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Development of Low Cost Solar Rack Dryer and Comparative Biochemical Quality Evaluation of Anchovies (*Stolephorus commersonii*) Dried in Sun and Solar Rack Dryer

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A B S T R A C T

A low cost solar rack dryer was fabricated with an aim to popularise hygienic drying of fish among fisherwomen and it was evaluated for drying of Anchovy (*Stolephorus commersonii*) at Central Institute for Women in Agriculture, Bhubaneswar, Odisha. It was observed that on an average the solar dryer attained 17.5 % higher temperature than the ambient temperature. Within a total drying time of 13 h, the moisture content of the fish reduced from about 81.97% to 28.87% and 34.43% by the solar rack dryer and open sun drying respectively. There was significant differences in the moisture content, crude protein and ash content of fish dried using the two methods with the solar rack dried fishes significantly faring better. The values of biochemical quality indicators like Total Volatile Base Nitrogen and Peroxide value were significantly low in solar rack dried fishes indicating a longer shelf life of these fishes. Hence it can be concluded that wide scale dissemination of the low cost solar rack dryer among the coastal fisherwomen population will help them to earn better returns in their occupation through sale of the hygienic dry fish.

Keywords

Low cost solar rack dryer, Anchovies, Biochemical quality

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Introduction

Dry fish is referred to as poor man's protein. Dry fish segment constitutes 20% of the total fish production in India. Marine fish drying is the most common form of processing throughout the coastal belt of India and is the cheapest means of fish value addition. The economic returns from fish drying still remains low because of the unhygienic drying practices, lack of adoption of scientific protocol for curing, improved drying practices and packaging. Improved technologies for drying include the use of mechanical dryers or solar dryers. The initial investment in mechanical drying systems is high but dried fish is stable for extended periods of storage and is safe for consumption throughout storage (Reza *et al.*, 2009; Dagne *et al*., 2016). The non adoption of these improved technologies by fisherwomen in developing countries like India is because of the high capital investment involved. As a result sun drying is still the simplest and economical method of fish preservation practiced all over the world. But sun drying has many limitations, such as extended periods of drying which affects the keeping quality, inability to dry during rainy season or cloudy weather conditions, non suitability to high humid regions etc. Because of these reasons sun drying of fish often results in low quality, insect infested and contaminated product. Hence development and popularisation of dryers which are cheap yet will serve the purpose of hygienic and faster drying of fish is the need of the hour.

Methods of drying vary with the species used. The ultimate objective is the reduction in moisture within the range of 10-35%. The effect of different drying methods on different fish species have been studied (Immaculate *et al*., 2012; Hasan *et al.*, 2016; *Rasul et al.*, 2018). The present paper deals with the development of a cost effective solar rack dryer to be popularised among fisherwomen for hygienic drying of fish and to compare the drying characteristics, nutritional and biochemical characteristics of Anchovy (*Stolephorus commersonii*) dried in the solar rack dryer and in open sun.

Materials and Methods

Dryer specifications

A suitable size natural-convention type solar dryer for drying fish was designed for the humid climate condition of Odisha state of India (Table 1). This natural convection type solar dryer was designed to bring down the moisture content of fish from about 80 % to 25 %.

Design procedure

Design of the solar rack dryer was done according to Jhajharia and Seveda (2012) with some modifications**.** The size of the dryer was determined as a function of the drying area needed per kilogram of fresh fish. The drying temperature was established as a function of the maximum limit of temperature which the fresh fish may support.

The mass of water to be removed during drying, M_w, kg,

$$M_w = \frac{mi - mf}{100 - mf} \text{ X W}$$

The mass of water removed per hour m_w, kg/h,

$$m_w = \frac{Mw}{td}$$

The total energy required Q kcal,

$$Q = W^* C_p * (T_d - T_a) + (M_w * \lambda)$$

The energy required per hour Q_t, kcal/h,

$$Q_t = \frac{Q}{td}$$

Collected area required, Ac, m^2,

$$A_c = \frac{Qt X 100}{It * \eta}$$

Construction of the solar dryer

The solar dryer (Fig. 1) was designed as per the above procedure. The required area of collector be 3.00 m^2, hence the length and width of dryer was taken 2.45 m and 1.22 m respectively. The height of the dryer was kept 1.52 for ease of loading and unloading by women. Slope was also provided to the dryer roof to avoid pooling of water or debris on top of it.

The standard components solar rack dryer are frame structure, covering material and drying trays. These materials used for their construction are affordable and easily available in the local market.

According to the material for construction (Either mild steel or stainless steel), the cost of construction ranges from Rs 8000 to Rs 12000/dryer.

Frame structure: The frame structure consists of base frame and doors. The mild steel angle of 25 X 25 X 3 mm was used in the fabrication of base frame of the solar dryer. Mild steel flat of 20 X 3 mm was used in the fabrication of supporting frame of the solar dryer and to hold trays. Doors were provided for ease of loading and unloading.

Drying trays: The drying trays were contained inside the drying chamber and were constructed from wire mesh and wood, it allowed drying air to pass through the fish. Total 12 no. s of trays of dimensions (LXBXH:: 1.2 X 0.52 X 0.75) can fit inside the dryer.

Covering material: The transparent 200 micron UV stabilized plastic sheet was fixed on the four side of the frame for the interception of solar energy. But the bottom and back sides were fixed by black colored plastic. It was fasten to the frame using fastening strips.

Ventilation: 4 chimneys were provided for ventilation..

Performance evaluation

Anchovy fish (*Stolephorus commersonii*), locally known as kokali, was considered for study in the open sun drying and the natural convention solar rack dryer. The fresh fish obtained from local markets of Bhubaneswar were bought in iced condition to the laboratory, gutted and washed with clean water. The initial moisture content of the sample was determined by drying at 105^0C for 6 hours and was observed to be 81.97 $\pm$ 0.31 %. The fish was salted (1:8:: Salt: fish) and kept for 24 hrs in plastic trays covered with polythene. The polythene was given holes. After 24 hrs the fish was rinsed in clean water to remove the excess salt and the water was drained off. The fishes were divided into 2 batches. Each batch was further divided in 3 replications of 200 g each. One batch was dried in open and the other in the developed solar rack dryer.

A wire mesh tray was used to dry the fish in open sun as well as solar rack dryer. The fish were arranged in a single layer over the mesh on nylon net. The dryer was properly oriented for maximum sunlight reception. The experiment was conducted in the month of June, 2019 under the climatic condition of Bhubaneswar, Odisha, India.

Proximate and biochemical analysis

Samples were drawn from each lot in predetermined intervals to estimate the moisture content and thence the drying rate. Once the weight got stabilised, the samples were packed in HDPE Polythene pouches and sealed till further analysis. The proximate composition analysis was done according to AOAC (2000) All the chemicals used in the analysis were of analytical grade and supplied by Himedia, India. Moisture was estimated by drying in a hot air oven, fat by the ether extraction and crude protein by the

Microkjeldahl method and ash was determined by using Muffle furnace. The biochemical parameters of The Total volatile base nitrogen (TVB-N) values were estimated by the Conway micro diffusion method (Conway, 1950). Free fatty acid was estimated from the chroloform extracts of the sample according to AOAC (2000). Peroxide value (PV) of dried anchovy was estimated by a titrimetric method (Yildiz *et al.*, 2013)

Statistical analysis

Data sets were analysed parameter wise using Analysis of Variance (ANOVA). The data were statistically analysed by statistical package SAS 9.3. The differences between the experimental groups were considered significant at a level of $P<0.05$.

Results and Discussion

Drying characteristics

As expected in the month of June, when monsoon initiates in Odisha, the weather was cloudy and humidity was high during the time of experiment. Hence the process of drying was spread over 4 consecutive days and different time of day owing to intermittent bouts of clouds and rain. The temperature for open condition ranged from 44 to 29^{0}C, while for solar dryer it ranged from 47 to 28^{0}C throughout the test period. The ambient relative humidity ranged from 93 to 49 % and for solar dryer is was between 84 to 44 %. The solar radiation for the duration was as low as 126 W/ m^2 and as high as 773 W/m^2. Hence the moisture loss was recorded at one hour interval from 9-17 h as and when the ample sunshine or clear sky was available, till the samples no longer showed reduction in weight. The details of the weather condition are given in Table 2.

It was observed that with an increase in drying time, the rate of moisture removal was decreasing (Fig 2). This is in concurrence with the findings of Pathare and Jain (2007). The fish was dried to a constant moisture content of 28.89$\pm$0.31% in 13 hours in solar dryer, where in the same time the moisture content was reduced to only 34.43$\pm$0.32% in fish dried in open condition. There was no further weight reduction observed in the fish in the open condition. Thus, the dryer gives desirable moisture content in lower time as compared to the open condition, saving drying time.

Proximate composition

The moisture content was significantly lesser ($p<0.05$) in solar dried fish than the open dried fish (Table 3). This could be because of the comparatively elevated temperatures and lower relative humidity inside the dryer. This is advantageous as higher moisture content is one of the accelerants for microbial and fungal growth in dried fish. The crude protein and ash content was significantly ($p<0.05$) higher in solar dried fish. This is because of the significant reduction in moisture content of the fish which results in aggregation of other proximate parameters. Several authors have reported the inverse relationship of moisture and other proximate parameters in dried fish (Shrivastava *et al.,* 1974; Relekar *et al.*, 2014).

Usually open dried fish has a significantly higher ash content because of deposition of dust and dirt particles on the fish (Immaculate *et al.,* 2012; Rasul *et al.,* 2018). In the present study, the inverse condition occurred probably because of settling down of dust particles by the intermittent rains in the month of June in Odisha. The lowest lipid content was observed in the dried fish produced by the open drying method, which might be due to comparatively higher oxidation of lipids caused by the uninhibited exposure to the sun.,

Biochemical quality

The total volatile bases in fish tissues include ammonia, monomethyl amine, dimethyl amine, and trimethyl amine etc. which gets accumulated due to bacterial decomposition of fish. The increase in these volatile bases leads to deterioration of odour and flavour in fish. The average TVB-N values of the dried anchovy was 50.92 mg/100 g and 76.29 mg/100 g (Table 3) for solar dried and open dried fish respectively, which is much lower than the recommended value (100–200 mg/100 g of muscle) for different dried and salted fish products (Connell, 1995). The fishes dried in open are prone to all sorts of contamination like environmental, contamination by pest or animals. The significantly higher ($p<0.05$) TVBN content in open dried fishes shows the faster deterioration of quality by traditional drying. Abraha *et al.,* (2017) has reported a much lesser TVBN content of 20.12 mg% in dried anchovies. This may be because of the fact that TVBN in dry fish will also depend upon the initial quality of fresh fish.

Peroxide value is commonly used to assess rancidity development by oxidation of fats. As per Sankar *et al.,* (2013), the fat content of *S.commersonii* ranged between 1.25 to 2.41% which puts it under the category of low to medium fatty fish. Fat oxidation is one of the factors which affects the quality and shelf life of dry cured fish especially those of high and medium fatty fishes. It has been reported that the peroxide value of herring (*Clupea pallasii*) lipids (5.52–11.86 meq/kg), a fatty fish increased significantly during the drying period (Shah *et al.,* 2009).

Table.1 Assumptions and conditions for designing of solar rack dryer

Items	Conditions/ Assumptions
Location	Bhubaneswar (20^0 16'N 85^0 50' E)
Product dried	Anchovy Fish
Drying Period	June 2019
Initial moisture content (wb, %)	80
Final Moisture content (wb, %)	25
Loading Capacity, kg	5
Assumed drying time, hrs	24
Global solar radiation, kWh/m^2	3.72
Sunshine hours per day , hrs	4.7

Table.2 Weather parameters during the experiment of drying of Anchovy *(S. commersonii)*

Particulars	Temperature, °C				RH, %				Solar Insolation, W/m^2	
	dryer		open		dryer		open		min	max
	min	max	min	max	min	max	min	max		
Day 1	28	32	29	32	61	80	73	93	126	284
Day 2	36	47	32.5	40	49	77	57	77	191	434
Day 3	35	46	35	44	48	84	50	93	411	773
Day 4	37	45	36	42	44	76	49	87	419	606

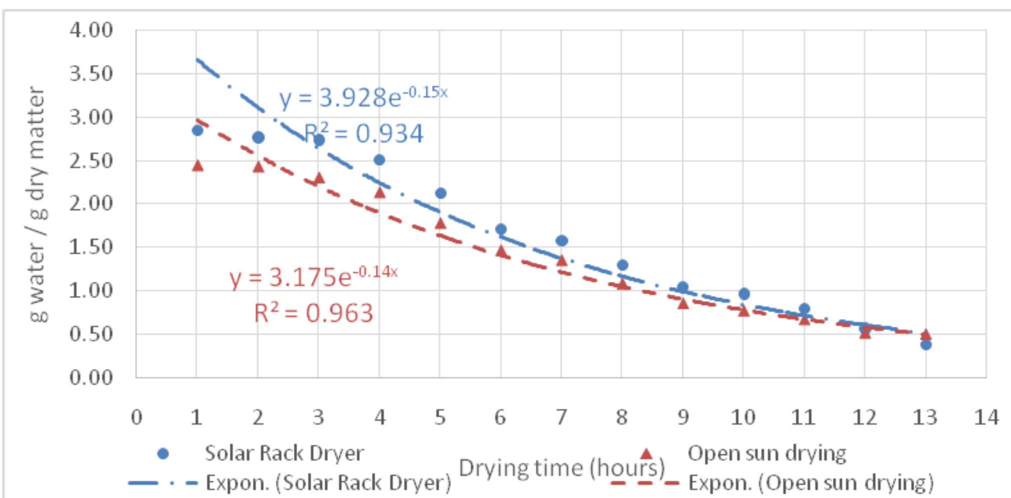
Table.3 Proximate and biochemical characteristics of dried Anchovy (*S. commersonii*)

Drying methods	Moisture (%)	Crude protein (%)	Crude fat (%)	Ash (%)	FFA (% Oleic acid)	PV (meq O2/kg fat)	TVBN (mg%)
Open sun dried	34.43±0.32	34.5±0.38	3.22±0.48	6.8±0.05	1.43+0.15	5.08+0.19	76.29+1.31
Solar rack dried	28.89±0.31*	41.33±0.41*	4.31±0.14	8.39±0.25*	1.59+0.03	2.33+0.34*	50.92+0.91*
P value	<0.0001	0.0021	0.0621	0.0027	0.1362	0.0002	<0.0001

Values represent Mean±SD of 3 replications; Means bearing asterisks differ significantly

Fig.1 Low cost solar dryer

Fig.2 Drying rate of anchovy (*S.commersonii*) in solar rack dryer and open sun



A rancid taste often becomes noticeable at peroxide value of 10–20% (Oparaku *et al.*, 2010; Enamul *et al*., 2013). The open dried fish had a significantly higher highest peroxide value probably due to the uninhibited exposure to sun. The peroxide value in both solar dried and sun dried anchovies was lower than the recommended value of 20 meq/kg oil (Table 3).

Free fatty acids are formed through chemical or enzyme linked hydrolysis of triacylglycerides and it indicates the post mortem degradation of fish. The free fatty acids are further oxidized to produce secondary oxidation products, which causes rancidity of fish and fishery products (Toyamizu *et al.*, 1981). Generally, lower acid values indicate better quality of a product. In this study, the average free fatty acid values were 1.43 and 1.59 % oleic acid of lipid in solar dried and open dried anchovies respectively (Table 3) which is much less than reported by many authors in dried fish (Majumdar *et al.*, 2017; Razul *et a.l*, 2018). This could be due to the reduced activity of fish muscle enzyme and microorganisms because of the removal of moisture from fish by drying.

Hence it can be concluded that by achieving increased drying temperatures and reduced relative humidity, the low cost natural convection solar rack dryers can comparatively increase the drying rate to produce a product with low moisture content and improved quality compared with the traditional open sun drying method. This improvement in terms of quality can help the fisherwomen get better prices for their fish and enhance the preferences of consumers.

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