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Research Paper :

Experimental investigation of solar tunnel dryer for drying prawns

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ABSTRACT

Fish has usually played an essential part in man's diet. The production of dried fish and preparation of value added products from low cost fish will have great prospects in near future. The solar dryer may be the best viable option for drying of fish using the abundantly available free solar energy in the region. The objective of this study was to evaluate the performance of solar tunnel dryer. The comparative performance revealed that fish attained safe moisture limit in 18-28 hours in solar tunnel dryer as compared to 34 hours in open sun drying, the moisture content reduced from 344.86% d. b. to about 19% d. b. The average drying efficiency of fish dried by solar tunnel dryer was found about 18% higher than the open sun dried fish. The solar tunnel dried fish was found of better organoleptic and keeping quality upto 3 months.

Key words : Tunnel, Dryer, Fish, Drying time, Drying efficiency

Fish has usually played an essential part in man's diet, in all periods and all levels of technological progress. Fish is a good source of readily digested high quality animal protein. Fish proteins occupy an important place in human nutrition, as they have high digestibility, biological value and growth promoting value. Fish contains lysine and sulphur containing amino acids which complement cereal based diets. Most fishes contain 15-25 % protein and 1-5 % fat. Fish is a good source of vitamin A, D and B. Fish contains high polyunsaturated fatty acids specially omega-3 which can be important in lowering blood cholesterol levels and refreshes brain cell membrane. Nutritional studies have proved that fish proteins rank in the same class as chicken protein are superior to milk, beef protein and egg albumen. The production of dried fish and preparation of value added products from low cost fish will have great prospects in near future.

The conventional method of fish drying causes the loss of material and quality of the product and requires large time during the drying and hence, reduces the cost of final product. The solar dryer may be the best viable option for drying of fish using the abundantly available free solar energy in the region.

Condori *et al.* (2001) designed and tested a forced convection greenhouse drier with plastic greenhouse cover, a drying tunnel made with transparent plastic walls, trays and an electrical fan that moves the hot air from the greenhouse into the tunnel. A linear relation between the drier temperature and the solar radiation was obtained. Abedin *et al.* (2007) developed and constructed solar tunnel dryer with transparent foil covered flat plate collector, drying tunnel, two d.c. fans powered by 40 watt solar cell module for drying fishes, vegetables and fruits. The moisture removal rate with solar tunnel dryer and open sun drying was observed as 120.96 g/hr and 65 g/hr, respectively for drying jackfruit juice. In present investigation the drying characteristics of solar tunnel dried prawns were evaluated in relation to open sun drying method.

METHODOLOGY

Construction of dryer:

The present study was undertaken at the Department of Electrical and Other Energy Sources, College of Agricultural Engineering and Technology, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri, Maharashtra State (India) during the year 2008-09. The solar tunnel dryer mainly consisted of a cover of U.V. stabilized polyethylene sheet of 200 μm fixed on the cladding material with the help of zig-zag springs. The dryer was large enough that one can enter inside to load and unload the raw fish to be dried. The floor of the solar tunnel dryer was constructed with cement concrete and painted black for absorbing more solar radiation to increase the temperature inside the dryer. The supports for chimney, door and exhaust fan were welded. The north wall was placed at north side of solar tunnel dryer to minimize energy loss. Isometric view of sonal tunnel dryer has been shown in Fig. 1.

The technical specifications of solar tunnel dryer for fish are given in Table 1.

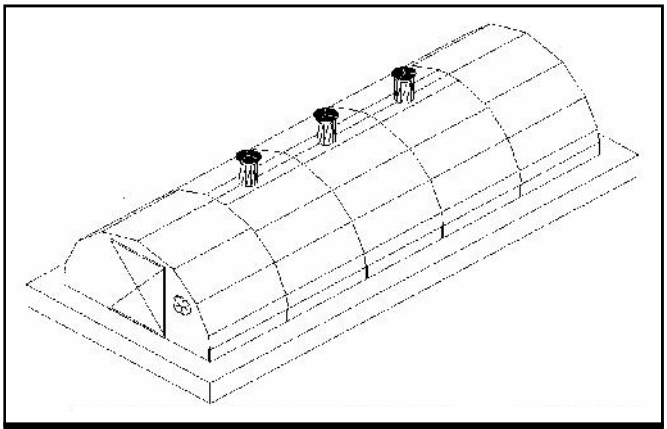


Fig. 1 : Isometric view of solar tunnel dryer (100 kg/batch)

$$\text{Moisture Ratio (M.R.)} = \frac{(M - M_e)}{(M_0 - M_e)} \quad (33)$$

$$\eta_d = \frac{(W_i \times C_f \times \Delta T) + (Ww \times C_w \times \Delta T) + (W_w \times \lambda)}{I \times A_C \times N} \quad (34)$$

where, W_1 is weight of sample before drying(g), W_2 is weight of bone dried sample (g), M is moisture content (per cent d. b.), M_e is EMC (per cent d. b.), M_0 is IMC (per cent d. b.), W_i is Initial weight of material (kg), C_f is specific heat of fish (0.70 kcal/kg^{0}K), ΔT is temperature rise, W_w is mass of water evaporated (kg), C_w is specific heat of water (1 kcal/kg^{0}K), λ is latent heat of vapourization (540 kcal/kg), I is incident solar radiation on collector (kcal/m^2-h), A_c is drying area (80% of collector area) and N is drying hours (h).

Table 1 : Technical specifications of solar tunnel dryer for fish (100 kg/ batch)

Sr. No.	Particulars	Specifications	Material
1.	Collector Area, sqm	37.5 (3.75 m width x 10 m length)	--
2.	Drying tray area, sqm	2.5 (1.6 m x 1.6 m)	Al. wire mesh
3.	Number of trays	04 on each trolley	MS angle
4.	Number of trolleys	3 Nos., width 1.67 m, length 3.12 m	----
5.	Height of tunnel, m	2.0	--
6.	Chimney, m	3 Nos., Ø 0.30 m, length 0.50 m	20 SWG MS
7.	Fresh air vent area, sqm	0.05	--
8.	Exhaust fan, single phase	2 Nos, Brushless AC, 410 Wp, 1400 rpm	---
9.	Door	1.75 m x 1.75 m	MS angle
10.	North wall	Height 1.55 m, length 10 m	GI sheet

Evaluation of dryer:

The solar tunnel dryer was evaluated for finding the performance in actual loaded condition with fish. Fish with known moisture content were taken and loaded on trolleys over trays in dryer as per predetermined salting, cutting treatment. Variation in temperature and relative humidity was measured at 1 hour interval at the centre of solar tunnel dryer alongwith ambient condition. Initial and final moisture content of the fish was measured by oven drying method. Drying was continued till the moisture content of the fish tended to a value of safe moisture content *i.e.* 16% w.b. (Ali and Agarwal, 1980).

The moisture content, moisture ratio and drying efficiency were determined by formula given as under:

$$\text{M.C.(d.b.)} \quad \% = \frac{(W_1 - W_2)}{W_2} \times 100 \quad (32)$$

RESULTS AND DISCUSSION

The no load performance trials were carried out for the solar tunnel dryer at site for winter (October to December) and summer (February to April) season for testing of design parameters. It was observed that average rise in temperature inside the solar tunnel dryer was about 11.24^{0}C and 18.29^{0}C over the ambient temperature during no load test in winter and summer, respectively.

The maximum average temperature inside the solar tunnel dryer during winter and summer no load test was

Table 2 : Experimental and treatment details for drying of tiny prawns

a) Peeling	:	Two	b) Salting	:	Two	c)Tray location	:	Three
		F_1-Whole			S_0-Unsalted			L_1-Upper
		F_2-Peeled			S_1-Salted			L_2-Lower
d) Replication	:	Three						L_3-Open

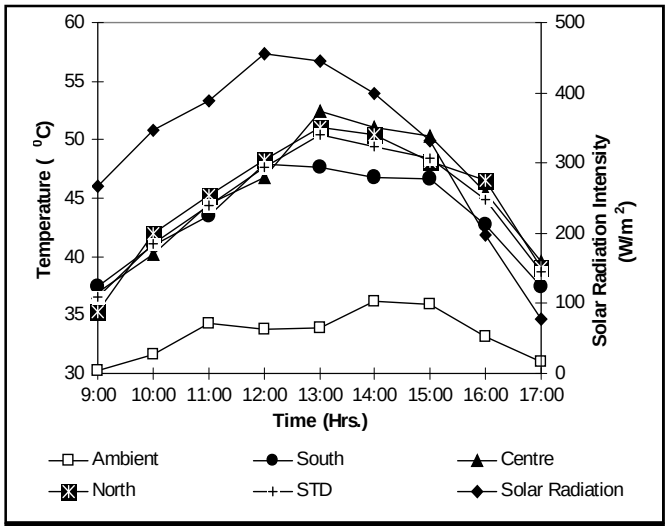


Fig. 2 : Variation in temperature inside the solar tunnel dryer during winter no load test

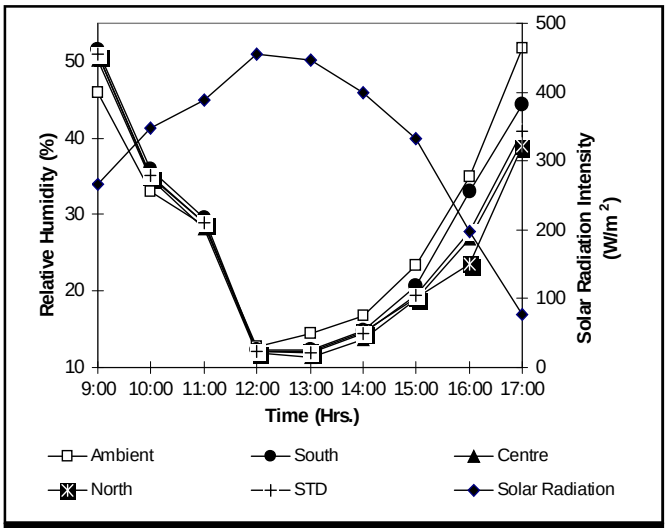


Fig. 4 : Variation in RH inside the solar tunnel dryer during winter no load test

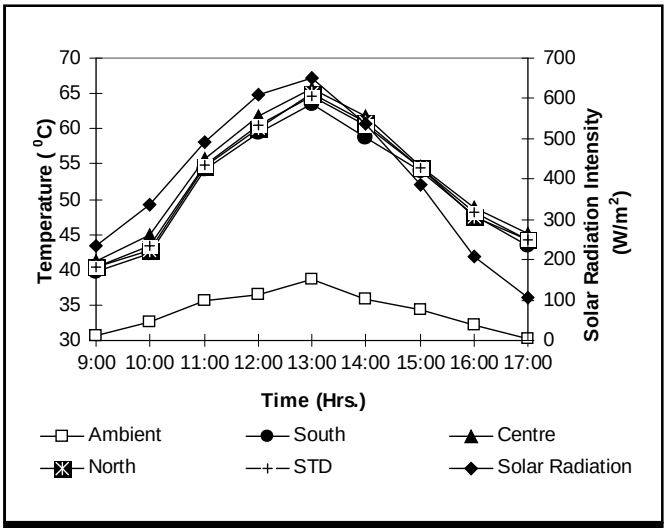


Fig. 3 : Variation in temperature inside the solar tunnel dryer during summer no load test

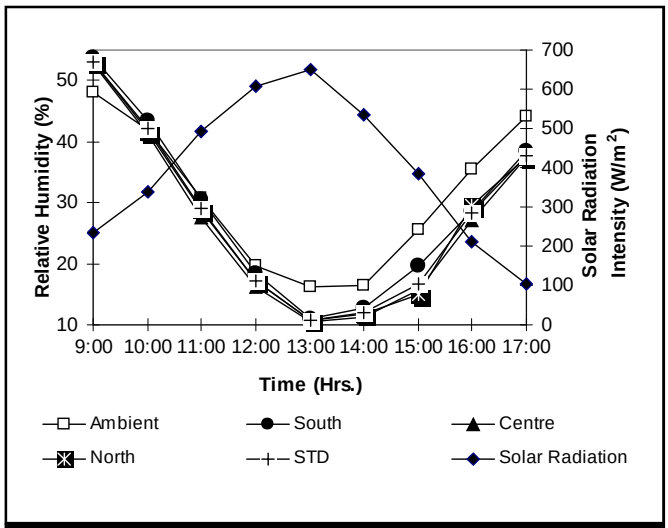


Fig. 5 : Variation in RH inside the solar tunnel dryer during summer no load test

found to be 52.41 and 65.69^{0}C at centre of solar tunnel dryer followed by north side (51.06 and 64.94^{0}C) and south side (47.69 and 63.48^{0}C), respectively (Fig. 2 and 3). The increased temperature and decreased relative humidity at centre side could be due to maximum direct radiations reaching the absorber surface and consequent temperature rise in solar tunnel dryer by convection heat transfer to air inside the dryer. The lower temperature and increased relative humidity at south could be due to incoming air through air inlets provided at south of solar tunnel dryer (Fig. 4 and 5).

Full load testing of dryer was carried out by loading whole and peeled tiny prawns (*Parapaeneopsis stylifera*) with salting (10% concentration salt for one hrs) and without salting. During full load testing, the average rise in temperature of drying air was 14.43^{0}C over the ambient temperature whereas the relative humidity varied inside the dryer was about 31.28 to 49.95 per cent as against the ambient relative humidity 23.1 to 52.57%. It was observed that, the temperature inside solar tunnel dryer at upper tray and lower tray was 60.99^{0}C and 56.09^{0}C, respectively at 13:00 h with average relative humidity 31.45%. The corresponding ambient temperature, relative humidity and solar intensity were found to be 33.24^{0}C, 33.66% and 630.94 w/m^2, respectively. It was found that the average temperature and relative humidity inside the solar tunnel dryer were 45.14^{0}C and 39.22%, respectively while average ambient temperature and relative humidity

were 30.71 ^{0}C and 36.90 %, respectively.

Direct sun drying:

Drying curves showed a relatively rapid decline in moisture content during initial stages and subsequent slowing down of the drying process. In case of whole fish, the sudden fall in moisture content after four-five hours in morning hours was due to hastening of moisture migration from the fish body. The drying rate was enhanced due to favourable environmental conditions. The drying curve with respect to drying time for drying of whole and peeled tiny prawns in open sun drying were shown in Fig. 6 and 7.

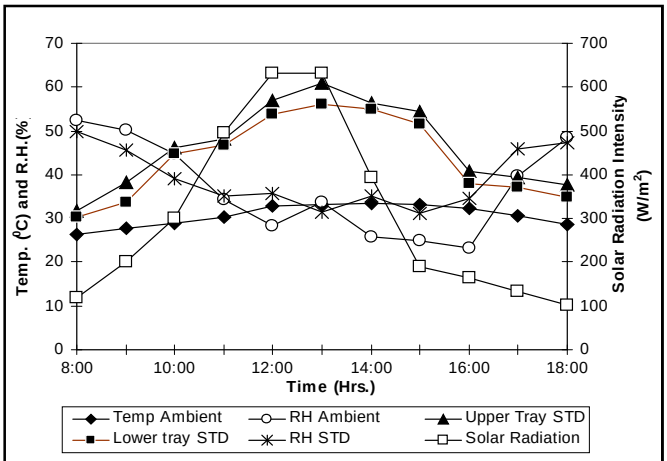


Fig. 6 : Variation in temperature and relative humidity inside the solar tunnel dryer during load test

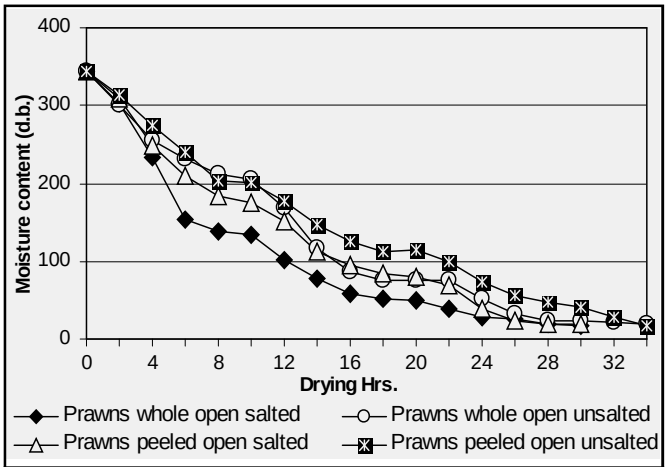


Fig. 7 : Moisture content vs drying time for tiny prawns in open sun drying

It was observed that, the drying time required for salted whole, unsalted whole, salted peeled and unsalted peeled tiny prawns from 344.86% d. b. to about 19% d. b. required 30, 34, 30 and 34 hrs, respectively in open sun drying. The average moisture ratio for drying of salted whole, unsalted whole, salted peeled and unsalted peeled tiny prawns in open sun drying was observed to be 0.28, 0.34, 0.36 and 0.39, respectively.

Solar tunnel dryer:

The variation in moisture content and moisture ratio with respect to drying time for drying of whole and peeled tiny prawns in solar tunnel dryer at upper and lower tray position are shown in Fig. 8 and 9. It was observed that, the drying time required for drying of salted prawns from initial moisture content of 344.86 % d.b. to about 19% d.b. was found to be 32 hrs in open sun drying method. The drying time for salted whole, unsalted whole, salted peeled and unsalted peeled tiny prawns from 344.86% d. b. to about 19% d. b. required 18, 24, 26 and 28 hrs, respectively at upper tray of solar tunnel dryer. Whereas for drying of salted whole, unsalted whole, salted peeled

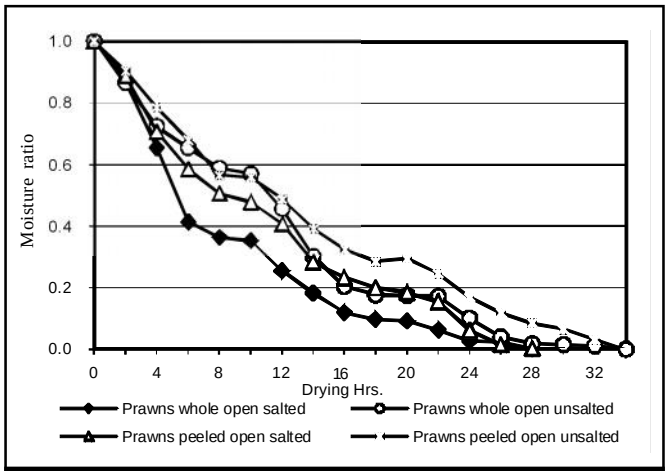


Fig. 8 : Moisture ratio vs drying time for tiny prawns in open sun drying

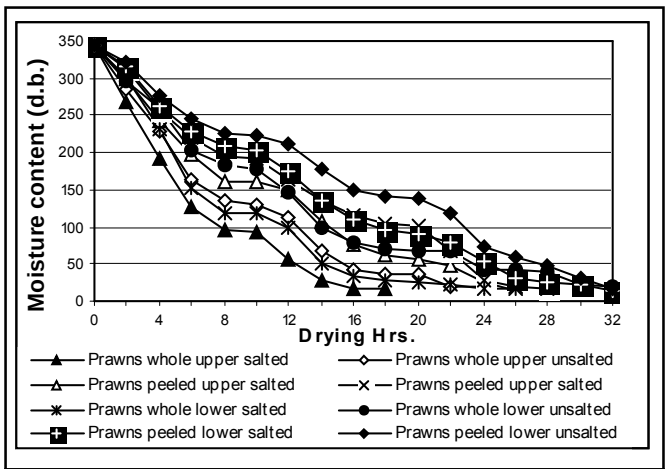


Fig. 9 : Moisture content Vs drying time for tiny prawns in solar tunnel dryer

and unsalted peeled tiny prawns from 344.86% d. b. to about 19% d. b. required 26, 32, 32 and 32 hrs, respectively at lower tray of solar tunnel dryer.

The average moisture ratio for drying of salted and unsalted whole tiny prawns was 0.36 and 0.35, respectively at upper tray and 0.33 and 0.33, respectively at lower tray. Whereas for drying of salted and unsalted peeled tiny prawns at upper tray was observed to be 0.40 and 0.44, respectively and 0.40 and 0.45, respectively at lower tray inside the solar tunnel dryer (Fig. 10).

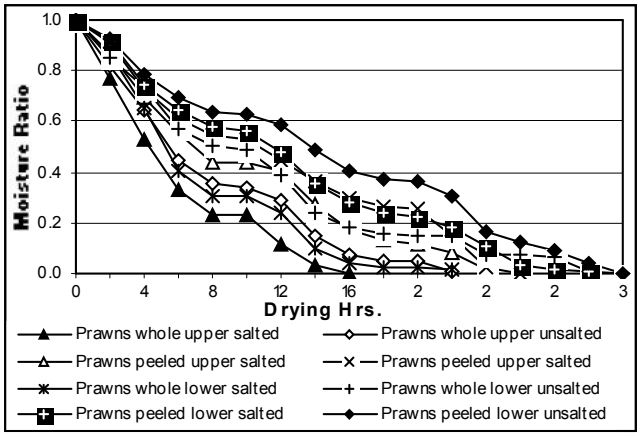
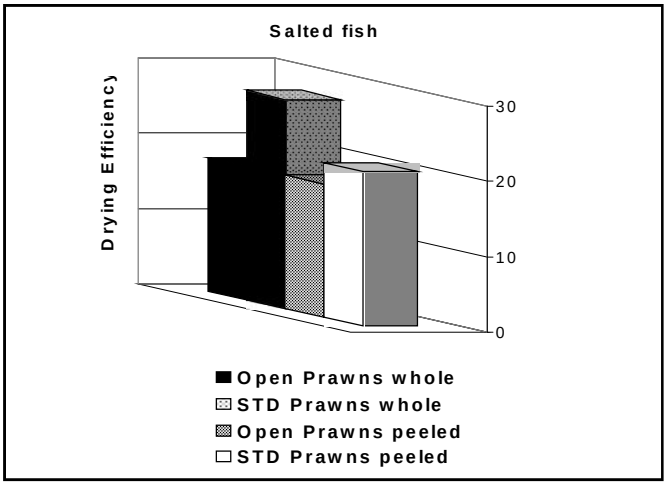
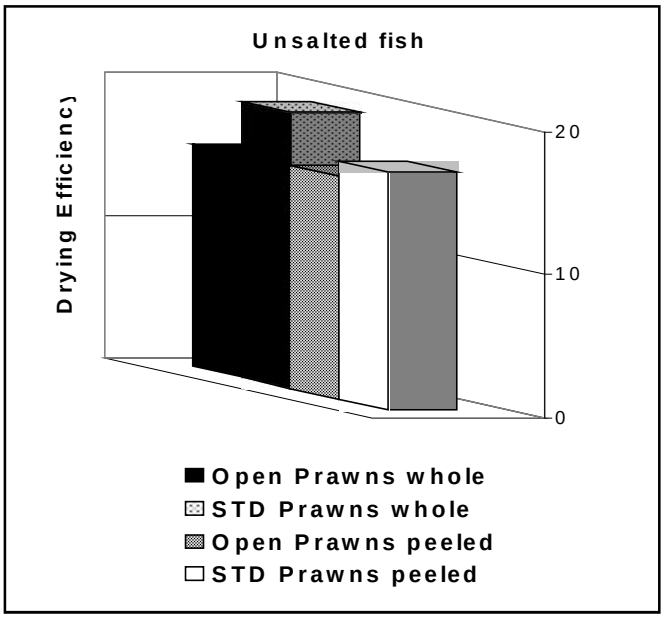


Fig. 10 : Moisture ratio vs drying time for tiny prawns in solar tunnel dryer

The drying efficiency of unsalted whole tiny prawns, unsalted peeled tiny prawns, salted whole tiny prawns, salted peeled tiny prawns was 19.29, 16.59, 27.66 and 20.41 per cent, respectively in solar tunnel dryer. Whereas the drying efficiency of unsalted whole tiny prawns, unsalted peeled tiny prawns, salted whole tiny prawns, salted peeled tiny prawns was 15.55, 15.61, 17.67 and 17.63 per cent, respectively in open sun drying.





The results show that, drying efficiency was significantly more for salted fish over unsalted one which may be due to binding of water molecules with salt (osmosis) and the drying efficiency of whole tiny prawns was comparatively more than the peeled tiny prawns in solar tunnel dryer which may be due to moisture uptake during the pre-processing of peeled tiny prawns than whole tiny prawns. In organoleptic analysis, the overall acceptability of solar tunnel dried whole tiny prawns (28.5) was high followed by solar tunnel dried peeled tiny prawns (56.5). The open sun dried whole and peeled tiny prawns (95.5 and 120, respectively) were least accepted.

Conclusion:

The comparative performance revealed that fish attained safe moisture limit in 18-28 hours in solar tunnel dryer as compared to 34 hours in open sun drying, the moisture content reduced from 344.86% d. b. to about 19% d. b. The average drying efficiency of fish dried by solar tunnel dryer was found about 18% higher than the open sun dried fish. The solar tunnel dried fish was found of better organoleptic and keeping quality upto 3 months.

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