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Experimental studies on a parabolic-shaped solar tunnel dryer for Andrographis paniculata drying

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Abstract

Andrographis paniculata was dried using a parabolic-shaped solar tunnel dryer developed in the Faculty of Science and Technology, Nakhon Pathom Rajabhat University, Nakhon Pathom, Thailand. It is constructed with local materials, and then tested experimentally in food stuff drying Andrographis paniculata. With this dryer, 50kg of Andrographis paniculata can be dried within 4 hours. The dryer reduces drying losses as compared to sun drying and shows lower operational costs than the artificial drying. The color and the flavor of the food stuff dried with this dryer are comparable to that of a high- quality dried in markets. The dryer could be used for Andrographis paniculata of 80% (wb) moisture content, and they could be dried within 4 hours, with 0% (wb) remaining moister. The products being dried in the dryer got the heat from both the sunlight and the collectors. They were completely protected from rain, animals, insects and the dried products are of high quality. However, the temperature of the drying air was varied between 31 - 46 ^{o}C, depending on the weather conditions.

Keywords: Parabolic-shaped, Solar drying, Andrographis paniculata, Solar tunnel dryer

1. Introduction

Andrographis paniculata is one of the major medicinal plants commonly known as “Kalmegh” or “King of Bitters” in family of Acanthaceae. It is an ancient medicinal herb with extensive ethno botanical uses that grows abundantly in southeastern Asia, in moist and sunny situations. It is an erect annual herb with dark green and quadrangular stem, small leaves, white flower, linear-oblong capsules and tiny yellowish brown seeds. It is a source of several diterpinoids of which Andrographolide is the main compound with immunostimulant, antipyretic, anti-flammatory and anti diarrhea properties [1]. Drying is one of the most used methods for product preservation, and as a result, it adds higher value to the products. A dryer can achieve this purpose by supplying

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more heat which in turn increases the vapor pressure of the moisture in the product, reduces relative humidity of the air, then increases its moisture loading capacity and ensures sufficiently low equilibrium moisture content. Solar energy can be used as an important and environmental compatible source of renewable energy. The use of solar energy for drying effectively reduces the problems arising from generating energy by convention method. This is because the use of the conventional energy source for drying purposes is costly and hazardous to environment [2]. The purpose of this paper is to present the developments and potentials of solar drying technologies for drying Andrographis paniculata and to study on temperature, relative humidity, solar radiation and moisture content of the products.

Nomenclature

A	total area of collector
H_T	intensity of solar radiation on the ground
L	heat required to evaporate water 1 kg
m_i	mass of the dried product
m_w	mass of water to evaporation
M_i	initial moisture of product
M_f	final moisture of product
N_D	number of days required for drying
Q_{drying}	amount of heat required
η	efficiency of collector

2. Materials and Method

2.1 Design of Solar Tunnel Dryer

To carry out design calculation and size of the parabolic-shaped solar tunnel dryer, the following assumptions and conditions were made as summarized in Table 1.

$$m_w = (M_i - M_f)/(100 - M_f)m_i \tag{1}$$

where m_w is mass of water to evaporation, (kg), m_i is mass of the dried product, (kg), M_i is initial moisture of product, (%, wb) and M_f is final moisture of product, (%, wb), then calculate the amount of heat required from the equation [3];

$$Q_{drying} = m_w L. \tag{2}$$

when Q_{drying} is amount of heat required, (MJ) and L is heat required to evaporate water 1 kg, (MJ/kg). In the final step, calculated area of collector from the equation [3];

$$A = Q_{drying} /(\eta H_T N_D) \tag{3}$$

where A is total area of collector, (m^2), η is efficiency of collector, (decimal), H_T is intensity of solar radiation on the ground, (MJ/m^2- day) and N_D is number of days required for drying

The parabolic-shaped solar tunnel dryer has the area of $12.2 \times 1.22\ m^2$. The parabolic-shaped solar tunnel dryer consists of a solar collector, drying tunnel, and three radial flow fans to drive the moist air out of the drier. The product to be dried is placed as a single layer inside the drying tunnel. Air entering the solar collector is heated and is forced on the products placed in the drying tunnel using three fans at the air inlet of the solar collector. For experiments with DC power from solar PV panels could be used. Metal plates are curved to be S-shaped and used as side walls. Moreover, top of the dryer is covered by transparent materials. The characteristics of the parabolic-shaped solar tunnel dryer as shown in Fig. 1-2**.**

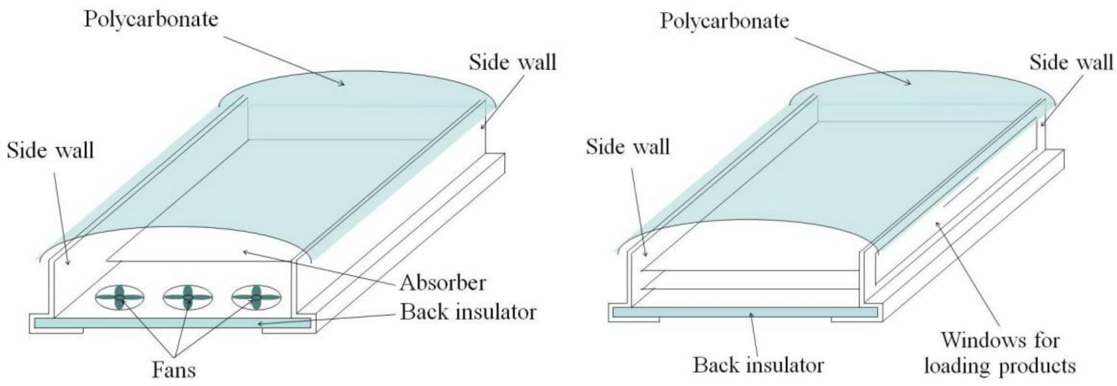

Fig. 1. The characteristics of parabolic-shaped solar tunnel dryer (a) The solar collector and (b) the product container

Fig. 2. Illustration of parabolic-shaped solar tunnel dryer

Table 1. Design conditions and assumptions

Items	Condition or assumptions
Location	Nakhon Pathom Rajabhat University
Product	Andrographis paniculata
Loading rate in each batch(m)	50 kg
Initial moisture content(M_i)	80% wb
Final moisture content(M_f)	0% wb
Ambient air temperature	34°C (Average for 9 February 2012)
Ambient relative humidity	25% (Average for 9 February 2012)
Maximum allowable temperature	57°C
Sunshine hour	10 h
Drying period (Td)	4 h
Incident solar radiation (I)	540 W/m^2
Dryer efficiency (η)	31.67%

2.2 Experimental

To measure the solar radiation and another parameters that effect on the performance of dryer, different devices were employed. A pyranometer (Kipp & Zonen model CM 11, accuracy ± 0.50%). Relative humidity from ambient and in any parts of dryer were employed, used hygrometer (Electronik, model EE23, accuracy ± 2%). Temperatures in the collectors, product container, air duct and ambient were measured by Thermocouple Type K (accuracy ± 0.1°C) [4]. All voltage data from pyranometer, hygrometer and Thermocouple Type K devices were recorded by data logger (Yokogawa, model DC100) every ten minutes. For air speed was manually monitored at 3-hour intervals during the experiment. The performance of the drier was evaluated by conducting tests at by loading with Andrographis paniculata, by measuring the following parameters: (a) radiation incident on the collector (I_D), (b) air temperatures at various locations in the collector (T_1-T_{12}) and dryer, (c) relative humidity (H_1-H_3) and weight of samples. To measure the temperature of air at various locations of the collector and dryer, K-type thermocouples were installed at various points along the length and breadth of the solar tunnel dryer, as shown in Fig. 3. All temperature data were registered at an interval of ten minutes by a data logger. Drying test was started at 8:00 hours and stopped at 12:00 hours. Moreover, the sample products were also prepared and placed on product container parts (Ex_1 – Ex_8) and outside (Ex_{out}). Every 10 minute intervals, the samples were brought to weight until the end of process and they were taken in an oven to bake at 103°C for 24 hours to determine the moisture content of the products. The relative humidity of air inside the dryer was determined from the dry bulb and wet bulb temperatures recorded by a data logger. Andrographis paniculata is chosen to investigate the performance and then compare data with natural sun drying. The performance tests were carried out two times during February, 2012 and weight 50 kg of Andrographis paniculata was used for each test. In the morning, cut Andrographis paniculata was manually loaded into the product containers to be dried and the fans were started at the same times, from 8 a.m. and stopped at 12 a.m.

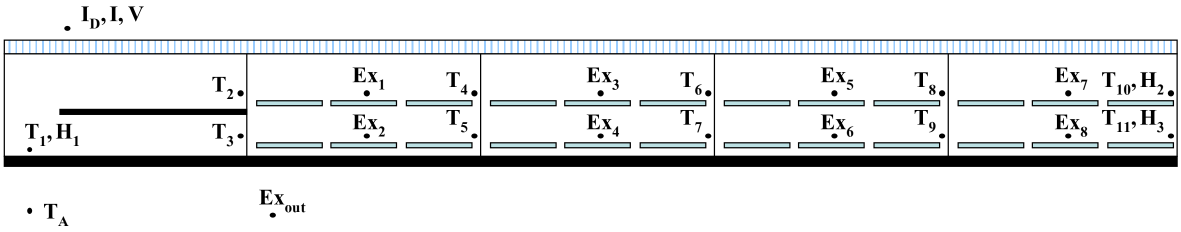

Fig. 3. Position of thermocouples in the parabolic-shaped solar tunnel dryer

3. Results and Discussion

The two experiments were carried out 9th February, 2012. In each experiment, 50 kg Andrographis paniculata was used for drying and the weather was clear sky day and windswept with the maximum global radiation of 783 W/m^2 (Fig. 4).

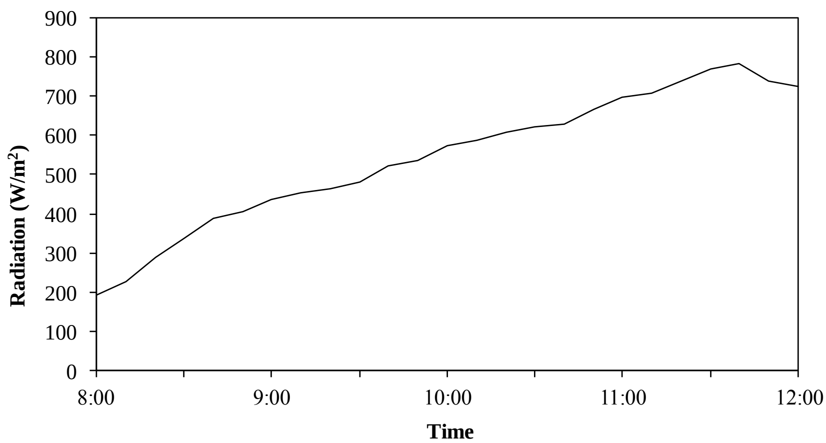

Fig. 4. Variations of global solar radiation during the experiment

At the middle of the dryer, the drying air temperatures at the top and the bottom of the tray were found to be varied in the range of 31 - 46 ^oC during 8:00 a.m.–12:00 a.m. Temperature from the top (T_6) and bottom (T_7) of solar collector were compared with ambient temperature (T_a) and shown in Fig. 5.

As the fans were powered by a solar cell module, the air flow varied with solar radiation. This flow rate help to control the drying air temperature in the dryer. Electrical current and voltage that produced from solar panel were also considered, From Fig. 6 and Fig. 7 were found that the variations of these values depend on the solar radiation.

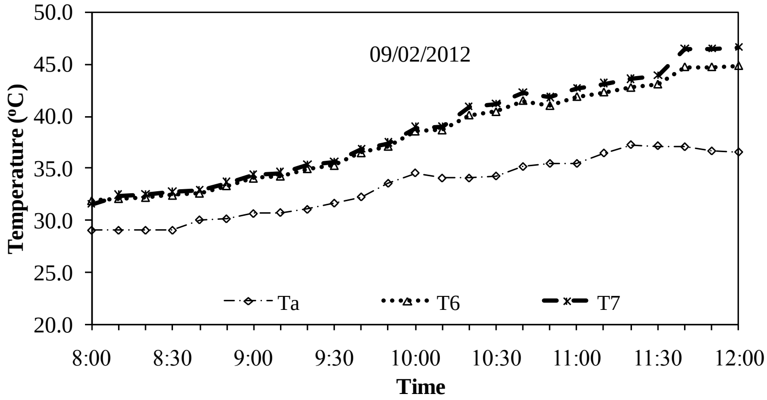

Fig. 5. Variations of the ambient temperature (T_a) and temperature of the outlet air at top (T_6) and bottom (T_7) dryer

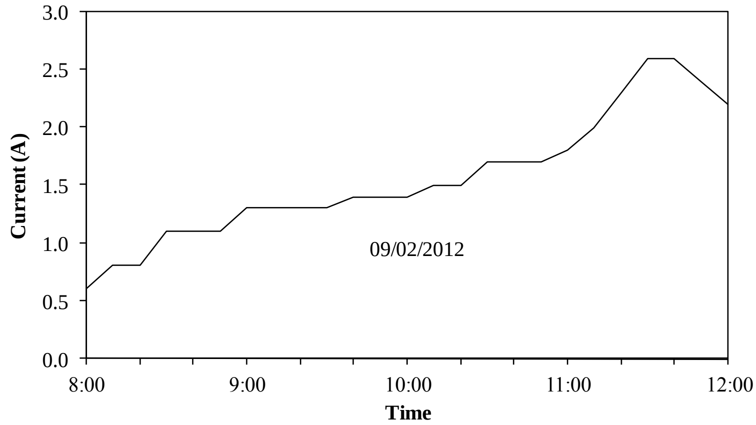

Fig. 6. Variations of the electrical current from solar panel

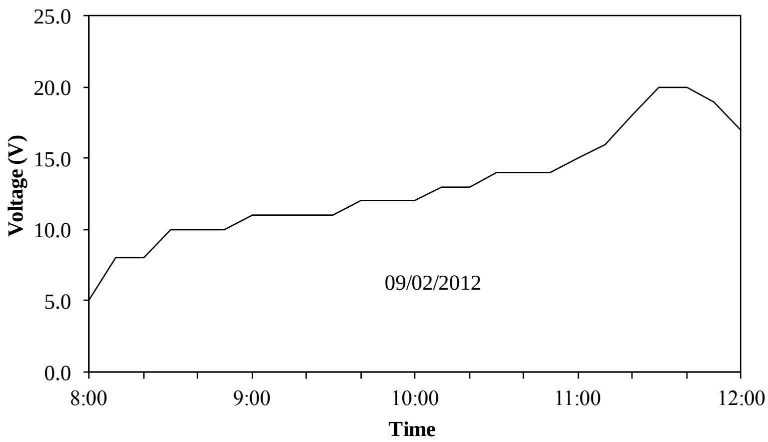

Fig. 7. Variations of the voltage from solar panel

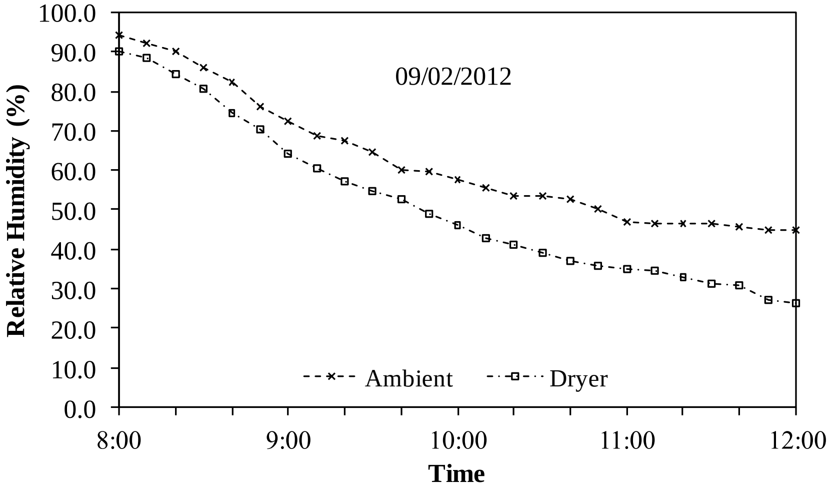

Fig. 8. Variations of the relative humidity of the ambient air and the air at top and bottom dryer

This relative humidity is much lower than that of the ambient air for most time of a day. Therefore, the air in the dryer has significantly higher drying potentials than the ambient air (Fig. 8).

The drying rate of Andrographis paniculata in the dryer is significantly higher than that of the natural sun dryer. The variations of moisture of Andrographis paniculata was shown in Fig. 9. After 4 hours of drying, the remaining weight of Andrographis paniculata was about 11.5 kg. The quality of dried

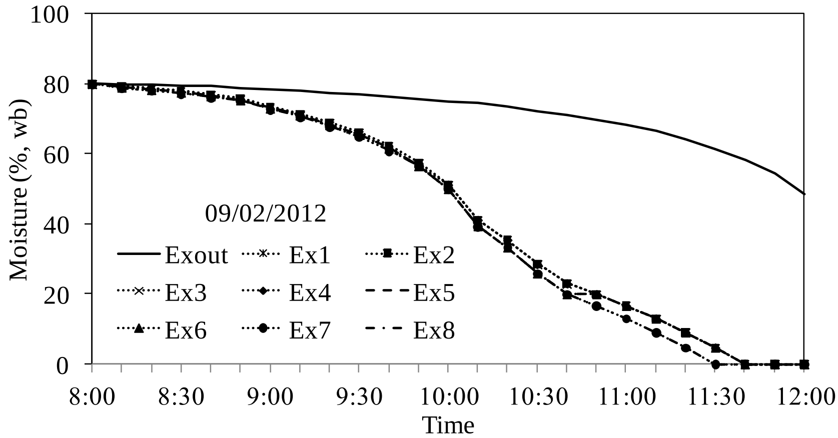

Fig. 9. Comparison of the moisture changes inside parabolic-shaped solar tunnel dryer ($S_1 – S_8$) and open sun drying (S_{out}) during drying of Andrographis paniculata

3.1 Cost of operation

Cost for material and construction of the parabolic-shaped solar tunnel dryer for drying 50 kg of Andrographis paniculata in a dryer was estimated at around USD 5000.00 (1 USD = 30.23 Baht, June 2011). The economics of Andrographis paniculata dried in parabolic-shaped solar tunnel dryer economics is presented in Tables 2.

Table 2. Economics of Andrographis paniculata dried in parabolic-shaped solar tunnel dryer

Initial investment	5000.00 USD
Cost of fresh Andrographis paniculata	0.33 USD per kg
Cost of drying through solar tunnel dryer including cost of labor etc.	40.11 USD per day
Cost of dry Andrographis paniculata	109.16 USD per day
Benefit	52.55 USD per day
Payback period of dryer	96 working days

4. Conclusion

Tests of the parabolic-shaped solar tunnel dryer demonstrate the potentiality of the parabolic-shaped solar tunnel dryer for drying of Andrographis paniculata in Thailand. It is worth adoption since the product has a market and the quality of the product is reflected in its price. There is a considerable reduction in drying time of Andrographis paniculata in parabolic-shaped solar tunnel dryer as compared to sun drying of Andrographis paniculata. The maximum global radiation is 783 W/m^2. At the middle of the dryer, the drying air temperatures at the top and the bottom of the tray are found to be varied in the range of 31 - 46 ^{o}C. This relative humidity is much lower than that of the ambient air for most time of a day. The drying rate of Andrographis paniculata in the dryer is significantly higher than that of the natural sun dryer.

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