Dhaka Univ. J. Bio. Sci. **14**(2): 169-176, 2005 (July)

THE PERFORMANCE OF A SOLAR TUNNEL DRYER AND EVALUATION OF THE QUALITY OF DRIED AND DEHYDRATED FISH

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Key words : Solar tunnel dryer, dehydrated fish, solar radiation, relative humidity

Abstract

A solar tunnel dryer is designed and developed to study its performance and evaluate the quality of the dried and dehydrated fish. The solar tunnel dryer was developed by locally available raw materials. The dryer consisted of a flat plate air heating collector, a tunnel drying unit and two solar driven DC fans. The collector and the drying unit were covered with transparent plastic foil. The fishes to be dried were placed in a thin layer of bamboo splitted net within the dryer. The whole system was placed horizontally on a raised platform. The inside drying air temperature of the solar tunnel dryer was controlled by the air velocity created by operation of two DC fans connected with a solar panel of 40 Watt. During three experimental runs in the month of June, 2004 the inside drying temperature varied from 36 to 49^{0}C as against the outside drying temperature of 25 to 35^{0}C. The relative humidity inside the tunnel dryer varied from 36 to 63% and with and without that of outside varied from 64 to 93%. The solar radiation recorded was 28 to 866 W/m^2 in the month of June, 2004 cloud cover. Twelve and 28 drying hours were needed for complete dehydration of *Amblypharyngodon mola* and *Pampus argenteus,* respectively. The solar tunnel dryer also took less drying period in comparison with the drying time required for the sun dried fish. It has been observed that the performance of the solar tunnel dryer for improved quality dehydrated fish was better in comparison with the sun dried fish in terms of physical and chemical variables.

Introduction

Fish is one of the most perishable food items. Processing and preservation of fish have been introduced to retard spoilage change of the fish during post harvest period. Among many other processing and preservation methods of fish, sun drying of fish is most abundantly used in Bangladesh.

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Sun drying of fish is a very popularly known processing and preservation method of fish in commercial scale for consumption by all sections of people in Bangladesh. But during sun drying of fish it has been observed that about 50% of the dried fish was wasted, 30% during drying and 20% during subsequent storage in high humid and high temperature condition, especially in the subtropical countries like Bangladesh as estimated in a study for improved sun drying of fish.(1)

To overcome this problem of wastage of fish during sun drying of fish, polythene tent dryer was developed for drying of fish in Bangladesh. (1) The dryer was effective in controlling fly larvae in dried fish. But there was little merit of the tent dryer in the early stages of drying fish when the drying process is governed by the transmission of moisture from the surface and exposure to wind.

While working with polythene tent dryer attempt was made for designing and development of a solar tunnel dryer to overcome the difficulties faced by polythene tent dryer for dehydration of fish on commercial scale. Muhlbauer *et al.*(2) at the Institute of Agricultural Engineering in Tropics and Subtropics, University of Hohenheim developed solar tunnel dryer in which fan was provided and the air flow removed the evaporated moisture.(2) The electric power requirement of the fan was found to be very low and could be operated one photovoltaic module independent of electric grid. Numerous tests in regions of different climatic conditions have shown that fruits, vegetables, cereals, grain, legumes, oil seeds, spices and even fish and meat could be dried properly in the tunnel dryer. (2- 4)

So, it was felt necessary to design and develop a solar tunnel dryer to produce improved quality dehydrated freshwater and marine fish.

Materials and Methods

Development of a solar tunnel dryer: A solar tunnel dryer having 20 ft length and 3 ft width was designed and developed with locally available raw materials. The dryer consisted of a flat plate air heating collector chamber, the tunnel-drying unit and two DC fans (6 inches, 12 Volt) to provide the required air flow over the fishes to be dried. Both the collector and the drying unit were covered with plastic foil. The collector was painted with black color to increase the absorption of heat. The fishes to be dried were placed in a thin layer of bamboo splitted net within the dryer. Glass wool was used as insulation to reduce the loss of heat from the bottom of the dryer. The whole system was placed horizontally on a raised platform. Two DC fans were operated by PV module. Solar radiation passing through the transparent cover of the collector got absorbed by black-coated MS sheet that converted the incoming energy into heat as shown in Fig. 1. The solar tunnel dryer was placed at the premises of

Renewable Energy Research Centre, Dhaka University to produce quality dehydrated *Amblypharyngo-don mola* and *Pampus argenteus* fish.

Experimental procedure: Three experimental runs for drying and dehydration of *A. mola* and *P. argenteus* fish were carried out at the premises of Renewable Energy Research Centre, University of Dhaka in the month of June, 2004. During the experimental runs variables related with the performance of the solar tunnel dryer were recorded at different time interval. The air velocity at the outlet of the tunnel dryer was recorded by aenomometer. Relative humidity and drying air temperature inside and outside the solar tunnel dryer were recorded by hygrometer and thermocouple, respectively. The solar radiation during the experimental period was measured by pyranometer. Weights of the experimental fish at the initial time and at different time interval were measured by two pan balance.

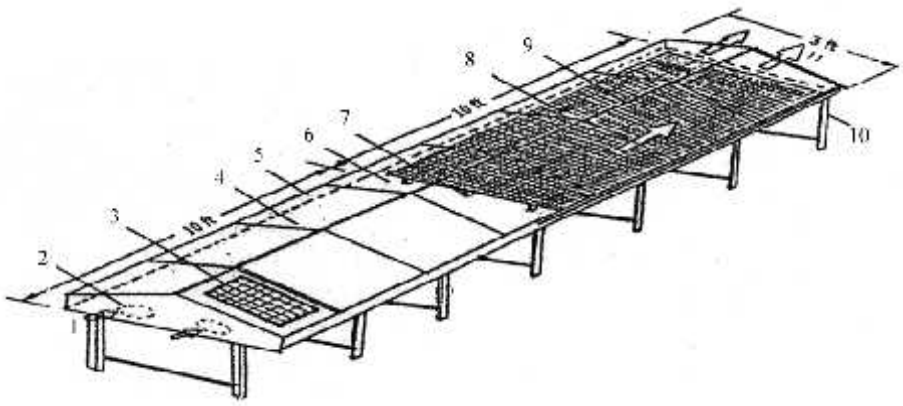

Fig. 1. Design of the tunnel dryer.

1. Fan (not shown in Fig.), 2. air inlet, 3. solar module, 4. collector, 5. metal frame, 6. outlet of the collector,7. wooden support, 8. bamboo splitted net, 9. roof structure for supporting the foil, 10. base structure for supporting the tunnel dryer and 11. outlet of the drying tunnel.

Physical and chemical methods: Moisture and protein content of the dried and dehydrated fish samples were determined by AOAC[5] method. Total volatile nitrogen (TVN) value of the dried and dehydrated fish samples were estimated by Conway micro diffusion technique.[6] Sensory score evaluation was done by using 9 point hedonic scales.[7] The hedonic scale was as follows: 9-like extremely, 8-like very much, 7-like moderately, 6-like slightly, 5-neither like nor dislike, 4-dislike slightly, 3-dislike moderately, 2-dislike very much, 1-dislike extremely. The average score of 5 was considered to be the borderline of acceptability.

Results and Discussion

Performance of the experimentally designed and developed solar tunnel dryer for producing improved quality dehydrated fish samples were studied while installing the solar tunnel dryer at the premises of Renewable Energy Research Center, University of Dhaka. Three experimental runs for drying and dehydration of *A. mola* and *P. argentues* fish samples were carried out in the month of June, 2004. Variation in temperature and relative humidity of the drying air inside the solar tunnel and in the sun drying air during first experimental run are represented in Fig. 2. Similar results were obtained during second and third experimental runs.

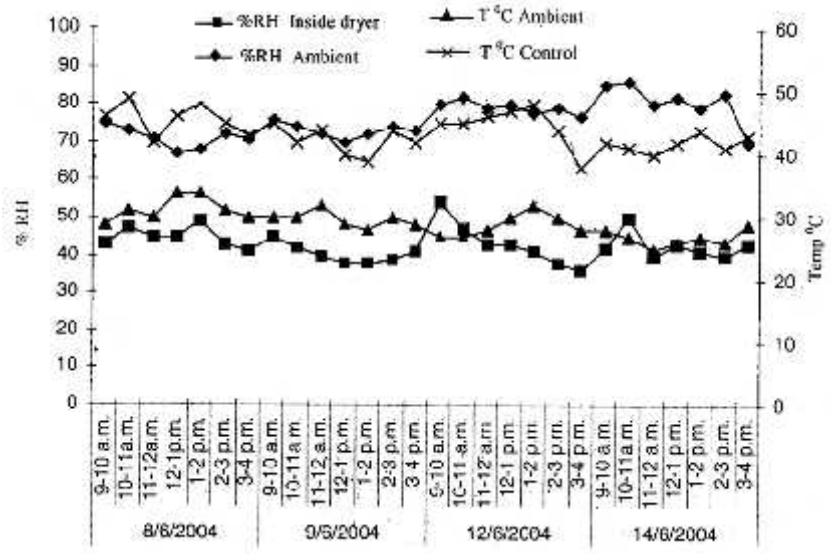

Fig. 2. Temperature and relative humidity of the open air and solar tunnel dryer air during first experimental run.

Results shown in Fig. 2 revealed a clear variation in temperature and relative humidity between the sun drying air and the drying air inside the solar tunnel dryer. The drying air temperature and relative humidity inside the solar tunnel dryer was found to vary from 36 to 49^{0}C and from 36 to 63% during the experimental runs whereas during the same period the drying air temperature and relative humidity in the sun varied from 25 to 35 ^{0}C and from 64 to 93%. It is understood from the results (Fig. 2) that the RH value is lower inside the tunnel dryer than that of the drying air in the sun. Drying air temperature inside the solar tunnel dryer is higher than that of the drying air temperature in the sun. The lower range of RH value and higher range of temperature of the drying air inside the solar tunnel dryer have been found to influence a speedy rate of dehydration of the experimental fish in comparison with

the sun dried fish during the same experimental period. Results presented in Figs. 3 and 4 showed drying rate period between the dehydration of fish in the solar tunnel dryer and drying of fish in the sun. It is evident from the results (Figs. 3 and 4) that the drying rate period is different due to two clear reasons. One is the difference in the use of solar tunnel dryer and drying of fish in the sun and other reason is the size of the fish species. It took 12 drying hours for dehydration of *A. mola* fish in the solar tunnel dryer whereas it was 28 hours for dehydration of *P. argentus* fish. On the other hand it took 17.5 drying hours for sun dried *A. mola* and 39 drying hours for *P. argenteus* fish.

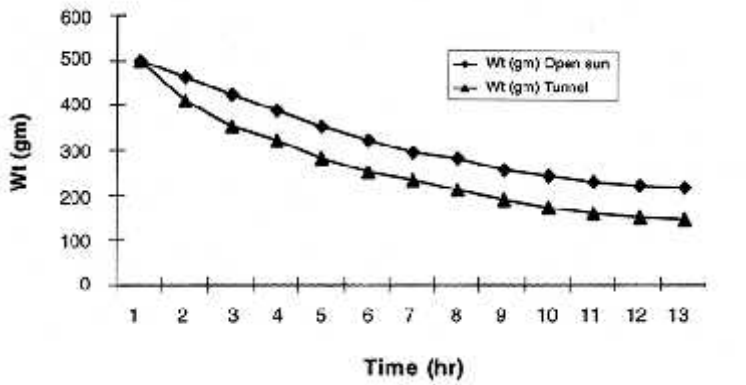

Fig. 3. Drying rate of *A. mola*.

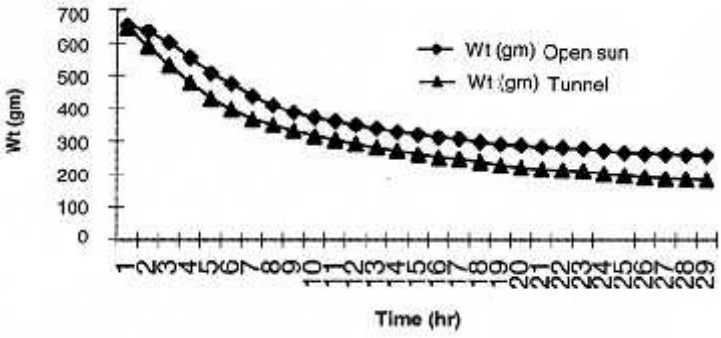

Fig. 4. Drying rate of *P. argenteus*.

Considering the use of solar tunnel dryer and drying of fish in the sun it has been observed that it took less drying period for dehydration of fish in the solar tunnel dryer than that of the sun dried fish. While fish was dehydrated in polythene tent dryer it is seen it took less drying period in comparison with the time required for sun dried fish. Doe *et al.*,[1] Ahmed,[8] Bala and Hossain[9] also reported that dehydration of commercially important fish in polythene tent dryer and in the solar tunnel dryer (Commercial type) takes less time than that of the time required for sun

dried fish. They also observed variation in drying rate period between dehydration of fish and drying of fish in the sun. In the present study irrespective of drying rate period has got similarities with the observations made by others.[1,8-9]

Airflow rate inside the solar tunnel dryer during the experimental period has been found to be dependent on the intensity of the solar radiation, i.e. with the increase or decrease of the solar radiation the air flow rate inside the solar tunnel dryer has been found to increase or decrease proportionately. More so the airflow rate has been found to influence on the increase or decrease of inside drying air temperature of the solar tunnel dryer. Solar radiation was found to vary from 28 to 866 W/m^2 during the experimental runs. This relationship between airflow rate and collector outlet temperature is shown in Fig. 5.

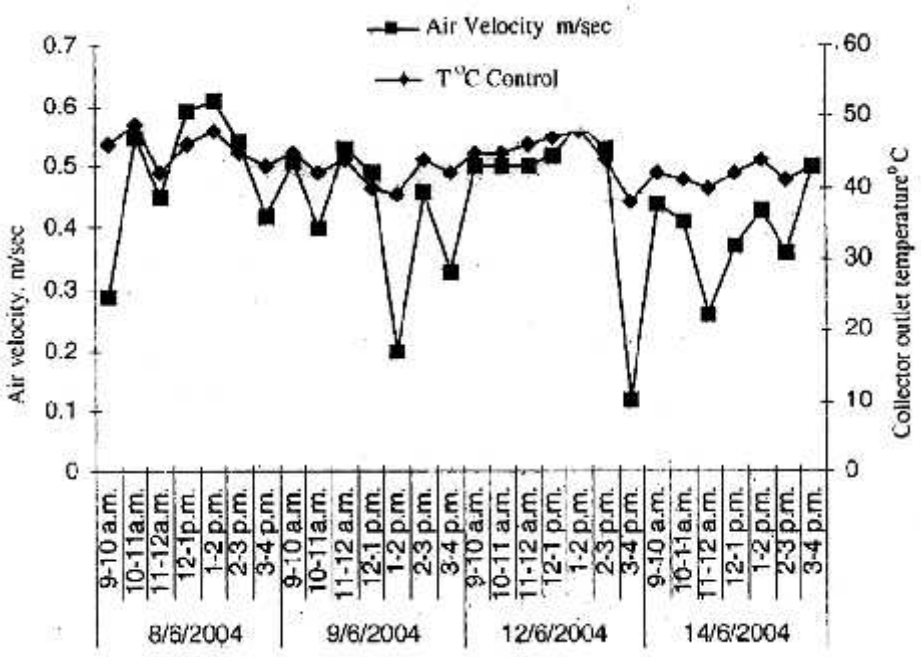

Fig. 5.Variation of collector outlet temperature and air velocity with time of day during first experimental run.

The quality of the dried fish samples in the sun and that of the dehydrated fish samples of the solar tunnel dryer produced by Experiment Nos. 1, 2 and 3 in the month of June, 2004 have assessed by both physical and chemical parameters (Table 1).

Overall acceptability score value indicates that the dehydrated *A. mola* fish samples and that of *P. argentues* are extremely acceptable in fresh dehydrated condition irrespective of the time of the experimental run. The sun dried *A. mola* fish

samples have been found to be better in quality than the sun dried *P. argenteus* samples. In fresh dried condition the *A. mola* fish samples have been found to be very much acceptable whereas the sun dried *P. argenteus* fish samples have been found to be moderately acceptable as per sensory score evaluation.

Table 1. Showing values of quality variables of the sun dried and dehydrated *A. mola* and *P. argenteus* fish samples indicating the extent of quality.

Expt. No.	Sample No.	% M	% P	TVN mg/100gm	Sensory score
Expt. 1	A	20.38	64.02	75	8
	B	14.1	70.5	60	9
	C	29	56.05	180	7
	D	14.9	69.05	85	9
Expt. 2	A	22.08	63.2	105	8
	B	14.5	69.6	65	9
	C	28.0	59.01	156	7
	D	15.2	68.02	83	9
Expt. 3	A	24.10	60.03	96	7.5
	B	14.45	68.5	64	9
	C	28.56	58.6	160	7
	D	14.5	68.4	82	9

A. sun dried *A. mola*, B. dehydrated *A. mola,* C. sun dried *P. argenteus,* D. dehydrated *P. argenteus*.

The sun dried fish samples of *A. mola* and *P. argenteus* have been found to contain 22.19 and 28.52% moisture (average), respectively. Similarly 14.35 and 14.77% moisture (average) in the dehydrated *A. molo* and *P. argenteus* fish, respectively in the tunnel dryer were found. According to Waterman[10] bacterial action stops at 25% water content and moulds ceased at 15% water content. TVN value has been found to have direct relationship with the increase of percent moisture content. The per cent protein content of the sun dried *A. mola* and *P. argenteus* fish samples have been found to have inverse relationship with the per cent moisture content. These results agree with the findings of a quality assessment study of dried Bombay duck.[11] An increased moisture content favors decreasing the quality of the sun dried fish samples. Whereas the dehydrated *A. mola* and the *P. argenteus* fish samples of the solar tunnel dryer have been found to be better in quality having lower level of moisture content, higher level of protein content and lower level of TVN value. Our findings irrespective of quality evaluation of the sun and dehydrated fish samples of the solar tunnel dryer have got similarities with the

findings of fish drying studies using tunnel dryer and fish drying by solar dryer in coastal belt.[9, 12]

The findings of the present study suggest the use of solar tunnel dryer for improved quality dehydrated fish on commercial scale in order to get both nutritional and economic benefit and to minimize the fish wastages during sun drying of fish.

Acknowledgements

The authors are thankful to Renewable Energy Research Centre (RERC), Dhaka University for financial support of this research. The authors are also thankful to the Institute of Food Science and Technology (IFST), BCSIR Dhaka for providing all laboratory facilities to carry out the experiment.

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(Manuscript received on 15 May, 2005; revised on 15 July, 2005)