Mediterranean Aquaculture Journal 2023 10 (2):25-35

Original Article

Effect of frozen storage on fish quality and fishery products: A Review

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ABSTRACT: One of the most significant problems for the food preservation industry is maintaining the quality of food products for an extended period. Fish and fishery products are highly perishable foods that degrade easily during harvesting and processing as a result to a combination of chemical, physical, and microbiological changes. The current study focuses on the changes in the chemical composition, nutritional value freshness indicators, quality features, microbiological safety, and sensory evaluation of fish and fishery products as affected by freezing storage periods. Therefore, this study aims to give a combined overview of the changes that occur to different types of fish and their various products during the process of preservation by freezing, so that it is a collected source for all these changes in one place, in order to facilitate the process of comparing the changes that occur during the freezing process between different types of fish and their products.

Key word: Fish products, Frozen storage, Chemical composition, TVB-N, Amino acid
Received: Sept. 1, 2023
Accepted: Oct. 21, 2023

INTRODUCTION

Fish is a highly nutritious, rich in micronutrients, minerals, polyunsaturated fatty acids and proteins, and it represents a valuable supplement in diets lacking these nutrients, essential vitamins and minerals. In many countries, especially developing countries, the average per capita fish consumption may be low–however, even in small quantities, fish can significantly improve the quality of dietary proteins by complementing the essential amino acids that are often present only in low quantities in vegetable-based diets (Gulyavuz and Unlusayin, 1999; Ryder *et al.*, 2014).

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Harvesting and processing of fish are usually accompanied by the gradual loss or the development of different compounds that affect quality of fish products. Since fresh fish spoil easily, they need to be processed and preserved. Preservation provides a long shelf-life for fish and fish products. Preservation affects food by two ways: (1) it keeps the original freshness and properties of fish; (2) it changes the original properties of the food and creates new product. The main purpose of both of these is to prevent spoilage, especially by microorganisms. Several preservation methods have been developed, some of them providing a longer shelf-life than others. The choice of a preservation method depends on the product, properties of the product, availability of energy, the storage facilities, and the costs of the method. It is sometimes necessary to combine methods. Freezing is the process that lowers the temperature to below the freezing point. The temperature allows most of the water to turn into ice. The freezing point depends on the substances dissolved in the fluid of the tissue. The freezing process concerns the removal of latent heat during the phase transition of water from liquid to solid and removal of sensible heat, depending on the reduction of temperature (Gokoglu and Yerlikaya, 2015).

1.Effect of Frozen Storage on Chemical Composition of Fish and its products

Chemical composition of fish and its products generally means percentage composition of basic constituents such as moisture, protein, fat, and minerals. In recent times, the importance of fishery products as a source of nutrients refers to high quality proteins, unsaturated lipids, vitamins, and minerals has been realized. Several fishery items have attracted the attention of nutritionists and dieticians as a source of therapeutically important polyunsaturated fatty acids (Venugopal, 2005). El-Akeel (1983) found that moisture content was gradually decreased in Bolti fish from 80.34 to 79.95% during storage at -30 ºC for 12 weeks. Abo-Zied (1995) reported that moisture content of Silver and Common carp decreased during storage at-10º C and -20 ºC for 16 weeks. The decrease in moisture during frozen storage may be due to of drip separation during thawing process of the frozen fish. Also, total lipid contents of Silver and Common carp were slightly decreased during the storage period and attributed to lipid oxidation. On the other side, crude protein (TNx6.25) was gradually increased in Silver and Common carp during storage which could be due to the corresponding decrease in moisture content and the dehydration of tissue during frozen storage. Abo-Taleb (1997) observed that protein content of Silver carp fish muscles was decreased during storage at -18±1ºC for 180 days. This alteration in protein content might be due to the loss of volatile nitrogenous compounds throughout storage period and protein hydrolysis by enzymes which improved-led to loss of water-soluble nitrogen with separated drip. Arannilewa *et al.* (2005) reported that the protein and fat contents of fresh Tilapia fish samples decreased from 60.65% and 9.72 % (on dry weigh basis), respectively, at zero time, to 43.70 and 7.20% after frozen stored for 60 days. Gomma (2005) noticed that moisture content of raw Catfish and Tilapia sausage decreased from 69.57 and 69.21% at zero day of storage at -18 ºC to 60.08 and 59.72% at the end of 4 months storage, respectively. Also, protein content reduced from 62.63 and 58.30% at zero time of storage to 59.97and 56.87% at the end of storage (on dry weight basis), respectively. While, fat content increased from 3.57 and 4.72 % at zero time of storage to 5.43 and 6.68 % at the end of storage period, respectively. Also, ash content increased from 1.66 and 1.88% at zero time of storage to 3.92 and 2.40% (on wet weight basis) at the end storage,

respectively. Ibrahim and El-Sherif (2008) reported that moisture content of frozen raw Tilapia fillets that treated with some plant extracts was slightly decreased during storage at -18 ºC for 4 months. Gandotra *et al.* (2012) investigated the effect of preservation at the temperature of -12.0 ± 2.0 ºC on the proximate composition of (*Labeo rohita*) fish stored for 3 weeks. The initial moisture content was 84.74% and decreased significantly to 80.84% after 21 of storage. Also, protein, fat and ash contents decreased significantly from 15.93%, 3.86% and 1.79±0.01% at zero day to 13.06%, 3.00% and 1.36 after 21 days of storage at -12±2 °C. El-lahamy (2018) found that moisture, protein, fat and ash contents of fresh Mullet fish steacks recorded 71.45%, 19.4%, 7.41% and 1.46% respectively. After 180 days of frozen storage, these values to 69.1%, 18.5%, 7.0% and 4.55% respectively. The moisture content of raw (uncooked) fish products burger and finger prepared from sand smelt fish was tested throughout a 90-day storage period at -18 C. The moisture content of burger samples immediately after producing was 60.22, 60.63, and 62.22% for the control sample and those produced with 15% Soybean flour and 15% Minced boiled potatoes, respectively. These moisture content levels gradually reduced during storage, reaching 56.31, 55.15, and 57.54%, respectively, at the end of 90 days. Fish finger moisture contents changed similarly after frozen storage (El-Lahamy *et al.*, 2018).

1.1.Amino Acids

Fish is a suitable source of good quality protein which is essential for health (Kim and Lall, 2000). The protein quality depends on its content of amino acids, essential amino acids ratios and the physiological utilization of amino acids after digestion, absorption and oxidation (Friedman, 1996). The nutritional quality of protein is connected to its content of essential amino acids (Acton and Rudd, 1986). The protein of fish muscle is rich in essential amino acids, has a high biological value and can be digested easily. The amount of connective tissue is low (1–2%) compared with warm-blooded animals (10–13% (Rehbein and Oehlenschlager, 2009). Several studies were carried out to determine effect of frozen storage on fish content of amino acids. Alvarez *et al.* (1990) showed that lysine diminished in Hake fish (*Merluccius sp*.) stored at -12°C for 4 months was attributed to the reaction between lysine with formaldehyde into formal lysine. Castrillon *et al.* (1996) showed that amino acid composition of Sardine (*Clupea pilchardus*) changed during frozen storage at -20°C, especially; S-amino acids have decreased, while histidine, tyrosine, leucine, lysine and phenylalanine were diminished during storage. Wesselinova (2000) showed that the extended storage at−35 ºC did not dramatically affect the amino acid values of several species of fish included Mackerel (*Scomber scombrus*), Black sea bream (*Spondyliosoma cantharus*) and Belted bonito (*Palamic sarda*). Their results showed that after 12 months of storage of these species, Methionene slightly decreased, Lys did not change, Iso was reduced in the Black sea bream and Belted bonito, while Thr showed significant variations only in Mackerel fish. Moreover, Val, Leu and Phe did not change at all up to the end of storage and Iso was reduced on the 12th month in the Black sea bream and Belted bonito. The investigators reported that the oxidation was only done in methionine, during frozen storage. Ziaeian *et al.* (2008) reported that lysine and methionine contents of long tail Tuna decreased during frozen storage at -18 for 9 months. El-Lahamy *et al.* (2018b) observed that frozen storage indicated no considerable changes on amino acids contents of fresh Mullet fish. Cystine showed the highest loss about 13.0%, while tyrosine, serine and argnine slightly increased. Data showed that after 6 months of frozen storage, the essential, non-essential and total amino acids were 40.35, 43.81 and 84.16 g /100g protein, respectively which represented more

than 97.0 % of their concentrations in the raw samples before storage.

2. Physiochemical Quality Parameters Fish and its products

2.1.pH value:

The natural pH of live fish is just above 7.0, typically about 7.3, but this falls markedly after death as the fish goes through rigor mortis and glycogen is converted to lactic acid. In most species, the post mortem pH is between 6.0 and 6.8, but in some species, for example tunas, it is below 6.0 because of high initial concentrations of glycogen. Within a species, the glycogen content in a fish at death depends on biological factors such as nutritional status and activity, which depletes glycogen content, just before death. The results of pH measurements during spoilage invariably show that after the resolution of rigor mortis the pH increases, usually after a dwell of a few days depending on the conditions of storage. However, the great variability of intrinsic pH between species, effects of biological conditions and harvesting procedures, and between fish within a batch, precludes it being an effective measure of spoilage (Rehbein and Oehlenschlager, 2009). Arannilewa *et al.* (2005) concluded that pH value of frozen Tilapia fish increased as the period of frozen storage increased. It was 5.20 at zero time of storage and increased to 6.90 after 60 days of frozen storage. Ozyurt *et al.*, (2007) determined the changes in the pH values of Sea bass, captured in autumn and winter, during storage at -18 ˚C and they found that the initial value slightly increased from 6.60 at zero time to 6.69 at the end of 9 months storage. Ibrahim and El-Sherif (2008) showed that pH value of Tilapia fillets slightly increased from 5.72 - 6.07 at the beginning of frozen storage to 6.13 - 6.50 at the end of 4 months storage at -18±1ºC. The pH values of *P. elevatus* and *S. undosquamis* burgers were 6.83 and 7.00 respectively, at the end of storage period at-18 ºC (Mahmoudzadeh *et al.*, 2010).

El-Sherif *et al.* (2011) observed that pH values of Tilapia and Mullet slightly increased during storage period at-18 ºC from 6.07 and 5.94 to 6.37 and 6.58 after 180 days of storage, respectively. This increase may be due to the deterioration of fish protein and liberation of ammonia and other volatile bases. Izci, *et al.* (2011b) reported that pH value of pre-fried fish fingers prepared from sand smelt fish was 6.49 at zero time of storage at -18ºC increased to 6.73 at the end of 6 months storage. The initial pH values of control, 15% soybean flour (SF) and 15% minced boiled potato (MBP) Sand smelt fish burgers increased from 6.48, 6.58 and 6.45 to 6.80, 6.68 and 6.60 after 90 days storage period at -18 °C. Also, pH values of control sample, 20% SF and 15% MBP Sand smelt fingers increased from 6.70, 6.69 and 6.79 to 7.03, 6.95 and 6.79 after 90 days storage period (Abd-Elsalam, 2013).

2.2.Total Volatile Basic Nitrogen (TVB-N)

Total volatile basic nitrogen (TVB-N) and trimethylamine nitrogen (TMA-N) content are the most important chemical parameters that are used for the assessment the quality of fish and fishery products. The levels of these compounds increase with the onset of spoilage. There is a good correlation between chemical compounds are the primary cause for the fishy odors with sensory analysis (Ozoğul and Ozoğul, 2000 and Ruiz-Capillas and Moral, 2001). Tokur *et al.* (2006) observed that TVB-N value was not stable during frozen storage of fish and could be changed according to species, processing methods and storage temperature. The increasing of TVB-N value during storage is related to the bacterial spoilage and the activity of endogenous enzymes (Chomnawang *et al.,* 2007). The European Commission as per the Council Regulation No. 95/149/EEC of March 1995 has permitted the use of TVBN for freshness determination of the freshness of fish. Critical

limits of TVBN ranging from 25 to 35 mg per 100 g were established for different families of fish species. Varlik and Gokoglu (1991) reported that Bluefish (*Pomatomus saltator*) samples packed with and without vacuum at -18˚C still retained the 'high quality' characteristic during the 9 months storage period. Abo-zied (1995) showed that TVB-N of Silver and Common Carp gradually increased during storage at -10ºC and -20ºC for 16 weeks which was attributed to the enzymatic activity beside the breakdown of proteins. Similarly, Abo-Taleb (1997) observed that TVB-N value of Silver carp fish muscle was gradually increased during storage at -18±1 ºC for 180 days. Such increment may be due to proteolytic enzymes of microbial origin which resulted in the breakdown of nitrogenous substances. Tokur *et al.* (2004) reported that TVB-N value decreased from 8.89 mg/100g in tilapia burger at zero time of frozen storage at -18 ºC to 7.69 mg /100gm flesh after 3 months then increased to 9.28 mg /100g after 5 months and decreased to 7.75 mg /100g at the end 8 months of storage. Ozyurt *et al.* (2007) determined the changes in the TVB-N values of Seabass during storage at -18˚C and found that the initial TVB-N value slightly increased from 12.72 at zero time to 15.59 mg /100gm sample at the end of 9 months storage. Asgharzadeh *et al.*, (2010) studied the sequence of washing process then frozen storage at 18 ºC for 6 months on the quality of minced Silver carp muscles. They reported that TVB-N of washed minced Silver carp muscles decreased from 5.8 mg/100g at zero time to 4.9 mg/100 g after 60 days of frozen storage, and then increased to 7.3 mg/100 g at the end of frozen storage period. On the other hand, TVB-N of unwashed minced Silver carp muscles increased from 13.2 mg/100 g at zero time to 17.6 mg/100 g at the end of storage for 6 months. The low TVB-N values in washed mince could be explained as a result of a partial removal of nitrogenous containing molecules susceptible to breakdown during washing.

Mahmoudzadeh, *et al.* (2010) found that TVB-N in fish burgers made from deep flounder (*Pseudorhombus elevatus)* increased from 11.66 mg /100g to 20.97 mg / 100g after 2 months storage at – 18 °C and then decreased to 14.60 mg/100g at the end of 5 months storage. Similarly, fish burgers made from brush tooth lizard fish (*Saurida undosquamis*) increased from 10.68 at zero time of storage to 22.44 after 3 months and then decreased to 14.60 mg/100g after 5 months. Also, Nazemroaya *et al.,* (2011) reported that (TVB-N) was 15 mg TVB-N/100g in Spanish mackerel (*Scomber commersoni*) stored at -18 ºC for 6 months. El-Sherif *et al.* (2011) determined the changes in the TVB-N of Mullet and Tilapia fishes during storage at -18 ˚C and they found that the initial TVB-N values increased from 12.90 and 14.31mg/100g at zero time to 27 and 29.31 mg/100g at the end of the 6 months storage, respectively. Izci, *et al.* (2011b) found that TVB-N of pre-fried Sand smelt fish fingers was 19.33 mg/100g at zero time of storage at -18ºC increased to 23.78 mg/100g after 4 months followed by decreasing to 19.58 mg/100g after 6 months. Talab (2014) determined TVB-N content of raw, fried, microwave and halogen cooked samples of Carp fish cutlets by 12.21, 11.75, 11.04 and 11.46 mg/100 g, respectively at zero time of frozen storage and these values increased significantly ($P<0.05$) during frozen storage. Agustinelli and Yeannes (2015) studied the effect of frozen storage at -19 ˚C for 9 months on the biochemical changes of Mackerel (*Scomber japonicus*) and they showed that TVB-N content increased significantly ($P<0.05$) during the 9 months of storage reaching to 47.9 mg /100g.

The initial TVB-N content of raw (uncooked) Mullet fish steaks were 13.25mg/100g. During storage, this value increased to 26.75 mg/100g at the end of 180 days storage period at -18 °C, (El-Lahamy *et al.* 2018a).

3. Trimethylamine nitrogen (TMA-N)

Trimethylamine-oxide (TMAO) is a natural nontoxic compound, generally associated with the osmoregulatory function of marine fish. After the death of the fish some bacterial species such as *Alteromonas, Proteus, Photobacterium, Vibrio,* and *S. putrefaciens*, and also intestinal bacteria of the *Enterobacteriaceae* present are able to carry out anaerobic respiration by using TMAO as an electron acceptor. The bacterial enzyme TMAO-reductase reduces TMAO to TMA. Formation of TMA depends primarily on the content of TMAO in the fish. Most marine animals contain TMAO in appreciable quantities, with elasmobranchs and deep-sea fish species containing higher levels (Venugopal, 2005). The perfectly fresh fish had 3.37 mg/100 g of TMA-N, good grade fish 3.79 – 5.90 mg /100g and fair grad had 12.56 – 16.02 mg / 100 g while spoiled fish contained 59.01 mg/100g (Maga, 1978).

Abo-Zied (1995) revealed that TMA-N of silver Carp and common Carp increased during storage period at-10 ºC and -20 ºC for 16 weeks. This increase may be due to the enzymatic activity and breakdown of proteins. Abo-Taleb (1997) reported that TMA-N value of fresh silver carp fish muscle was1.26 mg/100g (on dry weight basis) increased to 6.89 mg/100g at the end of 180 days of frozen storage at -18 ±1 ºC. The progressive increment of TMA-N during frozen storage was attributed to the activity of specific proteolysis enzymes which survived the conditions frozen of storage. Gomma (2005) found that TMA-N value of raw catfish and tilapia sausage increased from 0.69 mg/100g at zero time of frozen storage at -18 ±1℃ to 2.54 mg/100g (on wet weight basis) at the end of storage period (120 days). This increasing in TMA-N during storage might be due to several factors included the microbial action, cleavage of trimethylamine oxide naturally present in fish muscle and / or the formation of TMA itself from betaine and choline which also are present naturally in the fish. El-Sherif, *et al.,* (2011) investigated the effect of frozen storage at - 18 °C for 180 days on TMA-N of tilapia and mullet and they found that TMA-N values of frozen tilapia and mullet fish increased markedly from 0.92 and 0.68 mg/ 100 g at zero time of storage to 3.98 and 3.72 mg/ 100 g at the end of storage period, respectively. Such increasing in TMA-N during frozen storage might be attributed to the conversion of TMAO to TMA by non-enzymatic process, or by native tissue enzymes or by bacterial enzymes (TMAase) which are not completely inactivated at low temperature.

TMA-N content of control burger sample and 15% soybean flour (SF) and 15% minced boiled potato (MBP) formulated samples gradually increased from 1.30, 1.05 and 0.81mg/100g, before storage up to 2.17, 1.89 and 1.62 mg/100g, respectively at the end of 3 months of storage period. The initial TMA-N value in control sample of Sand smelt finger, the 20% SF and 15% MBP formulated samples increased from 2.23, 2.10 and 0.90 mg/100g, respectively to 2.87, 2.76 and 1.95 mg/100g 3 months of storage period, respectively (Abd-Elsalam, 2013).

4. Thiobarbituric acid (TBA):

At the first stage of oxidation, peroxides are formed through the connection of oxygen to the double bonds of the unsaturated fatty acids. As the peroxides are flavourless and odourless compounds, they cannot be distinguished by the consumers. However, peroxides lead to the production of secondary products, such as aldehydes, ketones and carboxylic acids, which resulted in the detection of oxidative rancidity (Melton, 1983). Thiobarbituric acid (TBA) test is one of the most commonly used methods to determine rancidity in fishery products. The test relies upon the reaction between 2-TBA and aldehydes to result a

colored alkanal which can be measured spectrophotometrically at 450 nm.

Despite its widespread use, there are a few drawbacks for the technique. These include uncertainty about the nature of the color generation reaction, lack of specificity of the TBA reaction, and its reactivity with only malonaldehyde, one of the components of lipid oxidation (Bremner, 2002). Slurry ice slowed down the formation of thiobarbituric acid reactive substances in horse mackerel (Losada *et al.* 2005). TBA values of horse mackerel significantly increased up to 14 day of storage in ice (Aubourg, 2001). Ice storage protected Rohu fish against oxidation; low TBA values and limited oxidative rancidity were observed during the storage (Dhanapal *et al.,* 2013). Yanar and Fenercioğlu (1999) made minced fish meat from Carp and determined TBA at the beginning and the end of 6 months storage at -18ºC by 0.6 and 2.2 mg malonaldhyde/kg sample, respectively. Tokur *et al.* (2004) reported that TBA value of Tilapia burger was still in acceptable level at the end of the 8 months of frozen storage. Ozyurt *et al.,* (2007) determined the changes in TBA values of Sea bass during storage at -18 ˚C and observed that TBA values were 0.066, 0.044, 0.047and 0.086 mg malonaldhyde/kg sample after 0, 3, 6 and 9 months of storage, respectively. Gomma (2005) found that TBA value of raw catfish and tilapia sausage increased from 0.48 and 0.66 mg MDA/ kg sample at zero time of storage at -18 ±1℃ to 2.33 and 2.12 MDA/ kg sample, respectively at the end of 120 days of storage. This increasing in TBA value during frozen storage was mainly due to autoxidation of fish lipids during storage. Mahmoudzadeh, *et al.* (2010) determined TBA of deep flounder and lizardfish burgers by 0.22and 0.26mg MDA/kg, respectively at the end of the 5 months storage (-18 ºC). Izci, *et al.,* (2011b) found that TBA of pre-fried fish fingers prepared from sand smelt fish was 0.283 mg MDA/kg at zero time of storage increased to 0.317 after 3 months of storage then decreased to 0.29 mg MDA/kg after 6 months of storage at – 18 °C.

El-Sherif *et al.* (2011) determined the changes in TBA values of Mullet and Tilapia fish during storage at -18 ˚C and they found that the initial TBA values were 0.95 and 0.55 mg MDA/kg sample at zero time, respectively. These values slightly increased during storage to 2.30 and 1.92 mg MDA / kg at the end of 6 months storage, respectively. This increase of TBA values may be due to the ice crystals formed which could injure the cell and cause the release of pro-oxidants for lipids oxidation, especially free iron. Agustinelli and Yeannes (2015) followed the development of lipid oxidation in the whole fish and muscles of Mackerel during frozen storage at -19 ˚C and they observed that TBA increased ($P<0.05$) in the whole round Mackerel and in both tissues during the frozen storage.

5. Microbiological Aspects:

Fish is considered one of the most perishable foods, mainly due to the action of the bacteriological activity that occurs on the surface of the newly caught fish. In fish technology, the microbiological control is an essential for controlling the quality of raw fresh and other ingredients used in order to produce the final fishery products has being safe for the consumers and having good quality, according to Egyptian and International Standard Specification and Legislations of food (Gerasimov and Antonova, 1979 and ACPSFPI2001).

The freezing process partially or completely hinders disruptive microbiological or enzymatic reactions, nevertheless, it cannot repair damage already caused. The fish should be frozen after handling for a better quality. The great advantage of the freezing process is the ability to achieve stability without damaging the initial quality. The material to be processed should be fresh and qualified, and handled in accordance with the technique of freezing in order to obtain long-lasting products. Çaklı *et al.* (2005) examined the microbial load of fish fingers made from

different species. The loads of microorganisms in fish fingers made from *S. pilchardus*, *M. merlangus* and *S. luciopercaw*ere fall down from 4.61, 4.62 and 4.50 log cfu/g sample to 4.34, 3.86 and 3.73 log cfu/g, respectively at the end of 240 days of frozen storage. Tokur, *et al.*, (2006) examined the microbial quality of Carp fish fingers as affected by washing process. The total bacterial counts of unwashed fish and washed fingers samples were 2 $\times 10^5$ and 8 $\times$ 10^4 cfu/g sample, respectively. These values did not exceed 10^6/g sample during frozen storage. EOS (2009) stated that frozen fish shouldn't have *Clostridium* and *E. coli*, while aerobic bacteria and *Staphylococcus auras* shouldn't exceed 10^6 and 10^3 cfu /g sample, respectively. Mahmoudzadeh, *et al.*, (2010) reported that burgers from *P. elevatus* and *S. undosquamis* had low number of microorganisms at the end of storage period (-18 ºC). El-Sherif *et al.* (2011) found that the total bacterial count (TBC) of raw Mullet fish during storage period at -18°C were 2.01, 4.32, 3.05 and 2.65 $\log_{10}$ cfu /g sample after 0, 60, 120 and 180 days of storage, respectively, while TBC of raw Tilapia fish were 2.35, 5.75, 4.15 and 2.95 $\log_{10}$ cfu /g sample after the same periods of frozen storage. Izci *et al.* (2011a) found that the total count of mesospheric aerobic microorganisms of fish fingers made from sand smelt fish decreased from 5.998 $\log_{10}$ cfu /g to 4.874 and 4.658 $\log_{10}$ cfu /g after 90 and 180 days of storage period at -18°C, respectively. Yeast and mold count were 0.989 log cfu /g in fresh fish fingers and did not detected during the storage period of 90 days. Gandotra *et al.* (2012) reported that the total plate count (TPC) of fish muscle *Labeo rohita* stored at -12±2 °C for 21 days increased from initial load of 2.04log (cfu/g) to 5.10± 0.2 log (cfu/g) at the end of storage.

The results indicated that the microbial growth increased with extending the storage. The microbiological examination of sand Smelt fish products indicated that the initial total bacterial counts (TBC) for control sample, 15% SF and 15% MBP burger before storage were 1.81×10^3, 5.24 $\times10^3$and 10.2×10^3 cfu/g sample, respectively. Also, the initial values of TBC for Sand smelt finger samples were 4.16×10^3, 13.1×10^3 and 28.18×10^3 cfu/g for control, 20% SF and 15% MBP finger samples, respectively. These values of TBC declined during frozen storage. The initial counts of mold and yeast in the different samples of burgers and fingers ranged between 1.04×10^2 to 7.07×10^2 cfu/g sample at zero-time storage and no detection could be found for mold and yeast during storage period of the sand smelt product (Abd-Elsalam, 2013).

El-Lahamy *et al.* (2018a) showed that the initial total bacterial count (TBC) for raw (uncooked), fried and grilled Mullet were 3.3, 2.95and 3.04log cfu/g, respectively. Upward trends were shown until the end of four month of frozen storage of raw sample to be 4.06, 3.71and 3.86$\log_{10}$ cfu /g, and then the downward was taken place until the end of storage period to reach 3.92, 3.11and 3.34cfu for raw, fried and grilled mullet respectively. Also, they found that the initial mold and yeast counts were 1.94, 1.3and 1.69 cfu/g for raw(uncooked), fried and grilled Mullet at zero time. During 180 days of storage period, raw (uncooked) sample, no detection could be found for mold and yeast in the cooked samples expect the raw sample; mold and yeast showed growth after 2.0 months.

CONCLUSION

Freezing technology is one of the most common methods of keeping quality and safety of fish and their products. Although, there are some changes in the chemical composition, chemical quality indicators, microbial quality and nutritional value, but these changes are minor during the frozen storage for fish and fishery products. Therefore, freezing process is one of the best

methods used in the keeping of fish and their products

REFERENCES

Abd-Elsalam, A. A. .2013. Production and evaluation of some high value added fish products from low economic fish. M. Sc. Thesis, Fac. of Agric., Fayuom Univ., Egypt.

Abo-Taleb, M. 1997. Studies on the utilization of Carp fish in some fishery products. Ph.D. Thesis, Fac., of Agric., Ain Shams Univ., Cairo, Egypt.

Abo-Zied, K. S. S. 1995. Chemical and histological studies on Carp fish preserved at low temperature. M.Sc. Thesis, Fac., of Agric., Cairo Univ., Egypt.

ACPSFPI 2001. Advisory Committee on Plant Schemes in Food Processing Industries. Annual Report on American Food Industrial at the web side Http:/www.Yahoo.com.

Acton, J.C. & Rudd, C.L. 1986. Protein quality methods for Sea foods in seafood quality determination. Proceedings of an International Symposium Coordinated by the University of Alaska Sea Grant College Program. Kramer, D.E., Liston, J. Eds, 1986: 453-472.

Agustinelli, S. P. & Yeannes, M. I. 2015. Effect of frozen storage on biochemical changes and fatty acids composition of Mackerel (*Scomber japonicus*) muscle. *Journal of Food Research; Vol. 4, No. 1; 2015.*

Alvarez, C., Huidobro, A., Tejade, M.,Vazquez, I., De Miguel, E. & Gomz De Segura, I.A. 1990. Consequences of frozen storage for nutritional value of Hake. *Food Sci. Tech., 5: 493-499.*

Arannilewa, S. T., Salawn, S. O., Sorungbe, A. A. & OlaSalawn .2005. Effect of frozen period on the chemical , microbiological, and sensory quality of frozen Tilapia fish (*Sarotherodun galiaenus*). *African J. of Biotechnology (8) 4: 855 – 852*

Asgharzadeh, A.; Shabanpour, B.; Santiago, P. A. & Hosseini, H. 2010. Chemical changes in Silver carp (*Hypophthalmichthys molitrix*) minced muscle during frozen storage: Effect of a previous washing process. Grasas y aceites, 61(1), enero-marzo, 95-101.

Aubourg, S.P. (2001). Damage detection in horse mackerel (*Trachurus trachurus*) during chilled storage. Journal of American Oil Chemists' Society, 78: 857–862.

Bremner, H. A. (Ed.). 2002. Safety and quality issues in fish processing. Elsevier.

Çakli S.; Taskaya L.; Kisla D.; Çelik U.; Ataman C. A.; Cadun A.; Kilinc B. & Maleki, R.H. 2005. Production and quality of fish finger from different fish species. Eur. Food Res. Technol. 220: 526-530.

Castrillon, A. M.; Alvarez-Pontes, E.; Arias M.T.G. and Navarro, P. 1996. Influence of frozen storage and defrosting on the chemical and nutritional quality of Sardine (*Clupea pilchardus*). *J. Sci. Food Agric., 70: 29-34.*

Chomnawang, C.; Nantachai, K.; Yongsawatdigul, J.; Thawornchinsombut, S. and Tungkawachara, S.2007 . Chemical and biochemical changes of hybrid Catfish fillet stored at 4ºC and its gel properties. *Food Chem., 103:420–427.*

Connell, J.J. and Shewan, J.M. 1980. Sensory and nonsensory assessment of fish. In: 'Advances in Fish Science and Technology". J.J. Connell (Ed.), Fishing News Books Ltd., Farnham, Surrey, U.K., 1980, PP: 56-65.

Dhanapal, K., Sravani, K., Balasubramanian, A. & Reddy, G.V.S. 2013. Quality determination of rohu (*Labeo rohita*) during ice storage. Tamilnadu Journal of Veterinary & Animal Sciences, 9(2): 146–152.

El-Akeel, A. T. M. 1983. The effect of processing and storage on fish quality. M. Sc. Thesis, Fac. of Agric., Cairo Univ.

El-lahamy, A. A. 2018. Effect of some processing methods on quality of some fishes of Wady El-rayan, Fayoum Governorate. Ph.D. Thesis, Fac. of Agric., Fayoum Univ., Egypt.

El-Lahamy, A. A., Khalil, I. K., El-Sherif, S. A. & Mahmud, A. A. 2018b. Effect of frozen storage and cooking method on amino acid composition of mullet fish (*Mugil cephalus*). MOJ Food Process Technol. 2018; 6 (6): 458–463. DOI: 10.15406/ mojfpt.2018. 06.00206.

El-Lahamy, A. A., Khalil, K. I., El-Sherif, S. A. & Mahmud, A. A. 2018a. Impact of cooking methods and frozen storage on quality parameters of mullet fish (*Mugil cephalous*) steaks. J. Food Technol Pres. 2018; 2(3):7-13.

El-Lahamy, A. A., Khalil, K. I., El-Sherif, S. A., Mohamed, H. R., & Mahmud, A. A. 2019. Effect of frozen storage on the chemical composition of sand smelt (*Atherina hepsetus*) fish burger and finger. Journal of Fisheries Sciences. com, 13(1), 7-13.

El-Sherif, S. A.; Ibrahim, S. M. & Abou-Taleb, M. 2011. Relationship between frozen pre-storage period on raw Tilapia and Mullet fish and quality criteria of its cooked products. *Egyptian J. Aquatic Res., 37(2):183-189*

EOS 2009. Egyptian Organization for Standardization and Quality**.** No. 889-1: Frozen fish, Part: 1 Whole fish, Arab Republic of Egypt.

Friedman, M. .1996. Nutritional value of proteins from different food sources", *J. Agri. Food Chem.,* Vol., 44:6-29.

Gandotra, R., Koul, M. Gupta, S. & Sharma, S. 2012. Change in proximate composition and microbial count by low temperature preservation in fish muscle of *Labeo Rohita* (Ham-Buch). IOSR *J. Pharm. and Biolo Sci.* (IOSRJPBS). Vol. 2, Issue 1 :13-17.

Gerasimov, G. V. & Antonova, M. T. 1979. Techno-chemical control in fish processing industry. Published by Gubal Primlani. Co. Prt. Ltd, New York.

Gökog˘lu, N. & Yerlikaya, P. 2015. Seafood Chilling, Refrigeration and Freezing: Science and Technology. Chapter 7 Freezing technology (Pages: 163-185). Online ISBN:9781118512210 |DOI:10.1002/9781118512210. John Wiley & Sons, Ltd.

Gomma, R. A. M. 2005. Studies on producing sausage from some fish types. M.Sc. Thesis, Fac. of Agric. Al-Azher Uni., Egypt.

Gulyavuz, H. & Unlusayin, M. 1999. Seafood processing technology. Egridir, Isparta: S.D.U. Agr. of Seafood. p359. (in Turkish).

Ibrahim, S. M. & El-Sherif, S.A. 2008. Effect of some plant extracts on quality aspects of frozen Tilapia *(Oreachromis niloticus L.)* fillets. Global Veterinaria, 2 (2).62-66.

Izci, L., Sengul B. & Ali G. 2011a. Production of fish chips from sand smelt (*Atherina boyeri*, RISSO 1810) and determination of some quality changes. Iranin Journal of Fisheries Sciences, 10 (2) 230-241.

Izci, L., Sengul B. & Ali G. 2011b. Production of fish finger from sand smelt (*Atherina boyeri*, RISSO 1810) and determination of quality changes. African Journal of Biotechnology Vol., 10 (21): 4464-4469.

Kim, J. D., and Lall, S. P. 2000. Amino acid composition of whole body tissue of Atlantic halibut (*Hippoglossus hippoglossus*), yellow tail flounder (*Pleuronectes ferruginea*) and Japanese flounder (*Paralichthys olivaceus*). *Aquaculture*, 187, 367–373.

Losada, V., Piñeiro, C., Barros-Velázquez, J. & Aubourg, S. 2005. Inhibition of chemical changes related to freshness loss during storage of horse mackerel (*Trachurus trachurus*) in slurry ice. Food Chemistry, 93: 619–625.

Maga, J. A. 1978. Amines in Foods. CRs Critical Reviews in Food Sci. and Nutrition, 373 – 403.

Mahmoudzadeh, M. Motallebi A. A. Hosseini H. Haratian P. Ahmadi H. Mohammadi M. & Khaksar R. 2010. Quality assessment of fish burgers from deep flounder (*Pseudorhombus elevatus*) and brushtooth lizardfish *(Saurida undosquamis*) during storage at -18ºC. Iranian Journal of Fisheries Sciences. 9 (1) 111-126.

Melton, S. 1983. Methodology for following lipid oxidation in muscle foods. *Food Technol*., 37(7): 111–116.

Nazemroaya, S. Sahari, M. A. & Rezaei, M. 2011. Identification of fatty acid in Mackerel (*Scomberomorus commersoni*) and Shark (*Carcharhinus dussumieri*) fillets and their

changes during six months of frozen storage at -18 °C. *J. of Agric. Sci. and Technol., 13*(4), 553-566.

Özogul, F., Polata, A. & Özogul, Y. 2004. The effects of modified atmosphere packaging and vacuum packaging on chemical, sensory and microbiological changes of sardines (*Sardina pilchardus*). *Food Chem.,* 85: 49–57.

Ozyurt, G. Polat, A. & Tokur, B., 2007. Chemical and sensory changes in frozen (-18ºC) wild Sea bass (*Dicentrarchus labrax*) captured at different fishing seasons *Inter. J. Food Sci. Technol.*,42:887–893.

Pearson, A.M. Gray, J.I. Wolzak, A. M. & Hcrenstein, N. A. 1983. Safety implications of oxidized lipids in muscle foods. *Food Technol*. 37:121-129.

Pearson, D., (1997): The Chemical Analysis of Foods 6th Edn., Long Man Group Ltd., Safiyari Sh ,Moradi.

Rehbein, H., & Oehlenschlager, J. (Eds.). 2009. Fishery products: quality, safety and authenticity. John Wiley & Sons.

Ruiz-Capillas, C. & Moral, A. 2001. Correlation between biochemical and sensory quality indices in Hake stored in ice. *Food Res. Inter.*, 34:441-447.

Ryder, J., Iddya, K., & Ababouch, L. 2014. Assessment and management of seafood safety and quality: current practices and emerging issues. FAO Fisheries and Aquaculture Technical Paper, (574), I.

Talab, S. A. 2014. Effect of Cooking Methods and Freezing Storage on the Quality Characteristics of Fish Cutlets. *J. of Food Sci. . Technol.,* 6(4): 468-479, 2014.

Tokur, B., Ozkutuk, S., Atıcı, E., Ozyurt, G. & Ozyurt, C. E. 2006 .Chemical and sensory quality changes of fish fingers made from Mirror carp (*Cyprinus carpio L.1758*) during frozen storage (-18 ºC). *Food Chem.,* 99 :335-341.

Tokur, B., Polat, A., Beklevik, G. & Ozkutuk, S. 2004. Changes in the quality of fish burger produced from Tilapia (*Oreochromis niloticus*) during frozen storage (-18C). *European Food Res. and Technol.*, 218, 420–423.

Varlik, C. & Gokoglu, N. 1991. Dondurulmus ¸lu ¨fer (*Pomatomus saltator*)'in raf o¨mru¨nu¨n belirlenmesi. Istanbul Su Uru¨nleri Dergisi,1, 107–112.

Varlik, C. Ugur, M. Gokoglu, N. & Gun, H. 1993. Quality control principles and methods. *Food Technol. Inst*., 17: 174.

Venugopal, V. 2005. Seafood processing: adding value through quick freezing, retortable packaging and cook-chilling. CRC press.

Wesselinova, D. 2000. Amino acid composition of fish meat after different frozen storage periods. *J. Aquatic Food Prod. Tech*., 9(4): 41-48.

Yanar, Y. & Fenercioglu, H. 1999. The utilization of Carp (*Cyprinus carpio*) flesh as fish ball. *Turkish Journal of Veterinary and Animal Sciences*, 23, 361-366.

Ziaeian, H., Moini, S. & Jamili, S. 2008. Consequences of frozen storage for amino acids and unsaturated fatty acids of Tuna (*Thunnus tonggol*) roe. *Journal of Fisheries and Aquatic Science, 3: 410-415.*