Quality and Stability of Liquid Smoked Kapreeta Fish During Refrigerated Storage

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ABSTRACT: In Egypt, Kapreeta fish (like tuna) as marine fish, is not appreciated among Egyptian consumers because it is bloody dark flesh and presence of many blood vessels. Therefore, this kind of fish must be utilized as fish products through different preservation methods as canning and smoking.

The aim of this study is to investigate the effects of liquid smoking and essential oils prior smoking on the quality of smoked kapreeta fish fillets just after smoking and during refrigerated storage up to 90 days. Proximate composition was determined in fresh and smoked fish fillets. Chemical, microbiological and sensory analyses of the samples as well as fatty acids composition of fresh and smoked kapreeta fish fillets were carried out during the storage to test their quality and lipid stability. Moisture content decreased while protein, lipid and ash increased after smoking. The pH values were slightly increased by storage time. Total volatile basic nitrogen, trimethyl amine nitrogen, peroxide values, thiobarbituric acid, free fatty acids and total viable count values were increased more in untreated fish samples than smoked fish samples treated with thyme or sage essential oils, while sensory scores decreased during storage. The total polyunsaturated fatty acids content was 35.14% of total fatty acids in untreated smoked fish and 35.80% in treated samples with 5% thyme oil and 36.14% in treated samples with 5% sage oil prior to smoking, with eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) being the prominent polyunsaturated fatty acids. The decrease of PUFAs may indicate the oxidation of these unsaturated fatty acids during storage. Such changes were not observed in sage or thyme extracts treated lots.

According to the results of physicochemical, microbiological and sensory analyses, it was found that untreated smoked kapreeta fish samples were in high quality and lipid stability for 30 days under refrigerated storage and smoked kapreeta fish samples treated with 5% thyme oil or sage oil were in high quality till 60 and 75 days under refrigerated storage. It can be concluded that kapreeta fish fillets treated with sage and thyme essential oils prior to liquid smoking have positive effect on quality and shelf life of smoked fish as well as induced the stability of fatty acids profiles without altering their composition and minimize oxidation.

Key words: Kapreeta fish, quality, shelf life, smoked fish, essential oils, Chemical and microbiological analyses, sensory evaluation

INTRODUCTION

Fish constitutes a very important component of diet for many people, and often provides much needed nutrients for human health. Fish serves as a principal source of dietary protein, which is very inexpensive in relation to other protein foods (Fawole et al., 2007).

Fish is known to contain high quality of lipids. The long chain polyunsaturated fatty acids (PUFAs), especially the n-3 PUFAs family including eicosapentaenoic acid (EPA or 20:5 n-3), docosapentaenoic acid (DHA or 22:6 n-3) present in marine lipids have beneficial health effects (Osman et al., 2001, Boran et al., 2006, Stołyhwo et al., 2006 and Karlsdottir et al., 2014).

Fresh fish have soft tissues and high amount of water and this enhances its susceptibility to microbial contamination (Olayemi et al., 2012). So that fresh fish is highly perishable and various preservation techniques such as chilling, freezing, drying, salting, and smoking have been used universally to extend...
shelf life. In developing countries, the most affordable and widely used fish preservation methods are drying and smoking (Oduor-Odote et al., 2010a,b and Darvishi et al., 2013).

Smoking of fish is one of the most ancient processing technology and one of many different preservation methods. Smoking is commonly carried out at temperatures of 70–80°C (Marc et al., 1997 and Erkan et al., 2011). In contrast, cold smoking is achieved without thermal treatment usually at temperature ≤ 30°C (Goulas and Kontominas, 2005). Smoked fish products are commonly salted. The use of salt is essential to complement the bacterial inhibitory effect of smoke by reducing water activity. For health and acceptability reasons, the practice is to have products with low salt content. Nevertheless, one of the problems faced in smoking process is no standard process implemented yet so that the quality of smoked fish produced can change. Different smoking temperature, different smoking duration, different number of smoking materials, different quality of smoking material, and different water content have caused different quality of smoked fish produced affecting the consumer’s demand level (Oduor-Odote et al., 2010a,b and Salindeho and Mamuaja, 2015)

Liquid smoke is a natural smoke from plant based material which has been condensed into a liquid and then refined to remove certain toxic compounds from it. Liquid smoke is used in several applications on meat and fish to impart the flavour, colour and preservative characteristics of natural smoke devoid of the toxic tar compounds (Varlet et al., 2010). These may be used to preserve quality and ensure safety of foods (Martin et al., 2010). The use of liquid smoke has several advantages over traditional smoking procedures having no detectable levels of benzo α-pyrene and no mutagenic activity. Liquid smoke performs all the desired functions, allows more rigid flavor control and has the added advantages of lowering costs, less environmental damage and greater availability and variety of application methods (Dillon et al., 1994). The liquid smoke is applied on the food by either marinating, drenching, spraying or injecting the food with the liquid smoke before heat processing. The liquid smoke can also be applied to the food through liquid smoke coatings or liquid smoke nets (Jenkins, 2010). The use of liquid smoke has been shown to be four to five times more efficient in converting wood biomass to useable smoke than the traditional smoking process (Red Arrow, 2014).

Although smoking increases shelf life of the fish products, hygienic standards of the fish products before, during and after smoking are suspects. However, investigations have shown the presence of microbial contaminants even on smoked fish (Nyarko et al., 2011). Most of the post processing microbial contaminants such as bacteria and fungi originate from poor handling practices while some could be from the air, the source of the fish, or from other degrading substances.

Oxidation of lipids that occurs in fish during processing, heat treatment, and in the final products during subsequent storage, is one of the basic processes causing rancidity in fish products (Donelli and Robinson 1995). Such oxidative deterioration may affect on the quality and the organoleptic
characteristics, including taste and aroma making the final product unacceptable for consumption. Therefore, several investigations have been undertaken with the aim to enhance the shelf-life extension, the stability of lipid containing products and food quality.

The use of synthetic antioxidants such as butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA) has been very effective in controlling rancidity (Frankel, 1993 and Karpinska et al. 2001). However, synthetic antioxidants have frequently been associated with certain health problems (Thompson and Trush, 1986 and Siripongvutikorn et al., 2009). This has necessitated the use of natural antioxidants, such as spices, herbs, and vegetable extracts in the prevention of rancidity in chilled and smoked fish (Kahkonen et al., 1999 and Patrick-Iwuanyanwu et al., 2007) due to their antioxidant and antimicrobial properties (Akhtar et al. 1998 and Abdel-Hamied et al., 2009). The spices, notably the Lamiaceae family, are well known for their antioxidative properties, especially rosemary, sage and thyme, which have been reported to have strong such characteristics (Aruoma et al., 1992, Al-Flailih, 2009).

Thyme has been commonly used as a spice to add flavor to food (Maksimovic et al., 2008). The phenolics monoterpene, thymol and carvacrol are the main compounds have identified with significant antioxidant and antibacterial activities (Lacroix et al. 1997 and Viuda-Martos et al., 2008). Sage extracts have exhibited potent antioxidant activity and are widely used in the food industry. The antioxidant activity of sage extracts has been associated with the presence of several phenolic diterpenes such as carnosic acid, carnosol and rosmarinic acid which break free radical chain reactions by hydrogen atom donation (Basaga et al., 1997). A number of researchers have reported the effectiveness of sage extracts for achieving higher sensory scores and retarding lipid oxidation in various foods (Stoick et al., 1991 and Zaki, 2010).

In Egypt, Kapreeta fish (like tuna) as marine fish, is not appreciated among Egyptian consumers because it is bloody dark flesh and presence of many blood vessels. Therefore, this kind of fish must be utilized as fish products through different preservation methods such as canning and smoking (Abou Tor, 2002 a,b and Korish et al., 2008).

The objective of the present work was to study the effect of liquid smoking on the quality and lipid stability of Kapreeta fish fillets treated with essential oils of sage and thyme as natural antioxidants during refrigerated storage.

MATERIALS AND METHODS

Materials

Kapreeta fish (Scombromous spp.) like Tuna was purchased from the Max Bay, Alexandria during the summer season of 2015. Fish samples (six fish with 30 kg) transported in iceboxes to fish Processing and Technology laboratory, National Institute of Oceanography and fisheries, Alexandria.
Sensory Evaluation of raw fish included eye, gill, belly and texture were carried out. Liquid smoke composition was 90% water, 2% phenols, 4% acids, 3% carbonyl and 1% tar. All chemicals used for analysis were of analytical grade.

Methods
1. Preparation of fish samples
   Fish samples were washed with tap water, beheaded, eviscerated, skinned and filleted. After traces of blood were removed by tap water, one hundred and twenty (120) fillet samples were prepared as steaks with the dimension of 10 cm (length), 5 cm (width) and 1.5 cm (thickness). The weight of each fillet sample was 135 ± 5 g.

2. Extraction of essential oils
   Fresh thyme and sage obtained from Siwa Oasis were properly cleaned, washed and ground. Essential oils were extracted by hydrodistillation procedure as described by Balbaa et al. (1981) and modified by Iheagwara, (2013). The essential oils were dried over anhydrous sodium sulphate and stored at 5 °C for further analysis.

3. Liquid smoking of fish fillet samples and storage
   The cleaned, brined and spiced fish samples were soaked for 30 min in 1000 ml of diluted liquid smoking solution (300 ml concentrated liquid smoke + 700 ml water in rectangle glass Jar) containing 0.0% (control), 5.0% and 10.0% of thyme essential oil (60 fish fillet samples) or sage oil at the same concentrations (60 fish fillet samples) with 10% salt. Hot smoking was carried out with liquid smoke, essential oils and salt at a temperature of 80 ± 2°C for 3 hours. Samples were stored at refrigerated temperature (5 ± 1°C) for three months and samples were analyzed every 15 days. Chemical and microbial analysis and organoleptic evaluation were determined.

4. Physico-Chemical Analysis
   1. Salt Content
      Sodium chloride content in smoked fish samples was determined by volumetric method of Volhard (AOAC, 1990).

   2. Determination of pH
      pH value was estimated according to Goulas and Kontominas (2005) as follows. Ten g of sample was homogenized in 100 ml of distilled water and the mixture was filtered. The pH of filtrate was measured using a pH meter (HANNA pH213) at ambient temperature.

   3. Proximate Composition
      Proximate composition included moisture, protein, fat and ash contents of the fresh and smoked fish samples were determined using the standard methods of AOAC (2007).
4. Determination of Total Volatile Basic Nitrogen (TVB-N)
Total Volatile Base Nitrogen (TVB-N) value was estimated by the semi-micro distillation procedure (AMC, 1979; Kirk and Sawyer, 1991). The bases are steam distilled into standard acid and back-titration with standard alkali.

5. Determination of Trimethylamine Nitrogen
Trimethylamine Nitrogen (TMAN) was determined using the above mentioned TVBN method after appropriate modification: formaldehyde was used to block the primary and secondary amines (AMC, 1979).

6. Extraction of Lipids
Lipid was extracted from the mixed smoked fish samples with a mixture of chloroform / methanol (2: 1 v/v) according to the method described by Folch et al. (1957).

7. Determination of 2-Thiobarbituric Acid (TBA)
2-Thiobarbituric acid (TBA) value of smoked fish samples was determined colorimetrically by using the method published by Kirk and Sawyer (1991).

8. Determination of Peroxide Value
Peroxide value (PV) was expressed in unit’s meq / kg lipid was determined by the titration method (Kirk and Sawyer, 1991).

9. Free fatty acids
Free fatty acid content of the fish samples was determined according to the method of Kirk and Sawyer (1991). A mixture of diethyl ether (25 mL), ethanol (70% v/v) (25 mL) and 1% phenolphthalein solution (1 mL) was prepared then neutralized with 0.1 M NaOH solution. Two grams quantities of fish samples were blended in the neutral solvent prepared above for about 20 min, and then titrated with 0.1 M NaOH with constant shaking until a pink color was formed which persisted for about 15 s. All samples were analyzed in triplicate and the free fatty acid content was expressed as oleic acid equivalent.

10. Fatty acid composition
Fatty acids Methyl Esters (FAMEs) were obtained by the method described by Metcalfe et al. (1966) and modified by Selmi and Sadok (2008). Ten gram of the lipid extract was saponified with 0.5 mol/L NaOH in methanol followed by a methylation in 12% boron trifluoride in methanol (BF₃/MeOH). The methylated sample was then extracted with n-hexane. All of these reactions were performed in quadruplicate for each sample. The resulting methyl esters were analysed by gas chromatography (GC) using an Agilent Technologies chromatograph 6890N (Agilent Technologies, Palo Alto, CA, USA) equipped with a flame ionization detector (FID), a splitless injector and a polar INNOWAX 30 M silica capillary column (0.25 mm i.d. & 0.25 µm film thickness). The temperature of the injector and detector were 220 °C and 275 °C, respectively. Helium was used as a carrier gas with a flow rate of 1.5 ml/min. Peaks were identified by comparison of their retention times with FAMEs standards (SUPELCO). The sequences of fatty acids were ranged according to their
chromatographic retention times and the values are given as percentages of the total fatty acids methyl esters.

**Microbial analysis**
Total bacterial count (TBC) was determined by using Nutrient agar, MacConkey agar, and Potato Dextrose agar media according to the procedures described by APHA (1976). The mould counts in the smoked fish samples were determined, according to the method described by Fawole and Oso (1995).

**Sensory quality assessment**
Organoleptic attributes of appearance, juiciness, saltiness, rancidity, flavour and general acceptability of the smoked fish samples were evaluated by a 10 selected members. A 9-point hedonic scale was used with 9 for like extremely, down to 1 for dislike extremely (Carbonell et al., 2002). For the evaluation, the samples were rinsed with water for 1 min, covered with aluminum foil, heated in an oven at 80°C for 30 min and allowed to cool at ambient temperature, before presentation to the panelists.

**RESULTS AND DISCUSSION**

1. **Sensory Evaluation of Raw Fish**
Score sheet of sensory evaluation used was based on Egyptian Organization for Standardization (2005). Eye, gill, belly and texture of fresh kapreeta (like tuna) fish were tested by five panelists with 10 for highest score. The results are present in Table (1). Samples of raw materials used for study were generally of high organoleptic value with the characteristics of eyes perfectly fresh, convex black pupil, translucent cornea, bright red gills, no bacterial slime, outer slime water-white or transparent, bright opalescent sheen. No reddening along the backbone and no discoloration of the belly flaps. The fish was fresh ‘seaweedy’ odours with firm, elastic to the finger touch.

2. **Proximate composition**
Preliminary experiments were carried out on pretreatments with concentrations from 1-5% sage or thyme extracts prior fish filets liquid smoking. Sensory evaluation recorded that adding 5% of essential thyme oil or essential sage oil to kapreeta fish fillets for 30 min prior smoking were generally of highest organoleptic values. The results of proximate composition are presented in Table (2). Moisture content decreased from 71.75% in fresh fish to 53.28% in liquid smoked kapreeta fish fillet without pretreatment, while decreased to 54.50% in smoked fish fillet pretreated with 5% thyme oil and to 54.74% in smoked fish fillet pretreated with 5% sage oil. The lower moisture content values with the sample might be due to the loss of water during smoking (Asiedu et al., 1991). Industrial specifications for smoked finished products generally are recommended with water content in the fish flesh of less than 65% (Cardinal et al., 2001). Kolodziejska et al. (2002) also reported that moisture content of smoked Mackerel was 56.7% while Goulas and Kontominos (2005) reported that the moisture content of smoked chum Mackerel samples varied from 58.1% to 59%.
Moisture content of treated smoked fish fillet was 54.50% and 54.74% for smoked fish pretreated with 5% thyme oil or sage oil, respectively. These results are in agreement with Iheagwara (2013) who found that pretreatment with ginger extract prior smoking effect on moisture content of mackerel fish. The protein, lipid and ash contents of fresh Kapreeta fish samples were 24.54%, 2.11% and 1.60%, respectively increased after liquid smoking in untreated smoked fish to be 36.15%, 4.13% and 5.84%, respectively. Decrease of moisture content and increase of protein, fats and ash contents due to reduction of moisture were the most prominent changes after smoking (Daramola et al., 2007, Bilgini et al., 2008 and Al-Reza et al., 2015).

Protein content of smoked fish treated with 5% thyme oil (36.90%) or 5% sage oil (37.03%) were slightly increased than untreated samples, while lipid content decreased to 3.40% in smoked fish treated with 5% thyme oil and to 3.02% in smoked fish treated with 5% sage oil. These results are in agreement with Iheagwara (2013) who found that pretreatment with ginger extract prior smoking effect on the increasing of protein and decreasing of lipid content.

3. Quality and lipid oxidation parameters of kapreeta fish fillets

The quality parameters of raw and smoked kapreeta fish fillets are given in Table (3).

1. Salt content

Salt content of the Kapreeta smoked fish sample was analyzed to be 1.75%. Birkeland and Bjerkg (2005) reported that acceptable salt content of smoked fish was 1.80g and it was increased in experimental sample by increasing the time of salting. Jittinandana et al. (2002) found that salt content of products soaked in higher brine concentration was greater than of those from the lower brine concentration for the same brining time. In this study, the salt content increased during storage of untreated smoked fish and slightly increased in kapreeta fish treated with essential oils prior smoking during storage at 5 ± 1°. This increase in sodium chloride content was oftentimes accompanied by partial dehydration and clear shortage of free water (Dessoiki, 1971 and El-Akeel, 1988).

2. pH

The pH of fresh kapreeta (like tuna) fish flesh was approximately neutral (6.4) which decreased to 6.1 after smoking (Table 3). This decrease could be due to the presence of different smoke components like acids which get deposited on the fish during the smoking process. These values are partially in agreement with that of Goulas and Kontominas (2005) who found that a pH value of 6.22 for smoked chub mackerel. pH slightly increased during storage. The increase in pH may be attributed to the decomposition of nitrogenuous compounds and the production of volatile basic components such as ammonia, trimethylamine and total volatile nitrogen by fish spoilage bacteria which indicates a loss of quality (Ruiz-Capillas and Moral, 2005, Can. 2011 and Topuz et al., 2014).
3. Total volatile base nitrogen (TVB-N)

Total volatile base nitrogen (TVB-N) is widely used as an indicator of fish spoilage; its increase is related to the activity of spoilage bacteria and endogenous enzymes and TVB-N levels are often used as an index to assess the quality and shelf life of products (Ruiz-Capillas and Moral 2005, Ozogul et al., 2006 and Ucak et al., 2011).

In the present study, TVB-N of Kapreeta fresh fish was 14.1 mgN/100g and decreased after liquid smoking to be 11.2 mgN/100g in untreated smoked fish fillets and to 9.4 and 8.1 mgN/100g in smoked kapreeta fish fillet treated with 5% thyme oil or 5% sage oil, respectively, prior smoking. This could be associated with lower moisture content and higher salt level which reducing spoilage bacteria growth and activity of endogenous enzymes. Results of current findings showed that on day 0, smoked fish fillets were within the accepted TVBN limits for raw and smoked fish samples, because fish samples had values less than 30 mgN/100 g (Daramola et al., 2007). Pearson (1982) and Connell (1995) reported and also recommended that the limit of acceptability of fish is 20 to 30 mgN/100 g, while Huss (1988) and Kirk and Sawyer (1991) suggested a value of 30 to 40 mgN/100 g as the upper limit. The TVB-N content of fresh chela was found 7.10 mgN/100 g of sample, which is below the level of 35 mgN/100 g, has been suggested as border line for various fish and fish products (Ghaly et al., 2010). Values similar to our TVB-N data have been reported for smoked fish (Gokoglu et al., 2004, Kilinc and Cakli, 2005, Can and Ersan, 2013 and Topuz et al., 2014).

During storage period at 5 ± 1 °C, TVB-N values were increased. Untreated smoked Kapreeta fish fillets increased to 23.3 after 15 days and to 32.2 after 30 days and to 48.1 mgN/100 g after 45 days, while smoked kapreeta fish fillet treated with 5% thyme oil increased to 25.3 after 45 days and to 32.1 mgN/100 g after 60 days. On the other hand, smoked kapreeta fish fillets treated with 5% sage oil increased to 27.3 after 60 days and to 33.2 after 75 days and reach to 38.1 mgN/100 g after 90 days storage. The highest TVB-N values were recorded in untreated fish fillets, while the lowest were shown in treated with sage followed by thyme essential oils.

Treated fish fillets with 5% sage oil recorded lowest TVB-N during storage because of the lower bacteria count (Erkan et al., 2011). Sage essential oil has stronger antibacterial effect than thyme essential oil (Mejlholm and Dalgaard, 2002). In the present study, the results establish the effectiveness of thyme and sage essential oils as antioxidants and antimicrobials due to reduction in TVB-N on treated samples as observed in Table (3).

4. Trimethylamine Nitrogen (TMA-N)

Trimethylamine Nitrogen (TMA-N) is produced from Trimethylamine Oxide (TMAO) possible partly by action of intrinsic enzymes but certainly through bacterial action, is the main component responsible for a pleasant “fishy” odor (Rodriguez et al., 1999 and Shakila et al., 2003). In the present study TMA-N content of fresh fish was 5.5 mg N/100 g and decreased after liquid smoking to be 4.2 mg N/100 g in untreated smoked kapreeta fish fillet but increased to 9.8 after 30 days and to 11.4 after 45 days. Treated fish fillets with
5% thyme or sage oils recorded lowest TMA-N during storage at 5 ± 1 °C. Treated samples with 5% thyme oil reached to 8.5 after 45 days and to 9.3 mg N/100 g after 60 days storage and in treated samples with 5% sage oil, TMA-N decreased to 7.1 after 45 days and to 9.4 mg N/100 g after 75 days refrigerated storage. According to the Egyptian Organization for Standardization (2005), for TMN-A values of smoked fish (10 mg N/100 g), smoked kapreeta fish fillets treated with sage oil had higher shelf life followed by thyme oil. Lower production of TMA-N in smoked kapreeta fish samples may be due to the antibacterial properties of thyme and sage essential oils (Erkan, 2012 and Yıldız, 2016).

5. Lipid oxidation parameters

Lipid oxidation is a major quality problem especially in fatty marine species. The highly unsaturated fatty acids found in fish lipids are very susceptible to oxidation. It leads to the development of off odours and off-tastes in edible oils and fat containing foods, known as oxidative rancidity. To evaluate the degree of lipid oxidation, the Thiobarbituric Acid (TBA) and Peroxide Value (PV) were determined. The TBA index value is an index of lipid oxidation measuring MDA content. MDA is formed through hydroperoxides, which are the initial reaction products of polyunsaturated fatty acids with oxygen (Rezaei et al., 2008).

In the present study, PV and TBA of fresh Kapreeta fish fillet were 2.1 meq peroxide/kg fish fat and 1.1 mg malonaldehyde/kg, increased after smoking to be 2.6 meq peroxide/kg fish fat and 2.9 mg malonaldehyde/kg in untreated smoked Kapreeta samples at zero time storage. On the other hand, PV and TBA of treated fish fillets were less than untreated samples (1.9 meq peroxide/kg fish fat and 1.8 mg malonaldehyde/kg treated with 5% thyme oil and to 1.7 meq peroxide/kg fish fat and 1.7 mg malonaldehyde/kg for treated with 5% sage oil). According to Augbourg and Ugliano (2002) and Yanar et al. (2007) lipid oxidation was enhanced by method of salting, salting time, smoking and drying method. In the present study lipid oxidation values were lower than the general PV and TBA limit for smoked fish as mentioned by Egyptian Organization for Standardization (2005). which reported that PV values should not be above 10-20 meq/kg fish fat and TBA values not exceed 4.5 mg malonaldehyde/kg (Frangos et al., 2010 and Emir and Ozpolat, 2013).

During storage period at 5 ± 1 °C, PV and TBA increased more than recorded by Egyptian Organization for Standardization (2005)., untreated smoked fish fillets increased to 15.4 meq peroxide/kg fish fat and 4.6 mg malonaldehyde/kg after 30 days. PV and TBA of treated fish fillets were less than untreated samples (12.5 meq peroxide/kg fish fat and 4.5 mg malonaldehyde/kg after 60 days for 5% thyme oil and 11.4 meq peroxide/kg fish fat and 4.5 mg malonaldehyde/kg for 5% sage oil after 75 days storage).

In food suitable for consumption, the TBA values might reach the upper limit of 7 to 8 mg of MDA kg⁻¹ (Emir and Ozpolat 2013); in “perfect material,” the TBA value should be less than 3 mg of MDA/kg, and in “good material,” the TBA value should be no more than 5 mg of MDA kg⁻¹. The TBA values indicate the degree of rancidity of products, and values greater than 3-4 mg of MDA kg⁻¹.
indicate a loss of product quality (Papadopoulos et al., 2003 and Frangos et al., 2010).

The use of thyme essential oil to protect muscle foods against oxidation has been reported in the literature. Mariutti et al. (2008) and Erkan et al. (2011) observed that sage oil and thyme oil was an effective means of controlling lipid oxidation in chicken and fish meat, as reflected in thiobarbituric acid reactive substance values. There are two possible reasons for this phenomenon in the effectiveness of this product: 1, reduction in TBARS using thyme and sage is related to peroxide-scavenging enzyme activity, which could reduce unsaturated fatty acid and total unsaturated fatty acid oxidation and 2, some active components in the sage and thyme essential oils may involve desaturase and elongase activities (Mariutti et al., 2008).

The initial free fatty acids (FFA) value for fresh kapreeta fish was 1.7% increased after smoking (zero time storage) in untreated smoked fish to 2.9 and to 2.6 and 2.2 oleic acid percentage in treated samples with 5% thyme oil and 5% sage oil, respectively. FFA values increased with storage time (Table 3); however the values in the control samples were higher than other samples during storage. FFA values found to be 4.6% after 30 days in untreated smoked fish and to 4.1 and 4.2 oleic acid percentage in treated samples with thyme or sage essential oils after 60 and 75 days. FFA is said to contribute to off flavor of the product and cause textural alterations by complexing with protein (Al-Reza et al., 2015). The results established the effectiveness of sage and thyme essential oils as antioxidants which were greater in activities to inhibit the synthesis of free fatty acid in the treated samples than control samples during refrigerated storage.

6. Fatty acids composition

Fatty acids composition of fresh and smoked kapreeta fish fillets during refrigerated storage are presented in Tables (4). In fresh kapreeta fish, polyunsaturated fatty acids (PUFAs) constitute the majority of the fatty acids composition (36.23% of total fatty acids), followed by saturated (33.07% SFAs) and monounsaturated fatty acids (30.70% MUFAs). The total polyenes content included eicosapentaenoic acid 20:5 (n-3) (EPA) and docosahexaenoic acid 22:6 (n-3) (DHA) were being the prominent polyunsaturated fatty acids. In smoked kapreeta fish, saturated (SFAs) constitute the majority of the fatty acids composition (37.26% of total fatty acids), followed by polyunsaturated fatty acids (35.14% PUFAs) and monosaturated fatty acids (27.60% MUFAs). Fatty acid profiles were followed and observed after storage. SFAs and MUFAs levels increased more while PUFAs levels deceased more in untreated samples during refrigerated storage.

The decrease of PUFAs percentage may indicate the oxidation of these unsaturated fatty acids during storage. Such changes were not observed in sage or thyme treated lot. The uses of natural antioxidant in fish fillets have induced the stability of fatty acids profiles without altering their composition and minimize oxidation. These results are in accordance with those reported by Serdaroglu and Felekoglu (2005). Due to their high degree of unsaturation, EPA and DHA are readily oxidized. Such characteristic has suggested the use of the
polyene index [(EPA + DHA)/16:0] and PUFAs/SFAs to evaluate oxidative deterioration of polyunsaturated fatty acid in fish lipids (Wada and Fang, 1992 and Rahimabadi et al., 2016). In this study, the polyene index and PUFAs/SFAs values in control samples decreased from 1.70 % to 1.52 % and from 1.35 % to 1.20 % following 15 days of storage, respectively. No changes were observed in polyene index and PUFAs/SFAs values for thyme treated lot. It has been reported that sardines treated with rosemary extract and onion juice, retained ratio of [EPA + DHA/16:0] statically constant during storage (Serdaroglu and Felekoglu 2005 and Colakoglu et al., 2011).

4. Microbial quality

The activity of microorganisms is the most important factor limiting the shelf life of fish and fish products. Total viable count (TVC) is the most common microbiological method aimed to detect and enumerate high proportion of the microbial population as possible. In practice, this usually means mesophilic, aerobic or facultatively anaerobic bacteria, which account for the major part of the microflora in fish. A TVC method can only provide an estimate of the microbial population based on those cells that are recoverable under the test conditions.

TVC of fresh kapreeta fish was 4.2 log10 cfu/g (Table 3) indicating good fish quality, but after the samples were subjected to hot smoking, the TVC was reduced to 2.8 log10 cfu/g in untreated samples and to 1.8 and 1.2 log10 cfu/g in treated samples with 5% thyme and 5% sage essential oils at day 0 of storage. Karra (1978) reported that smoking caused a decrease in total microbial count by an average of 94.7% of the original number in dogfish fillets. This occurrence could be attributed to the effects of dehydration and antimicrobial activity of the smoke constituents besides the high temperature during hot smoking (Rorvik, 2000).

TVC increased exponentially with storage time. At day 15 of storage, TVC in untreated samples was 4.1 log10 cfu/g and increased to 5.6 log10 cfu/g at day 30. On the other hand, TVC in smoked kapreeta fish fillets treated with 5% thyme or 5% sage oils was 2.9 and 2.1 log10 cfu/g at day 15 and increased to 4.5 and 3.3 log10 cfu/g at day 45. Microbial load sharply increased on the 75th day of storage and reached 7.3 and 6.2 log10 cfu/g in both treated smoked fish fillets. TVC is an important criterion for quality evaluation; the maximum recommended bacterial count for good quality products is 5.7 log10 cfu/g, and the maximum recommended bacterial count for marginally acceptable quality products is 7 log10 cfu/g (ICMSF, 1986). Considering these values, it is possible to say that TVCs of smoked kapreeta fish exceeded the microbiological limits of acceptability after 15 days of storage for untreated samples and for 60 days storage for treated samples with 5% thyme oil and 75 days for treated samples with 5% sage oil. Kolodziejska et al. (2002) reported that the initial TVCs of hot smoked mackerel were 1.6 log10 cfu/g prior to storage and 4.7 log10 cfu/g after 21 days of storage at 8˚C. These results showed that thyme and sage essential oils having the greatest antimicrobial activity. A number of essential oils and some of their components have been reported to have antimicrobial activity against a wide range of spoilage and pathogenic bacteria (Lambert et al. 2001; Burt 2004). Thyme contains high concentrations of
phenolic compounds including carvacrol, thymol, pcy mene and \( \gamma \)-terpinene (Komaki et al., 2015). The thyme and sage essential oils can be considered effectively inhibitory on the total aerobic flora. Similar results were observed by several researchers (Cadun et al., 2008, Duman et al., 2012; Can and Ersan, 2013). According to the results of fish quality and lipid stability, smoked Kapreeta fish fillets treated with 5% sage oil prior smoking recorded highest quality and high shelf life (up to 75 days), followed by fish fillets treated with 5% thyme extract (up to 60 days), while untreated fish fillet recorded the lowest quality and shelf life (from 15 to 30 days).

5. Sensory quality

Sensory evaluation together, with chemical and microbial characteristics have been used extensively to assess the quality of smoked kapreeta fish fillets. Therefore, the effect of storage at refrigerated temperature (5 ± 1°C) on the organoleptic attributes of appearance, flavour, texture and overall acceptability of smoked fillets was studied. Sensory evaluation in this study was conduct by panelists. A nine point hedonic scale was used, a score of nine being the best, one being the worst and four being the borderline of acceptability. The obtained results are shown in Table (5). The appearance of smoked fish is one of the most important organoleptic property mainly due to its effect on the acceptability of these products by consumers. Smoked fish fillets showed a good appearance score 8 after smoking at 0 time storage in both untreated and treated smoked fish fillets with %5 thyme or sage essential oils prior smoking. During storage the appearance scores tended to decrease until the smoked samples were completely rejected organoleptically after 30 days for untreated smoked fish samples (5) and after 60 days for smoked fish samples treated with 5% thyme oil (5) prior smoking and after 75 days for smoked fish samples treated with 5% sage oil (5) prior smoking. These data indicated the effect of thyme and sage extracts on the appearance scores acceptability of treated smoked kapreeta fish during storage.

Regarding to the effect of storage on the texture scores acceptability of smoked kapreeta fish fillets, the obtained results illustrated that the untreated texture score and treated with 5% thyme or 5% sage of smoked fish at 0 time storage was 7. The texture scores of smoked kapreeta fish fillets during storage showed the same trend as for appearance scores acceptability. Flavour is a major sensory attribute for smoked fish quality. The specific aroma and taste of smoked fish were formed due to the effect of volatile compounds from smoking and essential oils as sage and thyme extracts. Fresh smoked kapreeta fish fillets (0 time storage) recorded very good flavour (taste and odor). The flavour scores of smoked kapreeta fish fillets during storage showed the same trend as for appearance and texture scores acceptability. It could be observed that the overall acceptability scores of smoked fillets did not alter within 15 days of untreated fish and within 45 and 60 days of treated fish fillets with 5% thyme or 5% sage essential oils prior smoking, respectively. These finding for sensory evaluation were in a good agreement with the chemical and microbial characteristics of smoked kapreeta fish fillets. Similar results have been reported in other recent studies (Ozpolat et al., 2010, Duman et al., 2012, Egbal et al., 2013 and Yildiz, 2016).
CONCLUSION

From the above results, it can be concluded that liquid smoking can significantly influence the physicochemical properties of smoked kapreeta fish fillets by imparting antioxidant and antimicrobial properties and by influencing the sensory attributes. The present work has demonstrated that sage and thyme essential oils have antioxidative and antimicrobial properties that can retard oxidative rancidity and inhibit microbial growth, thus, extending the shelf life of the smoked fish. This is justified by the low TBA and peroxide values, as well as microbial count of the sage or thyme treated samples, compared to the untreated samples. Organoleptically, the general pattern of consumer preference to the products indicates that smoked kapreeta fish fillets treated with sage oil followed by thyme oil samples were most acceptable in relation to storage stability compared with control samples. According to the present results, the shelf life of kapreeta fish fillets was estimated as 15 days for untreated smoked fish and 60 days for smoked fish treated with 5% thyme oil and 75 days for smoked fish treated with 5% sage oil under refrigerator storage. Further research is required to focus on understanding the mechanisms of action, in particular concentrations of active ingredients of both sage and thyme essential oils which applied to liquid smoked fish products.

Table (1). Sensory evaluation of purchased fresh kapreeta (like tuna) fish

<table>
<thead>
<tr>
<th>Panelist</th>
<th>Eye</th>
<th>Gill</th>
<th>Belly</th>
<th>Texture</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7</td>
<td>8</td>
<td>7</td>
<td>7</td>
<td>7.5</td>
</tr>
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<td>8.5</td>
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<td>9</td>
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</tr>
<tr>
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<td>8.5</td>
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<td>8</td>
<td>8</td>
<td>9</td>
<td>9</td>
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</tr>
<tr>
<td>Average</td>
<td>8.2</td>
<td>7.6</td>
<td>8.2</td>
<td>8.2</td>
<td>8.1</td>
</tr>
</tbody>
</table>

Table (2). Proximate composition of fresh and liquid smoked Kapreeta (like tuna) fish filets (mean ± SE).

<table>
<thead>
<tr>
<th></th>
<th>Moisture (%)</th>
<th>Protein (%)</th>
<th>Fat (%)</th>
<th>Ash (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh fish</td>
<td>71.75 ± 2.45</td>
<td>24.54 ± 1.2</td>
<td>2.11 ± 0.40</td>
<td>1.60 ± 0.34</td>
</tr>
<tr>
<td>Smoked fish (no treatment)</td>
<td>53.28 ± 1.80</td>
<td>36.15 ± 1.50</td>
<td>4.13 ± 0.66</td>
<td>5.84 ± 0.86</td>
</tr>
<tr>
<td>Smoked fish (pretreated with 5% thyme oil)</td>
<td>54.50 ± 1.68</td>
<td>36.90 ± 1.22</td>
<td>3.40 ± 0.46</td>
<td>5.60 ± 0.76</td>
</tr>
<tr>
<td>Smoked fish (pretreated with 5% Sage oil)</td>
<td>54.74 ± 1.74</td>
<td>37.03 ± 1.20</td>
<td>3.02 ± 0.36</td>
<td>5.21 ± 0.46</td>
</tr>
</tbody>
</table>
Table (3). Quality and lipid stability parameters of smoked Kaprreta (like tuna) fish filets during refrigerated storage at 5 ± 1 °C for 90 days (mean ± SE)

<table>
<thead>
<tr>
<th>Storage Period (days) / Fish treatments</th>
<th>Salt (g)</th>
<th>pH</th>
<th>TVB (mgN/100g)</th>
<th>TMA (mgN/100g)</th>
<th>Peroxide value (meq peroxide/kg fat)</th>
<th>TBA (mg malonaldehyde/kg fat)</th>
<th>FFA (oleic acid %)</th>
<th>TVC (log10 cfu/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh fish</td>
<td>1.7 ± 0.02</td>
<td>6.4 ± 0.2</td>
<td>14.1 ± 1.1</td>
<td>5.5 ± 0.2</td>
<td>2.1 ± 0.1</td>
<td>1.1 ± 0.2</td>
<td>1.7 ± 0.1</td>
<td>4.2 ± 0.2</td>
</tr>
<tr>
<td>Smoked fish</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 days</td>
<td>1.75 ± 0.02</td>
<td>6.1 ± 0.1</td>
<td>11.2 ± 1.2</td>
<td>4.2 ± 0.3</td>
<td>2.6 ± 0.1</td>
<td>2.9 ± 0.2</td>
<td>2.9 ± 0.1</td>
<td>2.8 ± 0.2</td>
</tr>
<tr>
<td>15 days</td>
<td>1.78 ± 0.03</td>
<td>6.3 ± 0.1</td>
<td>23.3 ± 1.5</td>
<td>6.6 ± 0.4</td>
<td>8.3 ± 0.1</td>
<td>3.3 ± 0.3</td>
<td>3.3 ± 0.1</td>
<td>4.1 ± 0.2</td>
</tr>
<tr>
<td>30 days</td>
<td>1.80 ± 0.03</td>
<td>6.6 ± 0.2</td>
<td>32.2 ± 1.8</td>
<td>9.8 ± 0.4</td>
<td>15.4 ± 0.2</td>
<td>4.6 ± 0.3</td>
<td>4.6 ± 0.1</td>
<td>5.6 ± 0.2</td>
</tr>
<tr>
<td>45 days</td>
<td>1.85 ± 0.03</td>
<td>6.7 ± 0.1</td>
<td>48.1 ± 2.2</td>
<td>11.4 ± 0.5</td>
<td>19.8 ± 0.2</td>
<td>5.8 ± 0.4</td>
<td>5.4 ± 0.1</td>
<td>6.8 ± 0.2</td>
</tr>
<tr>
<td>60 days</td>
<td>1.85 ± 0.03</td>
<td>6.7 ± 0.1</td>
<td>53.2 ± 2.4</td>
<td>12.6 ± 0.4</td>
<td>24.1 ± 0.3</td>
<td>9.5 ± 0.4</td>
<td>5.9 ± 0.1</td>
<td>8.9 ± 0.2</td>
</tr>
<tr>
<td>75 days</td>
<td>1.90 ± 0.03</td>
<td>6.8 ± 0.1</td>
<td>55.8 ± 2.5</td>
<td>14.2 ± 0.4</td>
<td>27.7 ± 0.3</td>
<td>11.7 ± 0.5</td>
<td>6.6 ± 0.1</td>
<td>12.1 ± 0.3</td>
</tr>
<tr>
<td>90 days</td>
<td>1.90 ± 0.03</td>
<td>6.9 ± 0.2</td>
<td>58.9 ± 2.5</td>
<td>15.8 ± 0.5</td>
<td>32.8 ± 0.5</td>
<td>13.7 ± 0.5</td>
<td>6.9 ± 0.1</td>
<td>15.8 ± 0.3</td>
</tr>
<tr>
<td>5% Thyme oil</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 days</td>
<td>1.75 ± 0.02</td>
<td>6.1 ± 0.2</td>
<td>9.4 ± 0.8</td>
<td>4.1 ± 0.1</td>
<td>1.9 ± 0.1</td>
<td>1.8 ± 0.1</td>
<td>2.6 ± 0.1</td>
<td>1.8 ± 0.1</td>
</tr>
<tr>
<td>15 days</td>
<td>1.75 ± 0.02</td>
<td>6.2 ± 0.1</td>
<td>12.5 ± 1.1</td>
<td>5.6 ± 0.2</td>
<td>3.1 ± 0.1</td>
<td>1.9 ± 0.1</td>
<td>2.2 ± 0.1</td>
<td>2.9 ± 0.1</td>
</tr>
<tr>
<td>30 days</td>
<td>1.75 ± 0.02</td>
<td>6.3 ± 0.1</td>
<td>18.4 ± 1.3</td>
<td>7.5 ± 0.3</td>
<td>7.8 ± 0.2</td>
<td>2.2 ± 0.2</td>
<td>2.8 ± 0.1</td>
<td>3.3 ± 0.1</td>
</tr>
<tr>
<td>45 days</td>
<td>1.77 ± 0.02</td>
<td>6.4 ± 0.1</td>
<td>25.3 ± 1.5</td>
<td>8.5 ± 0.3</td>
<td>10.5 ± 0.2</td>
<td>3.5 ± 0.2</td>
<td>3.3 ± 0.1</td>
<td>4.5 ± 0.1</td>
</tr>
<tr>
<td>60 days</td>
<td>1.78 ± 0.02</td>
<td>6.4 ± 0.1</td>
<td>32.1 ± 1.1</td>
<td>9.5 ± 0.4</td>
<td>12.4 ± 0.3</td>
<td>4.5 ± 0.2</td>
<td>4.1 ± 0.1</td>
<td>4.5 ± 0.2</td>
</tr>
<tr>
<td>75 days</td>
<td>1.80 ± 0.02</td>
<td>6.5 ± 0.1</td>
<td>36.2 ± 1.3</td>
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<td>16.8 ± 0.2</td>
<td>5.3 ± 0.3</td>
<td>5.3 ± 0.1</td>
<td>7.3 ± 0.2</td>
</tr>
<tr>
<td>90 days</td>
<td>1.85 ± 0.02</td>
<td>6.6 ± 0.2</td>
<td>43.7 ± 1.4</td>
<td>13.6 ± 0.4</td>
<td>28.8 ± 0.2</td>
<td>6.5 ± 0.2</td>
<td>5.8 ± 0.1</td>
<td>10.3 ± 0.2</td>
</tr>
<tr>
<td>5% Sage oil</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 days</td>
<td>1.75 ± 0.02</td>
<td>6.1 ± 0.2</td>
<td>8.1 ± 0.5</td>
<td>3.7 ± 0.1</td>
<td>1.7 ± 0.1</td>
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<td>2.2 ± 0.1</td>
<td>1.2 ± 0.1</td>
</tr>
<tr>
<td>15 days</td>
<td>1.75 ± 0.02</td>
<td>6.1 ± 0.1</td>
<td>11.1 ± 0.5</td>
<td>4.5 ± 0.1</td>
<td>2.9 ± 0.1</td>
<td>1.8 ± 0.1</td>
<td>1.7 ± 0.1</td>
<td>2.1 ± 0.1</td>
</tr>
<tr>
<td>30 days</td>
<td>1.77 ± 0.02</td>
<td>6.2 ± 0.1</td>
<td>15.3 ± 0.7</td>
<td>5.5 ± 0.2</td>
<td>4.7 ± 0.1</td>
<td>2.5 ± 0.1</td>
<td>2.2 ± 0.1</td>
<td>2.6 ± 0.1</td>
</tr>
<tr>
<td>45 days</td>
<td>1.79 ± 0.02</td>
<td>6.2 ± 0.1</td>
<td>18.2 ± 1.1</td>
<td>7.1 ± 0.2</td>
<td>7.9 ± 0.1</td>
<td>3.1 ± 0.1</td>
<td>2.8 ± 0.1</td>
<td>3.3 ± 0.1</td>
</tr>
<tr>
<td>60 days</td>
<td>1.79 ± 0.02</td>
<td>6.3 ± 0.1</td>
<td>27.3 ± 1.2</td>
<td>8.5 ± 0.3</td>
<td>9.5 ± 0.2</td>
<td>3.4 ± 0.2</td>
<td>3.3 ± 0.1</td>
<td>4.3 ± 0.2</td>
</tr>
<tr>
<td>75 days</td>
<td>1.80 ± 0.02</td>
<td>6.4 ± 0.1</td>
<td>33.2 ± 1.4</td>
<td>9.4 ± 0.3</td>
<td>11.4 ± 0.2</td>
<td>4.5 ± 0.2</td>
<td>4.2 ± 0.1</td>
<td>6.2 ± 0.2</td>
</tr>
<tr>
<td>90 days</td>
<td>1.82 ± 0.02</td>
<td>6.5 ± 0.2</td>
<td>38.1 ± 2.1</td>
<td>10.8 ± 0.3</td>
<td>15.5 ± 0.2</td>
<td>5.3 ± 0.2</td>
<td>5.2 ± 0.1</td>
<td>7.1 ± 0.2</td>
</tr>
</tbody>
</table>
Table (4). Fatty acid composition of fresh and smoked Kaprreta (like tuna) fish filets during refrigerated storage at 5 ± 1 °C for 90 days Values are % of total fatty acid expressed as mean of three replicates

<table>
<thead>
<tr>
<th>Fatty acids</th>
<th>Fresh fish</th>
<th>Smoked fish (no treatment)</th>
<th>5% Thyme extract</th>
<th>5% Sage extract</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 day</td>
<td>30 days</td>
<td>60 days</td>
<td>90 days</td>
</tr>
<tr>
<td>12:0</td>
<td>0.80</td>
<td>0.43</td>
<td>0.53</td>
<td>0.85</td>
</tr>
<tr>
<td>14:0</td>
<td>5.40</td>
<td>6.30</td>
<td>7.40</td>
<td>7.20</td>
</tr>
<tr>
<td>16:0</td>
<td>21.10</td>
<td>23.52</td>
<td>24.58</td>
<td>25.52</td>
</tr>
<tr>
<td>18:0</td>
<td>5.22</td>
<td>6.26</td>
<td>7.20</td>
<td>7.50</td>
</tr>
<tr>
<td>22:0</td>
<td>0.55</td>
<td>0.75</td>
<td>0.70</td>
<td>0.75</td>
</tr>
<tr>
<td>SFAs</td>
<td>33.07</td>
<td>37.26</td>
<td>40.41</td>
<td>41.82</td>
</tr>
<tr>
<td>16:1 n-7</td>
<td>8.60</td>
<td>8.30</td>
<td>8.00</td>
<td>8.10</td>
</tr>
<tr>
<td>18:1 n-9</td>
<td>19.60</td>
<td>17.20</td>
<td>17.00</td>
<td>17.05</td>
</tr>
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<td>27.60</td>
<td>27.05</td>
<td>27.20</td>
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<td>4.50</td>
<td>3.10</td>
<td>2.80</td>
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<td>20:4 n-3</td>
<td>1.76</td>
<td>1.60</td>
<td>1.50</td>
<td>1.50</td>
</tr>
<tr>
<td>20:5 n-3 (EPA)</td>
<td>8.40</td>
<td>5.50</td>
<td>5.10</td>
<td>5.05</td>
</tr>
<tr>
<td>22:5 n-3</td>
<td>ND</td>
<td>1.50</td>
<td>1.30</td>
<td>1.40</td>
</tr>
<tr>
<td>PUFAs</td>
<td>36.23</td>
<td>35.14</td>
<td>32.54</td>
<td>30.98</td>
</tr>
<tr>
<td>PUFAs/SFAs</td>
<td>1.1</td>
<td>0.94</td>
<td>0.81</td>
<td>0.74</td>
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</table>
Table (5). Organoleptic quality of smoked kaprreta (like tuna) fish during storage at 5 ± 1 °C for 90 days (mean ± SE)

<table>
<thead>
<tr>
<th>Storage Period (days) / Smoked Fish treatments</th>
<th>Appearance</th>
<th>Texture</th>
<th>Flavour</th>
<th>Overall acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 days</td>
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<td>15 days</td>
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<td>30 days</td>
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<td>60 days</td>
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<td>75 days</td>
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<td>1</td>
</tr>
<tr>
<td>90 days</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5% Thyme extract</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 days</td>
<td>8</td>
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<td>15 days</td>
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</tr>
<tr>
<td>90 days</td>
<td>2</td>
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<td>2</td>
</tr>
<tr>
<td>5% Sage extract</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 days</td>
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<td>15 days</td>
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<td>30 days</td>
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<td>45 days</td>
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</tr>
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<td>60 days</td>
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</tr>
<tr>
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REFERENCES


Frankel, E. N. (1993). In search of better methods to evaluate natural antioxidants and oxidative stability in food lipids. Trends in Food Science and Technology, 4.. 220-225.


Thompson, D. C. and Trush, M. A. (1986). The toxicological implications of the interaction of butylated hydroxytoluene with other antioxidants and phenolic chemicals. Food Chemistry and Toxicology, 24.. 1189-1195.


المخصّص العربي

جودة وثبات سمك الكبيرةة المردم بسائل التدخين خلال التخزين المبرد

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يتواجد سمك الكبيرةة في مصر ضمن الأسماك البحرية ولكن لا يلقى قيولا لدى المستهلك المصري لاغتنام قوة لون اللحم المنشوب بالدم ووجود الدم ضمن خلايا اللحم بالداخل لذا فإن هذا النوع من الأسماك يجب تصديره وحفظه بطرق مختلفة من التعليب والتدخين. الهدف من هذا البحث هو دراسة تأثير التدخين بالسالى والزيوت العطرية والثقوب خاصة للسمك قبل التدخين على جودة سمك الكبيرةة خلال التخزين المبرد لمدة 90 يوم. تم تدقيق التحاليل الأولية في السمك الطازج والمدخن وهذا التحاليل الكيماوية والبيولوجية والخضرة لجميع العينات المدخنة. تم التعرف على تركيب الأحماض الدهنية خلال مرحل التخزين وذلك تقييم الجودة وثبات البيبودات لسمك الكبيرةة المدخنة.

أوضحنت النتائج انخفاض في نسبة الرطوبة وزيادة كل من نسب البروتين واللبيدات والبكتيريا بعد التدخين. وقد ارتفع قليلاً في pH والثقوب. كما أوضحنت النتائج أن كل من (TVB-N) (الثقوب النترولجيا) ومركب التراتي (TBA) (الثقوب النترولجيا) (FA) وكذا الأحماض الدهنية الحرة (FA) وكذا الأحماض الدهنية الحرة (FA) كان من الأمثل بتوثيق التدخين بشكل أعلى في السمك غير المعامل عن السمك المعالج بالزيوت الطازجة لكل من الزعتر والثقوب والرميدية وذلك التدخين. بينما انخفضت معدلات التحاليل الحيوية خلال التخزين. وقد أوضح تركيب الأحماض الدهنية أن نسبة 36.14% من اضخاض دهنية عالية درجة عند التخزين في السمك غير المعالج وازداد إلى 35% في السمك المعالج بواسطة 4.15% زيت الزعتر إلى 62.14% في السمك المعالج بواسطة 5% زيت المريمية وكانت أحماض (DHA) ديوكوزا هيدكسا إيبونيك هي أعلى نسبة للأحماض الدهنية عالية درجة عند التخزين. وربط أن تركيب (EPA) ديوكوزا إيبونيك ديوكوزا هيدكسا إيبونيك يرتبط بالسيارة السالى لذات الأحماض غير المشبعة ويدفع بيدها، يوضح مدى حدوث الأكسدة خلال مراحل التخزين. وكذا هذا الانخفاض والتغير في الحد الأولي في عينات السمك المعلجة بالزيوت الطازجة لكل من الزعتر والثقوب والرميدية قبل التدخين. ووفقًا لنتائج التحاليل الكيميائية والبيولوجية والخضرة فقد وجد أن سمك الكبيرةة المدخنة كان له درجة جودة عالية وثبات لثقوبه لمدة صلاحية 30 يوم في السمك غير المعالج وازدادت فترة الصلاحية إلى 60 يوم في السمك المعالج بزيت الزعتر وازدادت أكثر إلى 75 يوم في السمك المعالج بزيت المريمية تحت ظروف التخزين المبرد.

ويمكن تخصيص أن قليلة سمك الكبيرةة المعالج بالزيوت الطازجة لزبدة والرميدية قبل التدخين كان له تأثير إيجابي فعال على جودة وثبات البيبودات للسمك المدخن وكذا انخفاض فاعلية الأحماض الدهنية دون التأثير عليها وبالتالي تقليل الأكسدة.

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