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# Drying Characteristics of Chillies in Solar Tunnel Dryer

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**Solar Tunnel Dryer (STD) MPUAT design was installed at the Farmers Association of Singarayarpuram village of Ramnad District. The results showed that, temperature inside the solar tunnel dryer gets boosted up by 15-20° C more than the ambient. The results also revealed that the chillies dried in the solar tunnel dryer was completely protected from rain, insects and dust and the dried chillies were high quality compared to open sun dried product. Solar tunnel dryer dried chiilies are in good colour and it also reduces the cost of drying and drying time to 40 per cent.**

**Key words:** Solar Tunnel Drier, UV stabilized polyethylene, chillies, moisture content, and drying time

Chilli is a commercial crop in India. Tamil Nadu, Andhra Pradesh and Karnataka are the major chilli producing states in India. In tropical countries, the uses of solar energy technologies have large scope compared to other countries. The introduction of solar drying system seems to be most promising alternative in reducing post harvest losses (Esper *et al.,* 1993). Open sun drying is the most commonly used method for drying of chillies in most of the developing countries. Drying under hostile climate conditions usually leads to severe losses in the quantity and quality of the product. On the other hand, mechanical drying is an energy consuming operation. Solar dryers are now being increasingly used since they are a better and more energy efficient option. Sun shines in India over an average 3000-3200 h/yr delivering about 2000 kWh/m $^{2}$-yr of solar radiation on horizontal surface (Mani, 1980). This abundantly available solar energy can be used for drying of chillies. Mainly chillies contain moisture content in the range of 75 to 80 per cent at the time of harvesting.

Reduction of moisture content to the desired level is the essential function of solar drying operation. The moisture removal involves two operations like low temperature heating and exhaust of moist hot air. Both the operations will be easily carried out by solar tunnel structure.

Solar tunnel dryer has ample potential for drying products which required hot air less than 60°C. The solar dried products have much better quality as compared to open sun dried products. Studies on multi-purpose solar tunnel dryer were carried out at the Institute of Agricultural Engineering, University of Hohenheim (Bala *et al.,* 2003). Fuller (1995) also reported the experimental study on tunnel dryer and a comparison of its performance with conventional dryer. The MPUAT, Udaipur has developed a solar tunnel dryer for drying 1.5 tonnes of capacity Di-basic Calcium Phosphate at the factory site (Rathore, 2004). The present study on the solar tunnel dryer is the part of ongoing research work at Department of Bioenergy, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Tamil Nadu under local conditions.

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## Material and Methods

The solar radiations are transmitted through UV stabilized PVC sheet of the tunnel dryer. The plastic cover has the property of transferring short-wave radiations. These solar radiations are converted into long wave thermal radiations inside the solar tunnel dryer. As the plastic sheet is opaque to long wave radiations, these radiations are trapped inside the dryer and raising inside tunnel temperature. It is expected that a temperature increase of about 15-20°C above ambient temperature inside the solar tunnel dryer. This increase of temperature is suitable to reduce the initial moisture content of chilli from 75-80 per cent to fixed moisture content of 8-10 per cent. Hence it is proposed to integrate small poly cover in tunnel shape structure solar tunnel dryer for drying the chillies.

The solar tunnel dryer has a transparent cover material and a chamber-cum- drying tunnel. The air is passed through natural convection at one end and moist air is exhausted by exhaust fan at other end of the tunnel. As stated by (Garg and Kumar, 1998) solar irradiance on the absorbed plate and cover was estimated for the positioning of semi-cylindrical solar tunnel dryer and it was observed that E-W orientation of solar tunnel dryer is more appropriate than any other orientation.

The structural components of solar tunnel dryer are hoops, foundation, drying floor, UV stabilized polythene film, etc. The line drawing of the solar tunnel dryer was illustrated in fig.1. Solar air collector cum drying chamber of solar tunnel dryer consists of 18 m length and 3.75 m width for drying 1000 kg of chillies per batch. It is semi cylindrical shaped tunnel metallic frame structure covered with UV stabilized semi transparent polythene of 200 micron. A single layer polythene film for the cover of solar tunnel dryer is preferred due to material economy and easy handling. This polythene has been purchased from IPCL, Bangalore.

Solar tunnel dryer consists of metallic frame having circumference of 11.75 m., developed through 13 hoops of G.I pipes bent to 3.75 m diameter, these hoops are having horizontal spacing as 1.5 meter, over which UV stabilized polythene sheet is wrapped. One end of the frame consists of an iron gate of 1.6 m x 0.80 m size for loading and unloading the material inside the dryer. The tunnel has a tilt of 10-15$^0$ with horizontal to generate natural convection flow in the dryer. Equi-spaced fifteen centimeter hole covered with cowl to protect against rains and natural disorders was provided for natural convection. Periodically the exhaust fan will run to maintain the humidity. Exhaust fan is connected with automatic humidity controller. The design of the system is modular and therefore, length of the collector and the dryer and the radius of the cover are fixed as per the flow rate and temperature requirements about 15-20$^0$C above the ambient temperature. An exhaust fan of 1700-1900 m$^3$/hour

**Table 1. Drying of chillies in solar tunnel dryer at Singarayarpuram, Ramand**

| Time | Temperature,°C | | Relative Humidity % | | Solar intensity, W/m$^2$ | Wt. of chillies, Kg | |
|---|---|---|---|---|---|---|---|
| | ambient | hot air | ambient | hot air | | Dryer | Open sun |
| Day 1 | | | | | | | |
| 9.30 am | 30.5 | 36.9 | 67.5 | 74.5 | 685 | 1000 | 1000 |
| 11.30 am | 32.1 | 45.5 | 51.0 | 56.4 | 845 | 0.926 | 0.955 |
| 1.30 pm | 39.2 | 53.5 | 39.3 | 44.6 | 842 | 0.844 | 0.890 |
| 3.30 pm | 36.0 | 46.9 | 39.2 | 44.1 | 610 | 0.733 | 0.842 |
| 5.30 pm | 31.0 | 37.9 | 44.3 | 46.6 | 130 | 0.651 | 0.780 |
| Day 2 | | | | | | | |
| 9.30 am | 28.1 | 33.7 | 76.5 | 84.6 | 678 | 0.608 | 0.776 |
| 11.30 am | 31.4 | 42.7 | 59.8 | 65.8 | 833 | 0.554 | 0.750 |
| 1.30 pm | 35.2 | 48.3 | 43.3 | 50.2 | 842 | 0.543 | 0.690 |
| 3.30 pm | 37.6 | 45.6 | 37.6 | 44.7 | 596 | 0.402 | 0.636 |
| 5.30 pm | 33.6 | 38.2 | 48.2 | 51.5 | 190 | 0.376 | 0.617 |
| Day 3 | | | | | | | |
| 9.30 am | 29.4 | 35.9 | 75.4 | 89.2 | 742 | 0.361 | 0.582 |
| 11.30 am | 34.8 | 44.9 | 60.4 | 68.3 | 836 | 0.357 | 0.552 |
| 1.30 pm | 34.2 | 47.3 | 43.9 | 51.2 | 832 | 0.325 | 0.458 |
| 3.30 pm | 36.6 | 46.6 | 37.9 | 45.7 | 595 | 0.205 | 0.446 |
| 5.30 pm | 34.6 | 39.2 | 49.2 | 52.5 | 180 | 0.230 | 0.438 |
| **Day 4** | | | | | | | 0.425 |
| 9.30 am | 31.5 | 35.9 | 66.5 | 77.5 | 675 | | 0.410 |
| 11.30 am | 32.9 | 45.9 | 51.9 | 56.8 | 849 | | 0.351 |
| 1.30 pm | 38.2 | 54.5 | 38.3 | 45.6 | 832 | | 0.390 |
| 3.30 pm | 37.0 | 47.9 | 38.2 | 43.1 | 620 | | 0.289 |
| 5.30 pm | 32.0 | 36.9 | 45.3 | 47.6 | 160 | | 0.268 |
| **Day 5** | | | | | | | 0.250 |
| 9.30 am | 31.5 | 35.9 | 66.5 | 75.5 | 675 | | 0.247 |
| 11.30 am | 33.1 | 46.5 | 52.0 | 57.4 | 835 | | 0.240 |
| 1.30 pm | 38.2 | 54.5 | 37.3 | 45.6 | 832 | | 0.238 |
| 3.30 pm | 37.0 | 47.9 | 39.9 | 45.1 | 620 | | 0.234 |
| 5.30 pm | 32.0 | 38.9 | 43.3 | 47.6 | 150 | | 0.230 |

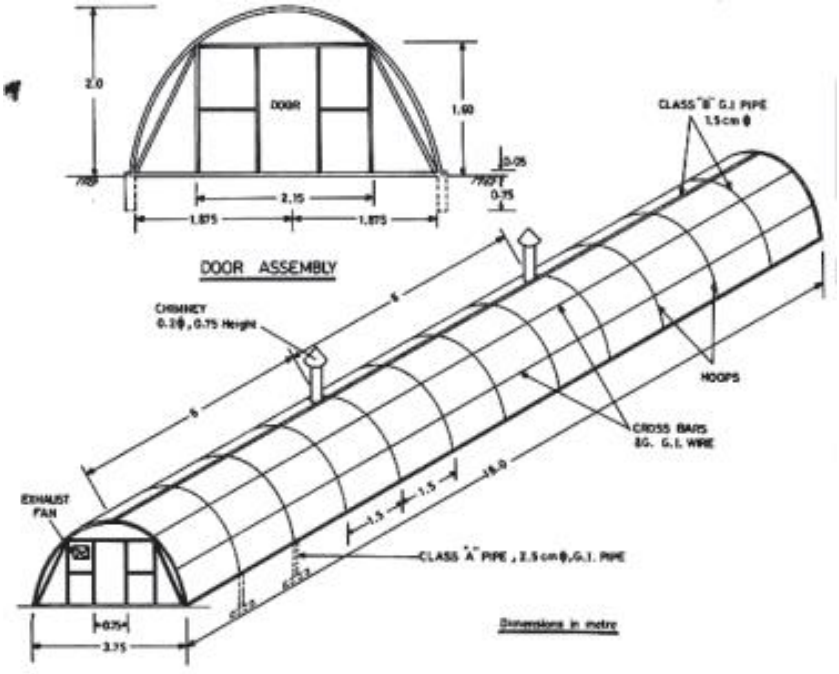


**Fig.1. Schematic diagram of solar tunnel dryer**

air flow rate capacity of 0.9 kw rating for removing moisture air was also provided near the door of the dryer. For running this exhaust fan 220 V A.C. 50 Hz supply is required. On an average 1-2 electrical units (kWh) were consumed to operate the exhaust fan for drying one batch. The temperature inside the solar tunnel dryer rises to 15-20°C higher than ambient temperature. Floor of solar tunnel dryer was made of cement concrete of 1:2:4 ratios and been painted black for better absorptions of solar radiation. The floor act as heat absorber in solar tunnel dryer.

***Location of the study***

The above specified solar tunnel dryer was installed at Farmers Association of Singarayarpuram village of

**Fig. 2. Solar tunnel dryer at Singarayapuram**

Ramnad District, Tamil Nadu, which is undertaking the processing of high quality chillies produced by the local farmers in and around. The village is located at about 10 kilometers from Paramakudi and situated at 9° 21'N latitude and 78° 22' E longitude. The altitude of the location is 39.83 m above mean sea level. It lies under southern agro-climatic zone and receives solar radiation throughout the year. The location is in the agricultural belt where the farmers are cultivating chilli as one of the main crop.

***Conventional drying of coconut***

In conventional drying, freshly harvested chillies were spread over in open yard to make drying operation by natural sun drying for 5- 6 days. Drying was continued another 48 hours till the moisture content of the chilli comes to around 8-10 per cent.

**Table 2. Comparison of drying cost for a capacity of 1 ton per batch**

| Drying method | Labour requirement, $t^{-1}$ | Labour cost Rs $t^{-1}$ | Savings | |
|---|---|---|---|---|
| | | | Rs | % |
| Solar tunnel dryer | 6 – 7 | 620 | 420 | 40 |
| Open sun drying | 10 - 12 | 1040 | | |

Thus the chilli contains 75 to 80 percent (w.b) moisture initially and it is to be brought down to 8-10 per cent (w.b) by drying. Unlike other crops, while drying, the pod of chillies is exposed so, it is susceptible for spading of colours and contamination due to dirt in open sun drying.

**Fig. 3. Solar tunnel dryer with chillies**

***Testing of dryer without product***

The experiments were conducted without product to find out the temperature profile at different locations in solar tunnel dryer. Under this condition the useful heat extracted by the tunnel drier was evaluated. For floor temperature measurements, thermometers were placed at every 4.5 m interval from 0 m (front end of the dryer) to 18.0 m (back end of the dryer) along the length of solar tunnel dryer location with North, center and south positions of every interval points. Similarly, the air temperature and RH inside the solar tunnel dryer were recorded by placing the thermometers and digital RH meter at different heights i.e., 0m, 0.5m, 1.0 m and 1.5 m from the floor level at 0 m to 18.0 m along the East-West orientation of the solar tunnel dryer.

***Testing of dryer with product***

The tunnel dryer was evaluated for finding the performance in actual loaded condition with 1000 kg of chillies. Chillies with known moisture content were taken and loaded in the floor of the solar tunnel dryer. Temperature variation inside the dryer and ambient temperature was measured with the help of thermometers. Initial and final moisture content of the chilli was measured by oven drying method. Drying was continued till the moisture content of the chilli tended to a constant value. A known quantity (1000 kg) of chilli sample was kept in open air for the purpose of comparison between open sun drying and drying in solar tunnel dryer. The weight reduction was measured at every one-hour interval for measuring the quantity of moisture removed.

## Results and Discussion

***Performance of solar tunnel dryer***

***No load test***

No load tests were conducted to find out the temperature profile and relative humidity at different locations in solar tunnel dryer. Under this condition the useful heat gained by the tunnel dryer was evaluated. The observed temperature (°C) and RH (%) at different locations (0, 9 and 18 m) under no load were recorded. In no load test an average maximum temperature and RH inside the tunnel dryer was 55 °C at 14:00 hrs and around 60 per cent at 12 noon, respectively while the minimum temperature and RH were 35.8°C and 45 per cent at 14:00 hrs, respectively.

***Full load testing***

The tunnel dryer was evaluated for finding the performance in actual loaded condition with chillies (Fig. 3). The known quantity (1000 kg) was taken for the drying test in the solar tunnel dryer. The temperature ($^{o}$C) and RH (%) at different locations

(0,9 and 18 m) were measured under load condition from first day to the end of drying and the results were observed. In load test, the maximum hot air temperature and relative humidity inside the tunnel dryer was 54.5 °C and 89.5% at 1.30 PM and 9.30 AM, respectively, while the minimum temperature and RH were 28.1°C and 43.1 % at 9.30 and 3.30 PM, hrs respectively. Drying was continued till the final weight of the chilli was reduced to 0.230 kg.

***Reduction in weight***

The weight reduction observations of chillies in solar tunnel dryer were presented in the table 1. At the time of loading, the initial weight was 1000 kg. Drying was continued till the weight was reduced to 0.230 kg. in both the solar tunnel dryer and in open air. Under full load condition drying takes only 24 hours in solar tunnel dryer and where as it was 40 hours for open sun drying. The gain of about 16 hours (40%) is achieved in the tunnel dryer over conventional open sun drying.

***Cost economics***

The economic feasibility of solar tunnel dryer was worked out for drying of one tonne of chilli in comparison with the conventional sun drying system and the results indicated a saving in cost of 40 per cent with solar tunnel dryer (Table 2). The saving in cost for drying coconut and chillies were about 40 per cent and solar tunnel had the advantage of cost savings of about Rs. 400 per tonne of chillies.

The cost analysis was carried out for the solar tunnel dryer installed at users' site. Discounted methods of analysis such as Net Present Value, Benefit Cost Ratio, Internal Rate of Return and Pay Back Period were worked out to evaluate the cost economics of the solar tunnel dryer. The NPV is worked out to Rs. 53,171 and the BCR is 1.33, indicating the economic viability of the solar tunnel dryer. The internal rate of return in solar tunnel dryer drying is more than 41 per cent. This indicates that the NPV will be zero only at the interest rate of 41 per cent. The PBP is worked out to be 5 years, which implies that the investment can be got back within a period of five years. The cost savings and economic analysis indicated that the solar tunnel dryer has economical advantage over open sun drying.

## Conclusion

The study concluded that drying of chillies in solar tunnel dryer has the following advantages over the conventional drying practice. Considerable reduction in labour for daily morning spreading in the drying floor and collection in the evening. During rainy season, there is a need of labourers for continuous monitoring and collection of produce, if raining. This has been avoided in the solar tunnel dryer. Good quality of dried chillies has been achieved with contamination from outer environment. Drying of chillies in solar tunnel dryer gives good colour and appearance because of controlled environment maintained inside the tunnel dryer. It reduces the cost of drying to 40 per cent and drying time to 40 per cent.

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## References

Bala, B.K., Mondol, M.R.A. Biswas, B.K., Das Chowdery B.L. and Jangai, S. 2003. Solar drying of pineapple using solar tunnel drier, *Renewable Energy,* **28:** 183-190.

Esper, A. and Muhlbauer, W. 1993. Development and dissemination of solar tunnel dryers, In: Proc. Of Workshop, Drying and Conservation with Solar Energy, ISES Solar World Congress, Budapest, 22 August, 1993.

Fuller, R.J., 1995. Comparison between solar tunnel dryers and conventional dehydrators for on-farm drying, *Drying Technology,* **13:** 1487-1502.

Garg, H.P. and Kumar, R.1998. Studies on semi-cylindrical soar tunnel dryers: estimation of solar irradiance, *Renewable Energy,* **13:** 393-400.

Mani, A. 1980. Handbook of Solar Radiation Data for India, Madras: Allied publishers, Private Limited Publication, 1981.

Rathore, N.S. 2004. Industrial Application of Solar Tunnel Dryer. IREDA News, Jan-Mar., 49-51.

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