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Thermal Performance Of Low Cost Solar Bamboo Dryer

M.Debbarma[1], P.Rawat[1], K.Sudhakar[1]*,

[1]Energy Centre, Maulana Azad National Institute of Technology Bhopal, Madhya Pradesh, 462 051, India

***Corres. author : sudha_k@sify.com**
Ph: 0755-405100, Fax: 0755-2670562,

Abstract: A low cost bamboo solar dryer was designed and developed at MANIT Bhopal to test its performance for crop drying. The dryer is a greenhouse-type designed for multi-crop solar drying. The solar bamboo dryer reduces the moisture content of green chillies from 90% to 10% in 20 hours with an average efficiency of 17%. The drying rate of solar bamboo dryer was estimated to be around 10g/hr. The economic cost of bamboo dryer is around Rs 400/- which is very much affordable for the poor farmers. The dryer developed can be used to substitute electrical/mechanical dryers in semi urban and rural areas of India for drying various agricultural crops.
Keywords: Drying Efficiency; Drying Rate; Moisture Content; Solar Bamboo Dryer; Chillies.

1. Introduction:

In India, natural open sun drying is one of the most common ways to dry and preserve agricultural products. Many agricultural products are spread on the ground to be dried by sun and wind. During the drying, these products are neither protected against dust and rain, nor against rodents, birds and insects. This results in poor quality products due to contamination and high loss caused by uneven or incomplete dehydration. Chili, ginger, pepper and garlic are important food products for India's economy. Drying is a complex process due to the fact that it involves simultaneous heat and mass transfer[10]. Solar dryers are in much demand to reduce energy consumption and moreover to improve the quality of food products. Hossain and co-workers studied a single-layer drying characteristics and the color kinetics of red chillis[4]. A comparative study of natural and solar drying for preservation of fruits and vegetables is given by Gallali et al[3]. The drying rate and drying efficiency of solar drier were made on the basis of solar intensity and ambient temperature[6]. Murthy Ramana[9] reviews various aspects of small-scale dryers for food products and presents new types of dryers with improved technologies; Natural convection driers do not require fans to pump the air through the drier[2]. A mixed mode type forced convection solar tunnel dryer was developed to dry hot red and green chillies[5]. Feasibility studies of a solar chimney to dry agricultural products were also performed[1]. In another study, a thermal model of a natural convection greenhouse drying for jaggery was also developed[7]. Experiments inside a wind tunnel were conducted to study the drying of red pepper in open sun and greenhouse conditions[8]. The purpose of the investigations is to design a low cost bamboo solar dryer and to find out its thermal performance.

2. Methodology:

The experiments were carried out under the meteorological conditions of Bhopal (latitude of 23.16ºN; longitude of 77.24ºE) in India during 25.10.2012 – 27.10.2012 from 9.00 a.m. in the morning to 5.00 p.m. in the evening.

2.1 Solar Bamboo drier construction: The low cost solar bamboo dryer was design to dry commodities under hot and humid conditions prevailing in Central region of Madhya Pradesh where most of the agricultural products need drying. Figure 1 shows a bamboo tent dryer covered with plastic material. Dryer (Figure 2) having a size 123 cm x 100 cm was made by locally available bamboo, which consist of three main parts, black painted base collector, bamboo frame and transparent polyethene covering .Capacity of the bamboo dryer is around 2 kg. Gelatin Polythene film was used for collection of solar energy. An opening is provided at the east bottom for air circulation.

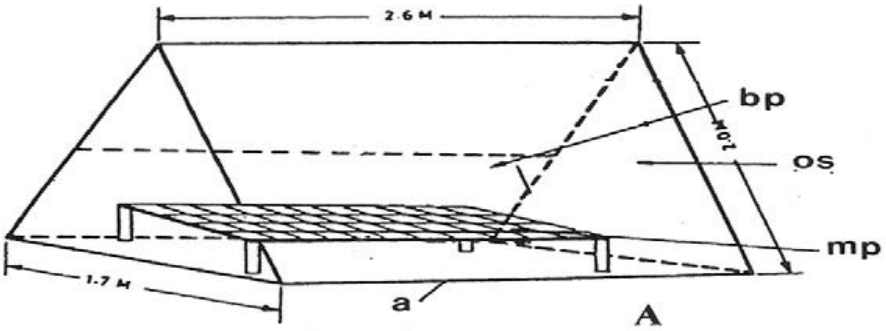

Fig. 1. Bamboo tent dryers covered by transparent plastic material

Fig 2. Photograph of Low cost solar bamboo dryer

2.2 Measurements

Total Instantaneous Global Solar irradiance was measured by using portable Solar Power meter (Tenmars TN-207, Taiwan) with an uncertainty of ± 10%. The temperature and humidity inside and outside the drying chamber was measured with digital thermo hygro meter. Air velocity at drier exit was measured by using portable anemometer (Lutron HT-3006A) having ± 0.5% uncertainty. A digital electronic balance (Precision Scientific Company, India) of 5 kg capacity having an uncertainty of ± 0.1% was used to weigh the samples.

2.3 Experimental procedure

Experiments were conducted for 3 days in the months of October 2012 under the meteorological conditions of Bhopal, M.P, India. Fresh green chillies obtained from the market was used to study the performance of drier

.Initial moisture content was calculated by taking 200 grams of samples taken from the drier. Solar intensity, dry weight, dryer temperature, ambient temperatures and relative humidity were measured every one hour interval till the end of drying.

(A) Moisture content:

Initial *(Wi)* and final mass *(Wf)* at time (t) of samples were recorded using electronic balance and repeated every 1 h interval till the end of drying. The percentage moisture content was determined by using the following formula, (Ranganna, 1986). Moisture content on wet basis (M_{wb}) was calculated using the "Eq.(1)."

$M_{wb} = (Wi - Wf)/ Wi$ ---------- (1)

Where, W_i= weight of sample before drying, kilogram

W_f= weight of sample after drying, kilogram.

(B) Thermal efficiency of drier

The amount of heat required to evaporate the moisture inside the product is called as drying efficiency. In case of solar dryer, total available solar radiation on collector surface of the dryer gives the total heat input. This thermal efficiency of bamboo drier was estimated using the "Eq.(2)."

$$\eta th = \frac{m_w x h_{fg}}{A x I} \times 100 \text{----------(2)}$$

Where,

η_{th} drier thermal efficiency;

m_w, the mass of water evaporated in time t = *(Wi - Wf)* kg;

h_{fg} , the latent heat of vaporization of water (kJ/kg);

A, the area of solar bamboo drier (m^2);

I, Solar irradiance (W/m^2).

(c) Drying rate

The drying was carried out by loading the weighted chillies in dryer from morning 9:00 am to 17:00 pm. The chilies were dried up to the final moisture content of 10% (w.b.). The drying rate (g/h/100g of dry weight) of sample during drying period was determined as follows,

Drying rate (D.R) = $\frac{\Delta W}{\Delta T}$ ---------- (3)

Where, ΔW = weight loss in one day interval

ΔT= difference in time reading (h)

3. Results & Discussion:

Solar radiation intensity, Relative humidity and temperature inside the collector were measured with time of day in the interval of one hour were plotted. About 200 gram of fresh green chillies with 90% average initial moisture content was taken for study and loaded in the drying chamber of solar bamboo dryer. The variation of solar radiation with time is shown in the "Fig.3." During the experiments, the sky was clear and the maximum solar radiation observed was 1055 W/m².

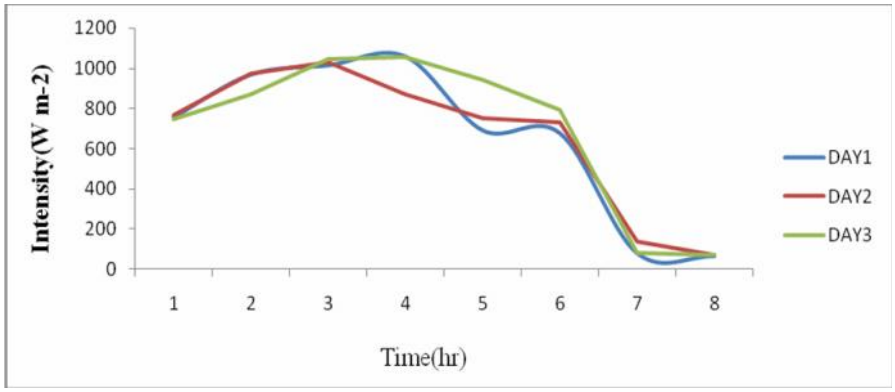

Fig. 3 Variation of solar intensity with time

The variation of ambient and drier temperature was illustrated in “Fig.4.” The maximum temperature observed inside the drying chamber on day 1 is 55° C, day 2 is 55.4°C and day 3 is 65.2°C . The maximum ambient temperature observed inside the drying chamber on day 1 is 37° C, day 2 is 31.8°C and day 3 is 38.8°C

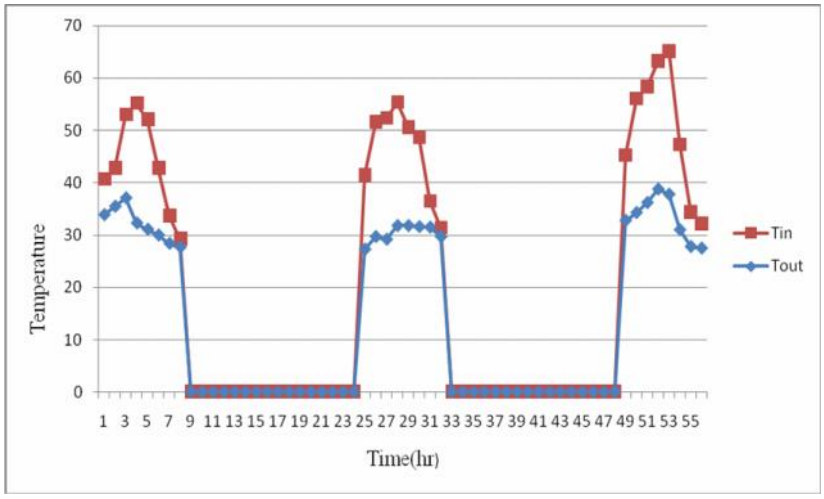

Fig. 4 Variation of temperature with time

The variation of ambient and drier relative humidity was illustrated in “Fig.5.” Humidity varies from 18.0 to 52.8% inside the solar dryer whereas outside humidity varies from 22.6 to 39.5% shown in Figure 4. Overall humidity inside the dryer was maximum as compare to outside condition.

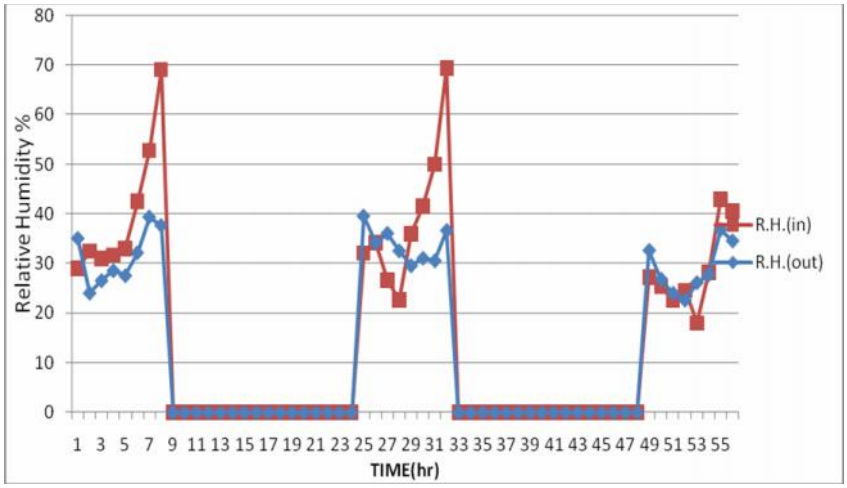

Fig. 5 Variation of relative humidity with time

The average moisture content of the chilli was reduced from about 90% (w.b.) to about 10% (w.b.) in 20 hours in the solar bamboo drier. The moisture reduction during the first, second and the third day of drying was found to be about 15. %, 35.29% and 70% respectively. The thermal efficiency of the solar bamboo drier was calculated using the “Eq.(2)”. The maximum efficiency of the drier was found to be around 17% and the minimum was 7% with an average efficiency of 14%. The drying rate of the solar bamboo drier was calculated using the “Eq.(3)”. The maximum drying rate of the drier was found to be around 11 g/hr and the minimum was 4.3 g/hr with an average efficiency of 8 g/hr.

4. Conclusion:

From the experimental work conducted for the drying of chillies in low cost solar bamboo drier, then following conclusions are drawn:

1.) The chili can be dried from an initial moisture content of 90% (w.b.) to the required moisture level of 10% (w.b.) in 24 hours.

2.) The mean thermal efficiency of the solar drier during the performance test was around 17.17%.

3.) The average drying rate of the solar dryer was around 10 g /hr.

4) The payback period of the solar dryer could be recovered within one to two month.

5) Solar dryer is suitable for domestic drying of agricultural crops up to 2 kg capacity.

6) The dryer can be used efficiently during sunny weather conditions and there is no requirement of electricity source for drying.

Also, the chillies obtained from the solar bamboo drier are of high quality, fetching more market price for the farmers. It can be concluded that this type of solar bamboo dryer is more suitable for the farmers for producing high quality product. It can therefore be used in rural areas as the source of renewable energy

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