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Drying Klunzinger's mullet fish *Planiliza klunzingeri* using Halogen Dryer and modeling the moisture content with artificial neural network

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Abstract: Salted and unsalted Klunzinger's mullet *Planiliza klunzingeri* were dried using infrared halogen dryer with different temperatures (60, 65, 70, 75 and 80)°C and different storage periods (0, 7, 14, 21, 28 and 35) days and studying their qualitative characteristics. The results showed that the moisture content decreased as drying time increased. The drying efficiency of the halogen dryer was 70.36 % at 60 °C and decreased as the drying temperature increased. Chemical composition of dried fish (salted and unsalted) showed that the moisture percentage was decreased, but the percentage of protein, fat and ash was increased after drying process. The percentage of moisture increased during the storage periods (0, 7, 14, 21, 28 and 35) days, unlike the other chemical composition percentages were decreased with increasing storage periods. The results showed that the rehydration was decreased with the increase of drying temperatures for salted and unsalted dried fish. Moreover, the results showed that there was an increase in TBA after the drying process and during the storage periods. In addition, the results revealed that the microbial content of dried salted and unsalted fish was decreased. The results illustrated that the first order model can be used to predict pH value during storage periods. Artificial neural network (ANN) model had a good result of predicted moisture content.

Keywords: Fish, *Planiliza klunzingeri* artificial neural network, halogen dryer, qualitative characteristics, Microbiological content.

Introduction

Drying leads to stop food damage by stopping the activity of bacteria, fermentation, and enzymes (Gates, 2015). Dried foodstuffs retains its flavor and nutritional value, easy prepared as well as it is light weight (Scanlin, 1997). Drying processes have been known since ancient times as a food preservation method (Guiné, 2018; Dubey *et al.*, 2020). The natural sun drying is one of the oldest conservation methods, which are known by humans and used by the people of the Arab countries to dry the fruits and vegetables from one season to another (Al-Rubai'y *et al.*, 2020). The natural sun drying needs great areas, high temperatures, low moisture, no rainy weather and needs to long drying time (Lasisi *et al.*, 2020). The natural sun drying method leads to occurrence of some negative changes in foodstuffs, and this related to the many factors, such as, weather conditions, pollution with microorganisms, dust and insects, this led to the non-exploitation economically on a large scale (Darvishi, *et al.*, 2013). Pochont *et al.* (2020) and Solanki

(2020) stated that the solar dryer has a better quality compared to open sun drying (natural sun drying). Dried fish should be stored in a hygienic cool and dry environment (Kubra *et al.*, 2020).

Fish represents a high source of protein and fats (Nath *et al.*, 2020). Fresh fish can be easily damaged, as well as its shelf life is short. The damage starts after 12 hours of fishing, especially in hot and warm weather (Darvishi, *et al.,* 2013). Fish meat is spoiled by self-decomposition (enzymatic), chemical reactions (oxidative stress), microbial activity and by the combined of these three factors (Huss, 1995; Chen *et al.*, 2020). In recent times, modern techniques have been used to drying fish. Kumar (2015) referred to the use of microwave drying technology or conventional oven in the drying processes. Fish dried with microwave gave a high drying efficiency. In addition, the increase in storage period of salted dried fish was higher than unsalted dried fish, and the possibility of using industrial solar collectors in drying different types of fish (Al-Rubaiy *et al*., 2020). Al-Temimi (2018) dried silver carp fish using microwave technology. Al-Fadhli (2009) dried Thelah fish (*Scomberoides commersonnianus*) using a solar dryer. Lithi *et al*. (2020) studied quality change of Mola (*Amblypharyngodon mola*) in open sun drying and solar tent dryer, the researchers found that the moisture content of Mola from solar tent dryer was significantly ($P<0.05$) lower compared to the open sun rack dryer and protein, lipid, ash and TVB-N content was significantly ($P<0.05$) higher in solar tent dried compared to the open sun rack dryer. Hardoko & Utami (2020) declared that the boiling time and drying duration had an effect on the chemical-physical properties of the rambak crackers of white snapper fish skin. Infrared ray is used to dry food with high efficiency (Aboud *et al*., 2019). Al-Temimi *et al*. (2019) stated that the radio-frequency heating can be used for food drying. Halogen oven is characterized with highly effective when it is used as a source of energy, which converts more than 85% of its electric energy into thermal energy (Pan & Atungulu, 2011). The same studies indicated that the use of halogen ovens to cook food is faster and cleaner than microwave ovens because of their characteristics are : the thermal emission outside the device is low and without fumes and there are not smells when they are used, in addition to that, the operating temperature ranges between 20-250^{o}C (Pan & Atungulu, 2011). Al-Hilphy, *et.al.* (2011) have used the halogen oven to dry some vegetables and fruits. Klunzinger's mullet *Planiliza klunzingeri* is a member of the Mugilidae family with 79 valid species around world (Fricke *et al*., 2020), including nine species and four genera which are *Ellochelon*, *Mugil*, *Osteomugil* and *Planiliza* in Iraq (Ali *et al*., 2018), with three species (*P. klunzingeri*, *P. subviridis*, *Osteomugil speigleri*) most common in Iraqi marine waters (Mohamed *et al*., 2016); All mugilid fishes are live in and temperate seas. Chiefly marine (coastal) and brackish water; some in freshwater (*Planliza abu* only is live in fresh and estuaries) (Froese & Pauly, 2019).

There are no published literatures in Iraq on drying fish by halogen energy. Therefore, the parameters of kinetic drying and effect of drying temperature on the qualitative characteristics of dried fish using halogen energy is un known. Moreover, Fish Klunzinger's mullet *Planiliza klunzingeri* are abundant in Basrah province, and they are highly perishable, therefore the study aimed to investigate the drying of Klunzinger's mullet fish using halogen dryer and study it is effect on the microbial and chemical properties of dried fish at different drying temperatures and storage periods. In addition, using artificial neural network to predict the moisture content.

Materials & Methods

Klunzinger's mullet *Planiliza klunzingeri* was obtained from local markets in Basrah province, with a weight of 200 g and a length of 20 cm. The samples were transported in a refrigerated container to the food engineering laboratory in Department of Food Sciences. The fish were washed by tap water, beheaded and opened from the ventral side as well as the internal organs and glands were removed. Some of the fish were unsalted and the others were salted with concentration of 10 % NaCl then left for 30 minutes at room temperature to remove the maximum amount of moisture. After that, fish was weighed and dried by halogen dryer (A digital halogen dryer made of HE. House Co.). It consists of a Pyrex container of 12 L capacity, glass cover provided with halogen lamp (1300 W power) as a heat source and fan with speed of 1500 rpm. Mercury thermometer was used to measure the temperature. The drying was done at five temperatures of 60, 65, 70, 75 and 80 °C and the weight was measured after every 10 minutes of the drying process. The moisture content (g water) based on the dry weight (moisture content on dry weight=moisture content %100-moisture content %) that was used. All the experiments in the present study were conducted in triplicates.

Drying rate was calculated as follows (Toledo, 2007):

$$DR = \frac{M_{t+d_t} - M_t}{d_t} \qquad (1)$$

Where M_t is moisture content at t and M_t+d_t is the moisture content at t+dt, d_tIs the drying time (min.)

The drying efficiency is calculated from the following equation (Toledo, 2007).

$$\eta = \frac{T_d - T_{out}}{T_d - T_a} \times 100 \qquad (2)$$

Where T_d is the drying air temperature, T_{out} is the out let air temperature from the dryer and T_a is the ambient air temperature. After the drying process, the dried fish were placed in vacuumed polyethylene bags and stored at laboratory temperature (25 ˚C) for 0, 7, 14, 21, 28 and 35 days, that was for fresh and dried samples during the storage periods.

Drying mechanism using infrared dryer

The fish were placed on the perforated tray inside the halogen dryer and the temperature required for drying was determined. When operating the halogen dryer, the halogen lamp emits infrared radiation and at the same time the air inside the dryer gets circulated by the fan. Infrared radiation falls on the surface of the fish and thus heat the fish as a result of heat transfer by radiation and conduction. The reason for heating is that vibrations occur in water molecules which their frequency matches the infrared frequency. Then the moisture evaporates from fish.

Chemical tests:

The chemical composition of fresh and dried salted and unsalted fish was studied. The percentage of moisture was estimated by using an electric oven at 105 °C until weight stability. Protein was estimated by the method of Semi-micro Kjeldahl . The total nitrogen was estimated and multiplied by the protein conversion factor (6.25). Fat percentage was estimated by the Soxhlet method using organic solvent petroleum ether with a boiling point range between 40-60 °C. Ash was determined via burn the fish sample in the Muffle furnace at 550 °C in order to get the white ash (Egan *et al.*, 1988).

Chemical indices

The pH meter (Jenway 3505, Bibby Scientific Ltd., England) was used to measure pH of fish samples. 10 g of fish samples were homogenized in 100 ml of distilled water for 30 s (Rossini *et al.,* 2009).

The thiobarbituric acid number (TBA) was estimated according to Egan *et al.* (1988). 10 g of fish samples were mixed with 50 mL of distilled water in a 250 ml beaker. After that, pH was adjusted to 1.5 using 2.5 ml of 4 N HCL. 5 ml of TBA solution was prepared by dissolving 0.2883 g of TBA reagents in 100 ml of glacial 90 (% $v.v^{-1}$) acetic acid. Next, the mixture was sealed, heated and then cooled to room temperature. The absorbance (D) of samples along with the blank sample (a mixture of 5 ml of distilled water with 5 ml of the TBA reagents) was measured at a wavelength of 538 nm using spectrophotometer. The value is expressed in (mg kg oil^{-1}). The TBA value of samples was calculated from the following Equation:

TBA (mg kg oil^{-1})=7.8×D,

where 7.8 is constant.

Microbial tests

Microbiological tests were performed under hygiene and sterilized conditions. A 10g was weighed from different fish samples and 90 ml of sterile dilution solution (0.1% peptone) was added under sterile conditions then the samples were mixed well. A series of dilutions was performed under sterile conditions. The dish casting method was used for the cultured process. The microbial counts were expressed in the unit. Total counts of bacteria were estimated using Nutrient Agar and incubated at 32°C for 24-48 hours. Total coliform bacteria were estimated using MacConkey agar and incubated at 37°C for 24-48 hours. *Staphylococcus aureus* was estimated using Mannitol salt Agar and incubated at 32 °C for 48 hours, while the estimation of yeasts and molds was achieved by Potato Dextrose Agar and incubated at 25 °C temperature for 24-96 hours. Andrews's method was followed to detect Salmonella after activation by Tetrathionata broth for 24 hours at a temperature of 35 °C then cultured on the Salmonella Shigella Agar media and incubated at 37°C temperature for 24-48 hours (Andrews, 1992).

Rehydration

The rehydration process of dried samples was calculated. A 2g from dried salted and unsalted fish was taken and placed in a flask (500 ml), then 80 ml of distilled water at a temperature of 30 °C was added. The flask was covered by a piece of glass and then boiled for 15 minutes using a heater. After that, the sample was left for 2 hours at room temperature of 25°C. The excess water was filtered by a Buechner funnel using Whatman NO.4 filter paper. The duration of filtration was for one minute. The rehydrated samples were taken from the funnel and weighted. The rehydration was calculated from equation (3) (Rangana, 1976):

$$Re = \frac{W_r}{W_{ad}} \times 100 \qquad (3)$$

Where W_r is the dried sample weight after rehydration and W_{ad} is the dried sample weight before rehydration (after drying).

Mathematical modeling

The reactions that occur in foods during storage have two models, the first is called between the pH and the reaction time (t) which is represented by the general equations (4) and (5) (Özilgen, 1998):

$$\frac{d(pH)}{dt} = -k_0 \quad (4)$$

$$pH = pH_o - k_0 t \quad (5)$$

Another order is the first order reaction, represented by equations (6) and (7):

$$\frac{d(pH)}{dt} = -k_1(pH) \quad (6)$$

$$ln(pH) = ln(pH_o) - k_1 t \quad (7)$$

Where, pH is the potential hydrogen at given of storage time, pH_o is the initial potential hydrogen, k_0 is the rate constant of the zero order model (1/h) and k_1 is the rate constant of the first order model (1/h).

The modeling process was performed using Excel 2016 by solver to find the constant k and predict theoretical values of pH based on the determination coefficient (R^2), the chi square (x^2) and the root mean square error (RMSE) which were calculated from the following equations:

$$R^2 = \frac{\sum_{i=1}^{N}(pH_{th.} - \overline{pH_{th.}})^2}{\sum_{i=1}^{n}(pH_{exp..} - \overline{pH_{exp.}})^2} \quad (8)$$

zero-order reaction, i.e. a linear relationship

$$x^2 = \frac{\sum_{i=1}^{N}(pH_{exp.} - pH_{th.})^2}{N - n} \quad (9)$$

$$RMSE = \left[\frac{\sum_{i=1}^{N}(pH_{exp.} - pH_{th.})^2}{N}\right]^{1/2} \quad (10)$$

Statistical analysis

The complete random design (C.R.D.) with factorial experiment (2×5×7), was used. The treatments were salted and unsalted fish, five drying temperatures and seven storage periods. The data were analyzed statistically using the statistical program SPSS ver. 21. The comparison among means was conducted by using less significant difference (L.S.D.) at 0.05 level.

Artificial neural network (ANN) modeling

Multilayered perception artificial neural network was applied for prediction of moisture content (neuron output layer) and three neurons input layer (drying time and drying temperature) was used. SPSS Ver. 21 software was used in this study. Forward Back Propagation network was implemented to perform suitable answer. Training process is a repetitive process contained the changes of weights between different layers where during training gradually reaches to stability of these weights, and the error occurred between the experimental and the predicted quantities were minimum. The optimized conditions was found by using activation function (hyperbolic tangent function) as given in equation (11) (Hernandez-Perez *et al.*, 2004):

$$Y_j = \frac{2}{(1 + \exp(-2X_j))} - 1 \quad (11)$$

Where, Y_j is the output, X_j is the sum weigh inputs of every neurons of layer j.

X_j was calculated according to equation (12):

$$X_j = \sum_{i=1}^{m} W_{ij} \times Y_i + b_j \qquad (12)$$

Where m is the output layer neurons number, W_{ij} is the weight between layers i and j, Y_i is the neuron i output and b_j is the bias amount of layer j neuron. 52.3% of data for training and 16.8% for testing. To obtain a network with an appropriate topology by applying training algorithms, sum of square error (SSE) term was used to get minimized error. As well as determination of the important of the independent variables (drying time and drying temperature). Architecture of the artificial network used in modelling for moisture content is illustrated in fig. (1).

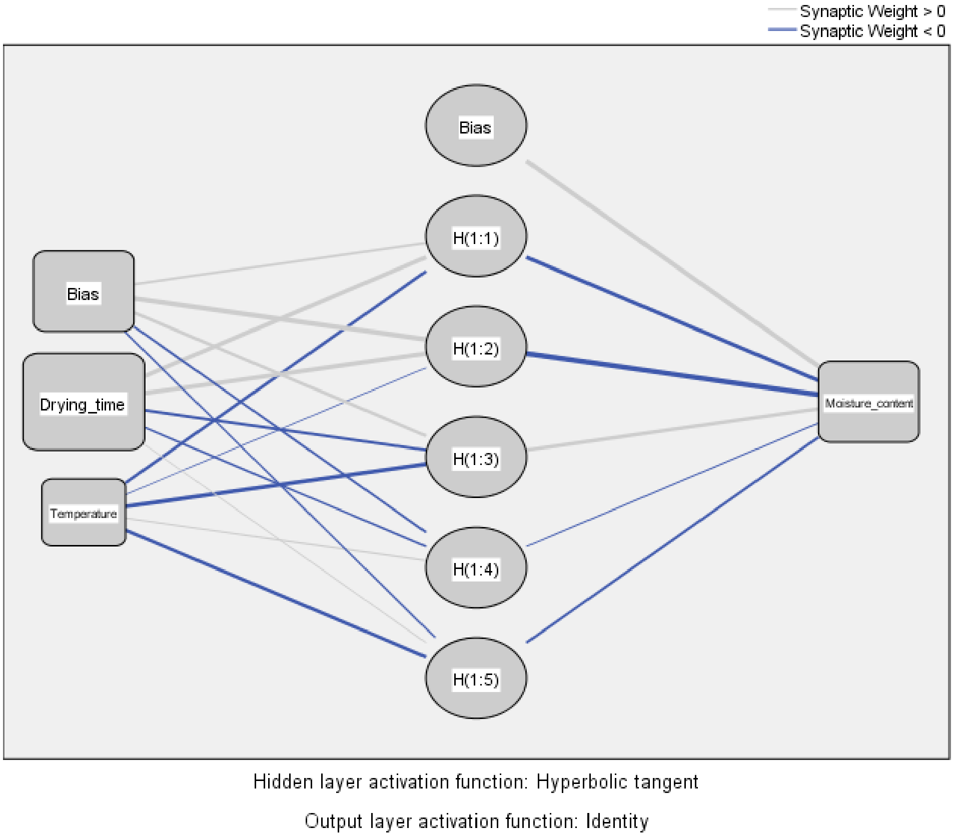

Fig. (1): Architecture of the artificial network used in modelling for moisture content.

Results & Discussion:

Moisture content

Figs.(2) and (3) showed the drying curve of Klunzinger's mullet (salted and unsalted) with different temperatures (60, 65, 70, 75 and 80°C). The results showed that the moisture content in all samples gradually decreased significantly ($P<0.05$) with increasing drying time at different temperatures. The moisture content decreased from 3.23 (g water. (g d.b.$^{-1}$) (d.b. means dry basis)in fresh fish to 0.28 (g water. (g d.b.$^{-1}$) in salted dried fish after 220 minutes of drying process using 60°C temperature. Also, the time required for drying fish was 180 and 210 minutes at 70 and 80 °C temperature respectively. In this case, the moisture content decreased to 0.25 and 0.24 (g water. (g d.b.$^{-1}$) respectively. As for unsalted fish, the moisture content decreased further and took longer time. The moisture content in fresh fish was decreased from 3.33 (g water. (g d.b.$^{-1}$) to 0.25 (g water. (g d.b.$^{-1}$) after 250 minutes of drying time by using 60 °C temperature for salted fish. In addition, it required 180 and 210 minutes at 70 and 80 °C temperature respectively. The moisture content decreased to 0.25 (g water. (g d.b.$^{-1}$) for both temperatures. The reason of the variation in moisture content was due to the high temperature and the duration of exposure. Increasing temperature led to ionize the water molecules and increase their movement, which in turn led to generate thermal energy, which caused an increase in the vapor pressure inside the foodstuffs, and that leads to the evaporation of moisture faster with increasing temperature (Patir *et al.*, 2006). This process occurred at a temperature of 80°C, which reduced the drying time by 70 minutes compared with 60 and 70 °C temperatures. The results showed that the drying process of salted fish was faster than the unsalted fish. This may be attributed to the salt which draws internal moisture out of the fish meat and transfers it to the surface of the fish, for evaporation. The use of halogen dryer in the drying process gave a high drying efficiency, because of halogen energy (infrared energy) and movement of air, which prevented fish surface hardness during the drying process compared with conventional drying, which depends on the high temperature only whether it is an electric dryer or a natural sun drying. Kumar (2015) and Al-Temimi (2018) indicated that the moisture content of fish carp was reduced with an increase of the energy levels when the microwave dryer was used, which led to reduce the drying time. Lithi *et al.* (2020) stated that the moisture content of fish was decreased from 80.71% to 7.5% by using solar dryer and reduced to 7.86% using open sun drying. Tanuja *et al.* (2020) disclosed that the moisture content of the fish (*Stolephorus commersonii*) reduced from 81.97% to 28.87% and 34.43% by the solar rack dryer and natural sun drying respectively.

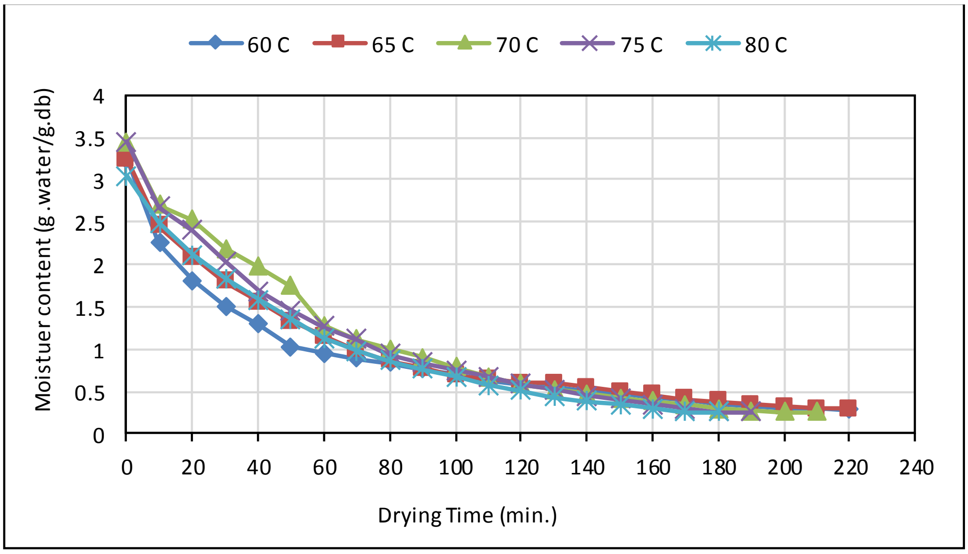

Fig. (2): The drying curve of salted Klunzinger's mullet at different temperatures.

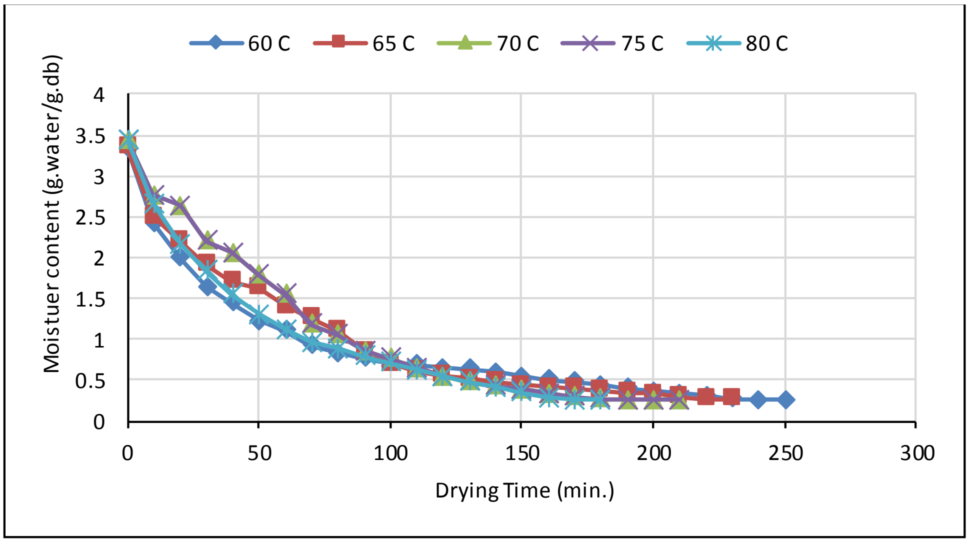

Fig. (3): The drying curve of unsalted Klunzinger's mullet at different temperatures.

Drying Rate:

Figs. (4) and (5) showed the drying rate curve for dried salted and unsalted Klunzinger's mullet at different temperatures (60, 65,70,75 and 80°C). The results showed that the drying rate in all samples significantly ($P<0.05$) decreased with increasing drying time at different temperatures. The drying rate decreased from 0.099 (g water.min^{-1}) for fresh fish to 0.0001 (g water.min^{-1}) after 220 min. of drying process at 60 °C for salted fish. Drying rate reached 0.0025 and 0.0006 (g water. min^{-1}) when drying time was 180 and 210 min. at 70 and 80 °C respectively. For unsalted fish, the drying rate decreased from 0.090 (g water.min^{-1}) to 0.000518 (g water.min^{-1}) for fresh fish after 250 min. of drying process at 60°C temperature for unsalted fish and it required180 and 210 min. at 70 and 80 °C temperature. The reason for the variation in drying rate was due to the water in the foodstuffs that is affected by the high temperature and the duration of exposure. Al-Temimi (2018) used the microwave for drying carp fish and found that the drying rate decreased as energy levels increased.

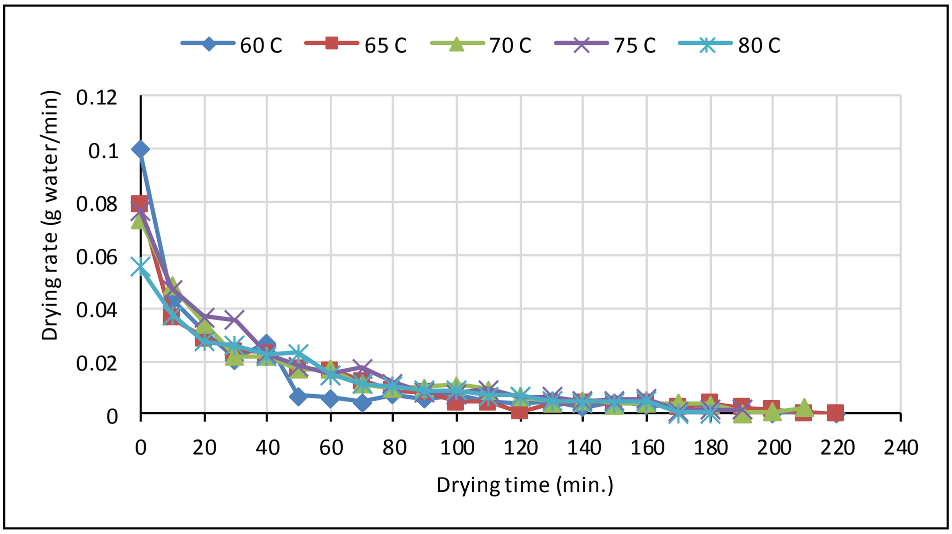

Fig. (4): The drying rate curve of salted Klunzinger's mullet at different temperatures.

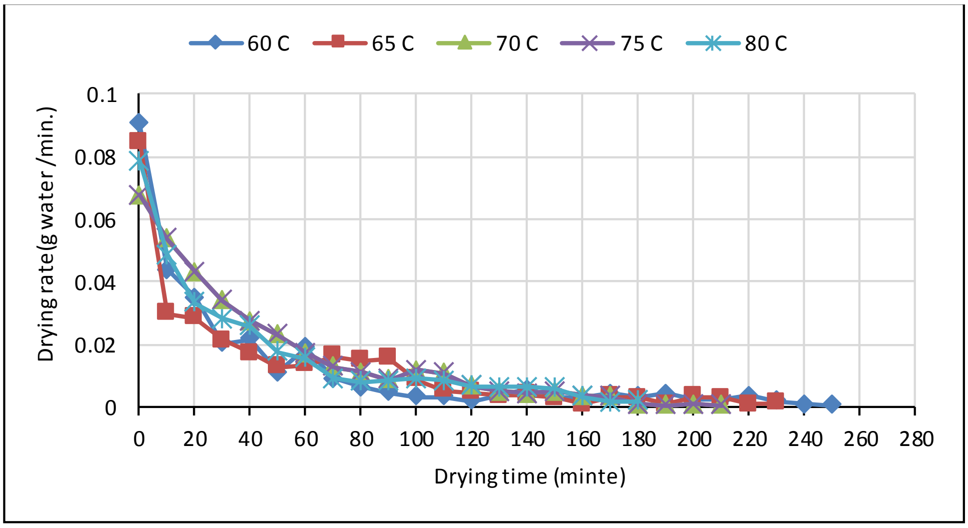

Fig. (5): The drying rate curve of unsalted Klunzinger's mullet at different temperatures.

Lim *et al.* (2020) stated that superheated steam drying produces a significant shorter drying time because of the drying rates were higher.

Drying efficiency

Fig. (6) showed the drying efficiency of the dried fish using halogen dryer at different temperatures. The results showed that drying efficiency decreased as drying temperature increased because of increase of the heat loss and output air temperature from dryer. The drying efficiency decreased from 71.36% to 68.74% when drying temperature increased from 65°C to 80°C respectively. The relationship between drying efficiency and drying temperature was linear as presented in equation (13):

$$\eta = -0.1328T + 79.292 \; ; R^2 = 0.9449 \qquad (13)$$

Al-Hilphy & Al-Rikabi (2013) found that the drying efficiency of strawberry by halogen dryer decreased with the increase of drying temperature, and the some researchers

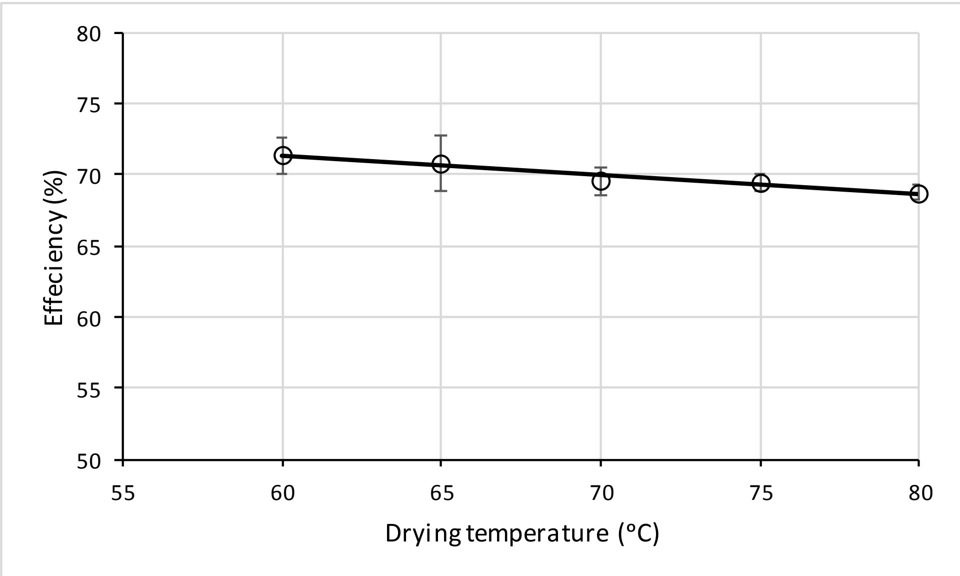

Fig. (6): The drying efficiency of dried Klunzinger's mullet at different temperatures.

found that the relationship between drying efficiency and drying temperature was polynomial. The differences between the current study and other studies it may attributed to use various dryers i.e., the current study used halogen dryer, but the other studies used hot air dryers.

Chemical Content:

The results showed that there are significant changes (P<0.05) in the chemical content of dried salted and unsalted Klunzinger's mullet at different temperatures of 60, 65, 70, 75 and 80 °C) during storage periods (0, 7, 14, 21, 28 and 35) days. The results showed that the chemical content of fresh fish was 76.4, 17.4, 4.68 and 1.52% for moisture, protein, fat and ash respectively. The results agreed with Al-Bayati & Ahmed (2008) who estimated the chemical composition of fresh Biayah fish, which was 76.6, 18.70, 2.70 and 1.50 % respectively. The variation in the percentages of chemical contents was due to different fishing times, feeding and fish age. The results illustrated that there were a significantly decrease (P<0.05) in the moisture content for all samples with increasing drying temperatures and that unlike in the other chemical composition percentages. These results were consistent with Al-Shatty *et al.* (2014) and Al-Temimi (2018) who stated that the moisture content decreased, and the other chemical composition percentage increased.

Table (1) showed that the moisture content (based on wet basis %) significantly decreased (P<0.05) with increasing drying periods at different temperatures for all samples. The results depicted that the moisture content decreased from 76.94 % in fresh Klunzinger's mullet to 22.89, 22.62, 20.22, 19.93 and 19.93 % for dried salted fish using 60, 65, 70, 75 and 80 °C temperatures respectively, whereas, for dried unsalted fish at the same temperatures, they were 20.18, 20.18, 20.18, 20.18 and 20.12 % respectively at zero-day of storage periods. The results were agreed with Al-Shatty *et al.* (2014) who observed that the moisture content of fresh carp fish was 79.50 % and decreased to 22.85 % using the electric dryer. The results showed that the moisture content slightly increased during the storage period. This is due to the difference in moisture content between fish meat and its surrounding which has a little moist air, as well as the moisture content in the outside air, as the packaging bags may be permeable to moisture, which led to different molecular pressures and then the moisture transferred from the outside air to the fish. Majeed & Al-Hilphy (2007) stated that the moisture can be transferred from ambient to unpackaged dried fish. The results were not consistent with Al-Fadhly (2009) who confirmed that the moisture content stayed low after drying process of fish and during increasing the storage periods. Also, table (1) showed that the protein content significantly increased (P<0.05) with drying temperatures, i. e., The percentage of protein increased from 17.4% in fresh Klunzinger's mullet to 55.30, 56.11, 59.20, 61.45 and 60.24 % for dried salted fish at 60, 65, 70, 75 and 80 °C temperatures respectively, whereas, for dried unsalted fish at the same temperatures, they were reached 59.77, 60.10, 59.11, 61.65 and 60.18 % at zero day of storage periods. The reason for this variation in the protein content may be due to heat which led to denaturing protein, which reduced its portability of water (Patir *et al.*, 2006). Azam, *et al.* (2003) who studied drying *Mugil cephalus*, the researchers found that protein levels increased in summer to 68.09 % and more than winter (60.58%). Also, the results agreed with Al-Fadhly (2009) who stated that protein content increased after the decreasing moisture for salted and sun-dried fish. The results showed a decrease in protein content for dried salted and unsalted fish with an increase of the storage periods, due to a slight increase in moisture during the storage periods. The results were agreed with El-Sebaiy & Metwalli (1989) who found that protein content decreased from 82.50 % to 71.10 % in small mullet meat. The reason may be due to the different types of fish, different ways and environmental conditions in fishing, as well as, the salt concentration used. These results were agreed with Al-Temimi (2018) who found a low protein content in microwaved dried carp fish during the storage periods.

Table (1) showed that the fat content significantly increased ($P<0.05$) with the drying temperatures. The percentage of fat increased from 4.68 % in fresh Klunzinger's mullet to 15.46, 15.34, 15.50, 14.82 and 14.22 % for dried salted fish at 60, 65, 70, 75 and 80°C temperature respectively, and for dried unsalted fish were 15.46, 13.93, 15.42, 14.50 and 14.34 % respectively at zero day of storage periods. This variation in fat content may be due to the decrease of moisture because of the drying process has effected on the chemical content of the fish. The results agreed with Azam *et al.* (2003) who studied of dried Biayah fish and noted that the percentage of fat in the summer increased to 8.22% and decrease to 4.87%. Also, the results agreed with Al-Shatty *et al.* (2014) who showed that fat percentage was increased after decreasing moisture of dried salted fish using sun drying. Tanuja *et al.* (2020) declared that the fat content of dried Anchovy (*S. commersonii*) was 3.22% and 4.31 % using open sun drying and solar dryer respectively. The results disclosed a decrease in fat content for dried salted and unsalted fish with an increase in the storage periods, due to a slight increase in moisture during the storage periods. The results were agreed with El-Sebaiy & Metwalli (1989) who showed that the percentage of fat for dried fish *Puntius* sp. (stored for 135 days) was decreased from 25.12 % to 20.90%. These results were agreed with Al-Temimi (2018) who found a low-fat content in microwave dried carp fish during the storage species. This may be due to the ability of dried fish to absorb moisture from the atmosphere, which directly effects on the chemical composition of dried fish. Table (1) illustrated that the ash content significantly increased ($P<0.05$) with the drying temperatures. The percentage of ash increased from 1.52 % in fresh Klunzinger's mullet to 6.35, 5.93, 5.05, 3.75 and 5.60 % for dried salted fish at 60, 65, 70, 75 and 80 °C temperatures, and for dried unsalted fish at the same temperatures was 6.12, 5.61, 5.29, 3.67 and 5.36 % respectively at zero day of storage periods. This variation in ash content is due to the decrease of moisture which caused by drying and salting process. The results agreed with Azam, *et al.* (2003) who studied dried Biayah fish, and explained that the ash content increased in summer to 10.35 %, and in winter reached 7.45%. Also, agreed with Al-Shatty *et al.* (2014) who showed an increase in the percentage of ash after decreasing moisture of dried salted fish by sun drying. The results showed a decrease in ash content for dried salted and unsalted fish with an increase in the storage periods, this was due to a slight increase in moisture during the storage periods. The results agreed with El-Sebaiy & Metwalli (1989) who found that the percentage of ash for dried fish *Puntius* sp. (stored for 135 days) decreased. The reason may be due to the different types of fish, the different methods and environmental conditions in fishing, as well as the salt

Table (1): Chemical composition of dried salted and unsalted Klunzinger's mullet at different temperatures during storage periods.

Temperature (°C)	Storage periods (day)	Dried salted Klunzinger's mullet				Dried unsalted Klunzinger's mullet			
		Moisture	Protein	Fat	Ash	Moisture	protein	Fat	Ash
60	0	0. 20±22.89	55.30±0.30	15.46±0.22	6.35±0.10	20.18±0.20	59.77±0.31	13.83±0.21	6.12±0.08
	7	23.19±0.18	55.30±0.30	15.45±0.21	6.06±0.07	20.47±0.21	59.67±0.29	13.92±0.21	5.94±0.10
	14	20.48±0.21	55.28±0.27	15.40±0.20	5.96±0.07	20.69±0.19	59.84±0.31	13.90±0.21	5.93±0.09
	21	23.65±0.18	55.17±0.26	15.33±0.18	5.85±0,06	20.78±0.20	59.41±0.30	13.88±0.20	5.93±0.09
	28	23.77±0.20	55.10±0.26	15.30±0.18	5.83±0,05	20.92±0.21	59.35±0.29	13.82±0.20	5.91±0.10
	35	24.19±0.19	55.00±0.25	15.00±0.19	5.81±0.05	21.22±0.22	59.30±0.28	13.80±0.19	5,68±0.11
65	0	22.62±0.20	56.11±0.31	15.34±0.21	5.93±0.06	20.18±0.19	60.10±0.32	13.93±0.20	5.61±0.11
	7	22.77±0.18	56.08±0.30	15.28±0.20	5.87±0.07	20.48±0.18	59.96±0.31	13.92±0.21	5.48±0.09
	14	22.93±0.18	56.01±0.31	15.24±0.19	5.82±0.05	20.70±0.19	59.95±0.31	13.90±0.21	5.29±0.10
	21	23.11±0.21	55.92±0.32	15.18±0.18	5.79±0.05	20.92±0.21	59.88±0.30	13.88±0.20	5.17±0.09
	28	23.56±0.20	55.88±0.31	15.14±0.19	5.45±0.06	21.13±0.19	59.82±0.29	13.82±0.20	5.07±0.09
	35	23.80±0.21	55.80±0.29	15.11±0.20	5.29±0.07	21.22±0.20	59.77±0.30	13.80±0.21	5.04±0.10
70	0	20.22±0.19	59.20±0.31	15.53±0.22	5.05±0.06	20.18±0.19	59.11±0.28	15.42±0.22	5.29±0.12
	7	20.43±0.19	59.16±0.31	15.50±0.22	4.91±0.05	20.45±0.21	58.08±0.28	15.36±0.21	5.11±0.09
	14	20.76±0.20	59.14±0.29	15.46±0.21	4.64±0.05	20.71±0.20	58.94±0.29	15.32±0.20	5.03±0.10
	21	20.84±0.19	59.14±0.29	15.43±0.20	4.60±0.06	20.96±0.22	58.88±0.30	15.28±0.19	4.88±0.08
	28	21.05±0.18	59.10±0.28	15.40±0.20	4.45±0.05	21.24±0.22	59.82±0.30	15.20±0.18	4.84±0.08
	35	21.31±0.18	55.80±0.28	15.38±0.19	4.38±0.07	21.57±0.20	58.61±0.29	15.18±0.18	4.59±0.08
75	0	19.93±0.19	61.45±0.32	14.87±0.16	3.75±0.08	20.18±0.21	61.65±0.32	14.50±0.16	3.67±0.11
	7	20.11±0.18	61.40±0.31	14.82±0.16	3.67±0.08	20.49±0.19	61.45±0.32	14.45±0.16	3.61±0.11
	14	20.34±0.20	61.22±0.31	14.78±0.17	3.66±0.07	20.85±0.19	61.34±0.31	14.26±0.15	3.55±0.12
	21	20.55±0.19	59.13±0.29	14.76±0.17	3.53±0.07	21.11±0.20	61.22±0.30	14.11±0.15	3.45±0.10
	28	20.76±0.21	61.00±0.33	14.67±0.16	3.46±0.08	21.43±0.21	61.11±0.31	14.08±0.15	3.38±0.09
	35	20.92±0.21	60.97±0.34	14.65±0.16	3.46±0.08	21.57±0.21	61.08±0.31	14.00±0.20	3.35±0.08
80	0	19.93±0.17	60.24±0.33	14.23±0.15	5.60±0.05	20.12±0.19	60.18±0.30	14.34±0.21	5.36±0.09
	7	20.23±0.18	60.18±0.32	14.22±0.16	5.37±0.05	20.41±0.19	60.15±0.31	14.30±0.21	5.14±0.11
	14	20.47±0.19	60.14±0.31	14.20±0.15	5.19±0.06	20.65±0.18	60.10±0.31	14.21±0.20	5.04±0.09
	21	20.63±0.19	61.16±0.32	14.20±0.16	5.07±0.06	20.93±0.19	60.07±0.32	14.18±0.20	4.82±0.10
	28	20.76±0.20	60.07±0.29	14.18±0.14	4.98±0.05	21.13±0.21	60.03±0.31	14.15±0.19	4.69±0.12
	35	20.82±0.20	60.06±0.30	14.17±0.14	4.95±0.05	21.37±0.20	60.00±0.31	14.10±0.18	4.53±0.11
Fresh fish		76.40	17.40	4.68	1.52	76.40	17.40	4.68	1.52
L.S.D.		0.051	0.045	0.032	1.20	0.051	0.045	0.032	1.20

concentration used. These results were agreed with Al-Temimi (2018) who found that the ash content in microwaved dried carp was decreased during the storage periods. Lithi *et al.* (2020) mentioned that the ash content in dried fish reached 9.60% and 10.16% using open sun drying and solar dryer respectively. The ash content in open sun dried fish was significantly higher because of deposition of dust and dirt particles on the fish (Rasul *et al.*, 2018). The thiobarbituric acid (TBA) values for dried salted and unsalted Klunzinger's mullet by using different temperatures during different storage periods were shown in Figs. (8) and (9).

Chemical indices

The pH values for dried salted and unsalted Klunzinger's mullet with different temperatures during different storage periods was shown in Figs. (7) and (8). The results showed that pH of dried salted fish was 5.90 , 5.95 , 6.01 , 6.11 and 6.10 at temperatures of 60 , 65 , 70 , 75 and 80 °C respectively at zero day of storage periods, and was 6.31 , 6.12 , 6.35 , 6.41 and 6.35 respectively after 35 days of storage. Furthermore, the pH values were 5.75, 5.79, 5.85, 6.01 and 6.08 at the same temperature respectively at zero day of storage periods. It was reached to 6.22, 6.13, 6.22, 6.30 and 6.30 respectively after 35 days of storage in dried unsalted fish. The results showed that pH of dried salted and unsalted Klunzinger's mullet increased with the storage periods and that the pH of salted fish was exceeded compared with unsalted fish. The reason for the increae of pH was the continuation of the protein decomposition process due to the continuation of the enzymatic activity, whether it was intrinsic or microbial which leads to the production and release of nitrogenous bases and amino acids, urea or ammonia, all of this led to an increase of pH (Elshehawy, etal., 2015). The results agreed with Fath El-Bab (2005) who found that the value of the pH was increased by using high salt concentration. The results were agreed with Patir *et al.* (2006) who found that the lowest and highest pH values of salted small mullet were 5.36 and 6.95 respectively.

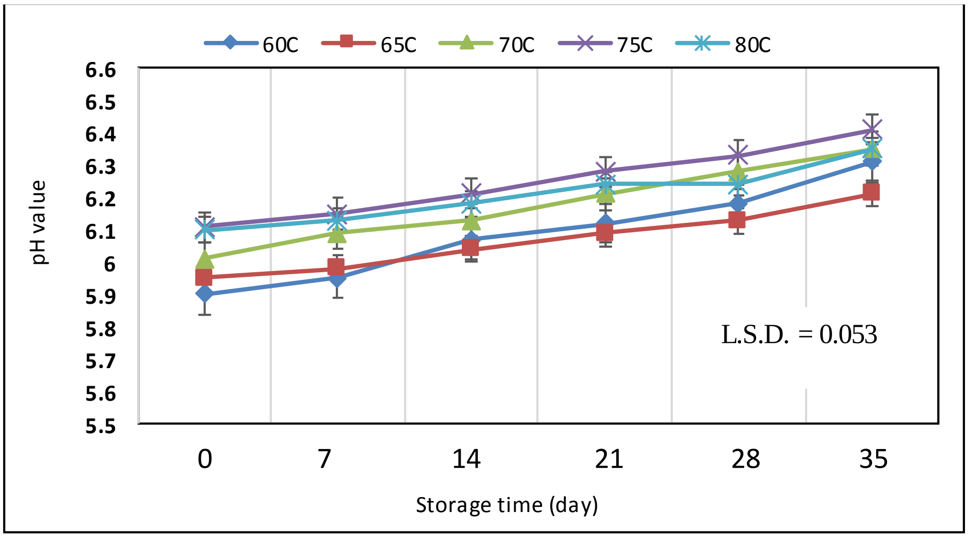

Fig. (7): pH value curve of Klunzinger's mullet (salted) at a different temperature during different storage periods.

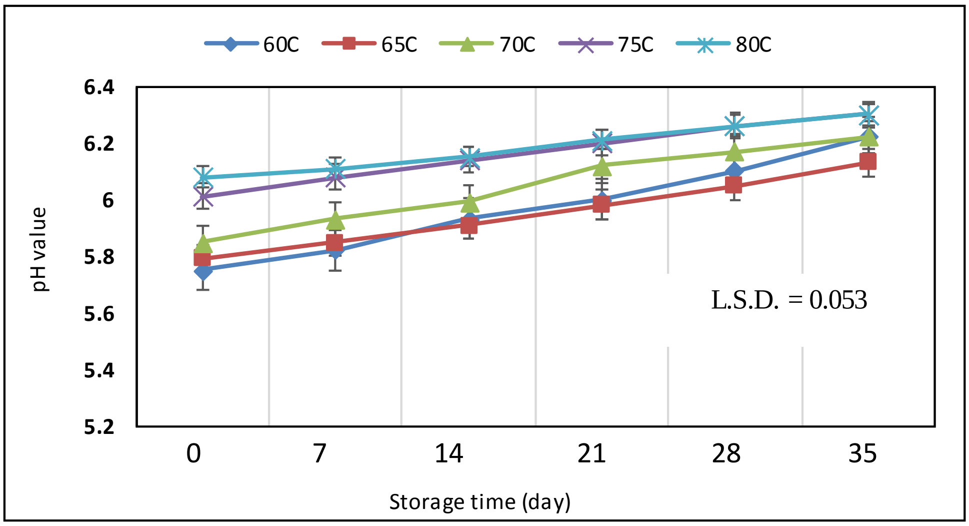

Fig. (8): pH value curve of Klunzinger's mullet (unsalted) at a different temperature during different storage periods.

Mathematical modeling of pH

The mathematical modeling used to predict deterioration of product and calculation of reaction rate, as well as determination better model for fitting predicted and experimental data. The results in table (2) illustrated that the first order model can be used to predict pH value during storage periods compare with the Zero order model. This is because the statistical parameters such as root mean square error (RMSE) and chi square (X^2) for the first order model were less than the Zero order model at all drying temperatures in the salted and unsalted fish. As well as, the determination of coefficient (R^2) for the first order model was higher at all drying temperatures in the salted and unsalted fish. For example, when drying temperature was 60ºC in salted fish, k_0 and k_1 were -4.57 ×10^{-4} 1.h^{-1} and -7.55×10^{-5} 1.h^{-1} respectively with RMSE, X^2 and R^2 reached 0.0189, 0.00357 and 0.9890 respectively for the zero order model, and reached to 0.01833, 0.000392 and 0.990335 respectively for the first order model. Rates constants were changed with temperature and process type (salted and unsalted). The relationship between rate constant and drying temperature was polynomial four orders in salted and unsalted fish as depicted in equations from (14) to (17):

$$k_{0\,(zero\,model, salted\,fish)} = -4\times10^{-8}T^4 + 1\times10^{-5}T^3 - 0.0012T^2 + 0.0585T - 1.0304 \quad ; R^2 = 1 \tag{14}$$

$$k_{1\,(first\,model, salted\,fish)} = -7\times10^{-9}T^4 + 2\times10^{-6}T^3 - 0.0002T^2 + 0.0098T - 0.1728 \quad R^2 = 1 \tag{15}$$

$$k_{0\,(zero\,model, unsalted\,fish)} = -8\times10^{-8}T^4 + 2\times10^{-5}T^3 - 0.0025T^2 + 0.1155T - 2.0302 \quad R^2 = 1 \tag{16}$$

$$k_{1\,(first\,model, unsalted\,fish)} = -1\times10^{-8}T^4 + 4\times10^{-6}T^3 - 0.0004T^2 + 0.0196T - 0.344 \quad R^2 = 1 \tag{17}$$

Table (2). Results of mathematical modeling and statistical parameters of pH.

Process type	Drying temperature (ºC)	Model order	Rates Constants (1/h)	RMSE	X^2	R^2
salted	60	Zero order model	k_0=-4.57×10^{-4}	0.0189	0.00357	0.989000
		First order model	k_1=-7.55×10^{-5}	0.01833	0.000392	0.990335
	65	Zero order model	k_0=-2.87×10^{-4}	0.01145	0.002061	0.993076
		First order model	k_1=-4.70×10^{-5}	0.00415	0.000834	0.993558
	70	Zero order model	k_0=-4.00×10^{-4}	0.00747	0.001310	0.997534
		First order model	k_1=-6.52×10^{-5}	0.00273	0.000516	0.997719
	75	Zero order model	k_0=-3.39×10^{-4}	0.01051	0.001882	0.996232
		First order model	k_1=-5.44×10^{-5}	0.00373	0.000735	0.996670
	80	Zero order model	k_0=-2.62×10^{-4}	0.01897	0.003582	0.971224
		First order model	k_1=-4.23×10^{-5}	0.00708	0.001590	0.971774
unsalted	60	Zero order model	k_0=-5.34×10^{-4}	0.01359	0.002480	0.996797
		First order model	k_1=-8.99×10^{-5}	0.00455	0.000920	0.997385
	65	Zero order model	k_0=-2.28×10^{-4}	0.04200	0.009060	0.940442
		First order model	k_1=-3.83×10^{-5}	0.01575	0.004652	0.941812
	70	Zero order model	k_0=-4.65×10^{-4}	0.01697	0.003160	0.990578
		First order model	k_1=-7.74×10^{-5}	0.00668	0.001470	0.989925
	75	Zero order model	k_0=-3.63×10^{-4}	0.00805	0.001410	0.997392
		First order model	k_1=-5.90×10^{-5}	0.00336	0.000650	0.996883
	80	Zero order model	k_0=-2.58×10^{-4}	0.00854	0.001500	0.995706
		First order model	k_1=-4.17×10^{-5}	0.00311	0.000590	0.995953

RMSE is the root mean square error, X^2 is the chi square, R^2 is the determination coefficient, k_0 is the rate constant of the zero order model l.h^{-1} and k_1 is the rate constant of the first order model l.h^{-1} .

The thiobarbituric acid (TBA) values for dried salted and unsalted Klunzinger's mullet by using different temperatures during different storage periods were shown in Figs. (9) and (10). The results showed that TBA values in fresh fish was 0.731 mg malaldehyde.kg^{-1} and they were 0.939 , 0.961, 0.966, 1.011 and 1.031 mg malaldehyde.kg^{-1} for dried salted fish at temperatures of 60 , 65, 70 , 75 and 80 ° C respectively at zero day of storage periods, whereas they reached to 0.985, 1.028, 1.035, 1.053 and 1.057 mg malaldehyde.kg^{-1} respectively after 35 days of storage . The results showed that TBA values were 1.221, 1.226, 1.221, 1.211 and 1.131 mg malaldehyde.kg^{-1} at the same temperature respectively at zero day of storage periods, and after 35 days of storage were 1.254, 1.259, 1.262, 1.262 and 1.167 mg malaldehyde.kg^{-1} respectively for dried unsalted fish. The results showed that TBA value for salted and unsalted dried fish was increased as the storage periods increased. This is due to the high percentage of fat after drying process. Also, it was due to the speed of drying process compared with conventional methods. Al-Shatty *et al.* (2014) indicated that TBA values was significantly affected by the drying method. The researchers noted that TBA values were higher when using solar drying than electric drying or using air drying. These results agreed with Al-Temimi (2018) who observed an increase in TBA values in microwaved dried carp fish with the increase of storage periods. The relationship between TBA and drying temperature and storage periods for salted and unsalted fish was given in the linear equations (18) and (19). In addition, the effect of drying temperature and storage periods on the TBA were significant ($P<0.05$).

$$TBA_{salted} = 0.677 + 0.004T + 0.001t \quad ; R=0.964 \; ; SE=0.0129 \tag{18}$$

$$TBA_{unsalted} = 0.962 + 0.003T + 0.001t \quad ; R=0.707 \; ; SE=0.029 \tag{19}$$

Where, T is the temperature (ºC), t is the storage period (day), R is the regression coefficient and SE is the standard error.

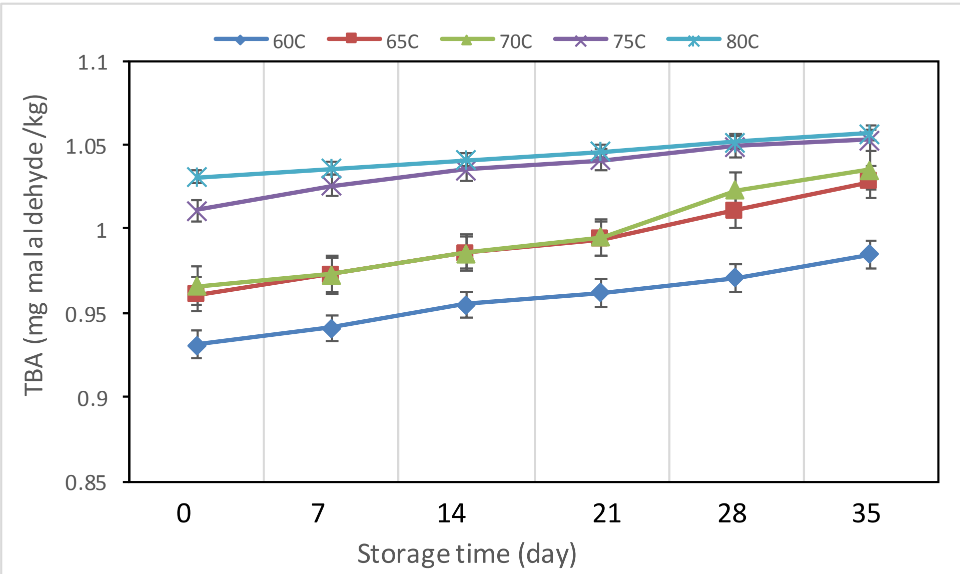

Fig. (9): TBA curve of Klunzinger's mullet (salted) at a different temperature during different storage periods.

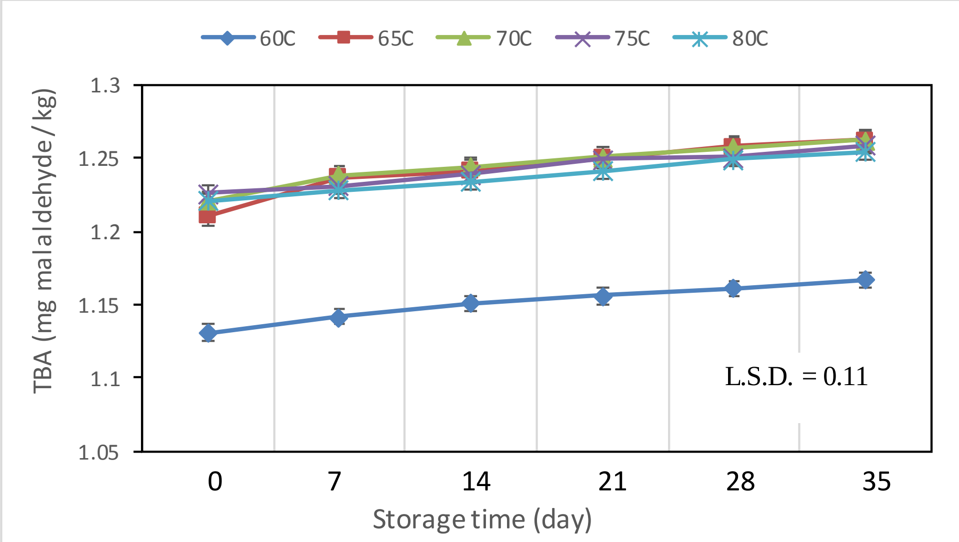

Fig. (10): TBA curve of Klunzinger's mullet at a different temperature during different storage

Microbial tests

Tables (3) and (4) clarified the microbial tests of dried salted and unsalted Klunzinger's mullet at different temperatures (60, 65,70, 75 and 80 ° C) and storage periods (0, 7, 14, 21, 28 and 35 days).Tables (3) and (4) showed that the total bacterial count was 9.00×10³ cfu.g⁻¹ and 7.00×10³ cfu.g⁻¹ in unsalted and salted fresh Klunzinger's mullet respectively. The results showed that the total bacterial count decreased after drying in unsalted fish to 3.50×10³, 3.46×10³, 3.00 ×10³, 2.90×10³ and 2.10×10³ cfu.g⁻¹ at temperatures of 60, 65, 70, 75 and 80° C at zero day of storage periods, and the total bacterial count were 4.12×10³, 4.12×10³, 3.80×10³, 3.10×10³ and 2.89×10³ cfu.g⁻¹ respectively after 35 days of storage. In salted fish, the total bacterial count were 2.11×10³, 2.39×10³, 1.35×10³, 1.21×10³ and 0.930 ×10³ cfu.g⁻¹ at the same temperature respectively at zero day of storage periods, and it reached 3.24×10³, 2.12×10³, 1.96×10³, 1.76×10³ and 1.011×10³ cfu.g⁻¹ respectively after 35 days of storage. The results disclosed that the total bacterial count was increasing in dried fish during storage because of storage temperature. The results were agreed with Al-Fadhly (2009) and Al-Temimi (2018) who noted that the total bacterial count increased in the microwaved dried carp fish with increasing storage periods. It can be seen from Tables (3) and (4) that the total coliform in salted fresh Klunzinger's mullet was 1.00 ×10³ cfu.g⁻¹ and in unsalted fresh fish was 0.6 ×10³ cfu.g⁻¹. The results showed that there was no growth of coliform in all studied samples of dried salted and unsalted Klunzinger's mullet. These results refer to improve the quality of the dried fish which be healthy and free from contaminated microbes. The results agreed with Al-Shatty *et al.* (2013) who found that the total coliform decreased significantly (P<0.05) in dried salted fish. The results were consistent with Al-Shatty *at el.* (2014) who showed that there was no growth of coliform in the dried carp fish and during the increase of the storage periods. Nur *et al.* (2020) found that the total viable count, total coliform count and fungal load were observed in dry fish up 3.50 x 105 CFU/g, 1.2 x103 CFU/g respectively.

Tables (3) and (4) illustrated that the total number of yeasts and molds in Klunzinger's mullet increased. The total number of yeasts in unsalted fresh fish was 2.50×10² cfu.g⁻¹ .

The results disclosed that the number of yeasts in dried unsalted fish decreased to 0.30×10^{2}, $0.16\ \times10^{2}$, 0.11×10^{2}, 0.16×10^{1} and 0.13×10^{1} cfu.g^{-1} using temperatures of 60, 65, 70, 75 and 80 °C respectively at zero day of storage periods. The number of yeasts was 0.43×10^{2}, 0.38×10^{2}, $0.31\ \times10^{2}$, 0.31×10^{1} and 0.26×10^{1} cfu.g^{-1}respectively after 35 days of storage. In salted fresh fish, the total number of yeasts was $1.50\ \times10^{2}$ cfu.g^{-1} and decreased to 0.25×10^{2}, 0.10×10^{2}, 0.10×10^{2}, 0.12×10^{1} and 0.43×10^{1} cfu.g^{-1} after drying at the same temperatures respectively at zero day of storage period. This number of yeasts was 0.40×10^{2}, 0.31×10^{2}, 0.22×10^{2}, 0.26×10^{1} and $0.17\times\ 10^{1}$ cfu.g^{-1} respectively after 35 days of storage. The results showed that the total number of molds in fresh unsalted fish was $4.00\ \times10^{3}$ cfu.g^{-1} and decreased after drying to 0.40×10^{2}, 0.36×10^{2}, 0.33×10^{2}, 0.24×10^{1} and 0.21×10 cfu.g^{-1} at temperatures of 60, 65, 70, 75 and 80 ° C respectively at zero day of storage periods. It was 0.59×10^{2}, 0.49×10^{2}, 0.44×10^{2}, $0.38\ \times10^{1}$ and 0.28×10^{1} cfu.g^{-1} respectively after 35 days of storage. In fresh salted fish, the total number of molds was $1.50\ \times10^{2}$ cfu.g^{-1}and decreased to $0.30\ \times10^{2}$, $0.20\ \times10^{2}$, $0.29\ \times10^{2}$, 0.20×10^{1} and $0.18\ \times10^{1}$ cfu.g^{-1}after drying at the same temperatures respectively at zero day of storage periods. Number of molds increased to $0.53\ \times10^{2}$, $0.46\ \times10^{2}$, $0.39\ \times10^{2}$, $0.29\ \times10^{1}$ and $0.25\ \times10^{1}$ cfu.g^{-1} respectively after 35 days of storage. The reason for the increasing number of yeasts and molds in dried fish may be attributed to increase of storage temperature, packaging and storage. The results agreed with Al-Shatty *at el.* (2014) who observed an increase in the number of yeasts and molds in dried fish after drying process. Tables (3) and (4) disclosed the number of *Staphylococcus aureus* in unsalted and salted fresh Klunzinger's mullet were 0.893×10^{3} and 0.716×10^{3} cfu.g^{-1} respectively.

Table (3): Microbial Tests (cfu.g^{-1}) for Fresh and dried unsalted Klunzinger's mullet at different temperatures and during different storage periods.

Drying temperature (°C)	Storage periods	Microbiological content cfu.g^{-1}				
		Total bacteria	coliform	yeast	molds	*Staph. aureus*
unsalted fresh fish	fresh	9.00×10^{3}	1×10^{3}	2.50×10^{2}	4.00×10^{3}	0.893×10^{3}
60	0	3.50×10^{3}	0	0.30×10^{2}	0.40×10^{2}	0.089×10^{3}
	7	3.55×10^{3}	0	0.34×10^{2}	0.44×10^{2}	0.089×10^{3}
	14	3.36×10^{3}	0	0.36×10^{2}	0.48×10^{2}	0.088×10^{3}
	21	3.75×10^{3}	0	0.38×10^{2}	0.53×10^{2}	0.087×10^{3}
	28	3.89×10^{3}	0	0.41×10^{2}	0.57×10^{2}	0.085×10^{3}
	35	4.12×10^{3}	0	0.43×10^{2}	0.59×10^{2}	0.086×10^{3}
65	0	3.46×10^{3}	0	0.16×10^{2}	0.36×10^{2}	0.066×10^{3}
	7	3.66×10^{3}	0	0.19×10^{2}	0.38×10^{2}	0.065×10^{3}
	14	3.87×10^{3}	0	0.22×10^{2}	0.41×10^{2}	0.065×10^{3}
	21	3.93×10^{3}	0	0.32×10^{2}	0.43×10^{2}	0.066×10^{3}
	28	4.10×10^{3}	0	0.37×10^{2}	0.46×10^{2}	0.067×10^{3}
	35	4.12×10^{3}	0	0.38×10^{2}	0.49×10^{2}	0.068×10^{3}

70	0	3.00×10^3	0	0.11×10^2	0.33×10^2	0.060×10^3
	7	3.22×10^3	0	0.17×10^2	0.35×10^2	0.058×10^3
	14	3.41×10^3	0	0.20×10^2	0.38×10^2	0.057×10^3
	21	3.53×10^3	0	0.23×10^2	0.41×10^2	0.057×10^3
	28	3.64×10^3	0	0.27×10^2	0.43×10^2	0.058×10^3
	35	3.80×10^3	0	0.31×10^2	0.44×10^2	0.058×10^3
75	0	2.90×10^3	0	0.16×10^1	0.24×10^1	0.446×10^2
	7	2.92×10^3	0	0.19×10^1	0.29×10^1	0.446×10^2
	14	2.94×10^3	0	0.21×10^1	0.31×10^1	0.442×10^2
	21	2.96×10^3	0	0.24×10^1	0.32×10^1	0.444×10^2
	28	3.01×10^3	0	0.27×10^1	0.36×10^1	0.445×10^2
	35	3.10×10^3	0	0.31×10^1	0.38×10^1	0.446×10^2
80	0	2.10×10^3	0	0.13×10^1	0.21×10^1	0.329×10^2
	7	2.21×10^3	0	0.16×10^1	0.22×10^1	0.326×10^2
	14	2.33×10^3	0	0.17×10^1	0.25×10^1	0.323×10^2
	21	2.55×10^3	0	0.21×10^1	0.25×10^1	0.327×10^2
	28	2.81×10^3	0	0.22×10^1	0.27×10^1	0.328×10^2
	35	2.89×10^3	0	0.26×10^1	0.28×10^1	0.328×10^2
L.S.D.		0.340×10^3	-	0.05×10^2	0.05×10^2	0.03×10^2

Table (4): Microbial Tests (cfu.g^{-1}) for Fresh and dried salted Klunzinger's mullet at different temperatures and during different storage periods.

Drying temperature (°C)	Storagep eriods	Microbiological content cfu.g^{-1}				
		Total bacteria	coliform	yeast	molds	*Staph. aureus*
salted fresh fish	fresh	7.00×10^3	0.6×10^3	1.00×10^2	1.50×10^2	0.716×10^3
60	0	2.11×10^3	0	0.25×10^2	0.30×10^2	0.070×10^3
	7	2.31×10^3	0	0.29×10^2	0.35×10^2	0.069×10^3
	14	2.57×10^3	0	0.31×10^2	0.39×10^2	0.069×10^3
	21	2.89×10^3	0	0.35×10^2	0.43×10^2	0.068×10^3
	28	3.10×10^3	0	0.38×10^2	0.50×10^2	0.068×10^3
	35	3.24×10^3	0	0.40×10^2	0.53×10^2	0.068×10^3
65	0	2.39×10^3	0	0.10×10^2	0.20×10^2	0.063×10^3
	7	2.52×10^3	0	0.14×10^2	0.26×10^2	0.062×10^3
	14	1.57×10^3	0	0.16×10^2	0.29×10^2	0.062×10^3
	21	1.96×10^3	0	0.20×10^2	0.32×10^2	0.061×10^3
	28	2.02×10^3	0	0.27×10^2	0.41×10^2	0.060×10^3
	35	2.12×10^3	0	0.31×10^2	0.46×10^2	0.060×10^3
70	0	1.35×10^3	0	0.10×10^2	0.29×10^2	0.051×10^3
	7	1.41×10^3	0	0.11×10^2	0.31×10^2	0.051×10^3
	14	1.55×10^3	0	0.14×10^2	0.34×10^2	0.051×10^3
	21	1.72×10^3	0	0.17×10^2	0.37×10^2	0.052×10^3

	28	1.84×10^{3}	0	0.20×10^{2}	0.37×10^{2}	0.053×10^{3}
	35	1.96×10^{3}	0	0.22×10^{2}	0.39×10^{2}	0.053×10^{3}
75	0	1.21×10^{3}	0	0.12×10^{2}	0.20×10^{1}	0.426×10^{2}
	7	2.28×10^{3}	0	0.15×10^{2}	0.23×10^{1}	0.426×10^{2}
	14	1.39×10^{3}	0	0.18×10^{2}	0.25×10^{1}	0.428×10^{2}
	21	1.41×10^{3}	0	0.19×10^{2}	0.27×10^{1}	0.432×10^{2}
	28	1.62×10^{3}	0	0.22×10^{2}	0.27×10^{1}	0.435×10^{2}
	35	1.76×10^{3}	0	0.26×10^{2}	0.29×10^{1}	0.437×10^{2}
80	0	0.930×10^{3}	0	0.10×10^{1}	0.18×10^{1}	0.316×10^{2}
	7	0.994×10^{3}	0	0.12×10^{1}	0.21×10^{1}	0.312×10^{2}
	14	0.996×10^{3}	0	0.14×10^{1}	0.22×10^{1}	0.309×10^{2}
	21	1.006×10^{3}	0	0.15×10^{1}	0.22×10^{1}	0.311×10^{2}
	28	1.008×10^{3}	0	0.15×10^{1}	0.24×10^{1}	0.312×10^{2}
	35	0.011×10^{3}	0	0.17×10^{1}	0.25×10^{1}	0.312×10^{2}
L.S.D.		0.340×10^{3}	-	0.05×10^{2}	0.05×10^{2}	0.03×10^{2}

The results showed that this number decreased in dried unsalted fish to 0.089 $\times10^{3}$, 0.066 $\times10^{3}$, 0.060 $\times10^{3}$, 0.446 $\times10^{2}$ and 0.329 $\times10^{2}$ cfu.g^{-1} at temperatures of 60, 65, 70, 75 and 80 ° C respectively at zero day of storage periods. It was 0.086 $\times10^{3}$, 0.068 $\times10^{3}$, 0.058 $\times10^{3}$, 0.446 $\times10^{2}$ and 0.328 $\times10^{2}$ cfu.g^{-1} respectively after 35 days of storage, whereas in dried salted fish, the number of *Staphylococcus aureus* was 0.716×10^{3}.

The results showed that this number decreased in dried salted fish to 0.070×10^{3}, 0.063×10^{3}, 0.051×10^{3}, 0.426×10^{2} and 0.316 $\times10^{2}$ cfu.g^{-1} at the same temperature respectively at zero day of storage periods. This number reached 0.068×10^{3}, 0.060×10^{3}, 0.053×10^{3}, 0.437×10^{2} and 0.312 $\times10^{2}$ cfu.g^{-1} respectively after 35 days of storage.

The results clarified that decreased numbers of *Staphylococcus aureus* in dried salted fish compared with dried unsalted fish may be due to the method of salting that made integrated hygienic conditions, which led to a reduce risk of *Staphylococcus aureus*, which causes staphylococcal poisoning. These results agreed with Fath El-Bab (2005) who showed that bacterial load decreases during drying and storing Sardine fish , and the results agreed with Al-Fadhli (2009) who observed an increase in the number of *Staphylococcus aureus* in dried Thelah fish (*Scomberoides commersonnianus*) using a solar dryer.

The results showed that *Salmonella* was not present in all samples of Klunzinger's mullet, whether fresh or dried, because of the drying process eliminated all microbes. All standard specifications indicated that *Salmonella* are not allowed in food (Stannard, 1997). The results agreed with Al-Shatty *at el.* (2013) who proved that *Salmonella* did not growth in dried salted fish .The results were consistent with Al-Shatty *et al.* (2014) who showed that there was no growth of *Salmonella* in dried carp fish` and during increase of storage periods. Deng *et al.* (2020) stated that the average counts of bacteria, yeasts and filamentous fungi in the dried fish were 3.2, 2.5 and 2.2 log cfu g^{-1}, and increased to 4.6, 3.6 and 3.9 log cfu g^{-1}, respectively after 50 days of storage.

Rehydration

Figs. (11) and (12) showed the changes in the rehydration of dried salted and unsalted Klunzinger's mullet at different temperatures (60, 65, 70, 75 and 80°C) and storage periods. The results showed that the rehydration of dried salted Klunzinger's mullet was 1.84, 1.87, 1.86, 1.84 and 1.81 % at temperatures of 60, 65, 70, 75 and 80 °C respectively at zero day of storage periods. After that the rehydration decreased with the increase of the storage periods until it reached to 1.60,1.58, 1.68, 1.54 and 1.58% respectively after 35 days of storage. The results illustrated that the rehydration of dried unsalted Biayah fish was 1.86, 1.76, 1.81, 1.79 and 1.74 % at the same temperature respectively at the zero day of storage periods. It was 1.61, 1.55, 1.64, 1.63 and 1.56 % respectively after 35 days of storage. This is due to the absorption of moisture from the atmosphere and it effected on the chemical composition. The results showed that the rehydration decreased with increasing temperatures and that may be due to increase of surface hardening of the fish at high temperature and because of the protein denaturation due to high temperature and weakened its capacity for water carrying. Krokida & Morinos- Kouris (2003) indicated that rehydration was influenced by a combination of factors such as cellular regulation, porosity of composition and mechanical properties for the dried material, as well as the drying method. Al-Shatty, *et al.* (2014) found that the rehydration of dried salted carp fish by oven was 1.34 % and decreased to1.30 % using natural sun drying. The results agreed with Al-Temimi (2018) who found that the rehydration in microwaved dried carp fish was decreased with the increase of energy levels from 100 to 500 watts and reached to 1.73 to 1.49 % respectively. Kiin-Kabari & Obasi (2020) indicated that the rehydration ratio of whelk was 1.47. Achaglinkame *et al.* (2020) clarified that freeze-dried samples of fish had higher percent rehydration where ranged between 27 to102%.

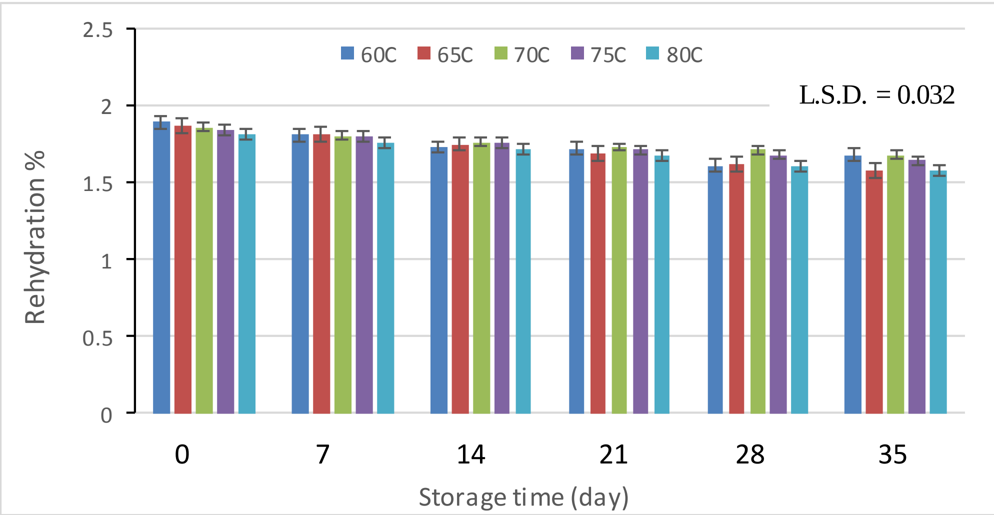

Fig. (11): Rehydration of Klunzinger's mullet (salted) at a different temperature during different storage periods.

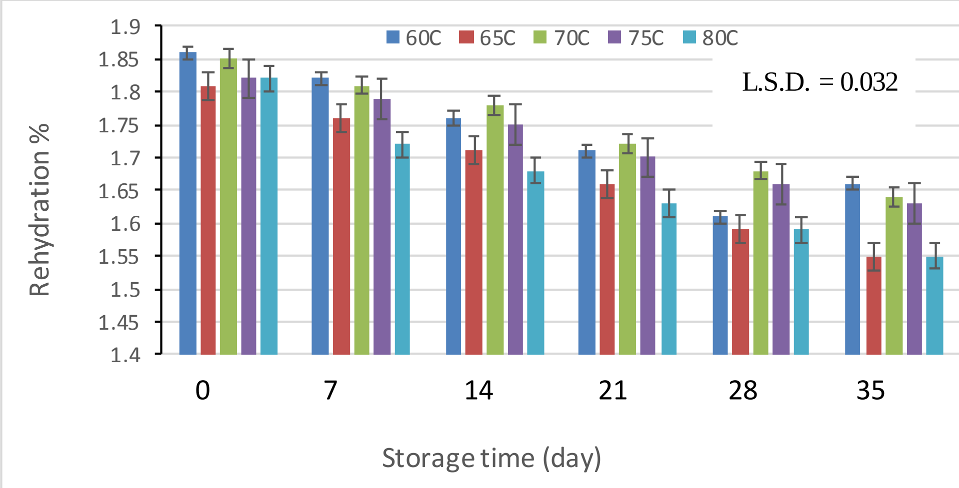

Fig. (12): Rehydration of Klunzinger's mullet (unsalted) at a different temperature during different storage periods.

Artificial Neural Network (ANN) for modeling of moisture content

ANN was used to predict moisture content of salted fish because their qualitative characteristics better than unsalted. Fig. (13) illustrated results of ANN for predicting moisture content of salted fish vs. drying time at different drying temperatures. The results showed that the predicted moisture content by ANN has a good fitting for experimental data at all drying temperatures. The relationship between predicted and experimental moisture content was strong with R^2=0.986 as illustrated in fig. (14). The errors of model were depicted in table (5) where the sum of squares error for training and testing were 0.33 and 0.045 respectively, as well as the relative errors of training and testing were very small. The residual vs. predicted moisture content by ANN was depicted in fig. (15). The important factor that effect on the moisture content was drying time (0.929) with normalize importance of 100%, but the importance of drying temperature was reduced and reached 0.071 with normalize importance of 7.6% (Fig. 16). It can be seen from the results that the ANN can be used to predict moisture content of fish. Boeri *et al.* (2011) stated that simulations with the ANN model had a good results of moisture content of salted codfish, in addition neural network model is a promising potential. Equations from 20-24 describe the predicted moisture contents at drying temperatures from 60-80 ˚C. Fig. 17. Illustrates photos of fresh and treatment of salted dried fish (at 80˚C) compared with unsalted.

$$MC_{60^\circ C} = 4E\text{-}09x^4 - 3E\text{-}06x^3 + 0.0006x^2 - 0.0622x + 3.01 \; ; R^2=0.9999 \quad (20)$$

$$MC_{65^\circ C} = -1E\text{-}11x^5 + 1E\text{-}08x^4 - 4E\text{-}06x^3 + 0.0007x^2 - 0.0651x + 3.2622 \; ; R^2 = 0.9999 \quad (21)$$

$$MC_{70^\circ C} = 5E\text{-}09x^4 - 3E\text{-}06x^3 + 0.0006x^2 - 0.0621x + 3.3981 \; ; R^2 = 0.9998 \quad (22)$$

$$MC_{75^\circ C} = -7E\text{-}12x^5 + 1E\text{-}08x^4 - 4E\text{-}06x^3 + 0.0007x^2 - 0.0651x + 3.4178 \; ; R^2 = 0.9999 \quad (23)$$

$$MC_{80^\circ C} = 7E\text{-}09x^4 - 4E\text{-}06x^3 + 0.0007x^2 - 0.0653x + 3.3022; R^2 = 0.9999 \quad (24)$$

Where, MC is the moisture content (g water/g d.b.) and x is the drying time (min.)

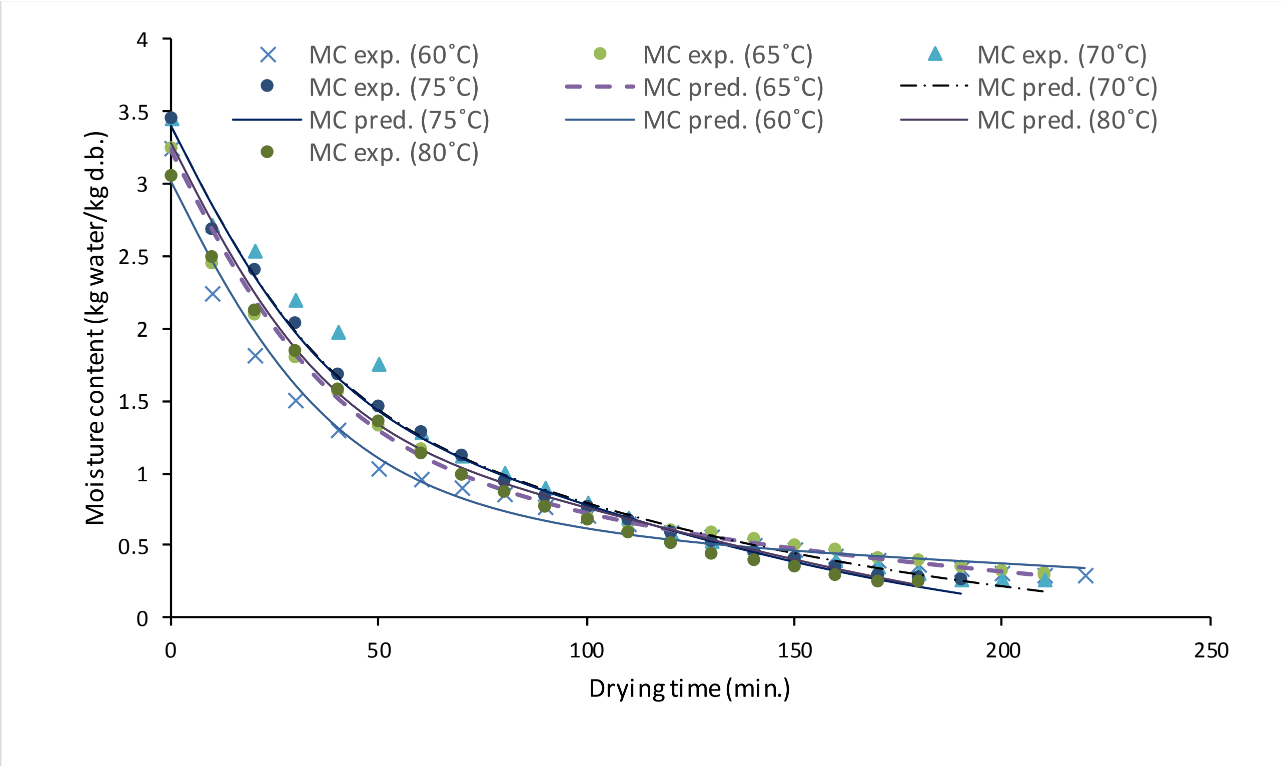

Fig. (13): Results of ANN for predicting moisture content of fish at different drying temperatures. MC exp.: experimental Moisture content, MC pre.: predicted moisture content.

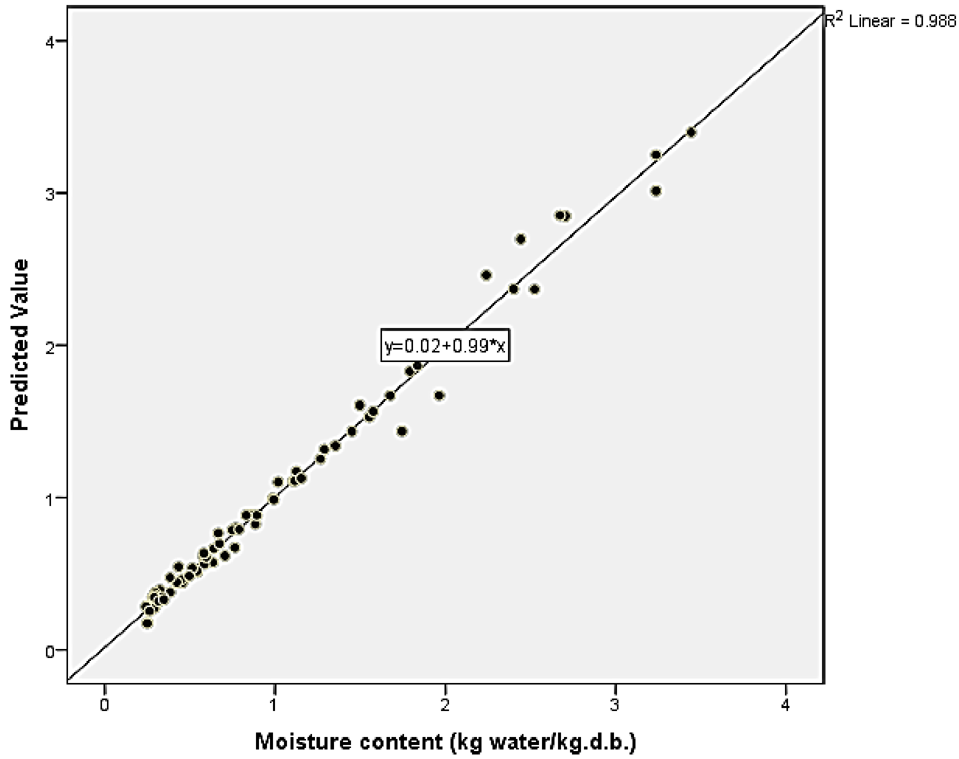

Fig. (14): Results of ANN for predicting moisture content of fish vs. moisture content (experimental).

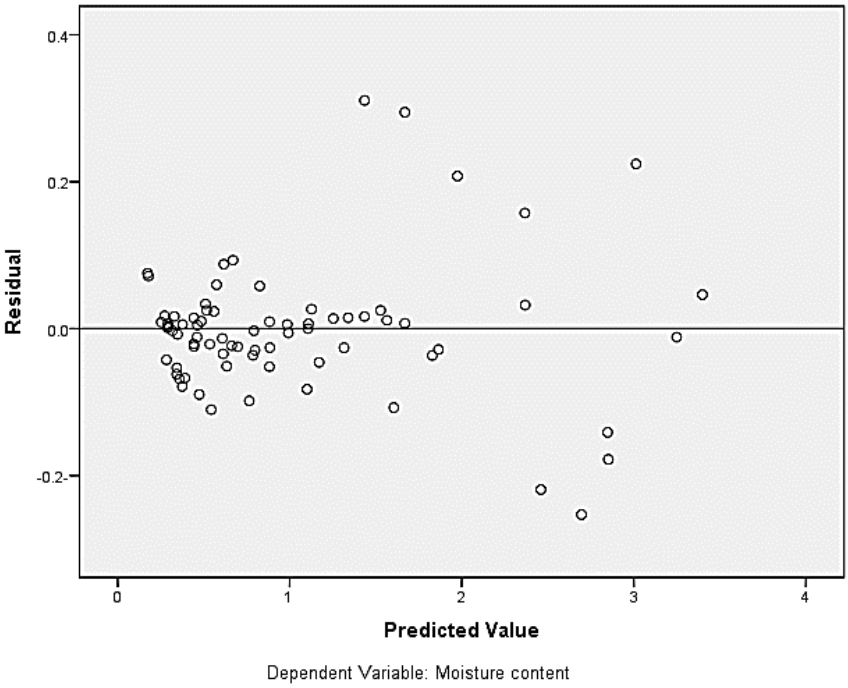

Fig. (15): The residual vs. predicted moisture content by ANN.

Table (5): Model Summary which predicted by ANN.

Training	Sum of Squares Error	.333
	Relative Error	.012
Testing	Sum of Squares Error	.048
	Relative Error	.019
Holdout	Relative Error	.012
Dependent Variable: Moisture content		
Error computations are based on the testing sample.		

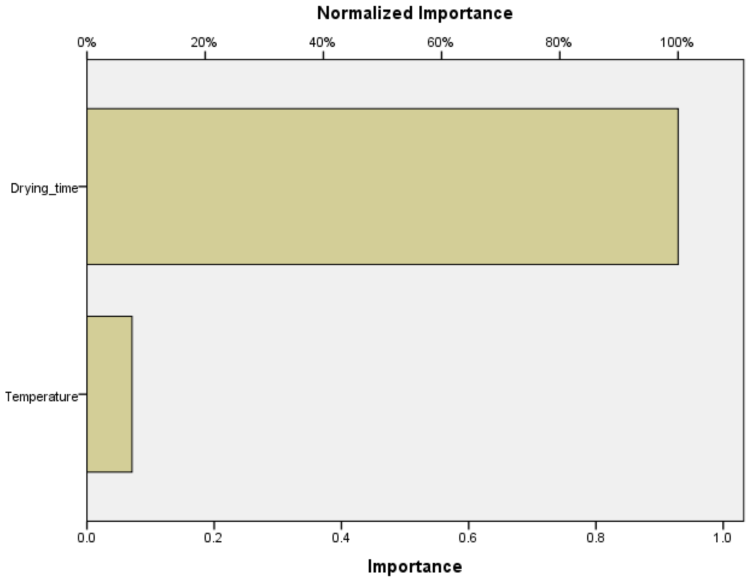

Fig. (16): Independent variables importance.

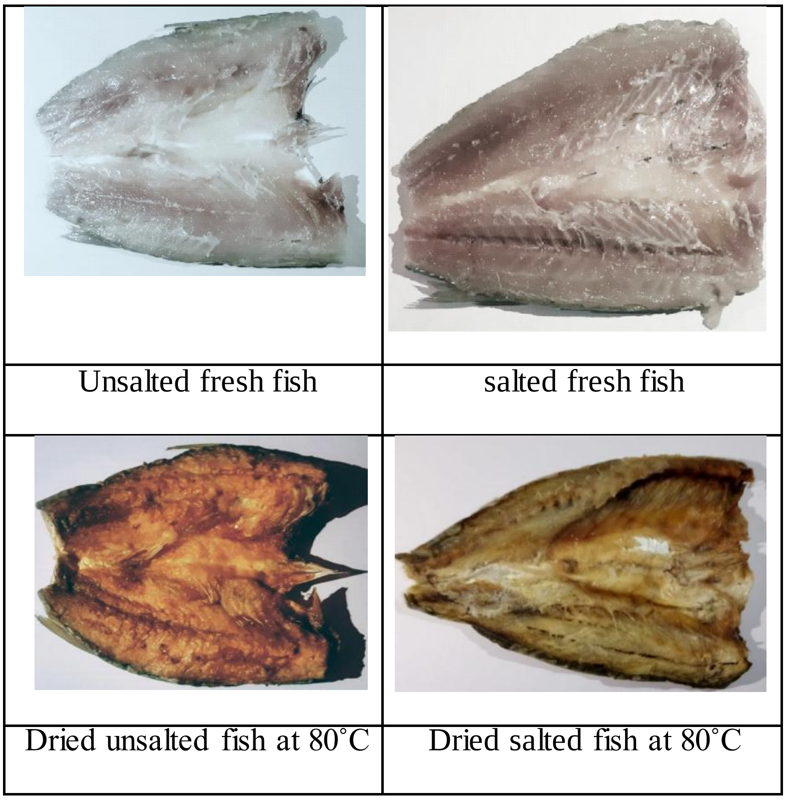

Fig. (17): Photos of fresh and best treatment of salted dried fish (at 80˚C) compared with unsalted.

The current challenges of halogen dryer

The current challenges of halogen dryer were the evaporated water which exist from fish is condensate in the inner wall of dryer and fall into the container of fish which reduces drying efficiency.

Future prospects

To develop the halogen dryer, a concave ban made of Pyrex put under drying container to prevent re evaporation of condensate water. Moreover, the halogen dryer should be continuous. In addition, A vacuum system with halogen energy can be used to improve drying kinetics and increasing drying efficiency and produce product with high quality.

Conclusions

The study showed that the use of halogen dryer in the drying process gave a high efficiency and a short time. The results showed that drying efficiency decreased as temperature increased. The results showed that salted fish were faster than unsalted fish in the drying process. The results revealed that the chemical composition, qualitative characteristics and microbiological content of dried salted and unsalted Klunzinger's mullet have been changed during storage periods. The results showed that the rate of rehydration at higher temperatures for dried salted and unsalted Klunzinger's mullet decreased. ANN was gave a good fitting for moisture content.

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Conflicts of interest

The authors declare that they have no conflict of interests.

Ethical approval

All applicable institutional, national and international guidelines for the care and use of animals were followed.

References

Aboud, S.A.; Al-Temimi, A.B.; Al-Hilphy, A.R.S.; Yi-Chen, L. & Cacciola, F. (2019). A comprehensive review on infrared heating applications in food processing. Molecules, 24(22): 4125. https://doi.org/10.3390/molecules24224125

Achaglinkame, M.A.; Owusu-Mensah, E.; Boakye, A.A. & Oduro, I. (2020). Effect of effect of size and drying time on the rehydration and sensory properties of freeze-dried snails (*Achatina achatina*). Int. J. Food Sci., 2020: 1-5. https://doi.org/10.1155/2020/5714140

Al-Bayati, M.M.A. & Ahmed, B.A. (2008). Albumin preparation and study of mullet fish chemical composition and functional properties. Diyala J. Food Tech. Humanity, 32: 242-254. https://www.iasj.net/iasj?func=article&aId=43376

Al-Fadhly, N.K.Z. (2009). Salting and drying of the Thelah fish (*Scomberoides commersonianus*) and studying its quality characteristics using sensory, chemical, physical and microbial indices. M. Sc. Thesis, Coll. Agric., Univ. Basrah. 195pp. (In Arabic).

Al-Hilphy, A.R.; Iskandar, M.Z. & Abdul Hassan, K.H. (2011). A study of drying some vegetables and fruit by halogen oven. Kufa J. Agric. Sci., 3(2): 216-232. https://www.iasj.net/iasj?func=article&aId=12431

Al-Hilphy, A.R.S. & Al-Rikabi, A.K.J. (2013). Mathematical modelling experimental study on thin layer halogen dryer of strawberry and study it is effect on antioxidant activity. Am. J. Agri. Biol. Sci., 8(4): 268-281. https://doi.org/10.3844/ajabssp.2013

Ali, A.H.; Adday, T.K. & Khamees, N.R. (2018). Catalogue of marine fishes of Iraq. Biol. Appl. Environ. Res., 2(2): 298-368. https://un.uobasrah.edu.iq/papers/10391.pdf

Al-Rubai'y, H.H.; Abdul Hassan, K.H. & Eskandder, M.Z. (2020). Drying and salting fish using different methods and their effect on the sensory, chemical and microbial indices. Multidiscip. Rev., 3: 1-7. https://doi.org/10.29327/multi.2020003

Al-Shatty, S.M.H.; Al-Fadhly, N.K.Z. & Salah, Y.A. (2013). Assessing the microbiological quality of salted and dried Thelah fish (*Scomberoides commersonianus*). Kufa J. Agric. Sci., 5(1): 214-227. https://www.iasj.net/iasj?func=article&aId=65811

Al-Shatty, S.M.H.; Al-Gwabrawy, A.A. & Al-Hilphy, A.R.S. (2014). Study of chemical and microbiological characteristics of dried *Cyprians carpio* by vacuum solar dryer (Locally manufactured) (Part 2). Thi-Qar Univ. J. Agric. Res., 3(1): 341-358. https://www.iasj.net/iasj?func=article&aId=94690

Al-Temimi, A.; Aziz, S.N.; Al-Hilphy, A.R.; Lakhssassi, N.; Watson, D.G. & Ibrahim, S.A. (2019). Critical review of radio-frequency (RF) heating applications in food processing. Food Qual. Saf., 3(2): 81-91. https://doi.org/10.1093/fqsafe/fyz002

Al-Temimi, W.K.A. (2018). Studying of physical and chemical properties and microbial content for dried fish by microwave. Diyala J. Agric. Sci., 10(1): 12-28. https://iasj.net/iasj?func=article&aId=161966

Andrews, W. (1992). Manuals of Food Quality Control, 4. Microbiological analysis. FAO Food and Nutrition paper No.14/4 (Rev.1), Rome: 347pp. http://www.fao.org/3/T0610E/T0610E.pdf

Azam, K.; Basher, M.Z.; Ali, M.Y.; Asaduzzaman, M. & Hossain, M.M. (2003). Comparative study of organoleptic, microbiological and biochemical qualities of four selected dried fish in summer and winter. Pak. J. Biol. Sci., 6(24): 2030-2033. https://doi.org/10.3923/pjbs.2003.2030.2033

Boeri, C.; Neto da Silva, F.; Ferreira, J.; Saraiva, J. & Salvador, Â. (2011). Predicting the drying kinetics of salted codfish (*Gadus morhua*): Semi-empirical, diffusive and neural network models. Int. J. Food Sci. Technol., 46(3): 509-515. https://doi.org/10.1111/j.1365-2621.2010.02513.x

Chen, X.; Fang, F. & Wang, S. (2020). Physicochemical properties and hepatoprotective effects of glycated Snapper fish scale peptides conjugated with xylose via maillard reaction. Food Chem. Toxicol., 137: 111115. https://doi.org/10.1016/j.fct.2020.111115

Darvishi, H.; Azadbakht , M.; Rezaeiasl, A. & Farhang, A. (2013). Drying characteristics of sardine fish dried with microwave heating. J. Saudi Soc. Agric. Sci., 12(2): 121-127. https://doi.org/10.1016/j.jssas.2012.09.002

Deng, Y.; Wang, R.; Wang, Y.; Sun, L.; Tao, S.; Li, X. & Zhao, J. (2020). Diversity and succession of microbial communities and chemical analysis in dried *Lutianus erythropterus* during storage. Int. J. Food Microbiol., 314: 108416. https://doi.org/10.1016/j.ijfoodmicro.2019.108416

Dubey, A.; Sagar, A.; Malkani, P.; Choudhary, M.K. & Ramnath, S.S. (2020). A comprehensive review on greenhouse drying technology. J. Agric. Ecol. Res. Int., 10-20. https://doi.org/10.9734/JAERI/2020/v21i130123

Egan, H.; Kirk, R.S. & Sawyer, R. (1988). Pearson's Chemical Analysis of Foods. 8th ed. Longman Scientific and Technical, The Bath Press, 591pp.

El-Sebaiy, L.A. & Metwalli, S.M. (1989). Changes in some chemical characteristics and lipid composition of salted bouri fish muscle (*Mugil cephalus*). Food Chem., 31(1): 41-50. https://dx.doi.org//0.1016/0308-8146

Fath El-Bab, G.F.A. (2005). Health hazard associated with salted fish in Egyptian market. Egyp. J. Agric. Res., 83(1): 405-410. https://doi.org/10.1016/j.jssas.2012.09.002

Fricke, R., Eschmeyer, W.N. & Fong, J.D. (2020). Species by family/subfamily. California: Institute for Biodiversity Science and Sustainability, California Academy of Science. Electronic version accessed 6 April 2020. http://researcharchive.calacademy.org/research/ichthyology/catalog/SpeciesByFamily.asp

Froese, R. & Pauly, D. (eds.) (2019). Fish Base. World Wide Web electronic publication. (Version 12/ 2019). http://www.fishbase.org./

Gates, K.W. (2015). Seafood processing: technology, quality and safety. J. Aquat. Food Product Technol., 24(1): 91-97. https://doi.org/10.1080/10498850.2014.954475

Guiné, R. (2018). The drying of foods and its effect on the physical-chemical, sensorial and nutritional properties. Int. J. Food Eng., 2(4): 93-100. https://doi.org/10.18178/ijfe.4.2.93-100

Hardoko, H. & Utami, S. (2020). Chemical-physical properties characterization of white snapper fish skin rambak crackers based on boiling and drying duration. J. Ilmiah Perikanan dan Kelautan, 12(1): 122-130. http://doi.org/10.20473/jipk.v12i1.14842

Hernandez-Perez, J.A.; Garcia-Alvarado, M.A.; Trystram, G. & Heyd, B. (2004). Neural networks for the heat and mass transfer prediction during drying of cassava and mango. Innov. Food Sci. Emerg. Technol., 5: 57-64. https://doi.org/10.1016/j.ifset.2003.10.004

Huss, H.H. (1995). Quality and Quality Changes in Fresh Fish. FAO Fisheries Technical Paper, No. 348. Rome, FAO: 195pp.

Kiin-Kabari, D.B. & Obasi, N. (2020). Effect of drying on the rehydration properties of some selected shellfish. Asian Food Sci. J., 14(1): 42-48. https://doi.org/10.9734/AFSJ/2020/v14i130122 .

Krokida, M.K. & Morinos-Kouris, D. (2003). Rehydration kinetics of dehydrated products. J. Food Eng., 57: 1-7. https://doi.org/10.1016/S02608774(02)00214-5

Kubra, K., Hoque, M. S., Hossen, S., Husna, A.U., Azam, M., Sharker, M.R. & Ali, M. M. (2020). Fish drying and socio-economic condition of dried fish producers in the coastal region of Bangladesh. Middle-East J. Sci. Res., 28(3): 182-192. https://doi.org/10.5829/idosi.mejsr.2020.182.192

Kumar, Y. (2015). Application of microwave in food drying. Int. J. Eng. Stu. Tech. Apr., 1(6): 9-24. http://ijesta.com/upcomingissue/02.06.2015.pdf

Lasisi, O.I.; Fapetu, O.P. & Akinola, A.O. (2020). Development of a solar dryer incorporated with a thermal storage mechanism. Dev. Int. J. Adv. Sci. Res. Eng., 6(1): 134-146. http://doi.org/10.31695/IJASRE.2020.33694

Lim, G.W.; Jafarzadeh, S. & Norazatul Hanim, M.R. (2020). Kinetic study, optimization and comparison of sun drying and superheated steam drying of asam gelugor (*Garcinia cambogia*). Food Res., 4(2): 396-406. https://doi.org/10.26656/fr.2017.4(2).288

Lithi, U.J.; Surovi, S.; Faridullah, M. & Roy, K.C. (2020). Effects of drying technique on the quality of Mola (*Amblypharyngodon mola*) dried by solar tent dryer and open sun rack dryer. Res. Agric. Livest. Fish., 7(1): 121-128. https://doi.org/10.3329/ralf.v7i1.46840

Majeed, G.H. & Al-Hilphy, A.R.S. (2007). Design of a solar dryer provided with back and heating systems and its testing in the drying of fishes and meats. J. Basrah Res., 33(3): 20-30. https://www.iasj.net/iasj?func=article&aId=57643

Mohamed, A.R.M.; Abood, A.N. & Hussein, S.A. (2016). Comparative taxonomical study of four mullet species (Mugiliformes: Mugilidae) from Iraqi marine waters, Arabian Gulf. Basrah J. Agric. Sci., 23(2): 11-23. (In Arabic). https://iasj.net/iasjAdmin?func=fulltext&aId=120189

Nur, I.T.; Ghosh, B.K. & Acharjee, M. (2020). Comparative microbiological analysis of raw fishes and sun-dried fishes collected from the Kawran bazaar in Dhaka city, Bangladesh. Food Res., 4(3), 846-851. https://doi.org/10.26656/fr.2017.4(3).368

Özilgen, M. (1998). Food Process Modeling and Control: Chemical Engineering Applications. CRC.: 518pp. https://www.routledge.com/Handbook-of-Food-Process-Modeling-and-Statistical-QualityControl/Ozilgen/p/book/9781439814864

Pan, Z. & Atungulu G.G. (2011). Infrared Heating for Food and Agricultural Processing. CRC Press: 300pp. https://www.routledge.com/Infrared-Heating-for-Food-and-Agricultural-Processing/Pan-Atungulu/p/book/9780367383787

Patir, B.; Gurelinanli, A.; Oksuztepe, G. & Irfan Ilhak, O. (2006). Microbiological and chemical qualities of salted grey mullet (*Chalcalburnus tarichii* Pallas, 1811). Int. J. Food Sci. Technol., 1(2): 91-98. https://doi.org/10.1016/j.sjbs.2017.04.003

Pochont, N.R.; Mohammad, M.N.; Pradeep, B.T. & Kumar, P.V. (2020). A comparative study of drying kinetics and quality of Indian red chilli in solar hybrid greenhouse drying and open sun drying. Mater. Today Proc., 21: 286-290. https://doi.org/10.1016/j.matpr.2019.05.433

Rangana, S. (1976). Manual of Analysis of Fruit and Vegetable Products. 1st Edn., Tata MaGraw-Hill, New Delhi: 634pp.

Rasul, M.; Majumdar, .C.; Afrin, F.; Bapary, M.A. & Shah, A.K. (2018). Biochemical, microbiological and sensory properties of dried silver carp (*Hypophthalmichtys molitrix*) influenced by various drying methods. Fishes, 3(3): 25. https://doi.org/10.3390/fishes 3030025.

Rossini, K.; Norena, C.P.; Cladera-Olivera, F. & Brandelli, A. (2009). Casein peptides with inhibitory activity on lipid oxidation in beef homogenates and mechanically deboned poultry meat. LWT-Food Sci. Technol., 42(4): 862-867. https://doi.org/10.1016/j.lwt.2019.108633

Scanlin, D. (1997). The design, construction, and use of an indirect, through-pass, solar food dryer. Home Power #57: 62-72. https://www.rivendellvillage.org/Solar_Food_Dryer.pdf

Nath, S.; Ranjan, A.; Mohanty, B.P.; Saklani, P.; Dora, K.C. & Chowdhury, S. (2020). Dry fish and its contribution towards food and nutritional security. Food Rev. Int., 2020: 29pp. https://doi.org/10.1080/87559129.2020.1737708

Solanki, J.B. (2020). Different types of fish drying methods in Gujarat. Int. J. Fish. Aquat. Stud., 8(1): 129-131. http://www.fisheriesjournal.com/archives/?year=2020&vol=8&issue=1&part=B&ArticleId=2102

Stannard, C. (1997). Development and use of microbiological criteria for foods. J. Food

Sci. Tech., 11(3): 137-177. https://doi.org/10.1.1.474.2198&rep

Tanuja, S.; Mhatre, C.S.; Mohanty, G.; Rout, E.; Rout, P. & Srivastava, S.K. (2020). Development of low cost solar rack dryer and comparative biochemical quality evaluation of anchovies (*Stolephorus commersonii*) dried in sun and solar rack dryer. Int. J. Curr. Microbiol. App. Sci., 9(3): 579-586. https://doi.org/10.20546/ijcmas.2020.903.068

Toledo, R.T. (2007). Fundamentals of Food Process Engineering. 1st edn., Springer, New York: 600pp. https://www.springer.com/gp/book/9781461570523

تجفيف اسماك بياح كلوزنجر *Planiliza klunzingeri* باستخدام مجفف الهالوجين ونمذجة محتوى الرطوبة باستخدام الشبكة العصبية الاصطناعية

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المستخلص: تم تجفيف اسماك بياح كلوزنجر *Planiliza klunzingeri* المملحة وغير المملحة باستخدام مجفف هالوجين الذي يعمل بالأشعة تحت الحمراء بدرجات حرارة مختلفة (60 ، 65 ، 70 ، 75 و 80 مئوي) وفترات تخزين مختلفة (0 ، 7 ، 14 ، 21 ، 28 و 35) يومًا و دراسة خصائصها النوعية. أظهرت النتائج انخفاض محتوى الرطوبة مع زيادة زمن التجفيف. كانت كفاءة التجفيف لمجفف الهالوجين 70.36٪ عند 60 درجة مئوية وانخفضت مع زيادة درجة حرارة التجفيف. أظهر التركيب الكيميائي للأسماك المجففة (المملحة وغير المملحة) انخفاض نسبة الرطوبة، ولكن نسبة البروتين والدهون والرماد زادت بعد عملية التجفيف. زادت نسبة الرطوبة خلال فترات التخزين (0، 7، 14، 21، 28 و35) يومًا، على عكس نسب التركيب الكيميائي الأخرى انخفضت مع زيادة فترات التخزين. أوضحت النتائج انخفاض الاسترجاع مع زيادة درجات حرارة التجفيف للأسماك المجففة المملحة وغير المملحة. علاوة على ذلك، أظهرت النتائج أن هناك زيادة في TBA بعد عملية التجفيف وأثناء فترات التخزين. بالإضافة إلى ذلك، أظهرت النتائج انخفاض المحتوى الميكروبي للأسماك المملحة وغير المملحة. أوضحت النتائج أنه يمكن استخدام موديل الرتبة الأولى للتنبؤ بقيمة الرقم الهيدروجيني خلال فترات التخزين. اعطى موديل الشبكة العصبية الاصطناعية (ANN) نتيجة جيدة لمحتوى الرطوبة المتنبأ به.

الكلمات المفتاحية: الأسماك، الشبكة العصبية الاصطناعية، *Planiliza klunzingeri*، مجفف الهالوجين، الخصائص النوعية، المحتوى الميكروبيولوجي.