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DEVELOPMENT OF LOW-COST EMERGENCY FISH DRYER IN BANGLADESH TO USE IN ABSENCE OF SUNLIGHT

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Abstract

Considering the high demands of the dried fish producer for a device by which they can produce dry fish at night and during the bad weather, three models of low-cost fish dryers were designed and developed using locally available materials in Bangladesh. The first model was developed to use in an emergency situation, i.e. to meet the emergency need in the absence of the sunlight. The second model was developed using transparent plastic wavy sheet (plastic tin) to utilize the solar energy during the sunny day and hence to make it useful for 24 hours a day. The third and final version of the transparent model was named as the BFRI Fish Dryer that was constructed using two layers of thin (0.20 mm) celluloid for better insulation and efficient utilization of heat energy. The size of the final version was 18' x 2.5' x 2.5' which was bifurcated in two units of nine feet each joined together on setting. A system to blow hot air (40-55 ^{0}C) inside the tunnel was developed using a hot plate and a table fan. After assessing the drying performances of the three models, the BFRI Fish Dryer model was found as the best one. The organoleptic (sensory) characteristics, water reconstitution properties and nutritional properties on the basis of proximate compositions of the dried fish products produced in the BFRI Fish Dryer were found very attractive compared to the traditional products. Thus, this technology can ensure food safety through producing hygienic dry fish.

Keywords: Preservation, organoleptic (sensory), fish dryer, emergency, transparent.

Introduction

Sun drying is one of the low-cost popular methods of fish preservation in Bangladesh, which plays a significant role in providing nutrition and income to the poor coastal people. A large number of people, especially women are employed in this sector. It is estimated that about 20% of the local artisanal fish catch are sun dried and consumed in the domestic market (Mazid and Kamal 2005). Traditional dried fish products are generally produced using cheap, partially spoiled or discarded fishes. The main bulk of this type of raw materials comes from the set-bag-net (Behundi Jal) fishery. The predominant species for drying in the Cox'sBazar areas are Croakers, Ribbon fish, Bombay duck, Pomfrets, Anchovies, Mackerels, shrimps and mixed varieties of samll fish/juveniles including crabs and snails for fish/poultry feed production (Hossain *et al*. 1999, Rahman and Uddin 2010). The physical and organoleptic qualities of most of the traditional sun dried

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products deteriorate remarkably due to bad weather (Hossain *et al*. 1999, Mazid and Kamal 2005). There are frequent complains from the consumers about the quality of the products and the major problems associated with sun drying fish are the infestations by house fly and insect larvae, poor sanitation and improper process that often lead to contamination and spoilage and ultimately the use of pesticide to prevent those (Kamruzzaman 1992, Khan 1996 & 1997, Saha 1999, Rahman and Uddin 2010). All of those problems are inversely associated with the presence of the scores rays of the sun. The more the scores rays of the sun, the less the problems encountered in fish drying and maintaining qualities of the dried fish products.

To improve the situations some research works were conducted to develop different models of solar dryers (Ahmed *et al*., 1979; Islam, 1982, Bala and Hossain 1998, Bala and Mandal 2001, Mazid and Kamal 2005). The solar dryer can ensure good hygienic quality of the product, but the model could not be operated in absence of the sun, so, about eight hours of a sunny day could be utilized for actual drying purposes and about two third of the time remains unutilized. Considering their highly justified demands for such a device and considering the economic strength of dry fish producer, the research work was undertaken to develop a low-cost fish dryer using locally available materials in Bangladesh. The technology would not only prevent the physical spoilage of the raw fish before drying, but would also improve the hygienic and nutritional status of the dried fishery products.

Materials and Methods

Description of the Study Site

Initially, the study was conducted in the Marine Fisheries & Technology Station, Cox's Bazar. After developing such indigenous technology, the final model was named as, 'BFRI Fish Dryer' was then demonstrated and disseminated to different fish dry-yards in Cox's Bazar areas.

2.2 Developing the design and construction of Dryer

Emergency Dryer Model

The first model was developed to use in an emergency situation, i.e. to meet the emergency need in the absence of the sunlight. To do this, a long rectangular shaped tunnel was prepared using locally available materials such as sliced wood, pitch board, tin sheet, polythene sheet, tripol etc. The dimension of a single unit of the dryer was 7' x 3.5' x 3.5' (Fig. 1). Parallel joining of six units constituted the main drying tunnel of the dryer having an approximate capacity of holding 300 kg raw fish (Fig. 4). Several horizontal wooden bars were set in parallel position along the top of the width of the dryer to hang the fish by dual hooks made of hard wire (Fig. 2).

Fig. 1: A single unit of the emergency dryer (7'x3.5'x3.5')

Fig. 2: Parallel joining of six units constituted the tunnel of the emergency dryer.

Transparent Model

In the second instance of the development of a low-cost fish dryer, another model was developed using single layer as well as double layer transparent plastic wavy sheet (plastic tin) (Fig. 3). The size of a single unit of the second model of the dryer was 18' x 2.5' x 2.5'. Locally available materials such as sliced woods, transparent plastic wavy sheets (plastic tin), etc. were used as the main materials to construct the dryer. Several horizontal wooden bars were set in parallel position along the top of the width of the dryer to hang the fish by dual fishing hooks were used (Fig. 4). During the bad weather and at night, an electric heater was used to produce hot air. In all the cases, an electric table fan was used to blow the hot air all the time (Fig. 4).

Fig. 3. Picture showing, (A) single layer, (B) double layer construction of the transparent model dryer usable in the presence as well as in the absence of the sun.

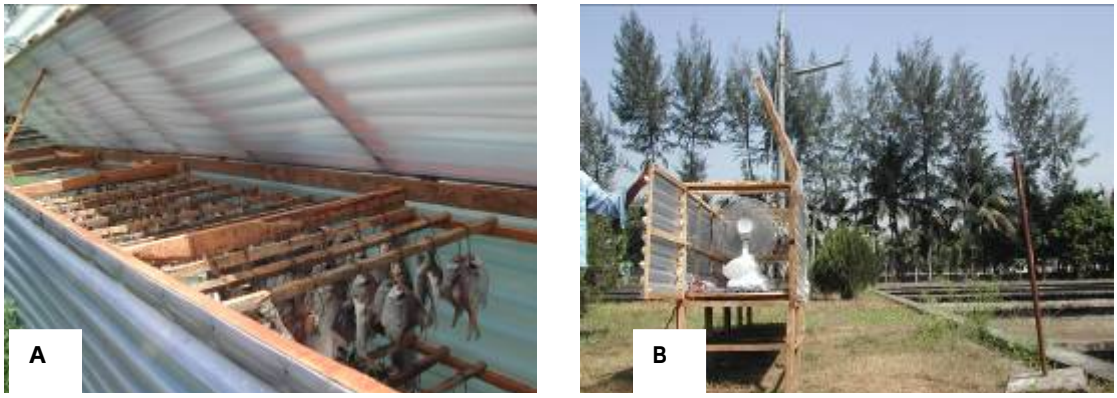

Fig. 4. Picture showing, (A) horizontal wooden bars to hang the fish by hooks, (B) electric table fan to blow hot air in the transparent model

BFRI Fish Dryer Model

The third and final version of the transparent model was named as the **BFRI Fish Dryer,** which was developed. The size of the final version was 18' x 2.5' x 2.5' bifurcated in two units of nine feet each joined together on setting (Fig. 5). Two layers of thin (0.20 mm) celluloid were used for better insulation and efficient utilization of heat energy (Fig. 5). A system to blow hot air (40-55 ^{0}C) inside the tunnel was developed using hot plate and a table fan. A maximum-minimum thermometer was used to monitor and control the temperature. Horizontal wooden bars were set in parallel position along the top of the width of the dryer to hang the fish by dual fishing hooks. All other structural details were remained in the second model.

Fig. 5. Picture showing a complete 18 feet BFRI Fish Dryer covered with 0.2 mm transparent celluloid

Efficiency Assessment of the three Fish Dryers

The drying performances of the three models, i.e. emergency model, transparent model and BFRI Fish Dryer were assessed using three commercially important fish species (Bombay duck, Silver Pomfret and Ribbon fish). The drying time, temperature, capacity, durability, energy efficiency and incidence of blowfly infestation were also assessed.

Physico-chemical Properties Analysis

Organoleptic quality assessment

For the sensory (organoleptic) evaluations, a representative whole samples (20kg) of dried products produced by the BFRI Fish Dryer were taken randomly on a tray and different organoleptic characteristics such as general appearance, flavour, filthiness, scale & gut, texture, wetness and saltiness were assessed.

Water reconstitution property

Water reconstitution property, i.e. the percentage of water absorbed by the dried fish was assessed for the product produced by the BFRI Fish Dryer at normal temperature (30^{o}C) up to two hours with 30 minutes intervals. Results in this respect were expressed in terms of percentage of weight of water absorbed by the sample.

Proximate composition analysis

Proximate composition analysis, i.e. moisture, ash, lipid and crude protein contents were estimated on wet weight basis and expressed as percentage. The chemical analyses were carried out according to the methods given by AOAC (1980) with certain modifications as follows:

Moisture: Moisture content was determined by air drying of a given sample in a thermostat oven at 105 ^{o}C for 24 hours.

Crude protein: Crude protein was estimated by the Macro-Kjeldahl method by determining total nitrogen and applying the protein conversion factor of 6.25.

Lipid: Lipid content was determined by extracting required quantity of samples with analytical grade acetone for 16 to 18 hours in a ground joint Soxhlet apparatus. The oil obtained by evaporation of the solvent on a steam bath was weighed in a sensitive balance and percent lipid was calculated.

Ash: Ash content was determined by complete igniting of the sample in a muffle furnace at a temperature of 550 ^{0}C for 6 hours.

Benefit-Cost Ratio (BCR) Analysis

The benefit-cost ratio (BCR) was estimated considering both quantitative and qualitative factors related to the benefits and costs and measured exclusively in monetary terms. The following most popular formula to estimate the cost–benefit indicators was used:

BCR = PVB/PVC, and

PVB – PVC = NB, where,

BCR was the benefit cost ratio
PVB was the present value of all qualitative & quantitative benefits
PVC was the present value of all types of costs, and
NB was the net benefit, i.e. the difference between PVB & PVC

Results and Discussion

Emergency Dryer Model

The prepared rectangular shaped tunnel, having a dimension of 7' x 3.5' x 3.5' for a single unit, was found suitable for handling and holding a modest amount (about 50 kg) of raw fish for drying. Parallel joining of six of such units constituted the main drying tunnel of the dryer having an approximate total of 300 kg raw fish holding capacity (Fig. 2). The used locally available materials were found to be moderately cheap. The horizontal wooden bars that were set in parallel position along the top of the width of the dryer to hang the fish by dual hooks were found suitable.

Transparent Model

The transparent model that was constructed using single layer transparent plastic wavy sheets (plastic tin) to utilize sun energy during the sunny day was found very useful all the time, i.e. 24 hours a day, rain or shine (Fig. 3). The latest transparent model that was constructed using two layers of the plastic tin was also found very effective for efficient utilization of heat energy produced by electric heater in absence of the sun (Fig. 4). However, due to the higher construction cost than the single layered one and lower efficiency in using the solar energy during the sunny days, the single layer-model was found better and selected for the species specific efficiency tests (BCR). The capacity of a single unit dryer was about 50 kg of raw fish. Generally, the drying time was found to be about three days, but it may slightly vary depending on the size and condition of fish and weather condition, being longer in rainy days and shorter in sunny days.

BFRI Fish Dryer Model

To solve the problems encountered in the second model, another transparent model using two layers of thin (0.20 mm) celluloid for better insulation and efficient utilization of heat energy was developed. The size of the final version was 18’ x 2.5’ x 2.5’ bifurcated in two units of nine feet each joined together on setting was found suitable to hold 50 kg of raw fish for drying in a single lot. The system to blow hot air (40-55 ^{0}C) inside the tunnel using the regulated hot-plate and a table fan was found very effective to keep the temperature within the desirable range (40-55 ^{0}C). However, the maximum-minimum thermometer was found very useful to monitor and control the temperature.

The horizontal wooden bars that were set in parallel position along the top of the width of the dryer to hang the fish by dual hooks were found very suitable like other models. The dryer was found useful both in rainy or sunny days, throughout the day and year. Generally, the drying time for the 50 kg raw fish was

found to be about three days, but depends on size, condition of fish and weather.

The costs of electric energy to operate the dryer in absence of the sunlight would be much higher than that of sunny days. Therefore, it is wise to operate the dryer during the sunny day and use the hot-plate only at night. Nonetheless, in case of emergency due to sudden bad weather, the hot-plate would be very useful for saving the fish. As the availability of electricity is a prerequisite to operate this type of dryer, it can not be set in some remote places where sufficient electric supply may not be ensured.

Three species, Silver Pomfret (*Pampus argenteus*), Ribbon fish (*Lepturacanthus savala*) and Bombay duck (*Harpodon nehereus*) were dried using the newly developed BFRI Fish Dryer. Loittya (Bombay duck) was found unsuitable for the dryer for commercial production the reasons could be ascribes as: a) high water content in the body and straining of the part of that water inside the dryer creating extra costs and problems; b) market price of the dried product of the species is very low, so, the operation would not be economically viable; and c) sometimes the extra soft small body of the species was found unsuitable for hanging by hooks inside the dryer. All of those factors were found favourable for commercial operation of Silver Pomfret and Ribbon fish.

After getting satisfactory operational and economic output, the final version with two-layered transparent celluloid, has been finalized as 'BFRI Fish Dryer' for demonstration. Finally, six units of the dryer have already been constructed and demonstrated in six places, two in on-campus (MFTS, BFRI) and four off-campuses (Nazirertek, Kutubdia Para, Khuruskul and Ghotivanga) in Cox'sBazar. The technology is highly recommended for Small & Medium Entrepreneurship (SME) in the high quality export oriented fish drying sector.

The results obtained in this study could not be sufficiently compared with other works due to the lack of previous works on such type of emergency dryer although, different models of solar dryers were recently tested in Bangladesh (Bala and Hossain 1998, Bala and Mandal 2001, Mazid and Kamal 2005), none of them is suitable to function in absence of the sunlight. This is the first time attempt in Bangladesh to design and develop a low-cost emergency dryer in order to save spoilage of fish during rainy season. However, this work could be the basis to develop more improved and standardized devices in the coming days.

Efficiency of the BFRI Fish Dryer

The drying performances of the three models of dryers are summarized in Table 1 in terms of drying time, temperature, capacity, durability, energy efficiency and incidence of blowfly infestation.

Table 1. Comparative drying performance of three different fish dryers

Sl No.	Performance Indicators	Emergency Model	Transparent Model	BFRI Fish Dryer	Comments
1	Drying capacity (Raw fish in single unit)	50 kg	50 kg	50 kg	The "BFRI Fish Dryer" model is the most energy efficient and cost effective, so, this model was selected for further study
2	Drying time (12% moisture)	3 days	3-4 days	3 days	
3	Temperature maintenance	45-55 ^{0}C	45-55 ^{0}C	45-55 ^{0}C	
4	Efficiency to use solar energy	Inefficient	Efficient	Very efficient	
5	Durability	3 years with minor maintenance	3 years with major maintenance	3 years with minor maintenance	
6	Capital costs	Tk.12,000/-	Tk.18,000/-	Tk.12,000/-	
7	Operational costs (per 50 kg)	Tk.1,000/-	Tk.600/-	Tk.500/-	
8	Incidence of fly infestation	Occational	None	None	
9	Overall product quality	Excellent	Excellent	Excellent	

Physico-chemical Properties analysis

Organoleptic Characteristics

The seven organoleptic (sensory) characteristics of the dried fish products produced in the BFRI Fish Dryer were found very attractive compared to the traditional products. The characteristics of the dried fish products produced in the BFRI Fish Dryer are presented in Table 2 in comparison with the traditional products.

Water Reconstitution Properties

Water reconstitution property, i.e. the percentage of water absorbed by the dried fish was found excellent for the product produced by the BFRI Fish Dryer at normal temperature (30 ^{0}C). Within an hour, the product absorbed about 50% water and within two hours the product absorbed about 70% water, which could be considered excellent.

Table 2. Comparative organoleptic characteristics of the dried fish products produced by traditional method and BFRI Fish Dryer

Sl. No.	Characteristics	Dried fish products produced by-	
		Traditional method	BFRI Fish Dryer
1	General appearance	General grade, comparatively less shiny	Higher grade, comparatively more shiny
2	Flavour	Very strong flavoured and in some cases strong odour of decomposed fish remained	Different grade of the product (A, B & C) mild to strong flavoured but never like decomposed fish
3	Filthiness	Filthy materials generally present	Filthy materials generally not present
4	Scales & gut	Generally not descaled or gutted	Generally descaled or gutted
5	Texture	Generally soft but skin ruptured	Generally soft and good and skin not ruptured
6	Wetness	Generally high	Generally low
7	Saltyness	Generally highly salty	Generally not salty

Proximate Composition

The proximate compositions of the product produced by the BFRI Fish Dryer were found very good compared to that of the traditional products. The compositions of the product produced by the BFRI Fish Dryer in comparison with the traditional products are presented in Table 3. The nutritional contents were found better for the products produced by the BFRI Fish Dryer compared to the traditional one, mainly due to the removal of moisture in higher percentage. The percentage of actual protein content based on nitrogen was also found to be higher due to the lower degree of spoilage in the product produced by the BFRI Fish Dryer.

Table 3. Comparative proximate composition of the dried fish products produced by traditional method and BFRI Fish Dryer

Sl. No.	Constituent	Dried fish products produced by-	
		Traditional method	BFRI Fish Dryer
1	Moisture (%)	Generally moisture content high (25-30%)	Generally moisture content very low (10-12%)
2	Protein (%)	Generally protein content low (50-55%)	Generally protein content high (60-70%)
3	Lipid (%)	Generally lipid content low (08-10%)	Generally moisture content high (10-12%)
4	Ash (%)	Generally ash content low (10-12%)	Generally moisture content high (12-14%)

Benefit-Cost Ratio (BCR)

The benefit-cost ratios (BCR) that were estimated considering both quantitative and qualitative factors revealed that the product from higher priced species would produce better BCR, i.e. higher profit margin for the BFRI Fish Dryer (Table 4). This is simply because of the capital costs and operational costs, except the cost for raw fish and energy costs were the same for all types of fish, Drying cost of low priced fish, Bombay duck is almost double compared to other species, so, it produced no profit margin. On the other hand, Ribbon fish produced a medium profit margin (18%) and the high priced fish, the Silver Pomfret produced the highest profit margin (44%). Therefore, the technology would not be very suitable for low priced fish, but profitable for higher priced species (Table 4).

Operational Procedure before using fish dryer

On the basis of the results and experiences obtained for the three different models of fish dryers developed following operational procedures should be maintained:

Model Selection

Considering the relative advantages and disadvantages, especially the energy efficiency and costs effectiveness of the three models, the third model, "BFRI Fish Dryer" was recommended for demonstration and disseminations (Table 4).

Table 4. Comparative benefit-cost ratio (BCR) of the developed BFRI Fish Dryer for three species of commercially important fish products

Sl No.	Particulars of Costs/Benefits	Bombay duck (Loitta)	Ribbon fish (Churi)	Pomfret (Rupchanda)	Comments
1	**Costs** (per 12.5 kg dried fish production)	**BDT**	**BDT**	**BDT**	Product from Higher Priced species would produce better BCR, **i.e. higher profit margin** for the BFRI Fish Dryer.
	Capital costs	120.00	120.00	120.00	
	Energy costs	400.00	200.00	200.00	
	Fish costs	2,800.00	4,000.00	20,000.00	
	Labour costs	200.00	200.00	200.00	
	Packaging costs	130.00	130.00	130.00	
	Marketing costs	100.00	100.00	100.00	
	Total Costs	**3,750.00 (@ 300/kg dried fish = PVC)**	**4,750.00 (@ 380/kg dried fish = PVC)**	**20,750.00 (@ 1660/kg dried fish = PVC)**	
2	**Benefits** (per kg dried fish product)				
	Normal price	. 200.00	300.00	1,600.00	
	Price for 25% extra nutrient	50.00	75.00	400.00	
	Health benefit (25%)	50.00	75.00	400.00	
	Total Benefits (PVB)	**300.00 (= PVB)**	**450.00 (= PVB)**	**2,400.00 (= PVB)**	
3	Net Benefits (NB)/kg	0.00	70.00	740.00	
4	Benefit-Cost Ratio (**BCR) =PVB/PVC**)	300/300 = **1.0 (0% profit)**	450/380 = **1.18 (18% profit)**	2400/1660 = **1.44 (44% profit)**	

Operational Guidelines

The following sets of guidelines are strongly recommended to get best performances in producing high quality and hygienic dried fishery products using BFRI Fish Dryer:

- Generally fresh raw fish (badly spoiled raw fish must not be used) should be washed with clean fresh water to remove debris and mud.
- The washed fish should be sorted, on the basis of species, size and biological condition (gravid or oil content). Oily or gravid females should be kept out.
- On the basis of species & size and depending on the demand of the buyers the fish should be gutted, de-scaled and sliced. For example, gutting of Ribbon fish is important but not important for Pomfret, and slicing is important for Pomfret but not for Ribbon fish.
- After dressing, the excess water should be strained and then hanged by dual hook on the bar of the row. Care should be taken to keep little space between the fish during hanging to allow effective air flow through all fishes. In one unit of dryer, a maximum of 50 kg of raw fish should be kept for drying in a single lot.
- After hanging the fish, a maximum-minimum thermometer should be set to monitor the temperature. Then depending on the presence or absence of the sunlight, the hot-plate should be turned on/of or adjusted in a suitable level to adjust the temperature about at 45-55 ^{0}C range.
- After one day, the position of fish might be rearranged between front side and rear side of the dryer to ensure uniformity in the drying process.
- After continuous drying for three days, when the quantity of the product become 12-13 kg (i.e. one kg dried product from four kg raw fish of Churi and Rupchanda) then the drying process should be stopped and the product should be taken out for packaging.

- After taking out the product from the dryer, the product should be packed as 500 g and/or one kg size within an hour to get the best quality product. For a short period of stocking the product may be packed in good quality transparent polythene, for a medium period of stocking transparent celluloid and for long term stocking transparent plastic container should be used as packaging material. Finally, the dried fish product should be marketed and/or stocked after proper labeling.

Conclusion

The present research was successful in developing a profitable indigenous fish dryer (BFRI Fish Dryer) suitable for high priced fish but unsuitable for low priced fish. As this technology would not be very profitable for low priced fish, BFRI Fish Dryer is strongly recommended for the fish species like Pomfrets, Ribbon fish, Bombay duck, Seabass, Redsnappers etc and this technology is also highly recommended for Small & Medium Entrepreneurship (SME) in the high quality export oriented fish drying sector. Further research works are needed to develop more advanced technique as well as suitable dryers for low priced fishes.

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