ELSEVIER
Available online at www.sciencedirect.com
SciVerse ScienceDirect
Procedia Engineering 32 (2012) 433 – 439
Procedia Engineering
www.elsevier.com/locate/procedia

I-SEEC2011

Experimental investigation of the performance of a large-scale greenhouse type solar dryer for drying chilli in Thailand

J. Kaewkiew*, S. Nabnean , S. Janjai

Solar Energy Research Laboratory, Department of Physics, Faculty of Science, Silpakorn University, Nakhon Pathom, 73000, Thailand

Elsevier use only: Received 30 September 2011; Revised 10 November 2011; Accepted 25 November 2011.

Abstract

Solar drying is considered to be a useful solar energy technology for developing counties. In this work, the performance of a large-scale greenhouse type solar dryer for drying chilli was investigated. The dryer has a parabolic shape and it is covered with polycarbonate sheets. The base of the dryer is a concrete floor with an area of 8×20 m^2. Nine DC fans powered by three 50 W solar cell modules were used to ventilate the dryer. The dryer was installed at Ubon Ratchathani, Thailand. Three batches of chilli were dried in the dryer. It was found that five hundred kilograms of chilli with the initial moisture content of 74% (wb) were dried within 3 days while the natural sun dried needed 5 days. The chilli dried in this dryer was completely protected from insects, animals and rain. In addition, good quality of chilli was obtained.

Keywords: Large-scale greenhouse dryer; Chilli; Solar drying

1. Introduction

Chilli is an important ingredient in daily cuisine in Thailand. It is consumed both as fresh and dried products. A natural sun drying method is generally used to dry chilli in Thailand. With this method, substantial losses of chilli due to insects, animals and rain usually occur during drying. To overcome this problem, well-performed dryers are needed to dry chilli. Although mechanical dryers using fossil fuel-based energy are available, the drying cost is relatively high due to the high price of the fuel. In addition, the use of such dryers creates an environmental problem caused by carbon dioxide emission.

* Corresponding author. Tel.: +66-34-270761; fax: +66-34-271189.
E-mail address: jinda_kaewkiew@hotmail.com.

doi:10.1016/j.proeng.2012.01.1290

Situated in the tropics, Thailand receives abundant solar radiation [1]. Consequently, the use of solar dryers is a good alternative solution of the problem of chilli drying. Although several types of solar dryers have been developed in the last 30 years, most of them have loading capacity of 10-50 g of fresh fruits and vegetable [2] which could not meet the demand of farmers and small-scale dried fruits and vegetables in developing countries. Having realized this demand, our research group has developed a greenhouse type solar dryer. The first prototype of this dryer has a loading capacity of 300 kg [3]. The dryer were tested to dryer chilli and satisfactory results were obtained. In addition to the experimental work, the thermal performance of this type of dryer was also modeled and rigorous economics and product quality analyses were carried out [4]. This type of dryer was further developed by increasing the loading capacity to be 1,000 kg. With this capacity, it become a large-scale greenhouse dryer. This dyer was first tested in Loas and satisfactory results was obtained [5]. To gain more knowledges on the performance of this type of dryer, the dryer was constructed in Ubon Ratchathani, northestern Thailand. The dryer was tested to dryer chili and the results were reported in this paper.

2. Methodology

2.1. Experimental setup

The greenhouse type solar dryer was installed at Ubon Ratchathani, northestern Thailand. The dryer has a width of 8.0 m, length of 20.0 m and height 3.5 m. Nine DC fans operated by three 50-Watt solar cell modules were installed in the wall opposite to the air inlet to ventilate the dryer. The dryer consists of a parabolic roof structure made form polycarbonate sheets on a concrete floor. The dryer has the capacity about 1,000 kg of fresh product. The pictorial view of the dryer is shown in Fig. 1.

Fig. 1. Schematic diagram of the large-scale polycarbonate cover greenhouse solar dryer

Solar radiation passing through the polycarbonate roof heats the air, the products inside the dryer, as well as the concrete floor. Ambient air is drawn in through the air inlets at the bottom of the front side of the dryer and is heated by the floor and the products exposed to solar radiation. The heated air, while passing through and over the products absorbs moisture from the products. Direct exposure to solar radiation of the products and the heated drying air enhance the drying rate of the products. Moist air is sucked from the dryer by the nine DC-fans at the top of the rear side of the dryer

2.2. Experimental procedure

In this study 500 kg of Chilli (74% wb) was dried in the solar greenhouse dryer with polycarbonate cover to demonstrate its potentials for drying chilli. A total of three experimental runs were conducted during the period of November – December, 2009.

Solar radiation was measured by a pyranometer (Kipp & Zonen model CM 11, accuracy ± 0.5%) placed on the roof of the dryer. Thermocouples (type K) used to measure air temperatures in the different positions of the dryer (± 2%). Thermocouple positions for temperature measurement are shown in Fig. 2. A hot wire anemometer (Airflow, model TA5, accuracy ± 2%) was used to monitor the air velocity inside the dryer. The relative humidity of ambient air and drying air were periodically measured by hygrometers (Electronik, model EE23, accuracy ± 2%).

Voltage signals from the pyranometer, hygrometers and thermocouples were recorded every 10 minutes by a multi-channel data logger (Yokogawa, model DC100). The air speed at the inlet and outlet of the dryer were recorded during the drying experiments. Before the installations, the pyranometer was calibrated against a pyranometer recently by the manufacturer. The hygrometers were calibrated using standard saturated salt solutions.

Chilli dried in each drying test was of 500 kg. Chilli was placed in a thin layer on arrays of trays. These arrays of trays were placed on single level raised platforms with a passage between the platforms for loading and unloading the product inside the dryer. The experiments were started at about 8.00 am – 6.00 pm. The drying was continued on subsequent days until the desired moisture content was reached. Product samples were placed in the dryer at various positions and were weighed periodically at two-hour intervals using a digital balance (Kern, model 474-42, accuracy ± 0.1 g). Product samples about 100 g was weighed from the dryer at two hour intervals and the moisture contents of the product inside the dryer were compared against the control samples (open-air sun dried). The moisture content during drying was estimated from the weight of the product samples and the estimated dried solid mass of the samples. At the end of the experimental drying, the exact dry solid weight of the product samples was determined by oven method (103°C for 24 hours, accuracy ± 0.5%).

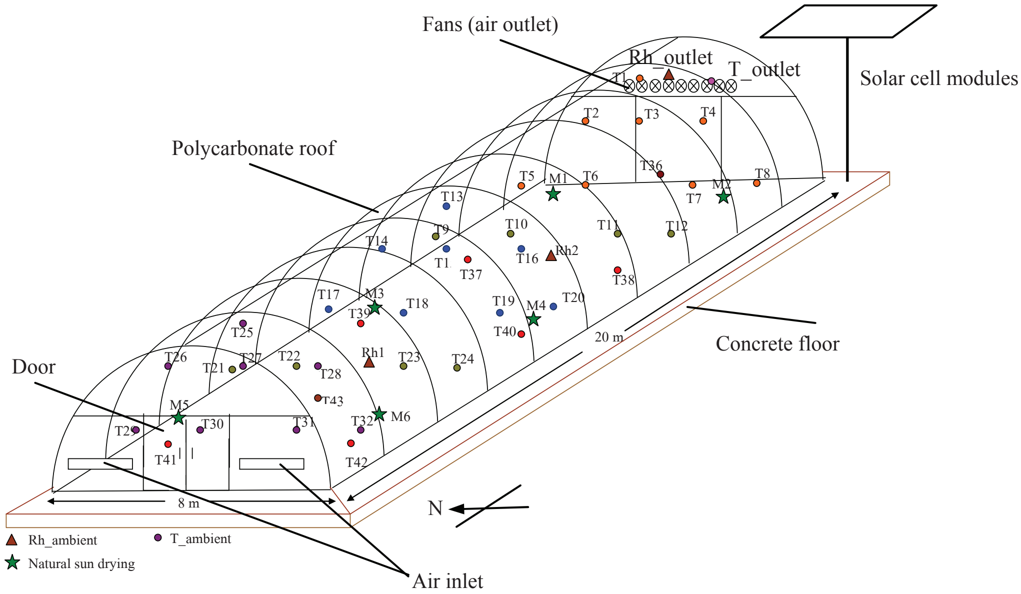

Fig. 2. The positions of the thermocouples (T) and measurements of relative humidity (Rh) and weights of the product samples (M)

3. Results and discussion

Drying experiments of chilli in the greenhouse dryer were carried out in November – December in 2009. During the drying of chilli, solar radiation increased sharply from 8 am to noon but it considerably decreased in the afternoon with fluctuations due to clouds. Example of the variation of solar radiation during the experimental run of solar drying of Chilli is shown in Fig. 3.

Fig. 4 shows the comparison of air temperature at five different locations inside the dryer and the ambient air temperature for the experimental runs of solar drying of chilli. The patterns of temperature changes in different positions were comparable for all locations. Temperatures in different positions at these five locations vary within a narrow band. In addition, temperatures at each of the locations differed significantly from the ambient air temperature.

Fig. 5 shows relative humidity at two different locations inside the dryer and ambient air relative humidity during solar drying of chilli. Relative humidity decreases over time at different locations inside the dryer during the first half of the day while the opposite is true for the other half of the day. No significant difference was found between relative humidity of different positions inside the dryer. However, there is a significant difference in relative humidity for all locations inside the dryer compared to the ambient air. The relative humidity of the air inside the dryer is lower than that of the ambient air. Hence, the air leaving the dryer has lower relative humidity than that of the ambient air and this indicates that the exhaust air from the dryer still has drying potential for recirculation to dry the product.

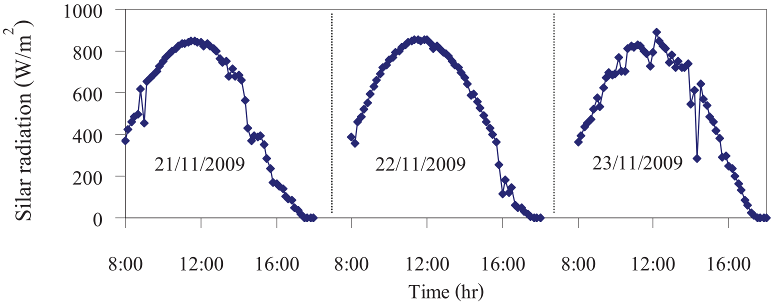

Fig. 3. Variation of solar radiation with time of the day during drying of chilli

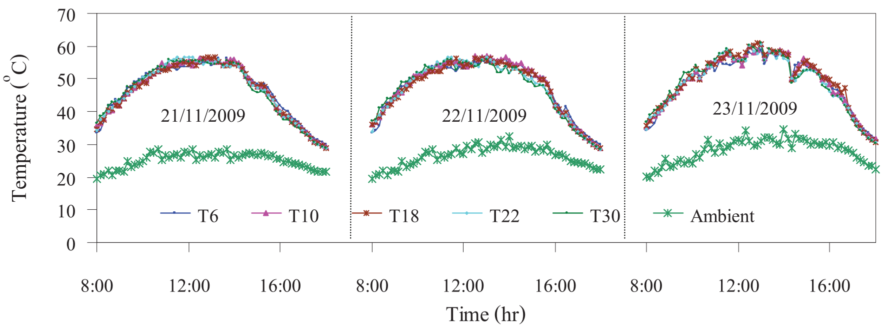

Fig. 4. Variation of ambient temperature and the temperature at different positions inside the greenhouse solar dryer during of chilli

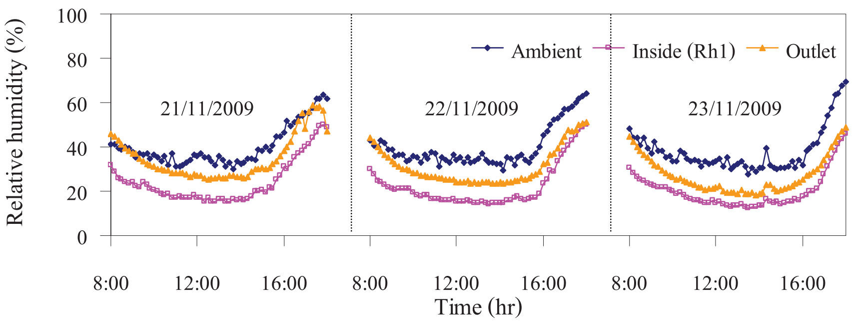

Fig. 5. Variation of ambient relative humidity and relative humidity inside the greenhouse dryer with time of the day during drying of chilli

The variations in moisture content of chilli that different positions inside the dryer compared to the control sample dried by natural sun drying were showed in Fig. 6. The moisture content of chilli in the solar dryer was reduced from an initial value of 74 % (wb) to a final value of 9% (wb) within 3 days whereas the moisture content of the natural sun-dried samples was reduced to 66% (wb) in the same period. There is no significant difference in solar drying of the products in the different positions inside the solar greenhouse dryer. In addition, the chilli dried in this dryer was completely protected from insects, animals and rain.

To evaluate the product quality, the colour of chilli was measured by using a chromometer (CR-400, Minolta Co, Ltd, Japan). The details of measurements are similar to those reported by Janjai et al. [4]. The results showed that the colour of solar-dried chilli was comparable to that of good quality dried-chilli in local markets.

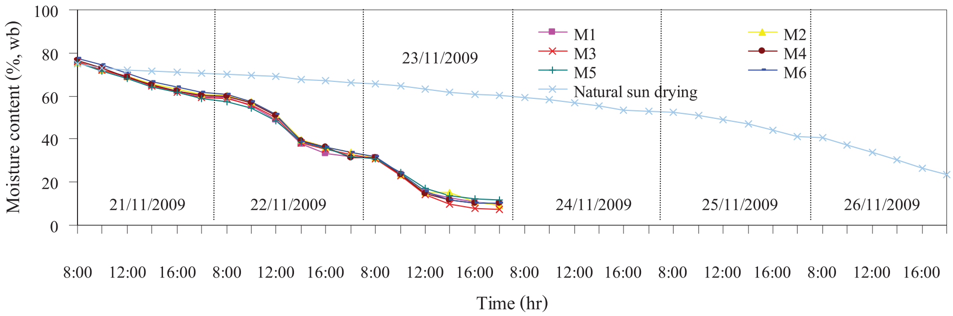

Fig. 6. Comparison of the moisture contents of chilli at different positions inside the greenhouse dryer with those obtained by the traditional sun drying method

In term of economic evaluation, the capital cost for construction and installation of the solar greenhouse dryer is estimated to be 25,900USD (1USD=30 baht) and capacity of dryer is 1,000 kg. It is estimated that the dryer can be used for drying fifty batches of chilli per year. From this estimation, approximately 11,500 kg of dry chilli are produced annually. Based on these production scales, capital and operating costs of the drying system and price of the dried products, the payback period of the greenhouse solar drying system for drying chilli are estimated to be about 2 years.

4. Conclusion

In order to investigated the performance of a large-scale greenhouse dryer, three batches of chilli were dried in the greenhouse dryer at Ubon Ratchathani. Solar drying in the solar greenhouse dryer resulted in considerable reductions in drying time as compared with the natural sun drying and the colour of products dried in the solar greenhouse dryer are better than natural sun dried samples. The estimated payback period of the greenhouse solar dryer is about 2 years. Due to its high technical and economic performance, this type of dryer has been included in the dissemination program of the Department of Alternative Energy Development and Efficiency, Thailand. More than ten units of this type of dryer are now used in small-scale food industries to produce dried products including chilli across the country.

Acknowledgements

The authors would like to thank the Department of Alternative Energy Development and Efficiency (DEDE) for inviting Silpakorn University to carry out this project.

References

[1] Janjai S, Laksanaboonsong J, Nunez M, Thongsathitya A. Development of a method for generating operational solar radiation maps from satellite data for a tropical environment. *Solar Energy* 2005;**78**:739–751.

[2] Fudholi A, Sopian K, Ruslan MH, Alghoul MA, Sulaiman MY. Review of solar dryers for agricultural and marine products. *Renewable and Sustainable Energy Reviews* 2010;**14**:1–30.

[3] Janjai S, Khamvongsa V, Bala BK. Development, Design, and Performance of a PV-Ventilated Greenhouse Dryer. *International Energy Journal* 2007;**8**:249-258.

[4] Janjai S,Lamlert N,Intawee P, Mahayothee B,Bala BK, Nagle M, Muller J. Experimental and simulated performance of a PV-ventilated solar greenhouse dryer for drying of peeled longan and banana. *Solar Energy* 2009;**83**:1550–1565.

[5] Janjai S, Intawee P, Kaewkiewa J, Sritus C, Khamvongsa V. A large-scale solar greenhouse dryer using polycarbonate cover: Modeling and testing in a tropical environment of Lao People's Democratic Republic. *Renewable Energy* 2011;**36**:1053-1062.

.