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## Performance Analysis of Chimney Type Solar Dryer for Drying Chilli

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**ABSTRACT:** The performance of a chimney type solar dryer is tested for drying chilli under the metrological conditions of Surat, India. The system consists of a flat plate solar collector with a drying chamber. The air, allowed to enter the dryer, through collector inlet is heated up in the solar collector and allowed to flow through the drying chamber where it is utilized for drying i.e. removal of the moisture content from the food substance or agricultural produce loaded. Then its performance analysis using various parameters is carried out.

**KEYWORDS:** Solar dryer, Chilli, Performance analysis, Chimney, Solar Collector.

### I. INTRODUCTION

Drying is an excellent way to preserve food and it is one of the most important post-harvest operations for herbs and spices. It involves the removal of moisture from agricultural produce so as to provide a product that can be safely stored for longer period of time. It also serves modification in tastes and flavours in order to increase their market values of spices such as chili and pepper. Solar food dryers are appropriate food preservation technology for sustainable development.

Solar dryers are specialized devices that control the drying process and protect the agricultural product from damage by insect pests, dust and rain. In comparison to natural sun drying, solar dryer generates higher temperatures, lower relative humidity, lower product moisture content and reduced spoilage during the drying process. In addition, it takes up less space, takes less time and relatively inexpensive compared to artificial mechanical drying method. Thus, solar drying is a better alternative solution to all the drawbacks of natural drying and artificial mechanical drying.

### II. RELATED WORK

Various types of driers are available to suit the needs of farmers [1]. A properly designed solar dryer can alleviate the drawbacks associated with open sun drying, and the quality of the dried product can be upgraded. It, in turn, causes high returns to the producers [2-6]. The natural convection solar drier appears to have potential for adoption and application in the tropics and subtropics. It is suitable at a household level for drying of 10–15 kg of fruits and vegetables [7]. Hossain and Bala [8] used mix mode type forced convection solar drier tunnel to dry red and green chillies under the tropical weather conditions of Bangladesh. Kaewkiewet al. [9] investigated performance of a large-scale greenhouse type solar dryer for drying chilli in Thailand. Montero et al. [10] presented the characteristics of the prototype, together with the variations of the properties of temperature, relative humidity, air mass flow, and efficiency for different operation modes. Whereas Nijmeh et al. [11] presented Design and testing of solar dryers for processing food wastes. Saleh and Badran [12] introduced, built, and tested domestic solar dryer with drying of local herbs at different operational conditions. Afriyiet al. [13] showed that the solar chimney can increase the airflow rate of a direct-mode dryer. Some reports on chimneys have also shown that, properly designed chimneys can boost the flow of the air through an enclosure [14-16].

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### III. DESCRIPTION OF THE DRYER

The solar dryer consisted of flat plate solar collector connected with drying chamber. The solar air collector had thick copper absorber plate coated with black paint to absorb the incident solar radiation. The absorber plate was placed directly behind the transparent cover (glass) with a layer of air separating it from the cover. The air to be heated was made to passthrough between glass cover and the copper absorber plate. The collector was connected with the drying chamber. The system was oriented to face south to maximize the solar radiation incident on the solar collector. The solar food dryer consisted of two major compartment or chambers being integrated together as shown in Figure 1:

- I. The solar collector compartment, which can also be referred to as the air heater.
- II. The drying chamber, designed to accommodate a single drying tray.

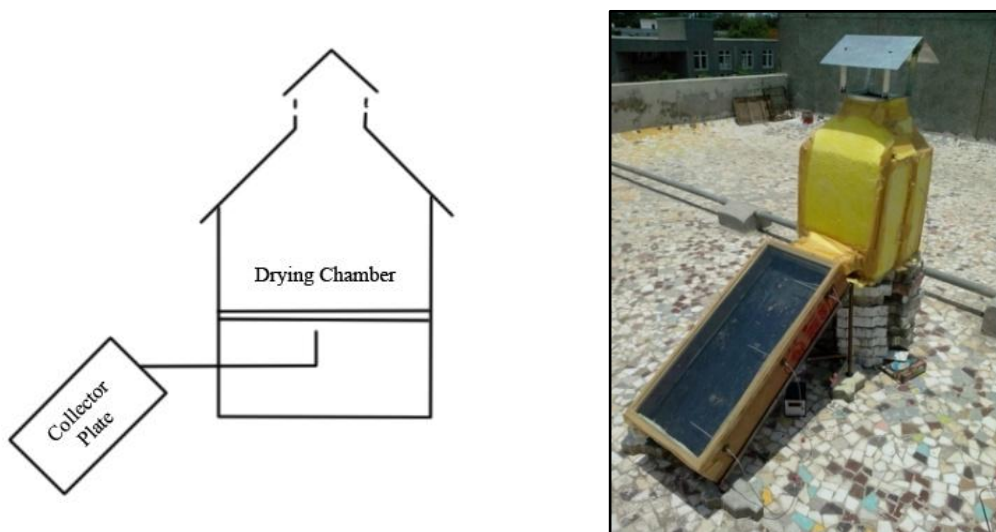


Figure 1: Schematic and actual figure of an experimental setup of solar dryer

The materials used for various components of solar dryer along with the specifications such as, area of drying bed, area of collector etc. are given in below Table 1.

Table 1: Materials Used and Specifications for Components of Dryer

COMPONENT	MATERIAL	SPECIFICATION	VALUE
Drying Plate	Metal Mesh	Chimney Height ( $h_2$ )	50 cm
Absorber Plate	Copper	Thickness of bed ( $h$ )	3 cm
Cover Plate	Glass	Height below bed ( $h_1$ )	20 cm
Insulating Material	Glass wool	Pressure drop of air ( $P$ )	0.03 mm of water
Outer Surface of Collector	Wooden Ply	Area of drying bed ( $A_d$ )	40 cm x 40 cm
		Area of collector ( $A_c$ )	0.36m <sup>2</sup>

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## IV. METHOD OF MEASUREMENT

### 1. Temperature Measurement:

Temperature was measured using RTD PT100. These were installed at six different places. Four of them were in the collector, first at the collector inlet to measure the collector inlet air temperature, second at the middle portion of the collector, third at the collector outlet to measure the collector exit air temperature and fourth was made contact with the copper plate inside of collector to measure a plate temperature. Other two were installed in the drying chamber, one below the drying bed and the other above the drying bed. Also one more was used to measure the atmospheric air temperature. All readings were taken in the interval of 1 hour for three days between 9:00 a.m. to 6:00 p.m.

### 2. Weight Measurement:

Weight measurement of chillies was carried out on a weighing machine certified by ISO: 9001. Thirteen samples of chillies were selected for experiment which was placed on the drying bed inside the chamber with the help of a thread. After every one hour these samples were taken out of the chamber from the top with the help of the thread and were weighted on the weighing machine and again placed inside.

### 3. Velocity Measurement:

The velocity of air at inlet was measured with the help of the Vane type Anemometer. The Anemometer was placed at the collector inlet to measure the velocity of air at the inlet. This velocity is then used to calculate the mass flow rate of the air. These readings were taken after every one hour.

### 4. Solar Incident Radiation Measurement:

Solar incident radiations were measured with the help of solarimeter. The instrument was placed directly below the sun and the reading was shown on the digital display calibrated in  $W/m^2$ . These readings were also taken after every one hour.

### 5. Dry And Wet Bulb Temperature Measurement:

A dry and wet bulb thermometer was used to measure the dry and wet bulb temperature of air and at the exit of the drying chamber. These were then used to calculate the relative humidity of air and exit of the drying chamber respectively.

## V. EXPERIMENTAL PROCEDURE

Only good quality chillies were used in the experiments. About 1 kg of fresh chillies was dried, without any chemical pre-treatment, until the required final moisture content was attained. The fresh chillies were loaded over the tray. The initial moisture content was calculated by taking thirteen different samples. The velocity of air at inlet of the tray was measured with the help of vane type anemometer. Solar intensity was measured using solarimeter. Temperatures at inlet and outlet of the solar collector and drying chamber were measured at every one-hour interval with help of thermocouples placed at required location. During idle conditions, the chillies was covered with polyethylene sheet to avoid deabsorption of moisture. All the experimental observations were made after the dryer attained the steady state condition. The experiments were repeated to determine and to consider the average values. The drying characteristics of chillies such as moisture content, drying rate, specific moisture extraction rate and dryer thermal efficiency were determined.

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## VI. RESULTS AND DISCUSSION

Successful test was conducted for continuous three days of May-2013 and these test data were used to calculate the collector efficiency, drying curves, humidity and temperature measurements in the dryer. During the tests period, the heated air was used to dry chillies.

### Collector efficiency:

The efficiency of the collector could be seen from difference in temperature of the exit and inlet of the air to the solar collector. In this dryer, by fully opening the inlet and the exit of the dryer, a temperature within 10-20°C higher than the ambient air temperature was recorded. The graph of ambient temperature (T<sub>atm</sub>) and collector exit temperature (C<sub>3</sub>) was plotted and can be seen from the Figure 2.

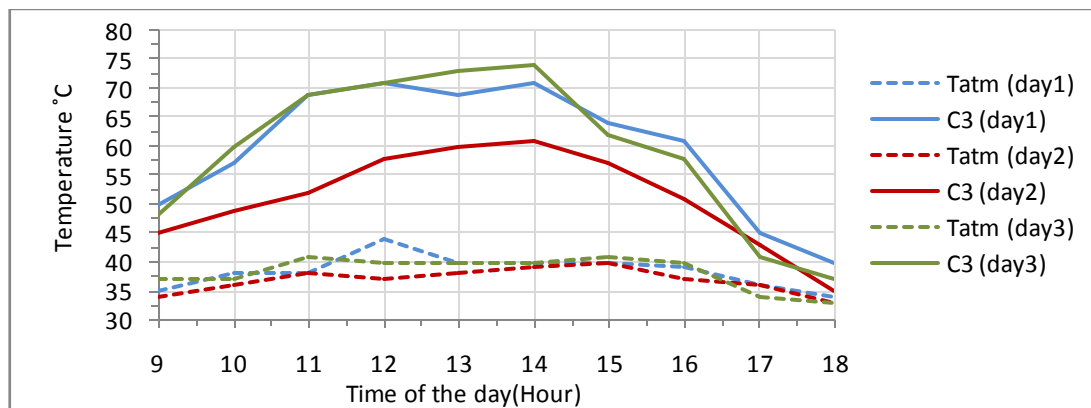


Figure 2: Ambient Air Temp. (T<sub>atm</sub>) and Collector Exit Air temp.(C<sub>3</sub>) V/S Time for Day 1, 2 and 3

The instantaneous efficiency of the solar collector started to rise in the morning period and was relatively constant about 35% from 12:00 pm to 2:00 pm and dropped down in late afternoon. The variation obtained is typical for a flat plate collector and indicates strong dependence of efficiency on the metrological data especially on wind velocity and atmospheric conditions. The daily efficiency, averaged over 9 hours (9:00 am to 6:00 pm) comes out to be 35.15%. Here, Figure 3 depicts the collector efficiency obtained on three different days.

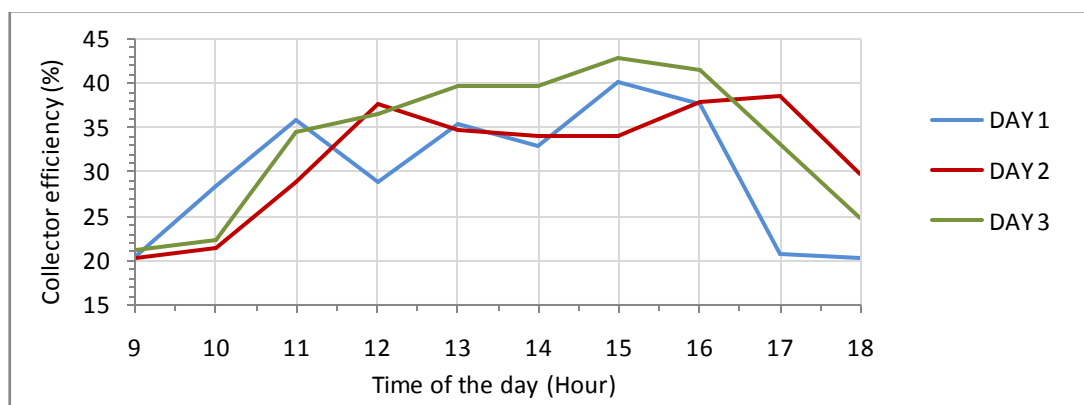


Figure 3: Collector Efficiency V/S Time for day 1, 2 and 3

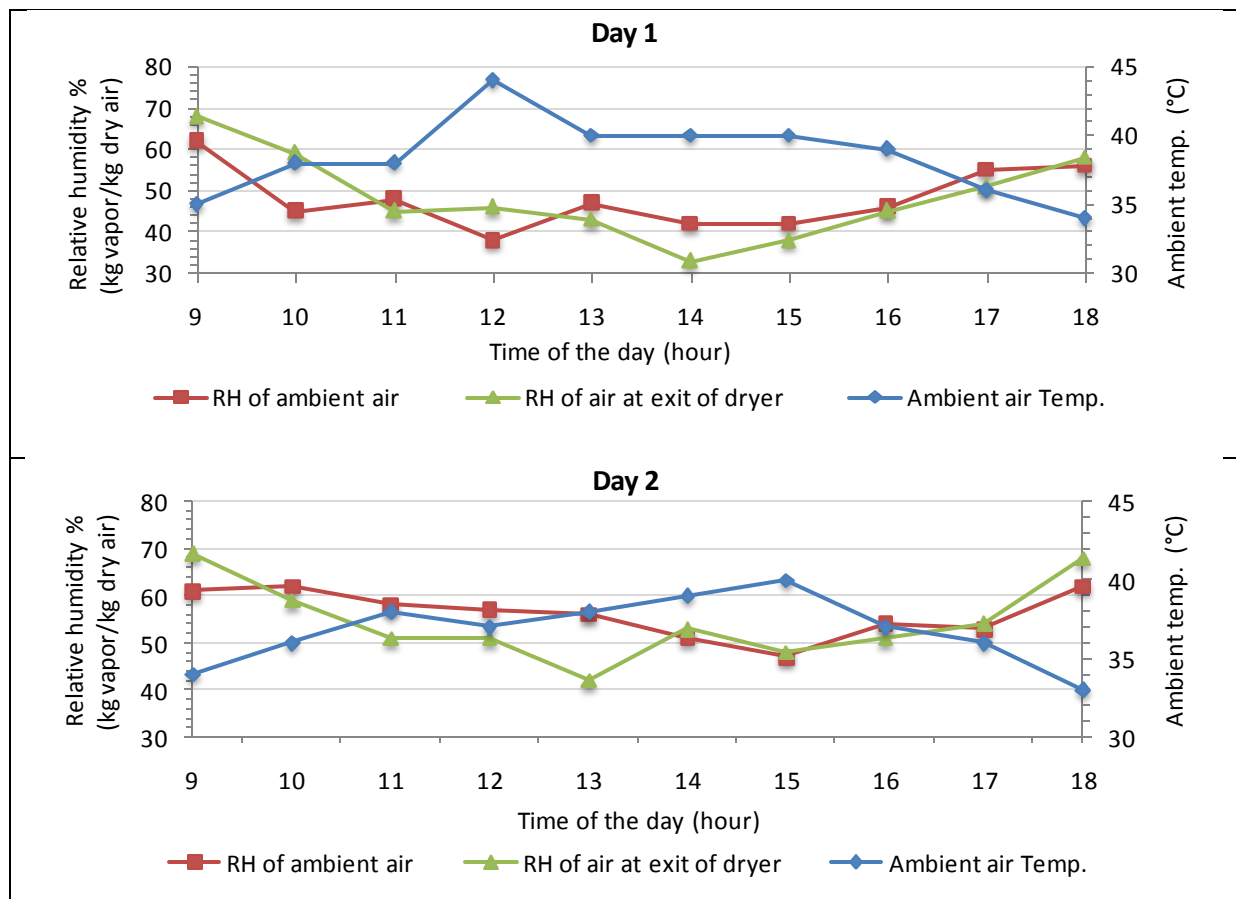
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### Relative Humidity and Capacity of the Air:

The Relative humidity during all the three days is plotted as shown in the Figure 4. The relative humidity is affected by the air temperature. Heating the air decreases the relative humidity and respectively increases the capacity of the air to carry away moisture during a drying process. The extent to which this is achieved depends on the weather conditions, namely the absolute humidity and the temperature of the ambient air. The relative humidity and temperature of the ambient air are included for comparison. The average relative humidity of the ambient air was 51.06%. However, the low relative humidity of the exhaust air shows that the potential of the drying air to remove moisture was not fully utilized. This can be improved through proper utilization of the drying potential of the air by increasing the number of the drying trays.



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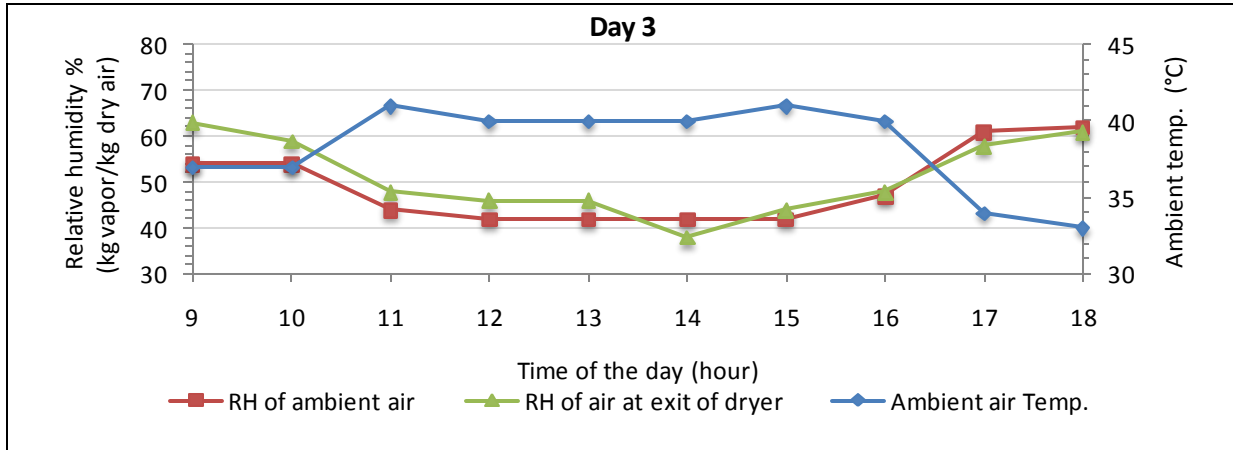


Figure 4: RH V/S Time for Day 1, 2 and 3

### Drying Tests

The experimental results obtained are shown in Figures 5, 6. Figure 5 shows the moisture content of Chilli as a function of the drying. It can be seen from figures that moisture content on the wet basis gradually decreases with the time. The maximum moisture content removed is 1.51% and minimum is 0.18% on wet basis. During night time there is also decrease in the moisture content, it is because during the night there was loss of moisture to the air in the dryer and in the room.

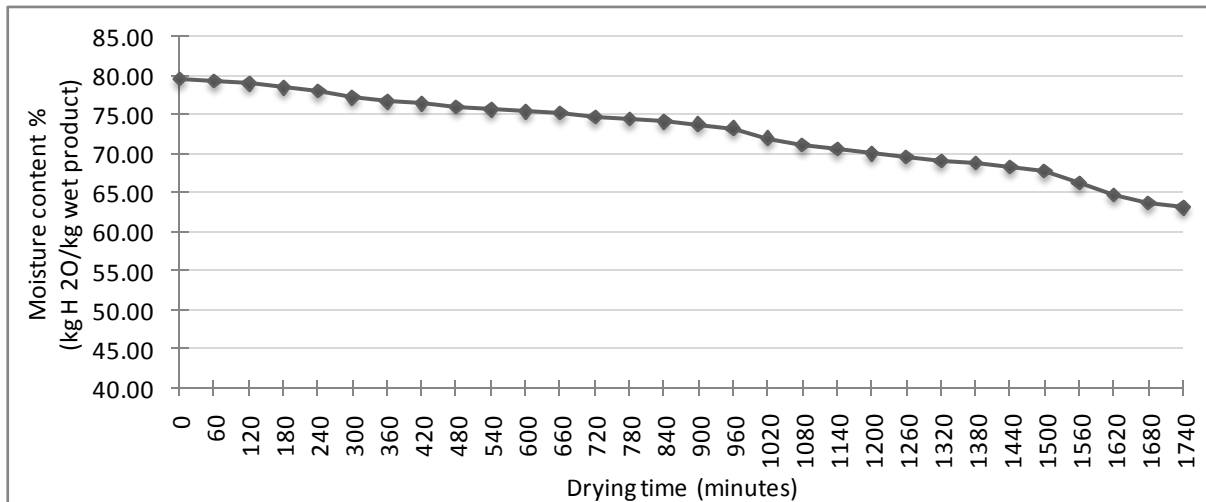


Figure 5: Moisture Content v/s Drying Time

Figure 6 shows the drying rate of chilli as a function of the drying time. In the practical environment it fluctuates at some point due to sudden change in the weather condition. Even though there was moisture loss during the night in bed but the drying rates were nearly zero this is because the moisture loss was the entire night. This effect is reflected in the figure below.

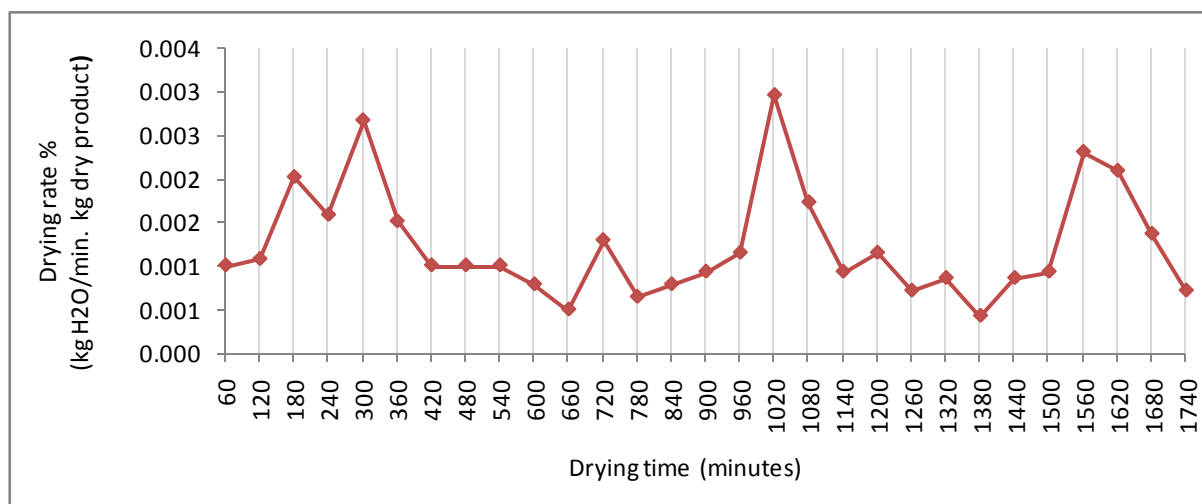


Figure 6: Drying Rate v/s Drying Time

## VII. CONCLUSION

The performance of chimney type solar dryer was evaluated using 1kg of fresh chillies with collector of area 0.36m<sup>2</sup>. The results were as below.

1. The collector performance is encouraging. Collector efficiency ranges from 20% - 43% and temperature rise was between 25 – 30 °C.
2. The drying material was protected from direct solar radiations, infestation by insects and contamination by dust. As a result, the quality obtained was high.
3. The maximum moisture content removed was 1.51% and minimum moisture content removed was 0.18%.

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