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PERFORMANCE OF NATURAL CONVECTION DIRECT TYPE SOLAR DRYER WITH OR WITHOUT REFLECTOR AND CHIMNEY

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Abstract
Various researchers have established the fact that solar drying has an edge over conventional open air sun drying. Especially, for developing country like India, where a very good solar radiation is available, solar drying is the economical and viable alternative. The dryers may be classified as direct, indirect or mixed mode based on exposure of the product to solar radiation. Further, depending on the mode of air flow, dryers are termed as natural convection or forced convection dryers.
The work reported here is carried out on a solar cabinet dryer, which is of direct type that uses natural circulation of air through it. The main aim of the study is to investigate the effect of provision of reflector and the chimney structure attached to the plain dryer. The prototype dryer is fabricated at the institute and is tested for high moisture content commodity. The performance of the dryer with reflector compared with the one without reflector is brought out. Also, the exclusive effect of provision of the chimney structure attached to the plain dryer, whether or not the reflector is provided, is investigated. It is pointed out that provision of the chimney and reflector is quite desirable and a good improvement in the drying rate is obtained.
Keywords: Solar dryer; Natural circulation; Drying rate; Reflector; Chimney.

Introduction

Solar dryer may be classified in the several general categories, depending upon the mode of heating or operational mode of deriving heat from the solar radiation and its use to remove the moisture from the wet product. The suitable solar drying system must be properly selected & designed to meet the particular drying need. Firstly, based on the criterion of exposure to insolation, solar dryers can be termed as direct, indirect and mixed mode dryers. Direct dryers are those in which the product is exposed to sun. On the other hand, indirect dryers make use of heated air from a separate solar collector that is ducted to an enclosed drying chamber, which is shielded from direct insolation. Mixed mode dryer also has solar air heater, however, the drying chamber is covered with the transparent glazing that allows the radiation to fall on the product.

Secondly, based on the criterion of mode of air flow, one may choose either natural circulation or forced circulation of air. There are numerous ways in which the dryer can be designed and constructed with the different combinations of above criteria and making use of local materials.

The literature is flooded with number of studies that employ innovative ways of collecting solar energy and using it for drying purpose. Detailed reviews on solar drying technologies are taken up in references [1-3]. One of the earlier studies reported was that of Lawand [4], who came out with the modified form of the solar cabinet dryer. Among the recent studies that have been reported, includes one by Bala, et al [5], who presented the experiments performed on forced convection tunnel type of dryer used for drying pineapple. Forson, et al [6] have designed mixed mode natural convection solar crop dryer that was used for drying cassava on large scale with a batch size of 160 kg. They also discussed basic design concepts and thumb rules for different parameters. Afriye, et al [7] performed tests on cabinet dryer using chimney. They suggested that such chimney, if designed properly, increases air flow rate through the dryer thereby increasing the drying rate. Onyinge, et al [8] investigated the performance of natural convection solar cabinet dryer that is loaded with thin layer of vegetable kales.

The present paper reports the tests performed on a natural convection direct type of solar dryer that does not need any external source of power for drying the commodities. It is felt that the reflector attached on the front side of the cabinet and also employing the chimney structure at the top of solar cabinet dryer would improve the drying efficiency and the performance of the dryer. An attempt is made to bring out the actual effect of using either reflector or chimney or both on the drying rate.

Description of dryer

A basic natural circulation direct type of solar cabinet dryer is fabricated along with the separate reflector assembly and the chimney

structure assembly. Thus, the performance of basic dryer could be compared with the dryer with reflector, the dryer with chimney and the dryer with both reflector and chimney. Figures 1 & 2 show the photographs of, respectively, the basic dryer and the dryer with reflector assembly attached on the front side and the chimney in place.

The basic dryer as shown in Fig. 1 consists of a structure made out of M.S. angle. The bottommost plywood surface has number of holes in it that serves as inlet for air. Similar holes are provided at the top of the vertical plywood surface on the back side to let the air leave. Arrangement for holding the perforated mesh tray horizontally above the bottom plywood surface is made so that the product can be loaded. The rest of the surfaces are provided with transparent glazing in the form of polythene sheet which allows solar radiation to be incident on the tray and all the surfaces. The non-transparent surfaces are painted with black board paint. Solar insolation heats all the surfaces along with the commodity, which sets in the upward natural circulation of air through the dryer.

As indicated in Fig. 2, the reflector assembly is hinged to the dryer on the front side, which allows the user to incline the reflector surface at a predetermined angle to the horizontal. Reflector surface is made out of aluminum foil pasted on the thin plywood.

Figure 2 also shows the chimney structure assembly mounted on the top of the basic dryer. It is made out of M.S. angle with back surface of plywood and has the shape of pyramid. Rest of the surfaces of chimney are covered with transparent glazing similar to basic dryer. When chimney structure is in place, the holes at the top of the vertical surface of basic dryer are sealed, so that air leaves through the opening provided at the top of the chimney.

Results and Discussion

Natural circulation direct type solar cabinet dryer fabricated at the institute is tested with four possible arrangements as enumerated below:

1. Plain dryer without chimney and reflector
2. Plain dryer without chimney and with reflector (angle 45°)
3. Plain dryer along with chimney and without reflector
4. Plain dryer along with chimney and reflector (angle 45°)

The place of test, Chandrapur, is located in the eastern edge of Maharashtra and is at the latitude 19°56′18″ North and longitude 79°18′54″ East. The dryer is tested in the month of March-April 2015. Commodity selected for the test is onion which has initial moisture content of about 80%. The safe moisture content for storage is about 10%. The quantity of onion to be dried in the particular run is taken to be 4 kg in case of all the four arrangements. The test is carried out for two consecutive days for each arrangement, so that the performance parameters like temperature levels at the tray and at the outlet and final moisture content and hence the drying rate can be compared.

Temperature variation with respect to time for different arrangements

One of the important parameter in drying any commodity is the temperature variation. The temperature at the inlet, at the tray and at the outlet is recorded over the Day-1 and Day-2 for each of the four arrangements. The typical variation of temperature over two days is shown in Fig. 3, as an example, for the plain dryer with both chimney and reflector.

It can be seen that, on each day, temperature at the tray and at the outlet rises sharply with time reaching its maximum at around 1 p.m. Thereafter, the temperature drops towards the end of the day. On Day-2, the tray temperature is noticed to be higher compared to that on Day-1, owing to the fact that commodity has shed out some moisture on Day-1 and is comparatively dry on Day-2.

Figs. 4 & 5 indicate the variation in tray temperature, respectively, on Day-1 and Day-2 for different arrangements. It may be noted that curve for the plain dryer is shown only upto 4 p.m. on Day-2. It is due to the fact that the atmosphere became heavily cloudy that day and the trial is to be terminated.

It is noticed that maximum temperature achieved in the different arrangements is in the ascending order for plain, plain with chimney, plain with reflector, and plain with reflector & chimney. It is noticed that maximum tray temperature reached for Day-1 in case of above arrangements in order is, respectively, 43°C, 43°C, 45°C and 47°C. While on the Day-2, maximum tray temperature, respectively, for above arrangements is found to be 46°C, 53°C, 57°C and 59°C.

It is observed that the maximum tray temperature reached on Day-1 is 4.65% higher in case of plain with reflector arrangement compared to the plain one. While, similar percentage change in maximum tray temperature is found to be 9.3% higher on Day-2. Thus, whether it is plain dryer or dryer with

chimney, the provision of reflector is seen to be advantageous.

Further, one can clearly make out the effect of employing chimney. It is noticed that overall temperature is always higher in the arrangements with chimney compared to the one without chimney. This underlines the fact that provision of chimney aids in getting the higher drying rate compared to the case when chimney is not used.

Similarly, variation in outlet temperature is plotted over the day as depicted in Figs. 6 & 7, respectively, for Day-1 and Day-2. It is observed that it is following the same trend as seen in case of tray temperature.

Variation in moisture content over the drying period

Figure 8 depicts the reduction in moisture content over the Day-1 & Day-2 for different arrangements. It may be noted that there is reduction in moisture content overnight between the Day-1 and Day-2. As expected, reduction in the moisture content for the plain arrangement is lesser as compared to plain with reflector arrangement. Reduction in moisture content is highest in the arrangement with reflector & chimney both. It is found that moisture content drops by 33.92 % on Day-1 for the plain arrangement, while reduction of 50.96% is noticed on Day-1 in case of plain with reflector & chimney arrangement. The drop in moisture content for the plain with reflector & the plain with chimney arrangement falls between the above two arrangements.

The reduction in moisture content over the Day-1 is found to be 17.04% more when reflector & chimney is employed compared to the plain dryer. On the second day as well, the reduction in moisture content is similarly noticed to be 4.54% higher, when the above cases are compared.

Figure. 1 Basic solar cabinet dryer.

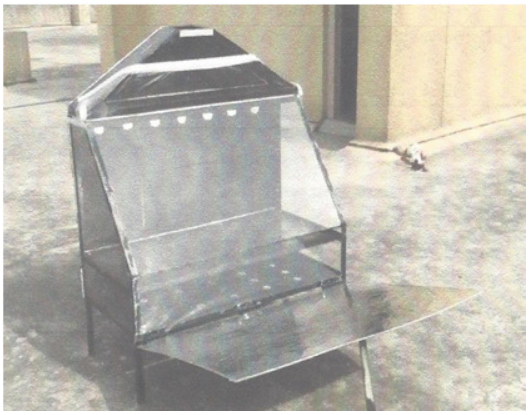

Figure. 2 Solar cabinet dryer along with reflector and chimney.

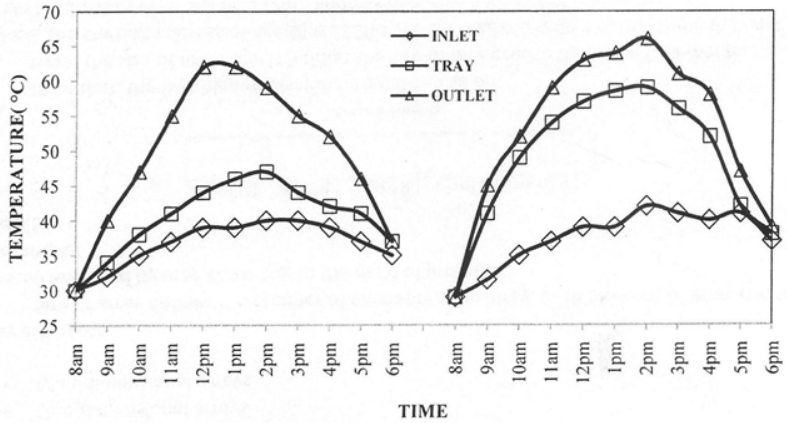

Figure. 3 Temperature variations with respect to time for dryer with reflector and chimney.

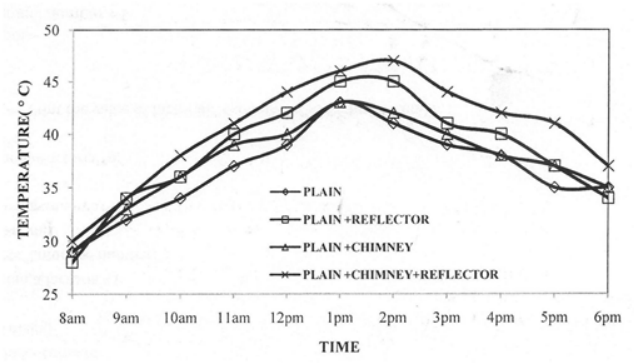

Figure. 4 Tray temperature over the Day-1 for all the arrangements.

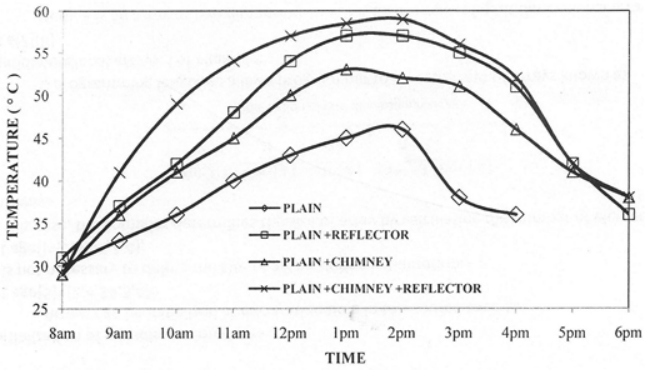

Figure. 5 Tray temperature over the Day-2 for all the arrangements.

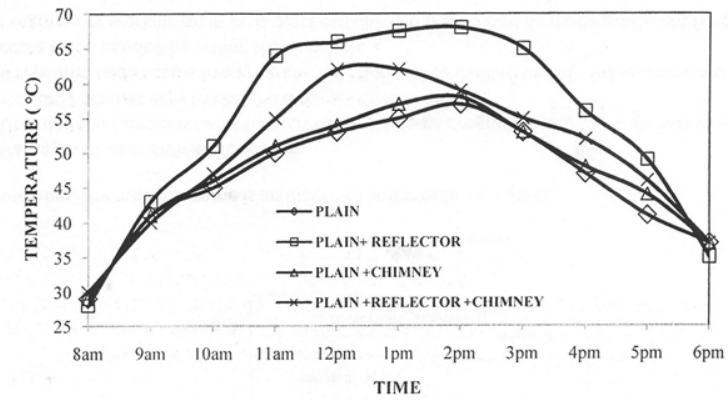

Figure. 6 Outlet temperature over the Day-1 for all the arrangements.

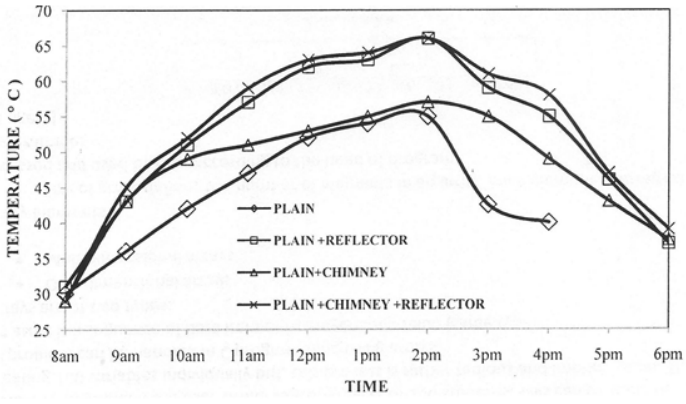

Figure. 7 Outlet temperature over the Day-2 for all the arrangements.

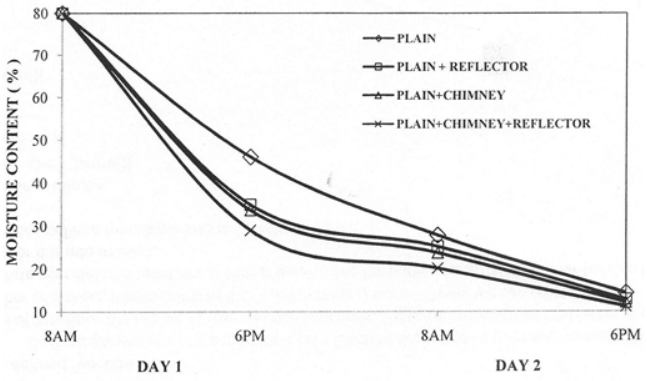

Figure. 8 Variation in moisture content over the total drying period.

Conclusion

The present work aims at the detailed probe into provision of reflector, chimney and both reflector and chimney as compared with the plain, natural circulation direct type solar dryer. The said dryer is tested for onion, keeping in mind that such dryers are more suitable for high moisture content commodity. The results obtained are quite encouraging and favour the use of reflector as well as chimney structure being attached to the plain dryer. It is pointed out that the final moisture content at the end of Day-2 is 11.14% in case of the arrangement when reflector & chimney are attached to the plain dryer, while it is 14.3% in case of plain dryer. Further investigations are underway so as to bring out the better comparison with variation in load and the reflector angle.

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