Fishery Technology 62 (2025) : 395 - 400

Empowering Women through CIFT Solar-Electric Backup Fish Dryers: Enhancing Livelihoods and Environmental Sustainability in the Coastal Districts of Nagapattinam and Puducherry

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Abstract

The fisheries sector plays an important role in generating income and employment among the coastal population, especially for women from economically weaker sections of society. Skill development training on hygienic fish and shellfish drying using solar-cum-electric backup dryer has the potential to facilitate self-employment, particularly in rural areas where other employment avenues are scarce. A survey was conducted among 50 women beneficiaries who participated in the hands-on training cum demonstration program organized by the ICAR-CIFT, collaboration in and installed solar dryer with KVK Sikkal, Nagapattinam district of Tamil Nadu and KVK-Madur, Karaikal, Puducherry, where solar dryers were also installed. The economics of operating the 10 kg capacity solar-cum-electric backup dryer were assessed, considering the capital investment. Income from the hygienic drying processes of locally available fishes (mackerel, ribbon fish and anchovy) and shellfish (Shrimp), following strict protocols on cleaning, drying, packaging and marketing the dried fish and shellfishes to nearby markets as well as through KVK sale counters, was estimated at ₹21,093 per household per annum. Since the dryer can be operated by both electric and solar power, it helps save electricity consumption worth ₹10,125 per annum, depending on the number of sunny days in the region.

Received 15 November 2023; Revised 6 May 2025; Accepted 7 May 2025

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Gender in Aquaculture and Fisheries: Paper Presented at GAF8 - Shaping the Future: Gender Justice for Sustainable Aquaculture & Fisheries

Keywords: Solar cum electric dryer, drying fish and shellfish, income & employment.

Introduction

The fisheries sector plays a crucial role in providing income and employment, particularly for women among coastal communities, and underpins their socio-economic well-being (Patel & Sethi, 2022). Dried fish is a significant contributor to food and nutritional security, providing essential micronutrients like calcium (Pradhan, Nayak, & Haque, 2023). However, traditional open sun-drying methods often present challenges, leading to unhygienic products and other environmental concerns such as contamination from dust and pests, improper waste disposal, the plastic sheet usage, and exposure to pollutants from surrounding activities. (Joshua & Vasu, 2012).

The ICAR-CIFT has developed an innovative and environmental friendly technology for drying fish and shellfish using renewable. Solar power and is found to reduce carbon emissions and improves hygiene (Chaudhari & Salve, 2014). The adoption of hygienic drying practices using solar-cum-electric backup dryers has the potential to foster economic independence, especially in rural areas where alternative employment opportunities are limited.

The coastal districts of Nagapattinam (Tamil Nadu) and Karaikal (U.T. of Puducherry), where fisheries are central to the local economy and communities depend on abundant fish resources, dried fish is also particularly important for food security during the off-season and monsoon period. Women play a vital role in fish drying but often face challenges related to limited resources and income. This study examines the impact of a training and demonstration program, conducted in partnership with Krishi

Vigyan Kendras (KVKs) in Nagapattinam and Karaikal, aimed at empowering women through the adoption of improved fish-drying practices. As part of a memorandum of understanding between ICAR-CIFT and coastal KVKs, solar-cum-electric backup fish dryers were installed at the KVKs for technology demonstration and skill-based training. This study analyzes the potential of these interventions on livelihood and the environment.

Materials and Methods

This study assessed the impact of improved fish-drying practices on the livelihoods of women in the coastal districts of Nagapattinam and Karaikal. Fifty women actively involved in fish drying (25 from each district) participated in the study. These women received training on the operation of ICAR-CIFT solar-cum-electric backup fish dryers installed at the Krishi Vigyan Kendras (KVKs) in their respective districts. In both districts, the 25 women operated the two dryers in coordinated groups, taking turns to clean, load, monitor, and collect the dried fish. This rotational use, guided by the KVKs, ensured efficient dryer utilization and promoted the hygienic practices learned during training.

The methodology involved a comprehensive survey to evaluate the adoption of solar dryers and their economic impact. The women procured fish from local landing centres, processed it using the solar-cum-electric backup dryers installed in their respective KVKs, and then packaged and marketed the dried fish products.

An economic analysis was conducted, focusing on the operation of a 10 kg capacity hybrid solar dryer. Key parameters considered included operational days, drying duration, fish prices, handling capacity, and dry weight percentage. The analysis included the following that took into consideration the cost of inputs like fish, salt, packaging materials besides costs incurred on marketing, repair, maintenance, electricity, and miscellaneous expenses.

Cost-Benefit Analysis (CBA) Model

A cost-benefit analysis (CBA) was employed to evaluate the economic viability of implementing solar-cum-electric backup fish dryers. The CBA compared the present value of the project's anticipated benefits with the present value of its associated costs. The general formula for calculating the Net Present Value (NPV) is as follows:

$$\mathrm{NPV} = \sum_{t=0}^{n} \frac{(B_t - C_t)}{(1 + r)^t}$$

Where:

NPV = Net Present Value, which represents the difference between the present value of benefits (B_t) and costs (C_t) over a specified time period.

B_t = Benefits in time period t

C_t = Costs in time period t

t = Time period (e.g., years)

r = Discount rate

The benefits (B_t) can include additional household income generated from improved fish-drying practices, cost savings from reduced electricity consumption, and any other positive impacts. The costs (C_t) encompass expenses related to training, equipment, maintenance, and operational costs.

Benefit/cost ratio (BCR)

The BCR was calculated using the following formula:

$$\mathrm{BCR} = \frac{\sum_{t=0}^{n} \frac{B_t}{(1 + i)^t}}{\sum_{t=0}^{n} \frac{C_t}{(1 + i)^t}}$$

A BCR greater than 1 indicates that the benefits outweigh the costs, making the project economically viable.

Internal rate of return (IRR)

The IRR is the discount rate at which the Net Present Value (NPV) is zero (Fig. 2). It represents the annualized return on investment and can be used to compare the return with alternative investment opportunities (Poonia, Singh, Santra, & Jain, 2019). For normal investment cash flows, the NPV curve typically slopes downward from left to right as the discount rate increases. At a certain point, the curve intersects the horizontal axis, where the NPV equals zero. The discount rate at this point is known as the Internal Rate of Return (IRR). To determine the viability of the project, the calculated IRR was compared with the required rate of return (r). If the IRR was greater than or equal to r, the investment (e.g., solar dryer installation) was considered economically viable and expected to generate sufficient returns. If the IRR was less than r, the project was deemed financially unfeasible, as it would yield lower returns compared to alternative investment opportunities.

The formula for estimate of IRR using linear interpolation is:

$$IRR = r_1 + \left(\frac{NPV\ r_1}{NPV\ r_1 - NPV\ r_2} \right) \times (r_2 - r_1)$$

r_1 = Lower Discount Rate

r_2 = Higher Discount Rate

NPV r_1 = NPV at Lower Discount Rate

NPV r_2 = NPV at Higher Discount Rate

Payback Period

The payback period is the time it takes for the accumulated benefits to equal the initial investment. A shorter payback period indicates a quicker return on investment. This CBA framework will allow us to systematically evaluate the economic viability of skilling women in modern fish-drying practices, accounting for long-term costs and benefits.

Results & Discussion

In this study using the 10 kg capacity CIFT solar cum electric backup dryer revealed shrimp as the most efficient commodity, with the shortest drying time 10 hrs, highest annual output of (1600 ± 78.6 kg), and maximum dry fish yield (416 ± 21.8 kg) at a market price of ₹700/kg (Table 1). Ribbon fish showed moderate performance, while mackerel had the longest drying time and lowest yield. Dry yield remained consistent across species (25–26%). The study confirms the dryer's effectiveness in reducing drying time and increasing returns, especially for shrimp, supporting its adoption by small-scale and women entrepreneurs.

An economic viability analysis (Table 2) was carried out on the ICAR-CIFT solar-cum-electric backup dryer with a 10 kg capacity for fish drying, based on data collected from beneficiaries in Nagapattinam and Karaikal. The results indicated that the 10 kg solar dryer is the most advantageous investment

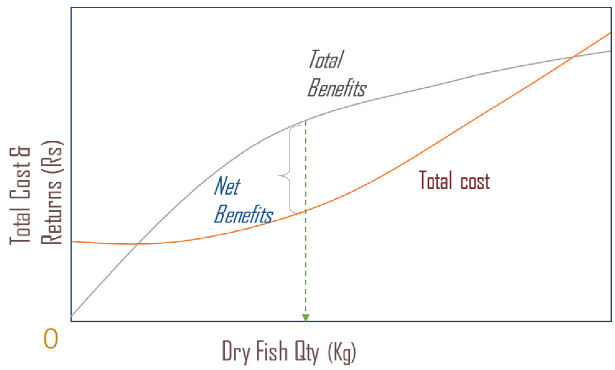

Fig. 1. Optimal net profit from total costs and returns in dry fish production

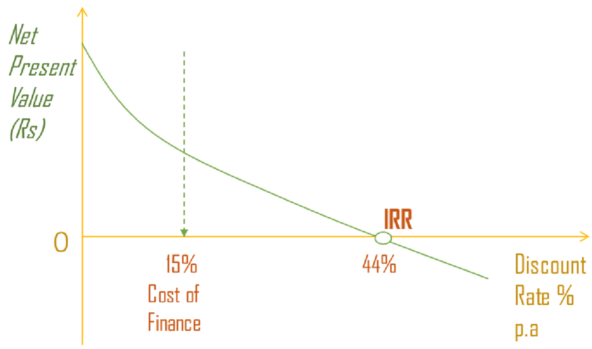

Fig. 2. Calculating Internal Rate of Return in dry fish production utilizing the ICAR-CIFT solar dryer

option for drying major fish and shellfish varieties like mackerel, ribbon fish, and shrimp. The total investment, which covers the cost of the solar dryer, installation charges, and government subsidies for the solar panel, remains constant at ₹75,000 across all fish types. For estimating the annual fixed costs, which is based on the beneficiaries' actual investment of ₹60,000 (excluding the ₹15,000 subsidy), was calculated at ₹6,000. The solar dryer is expected to have a lifespan of 10 years. Shrimp drying involved the highest operating cost ₹2.59 lakh, largely due to its high raw material cost of ₹2.4 lakh, while mackerel had the lowest cost of ₹67,469. Revenue from shrimp was the highest at ₹2.91 lakh, but due to high input cost, net profit after depreciation was lower at ₹19,623, compared to ribbon fish at ₹42,053 and mackerel at ₹8,231.

Notably, all three types of fish demonstrated positive net profits, indicating the financial viability of the solar dryer investment. Mackerel achieved the highest IRR (56%) and the shortest payback period (3 years), while both ribbon fish and shrimp had a

Table 1. Operational performance of 10 kg capacity CIFT solar cum electric backup dryer

Operational Parameters	Mackerel (₹ ± SE)	Ribbon Fish (₹ ± SE)	Shrimp (₹ ± SE)
Solar dryer operation days (8 hour/day)	3.1 (± 0.21)	2.3 (± 0.29)	1.3 (± 0.13)
Drying duration (hours)	25 (± 1.83)	18 (± 1.42)	10 (± 0.87)
Price of fish (₹/kg)	80 (± 4.6)	70 (± 3.7)	150 (± 9.2)
Fish handling capacity (kg)	10 (± 0.48)	10 (± 0.53)	10 (± 0.52)
Annual fish purchase quantity (kg, 200 days)	640 (± 32.5)	889 (± 45.2)	1600 (± 78.6)
Final dry weight yield (%)	25 (± 0.94)	25 (± 0.97)	26 (± 0.91)
Total dry fish produced (kg)	160 (± 9.6)	222 (± 12.4)	416 (± 21.8)
Market price of dry fish (₹/kg)	550 (± 28.5)	600 (± 32.2)	700 (± 35.6)

Table 2. Economic analysis on CIFT solar-cum-electric backup drier for fish and shell fish (10 kg capacity)

Investment Particulars	Mackerel (₹ ± SE)	Ribbon Fish (₹ ± SE)	Shrimp (₹ ± SE)
Capital Expenditure			
Cost of Solar drier including installation	75,000	75,000	75,000
Less: Government subsidy for solar panel cost	15,000	15,000	15,000
Net Capital Investment	**60,000**	**60,000**	**60,000**
Annual Fixed cost (Life span 10 years)	6,000	6,000	6,000
Operating Costs (Annual)			
Cost of fish	51200 (± 965)	62222 (± 1193)	240000 (± 4850)
Cost of salt	320 (± 17)	-	-
Packing (material & charges)	1600 (± 82)	2222 (± 115)	4160 (± 194)
Marketing (₹3/kg of dried fish)	480 (± 26)	667 (± 31)	1248 (± 58)
Repair and Maintenance (10% of capital)	7500 (± 325)	7500 (± 325)	7500 (± 325)
Electricity cost (750W heating coil)	5369 (± 193)	5369 (± 193)	5369 (± 193)
Miscellaneous	1000 (± 48)	1000 (± 48)	1000 (± 48)
Total variable cost	**67469 (± 2480)**	**78980 (± 3122)**	**259277 (± 7935)**
Total Cost per annum	**73469 (± 2715)**	**84980 (± 3438)**	**265277 (± 8125)**
Returns & Profitability			
Revenue from sale of Dried fish	88000 (± 3125)	133333 (± 4980)	291200 (± 9832)
Net Profit (after depreciation)	14531 (± 875)	48353 (± 1823)	25923 (± 1246)
Depreciation	6300 (± 287)	6300 (± 287)	6300 (± 287)
Net Profit	8231 (± 629)	42053 (± 1846)	19623 (± 1063)
Benefit-Cost Ratio (BCR)	1.34 (± 0.047)	1.28 (± 0.042)	1.09 (± 0.036)
Internal Rate of Return (IRR, %)	56 (± 1.9)	26 (± 1.3)	25 (± 1.3)
Net Present Value (NPV, ₹)	239381 (± 9735)	69253 (± 4120)	65424 (± 3975)
Payback period (years)	3 (± 0.17)	5 (± 0.28)	5 (± 0.28)

Note: Values within parentheses indicate ± standard deviation.

5-year payback. Positive NPV values (₹2,39,381 for mackerel, ₹69,253 for ribbon fish, and ₹65,424 for shrimp) imply positive net cash flows, affirming the positive economic impact. Mackerel drying showed the best financial viability BCR of 1.34, followed by ribbon fish at 1.28, and shrimp at 1.09. These findings suggest that while shrimp offers higher revenue, mackerel yields better returns on investment, making it ideal for small-scale processors.

The CIFT solar-cum-electric hybrid dryer saves 0.75 units of electricity per hour, reducing energy costs by ₹4.50 daily. Mackerel drying for 10 hrs/day saves 1,500 units/year (₹6,750), while ribbon fish and shrimp for 8 hrs/day save 1,200 units/year (₹5,400) (table 3). These savings reduce operating costs by 8–9%, thereby improving economic efficiency. Including energy savings, annual profits rise to ₹21,281 for mackerel, ₹53,753 for ribbon fish, and ₹31,323 for shrimp (table 4). Compared to electric-only drying, solar use increases profitability by ₹6,750–₹6,800, shortens payback periods, and enhances sustainability. The dryer proves effective for small-scale processors by lowering costs and improving profit margins through renewable energy integration.

The trained women entrepreneurs have a potential to sell dry fish worth ₹1.7 lakhs over 200 days, with an operational expenditure of about ₹1.35 lakhs for drying fish and shellfish using a solar dryer. The implementation of solar-cum-electric dryer gives women time to engage in other activities, such as agricultural labour to augment their income. This will result in an average profit of about ₹35,000 over 200 days, complemented by an additional annual income of ₹10,000 from MGNREGA. Following technological intervention, such as training on hygienic dry fish production and maintaining proper quality standards, these women now earn a total annual income of ₹45,000.

The hybrid solar-cum-electric backup dryer offers several advantages, including cost-effectiveness, increased efficiency, and versatility, serving as an income-generating tool for coastal fisheries households. It promotes hygiene and health, reducing fish losses, and fetching better prices for the products. This technology not only ensures hygienic drying but also leads to financial gains, increased income, and reduced debt among coastal rural women, thereby enhancing their livelihoods and contributing to greater economic resilience and food security.

In conclusion, the training and technological interventions, specifically the adoption of ICAR-CIFT solar-cum-electric backup fish dryers, have demonstrated a substantial positive impact on the economic outcomes of women entrepreneurs in the dry fish industry in Nagapattinam and Karaikal. The adoption of the 10 kg capacity CIFT solar-cum-electric hybrid dryer significantly enhances profit-

Table 3. Energy and cost savings from solar integration in CIFT hybrid dryer operations

Energy and Cost Savings	Mackerel (₹ ± SE)	Ribbon Fish (₹ ± SE)	Shrimp (₹ ± SE)
Operational hours per day	10 (± 0.87)	8 (± 0.79)	8 (± 0.79)
Working days per year	200 (± 0)	200 (± 0)	200 (± 0)
Units saved per hour by solar heater	0.75 (± 0.043)	0.75 (± 0.043)	0.75 (± 0.043)
Daily electricity savings (₹)	4.5 (± 0.19)	4.5 (± 0.19)	4.5 (± 0.19)
Annual electricity savings (units)	1500 (± 72)	1200 (± 58)	1200 (± 58)
Annual electricity savings (₹)	6750 (± 324)	5400 (± 261)	5400 (± 261)

Table 4. Comparative profitability analysis of solar-cum-electric vs electric-only drying methods

Profitability Analysis	Mackerel (₹ ± SE)	Ribbon Fish (₹ ± SE)	Shrimp (₹ ± SE)
Annual profit (with solar)	14531 (± 875)	48353 (± 1823)	25923 (± 1246)
Profit if using electricity alone	7781 (± 496)	42953 (± 1623)	20523 (± 1047)
Profit including electricity savings	21281 (± 1121)	53753 (± 2095)	31323 (± 1327)

ability, energy efficiency, and sustainability for small-scale fish processors. By utilizing solar energy, operational costs are reduced by 8–9%, leading to higher annual profits and shorter payback periods. The integration of solar heating not only improves economic returns but also promotes environmental sustainability. This technology is especially beneficial for coastal communities, offering a viable, cleaner, and cost-effective alternative to traditional electric drying methods. Furthermore, it fosters positive social impacts, including strengthened community roles for women.

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