6. Engineering interventions in fish handling and processing operations

S. Murali, D.S. Aniesrani Delfiya, P.V. Alfiya and George Ninan
Engineering Division
ICAR-Central Institute of Fisheries Technology, Cochin-682029, India
murali.s@icar.gov.in

Major areas of technological interventions in the field of fishery engineering cover design and development of fish processing equipment and machinery, energy-efficient and eco-friendly solar fish dryers, fuel-efficient fishing vessels and fiberglass canoes, indigenous electronic instruments for application in harvest and post-harvest technology of fish, quality improvement of Indian fishing fleet and energy and water optimization techniques for fish processing industries. Focused areas include the development of cost-effective solar dryers with LPG, biomass, Infra-Red or electrical backup heating systems, fish de-scaling machines, Fish freshness sensors, etc. Post-harvesting processing of fish is important to reduce wastage, increase shelf-life, add more value to the products and ensure higher returns. The major engineering interventions for fish post-harvest operations, processing, and value addition are given in subsequent sections.

1. Solar dryers

Fisherfolks catch fish as major aquatic products to sell in the local market, and in case of over catch tremendous losses occur due to inadequate cold chain management facilities in the developing countries. Alternatively, the fisherman could convert the excess catch of fish into a value-added product *i.e.* dried fish. For example, In India, about 20-30% total catch of fish is dried for export and or local consumption. Drying preserves fish from decay by removal of moisture from fish, thereby arresting the growth of bacteria, the action of enzymes, and chemical oxidation of the fat. Open-air sun drying is the traditional method employed by fisherfolks in India to dry fish and fishery products. It denotes the exposure of a commodity to direct solar radiation and the convective power of the natural wind. This form of energy is free, renewable, and abundant in any part of the world, especially in tropical countries. However, it often results in inferior quality of product due to its dependence on weather conditions and vulnerability to the attack of dust, rains, insects, pests, and microorganisms. Also, it requires a longer drying time (Murali et al. 2019).

Solar drying is an alternative that offers numerous advantages over the traditional method and is environmentally friendly and economically viable in developing countries. In solar drying, a structure, often of very simple construction, is used to enhance the effect of solar radiation. Compared to sun drying, solar dryers can generate higher air temperatures and consequential lower relative humidity, which are conducive to improved drying rates and lower final moisture content of the products. However, there exist some problems associated with solar drying i.e. reliability of solar radiation during a rainy period or cloudy days and its unavailability during nighttime. To overcome this limitation, an auxiliary heat source and forced convection system are recommended for assuring reliability and better control, respectively.

In a hybrid solar drying system, drying can be continued during off-sunshine hours by utilizing a backup heat source and also by storing the energy in the form of sensible or latent heat during sunshine hours. In this way, drying becomes a continuous process and the product is saved from possible deterioration by a microbial infestation. These types of hybrid solar dryers find useful applications in developing countries where the conventional energy sources are either scarce or expensive and the heat-generating capacity of the solar system is not sufficient.

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 continuous drying of fish even under unfavourable 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 labor requirement is considerably reduced compared to open sun drying in beaches/coir mats because of the elimination of the cleaning process due to sand and dust contamination. The re-handling process like spreading, sorting, and storing because of non-drying or partial drying due to unfavorable weather conditions and spoilage due to rain is also not required. The drying time is reduced considerably with improved product quality. Improved shelf life and value addition of the product fetches higher income for the fisherfolk. The eco-friendly solar drying system reduces fuel consumption and can have a significant impact on energy conservation.

ICAR-Central Institute of Fisheries Technology (CIFT), Cochin, has already developed low-cost, energy-efficient, and eco-friendly dryers like Solar cabinet dryers, Solar tunnel dryers, Infrared dryers, etc for uniform and hygienic drying of fishes (Fasludheen et al. 2017). These dryers are also suitable for drying agricultural products like fruits, vegetables, spices, and condiments.

1.1. Solar dryer with LPG backup (50-60 kg)

ICAR-CIFT designed and developed a novel system for drying fish using solar energy supported by environment-friendly LPG backup (Fig. 1). 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.

This dryer is ideal for drying fish, fruits, vegetables, spices, and agro 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 (Murali et al. 2020; Murali et al. 2021).

Fig.1. ICAR-CIFT Solar-LPG hybrid dryer

1.2. Solar dryer with electrical backup (20 kg)

Effective solar drying can be achieved by harnessing solar energy by specially designed solar air heating panels and proper circulation of the hot air across the SS trays loaded with fish (Fig. 2). 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 in night hours so that the bacterial spoilage due to partial drying will not occur. Improved shelf life and value addition of the product fetches higher income for the fisherfolk. The eco-friendly solar drying system reduces fuel consumption and can have a significant impact on energy conservation.

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

1.3.Solar dryer with electrical backup (40 kg)

The dryer consists of four drying chambers with nine trays in each chamber (Fig. 3). 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. 3. ICAR-CIFT Solar- electrical hybrid dryer

1.4. Solar tunnel dryer

ICAR-CIFT developed a low-cost, energy-efficient solar tunnel dryer for bulk drying of 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 tunnel dryer is 50 kg with a floor area of 12 m^2 (Fig. 4). The materials of construction are UV stabilized transparent polythene sheet for 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 fisherfolks.

Fig. 4. ICAR-CIFT Solar-tunnel dryer

2. Fish Descaling Machines

2.1.Fish descaling machine with variable drum speed

The fish de-scaling machine is designed and fabricated for removing the scales of fishes easily. This equipment can remove scales from almost all types/sizes/ species of fishes ranging from marine to freshwater species like Sardine, Tilapia to Rohu. The machine is made of SS 304 and has a 10 kg capacity (Fig. 5). 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 load. The drum is made of a perforated SS 304 sheet fitted in a strong SS Frame. A water inlet facility is provided in the drum for easy removal of the scales from the drum so that area of contact to the surface will be more for removal of scales. The water outlet is also provided to remove scales and water from the machine. An Electronic RPM meter was attached with the de-scaling machine which directly displays the RPM of the drum. The speed of the drum is a factor influencing the efficiency. The machine takes only 3-5 minutes to clean 10 kg fish depending on the size.

Fig. 5. Fish de-scaling machine with variable drum speed

2.2.Fish de-scaling machine with fixed drum speed- tabletop

The fish de-scaling machine is designed and fabricated for removing the scales of fishes easily. This equipment can remove scales from almost all types/sizes/ species of fishes ranging from marine to freshwater species like Sardine, Tilapia to Rohu. This machine is made of SS 304 and has a 5 kg capacity. It contains a 0.5 HP AC motor with a proper belt reduction mechanism to achieve the required drum speed of 20-30 rpm. The body is fabricated in dismantling type one-inch square SS tube with a suitable covering in the electrical parts (Fig. 6). The drum is made of a perforated SS sheet fitted in a strong SS Frame having suitable projections to remove the scale and provided with a leak-proof door with a suitable lock.

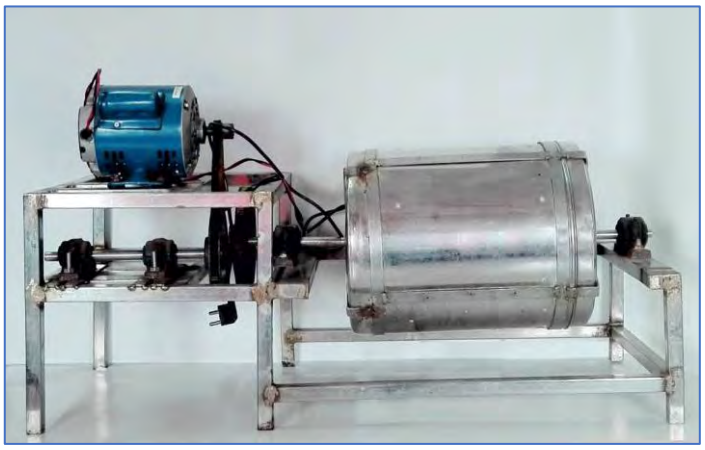

Fig. 6. Fish de-scaling machine with fixed drum speeD

2.3. Hand operated Fish descaling machine

The fish descaling machine is designed and fabricated for removing the scales of fishes easily. This equipment can remove scales from almost all types/sizes/ species of fishes ranging from marine to freshwater species like Sardine, Tilapia to Rohu (Fig. 7). This machine is made of SS 304 and has a 5 kg capacity. The body is fabricated in dismantling a type 1-inch square SS tube. The drum of 255.5 mm diameter and 270 mm length is made of a perforated SS sheet fitted in a strong SS Frame having suitable projections to remove the scale and provided with a leak-proof door with a suitable lock. A pedal is fitted in the side to rotate the drum manually (Delfiya et al. 2019).

Fig. 7. Hand operated fish de-scaling machine

3. Fish meat bone separator

A Fish Meat Bone Separator with variable frequency drive (VFD) to separate pin bones from freshwater fishes was designed and developed (Fig. 8). This can be used at a range of 5-100 rpm. With a unique belt tighten system developed; the new machine can be easily adapted to any species and need not be customized for specimen during the design stage. In existing imported models, only two speeds are possible which restricts the yield efficiency in a single span operation and also limits easy switching of the system for utilizing specimens other than

for which the yield has been originally customized. The meat yield of this machine was about 60% against 35% in imported models. The capacity of the machine is 100 kg/hour.

Fig. 8. Fish meat bone separator

4. Refrigerated Mobile fish vending kiosk

ICAR-CIFT has designed and developed a mobile fish vending kiosk for selling fish in the closed chilled chamber under hygienic conditions at the consumer doorstep. The mobile unit is mounted on a frame with wheels at the bottom. The kiosk can carry 100kg fish with 20kg under chilled storage display in a glass chamber and remaining in an insulated icebox. The main components of the kiosk are fish storage & display facility, a hand-operated descaling machine, and a fish dressing deck with a washbasin, water tank, cutting tool, waste collection chamber, and working space. The vending unit has been fabricated using stainless steel (SS 304 Food Grade. The stored fish is covered with a transparent glass cover through which consumers can see the fish and select according to their choice of purchase. A kiosk is attached with a hand-operated descaling machine for the removal of scales. The fishes coming out of de-scaler is free of scales, dirt, or slime. It also reduces human drudgery and avoids cross-contamination, consumes lesser time. Fish dressing deck with washbasin is also designed conveniently to prepare fresh clean fish under hygienic conditions. The unit also extends the keeping quality of fish for 4- 5 days and increases the marginal benefit to fish vendors. It also helps change the practice of unhygienic handling and marketing of fish.

Fig. 9. Refrigerated mobile fish vending kiosk

5. Electronics and Instrumentation

ICAR-CIFT identified the vast scope of electronics and instrumentation for fisheries technological investigations and started research and development activities. This resulted in a series of instruments for systematic monitoring, analysis, and assessment of the marine environment including the performance of the machinery used for harvesting the resources and post-harvest technology. Basic technologies developed in ICAR-CIFT include more than five dozen electronic instruments with fully indigenous technology and more than 50 sensors with novel features and designs. The notable achievement is the development of indigenous sensors, which are rugged to withstand the hostile marine environment and enable us to monitor field data from remote areas. The total instrumentation is built up around these sensors, with required electronics, new signal processors, and other peripherals for solid-state data storing, compatibility to PC, wireless transmission to distant points, *etc*.

Some of the instruments, which has got great attention and acceptance are as follows: environmental data acquisition system, freezer temperature monitor, salinity temperature-depth meter, hydro-meteorological data acquisition system, warp load meter, solar radiation monitor and integrator, shipborne data acquisition system, water level recorder, ocean current meter, remote operated soil moisture meter, water activity meter, rheometer, and microalgae concentration monitor. Since the instruments are designed to be compatible with the computer and solid-state memory module, the information can be stored for a long duration and retrieved at our convenience.

By effective use of efficient and appropriate engineering technologies which are cost-effective, adaptable, and environment friendly, the fishermen community, as well as the seafood industry, can reduce the harvest and post-harvest expenses and losses, add more value to the products, ensure better fish value chain dynamics and thereby obtain more income. The use of green and clean technologies also ensures less carbon and water footprints.

6. Energy and Water Use Optimization in Seafood Processing Industry

In the seafood industry, the increasing importance to ensure effective usage of energy and water needs the implementation of sustainable technologies and cleaner production practices. The review findings report that replacement of outdated technologies, use of renewable energy sources, and creation of awareness about energy consumption among manpower, and continuous energy auditing results in effective energy usage in the seafood processing sector. Similarly, adopting water optimization techniques such as automation of water flow lines, wastewater treatment, recycling and recirculation of water, continuous monitoring of water use patterns, and dry-cleaning process in the industry would result in water savings. The smart cloud-connected intelligent real-time energy and water use monitoring systems could be considered as suitable methods to optimize energy and water usage in the seafood industry. The application of software using the Internet of things (IoT) can help analyze the daily, weekly, monthly, or yearly consumption pattern. Mobile alert systems can be installed for giving warnings regarding peak specific energy consumption. Besides, developing new applications of byproducts and generating energy from wastes can reduce waste disposal and

environmental pollution issues in the seafood sector. It is also important to understand the nexus between energy, water, and seafood from the environmental and sustainability perspective. Each of these three sectors has an impact on the security of others in a variety of ways. The authors observed that additional studies should be carried out on the entire seafood supply chain, starting from harvesting to consumption for the sustainability of the whole sector. The government authorities should provide tax benefits and other financial incentives for the individuals and seafood firms for being eco-friendly with the effective management of energy and water with the generation of minimum waste and GHG emissions. The government should also form a committee of assessors for the periodic evaluation of seafood processing firms to improve their competence while being sensitive to socio-economic and environmental implications.

7. Commercialization of engineering technologies

A more pragmatic system for business incubation and promoting start-up companies concerning agricultural technologies have been evolved in recent times within the ICAR-CIFT. The Agri-Business Incubation (ABI) center along with Institute Technology Management Unit (ITMU) seeks to provide business consulting services to agriculture-related businesses and helps to develop a strategic business plan. ABIs facilities for incubation of new business ideas based on new agricultural technologies by providing cheap space, facilities, and required information and research inputs. The Agribusiness Incubator Program also seeks to provide business consulting services to agriculture-related businesses and helps to develop a strategic business plan. The Engineering Division of ICAR-CIFT has commercialized its technologies like solar fish dryers, fish descaling machines, refrigeration enabled fish vending machines, etc through the ABI.

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