Performance study of solar tunnel dryer for drying of fish variety Dhoma
P.P. BHOR, Y.P. KHANDETOOD, A.G. MOHOD AND S.H. SENGAR

ABSTRACT
Locally available fish variety Dhoma was selected for evaluation of solar tunnel dryer. These selected fish were treated with salt and without salt before drying in solar tunnel dryer and open sun drying. Drying rate was higher in solar tunnel dryer compared to open sun drying due to higher temperature (53.5°C) attained. Time required to reach safe moisture content was observed. Drying time required for salted fishes was more compared to unsalted fish. In case of the fish sample with salt treatment moisture content reduced upto 19.29 % (d.b.) within 35 hours for upper tray, 19.63 % (d.b.) within 37 hours for lower tray and 19.41 % (d.b.) within 39 hours for open sun drying. While for the fish sample without salt treatment moisture content reduced upto 19.05 % (d.b.) within 32 hours for upper tray, 19.90 % (d.b.) within 35 hours for lower tray and 23.73. % (d.b.) within 37 hours for open sun drying. In open sun drying method, moisture absorption during night was higher than solar tunnel dryer. In solar tunnel dryer contamination due to insects, birds, wind and the animals were not found as in case with open sun drying.

METHODOLOGY
The experiment was conducted in solar tunnel dryer and in open sun drying with treatments viz., with salt and without salt.

The essential components of the dryer are air inlet (air vent), absorber box, drying tray, transparent dome, GI frame and chimney. The wall of the solar drying system was made of Kaddapa to reduce the heat losses. Inside the wall flat GI plate with black paint were used as an absorber. The glass wool and thermocol material was used as an insulator between the absorber and wall of the solar dryer. A door was provided to the dryer for easy loading and un-loading of product. A dome was then provided for the resting of the transparent thick plastic sheet. The UV polythene sheet of 200-micron gauge was used to collect drying may add impurities like dust, sand, insects and bird waste. The open sun drying requires longer drying time as well as it is an uncontrolled drying process. The conventional method of fish drying causes loss of material and quality of the product during the drying and hence reduces the market value of final product. Use of solar dryer helps not only to reduce losses and maintain the quality of the product but also helps in conserving the conventional energy sources.

The present investigation was, therefore, undertaken to study the performance evaluation, quality assessment, and organoleptic evaluation of fish variety Dhoma dried in solar dryer.
the solar energy. The vertical distance between two trays was 25 cm.

The part of heated air passed directly through the material bed and the remaining hot air passed along the bottom of the layer. This heated air carried moisture from the wet fish while it was passing through the bottom of the fish bed of independent layers. Finally the air was discharged from the dryer through the chimney at an elevated location. The schematic diagrams of direct type solar tunnel drier for fish drying is shown in Fig. 1

Temperature above the 2nd tray (T_5 °C)
Temperature at the bottom of chimney (T_6 °C)

Similarly relative humidity at different locations recorded are,
- Relative humidity of the atmosphere (RH_1, %)
- Relative humidity at exit of the chimney (RH_2, %)
- Relative humidity above the 1st and 2nd tray (RH, %)

**Load test of tunnel dryer:**

Fresh fish of variety Dhoma available from the local fish market was taken for drying. Fish samples of 10 kg were taken and washed thoroughly. Salt treatment was given to 5 kg of fish in the salt solution of 30 per cent concentration for 1 hour. From salted and unsalted fish two batches were made of 2.5 kg each and spread on separate tray i.e. salted upper 1st tray, unsalted upper 2nd tray, salted lower 1st tray, unsalted lower 2nd tray. From each tray randomly three samples were selected and weighed before loading. The weight reduction of the sample was taken at 1-hour interval by using weight balance. The moisture content of fish sample was calculated using standard hot air oven method.

**Moisture content:**

The percentage moisture content was determined by using following formula, (A.O.A.C. 1980)

\[
M.C. (w.b.) \% = \frac{(W_1 - W_2)}{W_1} \times 100
\]

\[
M.C. (d.b.) \% = \frac{(W_1 - W_2)}{W_2} \times 100
\]

where, W_1 = weight of sample before drying, gram
W_2 = weight of bone dried sample, gram

**Drying rate:**

The drying rate (g/h/100g of bone dry weight) of fish sample during drying period was determined as follows,

\[
\text{Drying rate} (D.R.) = \frac{\Delta W}{\Delta T}
\]

where, \(\Delta W = \) weight loss in one hour interval (g/100g of bone dry wt)
\(\Delta T = \) difference in time reading (h)

The drying was carried out by loading the weighted fish in dryer from morning 8:00 am to 17:00 pm. The fish were dried up to the final moisture content of 19 % (d.b.).

Similar procedure was adopted for drying of fish sample in open sun drying. The drying time required for drying the fish sample from IMC to 19 % (d.b.) in solar tunnel dryer is shown in Fig. 1.
Moisture ratio:
The moisture ratio of fish sample was computed by using the initial moisture content (IMC) and equilibrium moisture content (EMC):

\[
\text{Moisture ratio} = \frac{(M - M_e)}{(M_0 - M_e)}
\]

where,

\( M = \text{Moisture content (d.b.), \%} \)
\( M_e = \text{EMC, (d.b.), \%} \)
\( M_0 = \text{IMC, (d.b.), \%} \)

The EMC for fish was considered as 19 \% (d.b.) (Ali and Agrawal (1989)). Drying tests of fish sample under solar tunnel dryer and open sun conditions was carried out.

Sensory evaluation of different organoleptic properties of the dried fish namely colour, texture and overall acceptability was carried out by a panel of 10 judges of different age groups on the basis of 9 point Hedonic scale.

The ranks were determined from the scores given by the judges. On the basis of ranks, Friedman’s test was conducted and value of ‘F’ was calculated by following formula:

\[
F = \frac{(b - 1) \left[ B - \frac{bn(n + 1)}{4} \right]^2}{E}
\]

where,

\( b = \text{number of judges} \)
\( n = \text{number of treatments} \)
\( B = \frac{1}{b} \sum R_j^2 \)
\( R_j = \sum r_{ij} \) for treatment \( j \)
\( A = \sum \sum r_{ij}^2 \)
\( E = A - B \)

The calculated ‘F’ values were compared with standard value of ‘F’ to determine significance of colour, texture and overall acceptability among all the treatments. From the ranks of the observations of treatments, most and least accepted treatments were pointed out as per the view of organoleptic properties.

RESULTS AND DISCUSSION
The performance evaluation of solar tunnel dryer was carried out by conducting no load test for testing of design parameters and loading test with fish in comparison with open sun drying of fish.

No load test for solar tunnel dryer:
The dryer was tested without loading fish in the dryer. Different atmospheric parameters like temperature, relative humidity and solar intensity at an one-hour interval were recorded. The change in temperature, humidity, and insolation with respect to time at various locations are depicted in Fig. 2 and Fig. 3.

It is clear from Fig. 2 that temperature inside the solar tunnel dryer with respect to time achieved its peak value at absorber plate was found to be 47.7 \(^\circ\)C at 13:00 pm of the day where as the atmospheric temperature was about 34.1 \(^\circ\)C. The temperature at upper tray was found to be 32.7\(^\circ\)C- 56.9 \(^\circ\)C; similarly at the exit of the chimney it was 35.3 \(^\circ\)C- 48.6 \(^\circ\)C. Solar insolation varied according to the drying time, reaching its peak value 549.00 W/m\(^2\) at 13:00 noon of the day. The atmospheric relative humidity (Fig. 3) varied from 25 \% to 81 \%, whereas at upper tray it varied from 13.4 \% to 63.4 \% and similarly at lower tray varied from 9.75 \% to 55.42 \%.
The airflow rate inside the dryer varied from 319.74 m$^3$/hr to 391.81 m$^3$/hr, having peak rate as 391.82 m$^3$/hr at 12.00 noon of the day.

**Load test for solar tunnel dryer:**

The load test was taken for fish variety Dhoma by giving treatment viz., with salt and without salt. Fig. 4, and Fig. 5 shows insolation, temperature and relative humidity at variations during loading of dryer. Fig. 6 shows the moisture reduction while Fig. 7 and Fig. 8 show variation in drying rate and moisture ratio during the test.

The temperature inside the dryer increased along with insolation. Insolation increased from morning to afternoon and attained its peak value at 12 noon of the day and after that it again reduced. The insolation varied from 69 W/m$^2$ to 574 W/m$^2$. The peak value of insolation was 574 W/m$^2$ and the corresponding atmospheric temperature was 33.5 °C. While maximum temperature attained inside the dryer was 53.5 °C. The atmospheric relative humidity varied from 39 per cent to 70 per cent and at upper tray it varied from 6.4 per cent to 67 per cent. (Fig. 4).

The moisture content of the Dhoma reduced from 316.67 per cent (d.b.) to 19 per cent (d.b.). The moisture was released rapidly at the beginning and then drying rate decreased. The moisture content decreases, as the time elapse. The drying was completed in 4 days (Fig. 6).
In case of the fish sample with salt treatment moisture content reduced up to 19.29 % (d.b.) within 35 hours for upper tray, 19.63 % (d.b.) within 37 hours for lower tray and 19.41 % (d.b.) within 39 hours for open sun drying. While for the fish sample without salt treatment moisture content reduced up to 19.05 % (d.b.) within 32 hours for upper tray, 19.90 % (d.b.) within 35 hours for lower tray and 23.73 % (d.b.) within 37 hours for open sun drying. It was observed that, the drying rate attained in a solar tunnel dryer was higher (55.65 g/h) as compared to open sun drying (29.41 g/h).

**Organoleptic evaluation of solar dried fish:**

The panel of ten judges evaluated the organoleptic properties of dried fish samples with treatments like without salt and with salt in solar tunnel dryer and open sun drying.

The results of Friedman’s test revealed that, samples of variety dhoma did not differ significantly for colour, texture and overall acceptability. As calculated ‘F’ values were smaller than standard value of ‘F’ that is 2.25 at 5 % level of significance all fish drying trials, therefore, reject the null hypothesis shown in Table 1.

**Statistical analysis of different drying curves**:

R² value and correlation equation of drying curves for different treatments, visualizing effect of drying parameters like moisture content and drying rate are summarized in Table 2 and Table 3, respectively.

From calculations in Table 2, treatment LUS (Lower unsalted) has maximum R² value of 0.9763, showing better correlation between moisture content and drying time as compared to open sun drying (0.9705).

From calculations in Table 3, treatment LS (Lower salted) has maximum R² value of 0.5774, showing better correlation between drying rate and drying time as compared to open sun drying (0.245).

**Conclusion:**

Solar tunnel dryer required less drying time followed by open sun drying. Among the different varieties, colour,
texture and overall acceptability did not vary significantly and there was good correlation between variation of, moisture content and drying rate with drying time in Solar tunnel dryer followed by open sun drying for all types of fish.

Authors’ affiliations:

Y.P. KHANDETOD, A.G. MOHOD AND S.H. SENGAR, Department of Electrical and Other Energy Sources, College of Agricultural Engineering and Technology, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, RATNAGIRI (M.S.) INDIA

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