Thermal Efficiency of Natural Convection Solar Dryer

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Abstract. The purpose of this research is to study the thermal efficiency of natural convection. The working principle of natural convection solar dryer is, once the air in the solar dryer is heated by solar energy, the air relative humidity will drop and floating up through the drying. This air will take moisture out of the product and flow out to the ambient air. It was found from the experiment that, in the duration of 8.00 am – 4.00 pm on a clear sky day, an all-day average ambient air and inside the chamber temperature were 38.34°C and 63.19°C respectively. At the solar radiation intensity of 759.53W/m2, mass flow rate of air was 0.023 kg/s and the thermal efficiency of the solar dryer was 2.59%.

1. Introduction

Solar energy is the most readily available source of energy [1]. Sun drying technique is one of the oldest and most common practices of preservation of grains fruits, vegetables and food without deteriorating the quality. Drying edible agricultural food products does not only prolong the storage lift of the product, but also enhances the quality. However, the process is largely dependent on the weather and is very difficult during the rainy season. Moreover, the traditional method usually yields products with high microbial load. The exposure to wind and to unfavourable weather conditions results in great loss, through spoilage, lack of uniformity in the final product and development of undesirable flavour. Solar tunnel drier helps in advocating the aforementioned problems. The rate of drying depends on various parameters such as solar radiation, ambient temperature, wind velocity, relative humidity, initial moisture content, type of crop absorptivity and mass of product per unit exposed area [2]. Soponronnarit (1995) studied solar drying of some crops such as paddy, multiple crops and fruit has proved to be technically feasible. However, there is a limited acceptance of solar dryers amongst farmer in Thailand. The major constraint may come from a long payback period and high initial investment [3]. The majority of the numerous solar driers which are available are mainly used for drying various crops either for family or for small scale industrial production.

2. Materials and Methodology

A natural convection solar tunnel dryer was designed and constructed at the Science Center, Songkhla Rajabhat University, Thailand. Figures 1 and 2 show the line diagram and the miniature model used for experimentation. The movement of air through the vents when the drier is placed in the path of airflow, brings about a thermos siphon effect which creates an updraft of solar heated air laden with moisture out of the drying chamber. The source of air flow is through natural convection and it blows away the moist air out of the tunnel through vents [4]. Since our model is for a study purpose, the total base area of the drier is 0.35 m^2 with the length of 0.7 m and the width of 0.5 m. Bead strand is used to build the support structure. The structure is covered with glass that is tinted black inside, and small air gap is provided to achieve natural draft [5]. Figure 2 shows the constructed model of solar tunnel drier. The setup is placed over an insulation material to avoid the heat loss due to conduction.

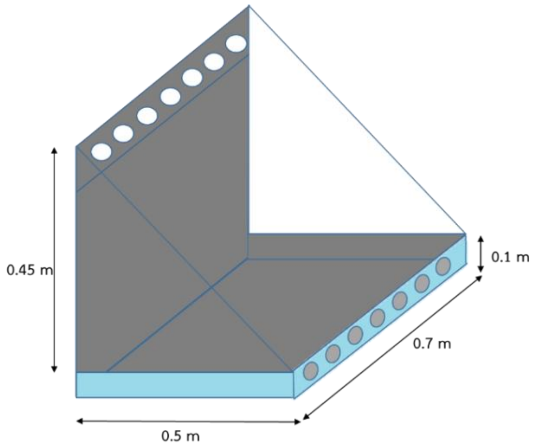


Figure 1. Schematic view of walk in type hemispherical solar tunnel drier.

Figure 2. The constructed model of solar tunnel drier.

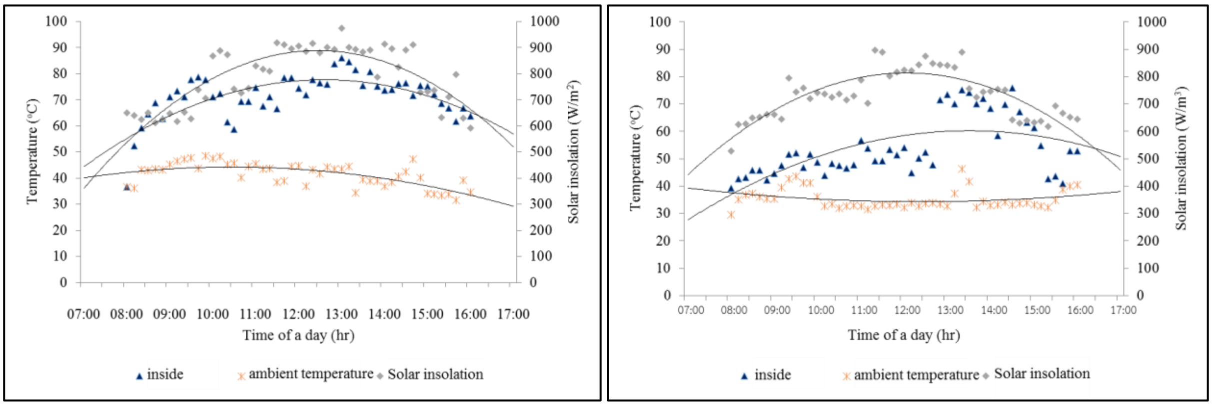
3. Experimentation and Procedure

During the experimentation, various measuring devices were used to investigate the effects of the environment and operation parameters on the performance of the proposed solar tunnel drier. Measurements were taken every 10 minutes during the operation period. The total incident solar radiation on the horizontal surface was measured using solar intensity meter and it gave direct cumulative readings of total global radiation [6]. The instrument was powered and kept near the drier for a while. The digital meter directly showed the intensity of the solar radiation in W/m^2. Temperature inside and outside the tunnel was measured with the aid of thermometer. The velocity of air passing through the system and the wind velocity is measured using digital anemometer. The speed range of anemometer is 0-45 m/s. The instrument is placed in the direction of solar drier (east-west) and the digital gauge directly gave the wind velocity. Since the tunnel used here is for study purpose and the dimension being small, wind velocity inside the drier is neglected.

4. Result and Discussion

The experiments were carried out under the climatic conditions of Science Center, Songkhla Rajabhat University during June 2016. Measurements were taken discretely at an interval of 10 minutes starting from 8.00 am to 4.00 pm and simultaneously the temperature, solar radiation, wind velocity inside the solar cabinet dryer and ambient temperature.

From the results of temperature versus time graph shown in Figures 3 (a) and (b), it is observed in Figure 3 (a) that the temperature inside the dryer on a typical day was 71.70 °C and the ambient temperature was 41.39 °C. It was also observed that the solar insulation was 786.40 W/m^3. While in Figure 3 (b), the temperature inside the dryer on a typical day was 54.68 °C and the ambient temperature was 35.28 °C. Also, the solar insulation was 732.65 W/m^3.



(a) (b)

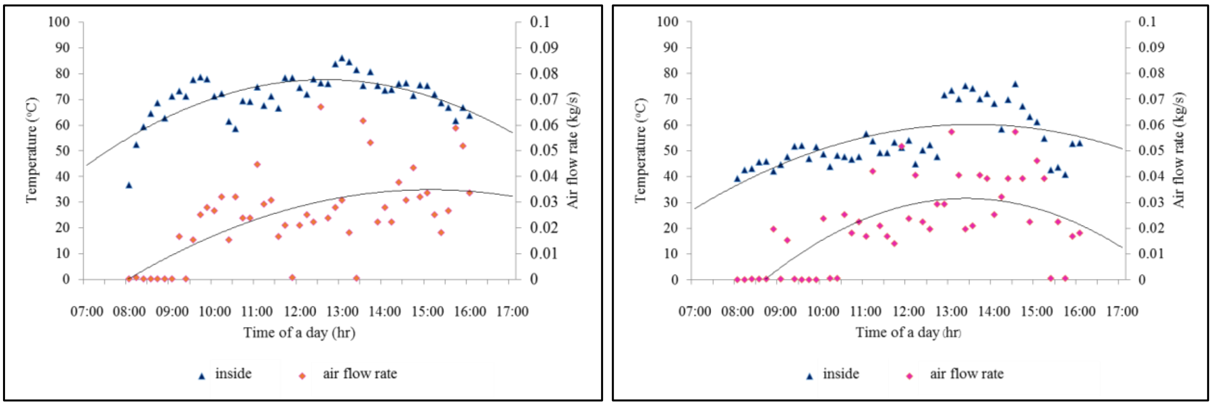
Figure 3. Temperature and solar radiation with respect to (a) time on 3-6-2016 and (b) 6-6-2016.

The average thermal efficiency of the solar collector [7] is calculated to be 2.59% at air flowrate of 0.023 kg/s (Table 1). The all-day average ambient air and inside the chamber temperature was 38.34 °C and 63.19 °C respectively.

Table 1. Tabulation of solar insolation, ambient temperature, inside temperature, air flow rate and efficiency with respect to time on 3-6-2016 and 6-6-2016.

Date	Solar insolation (W/m²)	Temperature)°C(		Air flow rate (kg/s)	Efficiency (%)
		ambient	inside		
3/6/2559	786.40	41.39	71.70	0.025	2.77
6/6/2559	732.65	35.28	54.68	0.021	2.41
average	759.53	38.34	63.19	0.023	2.59

From the results of air flow rate versus time graph shown in the Figures 4 (a) and (b), it is observed in Figure 4 (a) that the air flow rate was 0.025 kg/s with respect to time on 3-6-2016 while, Figure 4 (b) was 0.025 kg/s with respect to time on 6-6-2016.



(a) (b)

Figure 4. Relationship between temperature and air flow rate with respect to (a) time on 3-6-2016 and (b) 6-6-2016.

5. Conclusion

The thermal performance of the solar dryer is tested under the local weather condition considering the effect of wind, humidity and cloudiness. The average thermal efficiency of the solar collector is calculated to be 2.59% at air flow rate of 0.023 kg/s. In addition the maximum temperature of the solar dryer attained at the absorber plate is 63.19°C when the solar radiation intensity reached 759.53 W/m^3 during no load test.

6. Acknowledgement

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