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Research Article

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Development of Solar Tunnel Dryer for Drying Tomato (*Lycopersicum esculentum*) Slices

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ABSTRACT

A small solar dryer was designed to dry 10 kg of tomatoes per day. The dryer consisted of two sections in which the front portion of the dryer acted as a solar collector with an area of 1.22 m^2 and the area of drying chamber is 3.682. The dryer frame was in triangular shape with a slope angle of 310 which was covered with UV stabilized polythene sheet of 200 microns. Three fans of 15 cm diameter have been fitted at the front side of the dryer to provide air circulation inside the drying chamber whereas the other side was provided with ventilation. Tomato slices were dried in the developed solar drier at three different air velocities of 2 m/s, 3 m/s, 4 m/s respectively. The tomatoes were dried inside the solar dryer with an initial moisture content of 91 per cent (w.b.) to a final moisture content of 7.1 per cent (w.b.). During the experiment the maximum temperature obtained inside the dryer was 59.40°C at the air velocity of 3 m/s and 56.20°C and 52.30°C at 2 m/s and 3 m/s respectively. The relative humidity of 26.2 per cent, 33.2 per cent and 36.2 per cent at the air velocity of 3 m/s, 2 m/s and 4 m/s was obtained respectively and 3 m/s was found to be the optimum air velocity for drying.

Key words: *Solar Tunnel Dryer, Drying Tomato Slices*

INTRODUCTION

Tomato (*Lycopersicum esculentum*) is one of the most important “protective foods “because of its special nutritive value. In present days, the demand for the tomatoes is increasing steadily with an increase in population and its likeliness towards tomato. India is the 2nd leading tomato producing country occupying 11.2 percent of the world annual production next to China. The total production of tomato in India is about 182.27 lakh tonnes per year[7], and the total export quantity of tomato from India is about 343 tonnes[3].

The problem itself is relatively easy to define: there are simply too many tomatoes produced in a very short time period. In developed countries these excess tomatoes would be processed into tomato sauce, tomato paste, or ketchup; or they might be processed and canned whole, sliced, or diced.

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However, production of these value added products are energy intensive and prohibit the small players to enter into this area. Sun drying is a well-known traditional method of drying agricultural commodities immediately after harvest. However, it is plagued with in-built problems, since the product is unprotected from rain, storm, windborne dirt, dust, and infestation by insects, rodents, and other animals.

Solar drying

Solar energy is one of the most promising renewable energy sources in the world because of its abundance, inexhaustible and non-pollutant in nature compared with higher prices and shortage of fossil fuels[4]. The concept of a dryer powered by solar energy is becoming increasingly feasible because of the gradual reduction in price of solar collectors coupled with the increasing concern about atmospheric pollution caused by conventional fossil fuels used for drying crops.

Solar drying of tomatoes is not a novel idea. There are few drawbacks associated with existing solar dryers that must be considered i) capacity of the dryer is higher ii) and drying takes place due to natural convection. The moisture removal rate is inadequate and the required rate of moisture removal could only be achieved with forced convection arrangement[8]. If a small solar dryer with forced convection is developed it will be useful to farmers to dry the tomatoes in their farm itself which in turn will enhance their income.

MATERIAL AND METHODS

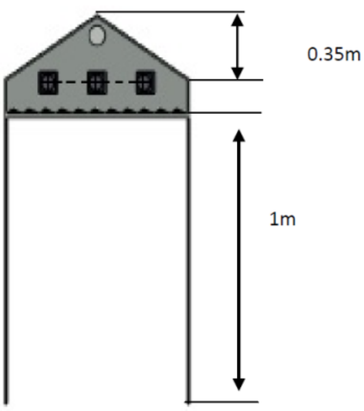
The studies were conducted using the Rupali variety of tomato (Lycopersicum esculentum) as this variety is grown in major areas of Tamilnadu. A farmer will be able to process about 10 kg of tomatoes in a day and accordingly it was decided to design and fabricate a solar dryer having a capacity of 10 kg per batch.

Location of the dryer

The solar dryer was installed at the terrace of the Food Process Engineering Laboratory, Tamil Nadu Agricultural University, Coimbatore. The orientation of the dryer was towards East-West direction since the light transmittance was high in this direction and maximum exposure of solar radiation is possible.

Design of drying chamber

The drying chamber was made of wooden plank at the bottom to keep the trays. The dimension of the drying chamber was calculated based on the arrangement of keeping the trays. It was decided to keep three trays in lengthwise and two trays in the breadth wise. A clearance of 5cm is required between the trays for smooth handling. The arrangement of the trays is shown in Fig. 1 and Fig. 2 respectively.



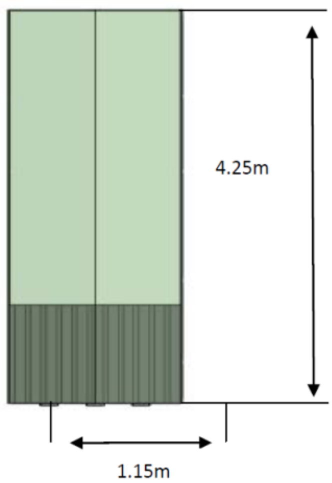


Fig. 1: Front and Top view of solar dryer

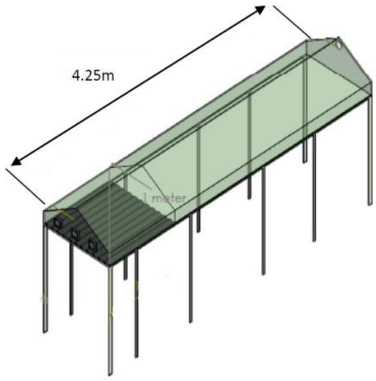


Fig. 2: Isometric view of solar

Drying chamber

Duffie and Beckman[6], suggested that slope of the tunnel should be maintained by subtracting and adding 10^{o} in the latitude of the site for summer and winter. Since our site has latitude of 36^{o} the slope angle of the tunnel was selected as 31^{o} so that it could receive maximum radiations perpendicular to the film.

Variable speed AC fans

Insufficient airflow can result in slow moisture removal as well as high dryer temperatures[1]. The air velocity (more than 1 ms-1) is required as suggested by Anjum *et al.*[2], for solar tunnel dryer - Hohenheim design. Three variable speed AC fans of 15cm diameter (Make-aestro, Model 2E-250) with power consumption 0.50 kW were fitted at the front side of the solar dryer so as to pass the air uniformly in the drying chamber. The other side of the dryer was provided with ventilation to remove moist air.

Measurement of Temperature and RH inside the dryer

The temperature and relative humidity sensor was used for the experiment (Make – Omega, OM-43 series). The data logger was fixed in the dryer for measuring the temperature and RH for the defined period of time. A double-sided tape was attached behind the sensor and mounted inside the dryer. The data logger was set to measure for every half an hour and the LED blinks brightly at every measurement. After the completion of the experiment, the data logger was connected to the computer interface cable and the data was displayed in the graphical form.

Measurement of air velocity

Anemometer of model AM-4201 was used to determine the velocity of air. While performing the drying experiment the anemometer was placed inside the dryer and the readings were recorded.

Measurement of solar intensity

An electronic type pyranometer was used to measure the solar intensity. It has a sensor, which senses the solar radiation falling over its surface, and displays the intensity in Watt per square meter. The sensor was kept over a horizontally levelled position. The solar intensity was recorded at one hour interval.

Sun drying

Fresh tomatoes were washed and cut into 10mm thickness spread uniformly on stainless steel (Food grade 304) trays and kept under sun till it reaches a constant weight. Weight of the tomato slices was measured for every 30min by using digital weighing balance. The drying was carried from 8 a.m to 6 p.m and the samples were packed in polythene films and kept for further studies

RESULTS AND DISCUSSIONS

Effect of solar intensity on the drying temperature inside the solar dryer

The temperature inside the solar dryer varied according to the solar intensity and was measured using the digital pyranometer. During the experiment it was found that the solar intensity varied from 385 – 710 W/m^2. The maximum temperature of 59.4°C was reached at 2 p.m when the solar intensity was 710 W/m^2 as shown in the Fig. 3 Similar studies were conducted by Dulawat *et al.*[5],and reported that the variation of temperature inside the solar tunnel dryer depended on the fluctuations in solar radiation.

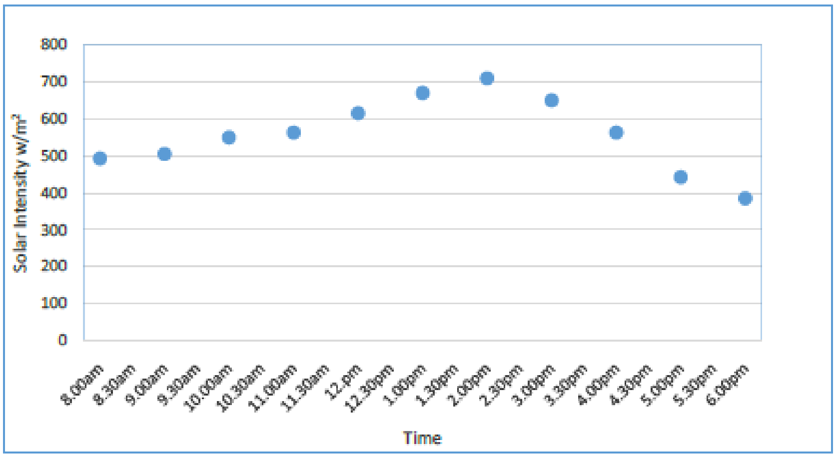


Fig. 3: Variation of solar intensity with respect to time

Effect of air velocity on drying temperature inside the dryer

The experiments for drying of tomato slices were carried out with three different air velocities of 2 m/s, 3 m/s, 4 m/s. The drying was carried out from morning 8.00 a.m to evening 6.00 p.m. The temperatures inside the drying chamber during three different air velocities are shown in Fig 4.

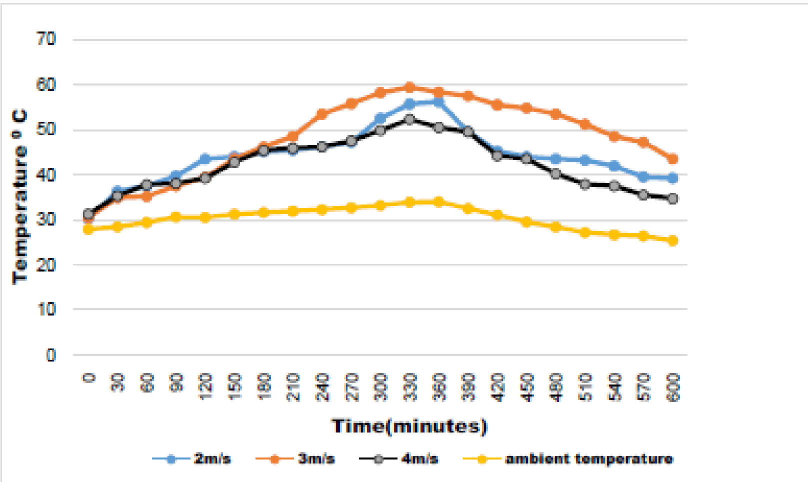


Fig. 4: Effect of air velocity on temperature inside the solar dryer

From the experiment conducted, it was found that the incoming air temperature had raised up to 15°C inside the dryer. The black coated plate in combination with corrugated surface caused an excellent heat transfer to the drying air. The air that was coming from the pre-heating zone had a greater potential than the ambient air, that is, low relative humidity and high temperature, where it was further introduced into the drying area.

Even though, the maximum temperature was achieved in both the velocities 3 m/s and 2 m/s, the temperature in the range of 50-60°C was maintained for about 3 hours at a velocity of 3 m/s whereas at the air velocity of 2 m/s it was found that temperature was in that range only for 1 hour and 15 min. Also when the solar intensity was decreasing, the temperature inside the dryer was found to decrease suddenly at an air velocity of 2 m/s whereas at the air velocity of 3 m/s, the optimum temperature range was maintained for three hours.

Effect of air velocity on relative humidity inside the dryer

The effect of air velocity on relative humidity inside the dryer is shown in Fig. 4.3. From the figure it is observed that the relative humidity inside the drying chamber in all the three air velocities was found to be in decreasing trend till 360 minutes and afterwards it followed a slight increasing trend due to removal of moisture from the product. Relative humidity inside the dryer was found to be less compared to the atmospheric relative humidity. The relative humidity inside the dryer was found to be a minimum of 26.2 per cent at the air velocity of 3 m/s. The incoming air when coming into contact with the pre-heating zone gets relatively dry and had greater rise in temperature. The relative humidity inside the dryer at air velocity of 2 m/s was 33.2 per cent which was higher when compared to the air velocity of 3 m/s. This was due to the higher airflow which was required to remove the evaporated moisture from the drying chamber.

From Fig. 5 it was also found that at the air velocity of 4 m/s the relative humidity was reduced to 36.2 per cent and was higher when compared with the other two air velocities. The required optimum temperature was not achieved inside the dryer and the air was not sufficiently heated to become relatively dry.

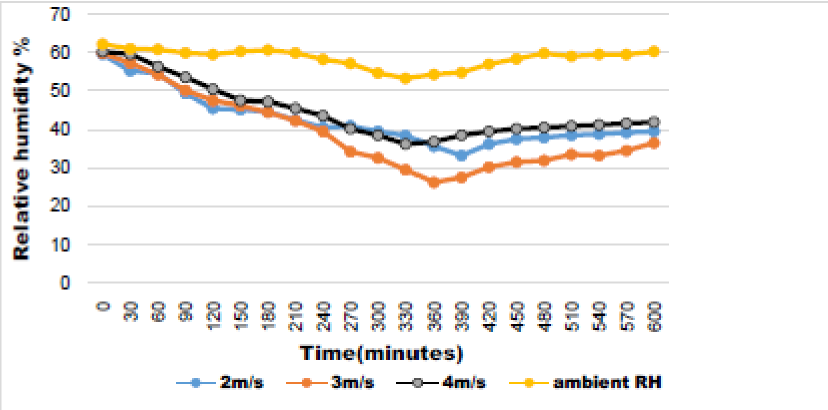


Fig. 5: Effect of air velocity on relative humidity inside the solar dryer

Similar results were reported by Mariem *et al.*[9], that the temperature of 50-55°C was achieved at an air velocity of 3m/s which facilitated increased drying rate and this was due to the increase in the coefficient of heat and mass transfer between the product and the drying air. From the experimental results it was decided that the air velocity of 3 m/s was found to be optimum for drying of tomatoes inside the solar dryer and further studies were carried out with the same air velocity.

Summary and Conclusion

There is a great demand for dried tomato especially the sun dried tomato in the form of slices or powder to develop new food products. The quality of the sun dried tomato that are available in recent times is not good since there is no control over temperature and relative humidity. Solar drying can be considered as an efficient system since it has lower operating cost than mechanical dryers. The existing solar dryers have the drawbacks of higher capacity and natural convection system and hence a small solar dryer with forced convection system was developed which can be used by the farmers in their farm itself.

A small solar dryer was designed to dry 10 kg of tomatoes per day. Six number of trays of dimension 1m x 0.5 m was fabricated and kept inside the drying chamber with a clearance of 0.05 m. The length of the drying chamber was kept as 3.20 m and breadth 1.15 m. The front portion of the dryer was kept with solar collector and a black corrugated GI plate was fitted with an area of 1.22 m^2 which is 25 per cent of the total area of the dryer and the remaining 75 per cent was used for drying chamber.

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