International Journal of Engineering Research and Technology.
ISSN 0974-3154 Volume 6, Number 4 (2013), pp. 441-448

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Experimental & Analytical Investigation on Modified Solar Dryer with Recirculation of Air

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Abstract

An indirect forced convection solar drier integrated with recirculation of air has been developed and its performance is tested for drying grapes under the metrological conditions of Coimbatore, India. The system consists of a flat plate solar air heater with lens and recirculation tube, a drying chamber and micro controller. Drying experiments have been performed at an air flow rate of 3.197kg/s. Drying of grapes in a forced convection solar drier reduces the moisture content from around 80% (wet basis) to the final moisture content about 10.6% in 22.6h. Average drier efficiency was estimated to be about 20.92%. The specific moisture extraction rate was estimated to be 0.87 kg/kWh.

Keywords: Solar drier, grapes drying, microcontroller, forced convection.

1. Introduction

In India, sun drying is the most commonly used method to dry the agricultural materials grains, fruits and vegetables. In sun drying, the crop is spread in a thin layer on the ground and exposed directly to solar radiation and other ambient conditions. The rate of drying on various parameters such as solar radiation, ambient temperature, wind velocity, relative humidity, and initial moisture content, type of crops, crop absorptive and mass of product per unit exposed area[1]. This form of drying has many drawbacks, such as degradation by windblown, debris, rain and insect infestation that will result in contamination of the product. Drying rate will reduce due to intermittent sunshine, interruption and wetting by rain. Solar driers using natural convection or forced circulation have been investigated to overcome the problems [2]. For commercial applications, the ability of the drier to process continuously throughout the day is very important to dry the products to its safe storage level and to maintain the quality. Normally copper plates are employed to increase the collector outlet temperature, which in turn increases the collector thermal efficiency. The solar drier is an energy efficient option in the drying process [3]. Use of forced convection solar driers seems to be an advantage compared to traditional methods and improves the quality of the product considerably[4,5]. Use of forced convention solar driers seems to be an advantage and improves quality of the product considerably [6]. Normally thermal storage systems are employed to store the heat, which includes sensible heat storage [7]. Common sensible heat storage materials used to store sensible heat are water, gravel bed ,sand, clay, concrete, etc. [8]. The objective is to develop a indirect forced convection solar drier integrated with recirculation of air to increase the collector outlet temperature for drying of grapes.

2. Materials and Methods

2.1 Experimental set-up

A schematic diagram of the forced convection solar drier is shown in the figure 1. The solar drier consists of flat plate solar air heater of area (60*60) cm^2 connected with the drying chamber. The solar air heater has 2 mm thick copper absorber plate coated with black paint to absorb the maximum solar radiation. The absorber plate is placed directly behind the transparent cover with a layer of air separating it from the cover (glass) with a layer of air separating it from the cover. In order to improve the mass flow rate of the air, the air to be heated is passed between the transparent cover (glass) and the absorber plate. To increase the temperature of air by green house effect, a glass cover of 5 mm thickness was placed. The gap between the glass and the absorber surface was maintained at 25 mm inlet. The drying chamber is made up of mild steel sheet of 2mm thickness with two trays of width, depth and height of (30*30*60) cm respectively. The drier is capable of holding about 500g of grapes per batch. The drying chamber was insulated with glass wool of 10 mm thickness. The system is oriented to face south to maximize the solar radiation incident on the solar collector. The potential sunshine duration was about 8 hours per day only.

2.2 Experimental procedure

Only good quality grapes were used in the experiments. About 500g of fresh grapes were dried as whole fruits, without any chemical pre-treatment, until the required final moisture content was attained. The fresh grapes were loaded over the trays of drier chamber having about 90% perforation. The initial moisture content was calculated by taking five different samples. Then the exhaust fan was switched on and the air flow rate through the solar flat plate collector was adjusted to 3.917 kg/s [9].The velocity of air at inlet of the tray was measured with the help of vane type anemometer. Solar intensity was measured using solar intensity meter. During sunshine hours the air flow over the absorber plate gets heated and simultaneously the grapes in the drying chamber get dried and its moisture gets reduced. Temperature at inlet and outlet of the solar collector and the drying chamber were measured at every one hour interval. The experiment was conducted for 8 hours during potential sunshine hours. During idle conditions, he grapes were covered with polyethylene sheet to avoid de-absorption of moisture. All the experimental observations were made after the driver attains the steady state condition. The experiments were repeated thrice and an average was considered. The drying characteristics of grapes such as moisture content, drying rate, specific moisture extraction rate and drier thermal efficiency were determined by using Eqns. (1) to (3) respectively.

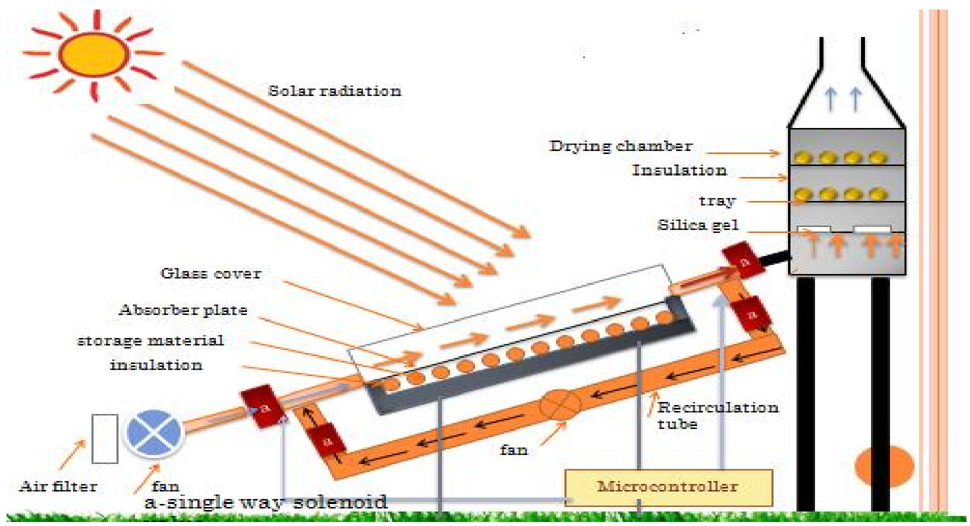

Figure 1: Forced convection solar drier.

2.3. Determination of moisture content

The quantity of moisture present in a material can be presented on wet basis and expressed as percentage. About 10g sample were taken and kept in a convective electrical oven, which was maintained at 105±1°C until constant weight has reached. The initial and final mass, M_t , and final mass , M of the samples were recorded with the help of electronic balance. The moisture content,M_{wb}, on wet basis was calculated by using Eq. (1). The procedure was repeated for every one hour interval till the end of drying.

$$M_{wb} = \frac{(M_t - M_d)}{M_t} * 100 \quad (1)$$

2.4. Determination of drying rate

The drying rate, DR, should be proportional to the differences in the moisture content between materials to be dried and the equilibrium moisture content [16]. The concept of thin layer drying was assumed for the experiments as reported by Eq. (2).

$$\mathrm{DR} = -K\,(M_t - M_e) \quad (2)$$

2.5. Determination of specific moisture extraction rate

The specific moisture extraction rate, which is the energy required for removing one kg of water. SMER was calculated using Eq. (3) as reported by Shanmugam and Natrajan [11]

$$\mathrm{SMER} = \frac{m_d}{p_d} \quad (3)$$

3. Results and Discussions

The variations of temperature of air at solar collector outlet and ambient temperature for a typical day during of copra are shown in Fig.2. The average drying air temperature recorded at inlet of the drier inlet were measured to be about 46.2 and 34°C during peak and off sun sunshine hours respectively.

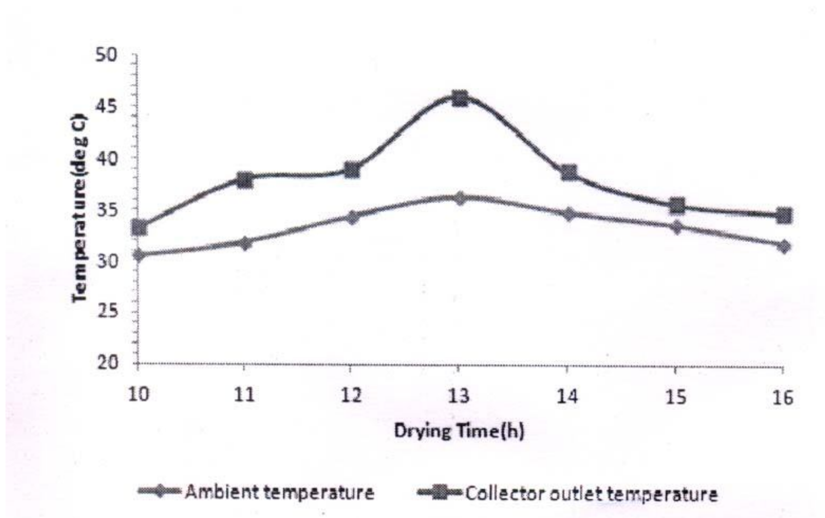

Figure 2: Variation of Ambient and Drier Outlet Temperature against drying time.

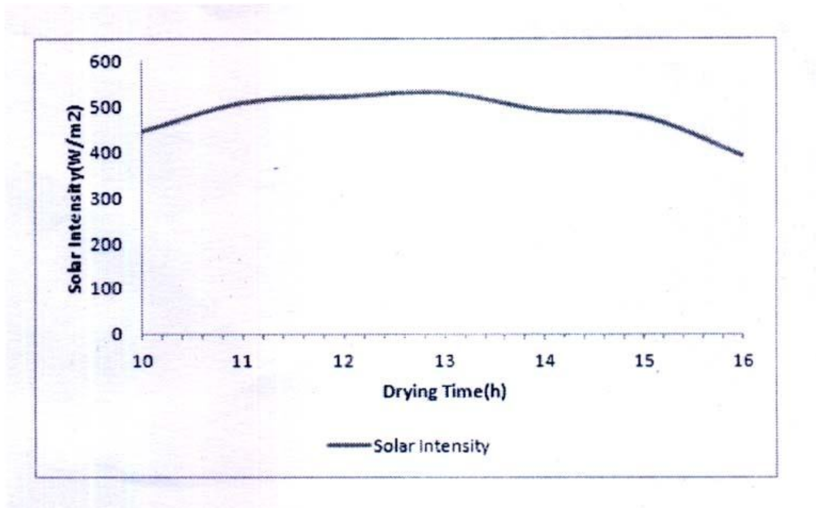

Figure 3: Variation of Solar intensity against Drying time.

Figure 3 and 4 shows the variation of solar intensity and ambient relative humidity during experimentation. Maximum solar intensity recorded was about 520 W/m² during peak sunshine hours. The average dry and wet bulb temperatures recorded were 30°C and 26°C respectively.

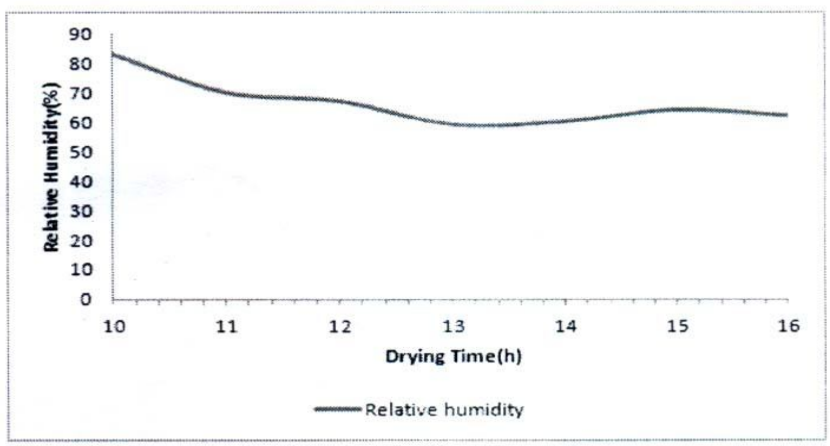

Figure 4: Variation of Relative Humidity against Drying Time.

The variation of moisture content (wet basis) with drying time illustrated in Fig.5. The average about 80% to 10.6% and 11% in bottom and top tray respectively after 24hour.The higher moisture reduction during initial stages of drying was observed due to evaporation of free moisture from the outer surface layers and then gets reduced due to internal moisture migration from thinner layers to surface ,which results in a process of dehydration. The reduction in moisture content at bottom tray was about 4 to 6% higher than that of top tray. Temperature inside drier was higher than ambient temperature and corresponding relative humidity in the drier was lower than ambient relative humidity. As a result, drying rate of grapes in a force convection drier was found to be higher than that of open sun drying.

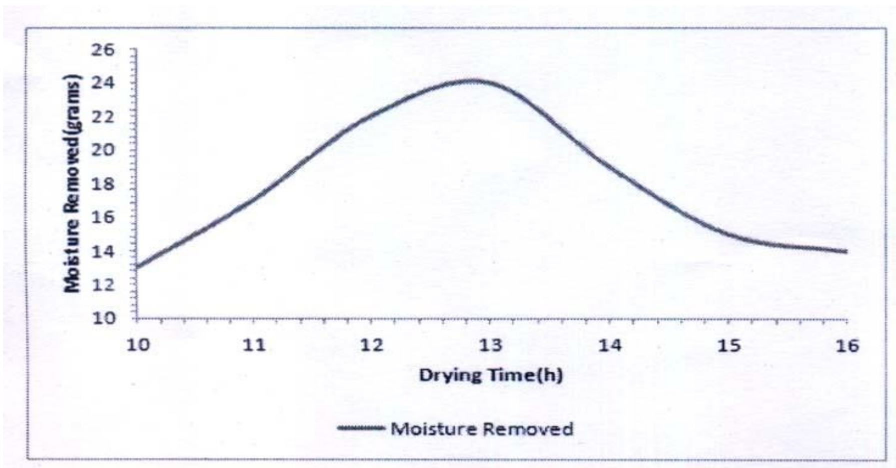

Figure 5: Variation of Drying rate against Drying Time.

The specific moisture extraction rate was estimated to be about 0.87 kg/kWh .Use of solar drier with the integration of heat storage materials will improves the efficiency of the drier and reduces the dependency of conventional energy sources, which reduces indirect global warming.

4. Conclusion

The performance of an indirect forced convection solar drier integrated with recirculation of air was designed, fabricated and investigated for grapes drying. The drier with copper absorber plate enables to maintain consistent air temperature inside the drier. The grapes was dried from initial moisture content 80% to the final moisture content about 10.6% and 11%(wet basis) in bottom and top tray respectively. It could be concluded that, forced convection solar drier is more suitable for producing high quality dried grapes for small holders. Thermal efficiency of the solar drier was estimated to be about 20.92% with specific moisture extraction rate about 0.87 kg/kWh.

References

[1] Jain, D.; and Tiwari, G.N (2003).Thermal aspects of open sun drying of various crops. *Energy*, 28(1), 37-54.

[2] Ong, K.S. (1999).Solar dryers in the Asia –pacific region. *Renewable Energy*, 16(1-4), 779-784.

[3] Pangavhane, D.R.; and Sawhney, R.L. (2002). Review of research and development work on solar driers for grape drying. *Energy conversion and management*, 43(1), 45-61.

[4] Sodha, M.S.; Dang, A.; Bansal, P. K.; and Sharma, S.B.(1985). An analytical and experimental study of open sun drying and a cabinet type dryer. *Energy Conversion Management*, 25(3), 263-271.

[5] Midilli, A. (2001). Determination of pistachio drying behaviour and conditions in a solar drying systems. *International Journal of Research*, 25(8) 715-725.

[6] Shanmugam, V,; and Natarajan, E. (2007). Experimental study of regenerative desiccant integrated solar dryer with and without reflective mirror. *Applied Thermal Engineering*, 27(8-9), 1543-1551.

[7] Hawlader, M.N.A.; Uddin, M.S.; and Khin, M.M. (2003). Microencapsulated PCM thermal energy storage system. *Applied Energy*, 74(1-2), 195-202.

[8] Ahmad, A.; Saini, J.S.; and Varma, H.K. (1996).thermodynamic performance of packed bed solar air heaters. *Energy Conversion and Management* 37(2), 205-214.

[9] Hegazy , A.A. (1999). Optimum channel geometry for solar air heaters of conventional design and constant flow operation. *Energy Conversion and Management*, 40(7), 754-774.