32–35 kg of fresh chamomile and 10–12 kg for the other separate drying chamber. The combined dryer was functioned about 30–33 h to decrease the moisture contents of chamomile from 72-75%–6% (wb) related to 60 h to reduce it to 9–10% (wb) using open sun drying method. Nine mathematical models for the drying kinetics of chamomile were tested to determine the parameters of the best suitable models for those plants. However, many works from research in the past.[8-12] showed that there have been developments of dryers with various technologies to make it more efficient. Therefore, the research team has an idea to develop a multipurpose herb dryer by using solar heat together with the heat from electrical energy that can dry many types of herbs. The electric coil can be controlled automatically, which will produce products quality and exact quantity regardless of the weather this will benefit farmers who can produce dried herbs continuously. Extending the results of using a blended herb dryer. This gives the community strength to be more self-reliant in terms of creating a career and generating income. The integrated herb dryer will decrease the problem of drying herbs in rainy season starved of sunlight, open-handed people in the community use herb dryer in all seasons.

Passive Solar Dryers

Passive solar dryers are regular vented solar dryers, where no exterior source of energy is essential to track the dryer. In this dryer, outside air is heated up with the contribution of solar Irradiation. The hot air, then passes over the product's surface. The thermosiphon consequence united with the greenhouse effect are the leading operators for ordinary ventilation. This makes these solar dryers an efficient and desirable choice for farmers in remote areas (Jain and Tiwari, 2004). Active mode (integral form), indirect mode (distributed form), and mixed-mode are the three basic types of passive solar dryers.

Direct Passive Solar Dryers[13]

In a direct passive solar dryer, the product is placed in a transparent-walled drying chamber. Solar irradiation directly on to the product through the apparent cover, is transformed to thermal energy by the greenhouse effect, and rises the temperature of the product. This primes to the removal of moisture from the product and decreases the inside relative humidity. The moisture dispersion process vaporizes the moisture.

Cabinet Dryers

Cabinet dryers have been used for dehydrating produces for a long time. Since 1957, numerous researchs were being approved on certain categories of dryers. The Brace Research Institute, McGill University, Canada, reported groundbreaking.

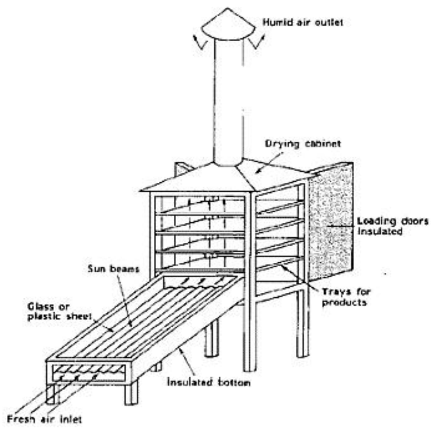

Fig. 1: Solar cabinet dryer.[14]

Concepts and principles for designing and constructing the drying cabinets using solar energy with electric heaters and control systems. There are physical components shown in Figure 1, which working principle is when the sun shines down on the flat plate light will cause the air inside the panel to become hot air, which is about 40-60 degrees Celsius according to the weather conditions, if any day it rains or has little sunlight will use the electric heating coil (Electric Heater) as an additional or alternative heat source, which the operation of the heating unit is automatically controlled By using a magnetic contactor with a solar sensor as a command to cut electricity. Makes the heat inside the dryer to be consistent according to the set value. Details as shown in Figure 1-2, which will result in a good quality product. Within a certain time able to generate income for farmers continuously, it also does not spoil the raw materials.

The solar dryer comprises of five essential components: flat plate collector, a drying chamber, fans, an electrical heater, and a PV system. The completed unit was created at Faculty of Industrial Technology, Vallaya Alongkorn Rajabhat University A sketch of prototype is shown in Figure 2. A complete fabricated dryer can be seen in Figure 3.

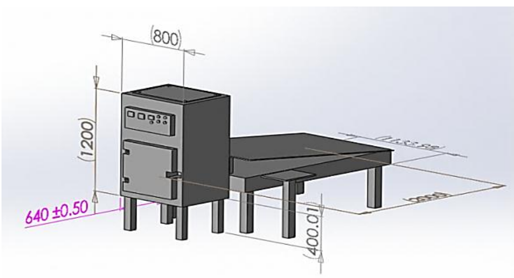

Fig. **2**: **Drawing of electric herb dryer with an automatic temperature control combined with solar energy.**

The advantage of the hybrid solar dryer in this work is non-complicated component required. A lot of herb can be dried and the cabinet generates not too high air temperature, but provides the appropriate drying condition process. The disadvantage is fluctuating temperature because it depends on solar radiation.

Fig. 3: Hybrid solar dryer design and fabrication.

The working principle of a solar sensor-controlled electric circuit of the hybrid herb dryer Circuit 1 Main power circuit or voltage source 220 Volts AC.

The main power circuit is a circuit capable of delivering high currents. The working principle is when opening a circuit breaker or opening a circuit control device, the mains voltage will wait on the main contact of the contactor. Magnetic (K1) until commanded by the control circuit When the control circuit operates, K1 receives a voltage from the control circuit through which the contactor coil operates. When the contactor is working Contactor contacts are connected through the contactor face to allow current to flow through the coils inside the incubator.

Circuit 2 Operation control circuit

When turning on the protective device Then press the switch to the ON position, the voltage will flow through the Photo Electric control of lighting with the Program control unit. Press the switch. S2 contactor K1 is working. Contacts in the NO state of K1 will close the circuit, causing the lamp run (Lamp Run) to come up with the internal ventilation fan will spin to ventilate the furnace. Thoroughly until it reaches the preset value. At the same time, the contact in the NC state of K1 will open the circuit causing the lamp stop to turn off because the NO, NC contacts of K1 are interlocking. Until the switch S2 is pressed or the light control circuit receives sunlight (Photo Electric control for lighting), it will disconnect the electrical circuit causing K1 to stop working, Lamp Run will turn off and The power circuit will stop supplying voltage to the coils inside the incubator. When the Photo Electric control of lighting receives sunlight, it will switch on and allow the 12V DC voltage from the solar cell (12V DC) power supply unit to work. Through the normally closed (NC) contact of K1, the 12V fan (Fan 12V DC) inside the heat sink is lit up. To send hot air into the herbal oven with a lamp indicating the working status of the DC circuit is on (Lamp Run 12V DC). If you want to turn off the circuit, disconnect the main control switch to the Off position (Switch Off.)

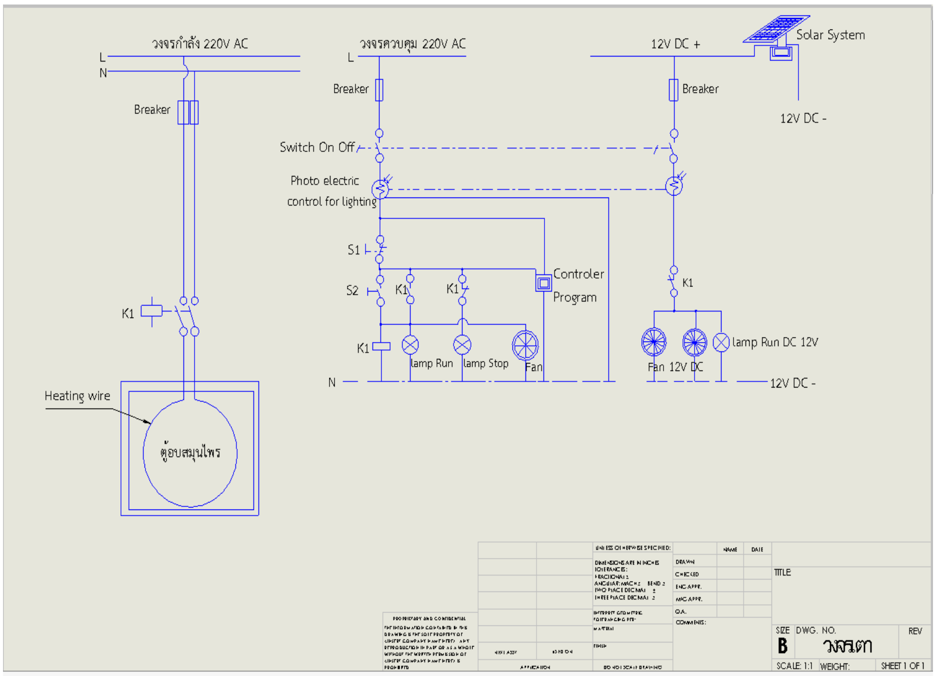

Fig. 4: A drawing of a solar sensor-controlled electric circuit of the hybrid herb dryer.

Thermal efficiency of the hybrid solar dryer

The thermal efficiency of the hybrid solar dryer is the ratio of the energy derived from solar radiation fed to the flat plate collector system. Thermal efficiency equation of the system is shown as follows

$$\eta_c = \frac{\dot{m} \times Cp \times (T_0 - T_i)}{It \times Ad} \times 100 \qquad (1)$$

When

η_c is the thermal efficiency of the drying system

Cp is specific heat capacity of the air (kJ/kg.K)

$m^{\circ}{}_{syngas}$ is the mass flow rate of the air (m^3/s)

It Biomass is the calorific value of biomass (W/m^2)

Ad Flat plate Area (m^2)

T_o Outside air temperature of the collector (K)

T_i Inlet air temperature of the collector (K)

Mass flow rate of the inlet air

Biomass fuel consumption of gasifier systems can be determined by measuring the amount of biomass fed to the system over time under the operating conditions. The fuel consumption rate can be obtained from the following equation.

$$\dot{m} = \rho \times A \times V \quad (2)$$

ρ is the density of air, (kg/m^3)

A is the area of solar collector, (m^2)

V is the velocity of the heated air, (m/s)

EXPERIMENTAL SET-UP

The assessment of the drying cabinet's competencies comprised of the temperature distribution study inside the drying cabinet in the empty cabinet condition and the study of drying Plai, Ma Kra Tueap Rong, and Do-mai roo lom with the apparatus and tools used for testing as follows:

1. Glass thermometer and infrared thermometer
2. Digital scale
3. Solar drying cabinet in combination with built-in hot air system.

Fig. 5: Herbs used in the experiment: Plai, Mah Gra Tueb Long, and Do Mai Rue Lom.

A. Solar Hybrid Dryer Startup and Operation

A huge portion of the method included in testing Solar Hybrid Dryer design is deciding the suitable working methods for the modern framework and a given feedstock. After taking the standard framework, startup and operation methods were received for testing this dryer.

Fig. 6: Solar Hybrid Dryer Startup and Operation.

The equipment was setup as shown in Figure 6. Herbs from SA Kaeo Province were loaded into container and were weighing, then sent to the drying cabinet; press the jerk button on the control panel, then start electric fan to permit air flowing through the cabinet. The fan rises the draught of hot air and thereby increase the drying rate. The measured temperatures were recorded by the operator.

Fig. 7: Control and display system.

Control and display system as shown in Figure 7 play important role in displaying volt while charging. In addition to another function of control and display, the system is to adjust speed of charging.

B. Methodology

The hybrid solar dryer was set up in the open air area on a sunny day during September-October, 2021 in East-West alignment. The cabinet was filled with herbs and sealed. The Graphtec data logger virtual instrument was initialized and temperature recording started. Throughout the drying process, the solar collector and drying chamber were monitored for temperature (Tair dry), relative humidity (RH air dry) and drying air velocity (Vair dry). Ambient air was monitored for temperature (Tair amb), relative humidity (RH air amb), light intensity and solar radiation. The parameters were obtained at regular periods every hour. Thermocouples connected to a millivoltmeter with an accuracy of 0.1 air dry and Tair are. RH air dry and RH air amb were measured using a wet bulb and dry bulb temperature meter. Solar radiation data along the solar drying period were obtained from the Department of Mechanical Engineering Technology, Faculty of Industrial Technology, Vallaya Alongkorn Rajabhat University.

In the experiment, the performance of the hybrid dryer was tested; solar radiation intensity, temperature, and relative humidity of the air were measured and the air flow rate including methods for determining the moisture content of the material to be dried. Then an experiment using a laboratory-scale dryer was discussed in order to use the data to create a thin-layer drying model and find the diffusion of moisture. Formerly, an experimental method was described to determine the equilibrium humidity. Take the solar radiation intensity data. Air temperature point relative humidity and the moisture content of the material to be dried were graphed with time to observe the relationship of these variables. In terms of material moisture variation, we often compare it to the case of natural sun drying and note the difference in drying time. In addition, the efficiency of the dryer can be analyzed from the ratio of energy used to evaporate water from the product of the energy generated by the solar radiation incident on the solar dryer. Measurement of the efficiency of the herb dryer's internal light panel at a hot air flow rate of 42.4 m^3/hr.

From Figure 5, the operational test of the solar dryer for drying bananas at the hot air flow rate of 42.4 m^3/hr. In hot weather, the maximum flat plate collector efficiency was 0.18 or 18 %, y = -0.141x + 0.0012, R^2=0.9973.

B. ***The results of the study of temperature distribution inside the drying cabinet in the empty cabinet condition***

By measuring the temperature inside the drying cabinet, which has not yet contained herbs in the tray level, 10 times, the data were recorded every 15 minutes between 9:00 a.m. and 5:00 p.m., while using only solar heat and while using a heater with solar energy. The results are shown in graphs as shown in Figure 8 and Figure 9, respectively.

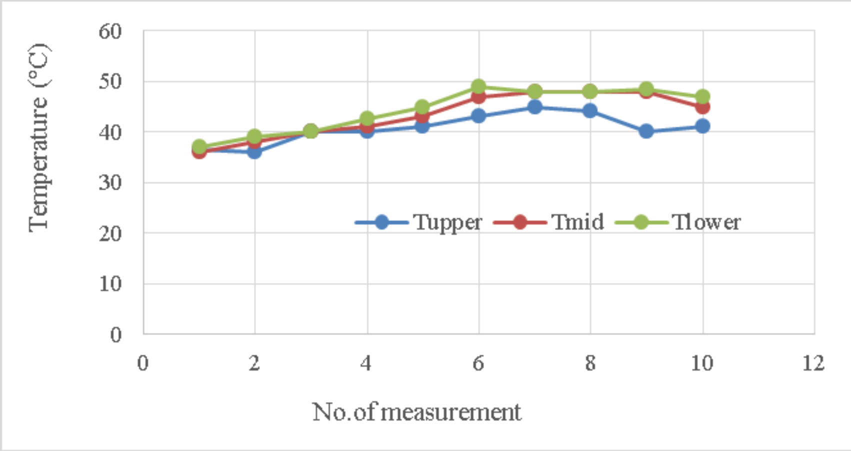

Figure 8: A graph comparing the temperature distribution of each tray inside the drying cabinet in the case of solar heat alone.

The temperature inside the drying cabinet in the empty cabinet condition when using only solar heat energy. First, the temperature rose rapidly and enters a stable state. The average temperature at the top of tray level, middle tray level, and the lower tray level were 42.18, 44.3 and 46.85 degrees Celsius, respectively. The temperature was fluctuating in some periods. Because during the experiment, sometimes clouds obscured the sun. The average temperature inside the incubator was about 44.8 degrees Celsius.

C. ***Comparison graph of the temperature distribution at each tray inside the drying cabinet in the case of heat from the heater combined with solar energy.***

When using a heater with solar energy, the temperature inside the drying cabinet increased rapidly and entered a stable state in 60-61 °C at the top of the tray level as shown in Figure 10. Middle tray level and at the lower tray level, the mean values were 60.37, 60.5 and 60.62 degrees Celsius, respectively. The temperature inside the drying cabinet had little variation. Because there was a heater working to provide additional heat when the temperature was lower than the set temperature. The average temperature inside the oven was around 60.5 degrees Celsius as designed, which shows that using a heater, it would increase the temperature inside the drying cabinet are more evenly distributed. In addition, the temperature level is higher. The values are as desired as well test results in case of using heat from heater alone or using heat from heater with heat from solar energy. It can be seen that the daily temperature inside the drying cabinet is set to 60 degrees Celsius. There may be a minimum change of 59.5 and a maximum of 60.5 degrees Celsius, while when using solar heat alone. The daily temperature inside the drying cabinet will be quite different during the afternoon and is not constant at each time depending on the intensity of the incident solar radiation on the solar panel of the dryer.

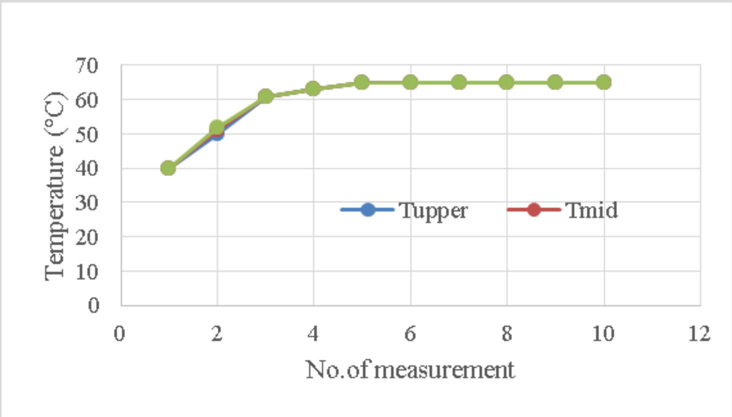

Fig. 9: Comparison graph of the temperature distribution at each tray inside the drying cabinet in the case of heat from the heater combined with solar energy.

The experiment can be shown in the Figure 10. It was found that the maximum temperature was 62 °C after 5 minutes and the upper and the mid temperature of air were equal after 3 minutes.

D. ***The results of the study of Plai, Ma Kratueb Long and Do Mai Rue Lom with drying cabinets.***

Measure the variation in humidity of Plai, Ma Kratueb Long and Do Mai Rue Lom. During drying by weighing each herb at the beginning and while drying, every 30 minutes until the end of the test (from 8.30 a.m. – 3.30 p.m.), the results are shown in the graphs in Figure 10, Figure 11 and Figure 12, respectively.

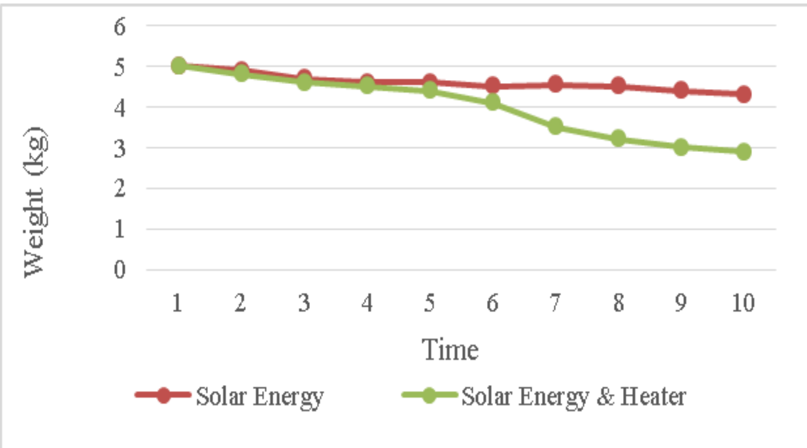

Fig. 10: Compare the rate of change of dried Plai.

From the experimental results, it can be seen that in drying play by using only solar dryer. The reduction rate of play weight ranges from 0–4 %, or on an average of 2.14%. It is expected that it will take nearly 48 hours to attain Plai at dry standard humidity, although when the heat from the heater was applied, the weight of the Plai was reduced at a rate of up to 9%, which was estimated to take around 20 hours to dry, reducing the time by approximately 58%.

E. *Compare the rate of change in weight of Ma Kratueb Long.*

For drying Ma Kratueb Long using solar heat alone. The rate of reduction in banana weight is between 0 and 7 %, or an average of 3.84%. It is estimated that it will take approximately 72 hours for horses to trample the dry barn at standard dry humidity. While when using the heat from the heater to help The weight of the horse trampling was reduced at an average constant rate of 6.4%, with an estimated drying time of approximately 18 hours, reducing the time by approximately 75%.

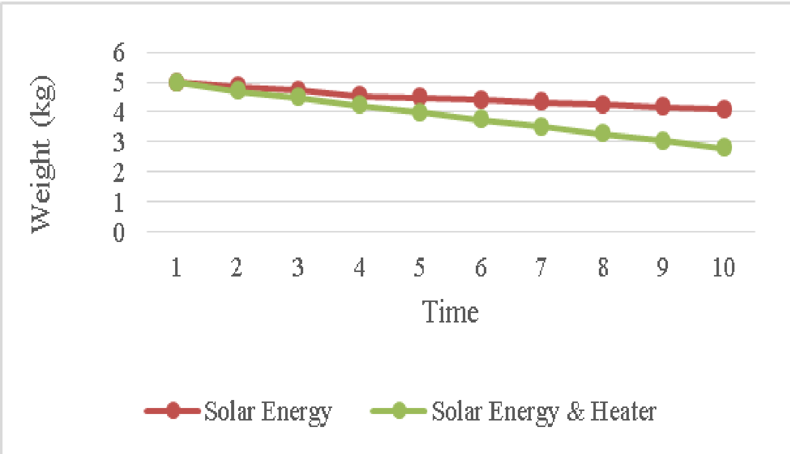

Fig. 11: Compare the rate of change in weight of Ma Kratueb Long.

F. *Compare the rate of change of Do Mai Rue Lom weight while drying.*

While drying herb without the sun's heat alone. The total weight loss rate is between 0 – 16.6%, or an average of 7.17%. It was estimated that it would take about 20 hours to reach the dryness at standard dry humidity. While when using the heat from the heater to help The weight of the dome was reduced at an average rate of 9.8%, which was estimated to take approximately 15 hours of drying time, reducing the time by approximately 25%. To heat the herbs that are dried using a heater. This will significantly reduce the drying time.

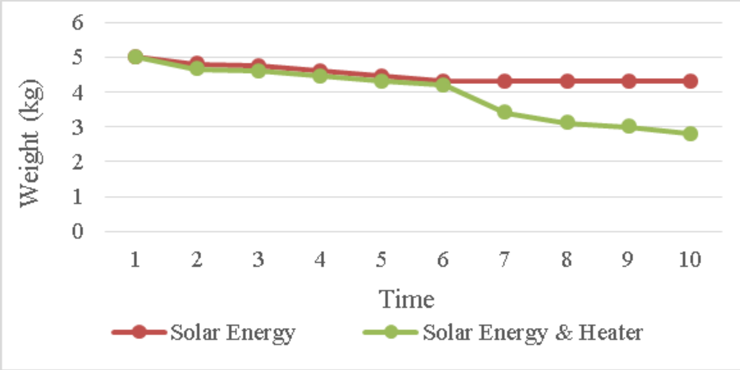

Fig. 12: Compare the rate change of Do Mai Rue Lom weight while drying.

CONCLUSION AND FUTURE SCOPE

The temperature inside the drying cabinet is consistent and distributed in each tray during the drying process. The humidity was in the standard and the quality was measured by the mean temperature difference of the upper tray, middle tray and lower tray compared to the desired temperature were 0.37 °C, 0.5 °C and 0.62 °C, respectively. The results of the herb drying experiment were found that at the airflow rate of 0.57 m^3/minute, the dryer can be used to dehydrated herbs, even if there is no sunlight or at night, subsequent in continuous output but consumes additional electricity. The maximum temperature of the cabinet during drying was 61 °C after 24 minutes. Some of these issues should be done in the next step. Programmed conveyer for an herb charging system may be furnished for convenience in operation. The stack extended as long as possible for reducing humidity rapidly in drying should be made. Various types of herbs, chosen from Sa Kaeo area should be investigated.

ACKNOWLEDGMENT

The author would like to thank the National Innovation Agency of Thailand for financial support for this research.

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