

Drying Characteristics of Salted Fish in a Greenhouse-type Solar Dryer

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In this study, the drying characteristics of salted fish (*Merlangius merlangus*) were investigated by the drying experiments carried out in a greenhouse constructed for dehydration and augmented by parabolic reflectors. Drying time of samples was 26 h in the greenhouse and 38 h for samples dried outside to 25% moisture content. It was decided to apply thin layer drying theory in order to explain and compare drying characteristics. Drying constant of that equation was minimum for samples dried in the greenhouse on the conveyor belt augmented by solar reflectors.

Methods of drying fish vary between different countries and within the same country depending on the species of fish used and the type of product desired. The process may use unsalted fish or various salt additions, and involve dehydration to varying degrees of moisture levels under different processing temperatures. The fish species used as raw material may be fresh water or marine and may range from very lean to fatty fishes (Opstvedt, 1988). Anon (1988) tabulated preparation and composition of dried fishery products of different countries and regions. A review of Japanese studies on fish drying methods were given by Motohiro (1988). Some studies of local fish drying methods were given by different researchers (Prabhu & Balachandran, 1982; Sumardi *et al.*, 1982; Carpio, 1982).

The traditional processes of drying in some aspects have not changed substantially. Improvements have been made in equipment and formulation. In tropical countries small fish and split large fish are simply spread in the sun for drying. In colder climates fish can be hung up to dry in the wind. Drying times vary considerably depending on the process and weather (Poulter, 1988). Specifically seafoods are subjected to spoilage and decomposition through contamination by micro-organisms and insects. Closed systems are beneficial

to obtain a better quality product (Deng *et al.*, 1979; Jason, 1965).

In the tropics where sunlight is abundant solar dryers can be used for rapid drying of fish. There are two basic methods of collecting and concentrating the solar energy: 1. Parabolic reflectors: Sunlight falling on a mirror is focused to a point where the temperature becomes much higher, 2. Absorption units: A black surface absorbs heat energy from the sun far more effectively than a light coloured surface and this heat in turn is used to heat the drying air (Clucas, 1982). Several studies on solar drying of fish and seafood products are reported (Chakraborty, 1976; Baird *et al.*, 1979; Deng *et al.*, 1979; Gregorio & Alcorido, 1980; Carpio, 1982; Yu *et al.*, 1982; Sewak, 1982; Trim & Curran, 1983; Camu *et al.*, 1983; Sachithanathan *et al.*, 1985; Curran *et al.*, 1985).

In Turkey, fish are dried in very small quantities by hanging them. Although solar energy potential of Turkey is very suitable for solar dryers that can be used for drying of fish especially in times of plenty, almost no study has been found in the literature.

In this study, a green house-type solar dryer including solar reflectors which has been tested for dehydration of some fruits

(Demir, 1989; Demir & Cakaloğlu, 1989) was employed for drying of Bakalyaro (*Merlangius merlangus*).

Materials and Methods

Bakalyaro (*Merlangius merlangus*) variety of fish (with a fat content 7%) purchased from Izmir wholesale fish market were scaled, eviscerated, headed, boned, filleted, washed and soaked in 30% brine for 1 h (Camu *et al.*, 1983). The thickness of the fillets was between 0.75 and 1.15 cm.

Drying experiments were carried out in the greenhouse designed for drying in the Bornova Campus of Ege University. Fig. 1 shows the cross sectional view of the system. The dimensions of the greenhouse were 15.4 m x 10.4 m x 4.5 m and glazed with 3 mm glass. The system was divided into two sections with an insulation wall, consisting of 50 mm glasswool covered with a polyethylene film layer on both sides,

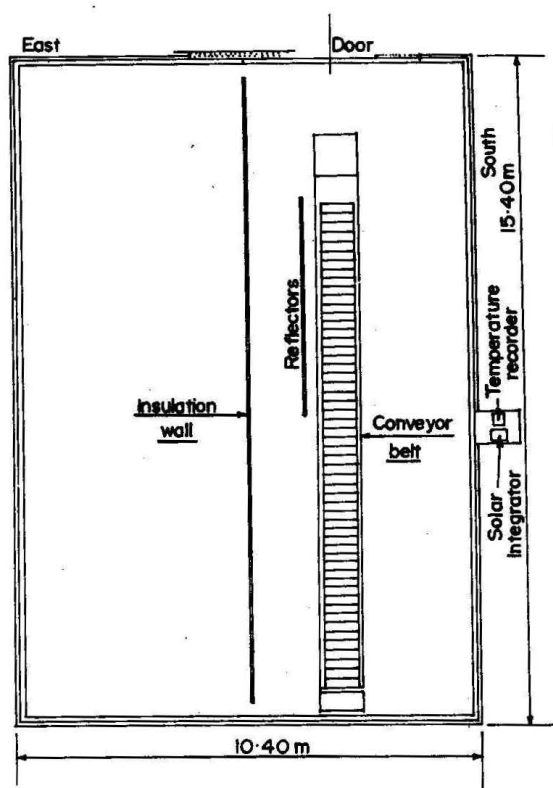


Fig. 1. Horizontal cross sectional view of the green house type solar dryer.

mounted to the main central axis in the east-west direction leaving 25 mm openings from the top and the bottom. The section in front of the insulation wall facing south was equipped with a conveyor belt, 12 m in length. Five parabolic reflectors each consisting of six stainless steel sheets (1 m x 2 m) were hung between the insulation wall and the conveyor belt. The bottom of this section was painted in black in order to collect the solar energy more effectively.

During the drying experiments the temperature at different points in the greenhouse and outside were recorded by a Cole-Parmer temperature recorder (Series no.8386, Range: 15-75°C). Solar radiation received by a horizontal surface in the greenhouse per hour was also measured by using CM11 Solarimeter and printed with CC11 Solar integrator (Kipp-Zonen Delft, Holland). Relative humidity (RH) in the greenhouse was measured manually using a RH and Temperature measurement device (T 69000 Model no.5500 London, England).

Drying experiments were carried out in the greenhouse on the conveyor belt with and without the influence of solar reflectors and control samples were dried in the open air by exposing the samples to direct sunlight on perforated metal racks with 0.7 m height. During the drying experiments samples were weighed periodically. Finally moisture content of samples were determined by the oven method (AOAC, 1980).

Results and Discussion

Meteorological data, recorded during the experiments are shown in Fig.2. During the period of drying the weather was clear. Data including relative humidity of outside air and solar insolation received by a horizontal surface outside the greenhouse were provided from Meteorological Experiment Station in Bornova Campus at a distance of a few hundred meters from the greenhouse. Maximum difference between

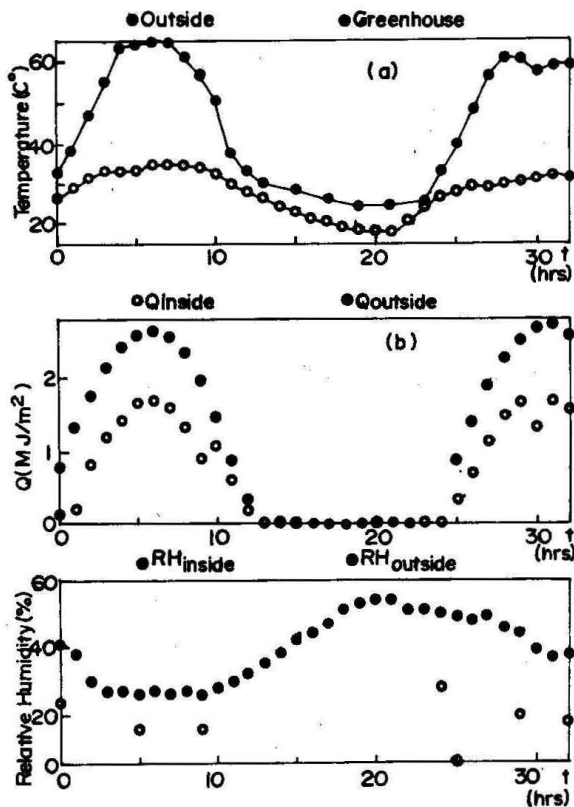


Fig. 2. Temperature (a), solar radiation (b) and relative humidity (c) changes during drying experiment.

meteorological data for outside and inside of the greenhouse were obtained at noon time. Maximum temperature difference between the conveyor belt in the greenhouse augmented by reflectors and the outside was 30°C and during nighttime minimum temperature differences were 4-6°C. Minimum and maximum relative humidity differences were found to be 10 and 24% respectively. Maximum solar insolation inside and outside of the greenhouse were 1.7 and 2.7 MJ/m², respectively.

All the drying experiments were started at the same time in order to compare the drying times for different operations. Times required to dry the samples to 25% moisture content (wet basis) were compared, as the final moisture content of the samples dried in the greenhouse was lower. Salted fish were dried in 26 h in the greenhouse and in 38 h outside, to 25% moisture level. Difference in drying times

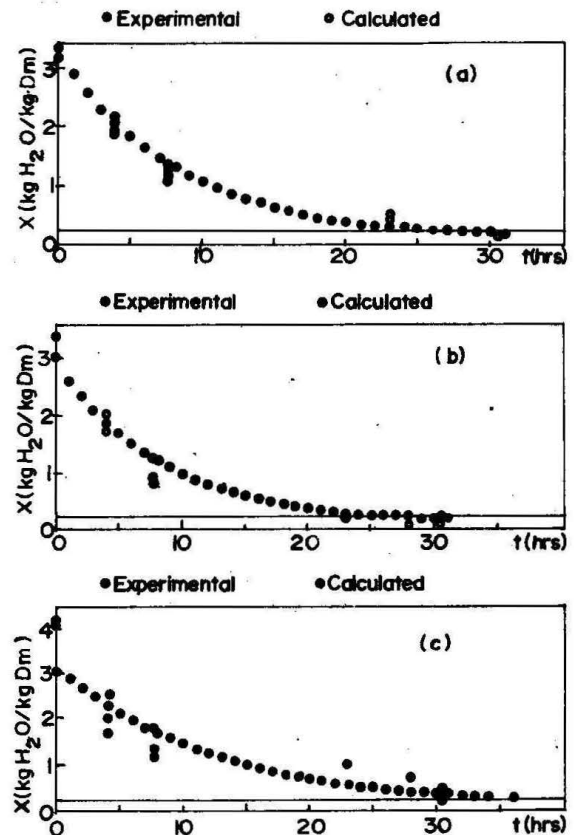


Fig. 3. Drying curves for salted fish, (a) dried inside the green house, (b) dried inside the green house on the conveyor belt and (c) control samples dried outside.

were due to the temperature and relative humidity differences. Fig.3 shows the changes in moisture content with time for the three samples dried in the greenhouse and outside.

It was decided to apply thin layer drying theory in order to explain and compare drying characteristics (ASHRAE, 1981; Demir, 1989; Riva & Peri, 1986; Garg et al., 1984; Akyurt & Selcuk, 1973).

$$(x-x_e)/(x_0-x_e) = e^{-kt}$$

Where

- x : Moisture content at time t (kg H₂O/kg DM)
- x_e : Equilibrium moisture content (kg H₂O/kg DM)
- x_0 : Initial moisture content (kg H₂O/kg DM)
- t : Time (h); k : Drying constant (1/h)
- DM : Dry matter

Table 1. Coefficients of the equation for drying experiments

Product code	Xo (kg H ₂ O/ kgDM)	k (1/h)	Correlation coefficient
SR	3.230646	0.11670	0.955394
SB	2.907941	0.11496	0.967829
SC	3.090195	0.07890	0.883928

S: salted, R: dried inside the greenhouse on the conveyor belt augmented by reflectors, B: dried inside the greenhouse on the conveyor belt, C: control samples dried outside

From the desorption isotherms at 43°C between 20 and 80% relative humidities for anchovy, mackerel and herring (Carpio, 1982) it was found that equilibrium moisture contents are similar for all of the varieties and equal to 0.1 at 20% RH. This value was used as equilibrium moisture content in the equation. Table 1 includes coefficients of the equation for the drying experiments.

The drying constant k is related to the drying rate and was found to be maximum for the samples dried in the greenhouse and it was about 1.5 times higher than the control samples.

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