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Research Paper :

Performance study of solar tunnel dryer for drying of fish variety *Dhoma*

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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^{0}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.

Key words : Fish drying, Organolyptic evaluation, Solar tunnel dryer

Preservation of fish is a great problem because it decays fast by the action of enzymes and bacteria on the fish and also by chemical oxidation of the fat in open atmosphere. Fish drying increases the storage time from catch till consumption. The annual fish production in the year 2004-2005 was 6.30 million tonnes from which 2.78 million tonne from the marine sector and 3.52 million tonne from the inland sector (Annual report 2005-06, Ministry of Food Processing Industries).

Maharashtra state offers an excellent opportunity in the fisheries sector because of the vast natural resources. The state stands at 3rd position in the marine fish production and 6th position in inland fish production in the country. The annual fish production of Maharashtra state was 3.9 lakh tonne in year 2002-2003. Total 720 km long seashore of Arabian Sea falls under the Konkan region of Maharashtra with average production of marine product of about 3.5 lakh tonnes per year. It is estimated that out of total marine products produced in the state, nearly 30 per cent are dried and sold as a dried food in the market mostly during the off-season from June to September. At present various types of fish such as Ribbon fish / Bala (*Trichiurus lepturus*), Golden anchovies/ Mandeli (*Coilia dussumieri*), Croker / Dhoma (*Johnius dussumieri*), Prawns / Kolambi (*Penaeus monodon*), Pomphlet (*Pampus argenteus*), Surmai (*Scomberomorus guttatus*) etc., are used as dried fish due to their availability and good market value. Dried fish can be stored for longer period without deterioration. Traditional method of fish 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.

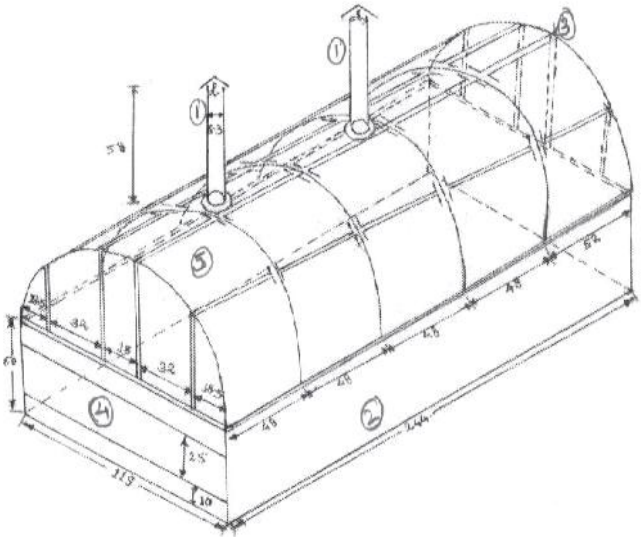
METHODOLOGY

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 G.I. 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

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



1- Chimney 2- Drying Chamber 3- Tunnel Frame
4- Dryer opening door 5- Dryer Tunnel with Polythene cover

Fig. 1 : Schematic (Isometric) view of solar tunnel fish dryer

The performance evaluation of solar tunnel dryer was carried out as per design layout for drying of fish variety Dhoma. The performance was carried by conducting the no load test for testing designed parameters and loaded test in comparison with open solar drying.

No load test of solar tunnel dryer:

No load test of solar tunnel dryer was carried out to evaluate the design parameters without loading of dryer. Different parameters like temperature at different locations, relative humidity, solar intensity and wind velocity were measured by using different digital instruments at an interval of one hour in a clear sunny day. The different temperatures recorded are,

- Ambient temperature (T_1 ^{0}C)
- Outlet air temperature (T_2 ^{0}C)
- Absorber plate tempearature (T_3 ^{0}C)
- Temperature above the 1st tray (T_4 ^{0}C)
- Temperature above the 2nd tray (T_5 ^{0}C)
- Temperature at the bottom of chimney (T_6 ^{0}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_3%)

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 lower1st 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)

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

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

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, Δ W = weight loss in one hour interval (g/100g of bone dry wt)

Δ 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 and under open sun drying condition was critically observed.

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 = Moisture content (d.b.), %

M_e = EMC, (d.b), %

M_0 = 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:

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

where,

b = number of judges

n = number of treatments

$B = 1/b\ \Sigma R_j^2$

$R_j = \Sigma r_{ij}$ for treatment j

$A = \Sigma\Sigma r_{ij}^2$

$E = A-B$

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 ^{0}C at 13:00 pm of the day where as the atmospheric temperature was about 34.1 ^{0}C. The temperature at upper tray was found to be 32.7^{0}C- 56.9 ^{0}C; similarly at the exit of the chimney it was 35.3 ^{0}C- 48.6 ^{0}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 %, where as at upper tray it varied from 13.4 % to 63.4 % and similarly at lower tray varied from 9.75 % to 55.42 %.

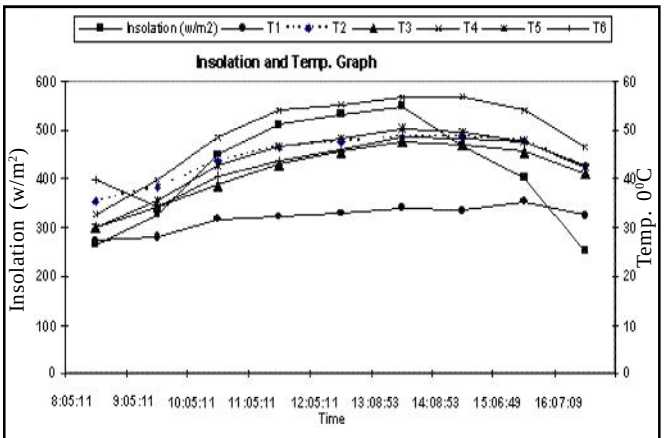


Fig. 2 : Variation of temp. along insolation during no load test

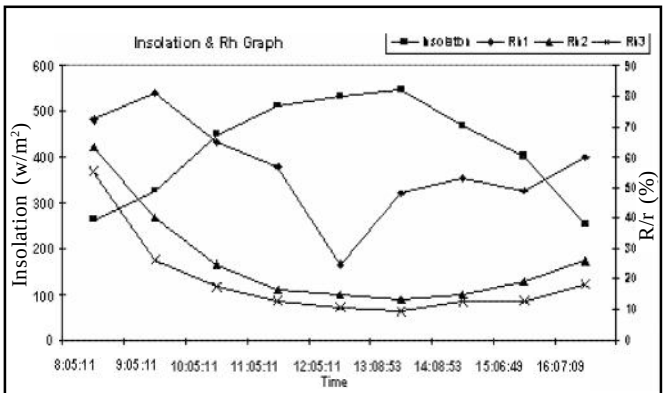


Fig. 3 : Variation of Rh along insolation during no load test

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.

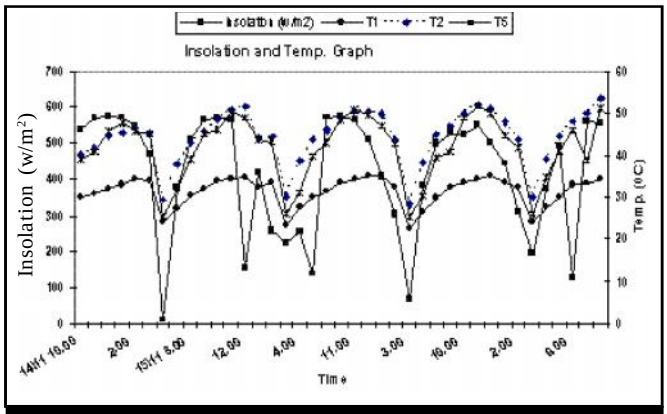


Fig. 4 : Variation of Temp. along insolation during load test

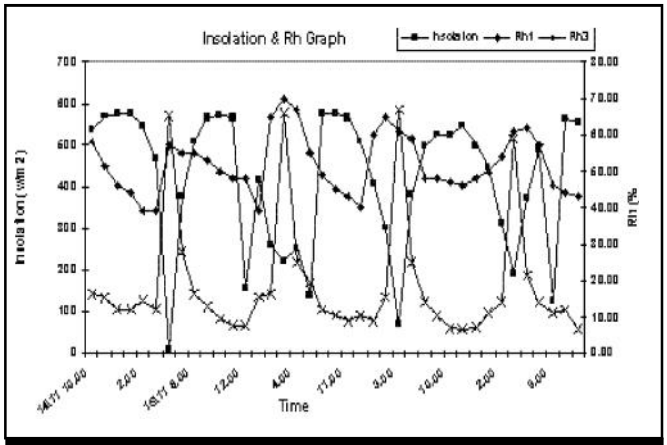


Fig. 5 : Variation of Temp. along insolation during load test

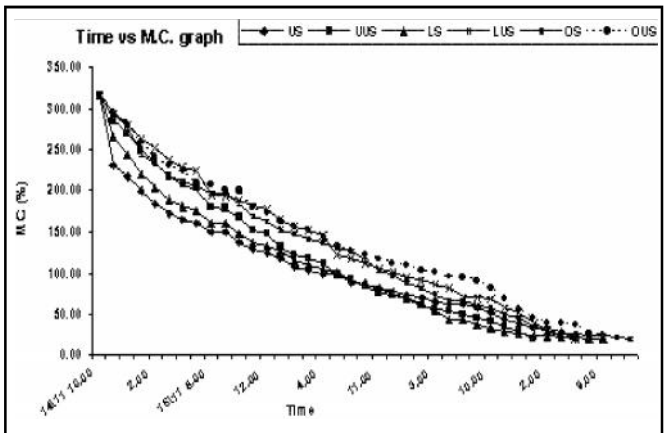


Fig. 6 : Moisture reduction along time during load test

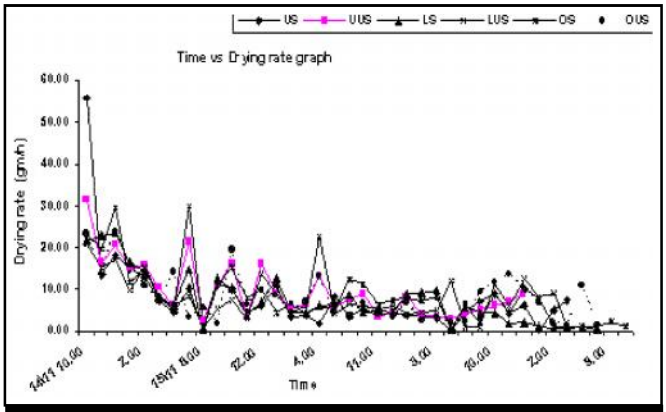


Fig. 7 : Variation in drying rate during load test

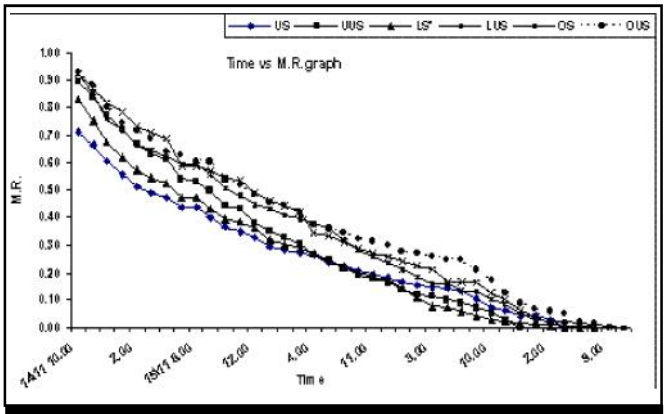


Fig. 8 : Variation in moisture ratio during load test

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 ^oC. While maximum temperature attained inside the dryer was 53.5 ^oC. 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).

Table 1 : Friedman's test evaluation for colour, texture and overall acceptability

Colour			Texture			Overall acceptability		
Treatment	R	R2	Treatment	R	R2	Treatment	R	R2
T_1	-111.8	12488	T_1	-84.5	7140	T_1	-6.25	39.06
T_2	-40.75	1661	T_2	-31.75	1008	T_2	-34.5	1190
T_3	7.25	52.56	T_3	22.75	517.6	T_3	-16.75	280.6
T_4	71.25	5077	T_4	7	49	T_4	-10.5	110.3
T_5	30.25	915.1	T_5	29.25	855.6	T_5	51.75	2678
T_6	28.25	798.1	T_6	25.25	637.6	T_6	18.25	333.1
T_7	15.5	240.3	T_7	32	1024	T_7	-2	4
F (cal.) =	1.108		F (cal.) =	0.003		F (cal.) =		-0.606
F(tab.) =	2.25		F(tab.) =	2.25		F(tab.) =		2.25
Result			Result			Result		
Rank not differ significantly			Rank not differ significantly			Rank not differ significantly		

Table 2 : Statistical analysis of drying curves showing variation in moisture content for different treatments

Treatment	R^2 Value	Equation	Constant of the equation
US	R2 = 0.8949	y = -6.1784x + 220.39	220.39
UUS	R2 = 0.953	y = -8.6363x + 272.59	272.59
LS	R2 = 0.9205	y = -6.9443x + 238.3	238.3
LUS	R2 = 0.9763	y = -8.0154x + 286.61	286.61
OS	R2 = 0.9611	y = -7.2476x + 269.01	269.01
OUS	R2 = 0.9705	y = -7.2672x + 279.64	279.64

Table 3: Statistical analysis of drying curves showing variation in drying rate for different treatments

Treatment	R^2 Value	Equation	Constant of the equation
US	R2 = 0.2516	y = -0.4763x + 16.192	16.192
UUS	R2 = 0.4355	y = -0.4868x + 17.386	17.386
LS	R2 = 0.5774	y = -0.4592x + 15.95	15.95
LUS	R2 = 0.1637	y = -0.27x + 13.41	13.41
OS	R2 = 0.4371	y = -0.3764x + 15.169	15.169
OUS	R2 = 0.245	y = -0.2788x + 13.308	13.308

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. 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 :

R^2 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 R^2 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 R^2 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

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