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*Research Paper :*

# Drying of lemon in M.P.U.A.T. solar tunnel dryer

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## ABSTRACT

The experiment was conducted to dry lemon in solar tunnel dryer designed by M.P.U.A.T., Udaipur. The minimum temperature was 38.1$^0$C at 8:00 am while maximum temperature attended in STD was 72.9$^0$C at 2:30 pm. Solar radiations received were increased from 300 W/m$^2$ at 8:00 am to more than 700 W/m$^2$ at 12:00 pm. The initial moisture content of lemon taken for drying was 80.7 and which was reduced to 5.88 % (wb) in six days drying period, where as open sun drying required ten days. Cost analysis revealed that the cost of dried lemon was Rs.100/- per kg and break-even point was 27.67%. The profit of STD per year was found to be Rs. 382560/-.

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**Key words :** Solar tunnel dryer, Lemon

Solar drying is in practice since time im-memorable for preservation of food and agriculture crops. This was done particularly by open sun drying under the open to sky. This process has several disadvantages like spoilage of product due to adverse climatic condition like rain, wind, moist, dust, loss of material due to birds and animals, deterioration of the material by decomposition, insects and fungus growth. Also the process is highly labour intensive, time consuming and requires large area. With cultural and industrial development artificial mechanical drying came in to practice. This process is highly energy intensive and expensive which ultimately increases product cost. Thus solar tunnel dryer may be the best alternative to overcome drawbacks of natural drying and artificial mechanical drying. Solar dryers are used for food and crop drying. In the present study a hemispherical solar tunnel dryer designed at M.P.U.A.T. was used to dry 1.5 tones of lemon. Solar tunnel dryer has become popular due to considerable reduction of drying time and significant improvement of product (Chow *et al.,* 1997). It has been used to dry fruits, vegetables, root crops, medicinal plants and fish (Gauhar, 1998). A solar tunnel dryer is a tunnel like framed structural covered with ultra violet stabilized polythene sheet. The performance and techno- economic feasibility was tested for drying of lemon fruits.

## METHODOLOGY

The experiment of drying of lemon in solar tunnel dryer was conducted in organic farm at village Nimkhed bajar in Anjangaon Surji block, Dist. Amravati. This organization was engaged in processing and drying of lemon, onion, pomegranate, rose petals, wheat grass etc.

### MPUAT solar tunnel dryer:

The Department of Renewable Energy Sources, College of Technology and Agricultural Engineering, Maharana Pratap University of Agriculture and Technology, Udaipur has designed and developed a solar tunnel dryer of 1.5 MT capacity. The design parameter were decided on the basis of quantity of moisture removed per day and flow rate required for removing moisture in stipulated time (Seveda *et al.*, 2004). The STD consisted of the following structural components:

Hoops foundation, Floor, UV stabilized polythene film, Drying trays, Chimney.

The salient features of STD are given bellow:

– It is hemi-cylindrical shaped with base area of 3.75 m × 21.00 m and maximum ceiling height of 2.0 m. Low cost materials possessing high rigidity, long life and superior thermal characteristics was used for construction.

– The metallic frame structure of the tunnel dryer covered with an UV rays stabilized semi-transparent

polythene sheet of 200 micron thickness. A gradient of 5-7° was provided along the length of the tunnel to induce natural convection air flow.

– Cement concrete floor was painted black for better absorption of solar radiation. Five cm thick glass wool insulation was provided to reduce heat loss though the floor.

– Inlets for fresh air were provided along the periphery of the tunnel near ground level. Two chimneys of 20 cm dia and 75 cm height have been provided on the top of curved surface to allow exhaust of hot and moist air from the tunnel depending upon product.

– Raised end of the tunnel was provided with a door of 1.60 m × 0.75 m size to facilitate loading and unloading of the product.

– An exhaust fan of 1000-1200 $m^3$/h airflow rate capacity and 0.75 kW power rating was provided on the raised end. The humidity sensors installed inside the dry automatically control on/off operations of the exhaust fan to maintain RH of the inside air in the range 50-70%.

– Arrangement for loading the product inside the tunnel dryer varies depending upon the product characteristics.

**Table 1 : The dimensions of solar tunnel dryer 1.5 MT capacity**

| Parameters | Specifications |
|---|---|
| Length of solar tunnel dryer | 21.0 m |
| Diameter of solar tunnel dryer | 3.75 m |
| Ceiling height | 2.0 m |
| Floor area of solar tunnel dryer | 78.75 $m^2$ |
| Area of semi-cylindrical shape of solar tunnel dryer | 134.74 $m^2$ |

## Procedure for drying lemon:

– Lemon fruits (*Citrus aurantifolia,* variety-Kagzi lime) having medium in size, green in appearance, less astringent were selected for drying.

– Lemons were washed thoroughly in water and placed in the tray.

– Fruits were kept in tray of dryer for drying.

– Lemon fruits after drying were removed from the tray and packed in polythene bags.

## RESULTS AND DISCUSSION

The results of the present study as well as relevant discussion have been summarized under following heads:

## Evaluation of solar tunnel dryer:

Evaluation and testing of the solar tunnel dryer was carried out under no load and full load conditions during the month of April, 2009 for drying lemon. Open drying was carried out as control test. Three trials were conducted for each treatment.

## No load test:

No load testing was conducted in April 2009 with a view to find out temperature profile and air flow velocity in first chimney, in second chimney and at an outside of solar tunnel dryer. It was observed that the minimum inside temperature was 38.1°C at 8:00 am in the month of April while maximum temperature attended inside the tunnel dryer was 72.9°C at 02:30 pm. Corresponding, minimum ambient temperature was 26.9°C at 8:00 am while maximum ambient temperature was 42.5°C at 02:30 pm. As shown in Fig. 1 It was also observed that the minimum and maximum solar radiation was 220 W/$m^2$ at 00:30 pm and 830 W/$m^2$ at 05:00 pm, respectively.

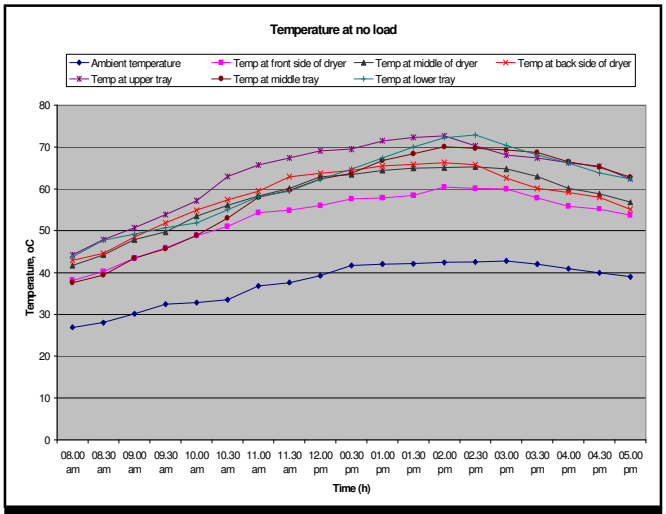


**Fig. 1 : Variation in temperature with time**

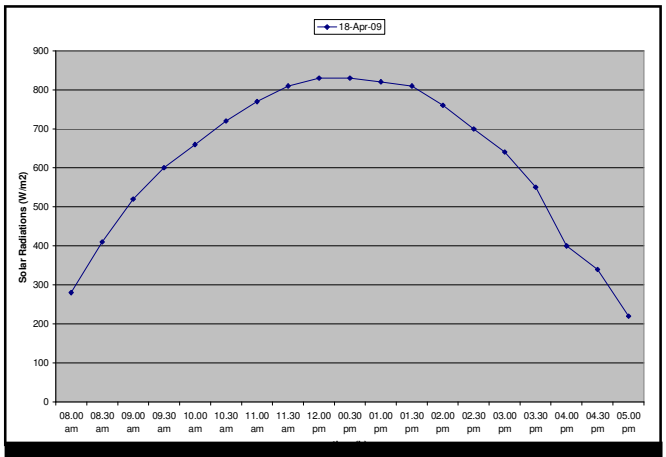


**Fig. 2 : Variation of solar radiation with time**

Fig. 3 shows the changes in air flow velocity. It is observed that there was change in air flow velocity of first chimney but very small change was observed in velocity of second chimney. Range of air flow velocity through first chimney was in between 2.4 to 5.4 km/h and range of air flow velocity through second chimney was 0.4 to 1.2 km/h, while range of air flow velocity outside the dryer was found to 0.0 to 9.0 km/h

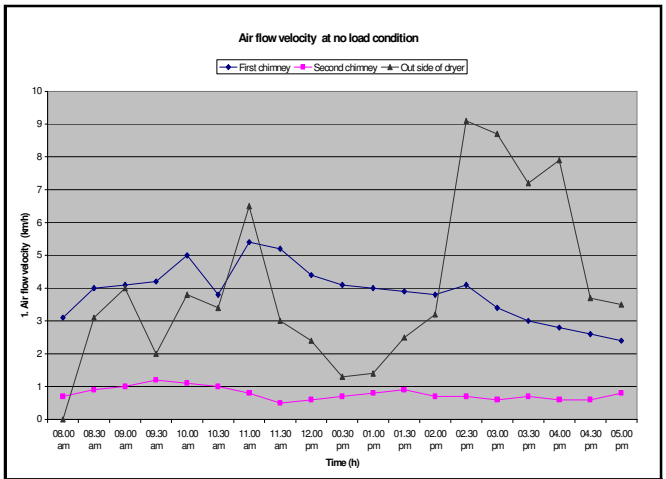


**Fig. 3 : Variation of air flow velocity with time**

It has been observed that there was increase in the temperature by 30.4°C at 02:30 pm inside the solar tunnel dryer as compared to corresponding ambient temperature in the month of April 2009.

## Load test:

Load testing of solar tunnel dryer was done for evaluating the performance of STD in actual loaded condition. Lemon fruits with initial moisture content of 80.7% were taken for study. Commodities selected *i.e.* lemon fruits were loaded in morning in the drying trays of STD.

For the purpose of evaluation of STD load test was done in the months of April for 6 consecutive days (Fig.4). In the first day of drying it was observed that the minimum inside temperature was 38.1$^0$C at 8:00 am in the month of April while maximum temperature attended inside the tunnel dryer was 72.9$^0$C at 02:30 pm. Corresponding, minimum ambient temperature was 26.9$^0$C at 8:00 am while maximum ambient temperature was 42.5$^0$C at 02:30 pm (Fig.4). It was also observed that the minimum and maximum solar radiation was 180 W/m$^2$ at 05:00 pm and 660 W/m$^2$ at 00:30 pm, respectively (Fig.5).

From the above figures it is revealed that due to the change in solar radiation falling on the surface of solar

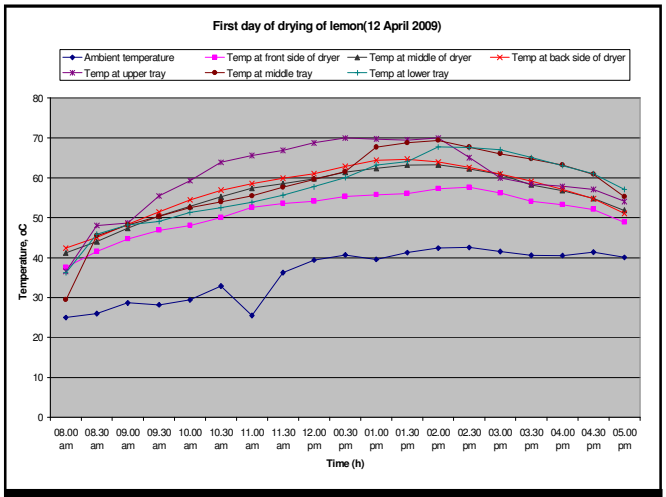


**Fig. 4 : Variation of temperature with time at first day of drying of lemon**

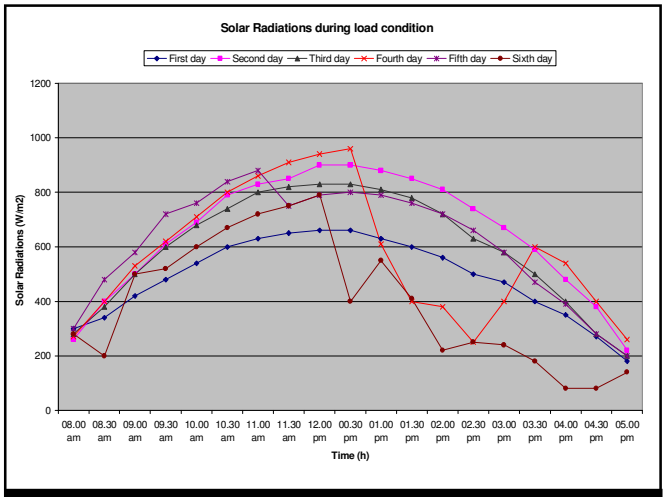


**Fig. 5 : Variation of solar radiations with time during drying of lemon**

tunnel dryer, relatively quick change occurred inside the temperature of STD but relatively slight change occurred in ambient temperature.

Fig. 6 shows the changes in external air flow velocity. It is observed that there was change in air flow velocity of first chimney but very small change was observed in velocity of second chimney. Range of air flow velocity through first chimney was in between 2.6 to 5.6 km/h and range of air flow velocity through second chimney was in between 0.6 to 1.8 km/h, while range of air flow velocity outside the dryer was found in between 0.3 to 7.2 km/h.

## Moisture content:

The variations in moisture content of lemon were recorded from 80.7% initial moisture content. The

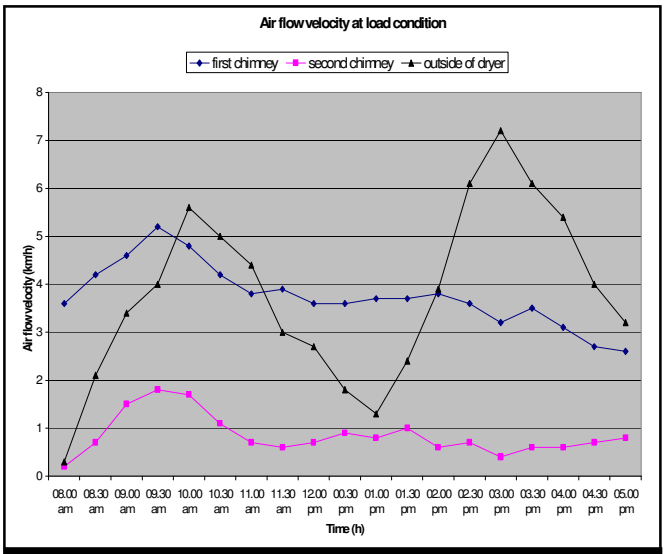


**Fig. 6 : Variation of air flow velocity with time during loading test**

**Table 2 : Moisture evaporation for each day of lemon**

| Drying time(day) | Moisture evaporation (wb),% | |
|---|---|---|
| | Drying in STD | Sun drying |
| 1 | 19.56 | 13.00 |
| 2 | 12.71 | 09.00 |
| 3 | 17.42 | 10.00 |
| 4 | 13.14 | 09.00 |
| 5 | 09.14 | 09.00 |
| 6 | 04.85 | 08.00 |
| 7 | | 08.00 |
| 8 | | 05.00 |
| 9 | | 03.00 |
| 10 | | 02.00 |

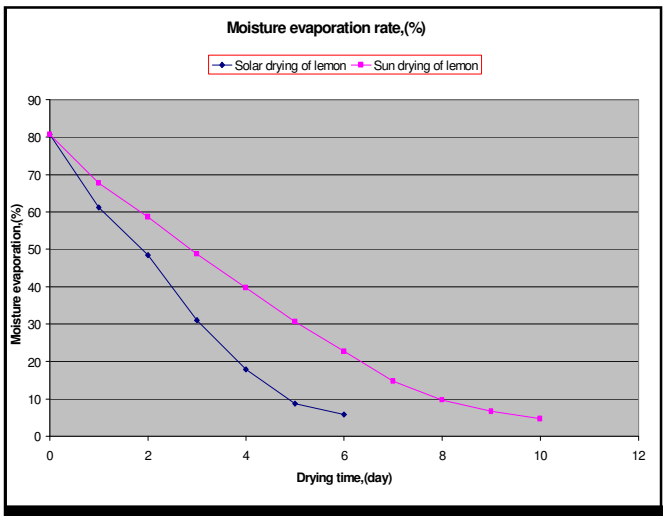


**Fig. 7 : Moisture evaporation rate**

moisture content of lemon was reduced from 80.7 per cent on wet basis to 5.88 per cent and 6.70 per cent on wet basis in six days and ten days during solar tunnel drying and open sun drying, respectively. From the analysis it is observed that as number of days increased the rate of drying decreased.

## Efficiency of MPUAT solar tunnel dryer:

Efficiency of MPUAT solar tunnel dryer was calculated considering a capacity of 1.5 MT lemon fruits drying requiring 6 days and 2 days, respectively.

From Table 3 it is observed that dryer efficiency was directly proportional to moisture evaporation *i.e.* efficiency decreased with moisture evaporation.

**Table 3 : Moisture evaporated average solar radiations and STD efficiency for lemon drying (12-17th April, 2009)**

| Days | Moisture evaporated per day (kg) | Average solar radiation ($W/m^2$) | Dryer efficiency, % |
|---|---|---|---|
| First day | 293.57 | 486.31 | 33.20 |
| Second day | 190.71 | 648.91 | 16.67 |
| Third day | 261.42 | 555.78 | 25.87 |
| Fourth day | 197.14 | 570.52 | 19.00 |
| Fifth day | 137.14 | 618.42 | 12.20 |
| Sixth day | 072.86 | 398.95 | 10.04 |

## Techno-economics analysis of lemon dried by MPUAT solar tunnel dryer:

The economic analysis for a MPUAT solar tunnel dryer for lemon was done by discounted cash flow method. Total cost of fabrication was found to be Rs 80000/-. The cost on lemon drying included the cost of raw material and workers used for fabrication and installation of dryer.

**Table 4 : Cost economics of drying lemon with MPUAT solar tunnel dryer**

| Sr. No. | Economic indicators | Values for lemon |
|---|---|---|
| 1. | Cost of MPUAT solar tunnel dryer, Rs | 80000 |
| 2. | Working capital, Rs | 998000 |
| 3. | Cost of production, Rs/kg | 72.44 |
| 4. | Annual net profit, Rs | 382560 |
| 5. | break even point, % | 27.67 |
| 6. | pay back period, years | 0.204 |
| 7. | Return on investment, % | 38.33 |
| 8. | Employment generation, man-day/ year | 300 |

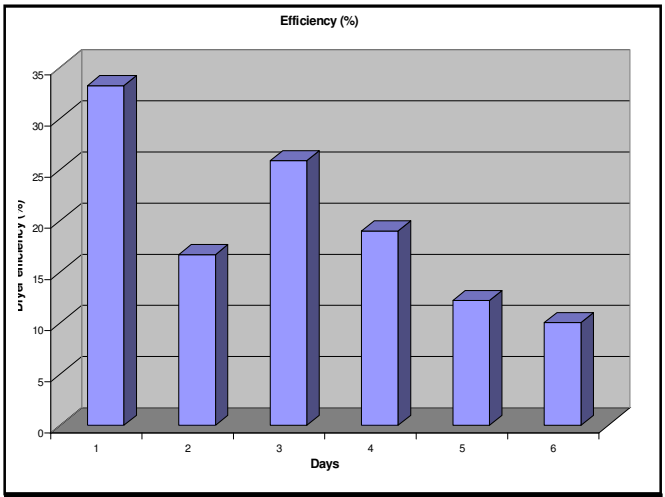


**Fig. 8 : Efficiency of STD each day of lemon**

Following parameter were assumed to carry out economic analysis of drying system

– The life span of solar dryer is 10 years. MPUAT solar tunnel dryer could used effectively for drying 300 days in a year.

– The cost of replacement of UV-sheet is Rs.13000/-and life 4 years.

– The cost of fresh lemon was taken as an average cost during peak production period. The manual labour for washing and keeping was considered.

– Cost of raw material *i.e.* lemon was Rs 15/- per kg, raw material required was 60 MT per year, so total cost of raw material comes to Rs 9,00,000/-

## Conclusion:

– In the first day of drying the minimum inside temperature was 38.1$^0$C at 8:00 am in the month of April while maximum temperature attend inside the tunnel dryer was 72.9$^0$C at 02:30 pm. Corresponding, minimum ambient temperature was 26.9$^0$C at 8:00 am while maximum ambient temperature was 42.5$^0$C at 02:30 pm.

– The solar radiations was increased from 300 W/m$^2$ at 8:00 am to 880 W/m$^2$ at 00:30 pm, which was maximum, it decreased after 00:30 pm. It has found to be 180 W/m$^2$ at 05:00 pm.

– The initial moisture content of lemon fruits was 80.7% which was reduced to 5.88% wb in six days, where as open sun drying required ten days.

– The complete cost analysis reveled that the cost of final product was Rs.100/- per kg. The break-even point found was 27.67%, which is excellent. The profit of STD per year was Rs.382560/-.

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## REFERENCES

**Chow, S.K., Howlander, M.N.A, Chau, K.J. and Teo, C.C. (1997).** A methodology for tunnel dryer chamber design. *Internat. J. Energy Res.,* **21**: 395-410.

**Gauhar, A.M. (1998).** Performance enhancement of the AIT solar tunnel dryer, Thesis, Asian Institute of Technology, Bangkok, Thailand.

**Seveda, M.S., Rathore, N.S and Singh, P. (2004).** Techno-economics of solar tunnel Dryer – A Case Study. *J. Agril. Engg.,* **41** (3): 13-17.

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