Novel drying techniques for fish processing and preservation

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Introduction

Fish is a highly nutritious food than meat and egg and it is highly perishable because of its high moisture content which is about 80%. Fish preservation is essential immediately after the catch to increase the shelf life of fish. Preservation methods help to maintain the quality of fish for a longer period of time, prevent spoilage and decomposition, retain its original nutritional contents, and make transportation and storage of fish easier. Fish preservation techniques vary with the type, nature, size, and condition of fish. Improper handling and processing of fish lead to immediate spoilage of fish resulting in poor quality. Conventional preservation techniques such as chilling, freezing, drying, and chemical preservation are widely used for fish preservation throughout the world. Among the various preservation techniques drying of fish is the oldest preservation technique and drying means the preservation of fish by removing water from it through heating. Drying removes the moisture content up to a certain level to prevent microbial growth thereby providing greater shelf life, and reduction in weight, volume, transportation, and storage space.

Two commonly used drying methods are natural and artificial drying. Natural drying includes sun drying, and solar drying, whereas artificial drying includes a microwave, fluidized bed, spouted bed, infrared, convective drying, desiccant drying, freeze drying, osmotic, vacuum drying, pulsed electric field, high hydrostatic pressure, superheated steam drying, heat pump and spray drying *etc*. Natural drying methods are associated with disadvantages like contamination and damage by dirt, insects, rodents, birds, and animals. Sun drying of fish often results in low-quality products since drying is slow normally it takes five to seven days. Therefore, it is necessary to choose an advanced method of drying to obtain good quality products (Curran and Trim, 1985). Artificial drying methods have advantages like less drying time, good quality drying, better process control, operational safety, and higher capacity.

Infrared drying

Infrared (IR) drying can be considered to be an artificial sun 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 – 1000µm) 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 required 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, 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. A pilot-scale hot air-assisted continuous infrared dryer was designed and developed by ICAR-CIFT, Cochin, India and it is presented in Fig. 1.

Description of pilot scale infrared dryer

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 (M/s MARC, Jharkhand). 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. 1 Pilot-scale hot air-assisted continuous infrared dryer

The hot air generation system consists of six axial air distribution fans (Make: EAF 200 S2/AS) and six finned U-shaped electrical heaters (each 750 W). Fans were provided to pull the air from the atmosphere to circulate in the drying chamber. The fan speed was controlled using a dimmer to provide the desired air velocity. Atmospheric air entered through fans was first heated up by the electric heaters and distributed in the drying chamber. The required air temperature was obtained by regulating the temperature of electrical heaters using an auto thermal cutoff device (Make: Selec TC513). A geared motor of 0.746 kW (Make: Siemens) was coupled with the bottom layer conveyor end roller. The reversion of belt direction was achieved by chain and sprocket mechanism to operate adjacent layers in opposite directions. The conveyor belt speed was controlled by a variable frequency drive (Make: Danfoss). The setting of running and residence time of the conveyor belt was achieved with the help of a PLC (Siemens LOGO X50) and HMI (Siemens LOGO TDI). The Control panel was made separately connected with the dryer which has a display and controls for all arrangements.

Squid drying in pilot scale infrared dryer

Squids are cephalopods, which are important source of food and nutrition and suitable for human consumption (Jeyasekaran *et al*., 2010). Squids are abundantly available in ocean and consumed as live feed, fish meal and as processed seafood across countries. They are good source of minerals and vitamins and are famous in traditional cuisines. Fresh squid has short shelf life because of its high moisture content (more than 80 %) (Deng *et al*., 2011). Hence, drying can be done to preserve squid by reducing its water activity.

Fresh squid were purchased from Vypeen fish landing centre, Kochi, for the experimental trials. Squid were iced immediately, and then transferred to the pre- processing facility in an insulated box. They were cleaned and washed using potable water and cut into squid rings of approximately equal sizes (5 mm thick ring), and then stored under chilled condition (below 5°C) prior to blanching and drying operations.

The drying of squid rings was carried out in the forced convection hot air-assisted pilot scale infrared dryer (Fig. 1). Two pre-treatments like blanching and marination were done prior to drying of squid rings. About 4 kg of squid rings were thoroughly washed in potable water and allowed to drain excess water, then it is spread over the tray as a single layer for blanching. Blanching of squid rings were done in an electrically operated steam blancher for 10 min at 100℃. Blanching causes half cooking of squid and is essential for texture improvement of squid which reduces the sticky nature of squid during drying. Marination of squid rings was done using salt, lemon juice and spice powders before drying. Marination was done for at least 30 min prior to drying. The drying operations were carried out at the infrared intensity of 3000 W/m^2 and 60℃ hot air inlet temperature. The parameters observed during drying were weight loss, dryer air temperature, *etc*. at 30 min intervals. The initial moisture content, dimension, colour and texture were measured for the fresh samples. Moisture content of the samples was calculated by hot air oven method (AOAC, 1990). The weight loss of squid was measured at 30 min intervals with a digital weighing apparatus by removing it from the drying chamber for approximately 30s. The experiments were stopped once the difference between consecutive weights were 0.01 g. The dimensions were measured using digital vernier caliper. The colour in terms of L*, a*, b* values and texture were analyzed using a hunter lab colorimeter and the texture analyzer, respectively in order to check the physical quality.

The amount moisture content in the product is expressed on the basis of dry matter content of the product. It is usually expressed in percentage and calculated using the following formula.

$$Moisture\ Content\ in\ wet\ basis(\%) = \frac{Weight\ of\ water\ in\ the\ product(g)}{Weight\ of\ the\ product(g)} \quad (1)$$

$$Moisture\ Content\ in\ dry\ \ basis(\%) = \frac{Weight\ of\ water\ in\ the\ product(g)}{Weight\ of\ the\ dry\ product(g)} \quad (2)$$

$$Drying\ rate\,(DR) = \frac{Weight\ water\ removed\ \ from the\ product\,(kg)}{Weight\ of\ \ dry\ matter\ of\ the\ product\,(kg) \times Unit\ time\,(h)} \quad (3)$$

The drying efficiency of infrared dryer was calculated by the amount of energy required to the energy supplied to remove the moisture from the squid rings. The amount of energy required is the total of sensible heat to raise the temperature of the product to dryer temperature and latent heat of vaporization at drying temperature. (Leon et al., 2002)
Energy supplied will be the energy consumed by the ceramic heaters, energy utilized by heating coil, exhaust fans, blowers *etc*.

$$Drying\ Efficiency\ (\%) = \frac{(Energy\ required\ to\ remove\ moisture, W)}{(Energy\ supplied, W\ )} \times 100 \quad (4)$$

After drying the samples were analyzed for its quality in terms of shrinkage, rehydration ratio, final moisture content, colour, texture and yield.

Summary

The marinated and dried squid rings are having a huge demand in ready to heat and eat products market. It is hygienically processed and easier to cook and having long shelf life due to preservative effect of the low water activity and bioactive components from spices in the product. The pilot scale infra-red dryer can be used for continuous production of marinated and dried squid rings at the rate of 1 kg/h.

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