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Effect of solar drying using a natural convective solar drier on bacterial load and chemical composition of bayad (*Bagrus bayad*) fish flakes

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Abstract

Solar drying experiments of bayad (Bagrus bayad) fish flakes using a natural convective solar drier were conducted at Food Research Centre (FRC), Agricultural Research Corporation, Shambat, Sudan. During June-August, 2008 and May-June, 2009. Tthe objectives of the present study were to investigate the effect of solar drying using a natural convective solar drier on bacterial load and the percentages (%) of chemical composition of bayad fish flakes. These are percentages of fats, protein, fibers and ach contents .The results showed that, there was a considerable decrease in bacteria present in the dried fish compared to the fresh one from the same fish. this could be attributed to the increase in temperature inside the solar collector of the drier . The total viable count of bacteria decreased from (1.13×10^8 cfu/g) in fresh fish to (2.16×10^6 cfu /g) in solar dryed fish. This means that, solar drying of fish affected bacterial load considerably due to the elevated temperature inside the solar drier. Regarding chemical compositions of fish flakes, the results showed that, the amount of fats as a percentage were similar in both fresh and dried fish flakes, fibers content were nil in both fresh and dried fish, while protein content was less in dried fish flakes .Ach content was increased in dried fish from 7.27% to about 30.68%.The increase in ach and decrease in protein were resulted from the addition of salt as a pre-treatment before fish were dried, so that the percentage of inorganic matter was increased (salt) and the percentage of organic matter was decreased (protein).

Keywords: *Solar drier, fish flakes, microbial load, chemical composition*

Introduction

Fish provides a good source of high quality protein and contains many vitamins and minerals, supplying approximately 6% of global protein requirement and 16% of total animal protein which is almost cheaper than any other type of meat and therefore available to large number of people (Fellows and Hamptum, 1992; Ayyappan and Diwan, 2003). Fish is less expensive compared to other types of meat and is available in rural areas. Also fish can be supplied fresh, dried, salted or smoked on varying degree of acceptance by consumers (Geog *et al*. 1985). Minor fish species consumed with bones and shell body, are a good source of calcium, protein, vitamin B and vitamin B_{12}.When the fresh fish is not utilized by consumers and converted into finished product then it remains surplus and goes waste. Around 20% of fish is wasted due to poor and insufficient methods of cold storage (Prakash *et al*., 2003). The difference in fat content between lean and fatty fish (g/100 gram of fresh fish) was found to be 0.0-0.7 for lean, 3-10 for semi-fat and 12-20 for fatty fish. The range of protein in fish flesh is between 30-90% of the dry weight (Borgstrom, 1962).

Every year large quantities of fish have been lost because of inadequate preservation and storage of fish meat. This is due to high moisture content present in fish meat and microorganisms, insect and mites which increase very rapidly (Ahmed, 1999). Cooling is widely used as an important technique to maintain quality and to prevent spoilage (Dincer, 1995). The simplest method of cooling fish is icing (Govindan, 1985; Jain D. *et al*., 2005). The traditional methods of fish preservation and storage in Sudan include open sun drying "*Kejek*" salting ''*Faseak*'' and smoking. These processes are neither effective nor economical and they are not possible under adverse conditions, it was done under unhygienic conditions. Freezing and transportation of fish in Sudan from rural areas are risky and expensive (Dirar, 1993). Drying is the oldest method of food preservation and it represents the important aspect of food processing. Hall (1980) and Doymaz I.(2004) defined drying as, the process

or procedure used to remove excess moisture from products to a level acceptable for save storage. Hall (1980) and Toledo (1980), defined drying as the removal of moisture to a certain limit (equilibrium limit), while they were defined dehydration as the removal of moisture from a product until it becomes bone dry (complete drying). As mentioned by William *et al.,* (1978). The use of drying as a means of preserving meat is still important especially when refrigeration is limited. Drying is very common practice of fish in many developing countries. It is described as a process of simultaneous heat and mass transfer where the energy applied to the fish is utilized to increase the temperature of fish and vaporize the moisture present in the fish through provision of latent heat of vaporization. The removal of moisture from the interior of the fish takes place due to the induced vapor pressure difference between the fish and the surrounding medium (Jain and Pathare, 2004; Doymaz *I*., 2004; Jain D., 2006). Therefore the objectives of the present study were to investigate the effect of solar drying using a natural convective solar drier on bacterial load and the percentages (%) of chemical composition of bayad fish flakes. These are percentages of fats, protein, fibers and ach contents .

Materials and Methods

Experimental Study

Sudanese fish bayad (Bagrus bayad) were considered for drying. The fresh fish was purchased from Mawrada local market, Umdorman, Sudan, were used as a drying material for the experiments. Fish were washed with fresh water, heads, tails and internal parts were removed. Fish were cut into pieces (5cm×4cm×o.5cm).

Fig. 1 Natural Convective Solar Drier

Surface water and some blood were removed by blotting with the absorber paper. The prepared fish were treated with salt (0.08 % of Sodium chloride) to avoid any deterioration to the fish before the drying were completed (Waterman, J. J., 1981). Three steel wire mesh trays with an effective area of (85cm×82cm) were used during the solar drying of the fish. The fish were arranged in a single thin layer in the drying trays. The trays with fish were kept in the drier (Fig. 1).

Experiments were conducted at Food Research Center (FRC), Agricultural Research Corporation, Shambat, Sudan. Longitude 32º32´E, latitude 15º45´N and altitude 381 m above sea level. During the season of June-August 2008 and May-June 2009.The drier was placed on the roof of a two-floor building in order to get a maximum exposure to solar radiation. The drier consists of three detachable components namely; solar collector (air heater), drying chamber and air duct, Fig. 1.

Data loger (DLze, Cambridge, England) to which thermocouples were connected for temperature measurements. A digital hygrometer (Testo GM 6H-6350, Germany) was used for measuring a relative humidity of the drying air. A digital sensitive balance (Yass- 620, Yamato, Japan) was used to weigh the sample during the drying. The sample was weighed every one hour interval. The moisture content of the sample was calculated using the following equation as described by the standard methods of Association of Official Analytical Chemist (AOAC, 1984).

$$MC\ (w.b.) = \frac{Ww}{Ww+Wd} \times 100 \quad (1)$$

$$MC\ (d.b.) = \frac{Ww}{Wd} \times 100 \quad (2)$$

Where:
MC (w.b.) = fish moisture content on wet basis, percentage
MC (d.b.) = fish moisture content on dry basis, percentage
Ww = mass of water, grams
Wd = mass of dry matter, grams

Determination of bacterial load of the fish

These tests were carried out for both fresh and dried fish samples to check up the effect of solar drying on the total bacteria present in the dried fish.

a) Preparation of plate count agar

This was obtained in powder form. The medium was composed of yeast extract, dry peptone, D-glucose and granulated agar. It was prepared according to manufactures instructions by using 17.5 g in one litre of distilled water. The medium was allowed to boil in a water bath until it was completely dissolved. The pH was adjusted to 7.0 levels and then the medium was sterilized in an autoclave at 121^{o}C for 15 minutes.

b) Preparation of serial dilution

The fish were soaked in sterile peptone water by taking a sample of 10 g (for each fresh and dried fish) each sample was placed in a conical flask containing 90 ml sterile 0.1% peptone water. The contents of the conical flask were shaken for 45 minutes using an electrical shaker at speed

of 150 rpm to release the bacteria trapped in fish sample. This sample extract was referred to as mother solution (dilution 10^{-1}). One ml of mother solution was pipetted aseptically, with a sterilized pipette into 9 ml sterile peptone water (dilution 10^{-2}) and serial decimal dilutions up to 10^{-6} were prepared as described by Harrigan, (1998).

c) Determination of microbial load for fresh and dried fish

The total viable count of bacteria were carried out using the pour-plate method as described by Harrigan (1998). One ml of each dilution was transferred aseptically into sterile Petri dishes. To each Petri dish 10 – 15 ml of melted agar were added. The inoculums were mixed with the media and allows to solidify. The plates were then incubated aerobically in an incubator at 37°C for 48 hours. A colony counter of Scientific and Cook Electronic LTD make was used to count the viable colonies of bacteria and the count was expressed as colony-forming units (cfu) per gram (Dirar, 1976a).

Quality Analysis of Fish

The quality analysis of fresh and dried fish were done by determination the following parameters:

Chemical composition of fish

(i) Crude oil determination

Crude oil (CO) was estimated according to the official method described by AOAC, (1984). Duplicate samples for fresh and dried fish were used and then an average was taken for each test. The crude oil was calculated as percentage by the following equation:

$$CO\% = \frac{W_2 - W_1}{S} \times 100 \quad (3)$$

Where:
W_1 = mass of empty crucible, g
W_2 = mass of crucible + oil, g
S = mass of sample, g

(ii) Nitrogen and crude protein determination

The nitrogen content for the fresh and dried fish was determined according to the Kjeldahl method, which is described by AOAC (1984). The nitrogen content was multiplied by a factor of 6.25 to obtain the percentage of crude protein by the following equation:

$$\text{Crude protein (\%)} = \frac{T \times N \times 14.0 \times 100}{W \times 1000} \times 6.25 \quad (4)$$

Where:
T = titration number of HCl
N = normality of HCl (0.02N)
W = mass of sample, g
14.0= mass of nitrogen molecular, g
6.25 = protein conversion factor
1000= number of milligrams in one gram

(III) Crude fiber determination

Duplicated samples of fresh and dried fish were digested in 200 ml boiling NH_2SO_4 for 30 minute, and then filtered using a screen filter to obtain a residue, which was washed with hot distilled water to remove any trace of the acid. A second alkaline digestion for the residue was done using 200 ml boiling 0.344 NaOH for 30 minutes and then a similar filtering was done. The residue was washed with hot distilled water and then dried at 105°C in an oven for overnight and weighed. The dried residue was burnt in Muffle furnace at 550°C for 2 hours and then re-weighed after cooling in desiccator. The crude fiber was calculated using the following equation:

$$CF\% = \frac{W_1 - W_2}{S} \quad (5)$$

Where:
CF % = crude fiber, percentage
W_1 = mass of sample after drying and before being ignited in a muffle furnace, g
W_2 = mass of sample after being ignited by muffle furnace, g
S = mass of the sample, g

(iv) Ash content determination

Total ash for fresh and dry samples was estimated according to the official method described by AOAC (1984). The ash content was calculated using the following formula:

$$\text{Total ash\%} = \frac{W_2}{W_1} \times 100 \quad (6)$$

Where:
W_1 = original mass of sample, g
W_2 = mass of sample after igniting, g

Results and Discussion

Uses of solar driers have several potential attractive features for aiding processing in tropical areas. They have no energy cost and may provide a potential method for drying foods. Their construction can be very simple. The solar drier designed in the study (Fig. 1) contains no mechanical parts, and it would be attractive for use in small scale fish or food processing. It could be, however till now there is a limited development done on solar fish and vegetables driers and there are dominant uses of conventional sun drying in a commercial situation.

Solar driers employ some means of collecting and concentrating solar radiation to achieve elevated temperatures and reduce relative humidity during the drying, this will increase drying rates, lower final moisture content and give high quality products.

Fig. (2), shows the average ambient air, heated air and exhausted air temperatures plotted versus drying time of

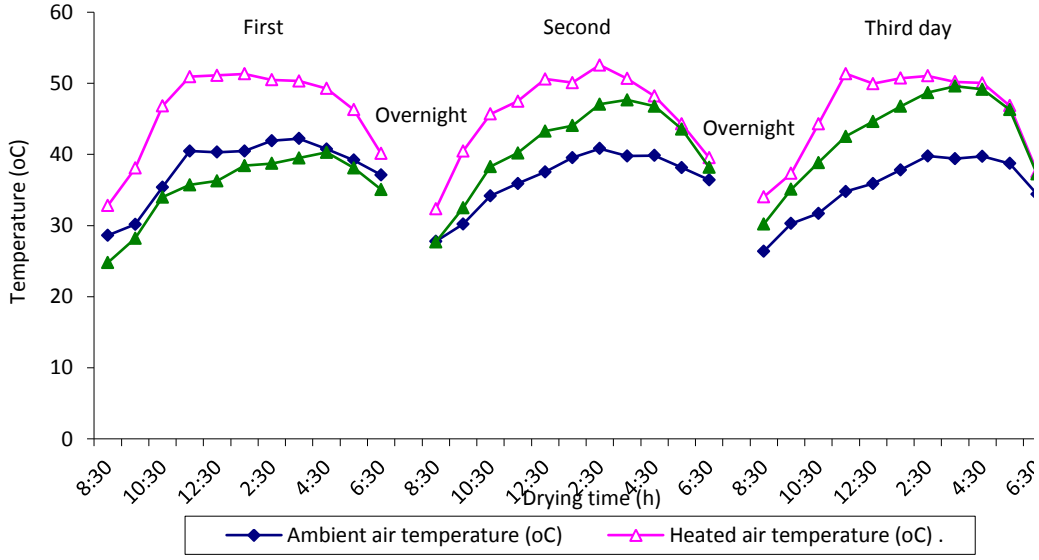

Fig.2 Ambient, heated and exhausted air temperatures with dying time

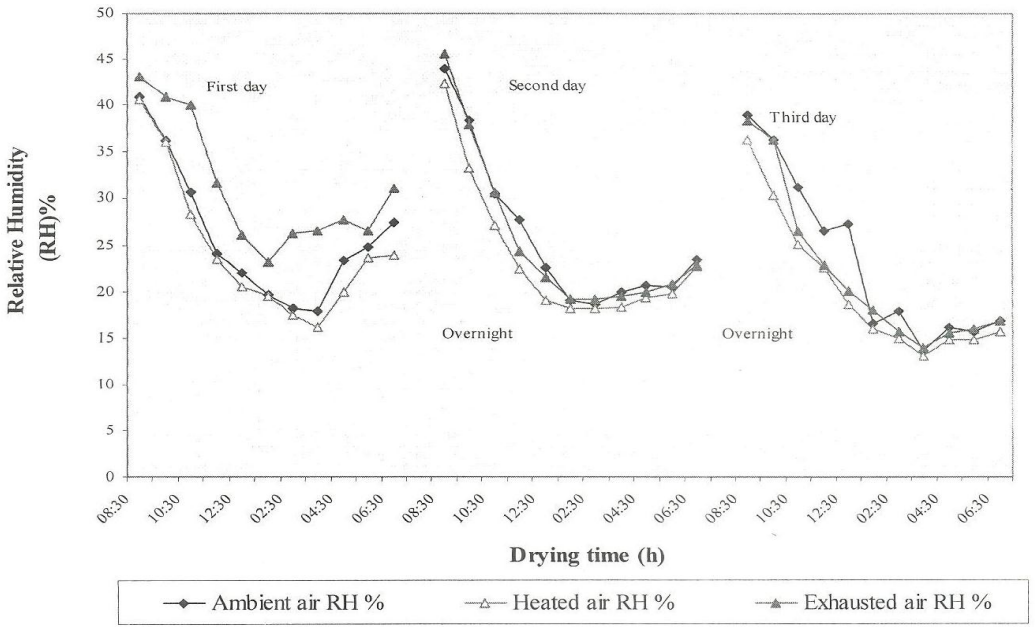

Fig.3 Average ambient, Heated and exhausted air relative humidities with drying time

bayad fish flakes during three consecutive days. The heated air (heated air inside solar drier) had a high temperature than the ambient air and exhausted air temperatures. The increase of heated air inside solar drier is due to the concentration of solar radiation inside the drier. The high temperature of the drying air is reduced when passes through moist fish inside the drying chamber and consequently the temperature of the exhausted air was reduced. This result is in agreement with Akoy, (2000) in his study of solar drying of onion slices and Jain D., (2006) in his study of solar drying of fish. They found that solar drier increases the temperature of the drying air significantly.

Fig. (3) shows the average results of ambient air, heated air and exhausted air relative humidities, plotted versus drying time for bayad fish flakes, during three consecutive days. There is a difference between ambient air and heated air relative humidities. The ambient air relative humidity is higher but when it was heated inside solar collector of the drier, it was decreased considerably as the effect of the increase in temperature inside solar collector and consequently its holding capacity to pull and carry water was increased. When this hot air with low relative humidity and high holding capacity passes through moist fish in the drying chamber, there is a simultaneous heat and mass transfer between product (fish) and heated air, so that there is an increase in the temperature of the fish and relative humidity of the drying air. This process continues with time till all the available water was removed. These results were in agreement with Jain D., (2006) in his study of solar drying of fish, he described drying process as simultaneous heat and mass transfer.

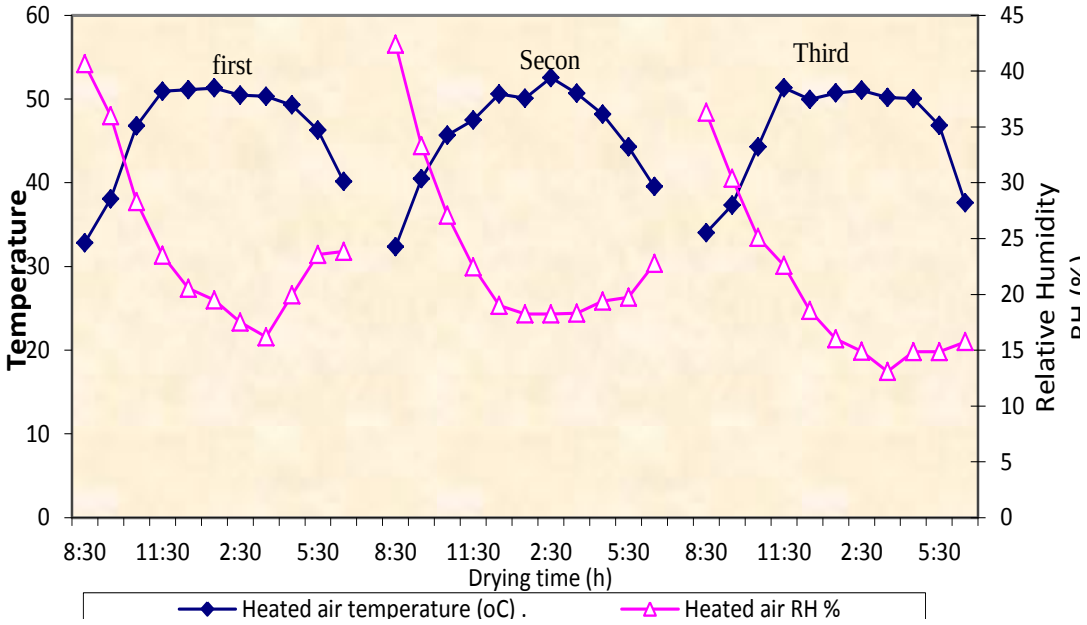

Fig 4 Drying air temperature and drying air RH versus time

Table 1 Average results of moisture content (mc) % and weight losses in grams for representive samples of fish flakes

Trial No.	Initial wt. (g)	Dried fish solar drying wt. (g)	Dried fish dry matter Wt. (g)	Initial mc% (w.b.)	Initial mc % (db)	Final mc% (w.b.)	Final mc% (d.b.)	Drying time (h)
1	30	9.33	6.2	79.33	383.87	10.43	50.48	33
2	30	9.99	6.3	79	376.19	12.3	58.57	33
3	30	10.15	6.7	77.67	347.76	11.5	51.49	33
average	30	9.82	6.4	78.67	369.27	11.41	53.51	33

Table 2 Total viable count of bacteria per one gram of fish samples

Sample No.	Fresh fish	Dry fish
A	1.3×10^8 cfu/g	4.0×10^6 cfu/g
B	9.6×10^7 cfu/g	3.2×10^5 cfu/g
Average	1.13×10^8 cfu/g	2.16×10^6 cfu/g

cfu/g = colony forming units per gram.

Fig. (4) shows the effect of heating for the same air, it is clear that when the air was heated in the solar collector, there is an increase in its temperature and decrease in its relative humidity.

Table 1 shows the average results of a representative samples for three drying experiments of fish flakes. The drying starts with an average initial moisture content of 78.67% (w.b.) and ended with an average final moisture content of 11.41% (w.b). These results were in agreement with Jain D. (2006), on his study drying of fish.

Total bacterial load of fish flakes

Table 2 shows the average colonies of bacteria count in one gram of fresh and dried fish. The total viable count of bacteria in the dried fish decreased considerably when compared to fresh one. This implies that, solar drying of fish flakes decrease the number of bacteria existed in fresh fish due to the Increase of temperature inside the drier. The temperature of the drying air was increased from 32.83 ^{o} C at early morning and it reached 52.56 ^{o} C in the mid day. It is known that most of intestinal pathogenic bacteria such as Cholera, Density and Typhoid die when they are exposed to temperature over 50 ^{o} C for certain time 45, 60, 75 and 90 minutes respectively (Alyan *et. al*.,2012). As indicated by the results (Fig 2) solar drier achieved these temperatures. This means that these pathogens would die in solar drier. A similar results were obtained by Khalifa, (2002) Investigated dried beef "Shermout". She reported that some-micro-organisms are destroyed during the drying process and this means drying also produce healthy food.

Table 3 Mean values of chemical composition in grams per 100 grams of dry matter for fresh and dried fish

Type	Fresh fish	Dry fish	SE
Protein	92.51	69.19	0.20*
Fat	0.22	0.23	ns
Fiber	Nil	Nil	ns
Ash	7.27	30.68	0.19*

* = Significant difference (P < 0.05), ns = No significant difference

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