ISSN 2229-5518

Experimental Performance and Neural Network Modeling of Solar Dryer for Drying Bamboo shoot strips in Thailand

J. Piwsaoad, C. Pusumpao

Abstract—This paper presents experimental performance and artificial neural network modeling of a solar dryer for drying of bamboo shoot strips. The dryer consists of a polycarbonate sheets on a metal sheet floor. The dryer is 1.5 m in width, 1.0 m in length and 2.0 m in height. Two 15-W DC fans powered by 50-W PV module were used to ventilate the dryer. To investigate its performance, the dryer was used to dry ten batches of bamboo shoot strips. For each batch, 10 kg of bamboo shoot strips were dried in the dryer. Results obtained from the experiments showed that drying temperatures varied from 31 °C to 50 °C and the use of the dryer led to a considerable reduction of drying time, as compared to the open air sun drying. In addition, the quality of the product from the dryer was high-quality dried products. A multilayer neural network model was developed to predict the performance of this dryer. The predictive power of the model was found to be high after it was adequately trained.

Key word— Solar energy; Solar drying; bamboo shoot strips; ANN model.

---

1 Introduction

BAMBOO shoots or bamboo sprouts are the edible shoots (new bamboo culms that come out of the ground) of many bamboo species including Bambusa vulgaris and Phyllostachys edulis. They are used in numerous Asian dishes and broths. They are sold in various processed shapes, and are available in fresh, dried and canned versions [1].

The utilization pattern of the bamboo shoots in most of the countries indicates that it is consumed in the forms of raw, dried, canned, boiled, fermented or medicinal. Bamboo shoots are found in China, Japan, US, North East India, Nepal, Bhutan, Korea, Australia, New Zealand, Malaysia, Indonesia and Thailand. Bamboo shoots are low in cholesterol and saturated fats contents, total fats (0.5%), carbohydrates (5.70%), protein (3.9%), minerals (1.1%) and moisture (88.8%) [2].

Situated in the tropical area, Thailand receives abundant solar radiation [3]. Consequently, the use of solar dryers for bamboo shoots drying is reasonable. Although several types of solar dryers have been developed in the last 40 years [4-6]; but, they could not meet the high demand of bamboo shoot strips drying.

As a result our research group has developed a solar dryer to dry agricultural products. It was successfully used for drying fruits and vegetable [6-9]. However, it has not been tested to dry bamboo dhoot strips. Therefore, the objectives of this research were to investigate the performance of the dryer for drying bamboo shoot strips and to develop an artificial neural network (ANN) model to predict the performance of this dryer.

2 Material and Method

2.1 Experimental Setup

The solar dryer was installed at Loei (17.48°N, 101.72°E), Thailand. The dryer consists of a polycarbonate sheets on a metal sheet floor. The dryer has a width of 1.5 m, length of 1.0 m and height of 2.0 m. Two DC fans operated by 50-W solar cell module were installed in the wall opposite to the air inlet to ventilate the dryer. The pictorial view of the dryer is shown in Fig. 1.

- *J. Piwsaoad Program Physics, Department of Science, Faculty of Science and Thecnology, Loei Rajabhat University, Loei 42000, Thailand. E-mail: jagrapan25@gmail.com.*
- *C. Phusampao Program Physics, Department of Science, Faculty of Science and Thecnology, Loei Rajabhat University, Loei 42000, Thailand. E-mail: joitoji@gmail.com.*

Fig.1. The pictorial view of the solar dryer.

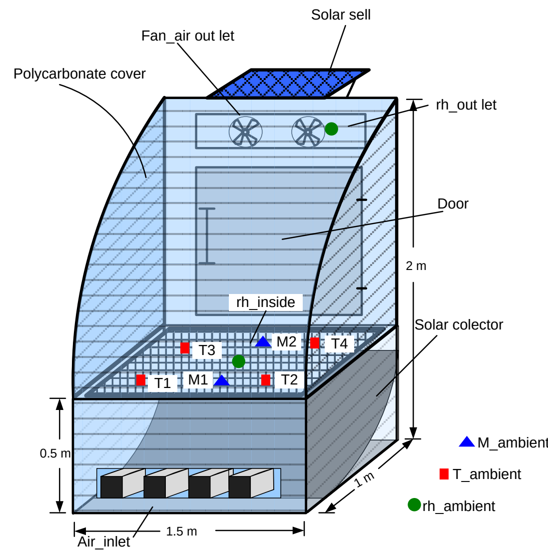

Fig. 2. The structure of the solar dryer and the position of the thermocouples (T), hygrometer (rh) and product samples (M).

Solar radiation passing through the polycarbonate roof heats the air, the products inside the dryer, as well as the metal sheet 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 products exposed to solar radiation. The heated air, while passing through 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 DC-fan at the top of the rear side of the dryer. The structure of the dryer is shown in Fig. 2.

2.2 Experimental Procedure

In this study, bamboo shoot strips were dried in the solar dryer to investigate its potentials for drying bamboo shoot strips. Ten experimental runs were conducted during the period of May 2015-June 2015, and 10 kg of bamboo shoot strips were dried for each run.

Solar radiation was measured by a pyranometer (Kipp&Zonen model CMP 3, accuracy ± 0.5%) placed on the roof of the dryer. Thermocouples (K type) were used to measure air temperatures in the different positions of the dryer (accuracy ± 2%). A hot wire anemometer (Airflow, model TA5, accuracy ± 2%) was used to monitor the air speed inside the dryer. The relative humidity of ambient air and drying air was periodically measured by hygrometers (Moisture content meter, model Extech SDL, accuracy ± 1%). The positions of all measurements are shown in Fig. 2.

The air speed at the inlet and outlet of the dryer was recorded during the drying experiments using the hot wire anemometer. Bamboo shoot strips dried in each drying test were 10 kg. The pictorial view of bamboo shoot strips being dried in the dryer is shown in Fig. 3.

Fig. 3. Bamboo shoot strips dried inside the dryer.

Bamboo shoot strips were place on tray inside the dryer.

ISSN 2229-5518

Each day, the experiment was conducted during 8:00 am-6:00 pm. The drying was continued on subsequent days until the desired moisture content was reached. Product samples were placed at various positions in the dryer and were weighed periodically at two-hour intervals using a digital balance (Kern, model 474-42, accuracy ± 0.1g).

To compare the performance of the dryer with that of natural sun drying, a control sample of bamboo shoot strips were placed near the dryer and dried simultaneously under the same weather conditions. 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 mass of the product samples was determined by the hot air oven method (103 °C for 24 hours, Memmert GMBH, model ULE500, accuracy ± 0.5%).

2.3 Neural Network Modeling

The neurocomputing methods are shaped after biological neural functions and structure. As a result, they are generally known as artificial neural network (ANN). Similar to biological neural network, the function of ANN are developed not by programming them, but by exposing them to given sets of input and output data on which they can learn how to perform a required task. In such modeling approach, a formulation of analytical description of a process is not required. Instead, a black - box process model is created by interacting the network with representative samples of measurable quantities characterizing the process**.**

In this work, a multilayer ANN model of the solar dryer for drying the bamboo shoot strips was developed. The model has a five – layered network. This network consists of a large number of processing elements, called neuron (Fig. 4).

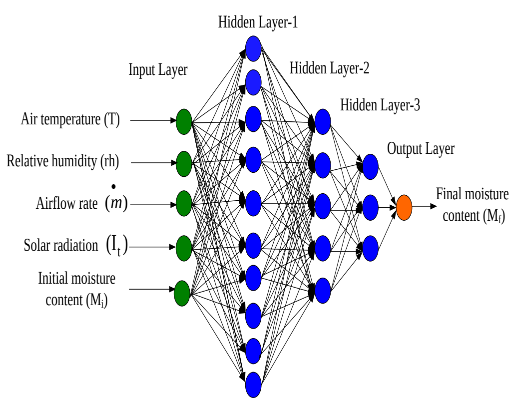

Fig. 4. The structure of the artificial neural network of the greenhouse solar dryer for drying bamboo shoot strips.

The input layer of the model comprises five neurons which correspond to solar radiation (I_t), airflow rate ($\dot{m}$), air relative humidity (rh), air temperature (T) and initial moisture content (M_i). The output layer has one neuron which represents the final moisture content (M_f). A selection of the number of neurons for hidden layers is optional. A large number of neurons can represent the system more precisely but it is more complicated to obtain proper training of the network. In this work, the selected number of neuron in hidden layer 1, 2 and 3 of the model are 10, 5 and 3 respectively.

ANN is able to modify its behavior in response to its environment. Unlike analytical model, the structure of ANN cannot represent the system behavior, unless it is properly trained. The aim of training the network is to adjust the weights of the interconnecting neurons of the network so that an application of a set of inputs produces a desired set of output. Initially, random values are given as weights. One input - output set can be referred to as a vector. Training assumes that each input vector is paired with target vector representing the desired output and these are called a training pair. In general, a network is trained over number of training pairs.

In this work, the ANN model of the solar dryer was trained by the back propagation algorithm [10-11]. The procedure of the training are as follows: (1) an input vector was applied; (2) the output of the network was calculated and compared to the corresponding target vector; (3) the difference (error) between the calculated and the target outputs was fed back though the network; and (5) weights were changed. This procedure was repeated over the entire training set until the error was within an acceptable value or until the outputs did not significantly change any more. The ANN model was programmed in C^{++}.

3 Result and Discutions

3.1 Experimental results

Drying experiments of bamboo shoot strips in the solar dryer were carried out between May 2015-June 2015. Ten batches of experimental runs were carried out. The typical results are shown in Fig. 5-8. It was observed that solar radiation was strongly fluctuated on the first day of the experiment because there were clouds on that day (Fig. 5). On the second day, solar radiation was low due to rain.

For comparison, air temperature at two different locations inside the dryer and the ambient air temperature were measured. The pattern of temperature change in different positions was comparable for all locations inside the dryer (Fig. 6). Temperatures in different positions at these five locations varied within a narrow band. In addition, temperatures at each of the locations differed significantly from the ambient air temperature.

Relative humidity at two different locations inside the dryer and ambient air relative humidity during solar drying of bamboo shoot strips was measured. Relative humidity decreased 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 (Fig. 7). No significant difference was found between relative humidity of different positions inside the dryer. However, there was 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 was lower than that of the ambient air. Hence, the air leaving the dryer had lower relative humidity than that of the ambient air and this indicated that the exhaust air from the dryer still had drying potential for recirculation to dry the product.

The moisture content of bamboo shoot strips in the greenhouse solar dryer was reduced from an initial value of 25% (w.b.) to a final value of 1.0 % (w.b.) in 2 days.

The decrease of moisture content of the bamboo shoot strips being dried in the dryer, as compared to the open air sun drying is shown in Fig. 8.

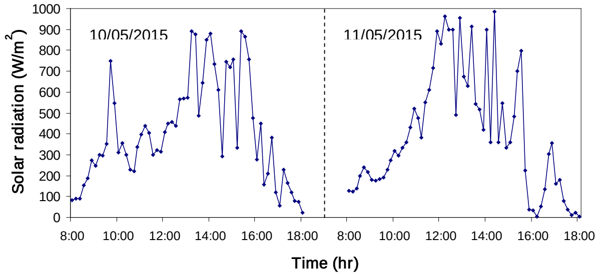

Fig. 5. Variation of solar radiation with time of the day during drying of bamboo shoot strips.

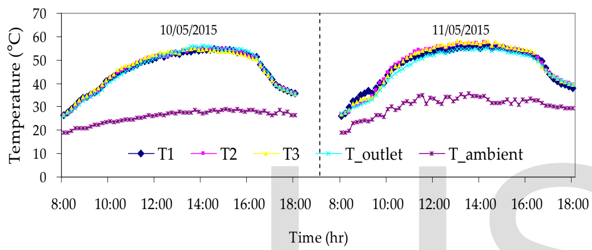

Fig. 6. Variation of ambient temperature and the temperature at different positions inside the dryer during drying of bamboo shoot strips.

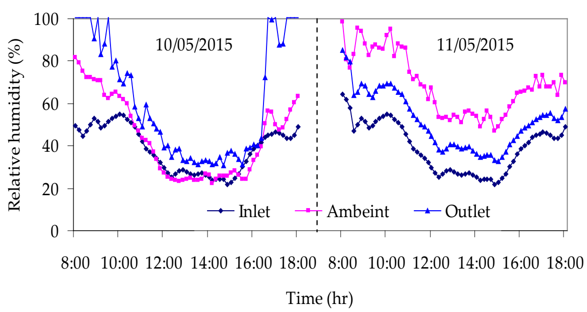

Fig. 7. Variation of ambient relative humidity and relative humidity inside the dryer with time of the day during drying of bamboo shoot strips.

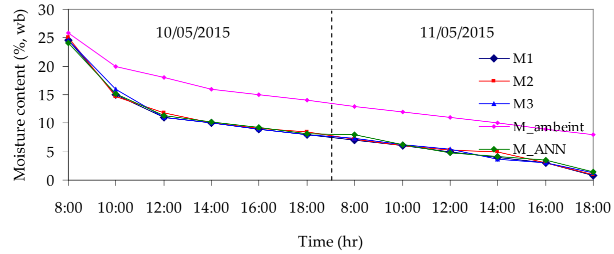

Fig. 8. Comparison of the moisture content of bamboo shoot strips inside the dryer with moisture content of the sample dried by the open air drying

3.2 Performance prediction by ANN model

The ANN model of the solar dryer developed for bamboo shoot strips drying were trained with the experimental data from nine experiments. The data from the tenth experiment were reserved for testing the model. After 100,000 times of iteration step of training, the square sum of difference (error) between the observed and the predicted output reached a significant low level. The comparison between the model-predicted and measured moisture contents of the dryer is shown in Fig. 9.

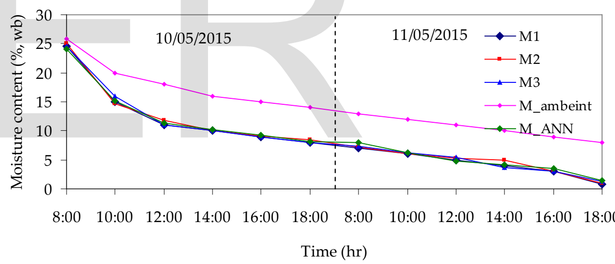

Fig. 9. Predicted and measured moisture contents of bamboo shoot strips.

From Fig. 9, it is found that the agreement between the predicted and measured moisture contents is good and the root mean square difference (RMSD) is 9.4% with respect to the mean measured value. Thus, if the model is adequately trained, it can appropriately predict the performance of the solar dryer for drying bamboo shoot strips.

ISSN 2229-5518

4 Conclusion

The performance of the solar dryer for drying bamboo shoot strips has been experimentally investigated. It was found that the use of this dryer led to considerable reduction in drying time in comparison of that of sun drying. An ANN model for this dryer has also been developed. This ANN with five input, one output and three hidden layers was found to be able to predict accurately the moisture content of bamboo shoot strips. It is expected that this ANN model can be used to predict the potential of this dryer for other locations.

References

[1] S. Satya, L.M. Bal, P. Singhal, and S. N. Naik,"Bamboo shoot processing," food quality and safety aspect (a review). *Trends in Food Science* & *Technology*, 21 (4), pp. 181–189, 2010.

[2] J.L. Chaves, "Pimenta longa reativa o safrol," Química e Derivados. (São Paulo, SP). Vol. 2, pp. 40–46, 1994.

[3] S. Janjai, J. Laksanaboonsong, and A. Thongsathitya,"Development of a method for generating operational solar radiation maps from satellite data for a tropical environmental," *Solar Energy*, vol. 78, pp. 739-751, 2005.

[4] S. Janjai, and B.K. Bala,"Solar drying technology," *Food Engineering Reviews,* vol. 4, pp. 16-54, 2012.

[5] A. Sharma, C.R. Chem, and N.V. Lan,"Solar-energy drying systems: A review," *Renewable and Sustainable Energy Reviews*, vol. 13, pp. 1185-1210, 2009.

[6] M.V. Murthy,"A review of new technologies, models and experimental investigations of solar dryers," *Renewable Energy Reviews*, vol. 13, pp. 835-844, 2009.

[7] H. Oueslati, S.B. Mabrouk, and A. Mami,"System Design, Mathematical Modeling and Simulation of Process Drying in a Solar-Gas Convective Tunnel Dryer," *International Journal of Scientific & Engineering Research,* vol. 3(5), 2012.

[8] S. Janjai, "A greenhouse type solar dryer for Small - scale dried food industries," Development and dissemination," *Journal of Energy and Envi ronment*, 3(3), pp. 383–398, 2012.

[9] S. Janjai, C. Phusampao, W. Nilnont, and P. Pankaew." Experimental performance and modeling of a greenhouse solar dryer for drying macadamia nuts," *International Journal of Scientific & Engineering Research,* Vol 5, pp. 1155-1161, 2014.

[10] D. W., Patterson, "Artificial Neural Networks," Theory and ap plications, Prentice Hall, New York, 1996.

[11] S. Janjai, J. Piwsaoad, W. Nilnont, and P. Pankaew,"Experimental performance and Neuron Network modeling of a Large-scale Greenhouse solar dryer for drying Natural rubber sheets," *Journal of Control Science and Engineering*, vol 1, pp. 48-53, 2015.