Fishery Technology 62 (2025) : 482 - 489

Technological Interventions and Quality Improvements of Dry Fish Products Through Demonstration Using a Solar-Electrical Hybrid Dryer in the Aspirational Districts of Assam

Bipul Kumar Kakati*, Inam Akhtar Hussain, Pranjyoti Sarma, Pradip Chandra Bhuyan, Nandita Barman, Hadi Ud Zaman and Irshadul Haque
College of Fisheries, Assam Agricultural University, Raha, Nagaon, Assam - 782103, India

Abstract

A hygienic dry fish preparation process using a solar-electrical hybrid dryer and packaging of dry fish products was demonstrated among 200 beneficiaries for the first time in four locations of two aspirational districts of Assam. Technology Demonstration Centres were established in the vicinity of the community involved in fish drying, with all necessary facilities at four selected locations for conducting demonstrations on hygienic fish drying and packaging. The standardization of the preparation process for dry fish products using the solar-electrical hybrid dryer was accomplished for the various fish species available in the region. Good-quality dry fish were produced following scientific interventions within 3–7 hours based on fish species used, instead of 3–4 days in traditional sun-drying methods. All problems associated with traditionally prepared dry fish products, like rancid odour, insect infestation, and contamination with dust and other contaminants, were solved with these interventions. The hygienically prepared and packaged dry fish were marketed in both rural and urban markets, including a few shopping malls, at a higher price (Rs. 550–750 per kg compared to Rs. 250–350 per kg), which was not possible earlier due to their inferior quality. After undergoing training and demonstration, the beneficiaries exhibited a heightened level of confidence in their ability to prepare hygienic dry fish products using solar-electrical hybrid dryer. Almost 70% of the selected beneficiaries adopted the technology demonstrated for their livelihood generation using the facilities created for them. The use of the solar-electrical hybrid dryer helped in increasing productivity and income of the producers, minimizing the waste and spoilage of fish during the peak harvesting period, thus helping to prevent protein loss as they could dry fish at any time.

Keywords: Hygienic Dry fish products, solar-electrical hybrid dryer, quality, packaging, livelihood, aspirational district, Assam

Introduction

Fisheries and aquaculture play a significant role in enhancing the socio-economic situation in Assam. The state possesses a vast expanse of aquatic resources, spanning approximately 4.9 lakh hectares. Consequently, the fisheries sector holds immense potential for addressing poverty, ensuring adequate nutrition, and offering affordable and healthy diets to the population of Assam. It is worth noting that over 95% of the people in the Northeastern part of India consume fish, with more than 80% of them enjoying dry fish products. The demand for dried fish in the region, coupled with its importance in the local diet, has resulted in the establishment of one of Asia's largest dry fish markets in Jagiroad, located in the Morigaon district of Assam. However, the locally produced dried fish, which are prepared using traditional methods, fail to command a high demand and fetch lower prices due to their inferior quality, characterized by rancid odour, insect infestation, the presence of dust,

Received 07 October 2024; Revised 22 October 2025; Accepted 24 October 2025

Handling Editor: Dr. Remya S.

**E-mail: bkkakati@gmail.com*

substandard packaging, and limited shelf life. Despite possessing significant nutritional value, traditional dry fish products are still perceived as a poor man's food due to their poor sensory qualities. Consequently, they have not been able to penetrate the urban markets of the region. These issues can be solved by the use of solar dryers, which result in shorter drying time, improved product quality, and require less area than traditional open sun drying.

At present, there are many mechanical dryers, solar-electrical hybrid dryers, solar tunnel dryers, solar-LPG dryers, and infrared dryers of different capacities available in the market (Delfiya et al., 2024). The performance evaluation and demonstrations of these dryers have been carried out for different aquatic organisms under different climatic conditions and were found to be suitable for operation in farmers' fields (Murali, Amulya, Alfiya, Delfiya, & Samuel, 2020; Cisni, Neethu, Murali, Delfiya, & Ninan, 2023; Delfiya et al., 2024). A skill development training on hygienic fish and shellfish drying using a 10 kg capacity ICAR-CIFT solar-cum-electric backup dryer was conducted among 50 women from two coastal districts of Nagapattinam (Tamil Nadu) and Karaikal (Puducherry). The adoption of this dryer significantly enhanced profitability, energy efficiency, and sustainability for small-scale fish processors, fostering a positive social impact (Chandrasekar, Mohanty, Geethalakshmi, & Gopal, 2025).

The current investigation was undertaken in order to standardize the preparation process for the production of hygienic dry fish products of better organoleptic and nutritional quality using a solar-electrical hybrid dryer (SEHD) for the first time in Assam. The SEHD was designed to utilize solar energy for drying and is supplemented with an electric heating coil to operate during off-sunshine hours. The use of solar dryers during cloudy or rainy days can be ensured by supplementary heating sources (heating coils, biomass backup, etc.). The maximum collector temperature obtained during operation of the dryer reached 64.4 °C with an average incident radiation of 710 W/m² (Cisni et al., 2023). The use of this dryer will help enhance productivity and commercialization of the prepared and packaged dry fish products in the Northeastern region of India for income generation and livelihood improvement of the fisher community.

Materials and Methods

Four sites were identified within two aspirational districts, namely Barpeta and Baksa districts in Assam, based on the potential for dry fish production and marketing. Among these sites, two locations, namely Errartari Gaon and Kawaimari 7 No. Block in the Pakabetbari Development Block of Barpeta Sub-division were chosen. Additionally, two other locations, Kokalabari in the Barama Development Block and Kataligaon in the Baksa Development Block, were selected within the Bodo Territorial Area District (BTAD), Assam. A total of 200 beneficiaries (50 from each site) were selected from the two aspirational districts. Beneficiaries were chosen based on their involvement in fish drying and marketing activities with the help of officials from the Department of Fisheries, Government of Assam. In addition, rural youth, school dropouts, and rural women were also considered as beneficiaries for the demonstration programme. Almost 90% of the selected beneficiaries belonged to SC and ST communities, within the age group of 23–60 years. The educational qualification of the beneficiaries ranged from primary to higher secondary level.

Drying fish under open sun using bamboo platforms is the traditional method used in the region. Freshly caught fish intended for drying were washed in water and subsequently arranged on bamboo platforms or, occasionally, directly on mats placed on the ground. The fish were subjected to solar exposure for 3 to 4 days, depending on prevailing weather conditions. During drying, the fish were turned upside down to expedite the process. The dried fish were packed in gunny bags for storage. Although sun-dried fish products were economically advantageous, the method was accompanied by several drawbacks, including a slow drying rate, potential unhygienic conditions, the presence of contaminants in the final products (such as sand and dust), substandard quality characterized by rancid odours and insect infestations, inadequate packaging, limited shelf life, and low market value.

Four Technology Demonstration Centres were established at the selected sites. These centres were located in the vicinity of the fishing community/beneficiaries to ensure maximum utilization of the facilities created for them. Arrangements for hygienic handling of raw materials, production of hygienic dry fish products, and packaging of the prepared products were made at the centres so that all scientific interventions could be demonstrated among the beneficiaries. The solar-electrical hybrid dryer (40–50 kg capacity), which was designed and developed by ICAR–Central Institute of Fisheries Technology (CIFT), Cochin, and marketed by Kraftwork Solar Pvt. Ltd., Kochi, was installed successfully at all the locations for the first time in the state of Assam. All other essential materials and facilities, such as water supply systems, fish dressing tables, weighing balances, impulse sealers, and utensils, were provided in each centre.

Fresh fish for drying and salt for brining were procured from the local markets in the designated areas. The primary sources of fish for demonstration were predominantly Charan Beel, Kokalabari Gangor Beel, Dabari Bundh in Baksa district, as well as Rowmari Beel, Bahuatapa Beel, and Jalkora Beel in Barpeta district.

Five popular dry fish products prepared traditionally at the experimental sites and samples from three products prepared using the solar-electrical hybrid dryer were collected for analysis of proximate composition, biochemical, microbiological, and sensory quality to determine the status of the products. Samples were packed in polybags aseptically and brought to the laboratory for analysis. Proximate composition, viz., moisture, crude protein, crude fat, and ash content of dry fish product samples, was determined by AOAC (2016) methods. Standard methods were used for the determination of peroxide value (PV) by Jacobs (1958), free fatty acids (FFA) following the method described by Olley and Loveren (1960), titratable acidity (TA) and non-protein nitrogen (NPN) by AOAC (2016) methods, and total volatile base nitrogen (TVB-N) by using Conway's micro diffusion method (Conway, 1947). pH was measured using a Systronics digital pH meter.

An amount of 10 g of muscle from different parts of the dry fish samples was collected aseptically and macerated with 90 mL sterile saline. The microbial quality of the samples was determined after making serial dilutions using the methods of USFDA (2001) and APHA (2001). Microbial quality was assessed by determining the total plate count, *Escherichia coli* count, faecal *Streptococci*, *Staphylococcus aureus*, and *Salmonella* spp. Potato dextrose agar was used for the isolation of yeasts and moulds by the pour plate method.

Sensory evaluation of the dry fish products was carried out using the 9-point hedonic scale by a trained taste panel consisting of 10 members. The sensory quality of the samples was judged for appearance, colour, texture, odour, and overall acceptability, following the methods described by Siddaiah, Reddy, Raju, and Chandrasekhar (2001).

Results and Discussion

A total of eight awareness programmes and forty-seven training and demonstration programmes were conducted batch-wise (15 beneficiaries per batch) for 200 selected beneficiaries from four locations of two aspirational districts on the preparation of hygienic dry fish products using a solar-electrical hybrid dryer for the first time in the state. The processing steps imparted for drying fish hygienically in a solar-electrical hybrid dryer are presented in Fig. 1. After undergoing training and witnessing demonstrations, the beneficiaries exhibited a heightened level of confidence in their ability to prepare hygienic dry fish products using a solar-electrical hybrid dryer. This was accomplished by adhering to scientific protocols, effectively resolving numerous issues commonly associated with traditionally prepared dry fish products, such as rancid odour, insect infestation, dust contamination, and the use of substandard packaging materials. The beneficiaries also developed a comprehensive understanding of the significance of each step involved in the hygienic fish drying process. Additionally, they acquired the necessary knowledge and skills to operate and maintain both the dryer and the packaging machine.

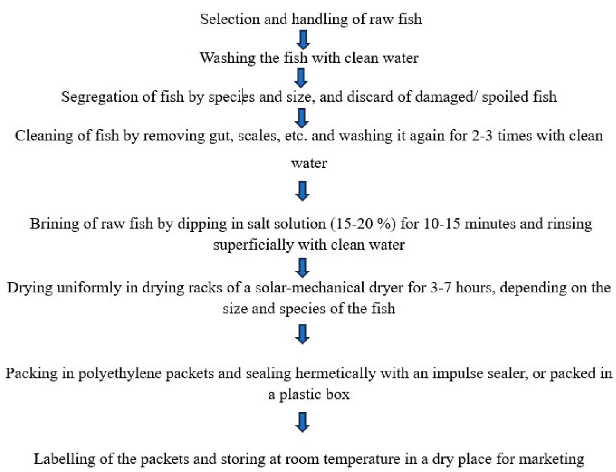

Fig. 1. Processing steps imparted while drying fish hygienically in a solar-electrical hybrid dryer

The raw fish selected for drying were thoroughly washed with clean water two to three times to eliminate insects or impurities. In accordance with proper protocol, the fish were dressed within 1 to 2 hours before the drying procedure. In selected cases, after dressing and cleaning, the fish were stored in a deep freezer to prevent oxidation or quality deterioration before drying. All small and medium-sized fish available locally were used for drying. Among the species, mainly *Amblypharyngodon mola*, *Puntius spp.*, and fingerlings of carps were dried using the solar-electrical hybrid dryer in the Technology Demonstration Centres.

The dressing process involved categorizing the fish by species and size and removing any spoiled fish from the batch. Larger fish were cut into smaller, uniform pieces to ensure even drying, following the removal of scales, fins, and gut. For smaller fish, thorough gut cleaning was essential to prevent bitterness and odour. Once the undesired parts were removed, the fish were washed with clean water 2–3 times. Subsequently, they were immersed in a salt solution (15–20%) for 10–15 minutes to reduce microbial load and enhance textural quality. This step also helped reduce the moisture content of the final products (POP, 2017).

After brining, the fish were placed properly on trays in the dryer and dried in a pre-heated chamber at 50–55 °C. The drying duration varied between 3 and 7 hours. The moisture content of shrimps could also be reduced from 76.71% (w.b.) to 15.38% (w.b.) within 6 hours using a solar-LPG hybrid dryer (Murali et al., 2020). The variation in drying time might be due to differences in composition (fat and

Table 1. Standardization of drying process for different fish species in solar-electrical hybrid dryer

Parameters	Activities performed under the project	Remarks
Peak drying period of fish	September - March	Though dry fish can be prepared throughout the year in a mechanical dryer, the fish drying was mostly carried out during September–March every year as the raw material availability is more in this period in the region.
Species mostly used for drying in the project sites	*Mola, Puthi,* Fingerling of carps	These species were abundantly available in the project sites. However, all types of fish of different species and sizes can be dried in the dryer.
Time requirement for drying of fish	*Mola:* 3 - 3.5 hours *Puthi*: 5-6 hours Fingerling of Carp: 6-7 hours	The time required for drying of fish varies based on the fat content, moisture content and size of the fish species.
Temperature maintained during fish drying in the dryer	50 – 55 °C	The temperature of the dryer depends on the intensity of the sunlight. However, if the sunlight is less, the electric heaters of the dryer are used to maintain the temperature at the desired level for proper drying.
Fresh fish required to get one kg of dry fish product	*Mola*: 4.5 kg -5.0 kg *Puthi*: 3.5 kg – 4.0 kg Fingerling of Carp: 3.5 kg – 4.0 kg	The raw materials requirement for per kg production of dry fish in the scientific method was more due to the removal of scale and gut content of fish during dressing to improve the quality of the end products. In traditional methods, 3 kg of raw fish is sufficient to produce 1 kg dry fish.
Packaging of dry fish	Packaging of dry fish was done using polythene bags of different capacities (50g, 100g, 200g, 500g) and plastic boxes (100g & 200g)	Different poly packs and plastic boxes were tried to check the consumer preference, and a 100g pack of both the types was mostly preferred by the consumers.
Benefit-cost ratio of the dry fish products (B: C ratio)	*Dry Mola:* 1.67: 1 *Dry Puthi:* 1.95 :1 Dry Carp Fingerling:1.77 :1	BC ratio mainly depends on the cost of raw materials locally, as it may vary from location to location.

moisture content) and size of fish species (Clucas & Ward, 1996). After uniform drying, trays were removed and cooled properly before packaging.

Packaging was done in polyethylene bags and plastic boxes of various capacities (50 g, 100 g, 200 g, and 500 g) depending on fish size and variety. Labels included manufacturing date and place, quantity per packet, and the organization involved in drying, which helped attract and build buyer's trust.

The preparation process for hygienic dry fish products using solar-electrical hybrid dryer was standardized for the various fish species available in the region. This dryer was used for the first time in the state. Both small and medium-sized freshwater species were dried, and the required duration for drying different fish sizes was examined repeatedly. It was determined that 3–7 hours at 50–55 °C were needed to obtain high-quality dry fish products, compared to 3–4 days in traditional methods. The beneficiaries were educated on hygienic dry fish

Table 2. Quality analysis of traditionally prepared dry fish products collected from experimental sites

Parameters N=5 nos.	Dry fish product samples collected from different project sites				
	Amblypharyngodon mola	*Puntius* spp.	*Mystus gulio*	*Pseudeutropius atherionoides*	*Corica soborna*
Proximate composition					
Moisture (%)	16.80 ± 0.55	17.50± 0.95	19.55± 0.75	13.85 ± 1.20	11.45 ± 0.55
Crude protein (%)	53.45 ± 0.68	52.55± 0.55	56.60± 1.23	54.64 ± 0.66	56.65 ± 0.74
Crude fat (%)	15.20 ± 0.85	12.25± 1.05	14.25± 1.15	18.50 ± 0.91	16.20 ± 1.14
Ash (%)	13.25 ± 1.02	12.45± 0.76	9.45± 0.55	14.70 ± 0.37	14.15 ±0.56
Biochemical parameters					
Non-protein nitrogen, (%)	2.3 ± 0.78	2.5 ± 0.68	2.4 ± 0.18	1.9 ± 0.26	2.3 ± 0.19
Total volatile base nitrogen, (mg%)	67.20 ± 1.10	105.50± 0.65	98.54 ± 1.75	90.65 ± 1.10	99.80 ± 0.88
Peroxide value (meq O_2/kg of fat)	35.40 ± 1.35	31.36± 0.40	28.55 ± 1.75	42.30 ± 0.86	77.45 ±1.30
Free fatty acids (% as oleic acid)	41.3 ±1.20	42.25± 0.83	37.6 ± 1.84	49.15 ± 0.77	56.00 ± 1.23
Ph	6.3 ± 0.01	6.5 ± 0.02	6.4 ± 0.02	6.3 ± 0.02	6.4 ± 0.01
Microbiological quality					
Total plate count (log cfu/g)	4.0	3.7	4.2	4.4	4.1
Yeast and mold (log cfu/g)	1.7	1.2	1.0	1.2	1.0
Staphylococcus aureus (log cfu/g)	1.8	2.5	2.1	2.6	1.8
E. coli (log cfu/g)	<1.0	<1.0	1.0	1.0	<1.0
Sensory Quality					
Appearance	7.0 ± 0.85	7.0 ± 1.22	6.5 ± 0.90	6.0 ± 1.30	7.2 ± 1.05
Colour	7.4 ± 0.75	6.8 ± 0.95	5.8 ± 1.10	5.5 ± 1.65	6.0 ± 0.85
Texture	7.0 ± 1.30	6.6 ± 0.85	6.0 ± 1.50	5.9 ± 1.70	6.7 ± 1.40
Odour	6.8 ± 0.55	6.8 ± 0.40	6.2 ± 0.65	5.7 ± 0.90	7.0 ± 1.30
Overall Acceptability	7.0 ± 0.25	6.8 ± 0.40	6.2 ± 0.45	6.1 ± 0.60	6.9 ± 0.70

Streptococcus species and *Salmonella* species were absent in the products.

preparation and packaging, including fish collection, handling, transportation, washing, brining, arranging fish on trays, drying duration, and hygienic packaging. The technology was standardized for small fish species such as Mola carplet (*Amblypharyngodon mola*), Puthi (*Puntius spp.*), and fingerlings of Indian Major Carps (*Labeo rohita* and *Cirrhinus mrigala*).

In the traditional rack-drying method, about 3 kg of fresh fish produced 1 kg of dry fish. However, in the hygienic preparation method, the requirement was slightly higher due to loss of weight from gut and scale removal before drying (Table 1). The quantity of fresh fish required for Mola, Puthi, and IMC fingerlings to produce 1 kg of dry fish was 4.5–5.0 kg, 3.5–4.0 kg, and 3.5–4.0 kg, respectively. The drying duration in the solar-electrical hybrid dryer for these species was 3.0–3.5 h, 5–6 h, and 6–7 h, respectively. Similar results were reported by Murali et al. (2020). Moisture content in traditionally dried fish (11.45–19.55%) was higher than that in fish dried using the solar-electrical hybrid dryer (7.80–12.63%), which made the products stable during storage. The present study revealed that the moisture content of the products was lower than BIS standards, which prescribe 10–35% for small fish and 40–45% for large fish (Gopakumar & Devadasan, 1982).

Fish drying was mostly carried out during September to March, when raw material availability was higher. During Katal/Jeng fishing (a popular fish aggregating method of Assam) in wetlands (Beels),

Table 3. Quality analysis of dry fish prepared in solar-electrical hybrid dryer

Parameters n= 5 nos.	Dry fish product samples collected from different project sites		
	Amblypharyngodon mola	*Puntius* spp.	Fingerlings of carp
Proximate composition			
Moisture (%)	7.80 ± 0.32	12.21 ± 0.81	12.63 ± 0.62
Crude protein (%)	57.65 ± 0.34	55.85 ± 0.63	56.60 ± 0.43
Crude fat (%)	12.32 ± 0.43	13.25 ± 1.01	11.25 ± 2.43
Ash (%)	19.71 ± 1.32	17.49 ± 0.43	17.11 ± 1.32
Biochemical parameters			
Non-protein nitrogen (%)	1.2 ± 0.22	1.1 ± 0.24	1.4 ± 0.13
Total volatile base nitrogen (mg%)	25.13 ± 0.23	27.43 ± 0.42	31.45 ± 0.51
Peroxide value (meq O_2/kg of fat)	23.33±0.28	30.43 ± 0.20	24.75 ± 0.35
Free fatty acids (% as oleic acid)	5.64±0.74	8.31 ± 0.83	6.54 ± 0.71
pH	6.5 ± 0.02	6.7± 0.04	6.4 ± 0.02
Microbiological quality			
Total plate count (log cfu/g)	2.0	2.3	2.6
Yeast and mould (log cfu/g)	<1	<1	<1
Sensory Quality (Rating as per 9-point hedonic scale)			
Appearance	8.37 ± 0.35	8.15±0.25	8.00±0.15
Colour	8.50 ± 0.15	8.30±0.25	8.10±0.51
Texture	8.10 ± 0.28	8.21±0.54	7.90±0.39
Odour	8.40 ± 0.55	8.20±0.33	8.13±0.47
Overall Acceptability	8.20 ±0.20	8.10±0.13	8.10±0.28

rivers, and tributaries, large quantities of small and medium-sized fish were caught. However, due to lack of preservation and transport facilities, much of the harvest was traditionally dried at the site using bamboo racks or mats, resulting in poor-quality products. Often, fishermen discarded fish due to spoilage, leading to financial losses and wastage of quality protein.

Five popular traditionally dried fish products, *A. mola*, *Mystus gulio*, *Puntius spp.*, *Pseudeutropius atherionoides*, and *Corica soborna*, were collected for proximate, biochemical, microbiological, and sensory quality analysis. The traditionally prepared products had good nutritional value (Table 2). Kakati, Sharma, and Goswami (2017) also reported similar protein values (52.20–58.30%) in small indigenous dry fish species in Assam. Sensory evaluation revealed lower overall acceptability. Although *Streptococcus* and *Salmonella* species were absent (a positive sign), the presence of *S. aureus* and *E. coli* indicated unhygienic handling during processing and storage (Table 2). Vijayan and Surendran (2012) similarly reported poor quality of dried fish in Northeast India, with significant health and hygiene issues.

The hygienically prepared dry fish products showed higher protein concentration (56.60–57.65%) compared to traditional samples. Sharma, Kashyap, and Goswami (2013) reported comparable protein contents (54.20%, 50.34%, and 60.24%) for different types of hygienically produced dry *Gudusia chapra*. The moisture content (7.80–12.63%) was lower than that of traditionally dried fish (11.45–19.55%), enhancing product stability during storage (Table 3), and the values were within acceptable limits (Gopakumar & Devadasan, 1982).

Organoleptic evaluation by a 10-member expert panel using a 9-point hedonic scale showed high acceptability scores (8.1–8.2). The rancid odour was completely absent, and the appearance and colour were excellent, increasing consumer appeal. The texture was slightly hard, but later rectified by adjusting drying time and temperature.

The total plate count of the products (2.0–2.6 log cfu/g) was well within acceptable limits (<5.0 log cfu/g) (ICMSF, 1986). With hygienic drying and good packaging, the moisture content remained within 7.80–12.63%, inhibiting microbial growth (Table 3). Drying times for Mola, Puthi, and carp fingerlings (Rohu, Mrigal) were 3 h, 5 h, and 7 h, respectively, at 50–55 °C. Drying time varied depending on fat and moisture content and fish size (Bala & Mondol, 2001).

The skilled beneficiaries have been producing hygienic dry fish products of good nutritional and organoleptic quality, fetching more than double the market price (Rs. 550–750 per kg) compared to traditionally prepared dry fish (Rs. 250–350 per kg), thereby increasing income. With the ICAR-CIFT solar-electrical hybrid dryer, beneficiaries could dry fish within 3–7 hours instead of 3–4 days, improving productivity. The use of the solar-electrical hybrid dryer minimized waste and spoilage during the peak harvest period, thereby preventing protein loss. The packaged dry fish products had better marketing potential, longer shelf life, and higher consumer acceptance. To promote these products in urban markets, market linkages were established with wholesalers, FPCs, and government agencies. The hygienically prepared and packaged dry fish products were successfully marketed in urban malls, unlike traditional ones that had a rancid odour.

Marketing channels established included:

(i) Producer group of TDC —> Retailers

(ii) Producer group of TDC —> Wholesalers —> Retailers/shopping malls

(iii) Producer group of TDC —> FPC group (Assembler) —> Retailers

About 70% of beneficiaries are regularly engaged in hygienic dry fish production and marketing. Moreover, the quality dry fish products were also used to prepare dry fish powder for nutrition programmes for children and pregnant/lactating women in Anganwadi Centres in Assam under a pilot project.

The introduction of the solar-electrical hybrid dryer for quality dry fish production in the region was the need of the hour to meet consumer demand and overcome the challenges of traditional drying. Almost all 200 beneficiaries are now skilled in using the dryer, and about 70% are engaged in regular production and marketing through local markets and agencies. The benefit-cost ratio (1.67–1.95), depending on species, was encouraging for enterprise development. The participants have realized the potential of hygienic dry fish production for nutrition and livelihood improvement. However, irregular power supply in rural areas sometimes creates problems during drying, especially in bad weather. This may be addressed in future studies by integrating the dryer with solar power backup. Marketing strategies should be developed for better commercialization across consumer segments. Some consumers were reluctant to pay higher prices due to limited awareness of product quality. Improved packaging and stronger market linkages could expand commercialization to international markets. The bilateral agreement between Southeast Asian countries and the Government of India to revive the Stillwell Road (from Ledo in Assam to Kunming in China) could potentially make Assam a future hub for international trade in dry and cured fish products.

Acknowledgement

The authors thank the Department of Biotechnology (DBT), Ministry of Science and Technology, Government of India, New Delhi, for funding the project under which this work was carried out (BT/PR30793/SPD/9/1321/2018; Dated: 11/02/2019). The assistance received from the FDOs of the offices of the District Fisheries Development Officers and fish farmers of Barpeta and Baksa districts is also sincerely acknowledged.

References

AOAC. (2016). *Official methods of analysis* (17th ed.). AOAC International.

APHA. (2001). *Compendium of methods for the microbiological examination of foods*. American Public Health Association.

Bala, B. K. & Mondol, M. R. A. (2001). Experimental investigation on solar drying of fish using solar tunnel dryer. *Drying Technology*, *19*(2), 427-436. https://doi.org/10.1081/DRT-100102915.

Chandrasekar, V., Mohanty, A. K., Geethalakshmi, V., & Gopal, N. (2025). Empowering women through CIFT solar-electric backup fish dryers: Enhancing livelihoods and environmental sustainability in the coastal districts of Nagapattinam and Puducherry. *Fishery Technology*, *62*(3), 395–400.

Cisni, F. M., Neethu, K. C., Murali, S., Delfiya, D. S. A., & Ninan, G. (2023). Design and development of solar-electrical hybrid dryer and its performance evaluation using shrimps. *Biomass Conversion and Biorefinery*, *14*(20), 25343-25356. https://doi.org/10.1007/s13399-023-04651-6.

Clucas, I. J. & Ward, A. R. (1996). *Post-harvest fisheries development: A guide to handling, preservation, processing, and quality.* Natural Resources Institute.

Conway, E. J. (1947). Micro diffusion analysis and volumetric error. Crossby, Lockwood and Sons Ltd.

Delfiya, D. S. A., Mathai, L., Murali, S., Neethu, K. C., Nair, A. R., & Ninan, G. (2024). Comparison of clam drying in solar, solar-hybrid, and infrared dryer: Drying characteristics, quality aspects, and techno-economic analysis. *Solar Energy*, *274*, Article 112554. https://doi.org/10.1016/j.solener.2024.112554.

Gopakumar, K. & Devadasan, K. (1982). The fish curing industry in India. In D. James (Ed.), *The production and storage of dried fish* (FAO Fisheries Report No. 279, pp. 63–68). Food and Agriculture Organization of the United Nations.

International Commission on Microbiological Specifications for Foods [ICMSF]. (1986). *Microorganisms in foods, Sampling for microbiological analysis: Principle and specifications.* University of Toronto Press.

Jacobs, M. B. (1958). *The chemical analysis of foods and food products*. New York Krieger Publishing Co. Inc.

Kakati, B. K., Sharma, P., & Goswami, U. C. (2017). Quality evaluation of dried fish products commerce in Assam, India. *International Journal of Advanced Biological Research*, *7*(3), 465-469.

Murali, S., Amulya, P. R., Alfiya, P. V., Delfiya, D. S. A., & Samuel, M. P. (2020). Design and performance evaluation of solar-LPG hybrid dryer for drying of shrimps. *Renewable Energy*, *147*(1), 2417-2428. https://doi.org/10.1016/j.renene.2019.10.002.

Olley, J., & Loveren, J. A. (1960). Phospholipid hydrolysis of cod flesh stored at various temperatures, *Journal of the Science of Food & Agriculture*, *11*(11), 644-652. https://doi.org/10.1002/jsfa.2740111109.

POP. (2017). Preparation of hygienic dry fish. In *Package of Practices on Fisheries and Aquaculture in Assam* (pp: 166-168). Directorate of Fisheries, Govt. of Assam.

Sharma, P., Kashyap, D., & Goswami, U. C. (2013). Preparation and storage of salted and dried products of freshwater fish, *Gudusia chapra* (Hamilton, 1822). *The Bioscan*, *8*(2), 455-458.

Siddaiah, D., Reddy, G. V. S., Raju, C. V., & Chandrasekhar, T. C. (2001). Changes in lipids, proteins and kamaboko forming ability of silver carp (*Hypothalmicthys molitrix*) mince during frozen storage, *Food Research International*, *34*(1), 47-53. https://doi.org/10.1016/S0963-9969(00)00127-7.

USFDA. (2001). *Bacteriological analytical manual* (8^{th} ed., rev.) U.S. Food and Drug Administration.

Vijayan, P. K., & Surendran, P. K. (2012). Quality aspects of dried fish marketed in the Northeastern states of India. *Fishery Technology*, *49*(1), 167-171.