Chapter 17

Novel Engineering Solutions for Postharvest fisheries sector

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Introduction

Fisheries and aquaculture are a significant source of food production, nutritional security, employment, and income generation in India. The fisheries sector offers a major contribution of livelihoods for more than 20 million fishers and fish farmers; pays INR 1.75 trillion annually to India's economy; and is a key export earner, with fish being one of the most important agricultural commodities to be exported from India.

Fishermen in India catch fish as major aquatic products and are intended mainly for domestic consumption and sale in the local market. Fish is being an important source of animal protein, and because of its highly perishable nature, fish has to be processed and stored appropriately to avoid any postharvest losses. But, in the case of over-catch, tremendous losses occur because the fishermen have neither access to domestic markets nor the international market due to low product quality and the absence of good marketing and distribution system. As an alternative, fishermen can convert the catch into value-added products *viz.*, dried fishery products, smoked fish, etc., while extending its shelf life and adding to its market value.

Drying techniques

Drying is one of the oldest methods of food preservation. It is one of the unit operations in the postharvest phase. Drying is the process of removing moisture from food by circulating hot air through it. Drying reduces the water activity of food which in turn helps to arrest or delay the microbial activity and chemical reactions thus dried food can be stored for longer time. The predominant food drying methods are open sun drying. It is one of the cheapest methods drying and energy is freely available, renewable and abundant. But it takes several days to dry agricultural commodities in out-doors. As the weather is uncontrollable, sun drying can be risky. And also, direct exposure of the food material to unhygienic open conditions may cause dust, excreta, pests, insects and microbial infestations and yield inferior quality product. To overcome the disadvantages of open sun drying, mechanical dryers with electric heating system are generally used. But this involve running costs due to high electricity consumption and are not

recommended due to exploitation of non-renewable sources of energy. Solar drying is most effective for fish drying as it is using renewable energy for drying. And also, numerous investigations have shown that solar drying can be a means of food preservation since the product is dried under controlled conditions and completely protected during drying from rain, dust, insects and animals.

Solar drying is an alternative that offers numerous advantages over the traditional method, apart from being environmentally friendly and economically viable. In solar drying, a structure, often of very simple construction, is used to enhance the heating effect of solar radiation. Compared to sun drying, solar dryers can generate higher air temperatures and consequential lower relative humidity, which are favourable to better drying rates and hence lower moisture content of the final products.

Solar dryer can perform drying for food preservation only during sunny days, and hence the drying efficiency depends largely on climatic conditions and the season (Nukulwar., 2022). Hybrid solar dryers are more reliable as there is a back-up system to provide heating in it. Solar-electrical hybrid dryer is more trustworthy as auxiliary system is electrical heating coil (Alfiya et al., 2019). Based on the aforesaid facts, CIFT had designed and developed, energy efficient and cost-effective solar hybrid dryers of different capacities for drying of fish/shrimps.

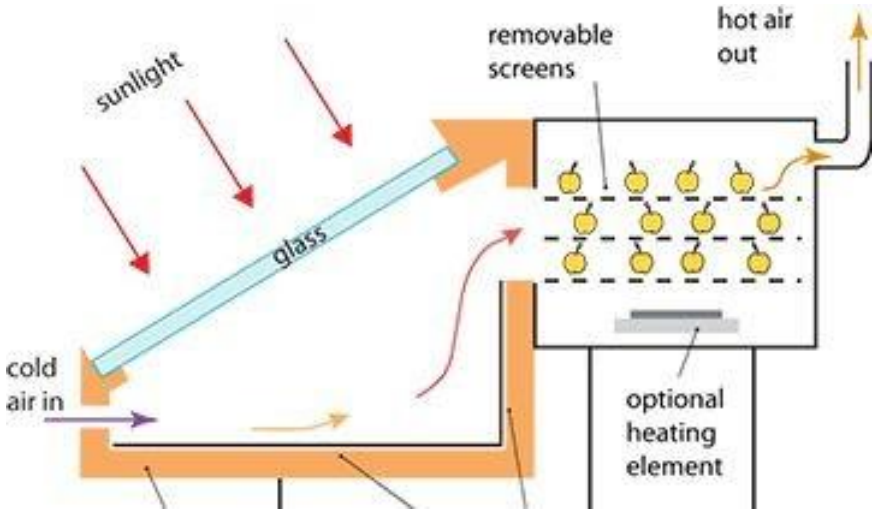

Fig.1. Solar drying technique

Different types of CIFT dryers

ICAR-Central Institute of Fisheries Technology (CIFT), Cochin, has been in the service of the nation since 1957 under the Indian Council of Agricultural Research (ICAR), New Delhi. CIFT has developed low-cost, energy-efficient, and eco-friendly dryers like Solar tray dryers, Solar cabinet dryers, Solar tunnel dryers, etc. based on solar energy for quality drying of fish. Apart from fish, this dryer is also suitable for drying other agricultural products like fruits, vegetables, spices, and condiments. All of these dryers are provided with alternative heating sources to continue the drying process during off-sunshine hours, especially during nighttime, cloudy and rainy days.

The design of solar dryers varies from simple direct dryers to more complex hybrid designs. Hybrid model solar dryers are having LPG, biogas, biomass, or electricity as alternate backup heating sources for the continuous drying of fish even under unfavorable weather conditions. ICAR-CIFT has developed different models and capacities of solar dryers for the hygienic drying of fish. The capacity of these hybrid solar dryers varies from 6 to 110 m^2 of tray spreading area for drying various quantities of fish varying from 10 kg to 500 kg.

The solar dryer is ideal for drying fish, fruits, vegetables, spices, and agricultural products. It helps to dry the products faster than open drying in the sun, by keeping the physicochemical qualities like color, taste, and aroma of the dried food intact and with higher conservation of nutritional value. A programmable logical controller (PLC) system can be incorporated for automatic control of temperature, humidity, and drying time. Solar drying reduces fuel consumption and can have a significant impact on energy conservation.

Fig.2. ICAR-CIFT Solar-LPG hybrid dryer

Solar dryer with LPG backup (50 kg)

ICAR-CIFT designed and developed a novel system for drying fish using solar energy supported by environment-friendly LPG backup (Fig. 2). In this dryer during sunny days fish will be dried using solar energy and when solar radiation is not sufficient during cloudy/ rainy days, LPG backup heating system will be automatically actuated to supplement the heat requirement. Water is heated with the help of solar vacuum tube collectors installed on the roof of the dryer and circulated through heat exchangers placed in the PUF-insulated stainless steel drying chamber. Thus, continuous drying is possible in this system without spoilage of the highly perishable commodity to obtain a good quality dried product.

Fig. 3. ICAR-CIFT Solar-electrical hybrid dryer

Solar dryer with electrical backup (20 kg)

Effective solar drying can be achieved by harnessing solar energy from specially designed solar air heating panels and proper circulation of the hot air across the SS trays loaded with fish (Fig. 3). Food-grade stainless steel is used for the fabrication of chamber and perforated trays which enable drying of fish hygienically. Since the drying chamber is closed, there is less chance of material spoilage by external factors. An alternate electrical backup heating system under controlled temperature conditions enables the drying to continue even under unfavorable weather conditions like rain, cloud, non-sunny days, and night hours so that bacterial spoilage due to partial drying will not occur. Improved shelf life and value addition of the product fetch higher income for the fisherfolk. The eco-friendly solar drying system reduces fuel consumption and can have a significant impact on energy conservation.

Solar dryer with electrical backup (40 kg)

The dryer consists of four drying chambers with nine trays in each chamber (Fig. 4). The trays made of food-grade stainless steel are stacked one over the other with a spacing of 10 cm. The perforated trays accomplish a through-flow drying pattern within the dryer which enhances drying rates. Solar flat plate collectors with an area of 7 m^2 transmit solar energy to the air flowing through the collector which is then directed to the drying chamber. The capacity of the dryer is 40 kg. Electrical backup comes into a role once the desired temperature is not attained for the drying process, particularly during rainy or cloudy days.

Fig. 4. ICAR-CIFT Solar-electrical hybrid dryer

Solar tunnel dryer (50 kg)

ICAR-CIFT developed a low-cost, energy-efficient solar tunnel dryer for bulk drying fish and fishery products. This dryer can be used by fishermen or small-scale fish processing units for bulk drying during seasonal higher catch/excess landing of fish. The capacity of the solar -

Fig. 5. ICAR-CIFT Solar-tunnel dryer

dryer is 50 kg with a floor area of 12 m^2 (Fig. 5). The materials of construction are UV-stabilized transparent polythene sheet for the roof cover, black absorber sheet for the floor, supporting frames of CPVC, and GI rod. Three ventilator fans of 0.5 hp were provided for air inlet and moisture removal. The trays with tray holders were placed inside the dryer for spreading and hooking the fish for drying. This tent dryer was designed as a stand-alone system as it does not require any external power source/electricity. The fans were operated through a solar PV panel fitted on the rooftop of the dryer and associated battery setup. It is also affordable and suitable for Indian fisherfolk.

Multi-purpose emission less biomass dryer

Biomass dryer consists of drying chamber, blower, biomass furnace and a hot air recirculatory system (Fig. 6). The capacity of this dryer is 30-40 kg with 10 trays. Biomass furnace capacity is 25 kg (wood) with the dimension 0.77 m x 1.76 m x 1.42 m. Biomass dryer is provided with a blower of 0.5 hp and axial fan of 0.25 hp. This dryer is suitable for drying fruits, vegetables, spices, condiments and fish. Biomass dryer is highly economical to operate where the biomass availability is abundant and free of cost.

Fig. 6. ICAR-CIFT Biomass dryer

Household electrical dryer

Electrical dryer consists of drying chamber, blower, exhaust fans and a heating coil (Fig. 6). The capacity of this dryer is 10 kg with 10 trays with dimension of 0.54 m × 0.55 m × 0.25 m. The trays are made of aluminium frame and stainless-steel wire mesh. Drying chamber is having the dimension of 0.56 m x 0.61 m x 1.65 m. The heat source is the electrical coil of 1500 W (2 Nos).

This dryer is suitable for drying agricultural commodities. The cost of electrical dryer is low, but the operational costs is high due to the sole electricity consumption.

Fig.7. Household Electrical dryer

Advanced drying techniques

Advanced drying methods have advantages like less drying time, quality drying, better process control, operational safety, and higher capacity. Infrared (IR) drying can be considered to be an artificial drying method and it can sustain throughout the day. In recent years, infrared drying has gained popularity as an alternative drying method for foods. IR is electromagnetic radiation that is in the region of 0.78 – 1000 μm. It is transmitted and absorbed by the food surface and gets changed into heat. Generally, the far-IR region (3 – 1000 μm) is used for food processing since most of the food materials are having the ability to absorb IR in this region. IR radiation impinges on the surface of the material which has to be dried and penetrated into it. Absorption of radiation increases the molecular vibration inside the material and resulted in heat generation on both the inside and surface of the material concurrently (Sakai and Hanzawa, 1994). Faster heat generation inside the material increases the movement of moisture towards the outer surface. External hot air movement over the surface of the material can remove the moisture from the surface and influence the further mass transfer from the material. IR drying provides less drying time, is highly energy efficient, uniform in drying, and has good quality dried products. Infrared offers faster drying of products with minimum energy consumption and

nutrient losses than conventional dryers. Also, IR heating provides high heat transfer with less drying time and energy cost. Drying using IR radiation will result in better quality products than another drying process since the heating is fast and uniform.

Advantages of using IR for drying include flexibility of operation, simplicity of the equipment, fast response of heating and drying, easy installation to any drying chamber, and low capital cost (Sandu, 1986). It can be used for various food materials like grains, flour, vegetables, biscuits, pasta, meat, and fish. A simple IR dryer consists of an inlet and outlet hopper, manual conveyor system, IR lamp arrangements, voltage regulator, and timer relay. Food product enters from the inlet hopper to the manual conveyor and it moves parallel to the IR lamps and dried. The IR radiation intensity can be adjusted via the voltage regulator and intermittent IR drying can be implemented by a timer relay.

Fig. 8. Batch type Infrared dryer

Batch type infrared dryer

A batch type infrared dryer was developed by ICAR-CIFT, which is having a loading capacity of 4 kg fish. The dryer consists of a chamber with a dimension of 1.22 m × 0.92 m × 0.38 m. The material of construction of this dryer is marine plywood coated with aluminium foil inside the chamber. The drying material can be kept in a single tray, which is made of food grade stainless-steel (SS304) material having a dimension of 1.0 m × 0.9 m. The heating source is infrared lamps of 150 W (8 Nos). The drying time of this dryer varies between 2-4 hours based on the type of the product. Fishery products or any agri products can be dried using this dryer.

Hot air assisted infrared dryer prototype

Fig. 9. Hot air assisted infrared dryer prototype

Pilot scale infrared dryer

A pilot-scale hot air-assisted continuous infrared dryer was designed and developed by ICAR-CIFT and it is presented in Fig. 10. The major components assembly of the pilot scale dryer comprised of belt conveyor, infrared radiation heating system, hot air generation and circulation, power transmission, feed hopper, discharge chute, and control panel. The drying chamber of 2.22 x 1.19 x 1.30 m was made from stainless steel sheets with 25 mm thick glass wool insulation and a folding door opening at the front. Both the outer and inner sides of the drying chamber were covered with 1 mm thick stainless-steel sheet. The conveyor dryer has a four-layer conveying system with a loading area of 2 m^2 on each layer. The conveying system was composed of end rollers and conveyor belts (2 x 1 m), both were made of stainless steel (SS 304) material. The size of the dryer and loading area was selected based on the calculations obtained from the assumed dryer capacity and bulk density of the product to be dried. Stainless-steel (SS 304) feed hopper (0.98 × 0.10 × 0.19 m) was designed in such a way to feed the sample throughout the width of the top layer conveyor belt as a single layer. Sample discharged from the feed hopper to the top layer conveyor belt was conveyed along and transferred first to the second layer, then to the third and at last to the fourth layer using stainless steel discharge fixed at the end of each layer. From the fourth layer, the dried sample will be discharged through the discharge chute. The drying chamber was fitted with a ceramic infrared heater of 250 W which emits radiation at a wavelength of 2.5 – 10 µm. A total of ninety-six IR heaters (twenty-four numbers in each layer) were fixed over each layer of the conveyor belt at a distance of 10 cm from the belt surface. The provision to cut-off IR intensity of each layer to its half load was

provided using a PLC (Siemens LOGO X50) and HMI (Siemens LOGO TDI) for situations where full power is not required. Switching on and off the IR heaters of each layer was also controlled by the PLC and HMI automatically. The drying chamber has six air inlets (d = 0.20 m) and two exhaust (rectangular mesh opening) ducts for hot air circulation and to remove humid air. A temperature sensor (J-type thermocouple) was fixed inside the chamber to measure the air temperature during drying. A discharge chute was placed to collect the dried samples.

Fig. 10. Pilot-scale hot air-assisted continuous infrared dryer

Fish descaling machineries

Descaling is the process of removal of scales from fishes. Removing the scales of fishes is a laborious and time-consuming activity which also requires skilled man power. Mechanization of descaling process could significantly reduce the handling time thereby shortening the pre-processing period. Moreover, it reduces the drudgery of labour involving in manual descaling of fishes. Use of descaling machine reduces the overhead costs and enhances the quality of the final product. In this context, ICAR-Central Institute of Fisheries Technology (CIFT) has designed and developed three types of fish descaling machines. These machines can be used to remove the scales of fishes from all types/sizes/species of fishes.

Hand operated fish descaling machine

The descaling capacity of the machine is 3 kg, and made of Stainless-steel (SS 304). The major parts of the machine are a base frame made of 1inch square shaped SS tube and a rotating drum. The drum is made of perforated SS sheet fitted in a strong SS frame and having diameter and length of 255.5 mm and 270 mm, respectively. Descaling is done inside the closed chamber by rotational action of cylinder. Friction between the fishes and projections of perforated SS

cylinder during the rotation of drum removes the scale. Leak proof door with lock is provided for loading and unloading purposes. A hand pedal is fitted on the side to rotate the drum manually.

Fig. 11. Hand operated fish descaling machine

Table top motorized fish descaling machine

It is made of SS 304 and has 5 kg capacity. It contains a 0.5 HP AC motor with belt reduction mechanism to achieve the required drum speed of 20-30 rpm. Frame is fabricated using 1-inch square shape SS tube with suitable covering in electrical parts. The drum is made of perforated SS sheet and having suitable internal projections to remove the scales. Drum is also provided with a leak proof door with suitable lock.

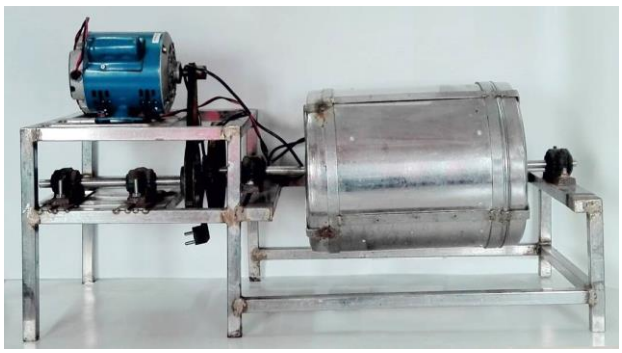

Fig. 12. Motorized fish descaling machine

Fish descaling machine with variable drum speed

It is made of SS 304 and has 10 kg capacity. It contains a 1.5 HP induction motor and a variable frequency drive (VFD) to vary the speed of the drum depending on the variety of the fish loaded. The drum is made of perforated SS 304 sheet fitted on a strong SS Frame. Water input facility is provided in the drum for easy removal of the scales from the drum. The outlet pipe also

provided to remove scales and water from the machine. Since speed of the drum is influencing descaling efficiency, an electronic RPM meter is attached with the descaling machine to set the required RPM. The machine takes 3-5 minutes to clean 10 kg fish depending on the size.

Mini fish descaling machine

To cater the household needs related to fish descaling, a motorized version of 1 kg capacity fish descaling machine was developed at ICAR-CIFT. It can be used in home kitchens and hotels for easy removal of fish scales. The equipment consists of a rotating drum, nylon brush, motor and frame to support the assembly. The diameter and length of the drum are 190 mm and 225 mm respectively. Inside of the drum is riveted with perforated stainless-steel mesh. The fish can be fed to the drum and motor switched on for descaling action. The machine can be loaded with 1 kg of fish in single batch for effective removal of scales. Cleaning of the machine can be done easily by detaching the drum with perforations inside. The system is ergonomically designed in such a way that even women can work on it without any drudgery. The drum speed of descaling machine is optimized with respect to the efficiency level and it was found that maximum efficiency can be attained at 22 rpm drum speed at the loading capacity of 1 kg of fish. Descaling of Sardine and Tilapia required 5 minutes to attain efficiencies of 84.60% and 79.59% respectively.

Fig. 13. Variable speed fish descaling machine

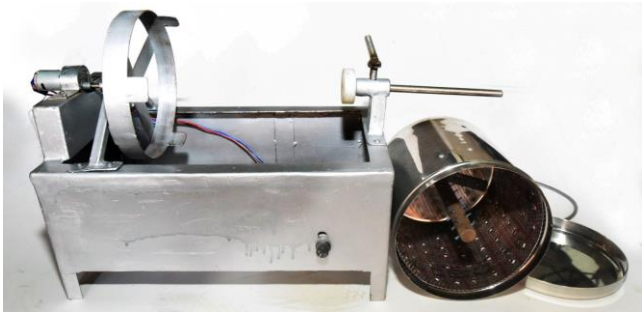

Fig. 14. Mini fish descaling machine

Refrigerated mobile fish vending Kiosk

Exposure of fishes to the atmosphere often leads to contamination by means of dust, insects and flies apart from deterioration of quality in terms of freshness and taste. ICAR-CIFT, Cochin, has designed and developed a low-cost energy efficient refrigerated hygienic mobile fish vending kiosk to sell fish at consumer's door step under hygienic conditions in village/urban/municipality areas with proper waste disposal system. The unit was fabricated mainly using food grade material stainless-steel (SS 304) with transparent poly carbonate/toughened glass sheets for the display. The kiosk can carry 20-30 kg fish under refrigerated storage. It was designed considering the maximum weight that a man pulls on a rickshaw. The main components of the kiosk model are chilled fish storage cum display unit with three chambers, a hand operated de-scaling machine (3 kg) and fish dressing deck with wash basin, water tank, cutting tool, waste collection chamber and working space. The main feature of the prototype is that consumer can see the fishes directly through transparent cover and select according to their choice of purchase. A digital sign board is attached in the front of kiosk to display the available fishes and their rates.

Fig. 15. Refrigerated mobile fish vending Kiosk

Under ideal operating conditions, the unit can extend the shelf life of fish for 4 to 5 days and increases marginal benefit to fish vendors/sellers. The kiosk is affordable to small scale and retail fish vendors/sellers. The technology also helps to change the unhygienic handling and marketing practices of fish by the vendors/sellers/fisherfolks. The traditional fish vending systems are soon going to be replaced with refrigerated mobile fish vending units developed by ICAR-CIFT.

Parameters	**Specifications**
Full body material	SS 304 Food grade material
Fish display unit top	Poly carbonate/toughed glass material
Loading capacity	20kg under chilled storage and 80 kg under Ice box
Refrigeration capacity	400 L
Insulation	Puff insulation (3-inch thickness)
Electric rating	220-240V (AC 50 - 60 Hz.)
Power consumption	300 watts
Temperature of chilled storage	2-3°C
Design variation	It can be customized according to the requirement (U shape, L shape, straight line etc.)

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